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Iran Second National Communication to UNFCCC

Islamic Republic of Iran

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بسم الله الرحمن الرحيم

In the Name of Allah

Inspired by Article 50 of its Constitution, the Islamic Republic of Iran is legally and unambiguously bound to protect the environment for present and future generations. In order to participate in the international effort to mitigate global climate change and to develop national policies for adaptation to climate change, Iran had signed the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio de Janeiro Earth Summit in 1992 along with more than 150 countries, and ratified the Convention in July 1996. Iran has also ratified the Kyoto Protocol in November 2005 when the Designated National Authority to implement CDM projects was established. Since then, Iran has actively participated in the Conferences of Parties (COPs) and the Meetings of Parties to the Kyoto Protocol. As a Non-Annex I Party to the Convention, Iran is committed to comply with its obligations, as reflected in the submission of its Initial National Communication to the COP in March 2003 and its Second National Communication (SNC) in 2011.

Iran's National Climate Change Office (NCCO) was established in January 1998 under the auspices of the Department of the Environment. Among other responsibilities, such as public awareness and national coordination of the Sub-committee for Climate Change under the National Committee for Sustainable Development, the NCCO has built national capacity to systematically address climate change issues and implement CDM projects under the Kyoto Protocol.

In preparing the SNC and in line with IPCC guidelines, several expert groups were formed to carry out the necessary research, collect the requisite data and prepare the sectoral inputs. The SNC contains new chapters including: Technology Needs Assessment, Education and Research, Climate Modeling and Global Climate Observation System. In addition, the National Action Plan was elaborated in more detail compared to the earlier version presented as per Iran's First National Communication. This GEF supported Enabling Activity Project was supervised and approved by the Steering Committee comprised of representatives from relevant ministries and organizations whose members reviewed the sectoral and final reports.

The experience of producing Iran's Second National Communication, has not only enhanced the national capacity to prepare Nationnal Communications, but also has prepared Iran for development of official national development policies addressing climate change. In this regard, I am delighted to inform that in 2008, the Department of Environment has prepared and proposed to the Government, the National Rules of Procedure to Implement the Convention and the Kyoto Protocol which was approved by the Cabinet for implementation in August 2009. However, there are still many areas that need improvement and enhancement of national capacity including sectoral coordination, inadequate data and information as well as uncertainties and constraints, that hinder the smooth implementation of the project for preparation of National Communications.

On behalf of the Islamic Republic of Iran, I am hereby pleased to share Iran's Second National Communication with the international community.

Mohammad Javad Mohammadizadeh

Vice President &

Head of the Department of Environment

Islamic Republic of Iran

Preparation of the Second National Communication (SNC) of Iran to UNFCCC has been made possible through the collaboration of many individuals and organizations. Our sincere thanks are expressed to all persons and groups that contributed to this effort. We are grateful for the financial support of GEF and the UNDP Country Office in Tehran for the cordial support and technical assistance of this Enabling Activity.

We appreciate the cooperation of the Ministry of Foreign Affairs as the "GEF Operational Focal Point" for their continued support and coordination. Our thanks also go to the Ministries of Petroleum, Industries & Mines, Agriculture (Jihad-e-Keshavarzi), Energy, Interior and Health; the Meteorological Organization of Iran, the Forest and Rangeland Organization, University of Tehran, Sharif University of Technology and the National Center for Oceanography for technically assisting the project and providing the requisite data.

More than 50 specialists, faculty members at different universities and research institutions in Iran, senior experts at different ministries and organizations have collaborated with the National Climate Change Office in preparing this report. We are very grateful for their invaluable contributions. A list of individual names and organizations contributing to the preparation of this SNC is provided in the Annex of this report.

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Introduction

Following the submission of Iran's Initial National Communication to UNFCCC in March 2003, the Islamic Republic of Iran continued with the implementation of its Phase II Enabling Activities on Climate Change (Top-up) in which Technology Needs Assessment (TNA) and participation in Global Climate Observation Systems (GCOS) were undertaken. However, as there were no reporting requirements for these two areas in Phase II, the relevant reports were not submitted to UNFCCC, rather, they were included in this Second National Communication (SNC).

In preparing the SNC, the UNFCCC's User Manual for National Communications from Non-Annex I Parties (2003) and the IPCC 1996 Revised Guidelines for GHG inventory were used. In addition, the UNDP's NEX Guidelines (2004) for project implementation provided project management and operational guidance. Where possible, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and GPG 2000 and GPG-LULUCF 2003 for Forestry and other sectors were also used.

The SNC comprises of the following chapters:

1. *National circumstances*
2. *Greenhouse gas emission inventory*
3. *Greenhouse gas mitigation policies*
4. *Vulnerability and adaptation*
5. *Other information including TNA, GCOS and Climate Change Research and Education*
6. *National Action Plan*

These individual chapters as well as the whole report have been extensively reviewed by the Steering Committee members comprising of the representatives of all relevant organizations and ministries and ultimately approved over the course of 13 meetings.

National Circumstances

Iran is a vast country with an area of 1,648,195 square kilometers located in the Middle East in western Asia with over 750 km of Caspian Sea coastline and about 2,250 km of coastline along the Persian Gulf and the Oman Sea. Geographical details have been described in the Initial National Communication.

Generally, Iran is a mountainous and semi-arid land, with a mean altitude of more than 1,200 meters above sea level. More than half of Iran's land consists of mountains, with one quarter being plains and deserts and less than one quarter constituting arable land. The southern coast of the Caspian Sea at an altitude of 28 meters is the lowest point in Iran and the summit of Mt. Damavand in the central Alborz Mountains range at 5,628 meters altitude is the country's highest point while the Lut Desert at 56 meters altitude is the lowest internal point. Almost 11.2% of the land of Iran is agricultural, while forests, rangelands and deserts account for 8.7%, 52.1% and 19.7%, respectively, with the remaining landmass allocated to industrial and the residential areas. Iran has 14.3 million hectares of forested areas, 93.53% is natural forest and the rest is planted forest. Forested area per capita is only 0.2 ha as compared with the global standard of 0.8 ha. The mean annual rainfall of the country is about 246 mm, with a range between 50 mm to 2000 mm, and the total annual volume of precipitation equals 413 billion cubic meters (bcm). Internal renewable water resources are estimated at 128.5 bcm/year. More than 80% of the country is arid or semi-arid. Extreme temperatures of -20 to +50 degrees Celsius are common.

Iran has a highly diverse climate and environment which is due to its unique geography and ecosystem, hence a habitat for a rich diversity of terrestrial and marine species. However, during the past decades, great pressure has been put on environmental resources due to lack of precipitation, persisting drought and heavy stress and pollution of scarce water resources, air pollution in urban and industrial areas, degradation of natural vegetation, as well as soil erosion and loss of biodiversity. Over the past decade, Iran had suffered from severe and persistent droughts causing tremendous damage to the agriculture, forests, water resources and other sectors comprising the national economy. Being located in one of the most seismically active areas of the world, Iran is the sixth most disaster-prone country in the world. An average of 4,000 people were killed and 55,000 affected annually by natural disasters over the last decade. Losses due to earthquakes and hydro-meteorological hazards such as droughts, floods, and landslides are severe and are estimated at some USD 1.1 billion per annum.

The population of the country stood at 60.1 million in 1996-97 and 70.5 million in 2006-07 with annual growth rate of 1.6 %. One of the most alarming economic and social trends that could be partially attributed to climate change is the increasing migration to cities due to droughts that had left in its wake decreased agricultural output and creeping environmental destruction. Consequently, the urbanization coefficient had increased from 61.3% to 68.5% over the decade from 1996 to 2007.

In the years 2004-05, Iran's gross domestic product (GDP) was 410,429 Billion Rials which showed a nominal increase of 45% compared to 1996-97. The per capita income in the same year was 5528 Thousands Rials which shows a 60% nominal increase compared to the years 1996-97. In the years 2004-05, the contribution of different sectors namely, services, agriculture, oil and gas, and industry and mines to the GDP were 52.4%, 13%, 11.6%, 24.3% respectively.

To streamline climate change concerns with the National Development Plans, in 2009 the government of Iran established and approved the National Regulations for Implementation of the UNFCCC and the Kyoto Protocol.

National Greenhouse Gases Inventory

The national greenhouse gases inventory was calculated for the year 2000 based on the UNFCCC guidelines for preparation of the national communications for Non-Annex I Parties. As mentioned in the Introduction above, the IPCC 1996 revised guidelines and where possible, the IPCC 2006 guidelines were used for the compilation of the GHGs emission inventory. To ensure quality control and quality assurance, key source analysis and uncertainty management, IPCC 2000 Good Practice and Uncertainty Management Guidelines and IPCC 2003 Guidelines for Good Practice Guidance for Land Use, Land-Use Change and Forestry have also been used. In addition, the UNFCCC software was used for GHGs calculations. Compared to the GHG inventory that was reported in the INC, this inventory has been improved with respect to the quality of activity data, scarce national emission factors notwithstanding. Furthermore, activity data is still not being collected on a continuous and systematic basis with systematic compilation of activity data requiring improvement in the future. All direct and indirect GHGs encompassing all sectors, i.e. the energy, industrial processes, agriculture, forestry and waste have been calculated.

In 2000, the total CO_2 emissions from different sectors was about 375,187 Gg, with the energy sector contributing about 90% of the total emissions and industrial processes and forestry contributing about 8% and 2%, respectively. The total CO_2 equivalent GHGs emission is estimated at 491,052 Gg in 2000. The energy sector has the largest share amounting to 77% with the forestry sector having the lowest share at 2% of overall GHGs emission. In regard to emissions of HFCs, PFCs and SF6, reliable information is non-existent. However, contribution of these gases to emissions of industrial processes is estimated at 0.248, 0.22 and 0.004 Gg, respectively

Within all energy sub-sectors the emission of CO_2 in the year 2000 was estimated at 337,351 Gg. This emission in comparison with the amount of emission in the year 1994 (285,891 Gg reported in INC), has increased at a compound rate of about 18% (i.e. at an average rate of 2.8% per annum). Comparison of GHGs emission in the years 1994 and 2000 in Iran's energy sector shows that the amount of NOx emission from fuel combustion has drastically decreased (i.e. almost halved) a result of natural gas substitution in the fuel mix. The fugitive emissions from oil and gas activities were respectively 33,325 Gg CO_2 (hot flare) and CH_4 1,722.8 Gg (cold flare), which show 5.7% growth for CO_2 and 16.5% growth rate for CH_4 in comparison to 1994 .

Within the industrial sector, iron and steel and mineral production account for about 90% of CO_2 equivalent emissions, while the chemical industry and fugitive emission from the use of HFCs and PFCs contributes about 10% of CO_2 equivalent emissions. Since the most important CO_2 emitting industrial processes are iron and steel (43.4%) and cement (40.3%) industries, with the balance of 16.3% attributed to other industries, these industries should be considered as priorities of emission reduction for climate change mitigation. The CO_2 equivalent of N_2O, CH_4, HFCs and SF6 contribute only to about 5% of total emissions, which again indicates the necessity of adopting measures to reduce CO_2 emissions from cement, iron and steel production.

In 2000, the total amount of CO_2 equivalent from agriculture sector stood at about 42,993 Gg with the share of CO_2 equivalent of N_2O and CH_4 of about 55.6% and 44.4%, respectively. Agricultural soils contributed to 55% of the total GHGs emission, whereas the share of enteric fermentation, rice cultiviation, animal waste and agricultural residue burning stood at 39%, 3%, 2% and 1%, respectivly. It should be mentioned that there is no emissions reports on prescribed burning of savannahs.

The net GHGs emissions and uptake from land-use change and forestry stood at 9,278 Gg CO_2 equivalent and the amount of CO_2 uptake in the land use and forestry sectors at about 523.93 Gg CO_2 equivalent. It should be noted that compared to the reporting year of INC (1994) the contribution of forestry to emissions has decreased from 7% to 2% which indicates a decreased rate of deforestation.

In 2000, the total CO_2 equivalent emission from sewage and waste was about 31,608.97 Gg. Methane was responsible for 59.3% of total GHGs emission from waste, whereas the share of N_2O amounted to about 40.7%. Moreover, liquid waste contributed to 44.4% of CH_4 and 66.9% of total GHGs emission in the waste sector. Comparison of GHGs emission in 2000 and 1994 reveals that the 2000 emission is about 3.8 times higher than the amount of GHG emissions in this sector. The rapid growth in GHGs emission in the waste sector is attributed to enforcement of new waste management regulations that provide a legislative framework for waste management in Iran. The new regulationss require all industries and large cities to construct wastewater treatment facilities and solid waste disposal sites.

Compared to INC, uncertainty management of GHGs emissions inventory due to activity data and emission factors in all sectors was carried out in preparing the SNC. As noted earlier, except for the energy and waste sectors, for which some national emission factors are available, there are no national emission factors for other sectors. This results in significant uncertainties in the estimation of the national emission inventory. The result of sectoral and overall uncertainty for CO_2 emission indicates that industrial processes have the lowest uncertainty in the CO_2 emission inventory, while the uncertainty of the forest sector is the highest with an overall uncertainty for CO_2 of about 15.2%. The overall uncertainties of equivalent GHGs emissions in industrial processes and the energy sectors are 10.4% and 13% respectively, while the agriculture and land-use change with 75% and 67.5% respectively register the highest uncertainty. The overall uncertainty of the national GHGs inventory is about 20.1%.

National Greenhouse Gases Mitigation Policies

Mitigation assessments have been carried out in two distinct sectors, energy and non-energy. As mentioned above, the energy sector is responsible for about 77% of total GHGs emission, thus requiring attention to this challenging and complex sector in Iran. The following mitigation policies are based on extensive and lengthy consultations with experts, institutions and academia undertaken in the country.

Energy Sector

Scenario Development

Three scenarios have been considered in mitigation assessment, namely: (1) *Business As Usual (BAU) Scenario*, where for the period 2000-2025 all of the exogenous variables of energy modeling vary based on 1994-2007 realities and using econometric functions and methods to evaluate the scenario; (2) *Official Development Plan* (ODP) *Scenario*, where the energy prices are considered to vary based on the energy subsidy removal program of the government during the 5th FYDP (Five Year Development Plan 2010-2015); and *Mitigation Scenario*, where eight different mitigation policies (MP), as described in Chapter 3, have been considered with different options. The choice of these plans are based on reviewing the past and future government schemes, expert judgment on the availability of the related technologies and financial resources, needs for rules and regulations and infrastructure development according to the future objectives and activities of the country over the long-term.

It is important to note that in developing mitigation scenarios in the energy sector, econometrics models have been used in this report to estimate the energy demand for different energy carriers in the future. These models are based on several assumptions on the rate of economic growth, GDP, energy carriers pricing and the share of low carbon and renewable energies. Therefore, GHGs emission estimates presented in this report vary with different assumptions and do NOT represent the actual emissions of the country in the future. In this regard, the mitigation policies are divided into the following two categories:

- National Mitigation Plan, consisting of the mitigation measures which will be funded by Government and is responsible for about 30% emission reduction by 2025 in comparison with BAU Scenario.

- Internationally Funded Mitigation Action, consisting of the mitigation measures which could be implemented only if international technical/financial assistance under UNFCCC becomes available. These mitigation options will be responsible for about 34% emission reduction by 2025 in comparison with BAU Scenario. Although these policies are the objectives of the Government in the «2025 Country's Vision for Development», reaching these objectives needs international financial/technical assistance under UNFCCC.

GHGs Emission Trend in BAU Scenario

Under BAU scenario, the energy sector emissions will increase from 486.1 million tonnes CO_2 equivalent in 2007 to 2,248.5 million tonnes CO_2 equivalent in 2025. This would mean a high growth rate of GHGs relative to the GDP growth rate. According to the study conducted, the average GHGs growth rate would be 8.4% per year with the annual growth rate increasing from 7.2% in 2007 to 9% in 2025 which would mean a slight acceleration in emission of GHGs.

GHGs Emission Trend in ODP scenario

Under the OPD scenario, the energy sector emissions of GHGs will increase from 486.1 million tonnes CO_2 equivalent in 2007 to 1,966.6 million tonne CO_2 equivalent in 2025. As a result, the average growth rate of the GHGs would stand at 7.63% per year. There will be variations in growth rate in future years. The growth rate will experience a shock in the initial years, solely due to implementation of strict energy pricing policies. In fact, from 2010 when the implementation of these policies would liberalize energy prices so that prices converge with FOB Persian Gulf prices, the growth rate will decrease in comparison to BAU. However, after 2015, the emission growth rate of GHG emissions under ODP will fall back to the same rate as emissions under the BAU scenario. This indicates that pricing policies though effective in the short-term, would have a limited impact on emission reduction in the long-term. However, on average, the total GHGs emissions under the ODP are 12.91% less than BAU in 2025.

GHGs Emission Trend in Mitigation Scenario

The impact of different policies and measures on GHGs emission rate under the Mitigation Scenario of energy sector are discussed in the context of three sub-scenarios, as follows:

- The aggregate effect of electricity sector mitigation policies,
- The aggregate effect of non-electricity sectors(demand side) mitigation policies and,
- The aggregate effect of all mitigation policies on emissions of the GHGs addressing the entire energy sector.

-The aggregate effect of electricity sector mitigation policies

The average growth rate of the emitted GHGs in this scenario stand at 7.04% per year which is close to that of the ODP scenario, but amounting to an average of 7.3% reduction in the emitted GHGs compared to the ODP.

However, if this group of policies were implemented, then the amount of the GHGs would stand at 1,728.0 million tonnes CO_2 equivalent in 2025- that is 12.1% less than ODP and 23.1% less than BAU emission in 2025.

-The aggregate effect of non-electricity sectors mitigation policies

This group of policies is the most effective. Surprisingly, the amount of the emitted GHGs is projected to rise to 892.1 million tonnes CO_2 equivalent in 2025 that shows 54.6% and 60.3% reduction of GHGs emissions in comparison to ODP and BAU respectively. The trend of the growth rate is also different compared to other policies. The growth rate reaches -3.1% per year in 2010 (the first year of implementation of the policies), then increases to its maximum value of 4.6% per year in 2015 and then decreases significantly to 1.7% per year in 2025. This decrease would mean significant superposition effect while policies are focused on demand side mitigation. The average growth rate during the period would stand at 3.25% per year.

-The aggregate effect of all mitigation policies

The aggregate effect of electricity and non-electricity sectors with the dominating contribution of the non-electricity sector (demand side) projects the emission of GHGs to stand at 696.6 million tonnes CO_2 equivalent in 2025, which indicates reductions of 64.6% and 69.0% of GHGs emissions in comparison to the ODP and BAU scenarios, respectively. The trend of growth rate is similar to that of non-electricity sectors mitigation policies with the mean value of 1.91% per year.

Conclusion of Mitigation Policies in the Energy Sector

This study shows that the most effective policy relates to energy efficiency improvement of the end-use sectors. Iran could therefore plan to make the end-use sector less energy consuming by applying market policies such as provision of subsidies on efficient equipment for end users through targeting producers who manufacture low energy consuming devices. This would be the lead policy over 2010 to 2025, whereas other policies could be more effective as short-term or long-term levers. The second most important initiative would be to increase the share of natural gas in the industry sector, followed by the increased use of natural gas in commercial and residential sectors. It should be noted that the aggregation of policies in the electricity sector is more effective than the application of natural gas in industries and buildings over the medium term (i.e. before 2017). In 2017 the reduction in the GHGs emissions resulting from implementation of these policies is equal to that of the aggregation of all electricity sector policies which would mean that this group of policies on the supply side (i.e. the electricity sector) has a medium term effect and cannot compensate the increasing emission rate of the GHGs in the long-term. The most important policy in electricity sector would be to increase the efficiency of power plants. This will result in an average emission reduction of 4.2%. It is noteworthy that the increase in the share of CNG in vehicles would be the least effective policy resulting in an average reduction of 0.5%.

There is a huge potential for GHGs mitigation in the energy sector in Iran. However, major barriers include lack of financial resources and access to climate friendly technologies under the framework of UNFCCC.

Non-Energy Sector

Scenario Development

The non-energy sector includes industrial processes, agriculture, forestry, land-use change and waste sectors. The framework of the study for the non-energy sector is identical for all sub-sectors and is based on developing three different scenarios: BAU, ODP and Mitigation. The year 2000 is used as the base year and the period from 2000 to 2025 is used as the time horizon of the study. To the extent possible the data figures in all scenarios (BAU, ODP and Mitigation) are the same from 2000 to 2005 and this is due to the availability of actual data over this period at the time the study was conducted. In development of Mitigation Scenario, options in different non-energy sub-sectors are identified and prioritization is undertaken in order to eliminate alternatives with lower potential of implementation in the country. We used several criteria to assess the options, the most important of which are: the cost of the selection including initial investment outlay, operation and maintenance costs and cost per unit of saved carbon; GHGs mitigation potential; environmental side effects; consistency with government programs; public acceptance; etc.

BAU Scenario Results for Non-energy Sectors

- *Industrial Processes:*

In developing the BAU scenario in industrial sector, an increase of about 150% in GHGs emissions is predicted in 2025 compared with 2000. The causes of this increase are prognosticated to be due to an increase in cement production from 23.9 million tonnes in 2000 to 77.7 million tonnes in 2025; an increase in steel production from 6.6 million tonnes in 2000 to 25.3 million tonnes in 2025; an increase in aluminum production from 116,000 tonnes in 2000 to 1,846,000 in 2025. Since 2000, nitric acid production has remained constant at 170,000 tonnes per year and it is anticipated to remain constant for the balance of the time period.

- *Agriculture:*

The agriculture and livestock statistical data of 2000-2006, and in certain cases 1996-2006, published by the Ministry of Jihad-e-Agriculture, have been used to predict the growth rate of emissions under BAU scenario between 2005 and 2025. The total CO_2 equivalent emissions from enteric fermentation, manure management, rice fields, burning of agricultural residues and agricultural soils increases from 42,993 Gg in 2000 to 52,025 Gg in 2025.

- *Forestry:*

In forestry sector, the rate of CO_2 emission and uptake is estimated based on analysis of the collected data for wood harvesting, plantation, forest rehabilitation, etc. in 2005 for five phyto-geographic regions and comparison of the results with 1994 and 2000 data. The analysis shows that there will be an increase of about 136% in CO_2 emission in 2025, compared with 2000. Fuel wood consumption and forest harvesting for commercial wood demand would have the highest contribution to this increasing figure.

- *Waste:*

In developing BAU in the waste sector it was assumed that: the municipal solid waste generation rate is about 0.8 kg/capita/day, the fraction of biodegradable materials is 0.18 with actual degradation of 77%, the per capita average amount of water consumption is 250 lit/day of which 80 percent of will turn into wastewater, and the average growth rate of CH_4 emission from industrial wastewater is about 20% between 1997 and 2000 (based on the inventory report). Based on these assumptions an increase of GHG emission up to 45% until the end of 2025 is predicted; from 892.57 Gg in 2000 to 1,663.16 Gg in 2025.

GHGs Emissions Trend in the BAU Scenario of Non-energy Sector

GHGs emissions trend under the BAU scenario indicates an increase in GHGs emission from 98,000 Gg in 2000 to 187,000 Gg in 2025, with annual average growth rate of 3.6%. In addition,, industrial processes and agriculture dominate accounting for more than 70% of the total non-energy sector emission under the BAU scenario.

ODP Scenario Results for Non-energy Sectors

- *Industrial Process*

The CO_2 equivalent emission of GHGs from industrial processes attributable to cement, iron and steel, aluminum and nitric acid production industries by 2025 would stand at 50,376.2, 45,079.1, 9,800.5 and 499.1 Gg, respectively.

- *Agriculture*

«The Agricultural Development Plan of Iran-2020 was used for developing the ODP in the agriculture sector. It was assumed that the annual population growth rate of livestock for dairy cattle stands at 1% and -8% and -4% for sheep and goats, respectively (due to the policy of substituting small livestock with large ones). In addition, the annual growth rate for wheat, barley and rice stand at 2%, 1.4% and 2.3%, respectively. Based on these figures, the total CO_2 equivalent emissions from enteric fermentation, manure management, paddy fields, burning of agricultural residues and agricultural soils will increase from 42,993 Gg in 2000 to 52,728 Gg in 2025.

- *Forestry:*

Implementation of the official development plans which includes protection of natural resources, increased distribution of fossil fuels among villagers and tribes and increased forest rehabilitation operation and afforestation, would result in an annual emission reduction of 10% compared to the present levels which amounts to net emission (uptake) of -1,143.9 Gg CO_2 in 2025. It is predicted that the net amount of CO_2 emission in forestry and land-use change will reduce to zero at the juncture of the 7th FYDP.

- *Waste:*

The main strategies under the ODP which would affect the GHGs emissions trend in the waste sector include implementing the rural waste management plan through establishment of landfills, increasing the solid waste production rate in urban and rural areas, reduction in wastewater generation through rationalizing consumption and enhancement of wastewater collection network as well as introduction of modern wastewater treatment plants. The implementation of these measures in waste sector indicates improvement in waste management programme, although biogas recovery was not included in the programme.

GHGs Emissions Trend Under the ODP Scenario for Non-energy Sector

The pattern of GHGs emissions under the ODP scenario of the non-energy sector shows an increase in GHGs emission from 100 million tonnes in 2000 to 225 million tonnes in 2025 with an annual average growth rate of 3.3%. The industrial processes and waste sectors have the highest growth rate in GHGs emissions under the ODP Scenario. The reasons for rapid emissions growth in industrial processes in 2010 are development plans of the cement and iron and steel industries, while in waste sector it is the result of waste disposal management in landfills unequipped with gas recovery systems.

Mitigation Scenario Results

- *Industrial Processes:*

The mitigation scenario in industrial processes consists of different policies and measures that would affect the GHGs emission trend in cement, iron and steel, aluminum and nitric acid production, as follows:

Cement industry: using industrial by-products to produce 30% of cement as blended variety;

Iron and Steel: using direct reduction and up to 20% recycled steel scrap.

Aluminum industry: use of appropriate methods and controls to reduce the emissions of PFCs in Anode Effects process, which could reduce the emission factor from 0.53 to 0.05 kg PFC per tonne of produced aluminum;

Nitric acid production: decomposition of N_2O with an average efficiency of 90%, which would result in reduction of emission factor from 7.5 to 1.8 (kg N_2O/tonne produced acid).

- *Agriculture:*

Anaerobic digestion of manures: manure management by using small and medium scales digesters (anaerobic lagoons) in industrial dairy farms can be considered as effective methods of managing animal wastes (production of fertilizer and biogas recovery), which would result in reducing GHGs emissions;

Reducing rice cultivation area and period of flooding: reduction of 200,000 hectares of paddy fields by 2025 which would result in reduced methane emissions;

Reducing the amount of chemical fertilizers applied in agricultural soils: an annual reduction of 5% in nitrogen-containing fertilizers from 2010, which would results in a reduction of 1,699,000 tonnes in 2000 (net nitrogen content) to 787,000 tonnes in 2025;

Improvement of irrigation method: intermittent flooding and drying of lands rather than continuous flooding could be applied to about 250,000 hectares of paddy fields;

Preventing crop residue burning: methane and nitrous oxide emissions would increase from 9.93 and 0.21 Gg in 2005 to 15.95 and 0.34 Gg in 2025, respectively. The mitigation potential in this sector would be realised through a 70% reduction of burning practices and use of the agricultural residues as feed for livestock.

- *Forestry*

Two main mitigation policies include forest and rangeland management and rehabilitation of forests by afforestation and reforestation. The latter includes prevention of livestock from overgrazing the rangelands and forests, reduction of illegal forest harvesting and land use change by 20% per annum, supply of fossil fuels to decrease wood harvesting by 10% per annum and 20 % GHGs reduction through the reforestation and forest rehabilitation by the end of 2025. It is expected that the implementation of these measures would result in the net CO_2 emission of the forestry sector to bottom out at zero in the time frame of the 6th Five Year Development Plan (2015-2020), while after 2020 becoming a source of emission again.

- *Waste:*

Solid Wastes: The main mitigation measures in the solid waste sector include commissioning sanitary-engineering landfills with appropriate biogas collection and recovery systems as well as changing landfill sites from anaerobic to semi-aerobic. These measures would result in 50%-80% reduction in methane emission from solid waste sector. Recovery of up to 100% of the emitted methane is also feasible by application of well-designed facilities. In terms of electricity production from landfill gas, it is assumed that 2% of methane will be recovered from landfills by 2025 for electricity production, which can be increased to 15% through international cooperation platforms such as CDM. Proper waste collection and suitable transportation to disposal site, proper planning, collection frequency, collection method, as well as capacity and type of waste containers, especially in hot zones of the country could reduce methane emissions. This reduction is predicted to amount to about 2% by 2025. Recycling, source separation and public participation have great potential for mitigating GHGs emissions from the solid waste sector. We assume that based on an expenditure of more than 8.8 billion Rials for training courses and workshops, a reduction of up to 12% in GHGs emissions till 2025 would be possible.

Liquid Wastes: optimization of wastewater collection and treatment, utilization of facilities and equipment suitable for country conditions, wastewater reuse and recycling, methane recovery from anaerobic wastewater/sludge digesters and public/industries training for improving water consumption patterns would result in 36% reduction of GHGs by 2025.

GHGs Emissions Trend in Mitigation Scenario for Non-energy Sector

GHGs emission in the non-energy sector would increase from 100 million tonnes in 2000 to 180 million tonnes in 2025, representing an annual average growth rate of 2.4 %, while under the ODP scenario the growth rate would be about 3 %.

Overall Mitigation Assessment

Considering the mitigation options in both the energy and non-energy sectors, as described above, it is obvious that Iran enjoys a significant GHGs mitigation potential. The energy sector with a mitigation potential of more than 1,270 million tonnes of CO_2 equivalent by 2025 has the largest potential followed by waste, agriculture, industrial processes and forestry sectors. GHGs emissions under the ODP scenario would increase from 490 million tonnes in 2000 to 2.2 billion tones, representing an annual growth rate of 6.2%, while under the mitigation scenario it peaks at 890 million tonnes of CO_2 equivalent, representing an annual average growth rate of 2.4%. This point to an enormous potential for GHGs mitigation in the country. Actual implementation, however, would be contingent upon receipt of financial and technical assistance under the UNFCCC. In 2025 the potential for GHGs mitigation in non-energy sectors would be about 54 million tonnes CO_2 eq., with waste sector accounting for some 28 million tonnes, having the highest potential, while forestry with 6 million tonnes would have the lowest potential; in GHGs mitigation.

Vulnerability and Adaptation Assessment (V&A)

Iran is highly vulnerable to the adverse impacts of climate change. It is a country with arid and semi-arid areas, limited water availability, low forest cover, liable to drought and desertification, prone to floods, high urban atmospheric pollution, fragile mountainous ecosystems and finally an economy highly dependent on production, processing and export of fossil fuels. The V&A study addressed climate variability and climate change modeling, water resources, agriculture, forests and rangeland, coastal zones, human health, biodiversity, and the impact of response measures- the latter assessing the vulnerability of Iran's economy to measures taken by Annex I Parties in reducing their oil and gas demand.

Climate Variability and Change in Iran

Climate Variability

Based on meteorological data of 1960-2005, the minimum and maximum temperatures, precipitation (the amount and the number of days with precipitation higher than 10 mm), wind speed, dew point temperature (as an indicator of humidity), cloudiness and daylight hours have been studied in seasonal and annual timescales. The analyses of results demonstrate that:

Temperature: temperature has risen between 2.5 and 5 degree Celsius on average, the increase in minimum temperatures is more widespread than the maximum temperatures, the discrepancies are remarkably higher in large, heavily populated and industrialized cities and due to the pattern of higher minimum temperatures, the daily temperature variability has reduced almost everywhere. There are also cities with clear temperature descent rates.

Precipitation: Southwestern parts of the Caspian Sea, northwest and west of the country have experienced the highest rate of reduction in the amount of their annual precipitation, i.e. the number of days with precipitation higher than 10 mm have reduced in the west, northwest, and southeast of the country whereas precipitation has increased in other regions except in the southeast of the Caspian Sea.

Wind: Over the period 1960-2005, the highest rates of decrease of wind speed are seen in central part of the country as well as in the northeast.

Humidity: The dew point temperature which is an indicator of humidity has consistently decreased in most parts of the country except in the north and northeast parts.

Daylight Hours: A rising rate pattern is visible everywhere throughout the country. The highest rate of increase is seen in the northwest of the country.

Cloudiness: The number of the days with clear skies changes between −12 to 12 per decade with the highest rise and fall in the number of the days with clear skies observed in a relatively small area of the country in the cities of Shahroud and Gorgan that could be due to the effect of the Alborz Mountains range on the climatic condition at different places.

According to MAGICC-SCENGEN (HadCM2 and ECHAM4 Models in combination with 18 available emission scenarios), until the year 2100, both models predict a higher temperature nationwide with very little variation. The temperature will rise between 0.4 to 3 degrees Celsius based on one model and between 0.5 to 4 degrees Celsius based on another model. However, there are remarkable differences between the projected changes in precipitation and its spatial distribution. According to HadCM2, the northern half of the country will see a rise in the amount of precipitation, while the southern half of the country will suffer a net loss in precipitation.

According to LARS-WG Weather Generator model and based on the data of 43 synoptic weather stations, the climate of the country has also been forecasted during 2010-2039 and the results have been compared with observations during 1976-2005 period. The results indicate that the amount of precipitation will, on average, decrease throughout the country by 9% between 2010-2039 compared with the 1976-2005 period. However, the number of heavy and torrential rains will increase by 13% and 39% over the same period, respectively. Temperature projections show an average increase in the amount of 0.9 degrees Celsius and minimum and maximum temperatures will on average rise by 0.5 degrees Celsius. The rise is more pronounced during the cold season. The number of hot days in most parts of Iran will increase. The highest increase will occur in the southeast of the country by 44.2 days. The study has also revealed that the number of freezing days in most parts of the country will decrease. The highest decrease will occur in the northwest of the country with freezing days decreasing by 23 per annum. Study of the changes in the number of wet days during 2010-2039 indicates that it will increase in some areas in the northwest, center, south, east, and southeast of the country. In other parts of the country the number of wet days will decrease. The highest decrease will occur in the cold season. The study on the number of dry days shows an increase in many parts of the country. The highest rise at 36 days is expected to occur in the west and southeast of the country.

Water Resources

Iran is located in the arid and semi-arid region of the globe with approximately 70% of the area in the dry and semi-arid region. In addition, in recent decades, climate change has also adversely affected the country's water resources through manifestation in the form of frequent droughts and floods that cause severe damage to water resources and poses a major problem in water management. In fact, watershed degradation is an outstanding factor in the overall water crisis that has resulted in reduced production capacity of soil and water resources.

Iran receives approximately 413 bcm of water from precipitation per annum, from which 296 bcm is unutilized through evaporation and evapotranspiration. In 2005, renewable water resources were estimated at 130 bcm, of which the total accessible water with return flow was estimated at about 111 bcm.

Some 105 bcm of the total renewable water is in the form of surface water and an estimated 25 bcm is stored as groundwater resources. At present, average renewable water per capita is about 1,900 cubic meters (2009), however, due to the increasing rate of population growth and the impacts of climate change, it is expected that the per capita water availability will be reduced to 1,300 cubic meters per capita by 2021.

Water supply projects covering more than 98% of urban areas and nearly 67.5 % of rural areas are being planned. Around 32 bcm of industrial, municipal and agricultural wastewaters flow into both surface and ground water resources, which need to be managed. Based on the estimated added value of major sectors in the national accounts and the volume of water use based on 2009 prices, the average added value is about 120 rials per cubic meter. The calculated gross yield cost of water is about 1,740 rials per cubic meters for agricultural water, 9,901 rials for domestic and industrial water and 10,596 rials for rural water. The total gross investments in the water sector based on 2001 prices are about 63,000 billion Rials; 20% of which amounted to investment by the private sector. In Iran, gross investments in the water sector are about 1.2% of gross domestic product (GDP) and 5.8% of total gross investments.

About 70% of grains and 90% to 100% of other crops and fruits are grown on irrigated lands which indicate the vital importance of water management for food security.

- ***Impact of climate change***

Modeling results indicate temperature and precipitation changes in the range of ±6°C and ±60%, respectively. Temperature rise not only increases evaporation and decreases runoff, but also accelerates melting snow that causes increased rate of runoff in winter and a corresponding decrease of runoff in spring. Modeling results also show that at a constant level of rainfall, an increase in temperature of only about 2 degrees creates a rise of 27.3 bcm in annual volumes of evaporation and transpiration. Furthermore, the results prognosticate that except for three provinces, runoff in most basins will decrease. As an adaptation measure and in order to preserve the already depleted ground water resources and meet the increasing demand for water, it is planned to increase the utilization of surface water resources from the present level of 46% to 55% within the next 20 years. Potential of hydroelectricity generation is over 25,000 MW, of which 6,700 MW is currently harvested with about 6,000 MW under construction with the regulatory capacity of water dams with hydroelectric potential of about 41 million cubic meters in 2008. Due to the reduction of river runoffs, the efficiency of the hydropower plants will decrease with adverse impacts on dam construction plans. As an another adaptation measure, construction of artificial aquifers using underground dams as a means of storing large quantities of good quality water is being considered.

Agriculture, Livestock and Fishery

Agriculture sector of Iran accounts for about 18% of national GDP, more than 20% of employment, 85% of food supply, 25% of non-oil products and 90% of raw materials used in agro-industry. Agricultural activities in Iran are quite diversified and include production of various crops, fruits and nuts, greenhouse cultivation, agro-forestry, poultry, small and large livestock industries, apiculture, silkworm farming and fisheries. Temporal analogical procedures, computer modeling results and expert judgment were the primary tools used in the assessment of the sector's vulnerability and adaptation measures to mitigate climate risk. The proposed adaptation strategies were based on the evaluation of stakeholders concerns, as well as technical, economic and social factors. Simulations of future climate change in Iran indicate that changes in the amount and distribution of rainfall, as well as temporal and spatial changes in air temperature, will increase the occurrence of flooding and drought events. With that in mind, the following vulnerability assessments of *soil*, *water*, *agricultural crops*, *fisheries* and *livestock* were made and adaptation strategies proposed.

- ***Soil:***

Many areas of the country are prone to soil degradation processes resulting from erosion and the predicted reduced rainfall, which makes them more vulnerable to climate change and reduction in natural and agricultural vegetative covers that further accelerates soil erosion.

Rain fed agriculture is very much dependent on the rainfall and moisture of the soil. The short-term climate predictions indicate that the country will experience a decrease in mean rainfall and an increase in temperature that results in a reduction in soil moisture content. The long-term climate predictions indicate that this phenomenon will happen in the west and northwestern provinces of the country. Soil salinity is another major limiting factor in the agricultural development of Iran. About 27% of the land in the country is already saline to different degrees. According to the long-term climate predictions the soil salinity hazard will increase in severity in all parts of the country.

- ***Water:***

In 2004, close to 90% of the total national agricultural production came from irrigated lands. The arid parts of the country are more vulnerable to the impacts of poor quality water and water storage. According to the long-term climate predictions, the provinces and areas south of the Zagros Mountains range will experience the greatest decline in snowfall. This will have important consequences on surface and underground water resources and thus the availability of water for irrigation in these areas.

- ***Agriculture:***

Cereals, particularly wheat, are the most important annual crops produced in the county. The results of available predictions in time frames 2020, 2050 and 2080 based on 1990 indicate that under various scenarios of economic growth, cereal production will decrease down to 30% without the CO_2 effect and up to 10% with the CO_2 effect. For rain fed wheat production, yield reduction of up to 26% by 2025 and 36% by 2050 is predicted. For irrigated crops, the results of future weather simulation for 500 ppm CO_2 concentration in Khorasan Province has shown a 0.3-9.8% increase in yield, and 4%-16% decrease in the water requirement of sugar beet. In arid and semi arid areas, if crop water requirement increases due to climate change against the backdrop of inadequate water supplies, the production of irrigated crops, particularly cereals, will suffer. Most rice producing provinces will experience decreased precipitation in the future. Although rice is also very sensitive to temperature but the effect of temperature increase is not significant in most provinces. In some provinces, a decrease in temperature may render the province more suitable for rice cultivation. Frost is a limiting factor in the agricultural production of the northwestern provinces of the country. The rise in mean yearly temperature, particularly in the winter, could extend the growing season in these areas, and allow for cultivation of long maturing crop varieties, or rotation between two crops per year. Permanent crops such as fruits and nuts are particularly prone to cold and frost damage. The number of frost days in the areas under study will decrease in most parts of the country by several days. It therefore seems that the conditions for fruits and nuts production will improve in most major fruit producing areas of the country.

Biotic Stresses:

Biotic stresses in agriculture include pests, diseases and weeds which are affected by temperature, wind, humidity and rain. Increased winter temperatures will stimulate the growth and reproduction of insect pests and pathogens and increased rain and humidity may also increase the invasion of pests and diseases to farms and orchards. According to the predicted short-term future climate of the country, the maximum, minimum and average temperatures during winter months will increase. On the other hand, increased rainfall is predicted for some parts of the country. Therefore, the possibility of pest and disease outbreaks may increase in these areas. Coastal provinces in the north will experience the highest rainfall reduction in the country. This may lead to the migration of some pests and diseases to the neighboring provinces in the north.

Livestock:

Climate change, in particular temperature changes, will impact animal husbandry directly by affecting animal physiology, and indirectly by affecting the forage and animal feed production. Based on the temporal analogical results, small livestock, such as goats and sheep, are more vulnerable to future climate change in the country than large livestock, such as cattle and camels. Livestock species adapted to desert and arid climates such as camel are much less vulnerable to future climate change. Higher rainfall and warmer temperatures, particularly in winter, probably improve the conditions for industrial animal production units in the north and northwestern provinces. There will be a decline in quality and capacity of rangelands, as well as rain fed forage production in provinces that experience reduction of rainfall and temperature rise. In addition, poultry production in these areas, due to more frequent occurrence of heat waves in summer, will face greater difficulties.

Fisheries:

- ***Caspian Sea***

The water inflow from Volga river may significantly change the present patterns of sea currents. The variations in air temperature may also divert the present patterns of wind currents. Due to the increased influx of nutrients from the river's algal blooms, extinction of some plankton and benthos species and an outbreak of certain diseases in the ecosystem may occur more frequently. Due to changes in air temperature, reduced water inflow in the rivers and water pollution, the conditions for spawning, reproduction and growth of migratory fish species may be less favorable in the future. The birth rate of the Caspian seal (Phoca Caspica), the only mammalian species of the Caspian Sea that requires cold and sub- zero temperature for birth are already endangered.

- ***Persian Gulf and the Sea of Oman***

The ecosystems of the Persian Gulf and the Sea of Oman are already under stress due to high temperature and salinity, decrease in oxygen supplies, as well as pollutants from the petroleum industry in the region and this pattern will intensify in the future. The changes in the Indian oceanic currents may adversely affect fishing activities, particularly tuna fishing. On the other hand, the conditions will become more favorable for salt and heat tolerant species, thus increasing their stocks in these ecosystems. Migratory fish species will suffer due to the degradation of their reproduction habitats, while the pelagic species and the benthic and semi-benthic fish species will experience greater stress. Outbreak of certain diseases in the marine ecosystem is another strong possibility.

- ***Aquaculture and Inland Fisheries***

Production of cold water fish, warm water fishes and shrimp constitute the largest aqua cultural activities in Iran. Trout which is the only cold water fish produced in Iran requires low temperature and high oxygen, thus, making it very sensitive and vulnerable to temperature rise and future climate change. Warm water fish species and shrimp production are less vulnerable to the future climate changes than cold water fish species. However, reduction in the quantity and quality of water supplies can adversely influence the integrity of fish farm operations in the future. With adequate water supply, the future climate change could provide the opportunity for increased yield per unit area, and in some cases, two harvests per year.

Adaptation Programs

Since climate change manifestations are already evident in Iran, the implementation of the following measures needs to be accelerated to mitigate the physical, economic and social impacts of climate change.

- ***Agriculture:***

In *agriculture*, increasing the production level up to the potential/theoretical crop yields is a first priority. Sustainable soil, water and crop management at farm level, transfer of knowledge and policy making at the national and regional levels towards enhancement of job security and providing incentives for agricultural production in rural communities are also vital. Enhancing soil management by increasing organic content matter that includes conservation tillage, soil fertility and salinity management are other items high on the national agenda. Plant breeding and appropriate agronomic techniques for seeding and seedling management are among adaptation measures. Management of weeds, pests and disease by monitoring their population growth patterns and migration routes, while preparing for the possible appearance of new species are amongst other possible measures. In *livestock*, protection of diverse Iranian animal breeds, striking a balance between the number of animals and grazing capacity of pastures, gradual replacement of low with highly productive breeds in industrial and semi industrial areas, increase forage production in the country through improved irrigation management and water use efficiency in irrigated forage farms, introduction of new drought resistant cultivars, reduction in forage losses and wastes, re-vegetation and improvement of rangelands, utilization of marginal and saline lands for production of xerophytes and/or halophyte forages and expansion of integrated production systems and prediction and management of outbreak of insect pests and pathogenic agents feature among adaptation measures. For *water management* in agriculture sector, increased water productivity and enhancement of water use efficiency including: reduction of water losses, utilization of unconventional water resources and improved irrigation methods such as pressurized systems are recommended. Selection of appropriate crops for cultivation will also have positive effects on water management and efficient water use at farm level.

- ***Fisheries***

Appropriate utilization of available resources and economical enhancement of production and fishing management are the fundamental adaptation strategies for this sector. This will improve the income security of the producers and reduce the pressure on marine stocks. Education and research, pollution prevention in marine environment and improved fishing methods are among the adaptation methods.

Forests, Rangelands and Deserts

Impact of climate change on biological diversity is already being evidenced by shifting migration ranges of insects and animals, modified flowering and fruiting cycles and species extinctions. Additional negative climate change impacts on forests includes: drought in Zagros forests in the west or flooding in Hyrcanian forest in the north or in central parts; conversion of forests to agricultural lands, grassland, steppe, or desert in the north, west and center; increased vulnerability to pests, fire and invasive species. The prospect of broad-scale growth of forests is slowing due to climate change. Climate change effects on rangeland have several similarities with forest ecosystems from vegetation cover, hydrological cycle and soil erosion perspectives. Our current knowledge and capacity is insufficient for reliable prediction of adaptations.

Forests

To assess the impacts of climate change on forest, rangelands and desert ecosystems, it is necessary to work on vegetation cover, water resources including underground and surface water and other matters like soil. Anthropogenic impact on vegetation cover, hydrological cycle and other sectors will result in changes in the balance of carbon stock and storage. Forests of Iran have undergone serious fragmentation and degradation from roads, agriculture and development, and are thus impeded in their ability to migrate as their local climate changes. Temperature and precipitation patterns in the *Hyrcanian* forest in the north of Iran have changed during the last half a century. A warmer climate and changes in precipitation precedents will cause disparate effects on forest ecosystems, making some species contract while others expand. Increases in CO_2 concentration will compound this effect in some systems while dampening the impact in other systems which may lead to extinction of some species. The open spaces of rangeland ecosystems, compared with the forest ecosystem may be more susceptible to invasive species as the consequence of climate change. In rangelands ecosystems, with limited water resources, plants employ special adaptation methods to survive. One of the strategies used by tolerant plant species is increasing root length to obtain and use available water in different soil layers. These species are more tolerant, but with changes in underground water resources, they will also face the challenge of critical conditions. Mangroves forest, which is a very sensitive ecosystem to climate change, is situated in the southern part of Iran in the Persian Gulf areas. Mangrove forests also protect sea grass beds and coral reefs from deposition of suspended matter that is transported seaward by rivers. The Persian Gulf contains the most extensive mangroves, which help stabilize a large part of the shoreline. Forming a dense barrier between sea and land, the mangrove is a crucial food reservoir for coastal people who rely on its supply of shrimp and crabs, as well as its wood for fuel. It is also a vital host to a number of endangered species. For the time being, the area is under stress from urbanization, industrialization and agriculture, and is experiencing impacts from timber and petroleum exploitation along the coastline of the Persian Gulf.

- ***Adaptation measures for forests***

Sustainable forest management criteria provide a framework into which adaptation strategies can be incorporated. These include: reduce present threats, avoid fragmentation and provide connectivity, maximize the size of management units – decision making on a large bio-geographical scale, provide buffer zones and flexibility of land uses, represent forest types across environmental gradients, protect mature forest stands, protect functional groups and keystone species, protect climatic refuges, maintain natural fire regimes, silvicultural techniques to promote forest productivity, prevent conversion to plantations and practice low-intensity forestry, maintain genetic diversity and promote ecosystem health via restoration, assist migration with species introductions to new areas and protect most highly threatened species in situ.

Rangelands

Climate change has impacted the Iranian rangelands in the following areas: decreasing vegetation cover and reduction of forage production; soil erosion caused by the destruction of plant cover; changing hydrologic cycles and decreasing the underground water level; increase of plants and diseases with destructive effect on agriculture sector; fires in rangelands; adverse effect on regeneration of plants and wildlife; extinction of sensitive species and increasing invasive plants; and social and economic consequences such as immigration. Based upon expert judgments, desertification leads to 1% annual quantitative and qualitative loss of Iran's natural resources. In 2000, the amount of this degradation was 1.5 million hectares. If this rate of desertification continues, the amount of land affected for the years 2010 and 2050 would be estimated to be 15 million and 75 million hectares, respectively.

- ***Adaptation measures for rangelands***

Adaptation options in rangelands include: represent grassland types across environmental gradients in protected areas, protect native-dominated communities as appropriate per system, minimize fragmentation by land use changes and roads, enhance connectivity versus fragmentation, practice low-intensity and sustainable grazing practices, prevent and control the spread of invasive species such as pathogens, grassland restoration, maintenance of natural fire regimes, provision of buffer zones, identify and protect functional groups and keystone species and protect climatic refuges at multiple scales.

Coastal Zones

Iran is a coastal country that is surrounded by three main water bodies at its northern and southern borders with coastlines of more than 3,500 km which is the habitat of more than 10 million Iranians. The annual precipitation on the Caspian coasts ranges from 200 mm in the east coasts to more than 2000 mm in the west coasts, whereas it is less than 50 mm in the coastal area of the Persian Gulf and the Oman Sea.

The dominant climate in the Caspian area is subtropical, the sea level is 27m below open sea level with fluctuations of up to 340 mm/yr. Agriculture, tourism and fisheries are the primary economic activities of the people that affect all other jobs in the region. Most of the economic activities are focused in a narrow coastal belt with a 10km width.

The length of the Iranian coastlines in the Persian Gulf is more than 1,700 km which are mostly tide-dominated but there are some wave-dominated and river-dominated parts also. The Iranian side of the Persian Gulf is mountainous and spreads northwest. The Persian Gulf is the hottest sea in the world with the temperature reaching 50°C in summer that in combination with strong winds increases the evaporation in the region resulting in high salinity. It is the habitat of coral reefs, mangroves, sea mammals and many other valued species. More than 5.5 million people live in the Iranian coastal provinces of the Persian Gulf and 70% of them settle within a 100 km width of the coastal zone. Because of fresh water availability and vast productive coastal plains in the northwestern parts of the Persian Gulf, this region is one of the most important agricultural regions in Iran but the importance of agricultural activities decreases eastward where the importance of aquaculture activities increases. Fishing and petroleum related industries are other primary activities of this region. The most important commercial ports of Iran are located along the Persian Gulf and the sea of Oman.

The Iranian coastline of the Oman Sea is more than 800 km long, with a very hot and arid climate, mean annual rainfall of less than 100 mm and extremely high rainfall variability. The tidal range is generally between 2 and 4 m which increase westward. The southwest monsoon is longer and stronger which begins in April and is very strong from June to September. Occasionally, tropical storms and cyclones occur usually during May–June and October–November and cross the west coast of the Arabian Sea but are fewer in the Oman Sea and along the Iranian coast. While the eastern side of the Oman Sea is influenced by monsoon, the western side is subject to the arid subtropical climate system. Aquiculture, mostly shrimp farming, trading, shipping and fishing are the main activities of people in this region.

Climate change impacts on coastal zones

- ***Caspian Sea***

The Caspian Sea, being a closed basin, demonstrates much higher rates of sea-level change (up to 340 mm/yr) than the oceans and it experienced a full sea-level cycle with a rise of 3m between 1929 and 1995. The sea-level fluctuation impacts the basin architecture and changes the coastal morphology which lead to forming new aquatic environments and forces living organisms to migrate from their old habitats and find new settlement places. In addition, the sea level oscillations can spread human induced pollutants into the marine and coastal environments. As the Caspian coast is the focal point for economic activities in the north of Iran and on the other hand is the most biologically productive area of the sea, any changes in sea level has a great influence on the region. A slight increase of the Caspian Sea level is expected in the first half of the 21th century but due to a large variability of precipitation over the Volga River basin (the major input of the sea) a definitive statement concerning the future impact on sea level cannot be made with confidence at the moment. The rise, along with increasing temperature, will retard the sea's water circulation and consequently decrease the oxygen and nutrient exchange in the water column while increasing organic bottom matter. Higher temperature, decreasing precipitation plus human activities in the watershed will result in desertification in the eastern parts of the Caspian coastal area. River discharge reduction caused by the changing climate and continuing human activities will alter the hydrodynamics and sedimentological conditions of river mouths and augment coastal erosion and inundation. Natural sea level rise in the Caspian Sea is not dangerous for aquatics and their habitats but is very destructive for man-made structures in the fluctuation zone. During a sea level rise, the narrow Iranian coastal area and its population of more than 2,000,000, plus important infrastructures along the coast like ports, harbors, power plants, maritime industry structures and fish farming will be very vulnerable to such changes. Based on some scenarios, a sea level rise will inundate more than 300 km^2 of the coastal area which results in an estimated damage in the range of USD 5b.

- ***Persian Gulf***

The average sea surface temperature of the Persian Gulf in some parts has risen up to 2.5°C during the last two decades. It is predicted that the increasing trend of atmospheric and sea surface temperature will continue as precipitation decreases on the average of about 0.6mm/yr in the next 100 years. In 2007 a hot summer and cold winter were observed in the region that were unprecedented in the last 50 years. The Persian Gulf has recently experienced high frequency recurrences of temperature related coral bleaching. Sea level rises of about 2.34mm/yr to 4.5mm/yr (up to 0.88m in the next 100 years based on some scenarios) are expected to be a problem in some low-lying areas (like the northwest Persian Gulf) and the coral communities. Long term sea level rise with 2-3 mm/yr in the Persian Gulf is not hazardous for the predominantly tide dominated coasts but when it is accompanied with increasing temperature and salinity, weakening the north wind and strengthening other wind currents, reduction of vertical mixing and increased layering of the water column, this combination will be especially dangerous for static target ecosystems. This region is also characterized by dust storms coming from the deserts of the west and southwest of the Persian Gulf that increases the suspended load of the water and its turbidity. Clearly the rise in temperature is already apparent as seen in the bleaching of the coral reef in the Persian Gulf during the last decades. Decreasing precipitation and the consequent reduction of river discharges accompanied with direct human activities create conditions for seawater intrusion into the coastal aquifers in the northwest flank of the Persian Gulf. The environmental changes along with human activities define the Persian Gulf as a stressful environment for its organic life especially the coral reefs and mangrove forests.

- *Oman Sea*

Tropical storms in the Indian Ocean are the primary factor for creating long waves in the Oman Sea. Their maximum speed and motion track, their durability and frequency are variable. The study of these storms reveals that their frequency and strength and the probability of leading them to the Iranian coasts have increased during the last 30 years as was witnessed by tropical storm Guno that hit the coasts in 2007. The increasing strength and frequency of the storms in combination with the sparse vegetation of the area will enhance soil erosion and carry large amounts of alluvium to the Oman Sea during flash floods. The stronger waves will also add to coastal erosion in the predominantly rocky shores of the area.

Adaptation Programs

- *Monitoring*

Monitoring programs are effective ways to control and follow up changes in the marine and coastal environments as a result of climate change. There are at least five climatologic and four synoptic weather stations plus four tide gauges and one buoy along the Caspian Sea coasts and there are some 17 coastal weather stations, nine tide gauges and several buoys in the southern coasts but there is a need to add more oceanographic stations to the network to achieve a better understanding of the changes. Regional and international cooperation is a key factor in studying and monitoring the coastal area and marine environments. Currently Iran is involved in some international and regional programs such as CEP (Caspian Environment Program), ROPME, GCRMN and ReefCheck and it is recommended that it becomes involved in other programs such as GOOS, GOSUD and JGOFS.

- *Integrated Coastal Area Management*

Integrated Coastal Zone/Area Management (ICZM, ICAM) promotes sustainable coastal development by adapting the use of natural resources to avoid serious damage to the environment. The ICZM program is relatively new in Iran but it is a high priority item for all governmental coastal related organizations.

- *Capacity of Coastal Area for Adaptation*

The first step in extending an effective adaptation plan is to develop a coastal classification scheme based on the natural and socio-economic properties of the coasts. According to the present classification the more sensitive environments to climate change effects include: coral reef (e.g., Kish Island in the Persian Gulf), mangroves (e.g., north of the Strait of Hormoz), wetlands (e.g, northwest of the Persian Gulf, east and west of the Caspian Sea), bays (e.g., east and west of the Caspian Sea coastal area), estuaries (e.g., north of the Persian Gulf) and river mouths. Capacity building should target the needs of each coastal segment based on its natural and socio-economic characteristics but generally it is focused on training programs for inhabitants especially in monitoring, protection and restoration plans.

Human Health

In Iran the major climate change health related issues include malaria, leishmaniasis, cholera, diarrhea, air and water pollution and some natural disasters. Two periods 1995-2005 and 2010-2039 were studied for climate change impacts (mostly due to temperature and precipitation) on human health. During 1995-2005 the epidemiologic study of the leishmaniasis disease shows the outbreak of this disease and sudden surge of more than 175% was observed in Isfahan province and Kashan in 2003. Study on cholera also revealed outbreak of this disease in some provinces. In addition, usage of fossil fuels in urban and industrial areas creates air pollution that has longstanding effects on human health and other consequences related to ecological changes. According to climate modeling results, during the years 2010–2039, the provinces of North Khorasan, East Azarbaijan, Gilan, West Azarbaijan, Markazi and Kurdistan will experience a maximum of 1.4°C to a minimum of 1°C increase in temperature, which will cause a surge in the number of hospital admissions for diarrhea and cholera. The indigenous zones of malaria disease are largely located in Sistan and Baluchistan province, Hormuzgan and the sub-tropical part of Kerman Province. The majority of the registered cases of the disease in other provinces originate with non-Iranian immigrants from neighboring countries like Afghanistan, Pakistan, Iraq, Armenia and Azerbaijan. Easy access to clean drinking water, isolation and containment of sewage from water resources as well as training and promotion of awareness among the rural population are effective for adaptation. Compilation and application of the approved protocols require the bodies in charge to upgrade knowledge and train health workers in more than 24,000 health and treatment centers located in the urban and rural areas of Iran.

Biodiversity

Although no systematic research has been conducted to show the linkage between climate change and biodiversity in Iran, national documents on biodiversity and scattered conservation activities have addressed climate change as an influential factor on biodiversity. Given the existing limitations in resources, the primary tools and methods used for studying vulnerability and adaptation of biodiversity to climate change have been based on academic studies, expert judgment and individual meetings and interviews. Generally accepted data and information have been taken from national documents such as National Biodiversity Strategy and Action Plan (NBSAP). So far no official linkage is established between biodiversity and climate change and it is expected that such linkage be established during preparation of the Third National Communication.

Iranian habitats support some 8,200 plants species of which 2,500 are endemic, over 500 species of birds, 160 species of mammals and 164 species of reptiles (26 endemic species). Rivers and wetlands including 22 international registered sites (By Ramsar Convention) with a total area of 1,481,147 hectares are considered as inland water ecosystems that are most valuable to climate change affecting biodiversity. The most important threatening factors to biodiversity are classified as follows: over exploitation of water resources and unsustainable development of agricultural development plans resulting in water scarcity so that inland water ecosystems are not functioning in a sound manner; over grazing and logging has reduced production of biomass in forests and rangelands of the country; unsustainable land-use conversions creating large scale habitat degradation and fragmentation; hunting and trapping practices have a direct negative impact on the population of wildlife and aquatics resulting in declining genetic resources; extended use of fertilizers and pesticides caused severe poisoning and utrification of the environment and water bodies; and natural drought that strikes large areas of the country causing significant socio-economic and natural difficulties. At present Iran is losing its biodiversity at an alarming rate. There is no convincing report on the existence of the two big mammals, i.e., Persian lion and Caspian tiger from their natural and endemic habitats during the last 50 years. Asiatic cheetah, Persian wild ass, Persian squirrel and three species of sea turtles are among critically endangered species and on the verge of extinction. According to scientific evidence many plant species are under severe threat.

Iran will experience a warmer and dryer climate during 2010-2039 resulting in increased water demand that could influence the timing of reproduction of animal and plant species and/or migration of animals, the length of the growing season, species distributions and population sizes and the frequency of pest and disease outbreaks. Some species may move pole-ward especially migratory species or upward in elevation from their current locations and many species are already vulnerable to extinction. During 2010-2039, the threshold for heavy and very heavy rainfall will increase which means that the number of floods will increase and heavy soil erosion and socio-economic catastrophes are expected. Vulnerability studies on the effect of changes in temperature, the number of hot days, the number of frost days and the number of dry and wet days also indicate significant loss of biodiversity.

Energy sector

Changes in regional temperature and precipitation patterns may have significant implications in the existing and future power system infrastructure. Weather and climate may affect all major aspects of the electric power sector, including thermal power plants, hydropower, solar and wind energies, transmission and distribution systems and end-user demand for power. A new study of the impact of climate change on the power and energy sector was not carried out during the course of the SNC as the estimates of the impacts and adaptation measures were made in this sector in the Initial National Communication. For more information on the vulnerability of energy sector as result of climate change and also adaption policies were explained very detail in Iran's Initial National Communication to UNFCCC.

Impact of Response Measures

The members of the Organization of Petroleum Exporting Countries (OPEC) continue to voice their concerns about the adverse impact of the implementation of response measures in reducing greenhouse gas emission on the oil exporting countries. Referring to Article 4.8 of UNCCC, OPEC is concerned that the agreed reduction targets will lead to a significant reduction of revenue from petroleum exports, with the result that OPEC countries will be unfairly affected by measures proposed to mitigate global climate change. The current study, aims to provide quantitative information on the impact of global climate change abatement policies generally on the revenue of OPEC countries and especially on Iran's economy as a member of OPEC. Based on a multivariable econometrics model, the Gross Domestic Product (GDP) was calculated as a function of independent variables: total private consumption, government expenditure, total individual investment and trade balance.

For estimating the impact of response measures on Iran's economy, oil revenue is considered as an exogenous factor which affects all economic indicators. For this purpose the impact of oil price fluctuation on macro-economic indicators was assessed in Business-as-Usual Scenario (where the oil revenues will continue with current pattern) and the following two scenarios: (1) 5% decline in Iran's oil revenues and (2) 10% decline in Iran's oil revenues as a result of response measures by Annex I Parties. The results show that with 5% reduction in oil income (Scenario 1), an average decrease of 1.12% per year occurs in GDP which will adversely affect the Total Private

Consumption, Total Individual Investment and Total Imports also decrease at a rate of 2.49, 2.09 and 2.12% per year, respectively. By considering a 10% reduction in oil income (Scenario 2) the indicators show a lower living standard in the country. In this scenario, an average of 2.33% decrease in GDP occurs which will adversely affect Total Private Consumption, Total Individual Investment and Total Imports decrease at a rate of 2.63, 2.23 and 2.25% per year, respectively. It should be noted that the effect of oil income reduction magnifies when considering the population growth rate which results in further decrease of per capita income and other welfare indicators.

Other Information

Other information in the Second National Communication includes information on:

- Research and Systematic Observation as it relates to the Global Climate Observation System (GCOS),
- Technology Needs Assessment (TNA)
- Climate Change Education (Article 6 of the Convention)

Global Climate Observation System (GCOS):

In this report climate observation systems were surveyed in the following five areas:

- Meteorological and atmospheric observations
- Oceanographic Observations
- Hydrometeorology Observations
- Terrestrial Observations
- Satellite Observation

Islamic Republic of Iran Meteorological Organization (IRIMO) is the national lead institution for weather and climate monitoring. IRIMO operates 230 synoptic stations. The network has an average density of one synoptic station per 12,200 km^2 which observe 33 meteorological parameters. About 59 of the synoptic stations are located in airports called «*Aeronautical Stations*», which in addition to standard synoptic observations, parameters that are normally applied to air traffic control are observed. The total number of rain gauge stations operated by IRIMO is 2,738 and the Ministry of Energy, which is responsible for water resources management in Iran; also operate 1,339 rain gauge stations and 675 evaporation gauge stations. IRIMO also operates 30 agro-meteorological stations. In marine meteorological stations the height and period of waves, seawater surface temperature, surface current velocity, surface current direction, seawater surface conductivity, wind direction, wind velocity, air pressure, air temperature, directional wave data and CTD profiles are observed. IRIMO has undertaken a major modernization program after 2003 to upgrade all technical and human components of the organization to meet the most global standards and provide vastly improved services to the user community including governmental authorities, general public, agriculture, industry and academia. This upgrading project addresses all components of the organization including:

- Observation,
- Telecommunications and information systems,
- Forecasting and climatology,
- Services to end-users and main sectors of activity,
- Research and training with special emphasis on Numerical Weather Prediction (NWP), oceanographic modeling and pollution.
- Meteorological and atmospheric observation

Oceanographic Observations

As oceanography is a multi-disciplinary field, several different organizations are responsible to collect the data and monitor the marine environment related to their field of expertise.

Of the 22 stations of IRIMO, 11 stations are in the Persian Gulf, seven in the Caspian Sea, two in the Gulf of Oman and two in the Strait of Hormuz. These stations have a close relationship with the WMO and NCDC. IRIMO is not yet involved in the GOOS program, however, it is planned to launch a ship for marine weather research by the end of 2010. NCC operates 65 stations that provide tide prediction information for the southerly water bodies. Iranian National Center for Oceanography (INCO) develops its own facilities and is in the process of deploying three deep-water mooring buoys in the Gulf of Oman and the Caspian Sea. In summary, the marine related organizations in Iran remain largely un-integrated in their oceanographic data collection efforts related to their specific needs and the lack of an integrated oceanographic data collection program in Iran creates obvious limitations and discontinuity in the collected oceanographic data. Accordingly, to fulfill the present gaps in the current oceanographic observation system, the Iranian National Center for Oceanography (INCO) has prepared an integrated program for collection and management of oceanographic data as well as for capacity building. Establishment of the National Marine Data Directory is another important action, which has been taken by INCO to help data dissemination in the country.

Hydrometeorology Observations

Hydrometeorology stations comprise of 2,048 facilities with advanced recording rain gauge stations, 526 storage rain gauges, 237 snow survey stations, 567 evaporation monitoring stations, 1,019 hydrometer stations (875 silt recording stations, 880 for water quality), 9,540 observation wells and 8,199 selective resources (5,898 selective wells, 793 springs, 1,508 qanats or subterranean irrigation channels). There is, however, great need for improvement of network, operation and primary processing of the data and most importantly the interrelationship among these elements.

Terrestrial Observations

In Iran, like other developing countries, terrestrial observations, especially in the agricultural sector, are not developed as atmospheric networks. The terrain changes related to climate change, like changes in cultivatable area, soil degradation, land use and land use change, afforestation, deforestation, carbon flux and carbon fixing in the vegetative cover and soil have become increasingly important given the need of UNFCCC for data on terrestrial carbon sources and sinks in the global carbon cycle. The agricultural observations have been mostly surface based. Moreover, monitoring of the agriculture resource base by traditional surfaced-based methods is generally costly, time consuming, laborious and as a large-scale undertaking practically impossible. Therefore, satellite and space–based observation in conjunction with the in situ observations and ground checks are practical sources of measurement that have to be developed and used in the country. The following sectors are to be covered: agricultural soils, carbon pool, forests and rangelands and agricultural meteorology. The country's participation in satellite observation of atmosphere, land and water to monitor climate change is divided in two sections. The first section includes the MESBAH satellite program and Small Multi Mission Satellite program. The second section includes the operation of data receiving stations for climate change observation.

Participation in Global Climate Observing System (GCOS)

- ***Global Surface Network (GSN) Stations:***

Iran hosts seven GSN stations that observe major parameters such as temperature, precipitation, cloudiness, dew–point, horizontal and vertical visibility, cloud base height, cloud types, radiation, pressure (QFE, QFF, QNH), wet and dry-bulb temperatures, maximum and minimum temperature, humidity, wind speed and direction, sunshine duration, evaporation and present weather.

- ***Global Atmospheric Watch (GAW)***

A Global Atmospheric Watch (GAW) station has been regularly observing air pollution and meteorological parameters in Firoozkooh (in the Alborz mountain range 150 km east of

Tehran) and is sending the data to the world ozone and UV radiation center in Toronto since 1995. It should be noted that the station is not included in the GCOS network because of technical and spare parts issues that originate with the supplier.

Technology Needs Assessment

Economic growth of Iran especially in the energy industries has caused rapid increase in greenhouse gas emissions and it is expected that this trend will continue during the next two decades. On the average it is expected that economic growth will be about 3.4% and 3% during 2011-2020 and 2021-2030, respectively. This pattern of economic growth indicates that there is a need for investment in energy intensive industries like oil and gas, petrochemicals, cement, iron, steel and power generation which have previously caused rapid growth in GHGs emission. Therefore, transfer of advanced technologies in energy sector which contributes to more than 75% of the national emissions is crucial for climate change mitigation. Two main strategies are followed by various mitigation technologies, which are energy efficiency improvement and renewable energies. In this report all technologies to abate GHG emissions in the energy sector were surveyed in energy supply, energy transmission and distribution and energy demand sectors. Based on the Analytic Hierarchy Process (AHP) approach and its software (Expert Choice 2000), the government's long term policies, and the following six main criteria, 40 priority technologies were proposed for different energy sub-sectors.

- Environmental benefits (GHG mitigation, other pollutants reduction),
- Availability of resources,
- Cost (investment, payback period, investment/ CO_2 tonnage reduction),
- Conditions for technology transfer (local capacity, localization of manufacturing),
- Economic development (effect on economic growth, job creation),
- Compatibility with government programs.

It was concluded that associated gas recovery and utilization of excessive pressure in the main pipeline have the highest priority, whereas the vehicle and transportation system and low fuel consumption technologies in the transport sector have the lowest priority.

Research and Education

This section is carried out under the guidance of Articles 5 and 6 of the UNFCCC with the objective of identifying the existing capacity of the country in climate change research and education and to propose a climate change course program for post graduate study and an organizational chart of a research center for climate change issues in Iran. Most of the works related to climate change issues implemented in research and educational institutions of Iran were reviewed and collected. This broad survey was conducted on books, journals, papers, projects, theses and educational programs relevant to climate change which have been implemented in universities, ministries and institutions. This included five ministries, over 70 universities and 40 research centers. The results revealed that more than 642 courses, 1,140 journal papers, 600 books, 200 projects and 1,100 theses were somehow related to climate change at different levels from BS to Ph.D. and in different disciplines including engineering, agriculture, human sciences and natural sciences. To compare the research and educational climate change activities of Iran with other countries, the priority research and educational activities of some developed countries were also collected and surveyed. Most of the national works have focused on the approaches to mitigation of climate change and little work was carried out on technology transfer with a gap in research on development of methods to localize mitigation technologies and the need to establish a national climate change technology research center. On the other hand, the number of works accomplished in other areas of climate change such as; the scientific basis of climate change and impact and adaptation of climate change is very limited. There is also no dedicated educational program for climate change issues at all levels of higher education. In this regard, we propose an educational program that contains the courses that cover all three primary aspects of climate change mainly; the scientific base of climate change, the impact of and adaptation to climate change and the mitigation of climate change. In this report an organizational chart for coordination of the national institutions related to climate change research has been proposed which encompasses the three different aspects of climate change fields namely; the scientific base of climate change, the impact and adaptation of climate change, and the mitigation of climate change.

National Strategies to Address Climate Change

The Islamic Republic of Iran has not yet developed its official national climate change action plan. However, the following strategies to address climate change are used as guidelines for development of *Action Plan*. In development of the national strategies three guiding principles were used:

- Sustainable development is the paradigm for the climate change planning process,
- Global and regional cooperation is a necessary part of the management,
- Reinforcement of integrity in development plans and programs.

Our vision of interrelationship of climate change and sustainable development can be stated as: prevention and control of negative socio-economic and environmental impacts of climate change through national integrated management and international and regional cooperation so that incorporation of necessary measures at the national and provincial development policy levels and other related measures , ensures sustainable development of I.R. Iran. This vision is being incorporated into the following official documents:

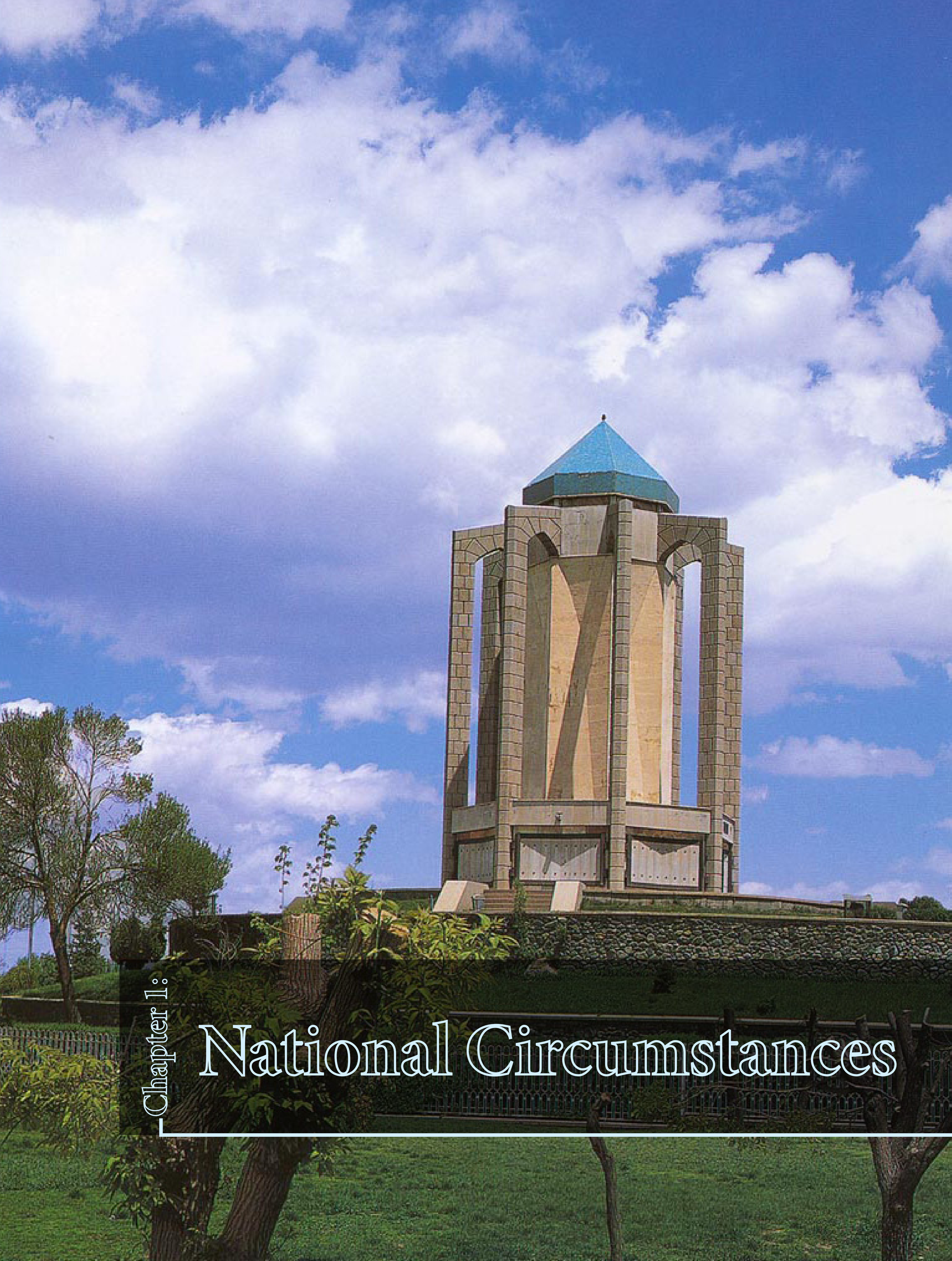
- 2025 Development Vision of I.R.Iran,
- Macro Policies of the Country,
- 5th National Development Plan,
- All sector-strategic plans and policies.

The strategies have been originated and developed based on «The National Rules of Procedure for Implementation of the UNFCCC and Kyoto Protocol»; approved by the Cabinet in July 2009. This "Rules of Procedure" provides a good path for implementation of strategies and the action plan. However, its organizational arrangement is not at a high enough level so that it may not be effectively implemented. A National Working Group, led by DOE's deputy, has been introduced to undertake responsibility for coordination and implementation of the strategies and action plan. Despite this shortage, it includes many principal policies and actions such as:

- Strengthening the institutional arrangements,
- Establishment of a systematic approach for preparation of the national GHGs inventory,
- Development of GHGs mitigation policies,
- Provision of adaptation programmes,
- Development of educational and research programs,
- Assessment and acquiring the technologies for mitigation of and adaptation to climate change,
- Enhancement of the national capacity for climate change observation systems,
- Active participation in international and regional cooperation.

It thus brings about both regulations and the organization required for the implementation of the climate change issue by providing the necessary institutional support and coordination.

Nevertheless, due to the managerial changes and the new cabinet, the Rules of Procedure have not been yet put into full operation. It is expected that during the next five years (5th National Development Plan) climate change action plan becomes fully operationalized.



Chapter 1: National Circumstances

1.1. Governance

With the inception of the Islamic Republic of Iran in 1979, the supreme authority in the governance system of the country has been vested in Velayat Faghih (the Supreme Jurisprudent-the Leader). Under his authority, there are three authorities: the Executive, Legislative and the Judiciary.

The President, the second highest-ranking official, is elected to a four-year term (there is a two-term limit) as the head of the executive branch. The Islamic Consultative Assembly (Majlis) is the legislative branch with 290 members who are also elected to a four-year term. As for the judiciary branch, the leader appoints the head for a five-year term that can be extended once. The 12-member Council of Guardians that vets candidates for the presidency and the Majlis also has a supervisory role in overseeing the elections. In addition, it ensures that legislation is in accordance with the Constitution and Islamic precepts.

The Expediency Discernment Council was formally incorporated into a revised Constitution in July 1989. The Leader designates its members for a five-year term and they rule on legal and theological disputes between the Majlis and the Council of Guardians.

1.2. Geographical Characteristics of Iran

1.2.1. Geographic Description

Figure 1.1 shows the map of Iran and its location in the region. The Islamic Republic of Iran with an area of 1,648,195 square km is located in the southern part of the north moderate zone between 25 03' and 39 47' north latitude from the equator and 44 05' and 63.5 18' east longitude from the Greenwich meridian. The country is bordered by the Caspian Sea and has as northern littoral neighbors Russia and Kazakhstan with northern land borders touching Azerbaijan, Armenia and Turkmenistan; by Turkey and Iraq to the west; by the Persian Gulf and the Sea of Oman to the south and by Pakistan and Afghanistan to the east-southeast. Nearly 90% of Iranian territory is situated on the Iran Plateau. Generally, Iran is a mountainous and semi-arid land, with a mean altitude of more than 1,200 meters above sea level. More than one-half of Iran consists of mountains, one quarter is plains and deserts and less than one quarter is arable land. The southern coast of the Caspian Sea at an altitude of 28 meters is the lowest point in Iran and the summit of Mt. Damavand in the central Alborz Mountains range at 5,628 meters altitude is the country's highest point while the Lut Desert at 56 meters altitude is the lowest internal point.

1.2.2. Climate

The climate of the country is mainly influenced by a subtropical high-pressure belt. January (monthly average temperature in the

Figure 1.1: Iran's location in Middle East.

range of -6 °C to 21 °C) and July (monthly average temperature in the range of 19°C to 39°C) are the coldest and the warmest months in most cities of the country. Precipitation varies greatly nationwide and changes from season to season and year to year. Most climatic regions

Table 1.1: Summary of Social, Demographic and Economic Indicators

Social and Demographic Indicators				
Area	1,648,195 sq. km			
Legal system	Based on the 1979 Constitution which was amended in 1989			
Legislature	Majlis-Shura-ye Islami (Islamic Consultative Assembly or Parliament) of 290 members. All Majlis legislation must be approved by the 12-member Council of Guardians, six of whom are appointed by the Leader (the Rahbar) and six by the Majlis. The Expediency Council mediates between the Majlis and the Council of Guardians.			
Electoral system	Universal adult suffrage			
Head of State	President, elected by universal suffrage for a four- year term.			
Population	70.5 million (2006-2007)			
Distribution of population	Urban areas 68.5%, Rural areas 31.5% (2006-07)			
Annual population growth rate	1.6% (1996-2006)			
Population density (people per sq. km)	41 (2005)			
Total fertility rate	2.1 (2000-2005)			
Life expectancy	Male 68 years; Female 72 years (2004)			
Adult literacy rate (% aged 15 and above)	82.4% (2005)			
Combined gross enrolment ratio for primary, secondary and tertiary education	72.8% (2005)			
Physicians (per 100,000 people)	87 (2000-04)			
Infant mortality rate	28.6 per 1,000 (2004)			
Nutrition (per capita daily calorie intake)	3,181 (1990)			
Access to safe drinking water	89% of population (1990); 95% of population (2004)			
Access to standard sanitation	84% of population (2004)			
Economic Indicators				
Distribution of GDP in 2004-05 at 1997-98 prices		**Agriculture 13.7%; Oil 11.5%; Manufacturing & Mining 18.8%; Services 51.4%**		
	2002-03	2003-04	2004-05	2005-06
GDP (US$ billions)	137.1	163.4	189.8	207.6
GDP (PPP USD billions)	464.1	504.2	543.8	587
GDP growth (%)	6.7	4.8	5.7	6.2
Inflation (%)	15.6	15.2	12.1	13.6
Oil export (thousands barrels per day)	2,678	2,809	2,847	2,699
Oil & gas exports (USD million)	27,355	36,315	53,820	62,458
Non-oil exports (USD million)	6,636	7,537	10,546	13,079
Total exports (USD million)	33,991	43,852	64,366	75,537
Imports (USD million)	29,561	38,199	43,085	49,292
Trade balance (USD million)	4,430	5,653	21,281	26,245
Services (USD million)	-4,535	-5,011	-5,379	-6,272
Current account (USD million)	816	1,442	16,637	20,650

Source: Central Bank of Iran, Human Development Report, World Development Report, 2003-2007.

have their highest seasonal precipitation in winter. Except for the northwest, southeast, and Caspian Sea coasts, Iranian summers see no rain. The average annual total precipitation ranges between 50 mm to about 2000 mm. The Caspian Sea coasts and some areas in the Zagros Mountains range on the average receive more than 1,000 mm per year while some areas in the largely desert or semi-desert central and southeastern parts of the country receive the least yearly rainfall.

According to the Koppen climate classification system, Iran can be divided into three climate types out of a total five types in its scheme. The dominant climate covering 81% of the country is arid and semiarid subtypes climates (**B**, dry main type). Different subtype climates of C (temperate-mesothermal main type) are experienced along the Caspian Sea coasts and some places in the Zagros Mountains region located in the west of the country. Different subtypes of C cover 17% of the country. The rest of the country (2% coverage), that includes some small areas in the Alborz Mountains in the north and the Zagros Mountains in the west, is primarily climate type **D** (continental- microclimate main type).

1.2.3. Land Use

The mountainous terrains of the Alborz and Zagros mountain ranges running from east to west and northwest to southeast respectively, are considered the most important topographic features of Iran. In addition to these two ranges, the coastal plains in the northern and southern parts of the country have specific characteristics, which create the diversity of climate. Almost 11.2% of the land of Iran is agricultural, while forest coverage, rangelands and deserts account for 8.7%, 52.1% and 19.7%, respectively, with the remaining landmass allocated to industrial and the residential areas. The major land uses in Iran is illustrated in Table 1.2.

1.2.4. Forests and Rangelands

Table 1.3 indicates the overview of the natural resources of Iran in the 14.3 million square hectares of forested areas, 93.53% is natural forest and the rest is planted forest. The forest area per capita is only 0.2 ha as compared with the global standard of 0.8 ha (Iran's forests are divided into two areas including the Caspian forests in the north and dry and semi-dry forests in the south. In addition, the forage demand for grazing livestock on rangelands is sufficient for feeding 37 million head of livestock during a seven-month grazing period, while 83 million animals currently graze over rangelands during this period.

Table 1.2: Agricultural and General Land Use in Iran

Land Use	Area (million ha)	Area - percent
Irrigated land annual crops Orchards Fallow	5.2 1.1 2.2	3.15 0.67 1.33
Subtotal	8.5	5.15
Rainfed annual crops Fallow	6.4 3.6	3.88 2.18
Subtotal	10.0	6.06
Unused but potentially productive land in arid environments	32.5	19.70
Forest and scattered woodland		7.52
Range, water land and mountains	90	54.55
Sand dunes, salt flats, others	11.6	7.03
Total area	165	100

Source: Soil and Water Research Institute of Iran, www.soiliran.org.

Table 1.3: Overview of the Natural Resources in Iran

Natural Resources	Area (million ha)	% of land area
Forest	14.2	8.8
Rangelands	86.1	53.1
Deserts	32.6	20.1
Shrubbery	2.5	1.5
Total	135.4	83.5

Source: Ministry of Jihad-e-Agriculture. Forest, Range and Watershed Management Organization, 2003.

1.2.5. Water Resources

The mean annual rainfall of the country is about 246 mm and the total annual volume of precipitation equals 413 billion cubic meters (bcm). Internal renewable water resources are estimated at 128.5 bcm-year. Surface runoff represents a total of 97.3 bcm-year and groundwater re-supply is estimated at about 49.3 bcm-year. Iran receives 6.7 bcm-year of surface water from Pakistan and 1.63 bcm from Azerbaijan and an un-quantified amount of water from Afghanistan via the Helmand River. The surface runoff to the sea and to other countries is estimated at 55.9 bcm-year. The total safe yield of groundwater (including non-renewable water or unknown groundwater inflow from other countries) has been estimated at 49.3 bcm-year. According to the above figures, and forecasting national water consumption of the country, the annual renewable water availability per capita will be about 1,300 cubic meters in the year 2021, which based on international measures is considered crisis level. Also, due to population growth and reduced water resources, the per capita water availability has sharply decreased in the past half a century and will further decrease through 2021.

1.2.6. Coastal Zones

Iran with 750 km of Caspian Sea coastline and some 2,250 km of coastline along the Persian Gulf and Oman Sea is under threat from various adverse effects of climate change. The Caspian Sea's southern coastal region has the highest precipitation rate in the country. It ranges from 1,800 mm in the west (Gilan province) to 400 mm in the east (Golestan

Damavand Entourage, The Highest Peak in Iran province). Relative humidity usually varies from 24% to 100%, and the average annual temperature is 17°C. These favorable conditions have created dense forests that extend towards the Alborz Mountains. Given the existence of huge reserves of groundwater as well as surface fresh water, people in this region have traditionally been farmers. Rice, tea, cotton, olives, and fruits, particularly citrus products are the primary crops in these areas making the three northern provinces (Gilan, Mazandaran and Golestan) one of the major agricultural regions of the country. Around 30% of these areas are irrigated agricultural lands. Forests cover 55.5% pastures cover 13% with the remainder given over to gardens and fruit orchards. Surface water resources vary from 4,000 million m3 in the west to 1,235 million m3 in the east. Roughly similar numbers can be found for ground water, which is estimated to be around 2,000 million m3 in the west to 1,200 million m3 in the east. In this region, traditional and industrial fishing produce 45,000 tons of different kinds of fish annually with an average value of USD 25m (including caviar). Industries based on aquaculture products, wood and paper comprise the bulk of the industrial sector in this region.

In the south of the country is the Persian Gulf and Oman Sea. Relative humidity in this region is usually low and the average precipitation varies between 144 and 500 mm. Development of the Persian Gulf coast in the past decades has centered on its large oil and gas reserves. Due to its free access to open seas, Iran's most important commercial ports are located along the southern coast from which 86% of Iran's needs are imported. Fishing and aquaculture activities undertaken by fleet 10,000 traditional vessels are the most popular business among the native people along the Persian Gulf and Oman Sea coastlines.

1.2.7. Natural Disaster

The Islamic Republic of Iran is the sixth most disaster-prone country in the world. An average of 4,000 people were killed and 55,000 affected annually by natural disasters in the last decade. Iran is located in one of the most seismically active areas of the world. Losses due to earthquakes and hydro-meteorological hazards such as drought, floods, and landslides are severe and estimated annually at some USD 1.1b. Uncontrolled urbanization has also increased vulnerability to disasters. Tables 1.4 and 1.5 show the disaster risk index and descriptive figures per disaster in Iran. The drought during the period 1988-2001 reduced aggregate agricultural land, rangeland and forests, and resulted in a shortage of drinking water in many urban and rural areas. An estimate of the losses in the agriculture sector in this period is nearly USD 2.6b. The government and the Red Crescent Society (RCS) of Iran have wide experience in dealing with natural disasters. However, even greater emphasis is needed on preventive and risk-management approaches. In addition, the United Nations Development Programme (UNDP) office in Iran is engaged in de-mining activities, supporting flood and drought management initiatives, and executing preparatory assistance for a sub-regional disaster risk management initiative.

Table 1.4: Disaster Risk Index and Vulnerability

Index	Description	
Casualties from four hazards (CRED)	Number of people killed by year in hazardous events.	2,393
Relatives Casualties from four hazards (CRED)	Relative number of people killed from hazardous events in proportion to the national population [killed per millions inhabitants].	40.3
Arable land	[% of land area]	10.6
Population density in flooded areas	[inhabitant- km2]	45.4

Source: UNDP, Disaster Reduction Unit, Crisis Prevention & Recovery, (1980-2000).

Table 1.5: Descriptive Figures per Disaster Types

	Disasters per year [1] (nb -year)	Casualties [2] (killed-year)	Physical exposure [3] (nb -year)	Relative vulnerability [4] (killed-mio. exp.)
Droughts	0.10	0	6,285,132	0
Earthquakes	1.43	2,250.8	2,094,097	1,074.8
Floods	1.90	131.2	10,903,040	12.0

1 Average number of recorded disasters per year as computed over the period 1980-2000.
2 Number of people killed by year from the hazardous events.
3 Average yearly population exposed to a selected hazard.
4 This approximate vulnerability Figure is obtained by dividing the average number of people killed by physical exposure, then multiplying the result by 1,000,000.

Source: UNDP, Disaster Reduction Unit, Crisis Prevention & Recovery, (1980-2000).

1.3. Population and Labor Force

1.3.1. Population

Controlling the population growth rate, despite an increase of population in the fertility percentile age group, was the most important achievement in the period of 1996-2006. The total population of the country was 60.1 million in 1996-97 and 70.5 million in 2006-07. This indicates the average annual population growth rate has been 1.6% during the years 1996-2006. The household size decreased from 4.84 to 4.08 persons per household. The distribution of the population per different age groups shows that the youth coefficient[1] declined from 33.3% in 2000-2001 to 25.1% in 2006-07. One of the most alarming economic and social dangers arising as a consequence of climate change is the increasing trend of migration to cities because of drought that translates practically as decreased agricultural output and creeping environmental destruction. As a result the urbanization coefficient increased from 61.3% to 68.5%.

1.3.2. Labor Force

The performance of the Iranian economy during period of the Third Five Year Development Plan (FYDP) (2000-01-2004-5) shows that the unemployment rate has decreased from 14% in 2000-01 to 12.3% in 2004-05. In this period the average annual growth rate of the active and employed population was 3.2 and 3.4%, respectively. The rate of unemployment is reported to be 17.6% among women, 10.2% among men and 21.6% among youth between 15-29 years old. Results of the labour market census in the spring of 2007 have shown that the service sector with 44.5% is the single largest employer. Next, are the industry and agriculture sectors that respectively register 31% and 24.5%.

Ashayer in Fars Culture

1.4. Macroeconomics

1.4.1. Economic Growth and Per Capita Income

As shown in Table 1.6, the average annual growth rate of GDP in the years of the Third FYDP (2000-01-2004-05) was about 5.4%. The average annual growth rate of non-oil GDP is also 5.8%. Based on the report of the World Bank, according to the purchasing power parity (PPP), the per capita income is calculated at USD 6,340 that has increased to USD 8,050 in the year 2004-05 (Table 1.7). Figure 1.2 shows a shift in the pattern of economic activities in the Iranian economy in the years 1996-2004. It can be seen from this figure that the added value of the oil sector in GDP has decreased

1- The ratio of population less than 15 years of age to total population

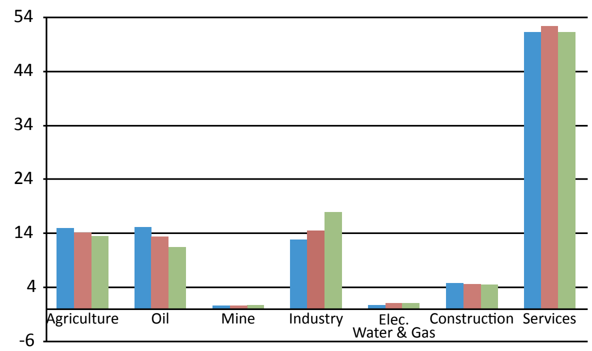


Figure 1.2: Contribution of different sectors to GDP (%)

Table 1.6: Gross Domestic Product (GDP) and Income by Economic Sectors (At constant 1997-98 prices, Billion Rials)

Sectors	1996-97	2000-01	2004-05
Agriculture	42,741.6 (3.3)*	45,774.2 (3.5)	53,488 (0.3)
Oil	43,044.6 (0.7)	42,795.0 (8.3)	47,406 (4)
Industries and Mines	54,819.3 (16.4)	67,227.1 (9.5)	99,924 (8.9)
Mining	1,683.1 (10.9)	1,828.7 (-2.7)	2,811 (3.5)
Manufacturing (Industry)	36,485.0 (18.4)	46,880.6 (10.9)	73,493 (11.5)
Electricity, gas and water	2,672.7 (7.9)	3,395.6 (5.8)	4,608 (9)
Construction	13,978.4 (13.6)	15,122.2 (7.6)	19,012 (0.8)
Services	145,899.3 (5.6)	167,737.2 (2.9)	214,889 (8.1)
Gross domestic product (at constant prices)	283,807 (6.1)	320,069 (5)	410,429 (6.4)
Gross domestic product (at current prices)	248,972	576,493	1,455,690
National income (at constant prices)	246,865 (6.4)	271,785 (4.9)	377,832 (9.5)
National income (at current prices)	206,950	496,884	1,274,736
* Annual % change in brackets			

Source: Central Bank of the Islamic Republic of Iran, National Accounts (2000-2005).

Table 1.7: National Income, National Income Per Capita and GDP Pre Capita Growth Rate

Years	Gross National Income ($ billions)	GNI Per capita $	PPP GNI ($ billions)	PPP GNI Per capita $	GDP Per capita % growth
2000-01	112.1	1,710	415	6,340	4.2
2004-05	187.4	2,770	545	8,050	4.9

Source: World Bank, World Development Report, 2003-2007.

due to the increase of oil prices in recent years. It should be noted that the role of increasing oil export revenues as the dominant financing source of imports for other economic sectors is very important. A combination of economic activities in the years under review indicates that the share of value added from agriculture to total GDP has decreased from 15.1% in 1996-07 to 13% in 2004-05, while the value added for the industry and mines has increased from 19.3% to 24.3% in the same period.

1.4.2. Government Budget

Figure 1.3 shows the government budget in the Iranian economy in the years 2000-01 to 2004-05. The impact of climate change and the corresponding response measures of the implementation of the Climate Change Convention and the Kyoto Protocol on the government budget were dependent on the structure of government revenues and spending. Between the years 2000-2004, the share of oil revenue in total government revenues increased from 54.9% to 68.4% and the share of taxes decreased from 33.8% to 25.8%. On the other hand, government spending, especially subsidies, in the most important sectors of climate change outlays (i.e. water, agriculture, health and environment) are crucial. The ratio of these subsidies to government consumption spending, total spending and GDP is calculated as 9.8, 7.7, and 1.5%, respectively. Based on Article 60 of the Third FYDP and Article 10 of the Government Financial Regulations the government also has provided some 11,183 billion Rls (USD 1.4b) for preventing drought from 1999 to 2004.

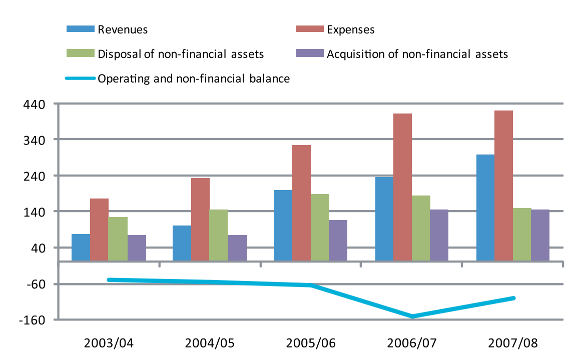


Figure 1.3: Government Budget

1.4.3. Foreign Sector

The foreign sector of Iran's economy is the most important macroeconomic indicator, which will be crucially influenced by the implementation of the Climate Change Convention and Kyoto Protocol. Economic output, employment and investment are vulnerable due to the dependency of the foreign sector of the economy on the revenues from oil exports and the generally non-diversified nature of national exports. The comparison between increasing imports, with other macroeconomics variables indicates that the fluctuations of capital, intermediate and consumption imports are proportional to investment, output and consumption, respectively. According to statistics of the Central Bank-Economic Trends, the whole of oil and gas exports in the total export mix of the country amounted to between 80-85% in 2000-04 (Figure 1.4), a stark indicator of the dependency of the country's trade balance on hydrocarbon exports.

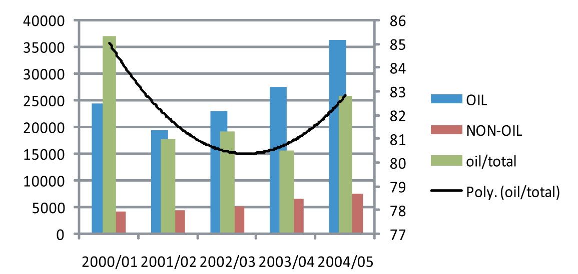


Figure 1.4: Oil and Non-Oil Exports and Shares of Oil and Gas Exports from Total Exports (%)

1.4.4. Money Supply and Inflation

During 2000-04, the average rate of annual inflation was reported at about 14.1%, the average annual growth rate of the real GDP was about 5.4% and the money multiplier has increased from 2.95 to 4.51 (Figure 1.5)[2] . In the review period, the net foreign assets of the Central Bank have had a very dominant role on the monetary base.

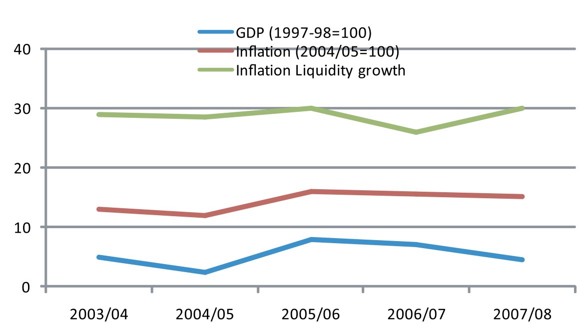


Figure 1.5: GDP, Inflation and Liquidity Growth (%)

2- *Central Bank of the Islamic Republic of Iran, Economic Trends, (2000-2004)*

Table 1.8: Major Oil Sector Indices

Index	Unit	2000-01	2004-05
Oil & gas production	million barrel crude oil equivalent (mboe)	1,733.6	1,295
Crude oil production capacity	thousand b-d	3,953	4,230
Crude oil export capacity	thousand b-d	2,271	2,421
Oil well gas injections	million cubic meters-d	71.14	78.8
Enriched gas production	million cubic meters-d	298.5	408
Crude oil recovery coefficient	%	26.5	28.1
Crude oil delivered to domestic refineries	thousand b-d	1,602	1,584
Oil products production	million liter p-d	223.3	224.2
Oil products consumption	million liter p-d	185.4	206.2
Liquefied petroleum gas		11.1	11.5
Gasoline		42.5	60.7
Fuel oil		25.7	21.4
Gas oil		66.7	75
Kerosene		39.5	37.6
Consumption per capita of oil products		1,066	1,114.8
Products exports		2,735	2,854
Products imports		416.7	2,966
Fuel and waste of refineries		4.22	4
Oil export revenues	million USD	24,280	31,506

Source: Management and Planning Organization

1.5. Sectoral Economics

1.5.1. Energy

1.5.1.1. Oil

Table 1.8 illustrates the performances of key indices of the oil sub-sector. In the year 2000 and 2001, Iran's average crude oil production and exports in adherence to OPEC quotas amounted to 3.7 and 2.3 mbd, respectively. In these years the average spot price of each barrel of exported crude oil also increased to USD 25.3. The oil delivered to refineries decreased to 1.3 mbd and the domestic consumption of oil products rose to 1.1 mbd. In 2000-01, the average domestic price of oil products increased just 10% and the price of each liter of gasoline, gas oil, fuel oil and kerosene reached to 385, 110, 110, and 55 Rls, (US cents 6, 1.7, 1.7, 0.85 cents) respectively.

Table 1.9: Natural Gas Production and Consumption[1] (bm^3)

	1996-97	2000-01	2004-05
Domestic consumption[2]	42.4	62.8	97.7
Flared	13.2	13.8	14.7
Export	0	0	3.5
Regional uses and wastes	8.6	6.6	9.4
Total Production[3]	64.2	83.2	119.4

1 Components may not sum to total because of imports.
2 Includes residential, commercial, industrial, power plants and refineries consumption.
3 Excludes gas injected into oil wells.

Source: Ministry of Petroleum; Central Bank of the Islamic Republic of Iran, Economic Report and Balance Sheet,(2000-01) and various issues.

With escalating domestic production of motor vehicles, the energy intensity in the transportation sector increased and gasoline imports in 2001-02 increased by about 48% (compared to 2000-01). In recent years automobile fuel efficiency and exhaust emission standards have been improved. According to statistics, vehicles produced in Iran achieved EURO 1 in 2000 and improved to EURO 2 in 2005. To mitigate air pollution, the government has applied specific policies including the distribution of unleaded gasoline, supplying low-sulfur gas oil, establishment of the infrastructure for greater utilization of CNG in the transportation sector, increasing the share of natural gas in the energy basket and electrifying the agricultural water wells to replace diesel engines.

1.5.1.2. Natural Gas

Table 1.9 is an overview of the performance of the natural gas sub-sector. In 2000-01 production of natural gas, excluding oil well gas injection grew by 3.9% in comparison to 1999-2000 and amounted to 83.2 bm3. Of this figure, 75.48% was allocated for domestic consumption or a 7% rise over 1999-2000. In addition, another 7.9% was allocated to other local and petrochemical uses. In the year under review, 83.4% of the natural gas produced was used domestically and the remainder was flared. In recent years, Ministry of Petroleum has developed a comprehensive plan to recover and reuse associated gas from oil fields for injecting into mature oil reservoirs.

In recent years, notable advances were made to increase the natural gas share in the energy consumption basket by increasing the refining capacity and expanding the domestic distribution network as well as positioning the country to export natural gas to international markets. The important actions in the upstream sector of oil and gas in recent years is the development activities of the Azadegan oil reservoir which is the largest domestic oil discovery during the past 35 years and development of the five phases of the giant South Pars gas field in the Persian Gulf.

1.5.1.3. Electricity

Tables 1.10 and 1.11 outline the performance of the electricity sub-sector in 2000-01. About 121 billion kWh of electricity was generated, evincing a 7.1% growth compared to the previous year. Of this, 95.3% was generated by the power plants affiliated to the Ministry of Energy, while the private sector companies produced the remainder. In the year under review, out of total electricity generated, about 64.5% was produced by steam power plants (10.1% increase over previous year), 27.5% by gas turbines and combined cycle plants, 3.0% by hydropower turbine (26.4% decline), and 3.0% by diesel power plants. The agricultural sector registered the highest consumption growth of generated electricity totaling 9.1 billion kWh, which was an increase of 14.1% over the consumption figure for the previous year.

Development of renewable energies has been the goal of the Third FYDP. In this regard by creating a governmental administrative structure under the Ministry of Energy, the initial steps have been taken which include: identifying and contracting with public and private domestic industries to promote renewable energies and encourage the private

Table 1.10: Generation of Electricity (Million kWh)

	1996-97	2000-01	2004-05
Ministry of Energy	85,825	114,976	158,951
Hydroelectric	7,376	3,636	11,555
Steam	62,364	77,846	87,388
Gas and combined cycle	15,475	33,135	59,763
Diesel	610	359	245
Other institutions2	5,026	5,624	2,823
Total	**90,851**	**120,600**	**161,774**

Source: Energy balance, 2005, Ministry of Energy

Table 1.11: Electricity consumption by sub-sector (Million kWh)

Sectors	1996-97	2000-01	2004-05
Residential	23,993 (34.4)*	31,266 (34.6)	41,196 (32.8)
Industrial	22,925 (32.9)	28,937 (32.0)	40,681 (32.4)
Public	6,595 (9.5)	11,271 (12.5)	14,575 (11.6)
Commercial	7,622 (10.9)	5,991 (6.6)	7,846 (6.3)
Agriculture	5,731 (8.2)	9,147 (10.1)	17,195 (13.7)
Others[1]	2,805 (4.1)	3,754 (4.2)	4,035 (3.2)
Total	69,671	90,366	125,528

1 Includes electricity for rural areas, religious and charitable institutions and street lighting.
* Share (percent) of electricity in brackets.

Source: Energy balance, 2005, Ministry of Energy.

Table 1.12: Major Water Sector Indices

	2000-01	2004-05
Dams regulated water capacity (Million cubic meters)	26,805.0	31,659.9
Underground water (Million cubic meters)	48,982.6	51,918.2
Water use for agriculture sector (Million cubic meters)	84,949.5	90,973.1
Water provision to cities and industries (Million cubic meters)	6,392.0	7,765.8
Irrigation and drainage networks (Million cubic meters)		
Major networks (Thousand hectares)	1,338.3	1,623.4
Minor networks (Thousand hectares)	579.0	5,97.9

Source: Management and Planning Organization

Table 1.13: Major Agriculture and Natural Resource Indices

	Unit	2000-01	2004-05
Equipping and renewal of arable lands	1,000 hectares	43	65.3
Vegetation Cover	1,000 hectares	54	65.3
Forestation	1,000 hectares	88	67.2
Livestock removal from northern forests	1,000 animal unit	144	152
Combating Desertification	1,000 hectares	390.8	67.7
Mechanization Coefficient of Agriculture	Horsepower in a hectare	0.54	0.63
Executive watershed management activities	1,000 hectares	626	1,153
Production of Major Farming Crops	thousand tons	17,694	27,313
Livestock Products	thousand tons	8,676	7,155

Source: Management and Planning Organization, Central Bank of the Islamic Republic of Iran, Economic Report and Balance Sheet, (2000-01) and various issues.

sector in this sphere. Other energy policies have also been presented in various national strategies during the period 2000-2004.

1.5.2. Water

Table 1.12 presents the performance of the water sector during the period 2000-2004. According to the water resource parameters of the country and despite the great investment of past years, the supply of required water is insufficient. In the years 1999-2000 to 2003-04, Iran has experienced one of the driest periods recorded in the past 50 years.

1.5.3. Agriculture and Natural Resources

The performance of the major indices of the agriculture sector and natural resources during the period 2000-01 to 2004-05 is illustrated in Table 1.13. The percentage share of value added of this sector in the GDP is 13.5% to 15% and registers some 20% of non-oil exports, near one fourth of total employment, more than 82% of food supply, 90% of the required primary goods of the agricultural processing industries and is the source of 7.3% CO_2 emission in the total GHG of the country. The role of the agriculture sector in Iran's economy is a dominant factor in food security, employment, and geographical distribution of the population. The sector provides raw materials for food industries and also utilizes a large share of subsidies. If no adaptation policies are undertaken in agriculture, the vulnerability to climate change will appear in different forms such as reduction of products, endangering national food security, increasing unemployment, accelerating the already ascending pattern of migration to cities with a resultant spike in non-productive jobs, increasing subsidies paid out and ultimately creation of a consistent rise in cultural and social abnormalities.

1.5.4. Manufacturing and Mining

During the period 2000-01 to 2004-05, the manufacturing and mining sector at 18.8% of GDP, jumped 11.1% in annual average growth rate of value added at constant 1996-97 prices (Table 1.14). The export transactions of this sector increased from USD 1.91b to USD 4.56b in 2004-05 and its contribution to non-oil exports jumped from 56.6% to 71.4% in the same period[3] .

Based on the Initial National Communication of Iran to UNFCCC, the industrial sector is the source of 7% of total greenhouse gas emission in the country, of which the shares of the mineral industry, petrochemical industry and metal production, are 41.5, 7.5, 51%, respectively. Therefore, moving towards diversification of industrial activities and completion of production chains with environmentally sound technologies in order to reduce the share of energy intensive industries in GHG emissions and to increase the efficiency of energy consumption, is being

Table 1.14: Major Manufacturing and Mining Indices

		2000-01	2004-05
Growth rate of value added	%	10.3	11.9
Value added in GDP	%	15.2	18.8
Growth rate of investment	%	11.6	??
Exploitation of metal ores	Million tons	28.1	69.35
Exploitation of non-metal ores	Million tons	82.5	109
Exploitation of iron ore	Million tons	12.2	18
Exploitation of coal	Million tons	2	2.1
Manufacturing and Mining Products			
		2001-02	2004-05
Cement	Thousand tons	26,645	32,199
Metal Industries	Thousand tons	7,228.5	9,354.3
Petrochemical products	Thousand tons	12,542.9	15,068.3

Source: Management and Planning Organization, Central Bank of the Islamic Republic of Iran, Economic Report and Balance Sheet, (2000-01) and various issues.

3- Statistical Centre of Iran, Statistics of large manufacturing establishments, (1996-2004) actively promoted by the government across a sizable range of development plans. In this sector implementation of CDM projects can have a significant impact.

1.5.5. Transportation

Iran's transportation sector is responsible for an estimated 17% of CO_2 emission as compared with the global average of 13%.

Reviewing the performance of this sector in 2004 indicates that 44.01 million passengers and 418.5 million tons of goods were transported. The average annual growth rate of the same figures during the period 2000-2004 is 3% and 14%, respectively. The divide of road, rail and air transportation of carried goods is 93, 7 and 0.02%, and for passengers the numbers are 93, 3.9 and 3.1%, respectively. The most significant achievement in the road transportation sector has been the upgrading of the public transportation fleet (buses and rail) for passenger transport.

1.5.6. Health

National health status has improved over the past two decades. However, considerable disparities remain; over 8-10% of the population are not covered by any insurance scheme and have to pay their own health care expenses directly.

Communicable disease morbidity and mortality have decreased. Maternal and child health have improved but malnutrition and low-weight births are higher than average in rural areas. Non-communicable diseases and accidents are increasing, accounting for 24% and 18% of all deaths, respectively. Cardiovascular diseases, hypertension, degenerative and stress-related disorders contribute to more than 45.7% of adult deaths. Accidents account for 14.8% of adult deaths and 8.9% of this figure is due to traffic accidents. Table 1.15 illustrates the health status indicators.

1.6. Environment

Iran is a vast country with diverse climatic and environmental conditions, hence a habitat for a rich diversity of terrestrial and marine species. Tremendous potential exists in Iran for eco-tourism because of this variety and, in many cases, uniqueness of its ecosystems. However, during the past decades, great pressure has been put on environmental resources. Iran is facing serious environmental challenges like air pollution in urban areas, the pollution of scarce water resources, degrading of natural vegetation, soil erosion and the loss of biodiversity.

Three subsequent Five-Year Development Plans called for the employment of environmentally friendly approaches when

Table 1.15: Major Health Indices

Index	2000-04
Male life expectancy at birth (years)	68
Female life expectancy at birth (years)	72
Infant mortality rate (per 1,000 live births)	28.6
Population with access to local health services, total (%)	94
Under-5 mortality rate per 1,000	38
Maternal mortality ratio per 100,000 live births (2000)	76
Population with access to improved drinking water source (%)	95
Urban Area (%)	99
Rural Area (%)	84
Population with access to improved sanitation (%)	84
Total expenditure on health as % of GDP	5.6
Government expenditure on health as % of total gov. expenditure	9.6

Source: World Health Organization, Regional Office for the Eastern Mediterranean, WHO Country Office in Islamic Republic of Iran, http://www.emro.who.int/iran implementing development programs. The need to incorporate environmental concerns into policies, plans and programs (PPPs) is increasingly voiced by government, non-governmental entities and the public. The recent boom in the number and activities of environmental NGOs is clear evidence of the above need.

In order to fulfill the mentioned needs, certain policies were included in the third and forth FYDP, the most important of them are as follows:

- Enabling and strengthening the institutional framework for environmental activities through improvement of educational programs and investment patronage,
- Improvement of air quality in eight mega-cities of Iran in order to reach the new approved standards by the High Council for the Environment,
- Scrapping of old motor vehicles,
- Establishment of an environmental information system at the regional, provincial and national level,
- Sustainable management of natural resources through balancing livestock population and rangeland, rehabilitation and management of grazing resources through participatory planning with local communities,
- Supporting environmental NGOs and CBOs.

1.6.1. Environmental and Climate Change Governance

The Ministry of Foreign Affaires and Department of the Environment are active as responsible bodies in international and national issues of climate change and coordinate climate change activities, yet there still exists a great need for national capacity building and institutional reforms in climate change governance. It is also necessary to integrate environmental considerations especially policy issues related to climate change in the country's sustainable development plans. In fact, the development plans of Iran are affected directly and indirectly by climate change. Hence, the national action plan for climate change has close correlation with official development plans.

Fortunately, the necessary steps have been taken in this direction during 2007-2008 and finalized in 2009. According to the National Climate Change Act and the National Rules of Procedure for CDM that were approved by the government in 2009, all ministries and organizations will be required to develop their own respective plans to deal with climate change. Their duties will include: preparation of greenhouse gas inventory of their activities on a regular basis, promotion of mitigation policies, assessment of the vulnerability of each sector to the impact of climate change and development of adaptation programs, assessing the technological needs for mitigation and adaptation, research and education programs, capacity building to raise the awareness of policy makers and experts and finally, enhancing their overall capabilities to monitor climate change.

1.6.2. The Framework for Preparation of the National Communication Report

The National Communication Report of Iran to UNFCCC is prepared by the National Climate Change Office of the Department of the Environment, in cooperation with other government ministries and administrative organizations, consultancy of private experts and academicians and is overseen by the Steering Committee[4] . The following working groups are responsible for preparing different chapters of the report:

- National Circumstances
- National Greenhouse Gases Inventory
- Greenhouse Gases Mitigation Policies
- Vulnerability and Adaptation
- Mitigation Policies and Economic Diversification

4- See the Iranian National Climate Change Office management chart in the figure 1.6.

- Conducting the Needs for Monitoring and Observing Network, Climate Modeling and Climate Change Education and Research
- Conducting the Technological Needs Assessment for Mitigation and Adaptation
- Education and Public Awareness Planning
- Integration and Preparation of National Action Plan

After preparing the draft reports by the working groups, the reports are reviewed by the Steering Committee members consisting of representatives from various relevant ministries and organizations for their comments (Figure 1.6). In order to improve the current procedure of preparation of the national report, and to enhance the participation of all governmental offices, a non-centralized preparation approach is proposed. Based on the Climate Change Act in this new approach, the National Climate Change Office, as coordinator, disseminates all instructions and procedures among the relevant organizations and synchronizes their activities. It then integrates the reports collected from different organizations in the national report. In this process data is collected and studies conducted by relevant government offices under the advisement of private experts and academicians. The other necessary reform is related to the action plans. Given the necessity of coordination in the preparation of the Fifth FYDP and the Second National Communication, it is expected that the national strategies and macro policies of climate change must be considered in the FYDP under supervision of the National Sustainable Development Committee.

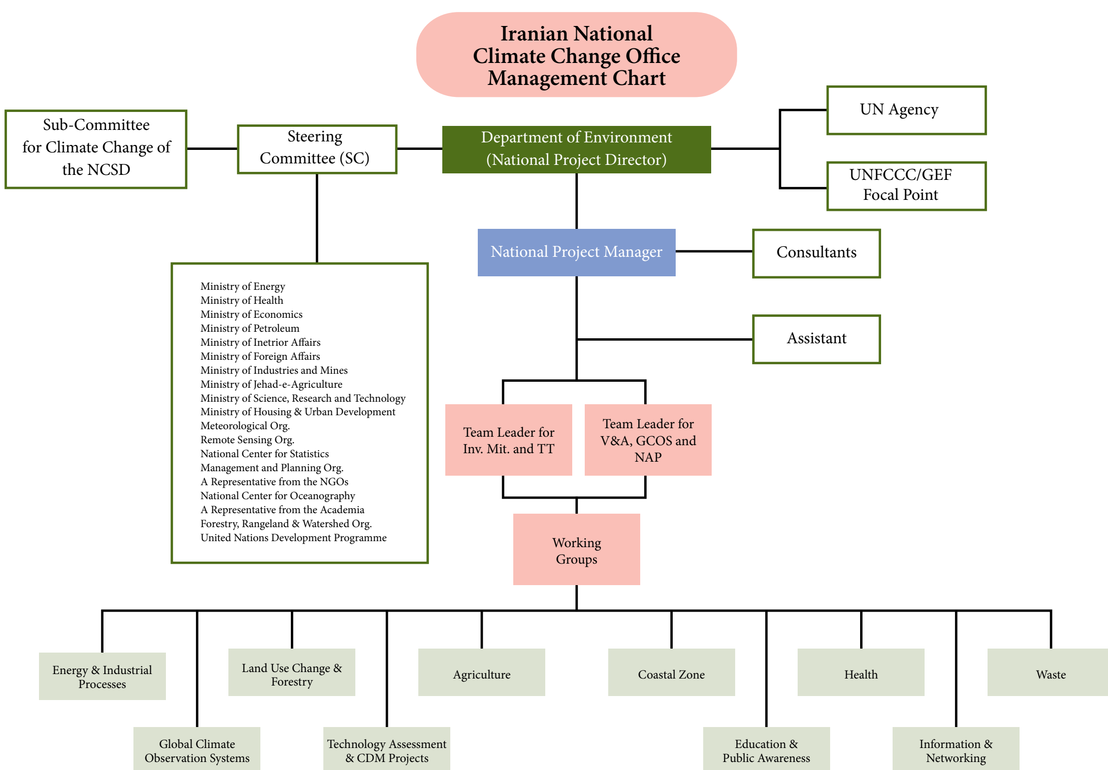


Figure 1.6: National Climate Change Management Chart

Chapter 2:

National GHGs Emission Inventory

2.1. Overview

This greenhouse gas inventory was prepared for the year 2000 for the purpose of Iran's Second National Communication to UNFCCC. In preparing this inventory, the National Climate Change Office of Iran has experienced extreme difficulties in obtaining the Activity Data (AD) required for calculation of emissions. Consequently, extensive work will be needed in the future to improve the quality of activity data and development of local Emission Factors (EF). It is planned that collection of AD and preparation of the sector-by-sector inventory be undertaken by the relevant organizations in preparing future national communications. Furthermore, based on the result of the inventory, it was observed that there is a greater uncertainty vis-à-vis the data gathered on the forestry sector, which needs real improvement in future inventories. It is noteworthy that the data needed to calculate the emission of carbon flow from soil were not available in Iran. Hence, this calculation has been omitted in the preparation of the inventory in this report.

The summary of direct and indirect GHGs inventory in Iran is shown in Table 2.1. As it is evident from this Table and Figure 2.1, the total CO_2 emission from different sectors in 2000 is about 375,187 Gg, with the energy sector contributing about 90% of the total emissions and industrial processes and forestry contributing about 8% and 2%, respectively. The total CO_2 equivalent emission is estimated to be about 491,052 Gg in 2000. As shown in Figure 2.2, the energy sector has the largest share of 77% and the forestry sector has the lowest share of 2% in overall GHGs emission. An important point is that the forestry sector with its contribution of 2% to CO_2 emissions has itself evolved into a source of emission.

In regard to emissions of HFCs, PFCs and SF6, reliable information is non-existent, however, contribution of these gases to emissions of industrial processes are estimated at 0.248, 0.22 and 0.004 Gg, respectively.

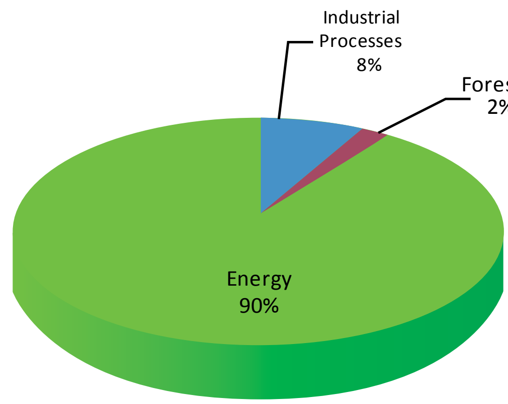


Figure 2.1: Share of Different Sectors in CO_2 Emissions in 2000

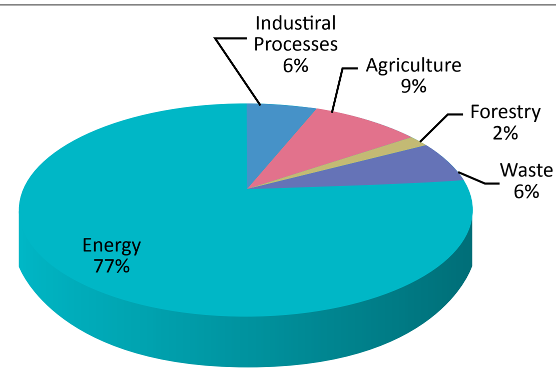


Figure 2.2: Contribution of Different Sectors to Total CO_2 Equivalent Emissions in 2000

2.2. Energy

The energy sector is the most important sector in the emission inventory of greenhouse gases in Iran. In order to estimate the amount

Table 2.1: Summary of GHGs Emissions Inventory (Gg) for all Sub-sectors in 2000

Source \ Gas	CO_2	CH_4	N_2O	CO	NOx	NMVOCs	SO2
1.Energy	337,351.85	1,801.27	8.47	3,308.21	585.6	1,143.82	110.15
Fuel Combustion	304,026.85	78.5	8.47	3,308.21	585.6	1,143.82	71.05
Energy Industries	90,560.48	0.85	1.892	49.42	103.03	0.85	
Manufacturing Industries & Construction	43,424.48	1.08	0.691	53	23.67	1.08	
Transport	73,453.47	63.45	3.93	2,916.76	376.91	1,075.92	
Commercial & Institutional	16,631.16	0.6	0.37	6.63	14.25	0.4	
Residential	68,792.11	11.98	1.312	217.09	21.88	47.33	
Agriculture, Forestry & Fishing	11,165.15	0.54	0.271	65.31	45.86	18.24	
Fugitive Emissions	33,325	1,722.77	0	0	0	0	39.1
Oil Activity		21.04					39.1
Gas Activity		584.44					
Coal Mining & Handling		6.65					
Venting & Flaring	33,325	1,110.64					
2.Industrial Processes	28,556.5	3.17	2.38	76.78	7.92	11224.7	
Mineral Production	13,320.34			1.44	3.45	11178.95	
Metal Production	13,495.95			65.03	0.49	0.4	
Chemical Production	1,740.21	3.17	2.38	9.75	3.83	23.76	
Other Production	NE			0.56	0.15	21.59	
3.Agriculture		908.41	77.15	199.04	7.24		
Enteric Fermentation		808.33	NE	NE	NE		
Manure Management		29.45	0.81	NE	NE		
Rice Cultivation		61.15	NE	NE	NE		
Agricultural Residues Burning		9.48	0.2	199.04	7.24		
Agricultural Soils		NA	76.14	NE	NE		
4.Forestry	9,278.28	0.311	0.0022	2.72	0.077		
Change in Forest and Other Woody Biomass Stocks	9,056.15						
Forest and Grassland Conversion	222.13	0.311	0.0022	2.72	0.077		
Abandonment of Managed Land							
5.Waste		892.57	41.5				
Solid Waste Disposal Site		497.54					
Domestic & Commercial Wastewater Treatment		50.5					
Industrial Wastewater & Sludge Handling		344.53					
Human Sewage			41.5				
Total GHGs Emissions	375,186.63	3,605.73	129.50	3,586.75	600.84	12,368.52	110.15
GWP	1	21	310	NA	NA	NA	NA
Total CO_2 Equivalent	375,186.63	75,720.35	40,145.68	NA	NA	NA	NA

NE: Not Estimated NA: Not Available

of greenhouse gases emission, the Tier l of the IPCC 1996 Guidelines and UNFCCC software was used Accordingly, the energy sector has been subdivided into two sectors of Fuel Combustion and Fugitive Emission. In Fuel Combustion, fuel consumption is classified in different sub-sectors.

The amount of greenhouse gases emissions was calculated based on the amount of consumption of different fuel types and considering the emission factor of different greenhouse gases for the fuels.

2.2.1. GHGs Emissions from the Energy Sector

Emission of direct greenhouse gases CO_2, CH_4, N_2O and indirect greenhouse gases NOx, CO, NMVOCs and SO_2 are estimated based on the statistics of activity data for the year 2000.

For calculating the CO_2 emissions, considering the amount of fuel consumption in the sector and the carbon emission factor, first the carbon content of the fuel is calculated, and then the specific net and actual carbon emission and finally the actual CO_2 emission is calculated.

The amount of other greenhouse gases (non-CO_2) including CH_4, N_2O, NOx, CO, NMVOC and SO2 is calculated considering the amount of fuel consumption and the gas emission factor.

2.2.1.1. CO_2 Emission

Total emission of CO_2 in the energy sector in the year 2000 is estimated to be about 337,352 Gg. As shown in Table 2.2 and Figure 2.3, the energy industries contributes the highest CO_2 emission with 30%, followed by transport, residential, manufacturing industries and construction, commercial/institutional and agriculture/forestry/fishery sectors with contributions of 24%, 23%, 14%, 5% and 4% of emission. Table 2.2 and Figure 2.3, quantifies the amount and contribution of CO_2 emission in different energy sub-sectors in the year 2000.

2.2.1.2. CH_4 Emission

Total emission of CH_4 in the year 2000 from the energy sector was 1,801Gg. This emission was calculated from fuel combustion activities (Sectoral Approach) and the fugitive emissions from production, processing and distribution of oil, gas and products. The amounts of emission in these two sectors were estimated to be 78.5 Gg and 1,722.8 Gg, respectively. Comparison of CH_4 emission in different energy sub-sectors shows that the transport and residential sectors with 81% and 15% have the major contribution to CH_4 emission, whereas the energy industries, manufacturing industries and construction, commercial/institutional and agriculture, forestry and fishing sectors, each had the small contribution of about 1%. However, most of CH_4 emission in the energy sector is related to oil and natural gas activities with a contribution of 1,716 Gg. The CH_4 emission from solid fuels is estimated to be only 6.7 Gg. Also in Tables 2.3 and 2.4, state of CH_4 emission has been indicated in each energy sub-sector.

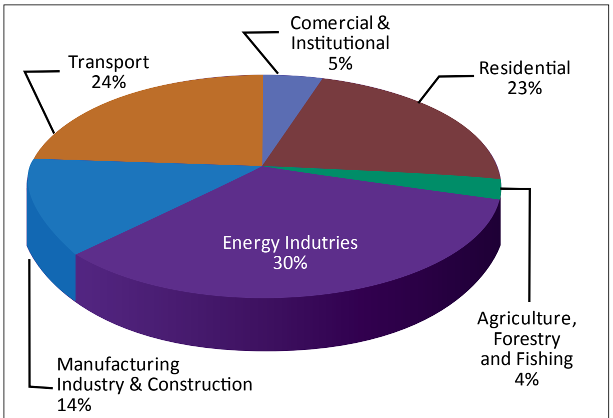


Figure 2.3: Contribution of Different Energy Sub-sectors to CO_2 Emissions in 2000

Table 2.2: CO_2 Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)
Energy Industries	90,560.48
Manufacturing Industries & Construction	43,424.48
Transport	73,453.47
Commercial & Institutional	16,631.16
Residential	68,792.11
Agriculture, Forestry & Fishing	11,165.15
Total	**304,026.85**

Table 2.3: CH_4 Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)	Percentage
Energy Industries	0.85	1
Manufacturing Industries & Construction	1.08	1
Transport	63.45	81
Commercial & Institutional	0.6	1
Residential	11.98	15
Agriculture, Forestry & Fishing	0.54	1
Total	78.5	100

Table 2.4: Fugitive CH_4 Emissions (Gg) in Oil, Gas and Coal Mining Activities in 2000

Sub sectors		Emissions (Gg)
Natural Gas and Oil	Oil Activity	21.04
	Gas Activity	584.44
	Venting & Flaring	1,110.64
Solid Fuels	Solid Fuel Conversion	0.0
	Coal Mining & Handling	6.65
Total		1,722.77

2.2.1.3.N_2O Emissions

The total emission of N_2O from the energy sector is estimated at about 8.47 Gg, with the highest contribution of 47% attributed to the transport sector. Energy industries, residential, manufacturing industries and construction, commercial and institutional and agriculture, forestry and fishery sectors contribute 22%, 16%, 8%, 4% and 3% of emission of N_2O, respectively. Table 2.5 shows the amount and contribution of different energy sub-sectors on N_2O emission.

2.2.1.4. Indirect GHGs Emissions

The total emission of NOx was estimated to be 585.6 Gg, with the contribution of different energy sub-sectors respectively 64% in transport, 18% in energy industries, 8% in agriculture, forestry and fishing, 4% in manufacturing industries and construction, 4% in residential and 2% in commercial/institutional sectors. Table 2.6 shows the amount and contribution of NOx emission in different energy sub-sectors in 2000.

The total CO emission was estimated to be 3,308 Gg. The transport sector has the highest contribution with 88% followed by residential, commercial and institutional, manufacturing industries and construction, agriculture, forestry and fishery and energy industries sectors with contributions of 7%, 2%, 2%, 1% and near zero, respectively. Table 2.7 shows the amount and contribution of CO emission in different energy sub-sectors.

The total emission of NMVOCs was estimated to be 1,143.82 Gg. Transport sector has the highest contribution of 94 % to the emission

Table 2.5: N_2O Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)	Percentage
Energy Industries	1.892	22
Manufacturing Industries & Construction	0.691	8
Transport	3.933	47
Commercial & Institutional	0.371	4
Residential	1.312	16
Agriculture, Forestry & Fishing	0.271	3
Total	8.47	100

Table 2.6: NO_x Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)	Percentage
Energy Industries	103.03	18
Manufacturing Industries & Construction	23.67	4
Transport	376.91	64
Commercial & Institutional	14.25	2
Residential	21.88	4
Agriculture, Forestry & Fishing	45.86	8
Total	**585.6**	**100**

Table 2.7: CO Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)	Percentage
Energy Industries	49.42	1
Manufacturing Industries & Construction	53	2
Transport	2,916.76	88
Commercial & Institutional	6.63	0
Residential	217.09	7
Agriculture, Forestry & Fishing	65.31	2
Total	**3,308.21**	**100**

of these gases, residential and agriculture sectors with 4% and 2% contribute the rest, with negligible amounts from other sectors. Table 2.8 shows the amount and contribution of NMVOCs emission in different sectors.

The total SO_2 emission was estimated to be 110.047 Gg. The contribution of fuel consumption to SO_2 emission was 71.047 Gg for all energy consuming sub-sectors, with the balance of 39 Gg originating from fugitive emissions.

2.2.1.5. Summary of the Energy Sector

The total emission of CO_2 from all energy sub-sectors in the year 2000 was estimated to be about 337,351 Gg. This emission in comparison with the amount of emission in the year 1994 (285,891 Gg reported in the Initial National Communication), has increased about 18% i.e. 2.8% per annum. Comparison of greenhouse gases emission in the years 1994 and 2000 in Iran's energy sector is shown in Tables 2.9, 2.10, 2.11 and 2.12. As indicated in Table 2.9, the amount of NO_X emission from fuel combustion is drastically decreased in comparison to 1994 emission as a result of natural gas substitution in the fuel mix from 25% in 1994 to 33% in 2000.

For the year 2000 inventory, as a result of improvement in the national energy statistics, the GHGs emission has not been accounted for in the "other sector".

Table 2.8: NMVOCs Emissions (Gg) in Energy Consuming Sectors in 2000

Sub sectors	Emissions (Gg)	Percentage
Energy Industries	0.85	0
Manufacturing Industries & Construction	1.08	0
Transport	1,075.92	94
Commercial & Institutional	0.4	0
Residential	47.33	4
Agriculture, Forestry & Fishing	18.24	2
Total	**1,143.82**	**100**

Table 2.9: Comparison of GHGs Emissions (Gg) from Energy Sector in the Years 1994 and 2000

Gas / year	1994	2000
CO_2	28,5891.33	33,7351.85
CH_4	1,559.11	1,801.27
N_2O	8.79	8.47
CO	2,907.44	3,308.21
NOX	1,114.39	585.6
NMVOC's	**1,091.9**	**1,143.82**

Table 2.10: Comparison of Fugitive Emissions (Gg) from Energy Sub-sectors in the Years 1994 and 2000

Gas / year	1994	2000
CO_2 (Hot flaring)	31,537	33,325
CH_4	1,478.45	1,722.77
SO_2	NA	39.1

2.3. Industrial Processes

Almost all of the industrial processes classified in the IPCC Guidelines, such as iron and steel, cement, aluminum, pulp and paper, petrochemicals, textile, etc., exist in Iran. Most of these industries are state-owned and the government has plans to privatize many of them in future. Also recently a National Standard for large industries has been adapted according to which the industries should reduce their resource consumption and therefore GHGs emission.

The activity data and emission factor in this sector, especially in consumption of HFCs, PFCs and SF_6 were not readily available and an inventory preparation was unprecedented in Iran. However, efforts have been made to obtain accurate and relevant information from various sources. Information for estimation of both direct GHGs (i.e. CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) and indirect GHGs (i.e. NOx, CO, NMVOCs and SO_2) has been collected.

In this report, emissions of HFCs and PFCs are estimated just for the import of R134a and emission from aluminum production.

Table 2.11: Summary of GHGs Emissions (Gg) in Energy Sub-sectors in 2000

Sources / Gas	CO_2	CH_4	N_2O	CO	NOX	NMVOCs	SO_2
Fuel Combustion	304,026.85	78.5	8.47	3,308.21	585.6	1,143.82	71.047
Energy Industries	90,560.48	0.85	1.892	49.42	103.03	0.85	-
Manufacturing Industries & Construction	43,424.48	1.08	0.691	53	23.67	1.08	-
Transport	73,453.47	63.45	3.933	2,916.76	376.91	1,075.92	-
Commercial & Institutional	16,631.16	0.6	0.371	6.63	14.25	0.4	-
Residential	68,792.11	11.98	1.312	217.09	21.88	47.33	-
Agriculture, Forestry & Fishing	11,165.15	0.54	0.271	65.31	45.86	18.24	-
Fugitive Emissions	33,325	1,722.77	0	0	0	0	39
Oil Activity	-	21.04	-	-	-	-	39
Gas Activity	-	584.44	-	-	-	-	-
Venting & Flaring	33,325	1,110.64	-	-	-	-	-
Coal Mining & Handling	-	6.65	-	-	-	-	-
Total GHG's Emissions	337,351.85	1,801.27	8.47	3,308.21	585.6	1,143.82	110.147
GWP	1	21	310	NA	NA	NA	NA
Total CO_2 Equivalent	337,351.85	37,826.67	2,625.7	NA	NA	NA	NA

Table 2.12: Comparison of the CO_2 Emissions (Gg) in Energy Sub-sectors in the Years 1994 and 2000

Energy Sub-sectors (1994)	Emissions (Gg)	Energy Sub-sectors (2000)	Emissions (Gg)
Energy Transformation	63,197.2	Energy Industries	90,560.48
Industry	48,179.3	Manufacturing Industries & Construction	43,424.48
Transportation	58,709.83	Transport	73,453.47
Residual/Commercial Buildings	66,512	Commercial & Institutional	16,631.16
Agriculture	12,689	Residential	68,792.11
Other	5,067	Agriculture, Forestry & Fishing	11,165.15
Total	**254,354.33**	**Total**	**304,026.85**

According to the official data, HFC and PFC were not produced in Iran. The other difficulty that was experienced was that there is no individual customs clearance code for HFCs and PFCs importation except for HFC 134 a.

In some cases, the emissions of GHGs from various sources in energy, industry and agriculture overlapped. For this reason in the instances listed below, double counting was avoided as recommended by IPCC Guidelines.

1. The emissions of CO_2 from combustion of fossil fuels for production of industrial products, for example, combustion of fuel in rotary kilns for cement production, combustion of coke in production of soda ash, and consumption of CH_4 both as fuel and feed in ammonia production;

2. In the production of iron and steel, it is not necessary to estimate the amount of CO_2 emission caused by heating of CaCO3, because the CO_2 equivalent emission is estimated in the share of limestone usage;

3. The emissions of CO_2 in fermentation processes of food industries accounting for biological carbon.

2.3.1. GHGs Emission from Industrial Processes

2.3.1.1. CO_2 Emissions

The amount of CO_2 emissions from various industrial processes is given in Table 2.13. It notes that the CO_2 emission from mineral products, metal production and chemical industries are about 13,320.34, 13,495.95 and 1,740.21 Gg, respectively.

Figure 2.4 shows the relative contribution of CO_2 emission from different industrial processes. It can be seen that metal and mineral production have an equal contribution of about 47%, chemical productions emit 6% and have the minimum effect. The total CO_2 emission from industrial processes is about 28,556.5 Gg in 2000. The comparison of the contribution of different industrial sub-sectors to 1994 emissions reveals that the share of mineral

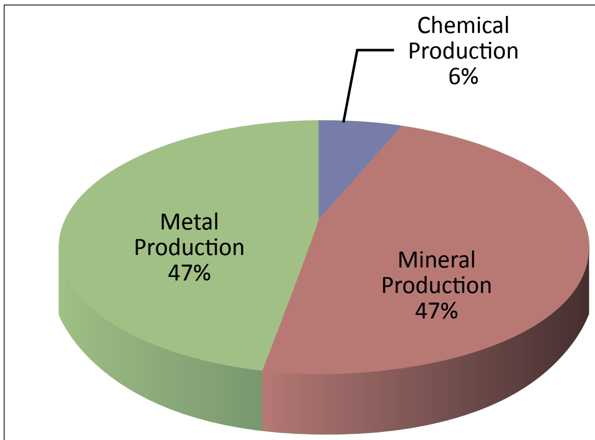


Figure 2.4: Share of Different Sub-sectors in CO_2 Emission for Industrial Processes in 2000

Dashtestan Cement Plant, Bushehr Province

Table 2.13: CO_2 Emissions (Gg) from different Sub-sectors for Industrial Processes in 2000

Sub sectors	Emissions (Gg)
Mineral Production	13,320.34
Metal Production	13,495.95
Chemical Production	1,740.21
Total	**28,556.5**

production in CO_2 emission has increased from 41% in 1994 to 47% in 2000, whereas the share of metal production and chemical industries has decreased. The fast growth in mineral production, especially cement during recent years is the one of the reasons for the growing percentage of mineral production in total CO_2 emission.

2.3.1.2. CH_4 and N_2O Emissions

Emission of CH_4 from industrial processes is about 3.2 Gg in 2000 and is derived in absolute terms from chemical industries including ethylene, dichloroethylene, styrene, methanol, coke and carbon black production. Also emission of N_2O is about 2.38 Gg in 2000 and is related to nitric acid production.

2.3.1.3. HFCs, PFCs and SF6 Emissions

The actual emission of HFCS and PFCs in 2000 is about 0.248 Gg that was estimated based on the amount of HFCs/PFCs in stock in existing systems and also consumed in 2000 within the country. Also emission of PFCs (CF_4 and C_2F_6) from aluminum production is about 0.2 Gg and 0.02 Gg, respectively.

HFCs, PFCs and SF_6 are not produced in Iran. Furthermore, there is no exact information about the quantities of halocarbons and SF_6 imported and exported in bulk or contained in existing appliances. Therefore, we have relied upon the data related to consumption and import of HFC134a for estimation of the emission, which makes the estimation of HFCs and PFCs emissions of the highest uncertainty.

SF_6 is not used in aluminum and magnesium foundries as a cover gas. However, the emission of SF_6 used in the gas-insulated switch gear and circuit breakers is about 0.004 Gg.

2.3.1.4. Indirect GHGs Emissions

Table 2.14 outlines the emissions of indirect GHGs from different industrial processes. It shows that the emissions of NO_X, CO, NMVOCs and SO_2 are about 7.92, 76.78, 11,224 and 29.31 Gg, respectively. Mineral production has a higher share of about 99% of total NMVOC emissions from industrial processes, whereas metal production with 84.7% has the highest share in CO emission.

2.3.1.5. Summary for Industrial Processes

Table 2.15 summarizes the national emission inventory of both direct and indirect GHGs for different industrial processes. It shows that iron and steel and mineral production account for about 90% of CO_2 equivalent emissions from industrial processes while the chemical industry and fugitive emission from the use of HFCs and PFCs contributes about 10%. Since the most important industrial units that emit the bulk of industrial process emissions are metal and mineral industries, we should consider these industries as priorities of emission reduction in our plans and programs related to climate change mitigation.

Table 2.14: Indirect GHGs Emission (Gg) from Industrial Processes in 2000

Sub sectors	NOx	CO	NMVOCs	SO_2
Mineral Production	3.45	1.44	11,178.95	11.9
Metal Production	0.49	65.03	0.4	6.44
Chemical Production	3.83	9.75	23.76	8.61
Other Production	0.15	0.56	21.59	2.36
Total	**7.92**	**76.78**	**11,224.7**	**29.31**

The 1996 IPCC's equivalence factors can be used to compute the CO_2 equivalent of direct GHGs. The results are presented in Figure 2.5.

As reflected in Table 2.15 and Figure 2.5, the CO_2 equivalent of N_2O, CH_4, HFCs and SF6 contribute only about 5% whereas CO_2 alone contributes to about 95% of the total direct GHGs. Therefore, it seems reasonable to adopt measures to reduce CO_2 emissions from cement, iron and steel production. In short, cement production contributes to about 40.3% whereas iron and steel production contribute to about 43.4% of the total CO_2 equivalent. The share of other industries was some 16.23% of the total direct GHGs CO_2 equivalent. The total CO_2 equivalent emission from direct GHGs is 30,028 Gg.

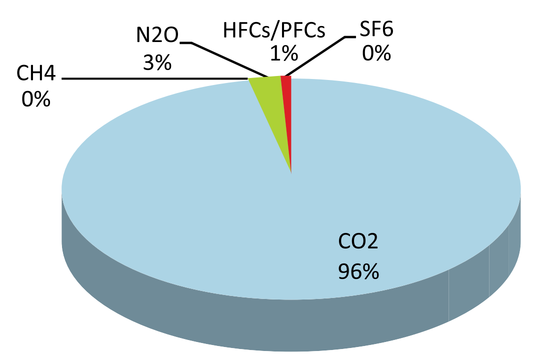


Figure 2.5: Contribution to Total CO_2 equivalent Emissions by Gas for Industrial Processes in 2000

2.4. Agriculture

Agriculture is considered to be one of the most important sectors of Iran's economy. The share of agriculture in GDP is about 14 percent and nearly 23 million (35%) of the population is engaged in this sector. It plays a vital role in achieving self-sufficiency in major staple food crops and ensuring food security for the country's increased population.

About 18.5 million hectares of arable land is under cultivation, out of which 8 millions are allocated for irrigated agriculture 6.5 million for rain-fed agriculture with the rest kept fallow. The 2005 figures on agricultural production indicate that the total annual production of agricultural crops (both annual and perennial crops) was about 84.8 million tonnes and the number of livestock including sheep and goats, cows, buffaloes, camels and solipeds (excluding poultry) is about 87,932,000 head or 125,396,000 animal units. Nevertheless, over utilization of base resources has undermined sustainability of fragile natural resources.

There are five major sources of GHGs emission from the agriculture sector as follows:

- Domestic livestock enteric fermentation and manure management,
- Cultivation of rice in flooded rice fields,
- Prescribed burning of savannas,
- Burning of agricultural crop residue,
- Agricultural soils.

Table 2.15: Total GHGs Emissions (Gg) for Industrial Processes in 2000

Subsector	CO_2	CH_4	N_2O	HFC134a	SF_6	PFCs		NO_x	CO	NMVOCs
						CF_4	C_2F_6			
Mineral Production	13,320	_	_	_	_			3.45	1.44	11,178
Metal Production	13,496	_	_	_	_			0.49	65.03	0.4
Chemical Production	1,740	3.17	2.38	_	_			3.83	9.75	23.76
Other Production	NE	_	_	_	_			0.15	0.56	21.59
Total	28,556	3.17	2.38	0.248	0.004	0.2	0.02	7.92	76.78	11,224
GWP	1	21	310	1,300	23,900	NA	NA	NA	NA	NA
Total CO_2 Equivalent	**28,556**	**66.57**	**737.8**	**322.4**	**95.6**	**NA**	**NA**	**NA**	**NA**	**NA**

Rice Cultivation, Gilan Province

The 2000 data regarding enteric fermentation and manure management, rice cultivation and anthropogenic nitrogen input into agricultural soils is collected from the 2003 edition of the Agricultural Statistical Yearbook, published by the Statistics and Information Technology Office of the Ministry of Jihad-e-Agriculture which is a specialized institute collecting and publishing data on an annual and other basis. However, in reality there are different institutes involved in collecting livestock data, namely the National Statistical Center of Iran, Department of Livestock Affairs of Ministry of Jihad-e-Agriculture, Veterinary Organization and Provincial Livestock Affairs affiliated to the Provincial Jihad-e-Agriculture Organization.

But, data regarding crop residue burned is not collected and therefore no official data is available in the country. However, an attempt was made in 2003 by the Sustainable Agriculture and Environment Office of the Ministry of Jihad-e-Agriculture to make a rough estimation of the crop residue burned in the country. The result of this survey was used in estimation of GHGs emission from agricultural residue burning.

2.4.1. GHGs Emissions from Agriculture Sector

2.4.1.1. CH_4 Emissions

CH_4 emissions from enteric fermentation of domestic livestock, manure management, rice cultivation and burning agricultural residue are about, 808.33, 29.45, 61.15 and 9.48 Gg, respectively. Therefore, the total CH_4 emitted from the agriculture sector is about 908.41 Gg. Table 2.16 and Figure 2.6 show the CH_4 emissions from different agricultural sub-sectors in 2000. As indicated in Figure 2.6, most CH_4 (89%) is emitted from enteric fermentation, whereas, rice cultivation, manure management and agricultural residue burning are responsible for 7%, 3% and 1% of total CH_4 emission, respectively.

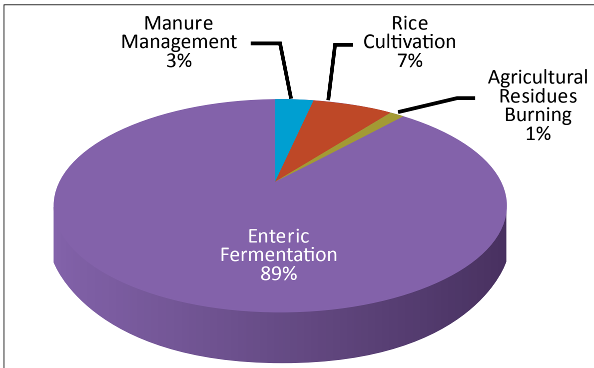


Figure 2.6: Contribution of Different Agricultural Sub-sectors to CH_4 Emissions in 2000

2.4.1.2. N_2O Emissions

The amount of direct and indirect N_2O emissions for agricultural soils is about 76.14Gg while N_2O emissions from animals and the burning of agricultural residue are about 0.81 and 0.2 Gg, respectively. Finally, the total N_2O emission from the agriculture sector is about 77.15 Gg. As shown in Table 2.17 agricultural

Table 2.16: CH_4 Emissions (Gg) from Different Agricultural Sub-sectors in 2000

Sources	CH_4 Emissions
Enteric Fermentation	808.33
Manure Management	29.45
Rice Cultivation	61.15
Agricultural Residue Burning	9.48
Total	908.41

Table 2.17: N_2O Emissions (Gg) from Different Agricultural Sub-sectors in 2000

Sources		Emission
Direct N_2O Emission from Agricultural Soil	Synthetic Fertilizer (F_{SN})	16.45
	Animal Wastes (F_{AW})	0.40
	Nitrogen Fixing Crops (F_{BN})	0.00
	Crop Residue (F_{CR})	10.19
	Sub Total	27.03
Indirect N_2O Emission from Agricultural Soil	Atmospheric Deposition of NH_3	3.94
	Leaching	19.72
	Sub Total	23.66
N_2O Emission from Agricultural Soil as result of Animal Grazing		25.45
Sub-total		76.14
Manure Management		0.81
Agricultural Residue Burning		0.2
Total		**77.15**

soil is responsible for 98.7% of N_2O emission in the agriculture sector, whereas the share of other sectors is about 1.31%. It should be noted that the information for estimation of N_2O emission from agricultural soil is very uncertain and thus there exists high uncertainty in N_2O emission from agriculture.

2.4.1.3. Summary for the Agriculture Sector

Table 2.18 tallies the total CO_2 equivalent of GHGs emissions for the agriculture sector. It is shown that the share of CO_2 equivalent of N_2O and CH_4 are about 55.6% and 44.4% of the entire CO_2 equivalent of GHGs emissions. In 2000, the total amount of CO_2 equivalent is about 42,993 Gg. It should be mentioned that there is no emissions reports about prescribed burning of savannahs.

As shown in Figure 2.7, agricultural soils contributes to 55% of the total GHGs emission of agriculture, whereas the share of enteric fermentation, rice cultiviation, animal waste and agricultural residue burning are 39%, 3%, 2% and 1%, respectivly.

2.5. Land-use Change and Forestry

Forests, ranges and soils play an important role in the global carbon cycle both as carbon sinks and sources of CO_2. The global carbon cycle is recognized as one of the major bio-geo-chemical cycles because of its role in regulating the concentration of CO_2. In this study, land-use change and its effects on emission and removal of CO_2 in Iran was determined and calculated[1]. The most important land-use changes were:

- Changes in forests and other woody biomass stocks,
- Forests and grasslands conversion,
- Abandonment of cropland, pasture, plantation forest, or other managed lands which revert into their natural grassland or forest conditions, and
- Changes in soil carbon.

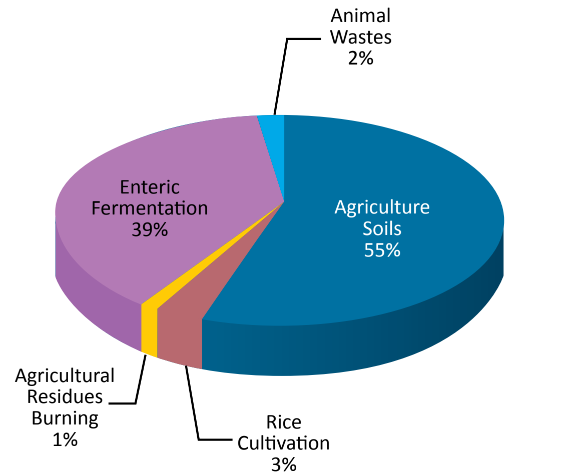


Figure 2.7: Contribution of Different Agricultural Sub-sectors to Total CO_2 Equivalent Emissions in 2000

1- This study was carried out using existing data and statistics available at the time of preparation of this report, which were not adequate for computing all items in the IPCC worksheets.

2.5.1. Natural Resource Situation in Iran

The country's geographic location affords Iran a highly diverse set of ecological conditions. This variety of climate has created an assortment of 7,576 plants, 517 birds, 208 reptiles, 170 fishes, 164 mammals and 22 amphibious species. The most important forests, rangelands and deserts of Iran are summarized below.

2.5.1.1. Forests of the Country

Almost 8.7 percent of Iran's land is covered with different types of forests. The area of these forests is about 143,188 km^2 [FRWO 2009]. There are five forest regions in the country described hereunder.

- *Hyrcanian forests*

This region stretches as a green narrow strip, from Astara in the northwest of Iran to Golidaqi Valley in the northeast and the total area is about 19,423 km^2. This site includes the southern prairie lands of the Caspian Sea and the northern slope of the Alborz Mountains with an altitude ranging from 25 to 3,000 m above sea level. Diversity of species in this habitat with more 80 types of wide leafed trees and shrubs has formed wide-ranging forest communities. The amount of standing plants is 280m^3 per hectare and the annual growth rate is 5m^3 per ha. Only five evergreen species are native to this habitat. Left over Common Hawthorn species from tertiary in this green humid forest can be seen. Hyrcanian forests also have industrial and commercial value. The most important species of Hyrcanian forests are Quercus, Fagus, Carpinus, Fraxinus, Tilia, Zelkova, Buxus, Ulmus and Sorbus species.

- *Arassbaranian forests (Semi-humid)*

This small region is in, the east and west of Azarbayejan, in northwest Iran with an area of about 1,487 km^2 and an altitude that ranges from 285-300 m. Not long ago, the forest cover in this habitat had noticeably greater density; the important specification of this region is the existence of 775 herbaceous species and 97 woody species that illustrates the high level of plant variation.

The Arassbaran region is also considered as a path through various growth regions. Rate of standing trees and plants is 80m^3 per hectare and the annual growth rate is 1.76m^3 per ha. The most important species in this region are Quercus, Pyrus, Acer, Juniperus, Pistacia and Cornus species.

- *Zagrossian forests (semi arid)*

This forest region is a narrow strip with an area of 60,740 km^2, located in the west of Iran along the Zagros Mountains. The absorption of humidity from Mediterranean Sea clouds by the Zagros Mountains provides the necessary conditions for having tree plantation with the Oak species being dominant. The amount of standing trees and plants is 15 m^3 per ha and the annual growth rate is 1.3 m^3 per ha.

These forests are not commercial zones but they have an important role in providing wood as fuel for villagers and livestock grazing which are the two primary destructive agents in forest

Table 2.18: Total GHGs Emissions (Gg) for Agricultural Sector in 2000

Sources	CH_4	N_2O	CO_2 eq.
Enteric fermentation	808.33	NE*	16,974.93
Animal wastes	29.45	0.81	869.55
Rice cultivation	61.15	NE*	1,284.15
Agriculture soils	NA**	76.14	23,603.40
Agricultural residue burning	9.48	0.2	261.08
Total	908.41	77.15	42,993.11
GWP	21	310	
Total CO_2 Equivalent	19,076.61	23,916.50	42,993.11

**Not Estimated*

*** Not Available*

plantations. The most important species in this region are Acer, Quercus, Pistacia, Amygdalus, and Fraxinus species.

- *Irano Touranian forests (arid zone)*

This region with an area of 41,240 km^2 is the largest plantation zone in Iran and includes the central plateau of Iran and it's surroundings except for the south of the Caspian Sea and the northern strip of the Persian Gulf-Sea of Oman and Zagros Mountains [FRWO 2009]. Most of the salty deserts, sandy places and salt marshes are in this wide region. Because of altitudinal ranges between 0 to 5,761 m, we can see various plant species such as small trees and shrubs resistant to dryness, heat and salinity. The rate of standing trees and plants is 7 m^3 per ha and the annual growth rate is 0.7 m^3 per ha. Forests of this region are divided into two low-density dry and arid sections. The primary species of these forests are Tamarix, Haloxylon, Zigophilum, Amygdalus, Astragalus and Pistacia.

- *Gulf Omanian forests (Subtropical zone)*

This region, also known as Sahara-Sandy, covers of 10,881 km^2 and is situated from Ghasr-e-Shirin in the west to the northern coast of the Persian Gulf and stretches cross-country to the border of Iran and Pakistan in the southeast. The average precipitation here is less than 100 mm per year and the zone is characterized by a long summer season with hot and dry weather and low floral diversity of subtropical species. Mangrove forests of Avecina officinalis with their concomitant high ecological value, is also an important community of tree species in this region. The rate of standing trees and plants is 7 m^3 per ha and the annual growth rate is 0.7 m^3 per ha. These forests are situated in the tidal coats of the Persian Gulf and the Sea of Oman and are significant because of the protective cover they provide for coastal marshes. The other vegetation species of this zone are Acacia, Populus, Prosopis, Pistacia, Zigophilum, Tamarix and Ziziphus.

2.5.1.2. Rangelands

Based on the data of the Forests and Rangelands Organization in 2000, the total amount of rangelands in the country was 84,746,971 ha, which of this amount, based on the crown density, 56,148,951 ha is related to low density rangeland (crown density between 5% to 25%) and 21,422,950 ha is semi-dense rangeland (crown density between 25% to 50 percent%) with another 7,175,071 ha classified as high density rangeland (crown density more than 50%).

2.5.1.3. Deserts

Iran's desert expanses are primarily in the central regions. Based on the latest data of the Forests and Rangelands Organization total desert coverage is 32,576,929 ha which includes sand dunes, out crops, bare land, saline land and so on [FRWO 2009].

2.5.2. GHGs Emission Inventory from Land-use Change and Forestry

Studies have been carried out in three sections including; change in forests, lands and woody stocks, forests and grasslands conversion and finally abandonment of managed lands. Because of lack of reliable information on changes in soil carbon, this indicator has been ignored in our calculation. Also, because of difference in definitions, units and so on in various forest zones in our country, the forests have been divided into five separate regions (zones). Each type of forest has been calculated separately and the effect of forests and grasslands in greenhouse gases uptake and release (emission) has been estimated. Finally, by using IPCC guidelines, modules and coefficients, calculations have been done. It should be noted however, that all information has been taken from illegal exploitation records and documents available in the Forests and Rangelands Organization.

2.5.2.1. Change in Forest and Other Woody Biomass Stocks

As described earlier, there are five forest regions in four climatic zones in Iran. Forest areas and reforestation activities are changing with a different increase of phyto-mass in every zone. According to the statistics obtained from Iran's Forest and Watershed Management Organization, the condition of absorption and release of greenhouse gasses, CO_2 in particular, is due to changes in forests and other wood resources and are estimated as follows:

- The release rate of carbon per year: 2612.75 (Gg C),
- The total carbon increment per year: 142.89 (Gg C),
- Net of carbon emitted (released) per year: -2469.9 (Gg C),
- The annual emission of CO_2: -9056.2 (Gg CO_2).

It should be noted that the negative sign in the above figures means released or emitted greenhouse gas from this sector. The statistics and calculations presented here are based on alterations and interferences with forests (including legal and illegal exploitation, forest fires) that is calculated and presented based on the countries' regional growing segmentation methods. Obviously the changes resulted from ecological and natural factors that cause growth reduction or similar effects that have not been considered in the calculations due to a lack of necessary data.

2.5.2.2. Forest and Grassland Conversion

The relation between absorption and release of greenhouse gases especially CO_2 and using of forests and pastures are as follows:

- The carbon released due to forest fires and burning on and off site of the biomass remains: 41.592 (Gg C),
- The carbon released due to decay of above ground biomass: 18.99 (Gg C) (average of 10 years),
- The gross carbon released per year: 60.582 (Gg C),
- The gross carbon released in this region: 222.134 (Gg CO_2).

2.5.2.3. On-site Burning of Forests

Some non-CO_2 greenhouse gases such as methane, nitrous oxide and nitrogen oxides (NOx) are emitted from on site burning of forests. As shown in Table 2.19 these emissions are in trace amounts.

Table 2.19: Non-CO_2 GHGs Emissions (Gg) from On-Site Burning in 2000

GHGs	Emission
CH_4	0.311
N_2O	0.0022
NO_X	0.077
CO	2.72

2.5.2.4. Abandonment of Managed Land

The statistics related to abandonment of managed lands are not reliable and therefore not considered in this inventory. Furthermore, if the land under management in the north of the country is not affected by the destructive factors for a long period of time, then the land would be covered by pioneer tree species. However, in these regions the trees would be eliminated by land owners once every few years to maintain establishment of their ownership; but this practice results in the loss of land potential for replanting as the years pass and the procedure continues.

2.5.2.5. Changes in Soil Carbon

Information about soil transformation and organic matter created by land use change, agricultural activities and so on are not available or not reliable. Therefore, no CO_2 emission estimates were made.

2.5.2.6. Summary for Land-use Change and Forestry

The GHGs emissions and uptake from land-use change and forestry are shown in Table 2.20. According to this Table, the land use and forestry sectors in Iran are sources for GHGs emissions with a net total of CO_2 equivalent of about 9,278 Gg. The amount of CO_2 uptake in the land use and forestry sectors is about 523.93 Gg. This tells us that the forest harvesting programs in Iran have not been planned on a sustainable basis.

Table 2.20: Emissions and Uptake (Gg) in Land-Use Change and Forestry in 2000

Source	CO_2 uptake	CO_2 emission	CH_4	N_2O	NO_x	CO
Change in forest and other woody biomass stocks	523.93	9,580.08	-	-	-	-
Forest and grassland conversion	-	222.134	0.311	0.0022	0.077	2.72
Abandonment of managed land	-	-	-	-	-	-
Total	523.93	9,802.22	0.311	0.0022	0.077	2.72
GWP	1	1	21	310	NA	NA
Net Total CO_2 Equivalent Emission	**9,278.29**		**6.531**	**0.682**	**-**	**-**

It is shown in Table 2.20 that in 2000 the carbon dioxide discharge rate has noticeably decreased due to changing forestland and its wood resources in comparison with the 1994 level. In addition, the rate of discharge has also been decreased due to changes in the forests and pastures. Finally, it can be concluded that, although the rate of absorbing resources in 2000 compared to 1994 does not show any increase, yet given the outstanding decrease in discharge recourses, destruction of forests and pastures has seen an overall decline. It should be noted that although the rate of physical destruction has declined markedly compared with previous years, the type and nature of destruction has changed today which could presage a great catastrophe in forests. The range of destruction caused by interference and poor management has created an imbalance in the ecosystem that outlines a continuing trend of degradation. The consequent future damages of these functions will be incomparable to the physical destruction of previous years. In the coming years we should expect growing internal destruction of the natural ecosystem structure. The signs are already in plain sight--among them we can refer to natural events that result from unnatural forces including the overflow of diseases that causes plant growth reduction, drought and changes in growth pattern sequence.

2.6. Waste

The outstanding source of GHGs emissions in the solid waste sector is related to CH_4 emissions from landfill sites. In Iran the percentage of CO_2 to CH_4 in Landfill Gas (LFG) may be smaller than other countries because of decomposition of substrates with a high hydrogen/oxygen ratio and because some of the CO_2 dissolves in water within the site.

Methane emissions result from the decomposition of organic landfill materials such as yard waste, household garbage, food waste and paper. Methane production typically begins one or two years after waste placement in a landfill and may last from 10 to 60 years.

Smaller amounts of CH_4 are emitted from wastewater systems by bacteria used in various treatment processes. Wastewater treatment systems are also a potentially significant source of nitrous oxide (N_2O) emissions, however, methodologies are not currently available to develop a complete estimate. Wastewater from domestic (municipal sewage) and industrial sources is treated to remove soluble organic matter, suspended solids, pathogenic organisms and chemical contaminants. In Iran approximately 25% of domestic wastewater is treated in septic systems or other on-site systems.

2.6.1. GHGs Emissions from the Waste Sector

2.6.1.1. GHGs Emissions from Solid Waste

Two methodologies have been used to estimate methane emissions from solid waste disposal sites (SWDSs) throughout this report as follows:

- The 1996 IPCC Revised Guidelines/ default methodology (Tier1) and
- Theoretical first order kinetics methodology or First Order Decay (FOD) Model (Tier2).

These methods vary widely, not only in the assumptions that they make but also in their complexity, and in the amount of data they require. The 1996 IPCC Revised Guidelines requires data (including information on the composition of the waste and on the conditions at the SWDSs) only for the inventory years, whereas the FOD method requires data for the past 20-25 or more years. In addition, the rate of degradation for waste disposed at SWDS needs to be determined in the FOD method.

Only if the yearly amounts and composition of waste disposed as well as disposal practices have been nearly constant for long periods, will the default method produce fairly good estimates of the yearly emissions.

Also the default methodology is a mass balance approach that involves estimating the degradable organic carbon (DOC) content of the solid waste, i.e., the organic carbon that is accessible to biochemical decomposition, and using this estimate to calculate the amount of CH_4 that can be generated by the waste. The IPCC default method can produce relatively good estimates of the potential future emissions.

The data required for calculating CH_4 emissions from SWDSs is listed in Table 2.21.

Based on the above data, the net annual methane emissions from landfills in Iran according to the IPCC Tier 1 and Tier 2 methods in 2000 are 497.54 and 468 Gg, respectively.

2.6.1.2. GHGs Emissions from Liquid Waste Sector

- ***Domestic Wastewater***

The Ministry of Energy reported that only 15% of cities that contain 24% of the total population, were able to treat their domestic wastewater[2] until 2000, other cities discharged their wastewater on land, into rivers etc. The population of Iran in 2000 was estimated at about 67 million and the per capita consumption of water was estimated to be 250 liters per day.

Domestic wastewater CH_4 emissions were estimated using the default IPCC methodology. The emission factor (0.18 kg CH_4/kg BOD_5) was taken from IPCC Good Practice Guidance (IPCC 2000). The amount of wastewater BOD5 that was anaerobically digested was assumed to be approximately 10%. This value also accounts for Iran's septic systems and is based on the data of the Ministry of Energy. According to the above information, CH_4 emissions from domestic wastewater are estimated at about 50.5 Gg in 2000.

Table 2.21: Specifications of Solid Waste Sector for Estimation of CH_4 Emissions in 2000

Specifications		Value
Municipal Solid Waste (MSW) generation rate		0.8 (kg/capita/day)
Population whose waste goes to SWDSs		40,873,494 Capita
Fraction of MSW disposed to SWDSs		0.85
Total annual MSW disposed to SWDSs		10,145 Gg
Methane Correction Factor (MCF)		0.60
Weighted Average Methane Correction Factor (MCF0 for each type of SWDs		0.56
Fraction of degradable organic carbon (DOC) in MSW		0.18
Fraction of DOC which actually degrades		0.77
Fraction of carbon released as methane		0.50
Methane recovery (R)		0.05
Oxidation correction factor		0
SWDSs categories	Managed	20%
	Unmanaged – deep(≥ 5 m waste)	10%
	Unmanaged – shallow(< 5 m waste)	70%

2 - 2004 annual report, Water and Wastewater Engineering Co., Ministry of Energy, 2005

- ***Industrial wastewater***

When wastewater containing large amounts of organic material is treated through anaerobic decomposition, methane is emitted. The best estimate of those emissions would be based on a systematic measurement of all point sources; however, due to the lack of such information an alternative method (IPCC 1996 Revised Guidelines) was used for estimation of methane emissions from industrial wastewater treatment.

The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, provides default data for wastewater generation and COD on an industry-specific basis. The default data are assumed to have an uncertainty range of minus 50% to plus 100% (although no justification for the range is provided). IPCC also provides a single default factor of 0.25 kilograms methane per kilogram of COD, premised on a general approximation of the theoretical maximum for this emission factor, and identifies an uncertainty of plus or minus 30% for this estimate.

Iran Small Industries and Industrial Parks Organization (ISIPO) reported that there were 27 industrial treatment plants in 2000 for the country's industrial parks.

Industrial emission sources include wastewater from the pulp and paper, meat and poultry processing and vegetables, fruits and juices processing industry which have a high volume of wastewater with high organic COD load. Based on the information that was collected from ISIPO, CH_4 emission from industrial wastewater is estimated at about 344.53 Gg. Table 2.22 shows the emissions of CH_4 from wastewater in 2000.

- ***Indirect nitrous oxide emissions from human sewage***

Calculation of N_2O emission from human sewage is based on per capita protein consumption. According to the reports presented by the food and nutrition authorities in Iran, the per capita protein consumption in 2000 is 54.75 kg/yr. Based on the above information the total annual N_2O emission from sewage is 41.5 Gg N_2O/yr.

2.6.1.3. Summary for the Waste Sector

In 2000, the total CO_2 equivalent emission from sewage and waste was about 31,608.97 Gg. Table 2.23 shows that methane is responsible for 59.3% of total GHGs emission from waste, whereas the share of N_2O is about 40.7%. Moreover, liquid waste contributes 44.4% of CH_4 and 66.9% of total GHGs emission in the waste sector.

Comparison of GHGs emission in 2000 and 1994 reveals that the 2000 value is about 3.8 times higher than the amount of GHG emissions in this sector reported in the Iran's Initial National Communication to UNFCCC. The rapid growth in GHGs emission in the waste sector is a result of new waste management regulations that provide a legislative framework for waste management in Iran. According to this legislative framework, all industries and large cities are obligated to construct wastewater treatment facilities and solid waste disposal sites. This waste facilities infrastructure development accounts for the GHGs emission growth.

Table 2.22: CH_4 Emissions (Gg) from Liquid Waste in 2000

Sources		Emission
Domestic & Commercial Wastewater	Wastewater treatment	46.22
	Sludge treatment	4.28
	Sub Total	50.5
Industrial Wastewater	Wastewater treatment	227.25
	Sludge treatment	117.28
	Sub Total	344.53
Total		**395.03**

Table 2.23: GHGs Emissions (Gg) from Different Waste Sub-sectors in 2000

Subsector	CH_4 Emission	N_2O Emission
Solid Waste Disposal Site	497.54	-
Domestic & Commercial Wastewater Treatment	50.5	-
Industrial Wastewater & Sludge Handling	344.53	-
Human Sewage	-	41.5
Total	892.57	41.5
GWP	21	310
Total CO_2 Equivalent	**18,743.97**	**12,865**

2.7. Uncertainty Management of GHGs Emissions Inventory

2.7.1. Estimation of Uncertainty in GHGs Emission Inventory

In this section, the uncertainty in estimation of greenhouse gases emission from all sectors is presented for the first time in a National Communication, which is calculated based on IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory and also the IPCC 1996 Revised Guideline for National GHG Inventory (vol.1). As mentioned earlier, except for the energy and waste sectors for which some national emission factors are available, there are no national emission factors for other sectors. This results in significant uncertainties in the estimation of the national emission inventory.

Some factors that cause uncertainty in greenhouse gas emissions estimates are as follows:

- Difference in interpretation and/or description of sources, sinks, other definitions, theories, units, etc.,
- Uncertainty in statistics and data of primary economic and social activities that are used in calculations,
- Uncertainty in scientific understanding of key processes resulting in emission and/or omitting of GHGs.

Based on the IPCC Guidelines, in order to estimate the uncertainty individually for sources and gases in the national inventory, different statistical methods and expert judgments can be used. In this report expert judgment was utilized to estimate the uncertainty.

Furthermore, based on the guideline for managing uncertainty, for estimation of the uncertainty in all sub-sectors both activity data and emission factors have been considered. The result of sectoral and overall uncertainty for CO_2 emission is shown in Table 2.24 that indicates industrial processes have the lowest uncertainty in the CO_2 emission inventory, while the uncertainty of the forest sector is the highest. Also, the overall uncertainty for CO_2 is about 15.2%.

Table 2.25 shows the sectoral and overall uncertainty of GHGs emissions. As indicated in this Table, industrial processes and the energy sectors with uncertainty of 10.4% and 13%, respectively, have the lowest uncertainty, while the agriculture and land-use change with 75% and 67.5% register the highest uncertainty. The overall uncertainty of National GHGs Inventory is about 20.1%.

Table 2.24: Overall and Sectoral Uncertainty for CO_2 Emission (%)

Sector	Uncertainty
Energy	14.4%
Industrial processes	10.7%
Land-use change and forestry	67.5%
Overall Uncertainty	**15.2%**

Table 2.25: Overall and Sectoral Uncertainty for GHGs Emission (%)

Sector	Sectoral Uncertainty
Energy	13%
Industrial processes	10.4%
Agriculture	75%
Land-use change and forestry	67.5%
Waste	25.4%
Overall Uncertainty	20.1%

2.7.2. Key Source Analysis and Recommendations for Uncertainty Management

The key factors of uncertainty and recommendations for uncertainty management are shown in Table 2.26. Among different sources of GHGs in agriculture, livestock is considered the outstanding source of uncertainty since the activity data related to this parameter has the greatest level of uncertainty. As discussed in the following sections, one reason for this is that different organizations are responsible for collecting and compiling livestock population data. The other source of uncertainty is the lack of national emission factors for livestock that led us to use the Tier 1 IPCC emission factors.

As the required data is not collected regularly for this source of GHGs emission, the uncertainty is considered to be relatively high. In 2003 an attempt at a rough estimation of livestock GHGs was made by a team of experts at the provincial level. This was accomplished without any measurements. Hence, assessments carried out by the experts working on this inventory indicated that the result of the estimation could only be considered a very rough estimation with relatively high uncertainty.

With respect to methane emissions from rice fields none of the concerned research institutions has developed a country-specific emission factor. The method used for estimating CH_4 from rice fields is based on the annual harvested area. But according to past experiences, for a number of reasons, including overestimation and inefficiency of the existing method of data collection, there may be a bias of ± 5%. Therefore, other uncertainty can be attributed to selecting the emission factor from the IPCC Guidelines that may not be appropriate for conditions in Iran.

Uncertainty in emission from agricultural soils can be mainly attributed to:

- Choice of emission factor,
- Activity data,
- Lack of appropriate field measurement and,
- Lack of representative data for most cultivated areas.

Additionally data regarding application of chemical fertilizer in the country is considered to be very rough. Usually the amount of fertilizer distributed is taken equal to the amount actually consumed.

In the solid waste sector substantial uncertainty in the estimates from this source results from the lack of data characterizing country–specific waste generation, waste management practices, CH_4 potential of the waste in place and CH_4 that is emitted from waste piles and open dumps.

There are several uncertainties associated with the estimates of methane emissions from landfills. The uncertainty estimates of current amounts of waste are based on differences between different statistics, and also on expert judgment.

In the liquid waste sector significant uncertainties are associated with the industrial wastewater emission estimates. Wastewater outflows and organic loads vary considerably for different plants and different sub-sectors (e.g., paper versus board, poultry versus meat and food versus juices).

Table 2.26: Sources of Uncertainties and Recommendations for Uncertainty Management

Sectors	Activity Data			Emission Factor		
	Source of uncertainty	Level of uncertainty	Recommendations	Source of uncertainty	Level of uncertainty	Recommendations
Energy	• Fuel smuggling from the borders • Substitution of gasoline consumption in transport sub-sector to solvent application • Uncertainty in volume of gases which is flared in oil and gas activities	• High • High • High	• Strict rules • Precise calculation of other applications • Use IPCC reference approach for estimation of flare gas emission	• Emission factor of CH_4 emission from hot flaring • Fugitive emission factor of CH_4 from coal mining and handling	• Low • High	• Development of national emission factor • Development of national emission factor
Industrial Process	• Consumption and import of HFCs and PFCs	• High	• Establishment of customs clearance codes for HFCs/ PFCs import and export	• Lack of national emission factor in industrial processes	• Medium	• Development of national emission factor
Agriculture	• Number of livestock population • Burning of agricultural residues	• Medium • High	• Precise census of livestock population • Collection of related data	• Lack of national emission factors in all agricultural sub-sectors	• High	• Development of national emission factor
Land-use change and Forestry	• Related statistics in estimation of carbon release	• High	• Preparation of up to date database regarding to generation, consumption and burning of forests	• Lack of national CO_2 emission/ absorption factor for each vegetation types and areas	• Medium	• Development of national emission factor
Waste	• Amount of rural solid and liquid waste • Amount of waste pile and open dump for methane emission	• Medium • Medium	• Establishment of efficient administrative office to gather the statistics • Change in waste management and handling and create an efficient data collecting systems	• Lack of local emission factor in both solid and liquid waste sub-sectors	• Medium	• Development of national emission factor

Chapter 3:

National GHGs Mitigation Policies

3.1. Introduction

Greenhouse gases (GHGs) are the prime cause of global warming and climate change. Therefore, mitigation of GHGs is a high priority global objective. Mitigation assessments in the country have been carried out in two distinct sectors, energy and non-energy. As mentioned in Chapter 2 on GHGs emissions inventory, the energy sector is responsible for about 77% of total GHGs emission, thus a great deal of consideration is needed while assessing mitigation potential in this sector. The outstanding challenge here is that the extant complexity exists both in the energy sector's supply and demand side and that necessitates a comprehensive study of the energy sector of the country.

The following mitigation policies are based on extensive and lengthy consultation with experts, institutions and research undertaken in the country.

3.2. Energy Sector

3.2.1. Overview of Energy Sector

3.2.1.1. Oil and Gas Sub-sector

Iran is a major producer of oil, with the second largest reserves in the world. In 2005, its share of world production was 5.9%, much less than its 11.8% share of world reserves. In 2005, Iran produced 4.09 million barrels per day (mbd) of oil, compared to 6.06 mbd in 1974, when national oil production was at it highest ever level. Iran has, after Russia, the second largest gas reserves and is the fourth largest producer of gas in the world, with some 16% of reserves. A pivotal re-evaluation of the size of the massive offshore South Pars gas field, estimates of the size of Iran's reserves have increased by 12% since 2000. In 2003, Iran produced 122 billion cubic meters (bcm) of gas. The amount sold in local markets was 78 bcm, re-injection into oil fields accounted for 35 bcm, flaring was 5 bcm and shrinkage 6 bcm. The Ministry of Petroleum has set a production target of 265 bcm for 2010. Technological progress in the upstream oil sector would reduce the need for re-injection, which is currently the most profitable use of gas. The development of the gas sector, especially in the South Pars field, will depend on the availability of foreign technology and capital. Domestic supplies will also depend on the re-injection needs of the oil sector. Therefore, if the existing barriers on transfer of technology are removed, Iran can supply fuels to the global market with reduced carbon content.

The Government has also encouraged the domestic use of gas in order to release more oil for export and promotes sustainable development as well as mitigating climate change. In 1971, oil accounted for 84% of the primary energy demand. In 2003, the share was 50%.

In 2004, Iran had an installed electricity generation capacity of 34.3 gigawatts (GW) that was expanded to 41 GW, in 2005. Most of electricity is produced in steam boilers and low efficiency gas-turbine technology. These are powered by gas in the summer, when consumers need less gas for heating. In the winter, fuel oil is used because gas is needed for home heating, thus reducing the amount of gas available for electricity generation and export.

3.2.1.2. Electricity Generation

The demographic trend and intensified industrial growth have grown electricity demand by 8% annually. Accordingly, the Iranian energy sector has focused its efforts on meeting this continuous demand. As a result, the electric power capacity expansion plans are configured to utilize oil efficient power plants while concentrating on natural gas production.

In 2004, electricity production was 165 terawatt hours (TWh). At 2,299 kilowatt hours (KWh) per capita, Iran has one of the lowest per capita levels of electricity production in the Middle East (about one third of the Saudi level and similar to the levels in Lebanon). Electricity demand has grown rapidly, partly as a result of the large subsidies that cost the government USD 2.63b in 2004. The low price of electricity means that power companies make no profit and cannot reinvest in upgrades without government help. At the same time low costs boost demand and encourages waste. In 2003, residential users in Iran paid about 22% of the cost of electricity. The average rate of subsidy for all sectors was 61% of the cost. In 2003, between 75 and 80% of electricity was generated by gas power plants, with oil supplying 16%. In the mid-1970s, oil accounted for 50% of electricity generation. Now, the government has engineered a master plan for price reform for energy carriers.

- ***The dominant share of gas fired power plants***

With the second largest estimated gas reserves in the world, Iran has already imposed a comprehensive fuel-substitution policy to change the pattern of domestic energy consumption toward greater utilization of natural gas among other energy carriers and to promote its position in international gas markets. During the past years, the share of gas-fired technologies including gas turbine and combined cycle technologies has increased. The total nominal installed capacity of electricity generation in Iran reached over 49.53 GW in 2007: a growth of 13% compared to 2006. In the same year, the divide of different types of power plants were as follows: steam turbines 31.5%, combined cycles and gas turbines 52.6%, hydro turbines 15.0%, diesel 0.9%, and finally solar and wind power plants 0.1%.

- ***High rate of GHGs emissions in electricity sector***

Since 1990, the per capita CO_2 emission has increased from 3.05 tonnes to 5.97 tonnes in 2006. Among all sectors, residential and commercial buildings, power plants and the transport sector play a crucial role in CO_2 emission. In the power sector, among the thermal power plants, the lowest emission per unit of generated electricity is in the combined cycle application, while diesel is the highest. Table 3.1 shows the CO_2 emissions by different thermal power plants in 2006.

Considering that Iran has ratified UNFCCC and the Kyoto Protocol, the transfer of efficient power generation technology under articles 4.5 of the Convention and 3.14 of the Protocol, would have an important role in eliminating GHGs emission in the country's power sector.

- ***Renewable energy resources***

The total potential of hydro electricity generation in Iran is estimated to be 50 TWh annually. Considering the importance of hydro power plants in providing the required electricity for the country, fundamental measures have been taken to utilize this kind of energy. In 2007 total economy of scale hydropower capacity amounted to 6,533 GW. Iran also has a large

Table 3.1: CO_2 Emissions by Different Thermal Power Plants in 2006

Power Plant	CO_2 emission (Million tonnes)	Share in total power sector CO_2 emission (Percentage)
Steam	58.11	52.67
Gas Turbine	32.25	29.23
Combined Cycle	19.68	17.84
Diesel	0.17	0.16

wind power potential estimated at between 12 to 15 GW. The average annual solar radiation in the country is estimated up to 5 KWh per square meter and the average hours of sunshine is 2,800 hours per year. In some regions such as the inner deserts and their surrounding cities (e.g. Khour-o-Biabanak and Yazd), the daily sunshine averages exceed 3,200 hours a year. In general, regions with annual direct solar radiation of at least 1,800 KWh/m2 (5.05 kWh/m2.day) are considered optimum sites to build solar power plants.

Regarding development of renewable energy in Iran, different policies have been pursued including: encouraging the private sector to invest in renewable energies, preparing power purchase agreements for all renewable energy sources, providing subsidies and supporting the manufacturers and design companies for technology development and transfer for competitive technologies in the mid-term like wind and PV power plants, etc.

3.2.1.3. Energy Pricing

The government plays a monopolistic role in the Iranian energy market. It is the only producer of oil, gas and electricity in the country and thus sets pricing policies. In the last three decades it has placed energy prices at substantially lower levels than world market prices. Also significant is that growth rates of domestic energy prices were lower than domestic inflation rates. The price gap range between national and world prices for fuel oil, gas oil and kerosene has increased during 1999-2003. For example, the gas oil international/domestic price ratio was 6.8 in 1999 but it increased to 9.88 in 2003. The gap also increased during 2004 to 2009 because domestic prices were constant but international prices increased faster with the oil price boom during 2005-2008.

The significant misalignment between domestic and international prices has imposed considerable missed opportunity for revenue on the economy. Statistics illustrate the amount of these costs, which are equal to 125,828 billion Iranian Rials that exceed 11% of the country's GDP. The pricing process distorted relative prices and encouraged massive energy inefficiency, environmental pollution and smuggling petroleum products to neighboring countries. Therefore, the Iranian government is planning to reform the energy pricing system. Obviously such a reform would create complicated obstacles for price levels, household welfare, government budget and the trade balance.

3.2.1.4. Methodology

For projection of energy demand and also mitigation assessment, a techno-economic model using "EViews" software has been applied. In the economic section of the model the demand for different energy carriers has been modeled. Energy prices, inflation, GDP growth rate and added value of different economic sectors are effective exogenous parameters on energy demand. In the technical section of the model, technical parameters and the relationship between demand and supply of energy carriers has been considered. In the energy sector, electricity sub-sectors are a common face of economic and technical sections. In other words, electricity demand is a function of economic variables and electricity generation is a function of technical parameters. Hence, the power sub-sector needs special attention and requires to be modeled separately so that the loss of electricity in the transmission and distribution network, power plant efficiency, fuel mix and the share of renewable energy in electricity generation have been considered as exogenous variables.

3.2.2. Scenario Development

It is important to note that in developing mitigation scenarios in the energy sector, econometrics models have been used in this report to estimate the energy demand for different energy carriers in the future. These models are based on several assumptions on the rate of economic growth, GDP, energy carriers pricing and the share of low carbon and renewable energies. Therefore, GHGs emission estimates presented in this report vary with different assumptions and do NOT represent the actual emissions of the country in the future.

3.2.2.1. Business As Usual (BAU) Scenario

In the Business As Usual (BAU) scenario (2000-2025) all of the exogenous variables of energy modeling vary based on 1994-2007 realities and using econometric functions and methods to evaluate the scenario. Then, the emissions of the GHGs are predicted based on those values (See Table 3.2 and 3.3).

3.2.2.2. Official Development Plan (ODP) Scenario

As mentioned before, there is a gap between domestic and global energy prices that imposes considerable missed opportunity costs on the economy. As a result, the government is focused on just pricing policies as its first priority. In order to estimate a prediction of the countries GHG emissions, energy prices are considered to vary based on the energy subsidy removal programme of the government in 5th FYDP (Five Year Development Plan/2010-2015).

3.2.2.3. Mitigation Scenarios

Eight different mitigation policies have been considered and different options are defined based on them. The choice of these plans are based on reviewing the government schemes in the past and future, expert judgment on the availability of the related technologies and financial resources, needs for regulations and rules and preparation of infrastructures according to the future objectives and activities of the country over the long-term. In this regard, the mitigation policies are divided into the following two categories:

- National Mitigation Plan, consisting of the mitigation measures which will be funded by Government and is responsible for about 30% emission reduction by 2025 in comparison with BAU Scenario.

- Internationally Funded Mitigation Action, consisting of the mitigation measures which could be implemented only if international technical/financial assistance under UNFCCC becomes available. These mitigation options will be responsible for about 34% emission reduction by 2025 in comparison with BAU Scenario. Although these policies are the objectives of the Government in the "2025 Country's Vision for Development", reaching these objectives needs international financial/ technical assistance under UNFCCC.

The details and definition of the defined scenarios (Mitigation Policies (MP)) are described below:

- MP1: Increase the energy efficiency of end-use sectors (demand side) at the rate of 2% per year until 2025 (energy intensity will be reduced from 2.04 BOE/million rials GDP in 2007 to 1.4765 in 2025). This mitigation policy consists of a basket of measures that will be implemented in the commerce sector, industry, agriculture, etc. through the use of efficient appliances and machinery, renovation in industries, process optimization and also installing Small Combined Heat and Power (SCHP) units. Most of this improved efficiency will be implemented through the small SCHP units in large buildings, public institutions and industries.

Table 3.2: Assumptions for Exogenous Variables in BAU Scenario (%)

Inflation	GDP growth rate	added values of different sectors		
		Industry	Agriculture	Commercial
20	3.5	3.5	3.5	3.5

Table 3.3: Assumption for Exogenous Variables in Electricity Sub-sector of the BAU Scenario (%)

Loss of Electricity	Power Plant Efficiency	Fuel Mix (Natural Gas ratio)	Share of Renewable Power Plants
23.94	34.08	73.227	8.9

- MP2: Increase of the share of CNG in transport from 2.5% in 2007 to 25% in 2025 at the rate of 1.25% per year.

- MP3: Increase of the share of natural gas (NG) in the industry sector from 59.4% in 2007 to 82% in 2025 at the constant rate of 1.8% per year.

- MP4: Increase of the share of NG in residential and commercial sectors from 66.5% in 2007 to 88% in 2025 at the constant rate of 1.55% per year.

- MP5: Increase of the share of NG in power plants from 73% in 2007 to 100% in 2025 at the constant rate of 1.74% per year.

- MP6: Increase of the share of renewable and low-carbon electricity production industries in total electricity generation of the country by increasing the capacity of hydropower from 7,073.8 MW in 2007 to 19,000 MW in 2025, wind from 74 MW in 2007 to 6,000 MW in 2025 and nuclear power plants from zero in 2007 to 20,000 MW in 2025 with a constant growth rate of 1% per year.

- MP7: Increase of the power plants efficiency from 34% in 2007 to 52% in 2025 at the rate of 1% per year. The policy will be implemented through different measures like installing combined cycle power plants and distributed electricity generation systems. In 5th FYDP, about 3000 MW of SCHP generators will be installed.

Shiraz Photovoltaic Project, Fars Province

- MP8: Decrease of the loss of the electricity distribution and transmission network from 24% in 2007 to 15% in 2025 at the rate of 0.5% per year.

3.2.3. GHGs Emission Trend in BAU Scenario

The results of the GHGs emission projection in BAU scenario in the energy sector shows that emission will increase from 486.1 million tonne CO_2e in 2007 to 2,248.5 million tonne CO_2e in 2025 (See Figure 3.1) This means that there will be a high growth rate of GHGs relative to the growth rate of GDP. According to the study conducted the average growth rate of the GHGs would be 8.4% per year and the annual growth rate increases from 7.2% in 2007 to 9% in 2025 which means emission of GHGs accelerates slightly (See Figure 3.2) In addition, the share of CO_2 emission in total emission is 99.65% in 2007 that slightly increases to 99.7% in 2025. Also, the share of N_2O decreases from 0.15% to 0.11% in the same period.

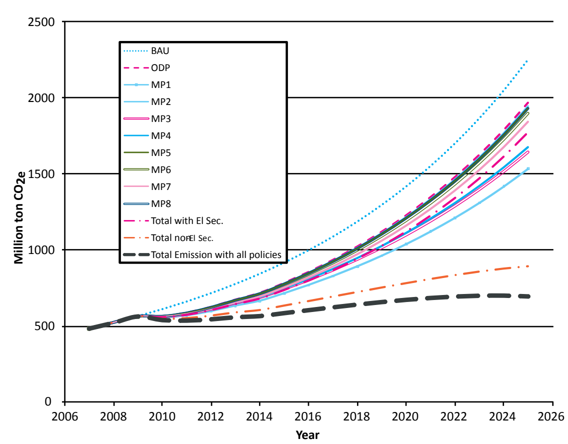


Figure 3.1: GHGs Emission Trends in Different Scenarios for Energy Sector (million tonne CO2e)

3.2.4. GHGs Emission Trend in ODP Scenario

The results of the study for the Official Development Plan (OPD) scenario in the energy sector shows that the emission of GHGs will increase to 1,966.6 million tonne CO_2e in 2025. As a result, the average growth rate of the GHGs would be 7.63% per year. As shown in Figure. 3.2, there are variations of growth rate in the future years. The growth rate will experience a shock in the first years that is solely due to implementing energy pricing policies. In fact, from 2010 when these policies free energy prices to reach world prices are implemented by the government, the growth rate will decrease in comparison to BAU but after 2015, the emission growth rate in ODP will fall back to the same rate in BAU. This indicates that pricing policies though effective in the short-term, in the long-term they have a limited impact on emission reduction. However, on the average the total GHGs emissions in ODP are 12.91% less than BAU.

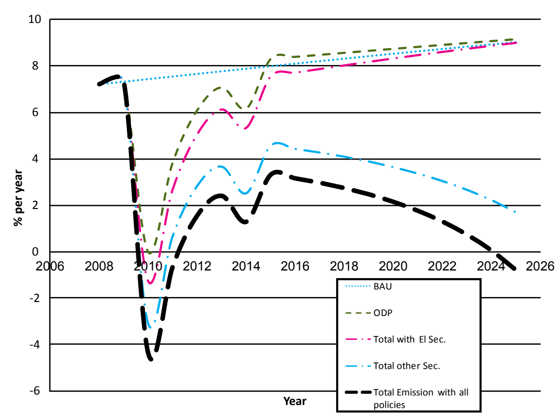


Figure 3.2: Yearly Growth Rate of Emission in Different Scenarios (%)

3.2.5. GHGs Emission Trend in Mitigation Scenario

The impact of different policies and measures on GHGs emission rate in the Mitigation Scenario are discussed in three sub-scenarios which are as follows:

- The aggregated effect of electricity sector mitigation policies,

- The aggregated effect of non-electricity sectors mitigation policies(demand side) and,

- The aggregated effect of all mitigation policies on emissions of the GHGs in the whole of the energy sector.

- ***The aggregated effect of electricity sector mitigation policies***

Based on the study conducted, these policies mostly affect the emissions of N_2O and CO_2 while the share of these greenhouse gases in the total emission of CO_2 equivalent are on average respectively 0.12% and 99.67%. The average growth rate of the emitted GHGs in this scenario is 7.04% per year which is close to that of the ODP scenario but it entails an average of 7.3% reduction in the emitted GHGs compared to ODP. However, if this group of policies were implemented, then the amount of the GHGs would be 1,728.0 million CO_2e in 2025 that is 12.1% less than ODP and 23.1% less than BAU emission in 2025. The comparison between the emissions and percent reductions during 2010-2025 for mitigation scenarios (MP5 to MP8), ODP and BAU are shown in Table 3.4.

- ***The aggregated effect of non-electricity sectors mitigation policies***

This group of policies is the most effective one. Surprisingly, the amount of the emitted GHGs is projected to be 892.1 million tonne CO_2e in 2025 that shows 54.6% and 60.3% reduction of GHGs emissions in comparison to ODP and BAU, respectively (Table 3.4). The trend of the growth rate is also different from other policies. The growth rate reaches -3.1% per year in 2010 (the first year of implementation of the policies), then increases to its maximum value of 4.6% per year in 2015 and then decreases significantly to 1.7% per year in 2025. This decrease means that there is a significant superposition effect while policies are on the demand side. The average growth rate would be 3.25% per year. The effect of the mitigation policies in the non-electricity sectors relative to ODP is shown in Table 3.4 (MP1 to MP4).

- ***The aggregated effect of all mitigation policies***

As discussed above, the effect of non-electricity sectors mitigation policies is much higher than the effect of electricity sector policies. Therefore, a major role of these policies in the future GHG mitigations is expected. As a result, the emission of GHGs is projected to be 696.6 million tonne CO_2e in 2025 which

Table 3.4: GHGs Emissions and Potential For Mitigation in Different Scenarios (million tonne-%)

Year*		2010	2015	2020	2025
BAU		611.2	916.7	1,416.0	2,248.5
ODP		565.6	783.6	1,227.0	1,966.6
Policies**					
Non-electricity Sectors	MP1	1.5	8.5	15.4	22.0
	MP2	0.1	0.4	0.7	0.8
	MP3	0.7	5.2	10.6	16.6
	MP4	0.7	4.6	9.4	14.8
Electricity Sector	MP5	0.1	0.8	1.4	1.8
	MP6	0.3	2.1	3.6	5.2
	MP7	0.8	3.8	5.6	6.5
	MP8	0.2	1.0	1.5	1.9
Aggregation (implementing non-electricity sectors policies)		3.0	19.0	36.3	54.6
Aggregation (implementing electricity sector policies)		1.3	6.4	9.7	12.1
Aggregation (implementing all policies- million tonne)		542.1 (4.2**)	589.4 (25.0)	678.6 (45.0)	696.6 (64.6)

* Total GHG emissions of 2000 was 377.8 million tonne CO_2e

** Values are in percent

indicates reductions of 64.6% and 69.0% of GHGs emissions in comparison to the ODP and BAU scenarios, respectively. As shown in Figure 3.2, the trend of growth rate is similar to that of non-electricity sectors mitigation policies with the mean value of 1.91% per year. Surprisingly, the growth rate is forecast at -4.4% per year in 2010, then increases to reach its maximum value of 3.3% per year in 2015 and then decreases significantly to -0.8% per year in 2025.

3.2.6. *Conclusion*

The relative position of the effectiveness of each policy on GHG mitigation can be summarized as shown in Figure 3.3 below. According to Figure 3.3, the most effective policy is the MP1 that relates to energy efficiency improvement of the end-use sectors. This means that Iran needs to plan to make the end-use sector less energy consuming by applying market policies like subsidies on efficient equipment for end users, establish incentives for producers who produce low energy consuming devices, etc. MP1 is the lead policy during the whole period of 2010 to 2025, whereas some policies can be more effective as short-term or long-term schemes. The next important initiative is the MP3 that is to increase the share of NG in the industry sector. The influence of MP3 is similar to MP4 (increasing the share of NG in commercial and residential sectors) but is more effective. It should be noted that the aggregation of policies in the electricity sector is more effective than MP3 and MP4 in the mid term (before 2017). In 2017 the reduction in the GHGs emissions caused by MP3 and MP4 is equal to that of the aggregation of all electricity sector policies which means that this group of policies (MP5 to MP8) has a mid term affect

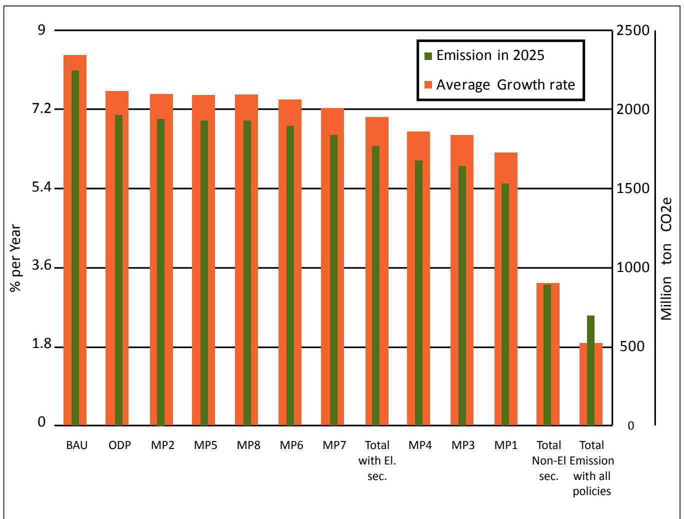


Figure 3.3: Impact of Different Policies and Scenarios on GHGs Emission (Left: Average growth rate - Right: Emission in 2025)

and cannot compensate the increasing emission rate of the GHGs in the long-term. The effect of all electricity sectors policies (MP5 to MP8) are the same and will result in a 2.28% reduction of the GHGs, on average, but the most important of them is MP7 (increase of the power plants efficiency) which causes an average of 4.2% reduction alone. It is noteworthy that the MP2 (increase of the share of CNG in vehicles) is the least effective policy by an average reduction of 0.5%. (Figure 3.4)

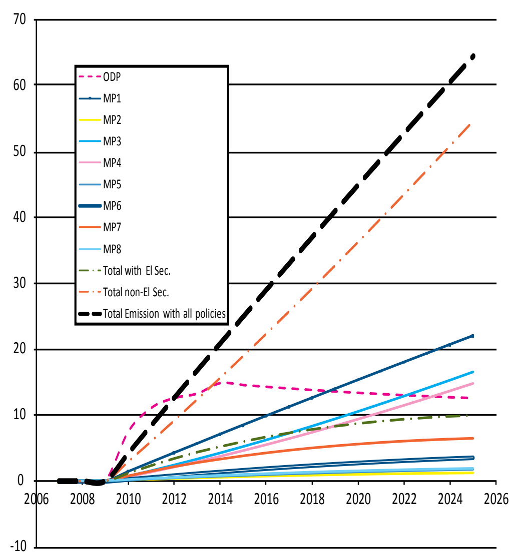


Figure 3.4: Reduction in GHGs Emissions Caused by Different Mitigation Policies (%)

By increasing the growth rate of GDP the influence of the demand side policies (MP1 to MP4) will be optimized and by decreasing this value, the electricity sector policies (supply side policies) will increase in importance but not enough to challenge non-electricity sector policies. It is to be noted that, there is a huge potential for GHGs mitigation in the energy sector, but the major problems are lack of financial resources and access to climate friendly technology. Therefore, transfer of advance technology under the UNFCCC Convention and Kyoto Protocol has an important role in combating climate change.

3.3. Non-energy Sector

The non-energy sector study is concentrated on sub-sectors like industrial processes, agriculture, forestry and land-use change and waste. The detailed study of these sectors considers all possible sources of GHGs emissions; for instance the industrial processes sector, cement industry, iron and steel industry, nitric acid, etc are all considered as sub-sectors. Sub-sectors for waste and agriculture sectors are "liquid and solid waste" and "agriculture and animal husbandry", respectively. In-depth studies of these sub-sectors provided us the opportunity to assess comprehensively the mitigation potential in the non-energy sector. In general, the framework of the study for the non-energy sector is identical for all sub-sectors and is based on developing three different scenarios: BAU, ODP and Mitigation. We choose the year 2000 as the base year and the period from 2000 to 2025 as the time horizon of the study. We tried to use actual data to the extent possible; so, the figures in all scenarios (BAU, ODP and Mitigation) are the same from 2000 to 2005 and this is because of the availability of actual data in this period at the time of study. All variants of the scenarios and assumptions within them are discussed in the following sections.

3.3.1. Scenario Development

3.3.1.1. BAU Scenario

The baseline or business as usual scenario is developed to estimate the emission of GHGs within the time horizon of the study assuming that in the coming decade all sectors will continue to develop, tracing their historical trends. We tried to use a wider range of data, generally from 1990 to 2005, in order to make a good estimate of future realities by using historical data.

3.3.1.2. ODP Scenario

Despite the historical trend of development in different sectors, there are some signs of rapid development in the government's programs, the most important of which are basic alteration in cement and iron and steel industries, waste management and fundamental changes in agriculture and forestry sectors. The ODP scenario was developed to assess the effects of Iran's official development plans, which are defined in official documents such as Iran's "Fourth Five Year Development Plan", "Iran 2025 Vision" on emissions of GHGs in different sectors. To develop this scenario, the mentioned plans were examined and probable effects were considered in emissions calculations.

3.3.1.3. Mitigation Scenario

In this scenario mitigation options in different non-energy sub-sectors are identified and the process of prioritization is undertaken in order to eliminate alternatives with lower potential of implementation in the country. We used several criteria to assess the options, the most important of which are: the cost of the selection including investment cost, operation and maintenance cost and cost per unit of saved carbon; GHGs mitigation potential; environmental side effects; consistency with government's programs; public acceptance; etc. The next step was to implement these options in developing the mitigation scenario.

As the final stage of mitigation assessment, all of the three scenarios were considered and we assessed mitigation potential by comparing the result that was obtained from the BAU, ODP and mitigation scenarios.

3.3.1.4. General Assumptions

There have been some general assumptions in developing different scenarios in the following sectors, which are as:

- ***Industrial processes***

In terms of GHGs emissions, we categorized different existing technologies into four different groups:

a) Mineral industries (cement production, line production, limestone use, etc.),

b) Metal industries (iron and steel production, aluminum production, etc.),

c) Chemical industries (ammonia production, nitric acid production, etc.), and

d) Other industrial processes (pulp and paper production, food and drink products, etc.).

Although we considered all of the above-mentioned industries in the initial stages of mitigation assessment, inventory results convinced us to focus on cement, iron and steel, nitric acid and aluminum production as the major GHGs emitting industries.

- ***Agriculture***

There are four sources of GHGs emissions considered in the current study:

a) Animal Husbandry: CH_4 emission from enteric fermentation of ruminant livestock and anaerobic fermentation associated with the decay of manure from livestock is considered in this sub-sector,

b) Rice cultivation: Decay of organic materials in the anaerobic growing condition of paddy, convinced us to consider rice cultivation as a source of CH_4 emission,

c) Preventing the burning of crop residues,

d) Agricultural soils.

- ***Forestry***

The most important sources of CO_2 emissions in forestry and land-use change are:

a) Changes in forests and other woody biomass stocks,

b) Forests and grasslands conversion, and

c) Abandonment of cropland, pasture, plantation forest, or other managed lands that re-grow into their natural grassland or forest conditions.

- ***Waste***

Anaerobic landfills are the most common solid waste disposal system (SWDS) in Iran and produce CH_4 emission from solid waste sector. On the other hand, the liquid waste sector's traditional methods of sludge processing with anaerobic digestion are common processes. During anaerobic digestion a considerable amount of the organic matter converts to CO_2 and CH_4. In terms of GHGs emissions from the liquid waste sub-sector, it is obvious that population growth and the amount of wastewater generated are key parameters. We made different assumptions on these parameters while developing various scenarios.

3.3.2. BAU Scenario Results

3.3.2.1. Industrial Processes

In developing the BAU scenario in industrial sector, an increase of about 150% in GHGs emissions is predictable when comparing 2025 with 2000. We can summarize the causes of this increase as follows:

- Cement industry is expected to develop rapidly in coming years in with cement production estimated to increase from 23.9 to 77.7 million tonnes between 2000 and 2025. Using IPCC default emission factors, we predict an increase of about 200% in CO_2 emission till 2025 as compared to 2000.

- Steel production is projected to increase from 6.6 million tonnes in 2000 to 25.3 million tonnes in 2025. It is worthy to note that in 2007, the percentage of indirect[1] and direct[2] reduction processes, in steel production were 30 and 70 percent respectively and we anticipate that these numbers will remain constant between 2007 and 2025.

- In terms of Gg CO_2 equivalent, emission in aluminum sector is measured as 574 in 2000 and an increase of some 1,397% is anticipated till 2025. A large increase in aluminum production, from 116,000 tonnes in 2000 to 1,846,000 in 2025, is the primary cause of the increase in emission.

- Since 2000 nitric acid production has been remained constant at 170,000 tonnes per year and it is anticipated as constant for the rest of the time period. Thus the amount of GHGs emission is 368,900 tonnes CO_2e per year in 2000 and is forecast to stay constant.

3.3.2.2. Agriculture

Considering available data in the 2006 performance report of the Ministry of Jihad-e-Agriculture[3], we have used historical data to predict the growth rate of agricultural products between 2005 and 2025. In addition, since agricultural production is vulnerable to droughts and unforeseen climatic condition, as is evident in the past two decades, in some cases we consider a longer time period - namely from

Table 3.5: GHGs Emission Trend in BAU Scenario for Agriculture Sub-sectors (Gg)

Source \ Year	2000		2005		2010		2015		2020		2025	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Enteric fermentation	808.33		815.00		789.40		765.34		742.71		725.84	
Manure management	29.45	0.81	30.79	0.83	31.15	0.79	30.72	0.76	21.96	0.72	20.1	0.69
Rice fields	61.15		65.90		62.70		59.60		57.00		56.10	
Burning of agricultural residues	9.48	0.20	9.93	0.21	10.05	0.21	10.23	0.21	10.48	0.22	10.98	0.24
Agricultural soils		76.14		74.75		90.47		96.11		103.95		113.18
Total	908.41	77.15	921.62	75.79	893.3	91.47	865.89	97.08	832.15	104.89	792.92	114.11
Total CO_2 (eq.)	19,077	23,917	19,354	23,495	18,759	28,356	18,184	30,095	17,475	32,516	16,651	35,374
Grand total CO_2 (eq.)	42,993		42,849		47,115		48,278		49,991		52,025	

1- Blast furnace
2- Electric arc furnace
3- These data were available up to 2006 at the time of preparing the report.

1996 to 2005- to calculate the average growth rates of various agricultural products.

Anticipating the amount of agricultural production as well as livestock population and nitrogen-containing fertilizers used in agricultural soils, we used the IPCC default emission factors to estimate GHGs emissions in the agriculture sector. Results of developing BAU are summarized in Table 3.5.

3.3.2.3. Forestry

In forestry sector, the rate of CO_2 emission and uptake is estimated based on analysis of the collected data for wood harvesting, plantation, forest rehabilitation, etc., in 2005 for five phyto-geographic regions and comparison of the results with 1994 and 2000 information. Developing this trend in forestry sector indicates an increase of about 136% in CO_2 emission, when compared 2025 with 2000. The calculations show that fuel wood consumption and forest harvesting for commercial wood demand have the highest levels of this increasing figure, respectively.

3.3.2.4. Waste

In the waste sector different sources of GHGs emissions in both solid and liquid sub-sectors have been considered while developing different scenarios. We assumed that:

- MSW (Municipal Solid Waste) generation rate is about 0.8 kg/capita/day,

- Fraction of DOC in MSW and fraction of DOC that actually degrades in SWDSs (DOC dissimilated) are 0.18 and 0.77, respectively,

- The per capita average amount of water consumption is 250 lit/day,

- 80 percent of water used will turn into wastewater,

- The average growth rate of CH4 emission from industrial wastewater was about 20% between 1997 and 2000 (based on the inventory report). We predict an increase of up to 45% till the end of 2025.

In BAU, only urban population has been considered in the calculation of GHGs emissions from the solid waste sector, because it is assumed that in rural areas solid wastes are mostly deposited in open land and decomposed in aerobic conditions, so that CH4 emissions are negligible. According to the baseline scenario, we estimate emission of methane to increase from 892.57 Gg in 2000 to 1,663.16 Gg in 2025.

It should be noticed that solid waste sub-sector for the rural population is considered after the year 2004. This is due to recent government policies to extend the solid waste management policies to the rural areas. These activities include most parts of the waste management system in Iran's rural zones such as generation, storage, collection, transportation and waste disposal. In the ODP scenario this rural population has been considered after 2004.

3.3.2.5. GHGs Emissions Trend in the BAU Scenario of Non-energy Sector

GHGs emissions trend in the BAU scenario is shown in Figure 3.5. The figure indicates the GHGs emission increased from 98,000 Gg in 2000 to 187,000 Gg in 2025, with annual growth rate of 3.6%. Also, industrial process and agriculture dominate at more than 70% of the total non-energy sector emission in the BAU scenario.

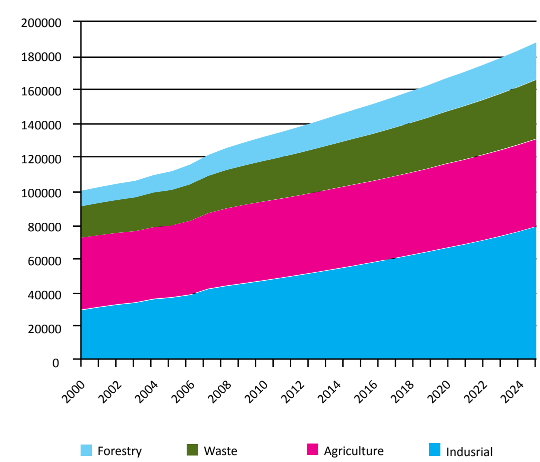


Figure 3.5: GHGs Emissions Trend in BAU for Non-energy Sector

3.3.3. ODP Results

3.3.3.1. Industrial Process

According to the 4th FYDP (2005-2009), cement production was to grow to 72.9 million tonnes by the end of 2009. However, when it comes to the long-term development plan, i.e. "vision 2025", 95 million tonnes is predicted to be the nominal capacity of cement production in 2025.

Of crucial importance in infrastructural development, capacity building in iron and steel industries is being emphasized in both the 5th FYDP and "vision 2025". According to the documented plans production of iron and steel is forecast to reach 17.3 and 64 million tonnes in 2009 and 2025, respectively.

In terms of aluminum production it is estimated that the capacity of production should reach 1.846 million tonnes per year in 2025 that will result in an emission of 9,800.5 Gg CO_2 of GHGs.

For nitric acid, the production capacity will reach 230,000 tonnes in 2015 and then remains constant, so the total GHGs emission from nitric acid production in 2025 should be about 499.1 Gg CO_2e.

In the general scheme, 50,376.2, 45,079.1, 9,800.5 and 499 Gg CO_2 equivalent are calculated to be the emissions from cement, iron and steel, aluminum and nitric acid production industries at the end of the time period of the study in 2025, respectively.

3.3.3.2. Agriculture

"The Agricultural Development Plan of Iran, 2020" is being used for developing ODP in the agriculture sector. Growth rates of different products except that of livestock population are being predicted in this document.

We estimate the population of livestock by taking into account the growth rate of livestock population growth during the 5th FYDP. At the same time, we used the proposed trend of agricultural production in order to estimate the amount of fertilizers consumed in the agriculture sector in coming years. Based on the 5th FYDP, production of all selected crops such as wheat, barley, rice, maize and soybean will be increased. Annual growth rate for wheat, barley and rice is 2%, 1.4% and 2.3% respectively. According to calculations, the livestock population has seen frequent changes based on the 5th FYDP. Although the annual growth rate for dairy cattle is 1%, this value for sheep and goats is negative and it is −8% and −4%, respectively, which represents a policy of

Table 3.6: GHGs Emissions Trends in ODP Scenario for Agriculture Sub-sectors (Gg)

Year / Source	2000		2005		2010		2015		2020		2025	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Enteric fermentation	808.33		815.00		822.40		827.50		836.10		843.28	
Manure management	29.45	0.81	30.79	0.83	23.81	0.88	23.799	0.91	23.89	0.94	24.01	0.99
Paddy fields	61.15		65.9		67.2		68.6		70		73.20	
Burning of agricultural residues	9.48	0.20	9.93	0.21	11.37	0.25	12.42	0.27	14.02	0.31	15.95	0.34
Agricultural soils		76.14		74.75		97.6		102.38		103.13		103.97
Total	908.41	77.15	921.62	75.79	924.78	98.73	932.319	103.56	944.01	104.38	956.44	105.30
Total CO_2 (eq.)	19,077	23,917	19,354	23,495	19,420	30,606	19,579	32,104	19,824	32,358	20,085	32,643
Grand total CO_2 (eq.)	42,993		42,849		50,027		51,682		52,182		52,728	

substitution of heavy livestock versus lighter species.

Due to the changes in different agriculture sub-sectors, emissions of GHGs in this sector will be altered as indicated in Table 3.6.

3.3.3.3. Forestry

Based on the existing documents in forestry and according to expert judgment, the government plan in the forestry sector includes the following three main procedures:

- Activating and development of protective systems of natural resources,
- Development of distribution systems of fossil fuel such as natural gas and supplying necessary fuel of villagers and tribes, and
- Increasing of forest rehabilitation operation and forest development.

With implementation of these procedures, the government could reduce the emission by 10% compared to the present levels, annually. It is estimated that the ODP will result in net emission (uptake) of -1,143.9 Gg CO_2 in 2025 for forestry (Table 3.7).

Based on the aforementioned data, in the ODP scenario the net amount of CO_2 emission in forestry and land-use change will reduce to zero in the 7th FYDP.

3.3.3.4. Waste

Government strategies which can affect the amount of GHGs from both the solid and liquid sectors are as follows:

- Rural waste management: In recent years there have been extended activities in terms of rural waste management from waste reduction through waste storage, collection and transportation to waste disposal sites. Therefore, in developing ODP we considered the rural population as well as the urban population as a source of solid waste production,
- Solid waste production rate: It is estimated to increase from 0.8 and 0.5 in 2000 to 0.9 and 0.7 kg/capita/day in 2025 in urban and rural area, respectively.

The previously planned programs of the Ministry of Energy for development of urban wastewater treatment units are expected to continue in the coming decade. Thus, installation of about 2,000 units of anaerobic wastewater treatment plants (septic or imhauf tanks) till 2025 is considered in developing ODP. Since these units have no flaring system, they act as a source of CH_4 emission. Despite that, there are some signs of development in terms of GHGs mitigation in these units. One such example is the Rasht composting factory in Gilan province, along the Caspian Sea, where a leachate treatment unit has been installed. This treatment unit includes an anaerobic digester as well as some aerobic ponds. The anaerobic digester is equipped with a methane recovery system that converts CH_4 to CO_2 by flaring the exhaust biogas. Since installation of this unit, the amount of Chemical Oxygen Demand (COD) has been decreased from 70,000 ppm to 5,000 ppm. The biogas thus generated is used for warming the digester in order to increase the efficiency of anaerobic treatment especially in the cold months of the year. Figure 3.6 shows the leachate treatment unit in the Rasht plant.

To a lower degree, industrial parks wastewater treatment plants can be assumed as

Table 3.7: CO_2 Emission and Uptake in ODP Scenario for Forestry (Gg)

Year / Options	2000*	2005**	2010	2015	2020	2025
Emission (+)	9,802.21	10,792.7	9,804.7	8,824.3	7942	7,147.8
Uptake (-)	523.93	101.4	1,152.20	3,104.5	5,568.4	8,291.7
Net emission	+9,278.28	+10,691.3	+8,652.5	+5,719.8	+2,373.6	-1,143.9

** The year 2005 was considered as the base year for calculation whereas the effects of forest plantation on CO_2 uptake will exist in the future years when the uptake in the mentioned years will be accumulated.*

*** Inventory of 2005 was not accessible on phytogeographic region thus the total of forest plantation was considered in calculations.*

Figure 3.6: Rasht Leachate Treatment Unit

an option that may affect the amount of GHGs emissions from this sector.

In brief, the major strategies of government in the liquid waste sector are:

- Prepare the conditions for the private sector to contribute in wastewater treatment projects,
- Capacity building and enhancing the capabilities of consultants and contractors,
- Continuous evaluation of administrators and project managers in terms of productivity increase,
- Financial support,
- Reduction in wastewater generation through consumption reduction, and
- Enhancement of wastewater collection network as well as introduction of modern wastewater treatment plants.

Considering government strategies in the domestic and industrial wastewater management, it is quite logical to forecast a GHGs emission rise from this sector. Results of ODP development are depicted in Table 3.8.

3.3.3.5. GHGs Emissions Trend in ODP Scenario for Non-energy Sector

The pattern of GHGs emissions in the ODP scenario of the non-energy sector is depicted in Figure 3.7. As is shown in the figure, the GHGs emission increased from 100 million tonnes in 2000 to 225 million tonnes in 2025 with an annual growth rate of 3.3%. The industrial process and waste sector have the highest growth rate in GHGs emission in the ODP Scenario. The reasons for rapid emission growth in 2010 in industrial processes are cement and iron and steel development plans, while in waste it is increased as a result of waste disposal management in landfills unequipped with gas recovery systems.

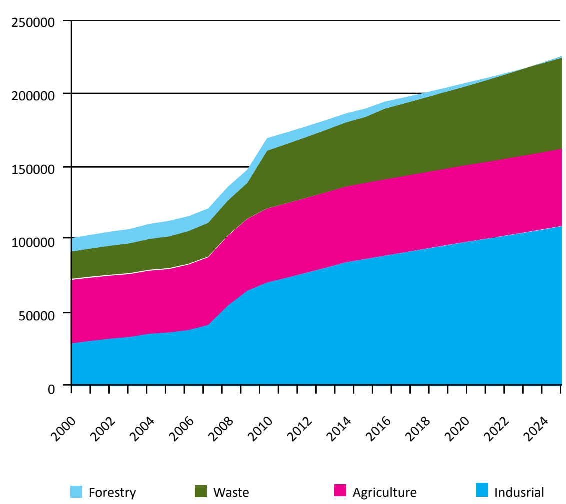


Figure 3.7: GHGs Emissions Trend in ODP of Non-Energy Sector

Table 3.8: Trend of GHGs Emissions in Liquid Waste Sub- sector

Policy	Increasing percentage of GHGs Emission till 2025
Urban and rural wastewater treatment plants development and installation	50
Septic tanks development and installation especially in rural areas	10
Industrial wastewater treatment plants development and installation	40

3.3.4. Mitigation Scenario Results

3.3.4.1. Industrial Processes

- ***Cement industry***

CO_2 in the cement industry is produced by the calcinations process. Therefore, the production of clinker causes large emissions of CO_2. In pozzolanic (blended) cement, a portion of the clinker is replaced with industrial by-products such as a blast furnace slag (a residue of iron production), or other pozzolanic materials (e.g. volcanic material and dry ash). These products are blended with clinker to produce a homogenous product; blended cement. The future potential for application of blended cement depends on the current application level, availability of blending materials, quality standards and legislative requirements.

The suitable amount of iron-furnace slag in cement ingredients is 10% and 20% according to the slag production procedure. It is also assumed that 30% of the total annual production of cement in Iran will be of the blended variety.

- ***Iron and steel sub-sector***

Depending on the type of process implemented for steel production, emission factors are different. The IPCC default emission factors of 1.6 and 0.705 tonne CO_2 per tonne produced steel are used for indirect reduction and direct reduction, respectively. Thus, it seems to be effective to implement direct reduction rather than indirect reduction in terms of GHGs emission reduction. It is also useful to use recycled steel scrap in electric arc furnaces (with 0.08 tonne CO_2 per tonne produced steel as default emission factor). It is important to mention that although the government has focused on iron and steel production in recent years, development programs in this sector are primarily based on direct reduction and use up to 20% steel scrap.

- ***Aluminum industry***

PFCs are formed as intermediate byproducts during processes called Anode Effects (AEs). When alumina ore content of the electrolytic bath falls below critical levels optimal for aluminum-production reactions to take place, rapid voltage increases occur. These AEs reduce the efficiency of the aluminum production process and at the same time result in PFCs generation.

The frequency and duration of AEs depend on various parameters such as cell technology and operating procedures. Emissions of PFCs, therefore, vary from one aluminum smelter to another, depending on these parameters. As a result, to reduce PFCs emission each smelter must develop a strategy, which may include some or all of the following measures:

- Improving alumina-feeding techniques by installing point feeders and computer regulation of the entire process. Adding small amounts of alumina - about one kilogram - at various short intervals, usually less than one minute is called point feeding. This is the best alumina feeding method at present, and point feeding is of undeniable importance in all new cells, as well as in modernization or retrofitting projects for older cell lines.

- Using Improved Computer Controls to optimize cell performance. These systems monitor the different parameters that contribute to the built-up of AEs. System operators would be alerted before an AE occurs, thus reducing the AE frequency. Improved computer controls can also work in conjunction with point feeders.

- Training cell operators in methods and practices to minimize frequency and duration of AEs. Also, operators can be trained to maintain strict control over alumina properties and cell operating parameters, and to provide timely and appropriate mechanical maintenance.

Using these methods can reduce the emission factor from 0.53 to 0.05 kg PFC per tonne produced aluminum. Because of the high GWP of PFCs e.g. 6500 for CF_4, the CO_2 equivalent emission reductions are relatively high.

- *Nitric acid production*

Nitric acid is produced through catalytic oxidation of ammonia at high temperatures, which creates N_2O, as a reaction by-product, released from reactor vents into the atmosphere. Nitric acid production is responsible for a considerable amount of N_2O emissions from industrial process. The N_2O abatement option has several variations developed by different companies, all based on decomposition of N_2O into nitrogen and oxygen, using various catalysts. The average estimated reduction efficiency is approximately 90%. Using these methods can on average reduce the emission factor from 7.5 to 1.8 (kg N_2O/tonne produced acid). Therefore, the projected CO_2 equivalent emission reduction from this sector is 300 tonnes annually in comparison with ODP.

3.3.4.2. Agriculture

In evaluating different sources of GHGs emission in the agriculture sector[4] as well as the national objective envisaged in mid and long term programs of the government; we recognized the following as the leading mitigation options in this sector:

- *Anaerobic digestion of manures*

Since manure management is in the primary stages of development, application of digesters or anaerobic lagoons in industrial dairy farms can be considered as effective methods of managing animal wastes and reducing GHGs emissions.

Small scale digesters of 4-5 to 75-100 cubic meters which can handle small and medium sized dairy farms, can not only be used for biogas recovery, but will also supply better quality and weed free manure fertilizer for farms.

Considering GHGs emissions from manure management in the Official Development Plan (ODP) for 2025, the amount of methane emission is expected to be 811.11 Gg CO_2eq. In applying anaerobic digesters we assumed that:

The total number of dairy cows and non-dairy cows are 5,550,000 and 4,940,000 heads, respectively. Based on Table B-1 of the Revised IPCC Guidelines for National GHG Emission Reference Manual, each dairy and non-dairy cattle produces 3.07 and 2.49 kg of dry matter per day. Therefore, the total manure produced by dairy and non-dairy cows will be about 10,652,744 tonnes of dry matter in the target year 2025.

Establishing livestock towns as well as development of industrial dairy farms and implementing manure management projects are all government programs that are expected to increase the total manure management to 30%. Accordingly methane emission is to be 3,195,823 tonnes based on dry matter.

Considering that each tonne of volatile solid is about 80 m^3 in volume, the amount of methane produced in the digesters is estimated to be 255,665,856 m^3 by 2025. As the weight of each cubic meter of methane is 0.67 kg, the total weight of methane produced in the digesters will be 171.3 Gg. The mitigated gases will substitute the fuels that are used for heating and electricity generation, especially in remote areas.

- *Reducing rice cultivation area and period of flooding*

Paddy growing is highly water intensive not only in areas with considerable rainfall, but also in regions with scarce water resources. As a mitigation option we consider reduction of the area under cultivation that can at the same time have some advantages with respect to water resource security. To compensate the decrease in rice production due to this initiative, cultivation of high yielding and short maturing cultivars, which is a common practice in Southeast Asia, is proposed. It is assumed that a reduction of 200,000 hectares of paddy field is feasible by the end of 2025.

- *Reducing the amount of chemical fertilizers applied in agricultural soils*

Increased use of fertilizers in the agriculture sector is not only harmful for human health but also results in N_2O emission to the atmosphere. Although there are some limitations in the volume of fertilizer usage in the agriculture sector, reduction of fertilizer use is amongst the government programmes, although at this time

4- As mentioned in inventory, sources of GHGs emission in the agricultural sector are emission from domestic livestock enteric fermentation and manure management, rice cultivation, burning of agricultural residues, agricultural soils and application of chemical fertilizers.

there is no defined target for its reduction. Thus, as a mitigation option, an annual amount of 5% reduction in nitrogen fertilizers from 2010 is being considered which results in reduction from the amount of 1,699,000 tonnes in 2000 (net nitrogen content) to 787,000 tonnes in 2025.

- *Improvement of irrigation method*

Another option for reducing methane emission from paddy lands is to improve irrigation practice through intermittent flooding and drying of lands rather than continuous flooding. Therefore, it is considered that improving irrigation methods, "on farm land improvement" is practicable in about 250,000 hectares of paddy lands.

- *Preventing crop residue burning*

As shown in Table 3.6, the methane and nitrous oxide emissions increase from 9.93 and 0.21 Gg in 2005 to 15.95 and 0.34 Gg in 2025, respectively. Therefore, assuming mitigation potential in this area it can be expected that emission of these gases due to burning of crop residue will be cut down by 70% and residues will be used for thermal applications in agricultural area and feed for livestock.

3.3.4.3. Forestry

In land-use change and the forestry sector there are two types of GHGs mitigation policies and measures which are:

- Decreasing the emission by using correct management rules, development of protective operations, public awareness and reduction of villager and tribes' reliance on forests and rangelands by supplying their life necessities,

- Increasing the CO_2 uptake by rehabilitation of forests, afforestation and reforestation.

Based on these policies, the mitigation measures in forestry and land-user change are as follows:

- At present the number of livestock is 2-2.5 times more than that of the existing capacity of rangelands, thus livestock overgraze and also use forest resources as their feed. It is therefore necessary to establish appropriate management systems for livestock feeding to protect the rangelands and forest as CO_2 sinks. Based on expert judgment, the improvement in forest and rangeland management could lead to the following results: Activation and development of protective systems of natural resources including:

- 20% reduction of illegal wood harvesting, forest and range land conversion to other land-uses per annum,

- 10% annually decrease in wood harvesting for fuel through the development of fossil fuel distribution systems such as natural gas and supplying the necessary fuels for villagers and tribes,

- Increasing forest rehabilitation operations and forest development such as;

  - 20% reduction in GHGs emission through reforestation and afforestation in Arasbaranian forests, Irano-Toranian forests and Khalidjo-Omanian forests,

  - Rehabilitation of damaged lowland and highland forests in the north of Iran (reforestation),

  - Afforestation in the highlands of the northern slopes of the Alborz Mountains,

  - Reforestation and afforestation in west of the country in the Zagros Mountains.

- Rangeland rehabilitation and development by dissemination of endemic species with higher capacity in CO_2 absorption and more resistance to drought and soil salinity.

- Balancing the amount of livestock to grazing capacity of ranges by developing animal husbandry (most importantly by fixing the habitation of traditionally nomadic tribes and changing the lifestyle of villagers and tribes based on using other rangeland ecological capacities such as secondary crops, pharmaceutical plant cultivation, beekeeping, aquaculture, etc).

Through the implementation of these measures, in the mitigation scenario, the net

CO_2 emission of the forestry sector will bottom out at zero in the time frame of the 6th Five Year Development Plan (2015-2020), while after 2020 it will again become a source of emission.

3.3.4.4. Waste

Mitigation policies in the waste sector can be categorized as follows:

- ***Solid waste sub sector:***

- Sanitary-engineering landfills with appropriate biogas collection and recovery systems as well as changing landfill sites from anaerobic to semi-aerobic.

- Implementing LFG (Landfill Gas) recovery systems and changing the structure of existing anaerobic landfills to semi-aerobic ones may result in 50%-80% reduction in methane emission from solid waste sector. A recovery of up to 100% of the produced methane is also feasible by application of well-designed facilities.

- LFG can be used as an energy source or be flared. It should be mentioned that it is applicable only in large landfills because the low capacity of small and medium size landfills lack the necessary efficiency parameters and cost ratios.

The biogas recovery system in Esfahan, Shiraz and Mashhad can be assumed as pioneer cities in the country. Figure 3.8 shows a picture of these recovery systems in these three cities.

- Considering the country's national plan, the Solid Waste Act and the capacity of the country to attract financial support from international bodies, e.g. CDM projects, methane recovery of up to 15% is possible till 2025.

Istahan *Shiraz* *Mashhad*

Figure 3.8: Biogas Recovery in Landfills (Isfahan, Shiraz and Mashhad)

- LFG can be recovered in order to generate electricity both for on-site use and for use in the national electricity network. Electricity production requires large amounts of LFG so it is not practical in small landfills in rural areas. Shiraz is the only site in the country that uses LFG for electricity production and the city of Mashhad is planning to use CDM for producing electricity. As depicted in Figure. 3.9, there is only a small generator used to provide small-scale lighting.

Figure 3.9: Electricity Generation from Shiraz Landfill Gas (pilot project)

- In terms of electricity production from LFG it is assumed that 2% of methane will be recovered from landfills till 2025.

- Although using LFG as a medium BTU gas is considered as a common option globally, it is not applicable in Iran because of the landfills' condition and the lack of modern technologies.

- 3% of methane emission from landfills can be mitigated by altering the condition of the landfills from anaerobic to semi aerobic and is considered a mitigation option in the present study.

- Proper waste collection and suitable transportation to disposal site: proper planning, collection frequency, collection method, suitable transportation to disposal sites, capacity and type of waste containers, especially in hot zones of the country could reduce methane emission. This reduction is predicted to reach about 2% by 2025.

- Reduction in utilization of waste transfer stations: reducing waste transfer stations and direct transportation to landfill sites will result in 2% reduction in methane emission by the end of 2025.

- Recycling, source separation and public participation: Of crucial importance, recycling, source separation and public participation are considered one of the greatest potentials for mitigating GHGs emissions from the solid waste sector. Having spent more than 8.8 billion Rials for training courses and workshops, we assumed that a reduction of up to 12% in GHGs emissions till 2025 is possible.

The mitigation potential in different solid waste sub-sectors is summarized in Table 3.9.

Table 3.9: Mitigation Policies in Solid Waste Sub-sector

Mitigation policy	Reduction percentage of GHGs emission till 2025
Sanitary-engineering landfills with correct biogas collection and recovery system and also changing landfill sites from anaerobic to semi-aerobic	20
Proper waste collection and suitable transportation to disposal sites	2
Reduction in utilization of waste transfer stations	2
Public training and people participation, source separation and enhancing recycling programs	12
Summation	36

- *Liquid waste sub-sector*

- Anaerobic conditions are common processes in both domestic and industrial wastewater treatment. It follows that new treatment plants and new methods of treatment are foreseen as impacting GHGs emissions with a 10% reduction predicted by end 2025.

- Wastewater treatment process optimization: both aerobic and anaerobic

- Considering national budget planning, proper management of wastewater treatment plants may result in 6% reduction in GHGs emissions till the end of 2025.

- Implementation of modern facilities which are compatible to existing wastewater treatment methods in the country can be considered as an option with a 1% mitigation potential in the liquid waste sector.

- Recycling and reuse of treated wastewater will result in methane emission reduction of about 2% till the end of 2025.

- Aerobic treatment (both in primary and secondary stages) of domestic and industrial wastewater: Aerobic primary wastewater

Table 3.10: Mitigation Policies in Liquid Waste Sub-sector

Mitigation policy	Reduction percentage of GHGs emission till 2025
Wastewater collection and treatment	10
Wastewater treatment process optimization	6
Utilization of facilities and equipment agreeable with country conditions	1
Treated wastewater reuse and recycling	2
Utilization of aerobic treatment (in primary and secondary processes) for domestic and industrial wastewater/sludge	10
Methane recovery from anaerobic wastewater/sludge digesters	2
Public/industries training for improving water consumption patterns	5
Total	36

treatment is achieved by sustaining sufficient oxygen levels during the primary phase of wastewater treatment, using controlled organic loading techniques or providing oxygen to the wastes through mechanical/diffusion aeration. Aerobic secondary treatment consists of stabilizing wastewater by prolonging its exposure to aerobic microorganisms that result in reducing GHGs emissions. In the final treatment stage, land treatment involves applying wastewater to the upper layer or the soil's surface, which acts as a natural filter and breaks down the organic constituents in the wastewater. With regard to the development of aerobic wastewater treatment plants in Iran, the amount of reduction from this option is estimated to be about 10 % till the end of 2025.

- Methane recovery from anaerobic wastewater/sludge digesters.

- Under anaerobic controlled conditions, it is possible to recover methane and use it is as a source of energy. According to Iran's Solid Management Rules of Procedure, the Ministry of Energy is mandated to buy the electricity generated from methane recovery. The amount of GHGs reduction due to this policy is estimated to reach about 2% till 2025.

Mitigation potentials of different options in various liquid sub-sectors are summarized in Table 3.10.

3.3.4.5. GHGs Emissions Trend in Mitigation Scenario for Non-energy Sector

GHGs emission patterns in the mitigation scenario for the non-energy sector is shown in Figure 3.10. As is indicated therein, the GHGs emission in the non-energy sector is increased from 100 million tonnes in 2000 to 180 million tonnes in 2025, with an annual growth rate of 2.4 %, while in the ODP scenario the growth rate was about 3.01%.

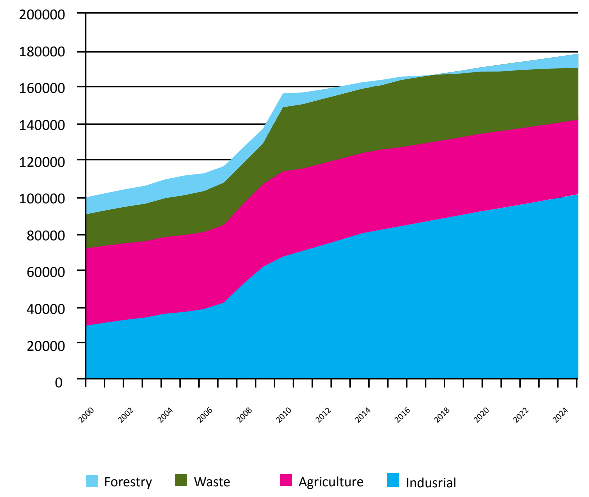


Figure 3.10: GHGs Emissions Trend in Mitigation Scenario for Non-Energy Sector

3.4. Overall Mitigation Assessment

Considering the mitigation options in both the energy and non-energy sectors as described above, it is obvious that GHGs mitigation potential is extremely high in Iran. The energy sector with a mitigation potential of more than 1,270 million tonnes of CO_2 equivalent in 2025 has the largest potential followed by waste, agriculture, industrial processes and forestry sectors, respectively. This is the maximum amount of available potential for mitigation of GHGs in Iran which may be achieved if international funding and technologies become available. A comparison of GHGs emissions' trends in the energy and non-energy sector is depicted in Figures 3.11 and 3.12, respectively.

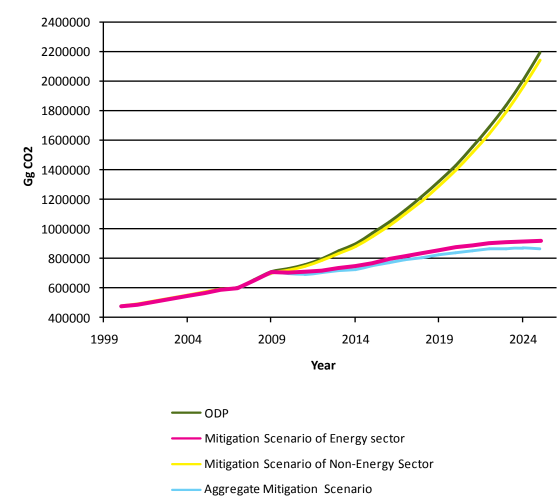


Figure 3.11: GHGs Emissions Trend in Different Scenarios for all Sectors

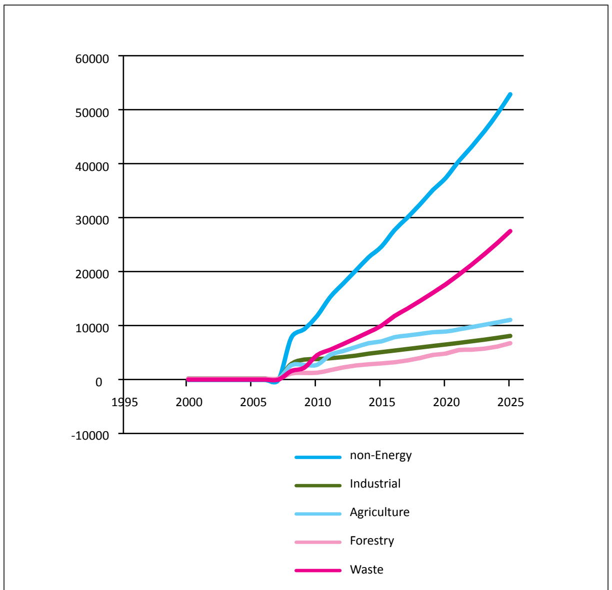


Figure 3.12: GHGs Mitigation Potential in Different Non-energy Sub-sectors

As is shown in Figure 3.11, the GHGs emission in the ODP scenario is increased from 490 million tonnes in 2000 to 2.2 billion tonnes with an annual growth rate of 6.2%, while in the mitigation scenario it peaks at 890 million tonnes of CO_2 equivalent, with an annual growth rate of 2.4%. This means there is an enormous potential for GHGs mitigation in the country, while actual implementation needs financial and technical assistance from the developed world.

Industrial processes, waste, agriculture are the major sources of GHGs emissions in the non-energy sectors. According to our study in different sectors we have calculated mitigation potential in various non-energy sub-sectors that are shown in Figure 3.12.

As is indicated in Figure 3.12, in 2025 the potential for GHGs mitigation in non-energy sectors is about 54 million tonnes CO_2 eq., which waste sector with some 28 million tonnes, is the highest while forestry with 6 million tonnes is the lowest source in GHGs mitigation.

Sustainable Transportation-Tehran's Metro

Chapter 4: Vulnerability and Adaptation Assessment

4.1. Introduction

In the contemporary era, study of the impact of climate variability and change at different time and space scales on earth's natural system and humanity has become the outstanding global priority of the international community. Iran is highly vulnerable to the adverse impacts of climate change. Most parts of the country are arid or semi-arid, prone to drought and desertification; limited forests are liable to decay; water resources are scarce; sea level rise is a threat to very long coastal zones of the country; many urban and industrial areas are heavily polluted; and the country is mountainous with very fragile ecosystems. As a prerequisite to carry out the vulnerability and adaptation (V&A) assessment, a study on climate variability and climate modeling was undertaken to predict the future climate of Iran based on the historical record. In addition, Iran is a country whose economy is highly dependent on the production, processing and export of oil and gas and the associated energy intensive products, which is adversely affected by the impact of response measures by Annex I Parties.

The National Climate Change Office of the Department of Environment has conducted the second round of the vulnerability and adaptation studies in the following areas and sectors:

- Climate variability and change – climate change modeling,
- Water resources,
- Agriculture,
- Forests and rangeland,
- Coastal zones,
- Human health,
- Biodiversity,
- Impact of response measures.

An attempt has been made to involve all relevant stakeholders in this study. A list of ministries, organizations, centers and institutions that made valuable inputs in the vulnerabilities and adaptation assessment are listed in the contributors' section. We have experienced a great deal of difficulty in carrying out this task due to the lack of information and data, limited skilled manpower and scarce financial resources. It is hoped that this V&A study presented here will lead to the development of the national action plan for adaptation that is of utmost importance.

4.2. Climate Variability and Change in Iran

As defined by the Inter-governmental Panel on Climate Change (IPCC), climate change is described as the variation in either the mean state of the climate or in its variability, persisting for an extended period of time, typically decades or longer, encompassing temperature increases "global warming", sea-level rise, changes in precipitation patterns and an increased frequency of extreme events. The global average surface temperature (the average of near surface air temperature over land and sea surface temperature) has increased since 1861. Over the 20th century the increase has been approximately 0.6°C. Since the late 1950s (the starting point for observations of markedly higher intensity), the overall global temperature increased in the lowest 8 kilometers of the earth's atmosphere at the rate of 0.1°C per decade. Data collected indicates that the global average sea level has risen between 10-20 cm in the 20th century [IPCC 2007].

The aggregate of these observations, plus broad range of other scientifically proven evidence, indicates that the global community overwhelmingly views this phenomenon as a definite consequence of industrialization and human interference with climate at an elemental level. Therefore, climate change is recognized as a human induced phenomenon caused by increased emission of greenhouse gases. Changes in climate occur as a result of both internal variability within the climate system, and external factors (natural and anthropogenic). The role of external factors specifically those originating with humans are glaringly prominent. Fresh and hard to refute evidence outlines most of the warming observed over the last 50 years is attributable to human activities. It is proven that the greatest portion of anthropogenic emissions of CO_2 to the atmosphere during the past several decades is due to burning fossil fuels, while land-use changes such as deforestation is ranked as the second most important factor.

The aim of this study, which was carried out by the Climatological Research Institute of Iran's Meteorological Organization with close collaboration of the National Climate Change Office, was three fold. First, to expand the knowledge of Iran's climate variability; second, to extend the knowledge beyond what has been achieved during the previous studies for the Initial National Communication about the possible changes in the country's climate due to human interference with the earth's climate system; and, finally to provide the vulnerability and adaptation assessment team with the necessary inputs to carry out their studies in the sections described in the introductory section of this chapter. To achieve these defined goals and objectives, the study has been divided in three main sections:

- Climate variability,
- Climate change projection,
- Downscaling.

4.2.1. Methodology

Study of the climate, its variability and change and the reliability of the results of those studies are largely dependent on the availability and quality of the data on the fundamental elements that comprise the climate. Thus, as one of the seminal studies on the country's climate, data availability and data quality, specifically data homogeneity is examined. As the next step the patterns of those parameters are calculated. To define the country's climate, the data for the period of 1961-1990 is considered as the representative period in accordance with WMO recommendations. Then, the longest period of duration with the least information deficiencies, considering the gaps in the observations and the outcome of the data homogeneity will be adopted for the above-mentioned studies.

Climate change is evaluated by means of two LARS-WG weather generators and all outputs from the available GCMs in MAGICC-SCENGEN software in combination with different emission scenarios and climate sensitivities. To address the uncertainties the output of the adopted scenarios will be compared with each other and with the results of the climate variability study.

Finally, considering the outcome of the climate variability study and the results presented in the Initial National Communication (INC) of Iran the best scenarios are adopted for use in other sections of the report.

4.2.2. Climate Variability

To study the country's climate variability, differences in parameters like the minimum and maximum temperatures, precipitation (the amount and the number of days with precipitation higher than 10 mm), wind speed, dew point temperature (as an indicator of humidity), cloudiness and daylight hours have been studied in seasonal and annual timescales

Figure 4.1: Trends in Maximum Temperatures at Selected Stations

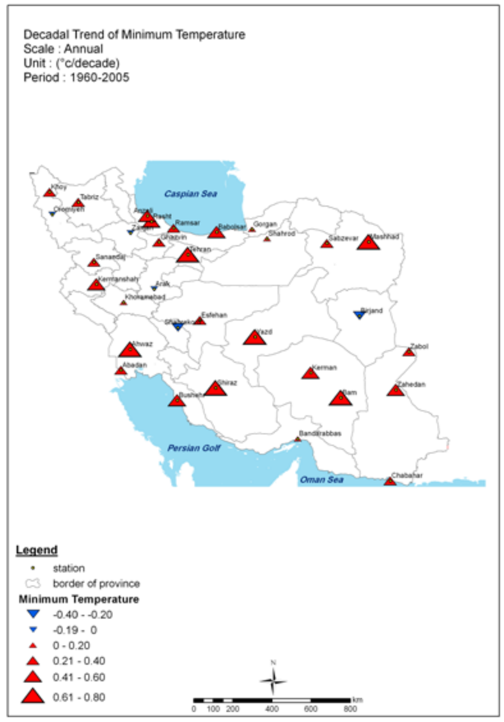


Figure 4.2: Trends in Minimum Temperatures at Selected Stations

over the 1960-2005 time span. Figures 4.1 to 4.8 illustrate the outcomes of that study.

4.2.2.1. Temperature

The study reveals that the increase in minimum temperatures is more widespread than the maximum temperatures. The discrepancies

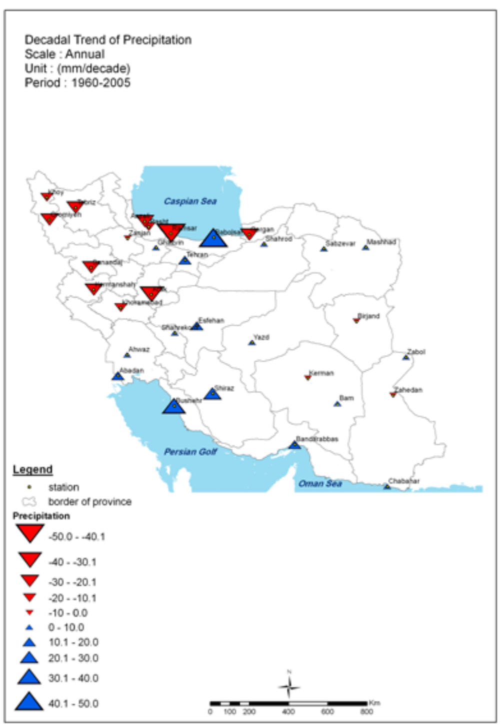


Figure 4.3: Trends in Precipitation at Selected Stations

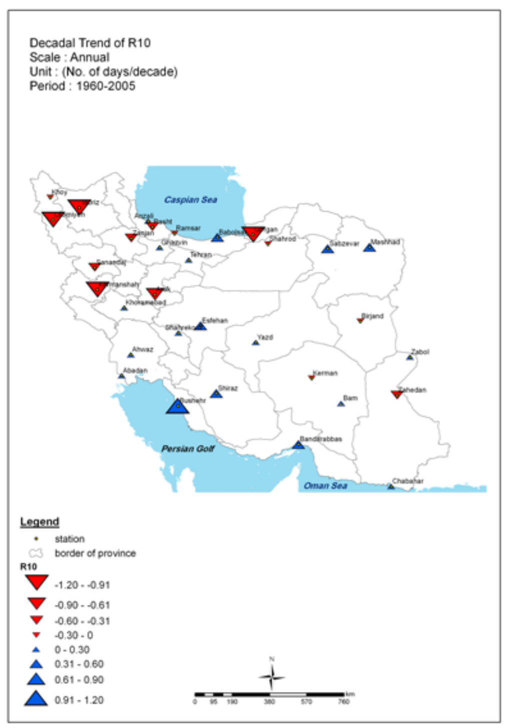


Figure 4.4: Trends in the Number of Days of Precipitation Higher than 10mm at Selected Stations

Figure 4.5: Trends in Wind Speed at Selected Stations

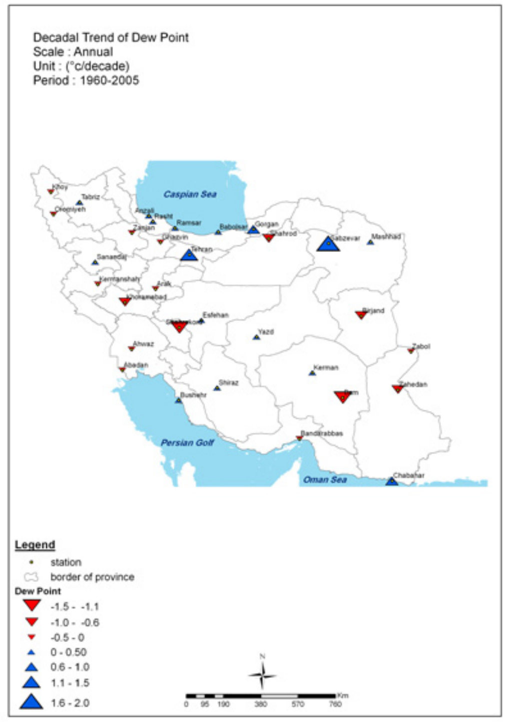


Figure 4.6: Trends in Dew Point Temperature at Selected Stations

are remarkably higher in the large, heavily populated and industrialized cities. Due to the pattern of higher minimum temperatures, the daily temperature variability has reduced almost everywhere. The analysis of results shows that the temperature has risen between 2.5 and 5 degrees centigrade during 1960-2005. There are also cities with clear temperature descent rates.

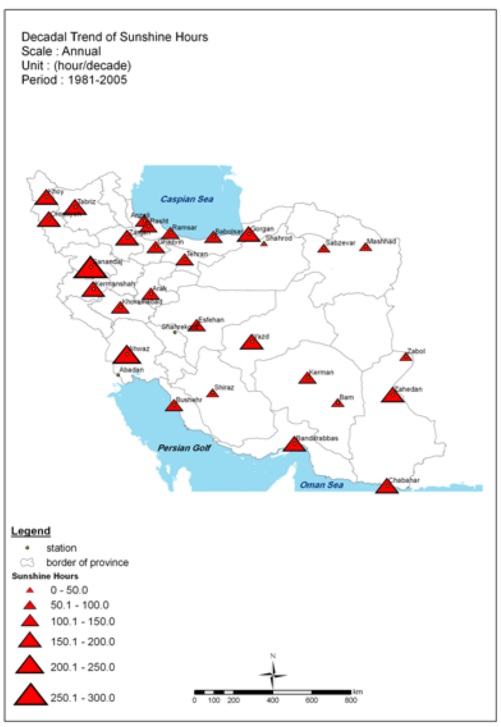


Figure 4. 7: Trends in Daylight Hours at Selected Stations

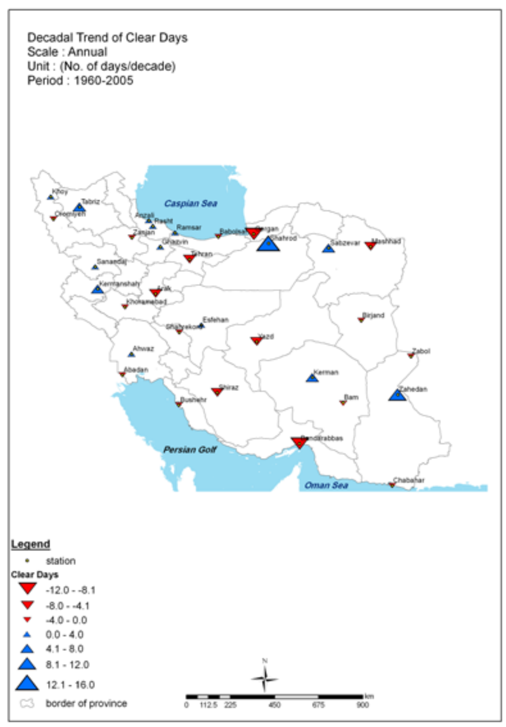


Figure 4.8: Trends in the Number of Days with Clear Skies at Selected Stations

4.2.2.2. Precipitation

Figure 4.3 illustrates the changes in the amount of precipitation in selected stations. Accordingly, it could be concluded that the southwestern part of the Caspian Sea, northwest and west of the country have experienced the highest rate of reduction in the amount of their annual precipitation.

Study shows that the number of days with precipitation higher than 10 mm, have reduced in the west, northwest and southeast of the country. That number has increased in the other regions except in the southeast of the Caspian Sea (Figure 4.4).

4.2.2.3. Wind

Figure 4.5 illustrates the changes in wind speed throughout the country between 1960-2005. The highest rates of decrease are seen in central part of the country as well as the northeast. The highest increase is being seen in Zabol (southeast Iran).

4.2.2.4. Humidity

Figure 4.6 illustrates humidity variability by considering the changes in dew point temperature. One of the most interesting results is related to the sharply ascendant dew point in the two cities of Bam and Shahr-é-Kord.

Generally, it can be concluded that the dew point temperature is consistently lowering in most parts of the country. However, in the north and northeast the dew point average is clearly ascendant. The highest rise is seen in the city of Sabzevar.

4.2.2.5. Daylight Hours

Figure 4.7 illustrates changes in daylight hours at selected stations. A rising rate pattern is visible everywhere throughout the country. The highest rate of increase is seen in the northwest of the country.

4.2.2.6. Cloudiness

Cloudiness is another important factor in the climate system. Figure 4.8 illustrates the trends in the days with clear skies. The results show that the number of the days with clear skies changes between −12 to 12 per decade.

The highest rise and fall in the number of the days with clear skies are seen in a relatively small area of the country in the cities of Shahroud and Gorgan that could be due to the effect of the Alborz Mountains range on the climatic condition at different places.

4.2.3. Climate Change Projection

The two models MAGICC-SCENGEN, Lars-WG have been used to project future changes in the country's climate at the regional scale while the PRECIS model has been used for projection at the local scale.

4.2.3.1. Climate Change Projection Using MAGICC-SCENGEN (HadCM2 and ECHAM4 Models)

The HadCM2 and ECHAM4 in combination with 18 available emissions scenarios have been utilized to project the changes in the country's temperature and precipitation (as the main contributors to the formation of the climate) until the year 2100. Both GCMs predict a higher temperature nationwide with very little variation. According to HadCM2, the temperature will rise between 0.4 to 3 degrees centigrade, while the results of ECHAM4 suggest that the rise will be in the range of 0.5 to 4 degrees centigrade. However, there are remarkable differences between the projected changes in precipitation and its spatial distribution. According to HadCM2, the northern half of the country will see a rise in the amount of precipitation, while the southern half of the country will suffer a net loss in precipitation. Surprisingly, the projection changes using ECHAM4 indicates that the northern half of the country will suffer from the loss of precipitation, while the southern part of the country will observe an increase in precipitation. (Figures 4.9 and 4.10)

4.2.3.2. Climate Change Projection Using LARS-WG Weather Generator

The Climatological Research Institute had already conducted climate change studies at 43 synoptic stations throughout the country by means of LARS-WG[1] (a stochastic weather

1- Long Ashton Research Station Weather Generator

generator that was developed by Semenov in 2002) in combination with the results of A1 scenarios of ECHO-G model (a GCM model that is being used in Hamburg University and South Korea Center for Meteorological Research).

That scenario has been used to project the country's climate during 2010-2039 and to compare the results with observations during 1976-2005. In the course of that study changes in the number of the dry, wet, freezing and hot days and extreme events like heavy and torrential rains as well as changes in temperature and precipitation have been examined.

The results indicate that the amount of precipitation will on average decrease throughout the country by 9% between 2010-2039 compared with the 1976-2005 period. However, the number of heavy and torrential rains will increase by 13% and 39% in the same period, respectively. Temperature projections show an average increase in the amount of 0.9 degrees centigrade and minimum and maximum temperatures will on average rise by 0.5 degrees centigrade. The rises are more pronounced during the cold season. The number of hot days[2] in most parts of Iran will increase. The highest increase will occur in the southeast of the country by 44.2 days. The study has also revealed that the number of freezing days in most parts of the country will decrease. The highest decrease will occur in the northwest of the country with freezing days decreasing by 23 per annum. Study of the changes in the number of wet days during 2010-2039 indicates that it will increase in some areas in the northwest, center, south, east, and southeast of the country.

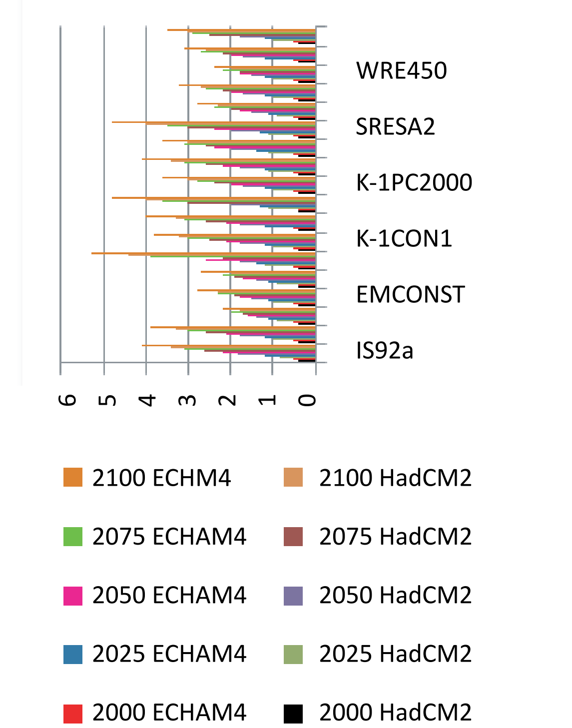


Figure 4.9: Temperature Changes Projected by Two HadCM2 and ECHAM4 Models for the 21st Century

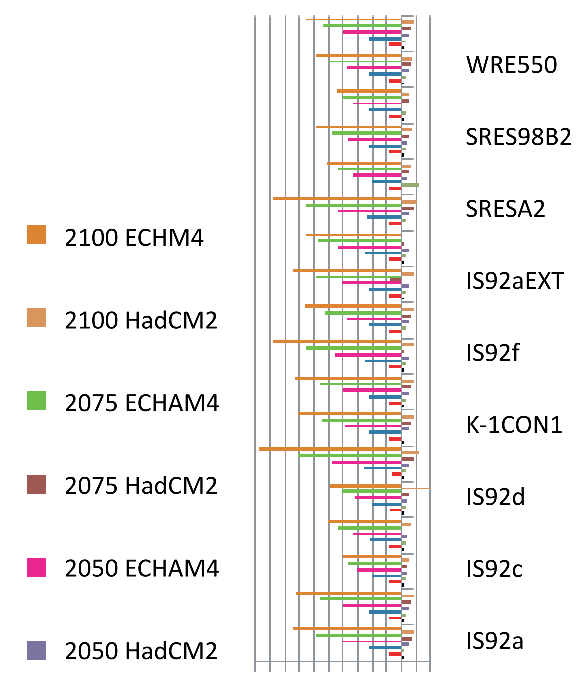


Figure 4.10: Precipitation Changes (%) Projected by two HadCM2 and ECHAM4 Models for the 21st Century

Table 4.1: Comparison between Changes of Precipitation and Temperature Projections by Different Models (2010-2039)

	Precipitation		Temperature	
	MAGICC SCENGEN IS92a(Hadcm2)	MAGICC SCENGEN A1(Hadcm2)	MAGICC SCENGEN IS92a(Hadcm2)	MAGICC SCENGEN A1(Hadcm2)
MAGICC SCENGEN A1(Hadcm2)	**0.99	---	**0.99	---
LARS WG A1 (ECHO_G)	**0.77	** 0.78	** 0.84	** 0.85

*** Correlation is significant at the 0.01 level (2-tailed-test)*

2- Hot days: the days with maximum temperature higher than 30˚C; Freezing days: the days with temperatures lower than 0˚C; Wet days: the days with precipitation higher than 0.1 mm; Dry days: the days with no precipitation or precipitation lower than 0.1 mm

In other parts of the country the number of wet days will decrease. The highest decrease will occur in the cold season. The study on the number of dry days shows an increase in many parts of the country. The highest rise at 36 days is expected to occur in the west and southeast of the country. Figures 4.11 to 4.16 illustrate the changes in the above-mentioned parameters in the 2010-2039 periods.

4.2.3.3. Comparison between Different Climate Change Projections

To address uncertainties in climate change projections, the outcomes of different models and scenarios have been compared with each other. The results for the two HadCM2 and LARS-WG models with the two IS92a and A1 emission scenarios are presented here. To be able to compare the results of the projections the baseline for climate change projection by MAGICC-SCENGEN was changed from 1961-1990 to 1976-2005. The results indicate that there are not any statistically meaningful differences between the projected changes in precipitation and temperature in the future according to those models and scenarios at 0.05 level of confidence. Table 4.1 shows the results of those studies for HadCM2 and LARS-WG.

4.2.3.4 Dynamic Downscaling

PRECIS (Providing Regional Climates for Impacts Studies) uses the output of GCMs as its boundary parameter to project future climate on a regional scale by producing higher resolution results. Therefore, it could be considered as a downscaling tool. Its outstanding difference with models like LARS-WG is that it uses the governing set of equations in the atmosphere to make the projection known as dynamical modeling.

At the time of carrying out this study the only available GCMs outputs from Hadley Centre were in relation to 2071-2100. Therefore, the regional climate projection was carried out for that period of time. The results of the projection of changes in the parameters like rainfall, snowfall, temperature and runoff are illustrated in Figures 4.17 to 4.24. The results show that temperature will increase drastically throughout the country with the highest rise seen from the northwest to the east and southeast along the Zagros Mountains range. The projected temperature changes by A2 scenario are higher on average by 2 degrees centigrade than those projected by the B2 scenario.

The projection of precipitation using the A2 emission scenario suggests that the country will loose part of its available territorial water due to the reduction of precipitation (more specifically snowfall) over the west, southwest, and north along the Zagros and Alborz ranges along with increase of runoff. Consequently, some of the important permanent rivers will face dryness as is already evident in the Zayandeh River. However, projection using the B2 emission scenario provides a different picture from changes in the amount of precipitation, but still shows drastic reduction in snowfall over the northwest, west, southwest, and north

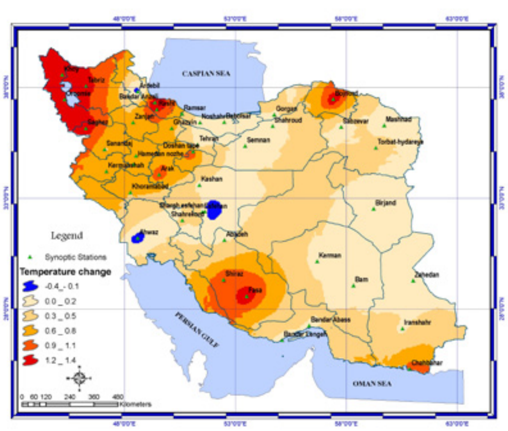


Figure 4.11: Temperature Changes Projected for the 2010-2039 with Respect to 1976-2005 projected by LARS-WG

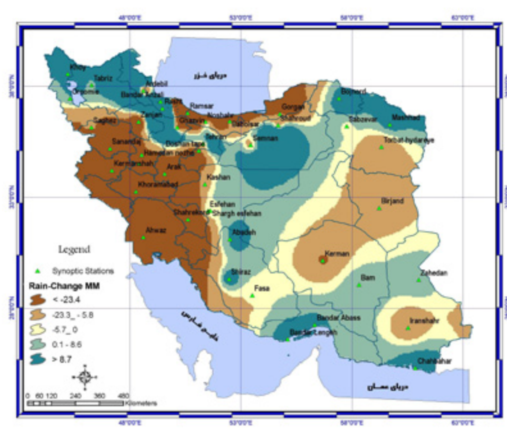


Figure 4.12: Rainfall Changes Projected for 2010-2039 with Respect to the 1976-2005 Projected by LARS-WG

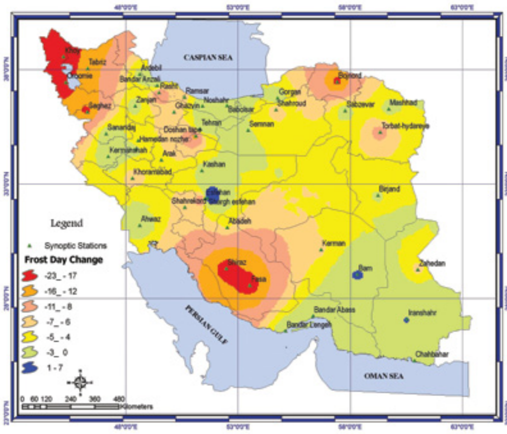


Figure 4.13: Freezing Days Changes During 2010-2039 with Respect to the 1976-2005, Projected by LARS-WG

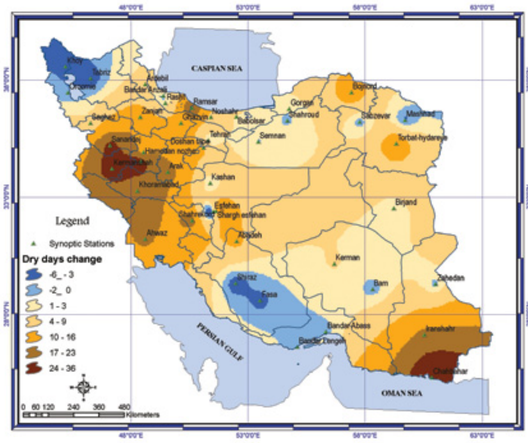


Figure 4.14: Dry Days' Number Changes in 2010-2039 with Respect to the 1976-2005, Projected by LARS-WG

Figure 4.15: Wet Days' Number Changes in 2010-2039 with Respect to the 1976-2005, Projected by LARS-WG

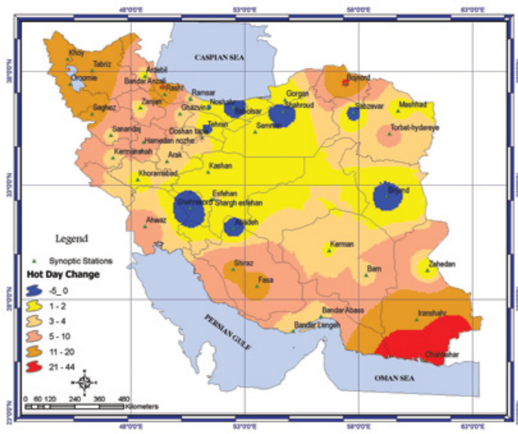


Figure 4.16: Hot Days' Number Changes in 2010-2039 with Respect to the 1976-2005, Projected by LARS-WG

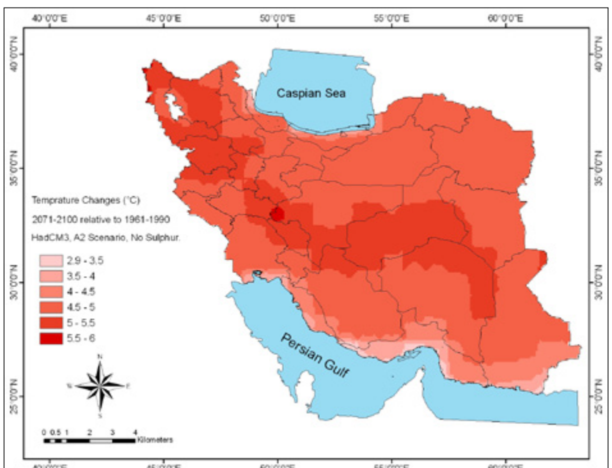


Figure 4.17: Mean Temperature Changes in 2071-2100 Relative to 1961-1990, A2 Scenario

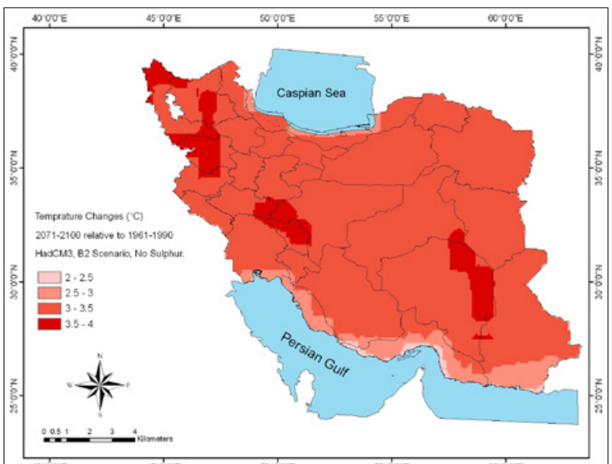


Figure 4.18: Mean Temperature Changes in 2071-2100 Relative to 1961-1990, B2 Scenario, No Sulphur

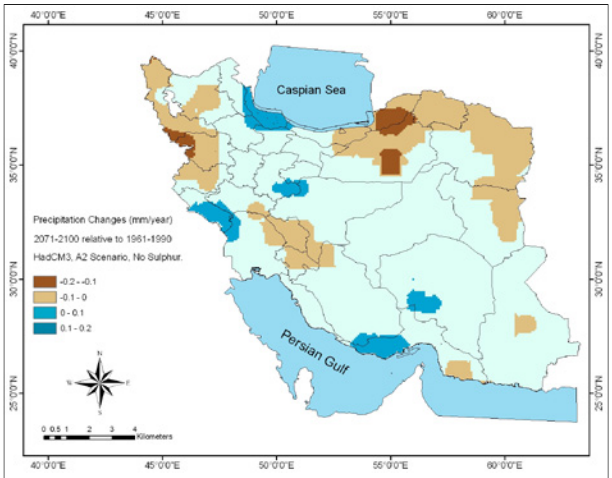


Figure 4.19: Mean Precipitation Changes in 2071-2100 Relative to 1961-1990, A2 Scenario, No Sulphur

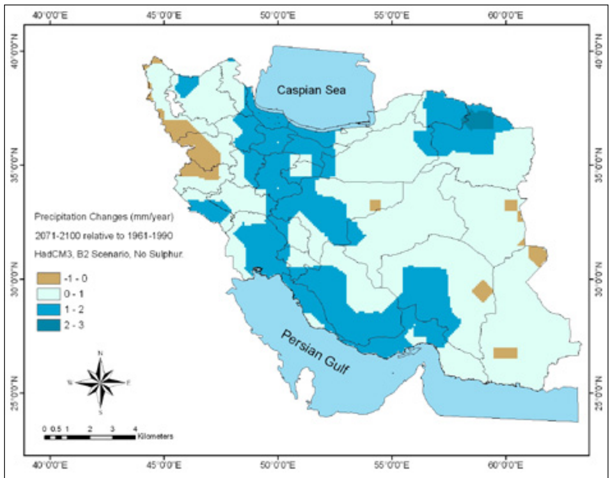


Figure 4.20: Mean Precipitation Changes in 2071-2100 Relative to 1961-1990, B2 Scenario, No Sulphur

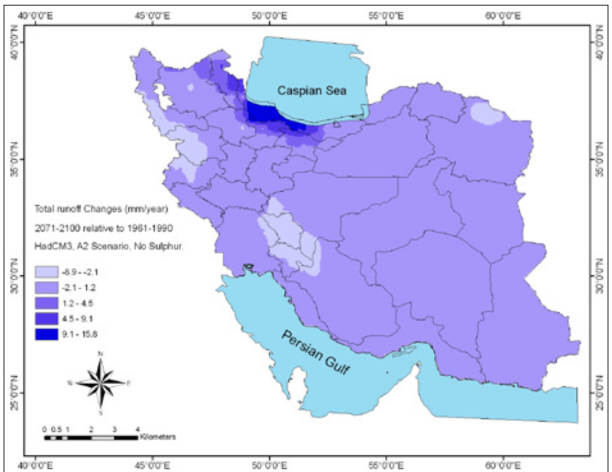


Figure 4.21: Runoff Rate Changes in 2071-2100 Relative to 1961-1990, A2 Scenario, No Sulphur

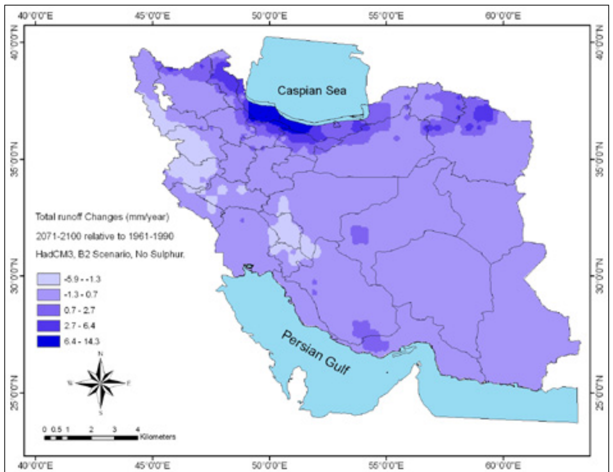


Figure 4.22: Runoff Rate Changes in 2071-2100 Relative to 1961-1990, B2 Scenario, No Sulphur

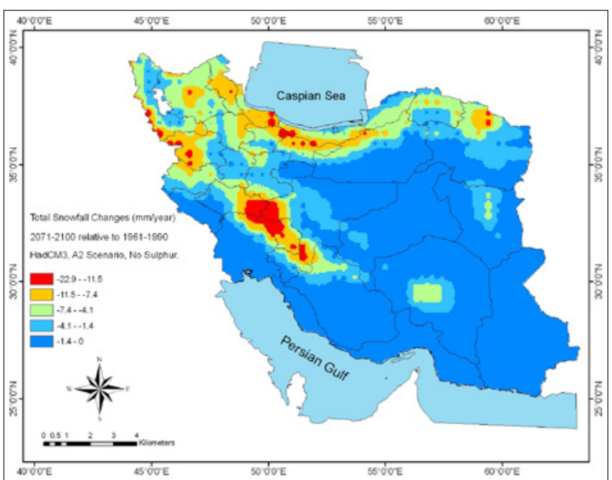


Figure 4.23: Rate of Total Snowfall Changes During 2071-2100 Relative to 1961-1990, A2 Scenario, No Sulphur

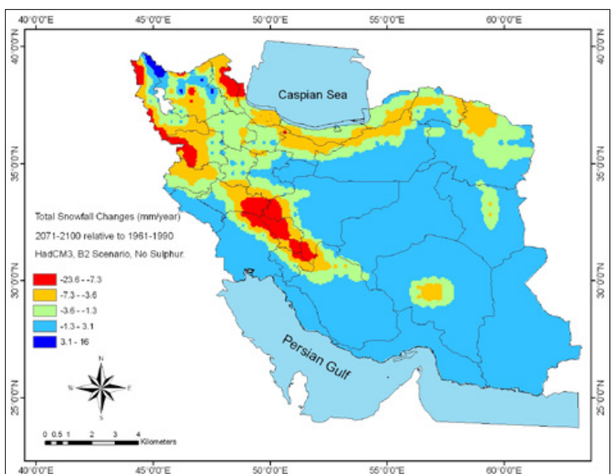


Figure 4.24: Rate of Total Snowfall Changes During 2071-2100 Relative to 1961-1990, B2 Scenario, No Sulphur

of the country plus an increase in runoff that may be interpreted as a possible greater risk of flooding. Both scenarios project less summer time precipitation along the south coast of the Caspian Sea that may have a great impact on the production of one of the very important crop yields of the region, i.e. rice.

4.3. Water Resources

4.3.1. Potential Water Resources

The Islamic Republic of Iran receives approximately 413 bcm of water from precipitation per annum, from which 296 bcm goes unutilized through evaporation and evapotranspiration. According to 2005 statistics the resources of renewable water are 130 bcm. Water supply and consumption by different sources are shown in Figures 4.25 to 4.27.

Iran is located in the arid and semi-arid region of the globe with approximately 70% of the area in the dry and semi-arid region. In addition, in recent decades climate change has also adversely affected the country's water resources. One of the consequences of climate change is increased frequency of floods that causes severe damage to water resources and is a major problem in water management. In fact, watershed degradation is an outstanding factor in the overall water crisis that has resulted in reduced production capacity of soil and water resources. Other consequences of climate change are the occurrence of severe and frequent droughts that cause reduced water resources for various uses and the loss of some water ecosystems. Lack of updated planning and management and adaptation appropriate to present conditions has exacerbated the reduction of water resources.

Average renewable water resources based on rainfall, vegetation, and other effective elements are about 130 bcm while the total accessible water with return flow is estimated about 111 bcm. Some 105 bcm of the total renewable water is contained by surface water. An estimated 25 bcm penetrates groundwater resources.

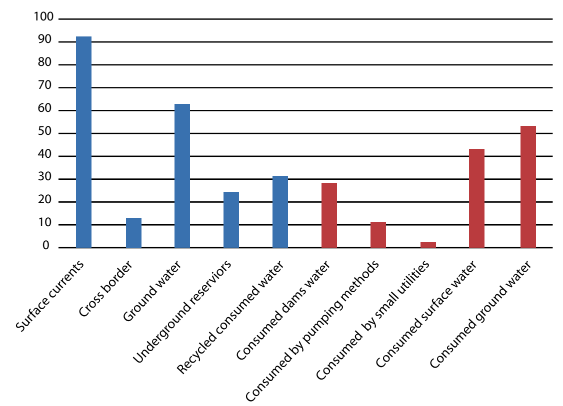


Figure 4.25: Water Sources and Consumption Trends in Iran

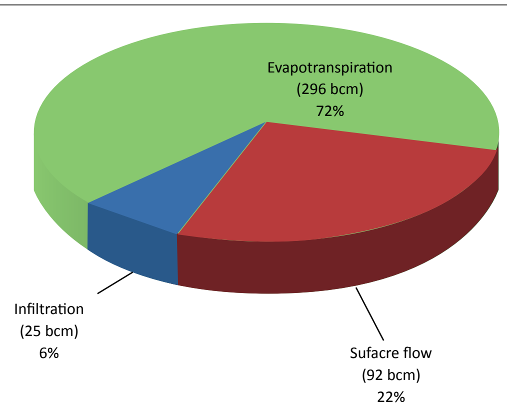


Figure 4.26: Total Renewable Water Resources

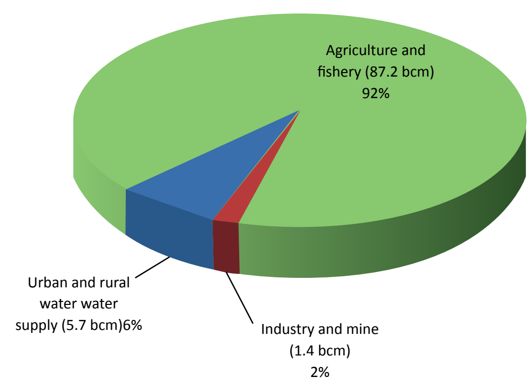


Figure 4.27: Water Use in Different Sectors

At present average renewable water per capita is about 1,900 cubic meters (2009), however, due to the increasing rate of population and the impacts of climate change, it is expected that the per capita water availability will be reduced to 1,300 cubic meter per capita by 2021. Regardless of the obvious differences in the country regarding water resources and the extensive arid area of Iran, this figure is much lower than the average rate in the country. Furthermore, the data of average per capita of water in the coming years forecasts that Iran is entering a new stage of water stress and scarcity.

4.3.2. Water, Sanitation and Protection of Environment

Providing safe and hygienic water for domestic use and hygienic discharge of sewage are very important for human survival and healthy living. By implementing water supply projects covering more than 98% of urban areas and near to 84 % of rural areas one of the basic national needs has been met to a considerable extent.

Around 32 bcm of industrial, municipal and agricultural wastewaters flow into both surface and ground water resources. In addition, the primary rivers within the country after crossing over plains and populated, economic and social centers are exposed to various pollutants and foster extensive environmental issues for the downstream plains. Thus, water management activities in this field are vital.

4.3.3. Water Economic Yield

Based on the estimated added value of major sectors in the national accounts and the volume of water use in the year 2009 prices, the average produced added value is about 120 rials per cubic meter.

The calculated gross yield cost of water is about 1,740 rials per cubic meters for agricultural water, 9,901 rials for domestic and industrial waters and 1,0596 rials for rural water. Whereas the output (yield) of dry and raw production is 0.9 kilograms per cubic meter of allocated agricultural water.

4.3.4. Water and Food Security

Based on recent statistics, some 70% of grains and about 90% to 100% of other crops and fruits are grown in irrigated lands. Various systems of water supply and water resources operation play different roles in providing food security. In addition, it is necessary to consider the drought management structure, in order to support the country's food security in periods of drought. Hence, supporting drought management is increasingly vital for national food security.

4.3.5. Water and Climate

4.3.5.1. Climate Change Impact on Water Resources

Methods for assessing the impact of climate change on hydrology and water resources are roughly categorized under three areas:

- Statistical analysis based on the past historical meteorological and hydrological records,
- Simulation study using climate change scenarios and basin-wide hydrological models,
- Simulation based on a macro-hydrological model that combines a general circulation model (GCM) and a hydrological model.

4.3.5.2. Climate Change Scenarios, Simulation and Their Impacts on Runoff

According to the studies conducted, temperature and precipitation change in the range of ±6°C and ±60%, respectively. (H. Fahmi, 1990).

The results of the model record that the rise in temperature not only increased evaporation and caused decreased runoff, but also accelerated melting snow that causes increased rate of runoff in winter and a corresponding decrease of runoff in spring. Model results also indicate that at a constant level of rainfall of only about 2 degrees, creates a rise of 27.3 bcm in annual volumes of evaporation and transpiration.

In order to study the climate system and climate change on a global scale, general circulation models (GCM) are used.

Results of GCM models show that this model despite its limitations, including lack of hydrological parameters for a simplified model, heterogeneous spatial distribution of network data that is used as the input model and finally large scale model results, will most likely be the touchstone of future climate simulations.

Using MAGICC-SCENGEN model and downscaling the results to fit Iran's geography, rainfall and temperature conditions has been modeled until 2100. The calculations were performed for the IPCC scenarios HadCM2 -18 and the results of the model have been used to predict surface runoff.

All of the defined scenarios of GCM are used in this model. However, results of more appropriate scenarios for Iran's condition are shown in Tables 4.2, 4.3, 4.4 and 4.5[3]. Using results of the GCM model as input data for the RAM model, a prediction is made for changes in thirty basins and runoff (H. Fahmi, 1990).

The model results show that:

- Increasing temperature caused increasing evapotranspiration and decreasing runoff,
- Increasing temperature caused a shorter snow melt period which results in a runoff increase in winter and decrease in spring,
- At constant rainfall, the annual evapotranspiration volume increased by about 27.3 bcm with increased temperature of only 2 degrees.

In general, based on the scenarios, Tshak-Bakhtegan and the Maharlu Basin see a probable 15.15% decrease in runoff while the Atrak Basin will witness a 7.24% increase. The greatest runoff decrease will be in the north provinces (Mazandaran and Qom) with 11.29% and the highest increase will be in the northeast's North Khorasan Province at 6.33%.

4.3.6. Water and Economic Activities

The total gross investments in the water sector based on 2001 prices are about 63,000 billion Rials; 20% of this amount was provided by the private sector. In Iran, gross investments in the water sector are about 1.2% of gross domestic product (GDP) and 5.8% of total gross investments.

Based on 2001 prices and from an economic point of view, the average marginal water prices at consumption points is estimated to be about 205 Rials per cubic meter for agricultural water and 410 Rials per cubic meter for industrial and domestic water. The Runoff Change (%) and income from surface water and changes in income from surface water on a provinces' income from surface water (%) are shown in Table 4.6.

The examination of results reveals:

- The greatest reduction of runoff is 38% in Karkheh and 36% in the large Karoon basin in the southwest,

Table 4.2: Estimated Changes in Runoff (%) Due to the Projected Changes in Temperature and Precipitation in 30 Sub-basins of the Country

Scenario / Sub-Basin	EMCONST	IS92A	IS92E	IS92F	K_1PC	K_1CON1
Aras	-2.52	-2.74	-2.92	-2.78	-2.42	-3.15
Atrak	4.81	7.24	5.60	5.41	4.65	-11.48
Bandar Abbas	-4.83	-5.21	-5.90	-5.69	-5.06	-0.30
Talesh-Mordab-Anzali	-3.22	-3.50	-3.78	-3.50	-3.05	-4.21
Tashak-Bakhtegan and Maharloo	-12.57	-13.80	-15.15	-14.82	-12.93	-5.67
Western border	-4.21	-4.67	-5.13	-5.02	-4.55	-1.96
Zohreh-Jarrahi	-5.67	-6.25	-6.90	-6.70	-5.94	-1.46

3- These scenarios are IS92A, EMCONSR, IS92AEXT, IS92B, IS92C, IS92D, IS92E, IS92F, K-1PC, K-1CON1, K-NOMOR, SRESA1, SRESA2, SRESB1, SRESB2, WRE450, WRE550, WRE650.

Table 4.3: Estimated Changes in Runoff (%) Due to Projected Changes in Temperature and Precipitation in Each Province

Scenario / Province	EMCONST	IS92A	IS92E	K_1PC	K_1CON1
Mazandaran	-10.250	-9.324	-11.115	-9.036	-11.291
North Khorasan	6.326	3.812	4.480	3.776	-7.395
Qom	-4.860	-4.541	-5.433	-4.267	-3.128

- The highest increase of runoff is 12% in the Talesh and Anzali basins in the northern part of Iran,
- Of the 30 basins under study, in 25 cases, runoff decreased and in five cases it increased,
- Calculation of income variation from surface water runoff shows that: The greatest losses occur in the southwest province of Khuzestan followed by the west and central provinces of Chaharmahal-Bakhtiyari, Kohkoliyeh-Boirahmad and Esfahan, respectively,
- The largest income increase of only 0.7% will occur in the southern province of Boushehr,
- Only three out of 30 provinces in Iran will have increased runoff and its related income.

4.3.7. Impact and Adaptation

Water supply is the crucial negative factor to national development given the drastic effects caused by occurrence of flooding and drought. Thus the impact of climate change on Iran's water sector is very important.

Table 4.4: Maximum, Minimum and Average of Changes in Runoff (%) Estimated by Different Scenarios in Each Sub-basin

Sub-Basin	Maximum	Minimum	Average
Aras	-2.18	-3.15	-2.57
Atrak	7.24	-11.48	4.30
Bandar Abbas and Sadig	-0.30	-5.92	-4.97
Talesh-Mordab-Anzali	-2.77	-4.21	-3.27
Tashak-Bakhtegan and Maharloo	-5.67	-15.15	-12.98
Western border	-1.96	-5.13	-4.40
Zohreh-Jarrahi	-1.46	-6.90	-5.89

Table 4.5: Maximum, Minimum and Average of Changes in Runoff (%) Estimated by Different Scenarios in Each Province

Province	Maximum	Minimum	Average
Ardabil	-2.19	-2.97	-2.59
Boushehr	-1.32	-7.33	-6.28
Charmahal Bakhtyari	4.76	-7.22	-5.60
Esfahan	-1.95	-4.21	-3.56
Hormozgan	-0.64	-6.83	-5.77
Ilam	-2.04	-5.50	-4.71
Khorasan-è-Razavi	5.41	-2.61	1.96
Khuzestan	0.79	-6.98	-5.62
Mazandaran	-8.10	-11.29	-9.51
North Khorasan	6.33	-7.39	3.46
Qom	-3.13	-5.43	-4.65
Tehran	-2.57	-3.52	-3.06

Table 4.6: Impact of Changes in Runoff on Provinces, Income from Surface Water (%)

Province	Area (km²)	Runoff Change (%)	Income from surface water (%)	Changes in income from surface water (%)
Ardabil	17800	-2.59	60	-1.6
Boushehr	22743	-6.28	40	-2.5
Charmahal Bakhtyari	16332	-5.60	70	-3.9
Esfahan	107029	-3.56	48	-1.7
Hormozgan	70669	-5.77	48	-2.8
Ilam	20133	-4.71	45	-2.1
Khorasan-è-Razavi	144681	1.96	4	0.1
Khuzestan	64055	-5.62	82	-4.6
Mazandaran	23701	-9.51	68	-6.5
North Khorasan	69555	3.46	3	0.1
Qom	11526	-4.65	18	-0.8
Tehran	18814	-3.06	72	-2.2

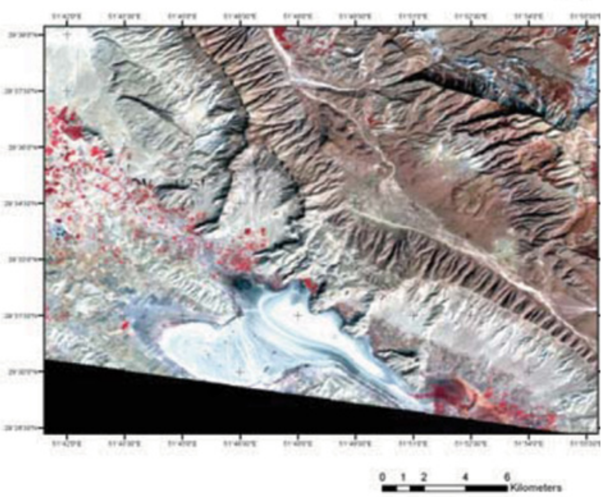
The following actions can be effective in assessing the impact of climate change on water resources:

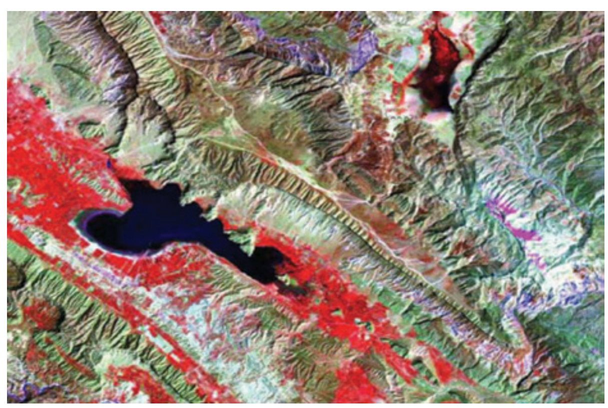
- Enhance the monitoring networks of hydrological and meteorological data,
- Comprehensive planning for optimized hydrological and meteorological monitoring networks is complete and recently put into implementation,
- Application of simulation models with different scenarios that use GCM models to predict the future climate of Iran,
- Water and wastewater planning to provide safe water for arid and semi arid areas.

4.3.8. Water and Public Health

The population coverage of the urban water network until 2009 is estimated at 98.8 % and in rural areas 73.5%. Also water loss from urban water supply networks in the past years has been reduced from some 30% to 26.3% in 2008. Considering that water shortage is predicted for future years, this index should be further improved.

The urban sewage network in many parts of the country has yet to be developed with only an estimated 31.5% of the total urban population





Sattelaite Image Parishan Lake-2003 and 2008, Fars Province benefiting from a sewage network. The sewerage network coverage consists of 10,500 miles and has increased some 7% as of 2004, indicating rapid growth in the network.

Rural sanitation coverage is around 1% with virtually no growth in recent years. The present rate of effluent production is about 34 bcm per year with 29 bcm from the agricultural sector and 4.2 bcm from the drinking and industry sectors. This rate of production is for wastewater treatment and only 1 bcm is for recycling.

4.3.8.1. Wastewater Treatment

Considering wastewater treatment, transfer of technology activities should focus on development of basic urban infrastructure and wastewater treatment services. The purpose of municipal wastewater treatment is to prevent pollution from entering the watercourse. Depending on the type of sewer collection system and industrial wastes entering the sewers, the characteristics of municipal wastewater vary from place to place. Factors such as the application of streams and lakes' water into which waste is dumped determine the degree to which waste treatment is required.

4.3.8.2. Improvement and Recovery of Ground Water Resources as Strategic Water Resources

The utilization of Iran's water resources in each basin must be planned to assure that the volume of the underground water exploited does not exceed the present volume of these resources' vitality and capacity.

Therefore, structural and nonstructural measures must be taken into consideration to meet growing demands to the extent that the amount of surface water resources utilized increases from the present 46% to 55% within the coming 20 years as a preservation strategy.

4.3.9. Water and Energy (Adaptation)

4.3.9.1. Hydropower Plants

Electricity production from hydroelectric power plants has a vital role in the electricity supply of the country, especially in the peak hours of consumption. In Iran due to the special geographical conditions and existence of numerous large basins there exists good potential for expanding hydroelectric power plants. Hydropower generation potential of the country is about 50 Terawatt per hour including the estimated potential production of Karoon Watershed at 30 Terawatt per hour, production potential of the Dez Basin at 9 Terawatt per hour and Karkheh's potential production of 6 Terawatt per hour. The potential of other rivers is estimated at about 5 Terawatt per hour. In this respect, the regulatory capacity of water dams with hydroelectric potential at the end of 2008, was about 41 million cubic meters.

Potential of hydroelectricity generation is over 25,000 megawatts, of which 6,700 MW is currently used. A 6,076 MW hydroelectric power plant is under construction with the completion of this project, hydropower generation capacity will increase twofold. In future the rate of runoff in some areas will be reduced, so the efficiency of the power plant of reservoir dams will be decreased. Therefore, the number hydropower plants should be increased. The mid-term plan for expansion of hydropower plants is shown in Table 4.7.

Table 4.7: The 5th Program of Hydropower Plants in Iran

Hydropower	Energy (giga watt/hour)	Power (MW)
2009	8065	17749
2010	758	1620
2011	1360	4870
2012	1330	2061
2013	263	490
2014	2998	5288

4.3.9.2. Underground Dams

Technical issues such as climate instability that may be a result of irregular rainfall and drought are important questions that should be considered in construction of underground dams.

Lack of a reliable water supply to meet even basic needs is a serious difficulty to human settlement in rural areas. Like other semi-arid regions of the word, Iran has shallow, rocky soils with low water retention capacity, a low organic material content and a high susceptibility to erosion. There are various options for creating and tapping water reservoirs in this region. Surface reservoirs are the most commonly used, since geological conditions are conducive to a high degree of surface drainage. However, the underlying crystalline bedrock lacks the porous structure necessary to store a large volume of water and maintain a high rate of extraction.

To overcome these shortcomings a further option of creating artificial aquifers using underground dams as a means of storing large quantities of good quality water for domestic use by animals, or even for small-scale irrigation has been devised. Under semi-arid conditions alluvial pools are a widely used phenomenon. This natural pooling of water, a common process in watersheds with crystalline bedrock, lends itself to construction of underground dams in the surface alluvium. Such dams have the advantage of being able to store a large volume of water in comparison with natural aquifers in this area, and of being less susceptible to evaporative losses as the water is stored underground.

4.3.9.3. Desalination of Brackish Water

Desalination is a costly process and the water obtained through desalination is much costlier than fresh water. By using modern technology for water desalination, the cost of producing fresh water from sea water has been reduced by about seven times, but is still about three to 10 times costlier than the cost of natural water treatment.

Technology transfer in the field of new technology such as nanotechnology for desalinating of brackish water is indispensable.

4.3.10. Weather and Climate Modification

4.3.10.1. Cloud Seeding

cloud seeding technology should be developed to provide the ways and means to achieve this kind of intervention in cloud processes.

Any consideration of climate modification technology transfer activities must address the following issues:

- Implementation of cloud seeding projects throughout the country in cooperation with countries that are pioneering in cloud seeding for gradual transfer of this technology with the final goal of being technically independent.
- Explore new water resources, climate modification,
- Spatial conditioning and timely transfer of rainfall,
- Flood control,
- Transform hail to rain,

Table 4.8: Summary of Some Key Technologies Required Catalogued by Objective

No	Option	Constraints
1	Hydropower	Insufficient investment, technology, experience and equipment
2	Underground dams	Insufficient investment, technology, experience and equipment
3	Desalination of brackish water	Insufficient investment, technology, experience and equipment
4	Wastewater treatment	Insufficient investment, technology and equipment
5	Weather and climate modification	Insufficient investment, technology, experience and equipment
6	Protection of soil moisture	Insufficient investment
7	Water harvesting	Investment

Table 4.9: Technology and the Action Required

No	Technology	Mitigation	Adaptation	Potential Impact	Relative Cost	Time Path
1	Hydropower	Yes	Yes	H*	M**	Years
2	Underground dams	No	Yes	H	H	Decades
3	Desalination of brackish water	No	Yes	H	M	Years
4	Wastewater treatment	No	Yes	H	M	Years
5	Weather climate modification	No	Yes	H	M	Years
6	Protection of soil moisture	No	Yes	H	M	Years
7	Water harvesting	No	Yes	M	M	Years
* H=high ** M=Medium						

- Postpone thunder and lightning,
- Increase hydropower plant capacity.

4.3.10.2. Electrified Wells

Electrifying pumps for water wells instead of using fossil fueled diesel generators is another ways for decreasing the emission of greenhouse gases.

4.3.11. Major Constraints and Challenges

The major challenges encountered in relation to the development and operation of hydropower plants in Iran is the restricted financial resources for investment in new plants and the relatively long construction time, which discourages foreign investment. There is also the necessity for watershed management to reduce sedimentation in dam reservoirs. Finally, large subsidies allocated to the energy sector, particularly in the oil and gas sectors, which in certain cases justifies the use of alternative power plants, especially gas power plants, instead of hydropower. Tables 4.8 and 4.9 indicate key technology and action required.

4.3.12. Importance of Integrated Water and Resources Management (IWRM) for Adaptation to Climate Change

Water is the first sector to be affected by changes in climate. The phenomenon leads to intensification of the hydrological cycle and subsequently it has serious effects on the frequency and intensity of extreme events. Sea level rise, increased evaporation, unpredictable precipitation and prolonged drought are just a few manifestations of climate variability directly impacting on the availability and quality of water.

Through management of the resource at the most efficient and proper level, IWRM instruments directly assist communities to cope with climate variability. In 2001 the Intergovernmental Panel on Climate Change (IPCC) recognized the potential of IWRM as a means of reconciling varied and changing water uses and demands. IWRM appears to offer greater flexibility and adaptive capacity than conventional water resources management approaches. It is critical that climate change in water governance be considered in the context of reducing the vulnerability of the poor, in maintaining sustainable livelihoods and supporting sustainable development. The IPCC report makes recommendation on adaptation, vulnerability and capacity enhancement; the main recommendation asserts that reducing the vulnerability of nations or communities to climate change requires an increased ability to adapt to its effects. Working to improve the adaptive capacity at the community level is likely to have a broader and more long-lasting effect on local needs and requires the following actions:

- Addressing real local vulnerabilities,
- Involving real stakeholders early and substantively, and
- Connecting with local decision-making processes.

IWRM offers tools and instruments that deal with access to water and protecting the integrity of the ecosystem, thus safeguarding water quality for future generations. In this way, IWRM can assist communities to adapt to changing climatic conditions that limit water availability or may lead to excessive floods or droughts.

Key water resources management functions are:

- Water allocation,
- Pollution control,
- Monitoring,
- Financial management,
- Flood and drought management,
- Information management,
- Basin planning, and
- Stakeholder participation.

These functions are instrumental for integrated resources management and can be of help in coping with climate variability. For example:

- In monitoring water quantity and quality development, management can pro-actively take action towards adaptation,
- Management of floods and droughts, as a key function of IWRM, allows for direct intervention in cases of extreme events,
- In basin planning, risk assessment and adaptation measures can be incorporated,
- Water can be allocated to the most efficient and effective uses in circumstances of climate variability in a flexible manner.

In brief, IWRM makes it easier to respond to changes in water availability. Risks can be best identified and mitigated in the process of basin planning. When action is needed, stakeholder participation helps to mobilize communities and generate action. Water consumers can well understand the incentives involved for use of the resource in a sustainable manner in the face of changing water conditions.

4.4. Agriculture, Livestock and Fishery

Agriculture sector of Iran accounts for about 18% of national GDP, more than 20% of employment, 85% of food supply, 25% of non-oil products and 90% of raw materials used in agro-industry. Some important trends are shown in Table 4.10 and Figures 4.28 and 4.29.

Agricultural activities in Iran are quite diversified and include production of various crops, fruits and nuts, greenhouse products, agro-forestry, poultry, small and large livestock industries, apiculture, silkworm farming and fisheries.

4.4.1. Methodology

Temporal analogical procedures, computer modeling results and expert judgment were the primary tools used in assessment of the vulnerability and adaptation of the agriculture sector to climate change. Due to the lack of data and information, the assessment in the livestock and fisheries sectors relies heavily on expert judgment while some conclusions are based on temporal analogical procedures. The economic impacts of climate change on agriculture were assessed based on the results of a preliminary economic study on the subject in Iran and the experiences of other countries. The

Table 4.10: The Trend in Production of Protein Products and Honey (1,000 ton)

Food item	Year				
	2001	2002	2003	2004	2005
Red meat	743	742	752	785	800
White meat	1298	1344	1546	1627	1760
Egg	581	547	629	655	759
Milk	5748	5877	6316	6720	7179
Honey	26	28	29	29	35

Initial National Communication of Iran to the UNFCCC was also evaluated and used in part as a source of information.

In assessment of the vulnerability, two time periods were considered. The 2010 to 2039 climate prediction, that was compared to the 1976 to 2005 baseline period, was considered for the short-term assessment. The 2071 to 2100 climate prediction, which was compared to the 1961 to 1990 baseline period, was considered for the long-term evaluations. The climate situation for these two periods has been forecast by the Climate Research Institute of Iran. They were based on A1 scenario of ECHO-G model for the short-term predictions, and A2 and B2 scenarios of PRECIS model for the long-term predictions as described above.

The suggested adaptation strategies were based on the evaluation of the stakeholders concerns. Technical, economic and social aspects were also considered in suggesting the adaptation strategies.

4.4.2. Key Stakeholders

Two key stakeholders at the national and local levels were evaluated. The first group consisted of directors and experts of various administrative and research institutes, who directly influence decision makers and policy makers at the national level. The second group consisted of young farmers with university degrees in various fields of agriculture. This group is the future generation of farmers. As such they are a vital key for the transfer of knowledge and implementation of policies at the local level.

The important common question of both key stakeholders was whether climate change has really occurred in Iran or not. The main concern of the first group was the impact of climate change on national food security. The second group's focus was concerned with the impact of climate change on the income security and quality of livelihood in rural areas.

4.4.3. Vulnerability Assessment

Simulations of future climate change in Iran indicate that changes in the amount and distribution of rainfall, as well as temporal and spatial changes in air temperature, will increase the occurrence of flooding and drought events. With that in mind, the following vulnerability assessments were made.

4.4.3.1. Basic Resources

- ***Soil***

Many areas in the central plateau, east, southeast and in the south coastal areas of the country have high to severe soil limitations and are more prone to soil degradation processes, which makes them more vulnerable to climate change.

Erosion is the primary cause of soil degradation. According to the national short-term climate prediction the western and southwestern provinces will experience decreased rainfall and according to the long-term prediction most parts of the country will experience this phenomenon. Therefore, the reduction in natural and agricultural vegetative covers, and thus, acceleration of erosion in these areas are quite possible. But the northwestern

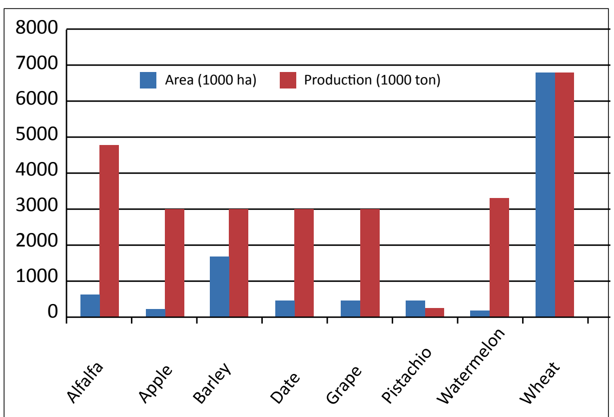


Figure 4.28: Production and Cultivation Area of Major Annual Crops (2005)

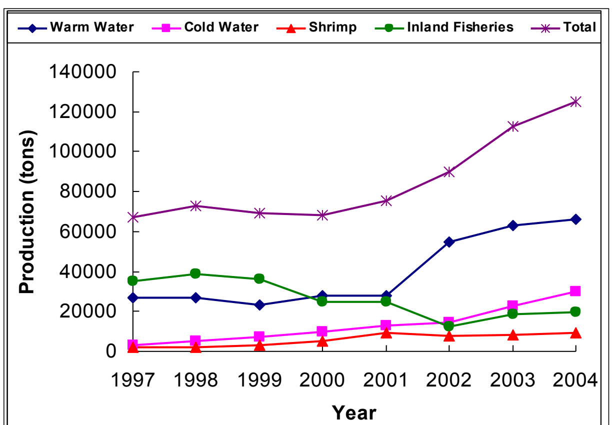


Figure 4.29: The Trends in Production of Aquaculture Activities

areas, south coastal areas, North Khorasan Province and the north of Fars Province will experience increased rainfall. Consequently the possibility of flooding and soil erosion is predicted to increase in these regions.

Rain fed agriculture is very much dependent on the rainfall and moisture of the soil. The short-term climate predictions indicate that the country will experience a decrease in mean rainfall and increase in temperature that results in a reduction in soil moisture content. The long-term climate predictions indicate that this phenomenon will happen in the west and northwestern provinces of the country: dry land farming areas that are vital. There will not be significant changes in soil moisture content during summer and fall.

Soil salinity is another major limiting factor in the agricultural development of Iran. According to the latest statistics, about 27% of the land in the country is salt-affected to some degree. Increase in rainfall and a decrease in evaporation demand will improve this parameter. Increase in soil salinity will make agriculture production uneconomical in some cases. According to the long-term climate predictions the soil salinity hazard will increase in severity in all parts of the country.

- ***Water***

Close to 90% of the total agricultural production of the country came from irrigated lands in the year 2004. The arid parts of the country (Central Plateau, northeast, east and southeast of Iran) are more vulnerable to the impacts of poor quality water and water storage. According to the long-term climate predictions the provinces and areas south of the Zagros Mountains range will experience the greatest decline in snowfall. This will have important consequences on surface and underground water resources, and thus the availability of water for irrigation, in these areas.

4.4.3.2. Agriculture

- ***Annual Crops***

Cereals, particularly wheat, are the most important annual crops produced in the county. The results of available predictions are shown in Table 4.11.

Yields of Iran in Comparison to the Year 1990 by HadCM3 SRES Model.

a. Rain Fed Crops

In general, temperature and rainfall have the greatest impacts on rain fed crop yields. According to the predicted future climate, the most significant dry land areas of the country,

Table 4.11: Potential Changes in Cereal Yields of Iran in Comparison to the Year 1990 by HadCM3 SRES Model

Scenario	Time frame	Potential changes in cereal yields (%)	
		Without CO_2 effect	With CO_2 effect
A1	2020s 2050s 2080s	-5 to -10 -10 to -30 -10 to -30	-2.5 to -5 -5 to -10 -10 to -30
A2	2020s 2050s 2080s	-5 to -10 -10 to -30 -10 to -30	0 to -2.5 -2.5 to -5 -5 to -10
B1	2020s 2050s 2080s	-2.5 to -5 -5 to -10 -10 to -30	0 to -2.5 -2.5 to -5 -5 to -10
B2	2020s 2050s 2080s	-5 to -10 -10 to -30 -10 to -30	-2.5 to -5 -5 to -10 -5 to -10
A1: very high economic growth and low population growth A2: high economic growth and high population growth B1: high economic growth and low population growth B2: high economic growth and moderate population growth			

particularly in the west, will experience the highest decrease in precipitation and increase in temperature. The impacts of short (the year 2025) and medium (the year 2050) term climate changes on the growth and yield of wheat are shown in Table 4.12.

b. Irrigated Crops

Irrigation is mandatory in this type of crop production system. The results of future weather simulation for 500 ppm CO_2 concentration in Khorasan Province has shown a 0.3-9.8% increase in yield, and 4%-16% percent decrease in the water requirement of sugar beet. In arid and semi arid areas, if crop water requirement increases due to climate change and there is an inadequate water supply, the production of irrigated crops, particularly cereals, will decrease.

Most rice producing provinces will experience decreased precipitation in the future. Rice is also very sensitive to temperature but the effect of temperature increase is less in most provinces. In some provinces a decrease in temperature will actually make the province more suitable for rice cultivation.

Frost is a limiting factor in the agricultural production of the northwestern provinces of the country. The rise in mean yearly temperature, particularly in the winter, could extend the growing season in these areas, and allow for cultivation of long maturing crop varieties, or two crops per year.

- ***Permanent Crops***

Based on the temporal analogical results, it seems that permanent crops are less sensitive than annual crops to climate change. Permanent crops also respond to increased CO_2 in the atmosphere and variations in temperature and precipitation. Limited studies on the effects of climate change on fruit phenology in Europe and US have shown the critical growth stages occur several days earlier, which makes these crops more vulnerable to cold and frost damage. The long-term studies (2090-2099) in Michigan, USA, indicate they may occur as much as 41-45 days earlier. These studies also have shown that, in general, the growing seasons have extended by several days. Rain fed fruit and nut orchards are more vulnerable to drought and climate change than irrigated orchards. But, since they are deep-rooted perennials and there is more time available to respond, they are less vulnerable than annual rain fed crops. Grapes are the largest and most important fruit crop in the country. Studies in France suggest that increased atmospheric CO_2 and temperature will increase biomass, fruit yield and water consumption. Most of the grape producing provinces will experience a 0.9-1.4°C temperature increase in the future. Provided that enough water is supplied for irrigation, the fertilization effects of CO_2 and increased temperature may improve the conditions for vineyards. This is a higher possibility in places that experience a slight increase in rainfall. But, decreased precipitation in the future will put more pressure on vineyard production.

Fruit and nut production is particularly prone to cold and frost damage. The number of frost days in the predicted climate change areas of Iran will decrease in most parts of the country by several days . Therefore, it seems that the conditions for fruit and nut production will improve in most major fruit producing areas of the country.

- ***Biotic Stresses***

Biotic stresses in agriculture include pests, diseases and weeds. Temperature, wind, humidity and rain are among the important weather variables that control the geographical

Table 4.12: The Mean Potential Changes in Wheat Production in Major Rain Fed Wheat Producing Areas of Iran

Parameters	2000	2025	2050
Growth rate reduction (%)	-	26	36
Yield reduction (%)	-	20	27
Potential growth days	207	192	177
Days with water deficit	179	188	197
Rainfall deficit index (mm)	73	87	99

distribution of pests and diseases. Therefore, climate change can impact their geographical distribution. Increased winter temperatures will stimulate the growth and reproduction of insect pests and pathogens. Increased rain and humidity may also increase the invasion of pests and diseases to farms and orchards.

According to the predicted short-term future climate of the country discussed above, the maximum, minimum and average temperatures during the winter months will increase. On the other hand, increased rainfall is predicted for some parts of the country. Therefore, the possibility of pest and disease outbreaks may increase in these areas. Coastal provinces in the north will experience the highest rainfall reduction in the country. This may lead to the migration of some pests and diseases to the neighboring provinces of the north.

The results of the limited amount of study on the interactive effects of important agricultural crops and weeds under increased atmospheric CO_2 conditions generally indicate the relative advantage of weeds over agronomic crops. The photosynthetic pathway and the characteristics of climate change in a particular region will determine the outcome of their competition. It seems that in those parts of the country that experience high temperature increase and decreased rainfall, more C4 species of weeds than C3 species will be present

The increased outbreak of weeds, pests and diseases will lead to greater utilization of different pesticides, which has important environmental and economical consequences. At the farm level, increased costs of weed, pest and disease control will increase production costs. At the regional and national level, the concern is over increased environmental pollutants, food quality and public health. In addition, this may lead to increased import of pesticides to the country, which requires additional budgeting and financing at the national level.

- ***Socio-Economic Impacts***

An important issue in socio-economic impacts of climate change is its effects on livelihood and income of farmers. There is no comprehensive evaluation of this issue in the country, except a recent preliminary study that is based on weather variables. The results for wheat are as follows:

- If the temperature of the growing season exceeds 6.2 °C, the net profit will decrease,
- During the harvest time, net profit will decrease due to increasing temperature, but will increase beyond 26.5°C. Net profit will decrease with a rainfall increase above 124.5 mm during planting season. The results for corn are as follows:
- Mean temperature above 17.5 °C during planting season increases net profit,
- Rain increase above 22.5 mm during planting season increases net profit,
- Mean temperatures of the growing season above 23.4°C increase net profit.

The simulated short and long-term climate change effects on the net profit of wheat and corn cultivation are presented in Table 4.13.

4.4.3.3. Livestock

Climate change will impact animal husbandry directly by affecting animal physiology, and indirectly by affecting the forage and animal feed production. Based on the temporal analogical results, it seems that small livestock, such as goats and sheep, are more vulnerable to future climate change in the country than large livestock, such as cattle and camels. This conclusion is general, and vulnerability of individual breeds within species could not be evaluated due to lack of information. Based on the visual observations of experts during the 1999-2002 drought in Sistan and Baluchistan Province, southeastern Iran, the Sistani breed of cow seemed to be more drought-tolerant than other local breeds. This breed is native to the Sistan area of the province, and is physiologically adapted to arid, dry climates. In addition, livestock species adapted to desert and arid climates are much less vulnerable to future climate change. The prime example of such species is the camel.

Temperature is the most important weather variable for livestock. Warmer temperatures

Table 4.13: Impacts of Future Climate Change on Net Profit from Wheat and Corn Cultivation in Iran

Time slice	Scenario*	Temperature increase (°C)	Rainfall decrease (%)	Change in net profit (%)	
				Wheat	Corn
Long term (2100)	1 2 3	1-1.5 2.5-4.1 5.9-7.7	11-19.1 30.9-50 58-80	+19 +8 -41	+18 +11 -29
Short term (2039)	A1	0.5	9	+22	+5
* Scenarios 1, 2 and 3 are for low, current and high greenhouse gas emission rates, respectively; A1: very high economic growth and low population growth.					

during winter reduce feed requirement and energy costs. However, warmer temperatures during summer increase the possibility of death, particularly in poultry. Reproduction, meat quality and milk production is generally reduced by heat waves.

Overall, warmer temperatures and increased atmospheric CO_2 levels should increase the growth rate of pastures. Higher rainfall and warmer temperatures, particularly in winter, probably improve the conditions for industrial animal production units in the north and northwestern provinces.

There will be a decline in quality and capacity of rangelands, as well as rain fed forage production in provinces that experience reduction of rainfall and temperature rise. Poultry production in these areas, due to more frequent occurrence of heat waves in summer, will face greater difficulties.

Changes in temperature and humidity will impact the reproduction and population of pests and pathogens. There is no information on this subject in the country. However, limited information available from other arid countries (Australia and New Zealand) indicates that the population of cattle ticks will grow in pastures due to extended dry seasons and warmer winters. This may be true for similar cattle pests in Iran. Also, due to increased temperatures in some cold regions of the country, it is possible that some of the pests and pathogens move to those areas where they were not able to grow.

Iran's nomadic population, being highly dependent on grazing and small livestock production for sustenance and income, are particularly vulnerable to future climate change. Reduction of the quality and grazing capacity of the rangelands along with changes in the distribution pattern of pasture dependent species, can greatly affect the migration routes of the nomads. These factors will have great impact on the economic conditions and livelihood of these people. If the nomads are challenged with decreased income, increased poverty and reduced quality of life, the pressure on natural resources will subsequently greatly increase. In that case, this will have grave detrimental effects on the degradation of natural resources than climate change itself and may result in massive migration of nomads.

4.4.3.4. Fisheries

- ***Caspian Sea***

The Caspian Sea is greatly influenced by the inflow of cold water from the Volga River that comprises 85% of its water supply. Climate change impact on the Volga River will consequently affect the conditions in the Caspian Sea. The water inflow from this river will greatly change the present patterns of sea currents. The variations in air temperature will also divert the present patterns of wind currents. Due to the increased influx of nutrients from the river's algal blooms, extinction of some plankton and benthos species may occur more frequently. An outbreak of certain diseases in the ecosystem is another strong possibility.

Most of the economically important fish species of the Caspian Sea are migratory. Due to changes in air temperature, reduced water inflow in the rivers and water pollution, the conditions for spawning, reproduction and growth of migratory fish species will be less favorable in the future.

The birth rate of the Caspian seal (Phoca Caspica), the only mammalian species of the Caspian Sea that requires cold and below zero temperature for birth are already endangered.

- *Persian Gulf and the Sea of Oman*

The ecosystems of the Persian Gulf and the Sea of Oman are already under stress due to high temperature and salinity, decrease in oxygen supplies, as well as pollutants from the petroleum industry in the region and this pattern will intensify in future.

The changes in these water bodies, particularly the Sea of Oman, are heavily influenced by the changes in the Indian Ocean. The changes in oceanic currents may adversely affect fishing activities, particularly tuna fishing. On the other hand, the conditions will become more favorable for salt and heat tolerant species, thus increasing their stocks in these ecosystems.

Migratory fish species will suffer due to the degradation of their reproduction habitats, while the pelagic species and the benthic and semi-benthic fish species will experience greater stress. Outbreak of certain diseases in the ecosystem is another strong possibility.

- *Aquaculture and Inland Fisheries*

Production of cold water fishes, warm water fishes and shrimp are the largest aqua cultural activities in Iran. Trout is the only cold water species that is produced in the country. Trout requires low temperature and high oxygen, thus, making it very sensitive and vulnerable to the future climate change. At the moment, many trout farms are operating at threshold optimal conditions. Hence, a continuation in temperature rise will adversely affect cold water fish production (trout farming) in those areas. Warm water fish species and shrimp production are less vulnerable to the future climate changes than cold water fish species. However, the reduction in the quantity and quality of water supplies can adversely influence them in future. With adequate water supply, the future climate change could provide the opportunity for increased yield per unit area, and in some cases, two harvests per year.

4.4.4. Adaptation Programs

Since climate change in Iran has already been started, the implementation of the following measures needs to be accelerated. This will increase the capacity and preparedness of the country before the physical, economic and social impacts of climate change reach critical stages.

4.4.4.1. Agriculture

Increasing the production level to the potential crop yields is a first priority. Sustainable soil and water management, sustainable crop management at farm level, transfer of knowledge and extension and policy making at the national and regional level towards enhancement of job security and providing incentives for agricultural production in rural communities are also vital. Enhancing soil management by increasing organic content matter that includes conservation tillage, soil fertility and salinity management is another item high on the national agenda.

- *Water Management*

Increased water productivity and enhancement of water use efficiency entails:

- Reduction of water losses,
- Utilization of unconventional water resources,
- Irrigation methods: expansion of pressurized irrigation systems, improvement of the scientific and applied skills of irrigation designers,
- Integration of sustainable technologies with modern technologies.

- *Seed and Seedling Management*
    - Plant breeding,
    - Appropriate agronomic techniques.

- *Weeds, Pest and Disease Management*

The general, recommendation of international agricultural agencies, such as FAO and ICARDA, and experts on weeds, pests and disease management in future climate change scenarios is to apply Integrated Pest Management. Monitoring of their population growth patterns and migration routes while preparing for the possible appearance of new species is mandatory.

• ***Selection of Appropriate Crops***

Selection of appropriate crops for cultivation will have positive effects on water management and efficient water use at farm level.

- Dry lands: annual crops in these areas are to be replaced with perennial crops, such as fruits, nuts and woody trees. Commercially cultivate some of the local natural plant species as forage or wood,
- Irrigated lands: shift from cultivation of crops with high water requirement to economical low water requirement crops. Greenhouse production of horticultural crops with high water requirements,
- Marginal lands: Production of various plant species, highly tolerant to drought and/or salinity, which grow naturally in these lands possess useful and economical values as forage, medicinal plants, oil crops and wood. In addition, they offer valuable

Table 4.14: Capacity Building for Agriculture Sector

Agriculture	
	Enhancement of water productivity and appropriate water use
	Regulation and monitoring of well drilling companies and implementation of tough regulatory laws against illegal well drilling
	Prevention of land fragmentation
	Reduction in agricultural wastes
	Expansion of agricultural insurance
	Reduction of risks from yield and price fluctuations through Farmers Income Stabilization Fund
	Compensating part of the expenses as incentives for environmental services
Livestock	
	Expansion of livestock and poultry insurance
	Income Stabilization Fund for Livestock and Poultry Producers
	Settlement of migratory nomadic communities
	Promotion of organic livestock and poultry production
	Expansion of industrialized production units by development of industrial camel production systems
	Rewarding those who improve the condition of the rangelands or for those who adopt integrated production systems
Fisheries	
	Artificial reproduction and release of different marine fingerlings
	Prevention of excessive fishing
	Reducing the by-catches and preserving the biodiversity by equipping the fishing vessels with modern fishing equipment and related techniques
	Providing the social needs of fishermen, such as fisheries insurance, social security insurance and retirement benefits
Cultural awareness	
	The ethics of respect for water should be raised
	Revitalize the historical and rich indigenous knowledge of adapting to drought and water scarcity
	The level of public awareness about various aspects of climate change, particularly among farmers, livestock producers and fishermen should be raised more efficiently
Education	
	Transfer of knowledge to agricultural producers will result in increased crop yields, better water productivity and enhanced economic efficiency
	Enhancement of the technical skills of agricultural producers

ecological safeguards to the society, such as combating desertification, greening of degraded areas, improvement of wildlife habitats and carbon sequestration.

4.4.4.2. *Livestock*

- Protection of diverse Iranian animal breeds,
- Balance between the number of animals and grazing capacity of pastures,
- Gradual replacement of low with highly productive breeds in industrial and semi industrial areas,
- Increase forage production in the country through improved irrigation management and water use efficiency in irrigated forage farms, introduction of new drought resistant cultivars, reduction in forage losses and wastes, re-vegetation and improvement of rangelands, and utilization of marginal and saline lands for production of xerophytes and/or halophyte forages,
- Expansion of integrated production systems: prediction and management of outbreak of insect pests and pathogenic agents.

4.4.4.3. *Fisheries*

Appropriate utilization of available resources and enhancement of production and fishing management for economical enhancement of fisheries activities are the fundamental adaptation strategies for this sector. This will improve the income security of the producers and reduce the pressure on marine stocks. The following adaptation measures for fisheries sector are proposed.

- *Research, Education and Extension*
    - Continuous monitoring of marine ecosystems and their components, including physical, chemical and biodiversity factors,
    - Development and expansion of intensive fish farming in controlled systems, particularly in marine areas,
    - Development and expansion of circulating and controlled fish farming (closed systems),
    - Research on the identification and introduction of new marine species tolerant to increased temperature, salinity and oxygen deficiency.
- *Protective Measures*
    - Prevention of the present trends in environmental degradation and pollution of marine ecosystems,
    - Appropriate control and monitoring of present conservation areas, and designation of new conservation areas,
    - Protection and improvement of reproduction and spawning habitats,
    - Prohibition of destructive fishing methods, such as bottom trawling and gill net harvesting.

4.4.4.4. *Capacity Building*

For implementing the mentioned adaptation programs in agriculture sector, consideration of the capacity building activities as listed in Table 4.14 is necessary.

4.5. Forests, Rangelands and Deserts

Impact of climate change on biological diversity is already being evidenced. This is seen in shifting migration ranges of insects and animals, modified flowering and fruiting cycles and species extinctions. Additional negative climate change influence on forests includes: drought (Zagros forest in the west) or flooding (Hyrcanian forest in the north or in central parts), conversion to agriculture, grassland, steppe, or desert (in the north, west and center), increased vulnerability to pests, fire and invasive species. The prospect of broad-scale growth of forests is slowing the rate of climate change.

For a reliable assessment, especially related to the vulnerability in forest, range and desert ecosystems, it is necessary to take the following steps:

- Organize research systems for identified vulnerable sectors,
- Establish permanent research stations to record and observe the needed data,
- Implement research project to determine vulnerability study methods and evaluate vulnerability with scientific based methods.

Iran with variable and diverse climate conditions, dominated by arid and semi-arid regions, constantly faces challenges and could benefit from some useful climatic features. The country is located in the Central Asia and West Asia sub-region. In this sub-region food and fiber, water resources and land degradation are in a very vulnerable condition. Some challenges and opportunities are shown in the Table 4.15.

4.5.1. Methodology

Based upon the Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies (UNEP, Version 20, October 1998), different procedures were used for evaluation of climate change effects on forest ecosystems. These include: "Analogues Procedures", which provides means of comparison, "Expert Judgment", which is based upon expert's views; "Field Survey", which needs field reports and data; "Experimentation", which is based upon implementing research and experiments; and "Modeling", which is based upon models identified according to assumption and recorded data.

Based on the method used, major categories of the changes expected in forest ecosystems as consequences of climate changes are as follows: disturbance, simplification, movement, age reduction and extinction.

Climate change effects on rangeland have several similarities with forest ecosystems from vegetation cover, hydrological cycle and soil erosion perspectives. Temperature and precipitation differences in rangeland ecosystems are considerable. In general rangeland ecosystems receive a lower amount of precipitation. Blowing winds in such ecosystems, with certain physiological condition of plants is important.

4.5.2. Gap and Constraints

Taking into account Iran's social and economic conditions, in assessment of climatic changes effects on forest, rangelands and deserts, human interference and exploitation of natural ecosystems needs to be considered. Adverse impacts of climate change on different sectors impose severe social and economic consequences on the people.

To obtain reliable data for cost analysis, it is necessary to evaluate and take into account

Table 4.15: Challenges and Opportunities to Respond to Climate Change in Forestry Sector

Challenges	
	Inadequate precipitation, in comparison with high evaporation potential
	Unsuitable time of precipitation with the needs of plant growth
	Relatively low available humidity in most parts of Iran except in the Caspian region and partly in Persian Gulf areas
	Limited vegetation cover in most parts, especially in central, east and south of Iran
	Repeated drought periods with deceasing interval time
	Anthropogenic deforestation and enhancement of the rate of natural desertification phenomena
	Great social and economic effects on environmental and sustainable development issues
Opportunities	
	Great potential of sunshine for solar energies
	Great variation of daily temperature for plantation of diversity of plants and energy use
	Potential of adequate winds during the year for energy power
	Urban forestry and urban tree plantation in big cities*
*Experiences in local, national, regional and international levels provided in the Centre of Excellence of Low Forest Cover Countries (CE of LFCCs - situated in Tehran), could be employed as an able tool for urban and pre-urban forestry.	

the synergy of different related aspects. The following evaluation subjects could be identified:

a. Evaluation of current laws and regulations,

b. Evaluation of technical implementation,

c. Evaluation of social matters,

d. Evaluation of economic issues,

e. Evaluation of national activities raised by regional and international commitments.

Through these evaluations we could possibly obtain data and information to judge whether adaptation does or does not reduce damages significantly?

Our current knowledge of adaptation and adaptive capacity is insufficient for reliable prediction of adaptations. It is also insufficient for rigorous evaluation of planned adaptation options, measures and government policies, but we will be able to implement definite findings at proper scales. During the last few years, we did not have enough knowledge to give definite answers to this question. Vulnerability is a function of exposure and sensitivity; and both can be influenced by adaptive capacities.

4.5.3. Key Stakeholders

The key stakeholders in the forestry sector are listed in Table 4.16.

4.5.4. Vulnerability and Adaptation

4.5.4.1. Forests

To assess the effects of climate change on forest, range and desert ecosystems, it is necessary to work on vegetation cover, water resources including underground and surface water, and other matters like soil. Anthropogenic impact on vegetation cover, hydrological cycle and other sectors will result in changes in the balance of carbon stock and storage.

According to the projections made by IPCC 2007 for the Asia region, Iran will experience different patterns of seasonal changes in precipitation and temperature, based upon various scenarios for three 30 year time slices in the next 30, 60 and 90 years. Climate change may force species to migrate or shift their ranges far faster than they are able to, thereby disrupting existing ecosystems. Forests may undergo changes in fire intensity and frequency, increased susceptibility to insect damage or

Table 4.16: Key Stakeholders of Forestry Sector

Government	
	Forest, Range and Watershed Management Organization (FRWO)
	Department of Environment (DOE)
	Research Institute of Forest and Rangelands (RIFR)
	Iran Meteorological Organization (IRIMO)
	Municipalities and Parks and Green Space Organizations
	Universities (colleges of forestry, natural resources and environment)
	Research institutes and laboratories
	Ministry of Energy (Water Department)
NGOs and private sector	
	Green Peace
	Green movement
	Environmentalists
Intergovernmental and international organizations	
	Tehran Processes Secretariat for Low Forest Cover Countries (TPS for LFCCs)
	UNDP
	UNEP
	FAO

diseases, and extreme weather events, which they may not be adapted to survive.

Forests in Iran are located in places with different climatic conditions. Hyrcanian forests in the southern part of the Caspian Sea zone in the Alborz range in northern Iran could be considered as the most important forest ecosystem followed by the western forests, including Arasbaran forests that are located in the Zagros range. Irano-Tooranian, Khalidge-Ommanian and mangrove forests are other sources of forest ecosystems in Iran. Changes in temperature and precipitation could lead to weather changes and finally to climate change.

Today's main forests of Iran, which are situated in the Alborz range in the north and Zagros in the west and northwest, however, have undergone serious fragmentation and degradation from roads, agriculture and development, and are thus impeded in their ability to migrate as their local climate changes.

Temperature and precipitation patterns in the Hyrcanian forest in the north of Iran have changed during the last half-century. A warmer climate and changes in precipitation precedents will cause disparate effects on forest ecosystems, making some species contract while others expand. Increases in CO_2 concentration will compound this effect in some systems while dampening the impact in other systems. Together this indicates that many areas, especially those habitats along environmental gradients, will be subjected to change, and if the population cannot adapt or move with changes in climate, they will face extinction.

During the last 50 years temperature and precipitation regimes as well as the frequency of stormy days in the Hyrcanian forests have changed and within the next 50-100 years, changes to ecosystem functions and plant demographic processes will be the imminent threats, though in the long term, large shifts in forest types are likely to occur (Jafari, 2008a, 2008b).

Some consequences resulting from climatic changes on different terrestrial ecosystems can be highlighted as follows:

- Re-location or even immigration of some plant species as a result of unpleasant habitat. This replacing could be: a) in elevation in the same geographical stand of growth; and or b) change in seasonal of phenological growth stages; and or c) move to other geographical habitat; and or d) endangerment or disappearance,
- The rate of sensitivity and tolerance of a species to the climatic conditions is among the primary factors affecting species when the climate condition is changing,
- Low tolerance species could be endangered or even face extinction in new climate conditions,
- Changing of natural regeneration regime of different plant or even animal species,
- Decrease or increase in wood and non-wood productions in forests,
- Changes in the rate of infection, reproduction and distribution of pests and plant diseases in forests,
- Vegetation cover and amount of precipitation are two main factors effecting soil change and erosion,
- Intensification of forest land erosion, particularly in arid and semi-arid zones,
- Water and the water cycle are principal factors that cause ecosystems to form,
- Changing the hydrological cycle could alter ecosystems and especially plant based ecosystems,
- Retrogression of mangrove forests and sometimes their destruction because of sea level rise in the Persian Gulf and Oman Sea,
- With changing ecosystem conditions, all related elements including fauna and flora will be affected and it may provide a non favorable habitat for wildlife,
- Increased fire frequencies in forests, especially in arid and semi-arid areas, whereby these dangerous conditions

are intensified by high temperature and aridity,

- Anthropogenic forest fire frequencies may even increase,
- Social and economic consequences like immigration of nomads and rural inhabitants,
- These changes may cause poverty, health and cultural problems in affected regions.

Changes in precipitation trends will affect the species that are sensitive to humidity, such as Alnus glutinosa, Alnus subcordata, Salix sp., and Pterocarya fraxinifolia in Hyrcanian forests. Some sensitive species such as Juniperus sp. that have been adapted to some specific climatic condition may be endangered by climate change. This new habit might also reduce growth or limit distribution and or cause the extinction of sensitive species.

The open spaces of rangeland ecosystems, compared with the forest ecosystem may be more susceptible to invasive species as the consequence of climate change. The introduction of invasive species could limit endemic species habitat conditions.

In range ecosystems, with limited water resources, plants employ special adaptation methods to survive. One of the strategies used by tolerant plant species is increasing root length to obtain and use available water in different soil layers. These species are more tolerant, but with changes in underground water resources, they will also face the challenge of critical conditions.

Forest, rangeland and desert ecosystems have different types of plants, including trees, shrubs, forbs, perennials and annuals. Plant composition in range ecosystems is mainly perennial and annual grasses. These plants may have lower tolerance potential to change in temperature and precipitation, and thus be negatively affected.

4.5.4.2. Mangroves

Mangrove forest, which is a very sensitive ecosystem to climate change, is situated in the southern part of Iran in the Persian Gulf areas. Mangrove forests also protect sea grass beds and coral reefs from deposition of suspended matter that is transported seaward by rivers. This forest type inhabits waterlogged, salty soils along coasts in the tropics and subtropics where they experience tidal flow.

Mangroves are dependent upon a relatively stable hydrographic and salinity regime, and they are susceptible to pollution and the alteration of salinity levels.

The Persian Gulf contains the most extensive mangroves, which help stabilize a large part of the shoreline. Forming a dense barrier between sea and land, the mangrove is a crucial food reservoir for coastal people who rely on its supply of shrimp and crabs, as well as its wood for fuel. It is also a vital host to a number of endangered species. For the time being, the area is under stress from urbanization, industrialization and agriculture, and is experiencing impacts from timber and petroleum exploitation along the coastline of the Persian Gulf.

4.5.4.3. Grasslands and Deserts

The structure and function of the grasslands makes them one of the most vulnerable to the global climate change of any terrestrial ecosystem.

In rangelands, the following consequences may occur because of climate change:

- Decreasing vegetation cover and reduction of forage production in rangelands,
- Soil erosion, caused by the destruction of plant cover,
- Changing hydrologic cycles and decreasing the underground water level,
- Increase of plants and diseases and the destructive effect on agriculture sector,
- Fires in rangelands,
- Effect on regeneration of plants and wildlife,
- Extinction of sensitive species and increasing invasive plants,

- Social and economic consequences such as immigration.

The condition of vegetation and soils will prove critical to grassland resilience to climate change. Healthy, vigorous stands of native vegetation are likely to be more resilient to warming temperatures and increasing frequency and duration of droughts than degraded grasslands because their roots have access to deeper soil moisture and they are better able to compete with invasive species.

In rangelands, trees and bushes, which are mostly evergreen, using their long roots to sink deeply into the soil and access necessary water, are very tolerant to insufficient precipitation. According to the level of their tolerance, these plants are classified into specific groups:

- Annual and seasonal plants which are greatly sensitive to inadequate rainfall,
- Perennial grasses which are more tolerant than the plants of the first group,
- Trees and bushes that are the most tolerant among rangeland plants.

Numerous human disturbances and stresses are causing substantial degradation to the crucial components of grassland ecosystems. These include habitat fragmentation and loss, the spread of invasive species, alteration of fire regimes, and pollution; and all may act alone or synergistically, leaving grasslands particularly vulnerable to climate change.

The nature of climate change effect especially on terrestrial ecosystems is a long-term process. It is necessary that assessment, prediction and projection in this field be considered in different time scales.

Quantity and degree of potential damages could be evaluated in economical terms. According to the kind and density of these damages on different community and social groups, it could be considered in terms of social evaluation. Nomads, rural inhabitants, farmers, livestock owners, forest inhabitants and other social groups are all, by one means or another, affected by these changes. According to the subjects and regions, the influence of these alterations is different.

General circulation models (GCMs) predict grassland ecosystems to experience climatic change including higher maximum (daytime) and minimum (nighttime) temperatures, and more intense precipitation events.

Based upon expert judgments, devastating factors lead to an annual quantitative and qualitative 1% loss of Iran's natural resources to desertification In the year 2000, the amount of this degradation was 1.5 million hectares. If this rate of desertification continues the amount of land affected for the years 2010 and 2050 would be estimated to be 15 million and 75 million hectares, respectively.

There are several different prepared and approved plans for various sectors in Iran. However, it seems necessary that because of the importance of climate change, all available plans, policies and measures be reconsidered taking into account climate change issues.

To implement this recommendation, an expert group or committee should be established at a high level in the government with clear terms of reference. This expert group with transparent responsibility could review in detail all available plans with the cooperation of the relevant stakeholders. In this process, synergy of all plans and programs should be taken into consideration. In developing such coherent programming watershed management plans could play an integrated role in different natural resource evaluations. Criteria and indicators (C&I) of sustainable forest management (SFM) need to be considered in all programs implemented.

After completing vulnerability analysis to determine how a forest system can be affected by changing climatic conditions, the next step is to look at the range of adaptation options available in order to promote resiliency. An effective vulnerability analysis will determine which components of the system, for example species or functions, will be most vulnerable to change, together with consideration of which parts of the system are crucial for ecosystem health.

The options listed below all seek to maintain the health of forest biodiversity as the overarching vehicle for successful adaptation. Criteria and indicators (C&I) for sustainable forest management (SFM) outlined in the Near East process for LFCCs and the Montreal Protocol of the United Nations Conference on Environment and Development include maintenance of forest ecosystem health, conservation of biodiversity, maintenance of forest productivity and conservation of soil and water resources. Sustainable forest management criteria provide a framework into which adaptation strategies can be incorporated.

- Reduce present threats,
- Avoid fragmentation and provide connectivity,
- Maximize size of management units – decision making on a large bio-geographical scale,
- Provide buffer zones and flexibility of land uses,
- Represent forest types across environmental gradients,
- Protect mature forest stands,
- Protect functional groups and keystone species,
- Protect climatic refugees,
- Maintain natural fire regimes,
- Silvicultural techniques to promote forest productivity,
- Prevent conversion to plantations and practice low-intensity forestry,
- Maintain genetic diversity and promote ecosystem health via restoration,
- Assist migration with species introductions to new areas,
- Protect most highly threatened species in situ.

Adaptation options in rangelands: Many possible adaptation strategies may prove useful for maintaining and restoring the resilience of grassland ecosystems to climate change.

- Represent grassland types across environmental gradients in protected areas,
- Protect native-dominated communities as appropriate per system,
- Minimize fragmentation by land use changes and roads,
- Connectivity is the antithesis of fragmentation,
- Practice low-intensity, sustainable grazing practices,
- Prevent and control the spread of invasive species, including pathogens,
- Grassland restoration,
- Maintenance of natural fire regimes,
- Provision of buffer zones,
- Identify and protect functional groups and keystone species,
- Protect climatic refugees at multiple scales: It makes sense to identify past climatic refugees wherever possible and focus conservation efforts on these areas so they can again function as refugees during present and future periods of climate change.

4.6. Coastal Zones

Coastal areas are particularly vulnerable environments to climate change because they lie on the contact zone between atmosphere, land and sea. More than 50% of the world's population lives in coastal zones and it is expected to increase dramatically in the near future. Climate change and its consequences on the coastal zone can seriously affect the natural environment and coastal communities.

Iran is a coastal country that is surrounded by three main water bodies at its northern and southern borders. Total length of the Iranian coastlines is more than 3,500 km. The area is home to more than 10 million Iranians. Depending on the natural and socio-economic characteristics of the coastal areas, climate change can influence them to different extents.

The Caspian Sea in the north of Iran is a landlocked body of water while the country is connected to open seas via the Persian Gulf and the Oman Sea in the south. Precipitation on the Caspian coasts is quite different from the southern coasts. It is less than 200 mm to more than 2,000 mm annually in different parts of the Caspian coasts and less than 50mm/yr in the coastal area of the Persian Gulf and the Oman Sea. The northwestern flank of the Persian Gulf (i.e., on the Iranian side) is a river-dominated coast and progressively changes easterly to tidal dominated coasts where there are a few rivers. The Caspian Sea has virtually no tides but is strongly influenced by sea waves. The coast of the Oman Sea is more a wave-dominated coast on the Iranian side. The climate along the southern coasts is hot and dry except for the easternmost flank of the Oman Sea coast, which is affected by the Indian Ocean monsoon cycle.

The Caspian coast has a temperate and humid climate. These various natural features make for real differences in the socio-economic characteristics of the different coastal zones. The northern coast has a high density of population while it is low in the south. Agriculture and tourism are the primary domestic economic activities of the Caspian coast while people in the southern coasts rely on fishing, petroleum industries, trading and shipping.

4.6.1. Methodology

Considering the multidisciplinary nature of coastal and marine studies and the involvement of several governmental and private organizations in studying, exploitation and development of the coastal zones, our attempt focused on studies of extant materials, information gathering and interviews. We did not do any independent fieldwork in relation to this study but utilized the results of previous research and merged it in this report.

4.6.2. National Circumstances

4.6.2.1. The Caspian Sea

The length of the northern Iranian coastline is more than 800 km that is 18% of the total length of the Caspian coastlines. Annual precipitation is more than 2,000mm/yr in the westernmost of the area that gradually decreases eastward to less than 200mm/yr. The dominant climate in this area is subtropical.

The Caspian sea level is 27m below sea level. Sea level fluctuation (up to 340 mm/yr) is the most important characteristic of the Caspian Sea that changes seasonally, annually and over longer periods. There are a wide variety of morphological and geological characteristics along the Iranian Caspian coasts (e.g., bays, lagoons, rocky shores, sandy and gravelly beaches and mud flats). 62 perennial and ephemeral rivers discharge into the Caspian Sea from the Iranian coasts. The area of their catchment basin is more than 135,000 km^2. Annual discharge and sediment load of the rivers in natural conditions are 16 km^3 and 40 million tons, respectively, however, under

Table 4.17: Sedimentological and Morphological Attributes of Different Parts of the Caspian Coastline on Iranian Side

Position Name	Sea floor gradient (up to 10m depth)	Beach gradient (up to -20 isoline)	Dominant sediment type in the beaches	Dominant sediment type off the coastline
Astara	0.0018	0.03	Sand	Sand
Anzali	0.009	0.002	Sand	Sand
Dastak	0.008	0.002	Sand	Sand
Kalachay	0.005	0.01	Sand	Sand
Neshtaroud	0.007	0.08	Gravel	Sand
Nour	0.01	0.04	Gravel- Sand	Sand
Babolsar	0.008	0.002	Sand	Sand
Gorganroud	0.0007	0.0009	Silt- Clay	Silt- Clay

present conditions they have been reduced to around 10 km^3 and 30 million tons, respectively (Table 4.17).

Although the area of the coastal provinces of the Caspian Sea is less than 3.5% of Iran, more than 10% of the people live there, with half of them settled in the narrow plain of the coast. Population density decreases from 152 person/km^2 in the west coast to less than 71 person/km^2 in the east coast in accordance with precipitation rates. Agriculture, tourism and fisheries are the primary economic activities of the people that affect all other jobs in the region. Most of the economic activities are focused in a narrow coastal belt with a 10km width.

4.6.2.2. *The Persian Gulf*

The Persian Gulf is a marginal epicontinental sea of the Indian Ocean that lies in the south of Iran and is connected to the Oman Sea via the Strait of Hormoz at its extreme southeastern coastline. The average depth of the Persian Gulf is 35m and increases eastward up to 110m in the Strait of Hormoz. The length of the Iranian coastline in the Persian Gulf is more than 1,700 km. The coasts are predominantly tide-dominated but there are some wave-dominated and river-dominated parts also. The northwestern flank of the Persian Gulf is a river-dominated coast but the number of rivers and their discharge decreases eastward as there is no perennial river on the eastern flank of the Persian Gulf. The Iranian side of the Persian Gulf is mountainous and spreads northwest. When the mountains are far from the coastline, we can see widespread mud flats at the coasts.

The Persian Gulf is the hottest sea in the world. In summer the temperature reaches 50°C that in combination with strong winds increases the evaporation in the region. The average annual precipitation is less than 50mm/yr and the salinity of the water is higher than other open seas (more than 40 PSU). It is the habitat of coral reefs, mangroves, sea mammals and many other valued species. Mangroves are more concentrated in the northern coasts of the Strait of Hormoz and Naiband Bay while coral reefs are found extensively around the islands of the Persian Gulf.

More than 5.5 million people live in the Iranian coastal provinces of the Persian Gulf and 70% of them settle within a 100 km width of the coastal zone. Because of fresh water availability and vast productive coastal plains in the northwestern parts of the Persian Gulf, this region is one of the most important agricultural regions in Iran but the importance of agricultural activities decreases eastward where the importance of aquaculture activities increases. Fishing and petroleum related industries are other primary activities of this region. The Persian Gulf gives Iran access to the high seas. Hence the most important ports are to be found along the Persian Gulf coasts and make it possible to develop trading and tourism in this area. Tourism is mainly focused on Kish and Qeshm islands.

4.6.2.3. *The Oman Sea*

The Iranian coastline of the Oman Sea is more than 800 km long, with a very hot and arid climate. The coast is marked by a series of prominent headlands separated by low areas. The coast was uplifted during the late Quaternary age with a rate of 0.2-1.1mm/yr. So the coast is subjected to complex interrelationships of tectonics, coastal erosion, sediments and eustatic sea-level changes. The maximum width of the coastal plain is 30 km that can be classified in three main coastal types: 1) elongated sand dunes, 2) mud flats and 3) marine terraces. The shelf off the Makran coast is 10 to 40 km wide reaching a depth of 100m along its edge. There is no perennial stream in the coastal zone but ephemeral rivers of the region can carry large amounts of alluvium to the sea during the flash floods in the rainy season.

The mean temperature in January is 20°C and the maximum temperature in August is 47°C. Mean annual rainfall is less than 100 mm and the rainfall variability is extremely high. The tidal range is generally between 2 and 4 m increasing westward. Winds and currents are parallel to the coastline in accordance with the monsoon circulation. The northeast monsoon, with moderate winds, begins in October but is a main characteristic between November and

March, with maximum impact in December and January.

The southwest monsoon is longer and stronger. It begins in April and is very strong from June to September. Occasionally, tropical storms and cyclones occur usually during May–June and October–November and cross the west coast of the Arabian Sea but are fewer in the Oman Sea and along the Iranian coast. While the eastern side of the Oman Sea is influenced by the monsoon, the western side is subjected to the arid subtropical climate system. As a result, the modern climatic setting of the region lies at the transition between the Mediterranean winter rain domain, the subtropical desert belt and the inter-tropical convergence zone.

The 800 km long area of Iran's Oman Sea coast is host to a population of not more than 400,000. The population density is less than 9 persons/km^2. Chabahar is the most populated city with more than 250,000 people in the easternmost part of the area. Aquiculture (preponderantly shrimp farming), trading, shipping and fishing are the main activities of people in this region.

4.6.3. *The Status of Climate Change*

4.6.3.1. *The Caspian Sea*

The Caspian Sea, being a closed basin, demonstrates much higher rates of sea-level change (up to 340 mm/yr) than the oceans. It experienced a full sea-level cycle with a rise of 3m between 1929 and 1995. The sea-level fluctuation impacts the basin architecture, changes the coastal morphology, leads to forming new aquatic environments and forces living organisms to migrate from their old habitats and find new settlement places. In addition, the sea level oscillations can spread human induced pollutants into the marine and coastal environments. As the Caspian coast is the focal economic activity point in north of Iran and on the other hand is the most biologically productive area of the sea, any changes in sea level has a great influence on the region.

Based on recent findings, a slight increase of the Caspian Sea level is expected in the first half of the 21th century but due to a large variability of precipitation over the Volga River basin (the major input of the sea) a definitive statement concerning the future impact on sea level cannot be made with confidence at the moment. According to paleoclimatological studies and climatological simulations the range of sea level fluctuation is -25 to -30m.

4.6.3.2. *The Persian Gulf*

According to new findings, the average sea surface temperature of the Persian Gulf in some parts indicates a rise up to 2.5°c during the last two decades. It is predicted that the increasing trend of atmospheric and sea surface temperature will continue as precipitation decreases on the average of about 0.6mm/yr in the next 100 years. In 2007 a hot summer and cold winter were observed in the region that are unprecedented in the last 50 years. The Persian Gulf has recently experienced high frequency recurrences of temperature related coral bleaching. Sea level rises of about 2.34mm/yr to 4.5mm/yr (up to 0.88m in the next 100 years based on some scenarios) are expected to be a problem in some low-lying areas (like the northwest Persian Gulf) and the coral communities.

Based on a greenhouse emission scenario, temperature in the Persian Gulf region will increase but winds will weaken. This will result in reduced vertical mixing and increase layering of the water column. Sea level will rise by just less than 1m and will flood low-lying areas. Flooding of these areas remobilizes the fine sediments that create a wide turbidity envelope. Additionally, wide shallow areas over the flooded areas are subject to intense heating/cooling in summer/winter that coupled with strong evaporation, generates hyperpycnal density flows influencing the near shore sub-tidal. Since weaker winds lowers vertical mixing the density currents also support vertical layering of the water column with dense cold/hot water.

4.6.3.3. *The Oman Sea*

Tropical storms in the Indian Ocean are the primary factor for creating long waves in the Oman Sea. Their maximum speed and motion track, their durability and frequency are variable. The study of these storms reveal that their frequency and strength and the probability of leading them to the Iranian coasts have increased during the last 30 years as was witnessed by tropical storm Guno that hit the coasts in 2007. The increasing the strength and frequency of the storms in combination with the sparse vegetation of the area will enhance soil erosion and carry large amounts of alluvium to the Oman Sea during flash floods. The stronger waves will also add to coastal erosion in the predominantly rocky shores of the area.

The warm, saline bottom water of the Persian Gulf flows out of the gulf via the Strait of Hormuz into the Oman Sea, cascades over the shelf's edge and extends into the sea for a distance of nearly 1,700 km. The increasing salinity and temperature of the Persian Gulf water can thus influence the Oman Sea to some degree.

Based on some measurements the pH of rainwater over the region is alkaline during the summer monsoon and acidic during the winter monsoon. Winter monsoon precipitation is more influenced by anthropogenic sources coming from the Asian region towards the Persian Gulf and carry more pollutants like NO_3^- and SO_4^{2-} that acidify the precipitation.

4.6.4. Vulnerability Assessment

4.6.4.1. The Caspian Sea

Studies forecast a slight sea level rise in the Caspian Sea in the next decades. The rise, along with increasing temperature, will retard the sea's water circulation and consequently decrease the oxygen and nutrient exchange in the water column while increasing organic bottom matter. Higher temperature, decreasing precipitation plus human activities in the watershed will result in desertification in the eastern parts of the Caspian coastal area. River discharge reduction caused by the changing climate and continuing human activities will alter the hydrodynamics and sedimentological conditions of river mouths and augment coastal erosion and inundation (Table 4.18).

Long term sea level change in the Caspian Sea is controlled by three factors including: 1) natural elements such as precipitation and evaporation over the sea), 2) human induced stresses on climate change and a corresponding emission of greenhouse gases and 3) human activities in the Caspian catchment basin and exploitation of water resources, opening or closing the Kara Bogaz Gol inlet.

Natural sea level rise in the Caspian Sea is not dangerous for aquatics and their habitats but is very destructive for man-made structures in the fluctuation zone. During a

Table 4.18: The Impacts of Climate Change on Natural Coastal Features of the Caspian Sea

Valuable coastal features	Sensitivity to climate change impacts			The impact of climate change on the features
	Sea level Oscillation	Temperature oscillation	Precipitation Oscillation	
Sandy and gravelly beaches	✓		✓	Shoreline migration, changing the coastal morphology due to erosion/accumulation, desertification of coastal area and developing coastal sand dunes
Mud flats	✓		✓	Intense shoreline migration due to sea level fluctuation, desertification and developing salt pans
Coastal wetlands	✓	✓	✓	Morphological changes in coastal wetland especially migration of wetlands due to sea level fluctuations, desiccation of wetlands and developing conflagrations,
Water circulation	✓	✓		Changes in rate of water circulation due to sea level oscillation and consequently changes in biological primary product

sea level rise, the narrow Iranian coastal area and its population of more than 2000,000 plus important infrastructures along the coast like ports, harbors, power plants maritime industry structures and fish farming will be very vulnerable to such changes. Based on some scenarios a sea level rise will inundate more than 300 km^2 of the coastal area. In this situation damages are estimated to be in the range of USD 5b (Table 4.19).

4.6.4.2. The Persian Gulf and the Oman Sea

Long term sea level change in the Persian Gulf is not hazardous for the predominantly tide dominated coasts but when it is accompanied with increasing temperature and salinity, weakening the north wind and strengthening other wind currents, reduction of vertical mixing and increased layering of the water column—this combination will be especially dangerous for static target ecosystems. The Persian Gulf as a semi-enclosed body of water heavily influenced by human activities such as petroleum extraction and 15 years of war in the last 30 years has little capacity to accept increased environmental stress. This region is characterized by dust storms coming from the deserts of the west and southwest of the Persian Gulf that increases the suspended load of the water and its turbidity. Finally, increasing the strength and frequency of tropical storms in the Oman Sea can lead to storm surges and high waves that impact the coasts of the Oman Sea and the Strait of Hormoz (Table 4.20).

Sea level rise with an average rate of 2-3 mm/yr in the southern coasts is not so dangerous in and of itself because the environment experiences 2.5-4m tidal ranges whereas other climatic events such as increasing storm surges created by tropical storms can be very destructive. Some studies, conducted by the Iranian National Center for Oceanography (INCO) in collaboration with Ports and Maritime Organization (PMO) to model the wave regime of Iranian territorial waters and beyond, show that tropical storm recurrences and their strength have increased during the last decades. Clearly the rise in temperature is already apparent as seen in the bleaching of the coral reef in the Persian Gulf during the last decades.

The growing occurrence of algal blooms in the Persian Gulf is also related to environmental changes. The strength and frequency of dust storms have increased in the last decades in the Persian Gulf region and increased the suspended load of water and its turbidity. Decreasing precipitation and the consequent reduction of river discharges accompanied with direct human activities create conditions

Table 4.19: The Impacts of Climate Change on Man Made Coastal Structures of the Caspian Sea

Valuable coastal structures	Sensitivity to climate change impacts			The impact of climate change on the structures	Compatibility methods
	Sea level Oscillation	Temperature oscillation	Precipitation Oscillation		
Ports and harbors	✓			Sea level rise has more impacts on the structures than sea level fall.	Dredging in the case of sea level fall, building new coastal structures to protect existing structures.
Cities, towns and tourist centers	✓	✓	✓	Changes in temperature have some impacts on the populated area and especially saps tourism. Flash floods inundate the low lands and infect fresh waters. Sea level rise will inundate coastal structures, villas and homes.	Making coastal dams in populated areas, policy making and legislating laws to prevent people from building homes during fluctuation extremes.

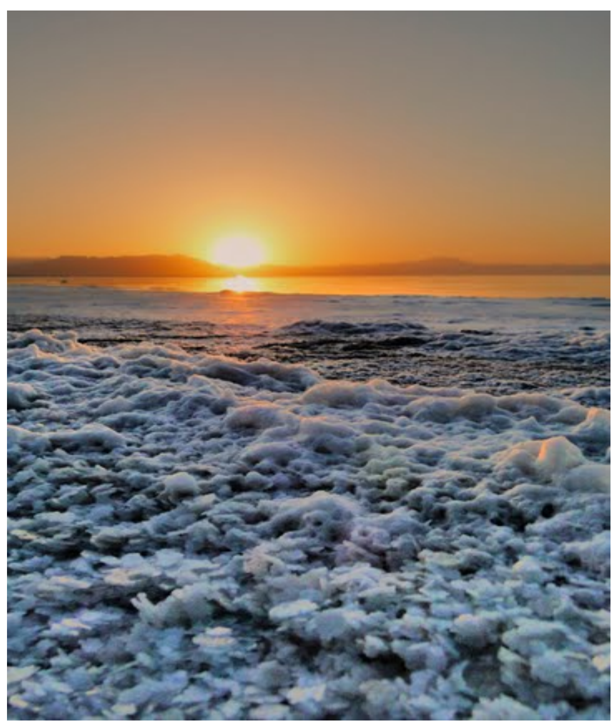
Table 4.20: The Impacts of Climate Change on Natural Coastal Features of the Persian Gulf and Oman Sea

Valuable coastal features	Sensitivity to climate change impacts			The impact of climate change on the features
	Sea level Oscillation	Temperature oscillation	Precipitation Oscillation	
Sandy beach	✓			The present rate of sea level rise has less effect on it. Other short time events such as storm surges and flash floods intensely impact it.
Rocky – gravelly shore	✓			Increasing the erosion due to increasing the strength and frequency of storms.
Mud flats	✓		✓	Intense shoreline migration due to sea level fluctuation, desertification and developing salt pans.
Estuary	✓	✓	✓	Morphological changes in coastal wetlands especially migration of wetlands due to sea level fluctuations, desiccation of wetlands and potential of developing conflagrations.
Coral reef	✓	✓		Changes in rate of water circulation due to sea level oscillation and consequently changes in biological primary product
Mangrove	✓	✓		Sea level rise can develop the mangroves towards the land. Changing in sediment load, salinity and temperature of water can intensely affect the mangrove ecosystem in the Persian Gulf.

for seawater intrusion into the coastal aquifers in the northwest flank of the Persian Gulf. Although there is no clear body of evidence to link these unusual conditions to global climate change, there does exist a logical connection to the observed climate extremes that deeper research may likely uncover. The environmental changes along with human activities define the Persian Gulf as a stressful environment for its organic life especially the coral reefs and mangrove forests.

4.6.4.3. Primary Stakeholders' Expectations

The coastal dwellers including fishermen, farmers and homeowners are the main stakeholders of the coastal areas. Moreover, investors, economic and other industrial actors including the governmental and private sectors are other prominent shareholders of the coasts. Any extreme changes in natural coastal conditions can directly influence them (Table 4.21). Some questions related to this influence can be answered at present but others need more investigation, legislation and policymaking. There are many unknown variables in relation to climate change consequences in the coastal area of Iran due to insufficient data and information but several impacts are observed in the region including a rise in temperature, increased recurrence of dust storms in the Persian Gulf region and a higher incidence of flash floods in the coastal area of the Oman Sea.



Drought and Its Impact: Salt Crystals in Urmia Lake, Weast Azerbaijan

4.6.5. Adaptation Programs

4.6.5.1. Monitoring

Monitoring programs are effective ways to control and follow up changes in the marine and coastal environments. In this environment, risk/hazard assessment and property damage mitigation are of primary concern and the monitoring programs should be reconciled with this purpose. Long-term monitoring projects should be initiated, but such studies often take years to provide useful information. Continuous observation of the environmental changes can provide a better understanding and accurate database for coastal managers to achieve an action plan for future changes.

In coastal areas determination and monitoring the historical shoreline position and the range of changes using different methods is essential to accurately characterize a coastal system (e.g., erosional or accretionary), and examination of its evolution through time. Some unique environments (e.g., coral communities and mangroves), because of their sensitivity to environmental changes, need more

Table 4.21: The Impacts of Climate Change on Man Made Coastal Structures of the Persian Gulf and Oman Sea

Valuable coastal structures	Sensitivity to climate change impacts			The impact of climate change on the structures	Compatibility methods
	Sea level Oscillation	Temperature oscillation	Precipitation Oscillation		
Ports and Coastal Infrastructures	✓	✓		It seems that the current rate of sea level rise in the Persian Gulf and Oman Sea is not so dangerous for the ports and infrastructures but changing the wind regime in the Persian Gulf and increasing the frequency and strength of tropical storms in Oman Sea and dust storms in the Persian Gulf can effectively impact the structures. The increasing of temperature in the region is harmful for developing the economy of the coastal area.	Strengthening the structures and considering the rate of future changes in building the structures.
Cities, towns and tourist centers	✓	✓	✓	The dust storms are a serious threat to the coastal cities in western half of the Persian Gulf. Decreasing precipitation and consequently desertification and mixing fresh and saline waters that is accelerated with sea level rise are other threats for the cities in southern coasts. Coral bleaching and coral death may lead to stagnation of tourism and related commercial activities.	Developing regional cooperation to stabilize sand dunes and extending the vegetation in the western deserts of the Persian Gulf. Developing a storm warning system for forecasting and sighting tropical storms.

detailed monitoring. The coral reefs of Iran are being monitored by the Iranian National Center for Oceanography (INCO) and Department of Environment (DOE) in the framework of GCRMN and ReefCheck international monitoring programs.

Sea level and climate monitoring is possible by means of coastal and oceanographic instrumental stations. Coastal monitoring stations should be twinned with the oceanographic monitoring stations network in order to define evolutionary patterns and evaluate the vulnerability to climatic change.

There are at least five climatologic and four synoptic weather stations plus four tide gauges and one buoy along the Caspian Sea coasts but there is a need to add at least two oceanographic stations to the network to achieve a better understanding of the changes. In the southern extended coasts of Iran, there are some 17 coastal weather stations, nine tide gauges and several buoys, but it is necessary to deploy at least three oceanographic stations for more comprehensive data collection.

It is obvious that regional and international cooperation is a key factor in studying and monitoring the coastal area and the broad question of marine environments. Currently Iran is involved in some international and regional programs such as CEP (Caspian Environment Program), ROPME, GCRMN and ReefCheck and it is recommended that it become involved in other programs such as GOOS, GOSUD and JGOFS.

4.6.5.2. Integrated Coastal Area Management

Integrated Coastal Zone/Area Management (ICZM, ICAM) promotes sustainable coastal development by adapting the use of natural resources to avoid serious damage to the environment. ICZM is a process that seeks to integrate different policies that have an effect on the coast whilst bringing together stakeholders to inform, support and implement these policies. Climate change scenarios are considered in coastal management plans with coastal defense strategies that are looking towards the management of long-term fluctuating coastal dynamics. The ICZM program is relatively new in Iran but it is a high priority item for all governmental coastal related organizations.

4.6.5.3. The Capacity of Coastal Area for Adaptation

Iran's coastal zones are characterized by a wide variety of environmental and socio-economic characteristics. Thus every region in the coastal area suffers its own problems. The importance of each segment depends entirely on our scientific information and knowledge about the environment. Our knowledge is our key to anticipate future stressors to coastal systems, design effective programs for coastal area protection and restoration, and predict the future evolution of coastal systems. The first step in extending an effective adaptation plan is developing a coastal classification scheme based on the natural and socio-economic properties of the coasts.

On the authority of earlier studies and classifications made in the Iranian coasts, the coral reef (e.g., Kish Island in the Persian Gulf), mangroves (e.g., north of the Strait of Hormoz) wetlands (e.g, northwest of the Persian Gulf, east and west of the Caspian Sea), bays (e.g., east and west of the Caspian Sea coastal area), estuaries (e.g., north of the Persian Gulf) and river mouths are more sensitive environments to climate change effects. This classification is based on our current level of knowledge while other coastal segments may be added to the above-mentioned regions by developing our understanding of coastal processes.

4.6.5.4. The Role of Capacity Building in Adaptation Plans

The initial focus in any adaptation plan should be identifying capacity building needs within each coastal region. Capacity building should target the needs of each coastal segment based on its natural and socio-economic characteristics but generally it is focused on training programs for inhabitants especially in monitoring, protection and restoration plans.

4.7. Human Health

Major climate change health related issues include malaria, leishmaniasis, cholera, diarrhea, air pollution and some natural disasters. Changes in temperature or precipitation lead to an increase in the number of malaria contractions, contamination of water resources and consequent outbreaks of water borne diseases plus the direct effect of heat-related stressors on human morbidity.

Drinking water health indicators and access to clean water are also health questions that may be affected by climate change. Air pollution is another health issue that is linked to heart attacks, respiratory diseases like asthma and lung cancer. Moreover, climate change may entail limited or reduced access to clean drinking water, thus indirectly affecting environmental and rehabilitation health indicators in different areas.

4.7.1. Methodology

This study was carried out in two phases. Phase I refers to the events of the years 1995 to 2005 with attention paid to the Historical Cohort study and Phase II forecasts the health problems associated with climate change based on predictions of LARS-WG model which may take place during the years 2010 to 2039.

4.7.1.1. First Phase

For the study of meteorological factors information was gleaned from 43 synoptic stations for every province from 1976-2005. The most significant indicators that are affected by temperature and precipitation include access to clean drinking water and the indicator of the drinking water's microbial quality.

In the epidemiologic study of the leishmaniasis disease, given that it is endemic in some of the country's provinces including Isfahan, Fars and Khuzestan, specific changes in the ecologic conditions for the host (a species of rodent that the disease agent grows and reproduces over its body) would lead to changes in outbreak levels of the disease at different times. An epidemic of this morbidity was witnessed in Isfahan Province in 2003; a number of measures to counter desertification including plantation of shrubs on the rim of the desert in the vicinity of some of Kashan Province's villages provided favorable conditions for the growth and reproduction of the main host and the intermediary host of leishmaniasis disease and as a result, an increase was observed in the number of persons bitten by the infected flies. Consequently, the instances of leishmaniasis that was earlier dormant and under control in these areas saw a sudden surge of more than 175%.

According to the Historical Cohort Study on Cholera conducted in the 41 branches of the country's medical sciences and healthcare services and treatment universities/colleges, the origin of the disease in some provinces stemmed from the travel of infected individuals from contaminated points in other provinces.

In addition, usage of fossil fuels in urban and industrial areas creates air pollution that has longstanding effects on human health and other consequences related to ecological changes.

4.7.1.2. Second Phase

This section deals with forecasts about how climate change will probably affect human health during the years 2010-2039. The question could be answered though by using the 2007 report of the Climatological Research Center based on LARS-WG model that was described above and which compares the climate change related health consequences in every province of the country that has taken place during the years 1995-2005. It is possible to assess health consequences related to climate change and the outbreak of diseases for every province in the country.

4.7.2. Vulnerability Assessment

4.7.2.1. Determination of Critical Points in Precipitation and Temperature Conditions

The level of decreased precipitation and the ensuing fall in access to clean drinking water appears significant as we take note that the affected provinces are supplying their own drinking water as well as some provinces in their vicinity.

This precipitation decline in the upcoming years will cause lower access to clean drinking water, followed by the outbreak of some water and food borne diseases (especially diarrhea and cholera).

During the years 2010–2039, the provinces of North Khorasan, East Azarbaijan, Gilan, West Azarbaijan, Markazi and Kurdistan will experience a maximum 1.4°C to a minimum 1°C increase of temperature, respectively. Based on the scenario presented by the World Health Organization, it was expected that a 1°C increase in mean annual temperature leads to an 8% surge in the number of hospital admissions for diarrhea while a 1°C increase in mean monthly temperature forecasts a 3% surge in contraction of diarrhea.

Taking the LARS-WG Model into consideration during the years 2010-2039 which was carried out during preparation of this Second National Communication, the vulnerability of the provinces of West Azarbaijan, Khorasan Razavi and Kurdistan towards temperature increase will be substantial. An increase of patients infected with chronic diarrhea is expected in the provincial villages during the forecast years.

In order to counter the problem, such measures as provision of healthy drinking water, promotion of health conditions, rehabilitation of villages and observance of individual health could help prevent the spread of the disease in the said areas and improve health indicators. The responsible bodies and officials would prove effective in preserving social health by providing easy access to clean drinking water, as well as in training and promotion of awareness among the rural population.

4.7.2.2. Climate Changes and Drinking Water Indicators

- Access to water resources: The drive could be realized by cooperation of the Ministry of Energy, which is responsible for the national supply and management of water resources, through such measures as capacity building and supplying of the needed water for different communities by constructing dams, exploitation of natural and artificial reserves, underground water resources and optimal use of the water cycle. The Meteorological Organization, Department of Environment, Ministry of the Interior and Ministry of Agricultural Jihad should synchronize their efforts in this regard.
- Purification and rehabilitation of water resources for drinking purposes largely implemented by the Ministry of Energy (Abfa Company) with small inputs from the Ministry of Health and Medical Education, as well as by private institutions.
- In terms of maintenance and protection of health of all social strata and the goals of the WMO, supply of clean water must be put on the agenda of all relevant sectors.

Accordingly, in light of the situation of the country in the years 1995–2005, it seems that the measures of the Kerman, Hormuzgan and southern Fars lag behind actual need and between 17% to 26% of these population groups suffer a lack of access to clean drinking water for villages covered by health programs. Based on the 2005 studies, among 6,812 villages covered by the Preliminary Healthcare System, 91% have access to drinking water and this indicates a gradual overall improvement in its availability.

4.7.2.3. Climate Change, Insect and Rodent-borne Diseases

Diseases like malaria and leishmaniasis are vector borne diseases that are transmittable through insects or rodents in Iran and based on the studies of the WMO, climate change may affect the spread of these illnesses. The endemic zones of malaria disease are largely located in Sistan and Baluchistan province, Hormuzgan and the sub-tropical part of Kerman Province. The majority of registered cases of the disease in other provinces originate with non-Iranian immigrants from neighboring countries like Afghanistan, Pakistan, Iraq, Armenia and Azerbaijan.

The spread of these diseases depends on the following factors:

- Arrival of infected individuals from neighboring countries and spread of disease inside the country,
- Provision of favorable conditions for the growth and reproduction of disease vectors.

A case in point can be seen in efforts to provide access to water resources as a measure against drought in Sistan and Baluchistan Province with the construction of Pishin dam in 1992. The accumulation of water behind the dam created a favorable environment for the reproduction of malaria transmitting mosquitoes and in the years 1991-1992 we witnessed the outbreak and spread of the disease throughout Sistan and Baluchistan province.

4.7.2.4. Climate Change and Endemic Water and Food-borne Diseases

Measures such as isolation and containment of sewage from water resources, preservation of water resources, improvement of the process of purification and decontamination of drinking water, provision of access to clean drinking water and observance of individual healthcare can allay the possibility of contraction of the disease to a minimum.

Moreover, when precipitation is high and rivers overflow their banks, because of a rise in the levels of underground water resources and sewage, there is a possibility of mixing and contamination of water resources with sewage, creating favorable conditions for the prevalence of such infectious diseases as diarrhea and cholera. Based on the results of the study during the years 1995–2005, the largest percentage of contraction of chronic diarrhea has been registered in the villages of Western Azarbaijan, Khuzestan, Sistan and Baluchistan, Lorestan, and Hormuzgan ranging from 16% - 22%; while the largest number of cases of cholera has been in the provinces of Khuzestan, Tehran, Sistan and Baluchistan, Qom, Golestan, Hamedan and Markazi ranging from 162 – 312 individuals in different provinces.

4.7.3. Adaptation Programmes

4.7.3.1. Current Programme

Based on international studies, the following are some health consequences related to climate change that are likely to emerge in Iran. In long term studies and epidemiologic evaluations, these results require a system of identification, protection, registration and follow-up as well as comprehensive protocols to be applied in 41 branches of the medical sciences and healthcare services and treatment universities in all rural and urban areas.

By establishing the protocols of the above diseases (Table 4.22) in the country's healthcare and treatment system, it is possible to specify how they are dispersed in the provinces and study how climate change would affect the distribution and prevalence patterns of diseases through meteorological phenomena. Based on the study conducted from 1995–2005, only a few of these morbidities had extensive information resources in all associated units that were touched on in the previous sections.

Compilation and application of the approved protocols require the bodies in charge to upgrade knowledge and train health workers in more than 24,000 healthcare centers located in the urban and rural areas of Iran. The goal could be realized through the following measures:

- To give regular and up-to-date training to health workers who serve in health and treatment centers,
- To upgrade clinical and paraclinical systems available in urban and rural areas in order to identify diseases in a timely fashion and provide health and treatment services,

Table 4.22: Health Consequences Related to Climate Changes in Iran

• All food-borne diseases	• Cataract
• All water-borne diseases	• Malnourishment
• All diseases transmittable through insects and rodents	• Heat stroke
• All post-disasters psychological and mental illnesses	• Cardiac and respiratory attacks related to air pollution
• Skin cancer	• Asthma

- To provide an information bank of diseases and the consequences of climate change in urban and rural areas separately for every province,
- To improve technical know-how in methods of identification, prevention, treatment and protection in order to prevent the prevalence of the said consequences and diseases in any area,
- To control immigrant workforce upon arrival in the country regarding communicable diseases and identification, treatment and protection of infected individuals upon arrival, application of laws and regulations related to quarantining through full recovery of individuals carrying pathogenic agents.

4.7.3.2. Future Programmes

The establishment of a comprehensive information network jointly by UNFCCC and WHO about the conditions of communicable diseases, particularly climate change related cases in the region, would help reduce the prevalence of emerging and remerging diseases and act as an alarm system for these countries. Some of the future programmes are listed in Table 4.23. Other items which would prove helpful to health studies in climate change namely the information related to meteorological factors were not available in the 1995–2005 research, which some of these points are listed in Table 4.23.

4.8. Biodiversity

Article 1 of the UNFCCC describes "adverse effects of climate change" as changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

Table 4.23: Future Programmes and Helpful Items To Study Health Related Climate Change

Future programs	Helpful items to health study
Quarantine legal and illegal immigrants & travelers for communicable diseases (malaria, cholera)	Rate of UV radiation
Raising awareness of political, economic and social leaders, as well as health workers, non-governmental organizations NGOs and other public sectors of the society	Number of sun hours
Provision of educational material for local communities, health workers and other workers and media as well as appropriate models regarding climate change and its effects on human health	Relative humidity
Establishment of a center for supporting health activities under climate change inside the region and international sharing of information and data resources and connecting meteorological centers to obtain forecasts of ecological changes, hazards and preparation for countering against crisis with the cooperation of UNFCCC, WMO and WHO	Number of days by high amount and short term in precipitation
Mainstreaming of special procedures and measures of climate change effects on health jointly by the WHO	Number of days with sandstorm events
Provision of technical support for the development of quick alarm systems related to diseases which are sensitive to climate changes in national policies (like the Fifth Development Plan)	Number of freezing days
Assessment of health consequences in all climate change projects taking into account the epidemiologic element of the existing diseases would prove highly effective in reducing the spread and prevalence of diseases and allow timely pre-emptive measures in epidemic conditions.	Number of days with heat waves and winds
Special attention to more vulnerable provinces and more accurate surveillance through family physician care and PHC	
Intervention and cooperation for sustainable development goals in some projects that will have a positive affect on climate change aspects for health purposes	
Health Impact Assessment (HIA) in all climate change projects and assistance to epidemic diseases	

Biodiversity as a dynamic and inseparable concept of ecosystems has been affected by climate change during the last century either directly or indirectly. Climate change directly impairs the functions of individual organisms (e.g. growth and behavior), modifies populations (e.g. size and age structure), ecosystem structure and functions (e.g. decomposition, nutrient cycling, water flows and species composition and species interactions) and the distribution of ecosystems within landscapes. Changes in disturbance regimes are good examples of the indirect impact of climate change on biodiversity. Like other countries around the globe, biodiversity is being impacted by climate change in Iran. Although no systematic research has been conducted to show the linkage between climate change and biodiversity in the country, biodiversity national documents and scattered conservation activities have addressed climate change as an influential factor on biodiversity.

4.8.1. Methodology

Given the existing limitations in resources, the primary tools and methods used for studying vulnerability and adaptation of biodiversity to climate change have been based on academic study, expert judgment and individual meetings and interviews.

Data on biodiversity resources in Iran seems to be broadly adequate. However, significant divergence is seen when reviewing different references. Since biodiversity is a multi-sectoral issue and different national bodies are responsible for various aspects of it, in order to avoid discrepancy, generally accepted data and information has been taken from national documents such as National Biodiversity Strategy and Action Plan (NBSAP).

In the study of the effect of climate change on biodiversity, climate data and scenarios have been taken directly from the first section of this chapter (Section 4.2).

In general, no holistic and systematic study has been conducted to explore climate change consequences in relation to biological resources in Iran. No linkage is established even at a high level of policy making between biodiversity and climate change. National Biodiversity Strategies and Action Plan is the most important national document regarding biodiversity conservation in the country. Although very limited, climate change has been addressed in the national biodiversity conservation action plan. This document proposed a comprehensive study to be accomplished and investigates inter-linkages of biological diversity and climate change in the country. I.R. Iran's Meteorological Organization (IRIMO) has been designated as the national coordinator to implement this activity while other relevant ministries and organizations are considered as cooperating bodies.

Although the Fourth National Development Plan (2004.2009) requested the government to implement the Biodiversity Conservation Action Plan, it seems that little action has been taken in this regard. The main reason for this might be lack of general awareness of the impact of climate change on biodiversity in the country. It has been verified through different interviews and meetings conducted in line with this study that many experts and managers don't acknowledge the role of this phenomenon vis-à-vis biodiversity. A majority of experts, managers and decision makers have limited knowledge on the matter.

Iran's second and third national reports to UNCBD (submitted in May 2001 and December 2005, respectively) confirm very limited actions were conducted in this regard. Despite the low general level of understanding, the issue is gradually receiving more attention especially from those who are working at the national level. All this clearly implies that nationally produced data is very limited and studying vulnerability of biological resources to climate change is limited to internationally produced data and information.

To study the vulnerability of biodiversity to climate change, analogue overlapping of biodiversity resources with zoning maps of different climatic features has been used. National Protected Area System has been considered as the main biodiversity distribution model across the country. Unique and important wildlife habitats and ecosystems e.g.

Hircanian forests, central sub-deserts (as the most important habitat for Asiatic cheetah and wild ass) have been considered as well.

4.8.2. National Circumstances

4.8.2.1. Biomes and Vegetation Regions

The combination of climate and topography in Iran has resulted in four main biomes. The following biomes are considered as general vegetation regions across the country:

- Irano-Touranian which covers arid and semi arid deserts, plains and mountains of central Iran,
- Zagrosian; which covers semi-arid Zagros Mountain range,
- Hyrcanian which covers semi-humid and humid Arasbaran and Hyrcanian mountains and Caspian plain,
- Khalijo-Ommanian encompasses dry southern coastal plains with high humidity.

4.8.2.2. Flora, Fauna and Natural Habitats

A large portion of Iran's territory is located in the Palaearctic realm and is considered as the center of origin for many commercially valuable plant species e.g. Medicago sativa or medicinal and aromatic herbs. The southwest has been characterized by Afro-tropical species, while the southeast has some species from the Indo-Malayan sub-tropical realm.

Iranian habitats support some 8,200 plants species of which 2,500 are endemic. Scientific evidence supports the presence of over 500 species of birds, 160 species of mammals and 164 species of reptiles (26 endemic species).

Wetlands and rivers are considered as inland water ecosystems. Investigations by the Department of Environment suggest that more than 100 big wetland sites are found nationwide. At this time 22 sites with a total area of 1,481,147 hectares are registered on the list of wetlands of international importance by the Ramsar Convention on Wetlands (Ramsar, 1971).

Wetlands are the most valuable ecosystems since they offer an abundance of ecological goods and services. Iran's wetlands play an important role in water balance and well being of the natural environment, wildlife and human beings given the fact that most of the climate is dry or semi-dry. Out of 22 registered internationally important wetland sites in Iran, seven are mismanaged and included in the Montreux Record that is "a record of Ramsar sites where changes in ecological character have occurred, are occurring or are likely to occur".

More than 3,450 permanent and seasonal rivers are extant in Iran. These rivers are categorized within six main watersheds and 37 sub-basins. Long time measurements suggest that the largest portion of annual water discharge is into the Persian Gulf and Caspian Sea respectively while other four watersheds produce less water in terms of quantity but not importance. Rivers are the natural habitat for aquatic species, small animals, birds and specialized flora. They offer important and valuable ecological services as well.

There are some 12 million hectares of forests and 8,900 hectares of mangroves along the Persian Gulf coasts. Iran's forests are classified into five main categories as follows (Figure 4.30):

- Caspian broadleaf deciduous forests; consist of a rather narrow green belt in northern Iran with a current area of about 1.9 million hectares,
- Arasbaran broadleaf deciduous forests; are in the northwest of the country. They support many endemic species in an area of 120,000 hectares,
- Zagros broadleaf deciduous forests; consists mainly of oak trees from three main species. With an area of 5.5 million hectares. Zagros forests are located in the west of Iran,
- Irano-Touranian evergreen Juniper forests; almost all high mountains of the country outside the deciduous forests used to be covered by Persian Juniper (Juniperus polycarpus). Optimistically

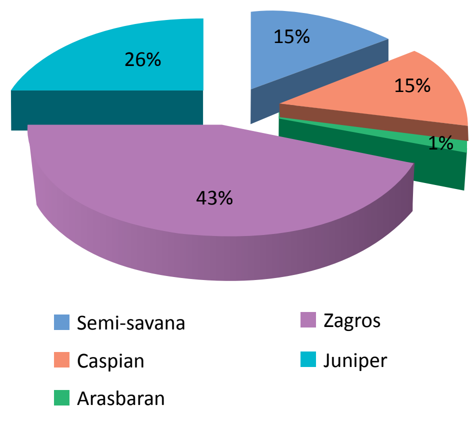


Figure 4.30: Forests of Iran

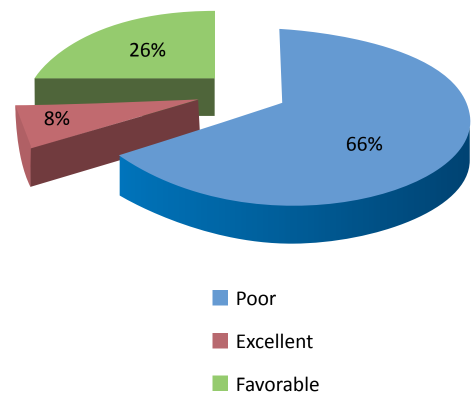


Figure 4.31: Rangelands of Iran

speaking, the area covered by this type of forest is about 500,000 hectares,

- Semi-savanna thorn forests; with an area of about 2 million hectares cover narrow bands in the west of the country and a wider belt in the south along the Persian Gulf and the Sea of Oman.

Rangelands cover some 55% of the total land area of the Country. While 8% out of 86.1 million hectares of Iran's rangelands are classified as excellent, 26% are favorable and 66% are classified as poor (Figure 4.31). Based on biomass production and grazing season, rangelands can be categorized as 1) summer rangelands; 2) winter rangelands; and 3) arid rangelands.

4.8.3. Vulnerability Assessment

4.8.3.1. Current Situation

Past changes in the global climate resulted in major shifts in species ranges and marked a reorganization of biological communities, landscapes and biomes. The present global biota was affected by fluctuating Pleistocene (last 1.8 million years), concentrations of atmospheric carbon dioxide, temperature, and precipitation, and coped through evolutionary changes, species plasticity, range movements, and/or the ability to survive in small patches of favorable habitat (refuges). These changes, which resulted in major shifts in species ranges and marked reorganization of biological communities, landscapes and biomes, occurred in a landscape that was not as fragmented as it is today and with little or no pressures from human activities. Anthropogenic habitat fragmentation has confined many species to relatively small areas within their previous ranges, with reduced genetic variability. Warming beyond the ceiling of temperatures reached during the Pleistocene will stress ecosystems and their biodiversity far beyond the levels imposed by the global climatic change that occurred in the recent evolutionary past.

The current levels of human impact on biodiversity are unprecedented, affecting the planet as a whole, and causing large-scale loss of biodiversity. Current rates and the magnitude of species extinction, related to human activities, far exceed normal background rates. Human activities have already resulted in loss of biodiversity and thus may have affected goods and services crucial for human welfare. The outstanding indirect underlying human causes include: demographic; economic; sociopolitical; scientific and technological; and cultural and religious factors. The primary direct human drivers (proximate causes or pressures) include: changes in local land use and land cover (the major historical change in land use has been the global increase in lands dedicated to agriculture and grazing); species introductions or removals; external inputs (e.g., fertilizers and pesticides); harvesting; air and water pollution; and climate change. The rate and magnitude of climate change induced by increased greenhouse gases emissions has and will continue to affect biodiversity either directly or in combination with the drivers mentioned above, and might outweigh them in the future. Biodiversity resources in Iran are currently under severe pressure due to unwise use of natural resources as well as unsustainable development measures at different levels.

The most important threatening factors to biodiversity are classified as follows:

- Over exploitation of water resources and unsustainable development of agricultural development plans resulting in water scarcity so that inland water ecosystems are not functioning in a sound manner,
- Over grazing and logging has reduced production of biomass in forests and rangelands of the country,
- Unsustainable land-use conversions creating large scale habitat degradation and fragmentation,
- Hunting and trapping practices have a direct negative impact on the population of wildlife and aquatics resulting in declining genetic resources,
- Extended use of fertilizers and pesticides caused severe poisoning and utrification of the environment and water bodies,
- Natural drought that strikes large areas of the country causing significant socio-economic and natural difficulties.

At present Iran is losing its biodiversity at an alarming rate. There is no convincing report on the existence of the two big mammals, i.e., Persian lion and Caspian tiger from their natural and endemic habitats during the last 50 years. Asiatic cheetah, Persian wild ass, Persian squirrel and three species of sea turtles are among critically endangered species and on the verge of extinction. No scientific study has been conducted to determine extinct plant species but according to scientific evidence many species are under severe threat.

All these imply a very vulnerable situation in terms of biological resources and socio-economic conditions since these are two heavily inter-linked issues.

Birds Migrate, But Aquatic Species?!, Zarivar Lake, Ilam Province

For a given ecosystem, functionally diverse communities are more likely to adapt to climate change and climate variability than impoverished ones. In addition, high genetic diversity within species appears to increase their long-term persistence. It must be stressed, however, that the effect of the nature and magnitude of genetic and species diversity on certain ecosystem processes is still little understood. The ability of ecosystems to either resist or return to their former state following a disturbance may also depend on given levels of functional diversity that unfortunately seems to be low in Iran. This can have important implications for the design of activities aimed at mitigating and adapting to climate change.

It must be kept in mind though that differentiating climate change impacts from other anthropologic factors and causes is very difficult since all have very complicated and complex functionalities, especially when they create synergy.

4.8.3.2. Future Situation

Generally speaking, Iran will experience a warmer and dryer climate during 2010-2039.

It means that water demand will increase when rainfall is more limited. It could influence the timing of reproduction of animal and plant species and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks. Some species may move pole-ward especially migratory species or upward in elevation from their current locations. It is very likely that many species are already vulnerable to extinction.

The livelihood of many endemic and local communities, in particular, will be adversely affected if climate and land-use change lead to losses in biodiversity. These communities are directly dependent on the products and services provided by the terrestrial, coastal and marine ecosystems, which they inhabit. Urban populations will be affected directly and/or indirectly as well.

- *Vulnerability to Change in Precipitation*

During 2010-2039 the average precipitation will decrease from 3% to 8%. This decrease will mainly occur in winter. It will result in less snowfall and less snow pack consequently. Water resources will decrease then and water scarcity threatens biological resources. Spatial deviation of precipitation suggests that huge portions of the Alborz and Zagros mountains will largely be affected and will result in less biomass and quality of forest and rangelands. Since the main portion of water supply of Iran is produced in these two mountain ranges, surface and ground water resources will be stressed. Many wetlands and other inland water ecosystems will be affected negatively which could lead to significant decrease in wildlife population.

- *Vulnerability to Heavy Rainfalls*

As projected, the threshold for heavy and very heavy rainfall will increase. It is estimated that for heavy rainfall it will increase from 210mm to 237mm and for very heavy rainfall from 273mm to 378.8mm. It means that the number of floods will increase during 2010-2039. Heavy soil erosion and socio-economic catastrophes are expected.

- *Vulnerability to Change in Mean, Maximum and Minimum Temperatures*

Mean temperature will increase in general during 2010-2039. This increase will be seen more sharply in winter (0.7°C) and autumn (0.6°C). The same pattern is seen in predictions of maximum and minimum temperatures. It reveals that wildlife species will shift to upper elevations to adapt themselves with this increase. It will cause a change in the habitat and behavior as well as limitation of territories and ecological niches. Temperature increase will result in shorter winters and early spring that will cause interruption in the reproduction schedule of animal and plant species. Spatial zoning of temperature rise suggests that in the northwest, a large area in the west and southwest will face the highest increase in mean temperature. It will occur is small spots of the northeast and southeast. Increase of water demand in these areas is a definite consequence that could especially affect the Urumiyeh Basin that is currently facing a crisis due to mismanagement of water resources. Coastal wetlands of the south are also susceptible to damage as well.

- *Vulnerability to Change in the Number of Hot Days*

The number of hot days (days with maximum temperature over 30°C) will increase. When that occurs water stress will be very likely in plant and animal species. Temperatures over 30°C may also be beyond the tolerance range of some species. Almost the whole country will experience an increase in hot days but it will be more pronounced in the southeast, northwest and northeast.

- *Vulnerability to Change in the Number of Frost Days*

The number of frost days (days with minimum temperature below 0°C) will decrease nearly nationwide and the country will experience this decrease but the northwest, south and southwest and northeast are more exposed to this phenomenon. Agro-ecosystems are in some ways dependent on frost days in winter. When the temperature falls below 0°C, many pests and diseases are destroyed while seeds, roots and other parts of plants will remain intact and safe in the next year.

- *Vulnerability to Change in the Number of Wet and Dry Days*

A day is considered wet when the amount of precipitation is more than 0.1mm, while in a dry day recorded precipitation is less than 0.1mm. The number of wet days will decrease almost nationwide except for limited areas of the northwest and the south and more prominently in the west. The number of dry days will increase and this rise will be more significant in the west and southeast. All this reveals a general deficit of rainfalls in the west and southeast that will affect valuable habitats of the western forests, southeastern rivers and wetlands. The oak forests of the Zagros range, Mesopotamian marshlands, Hamoun wetlands complex and the Iranian crocodile are among the most threatened species and ecosystems.

4.9. Energy Sector

Changes in regional temperature and precipitation patterns may have significant implications for the existing and future power system infrastructure. Weather and climate may affect all major aspects of the electric power sector, including thermal power plants, hydropower, solar and wind energies, transmission and distribution systems and end-user demand for power. A new study of the impact of climate change on the power and energy sector was not carried out during the course of the SNC as the estimates of the impacts and adaptation measures were made in this sector in the Initial National Communication. For more information on the vulnerability of energy sector as result of climate change and also adaption policies were explained very detail in Iran's Initial National Communication to UNFCCC.

4.10. Impact of Response Measures

4.10.1. Introduction and Objectives

The members of the Organization of Petroleum Exporting Countries (OPEC) continue to voice their concerns about the adverse impact of the implementation of response measures in reducing greenhouse gas emission on the oil exporting countries. Referring to Article 4.8 of UNCCC, OPEC is of the opinion that the agreed reduction targets will lead to a significant reduction of revenue from petroleum exports, with the result that OPEC countries will be unfairly affected by measures proposed to mitigate global climate change.

The current study, aims to provide quantitative information on the impact of global climate change abatement policies generally on the revenue of OPEC countries and especially on Iran's economy as a member of OPEC. The outcome of this study shows that the implementation of response measures under the Kyoto Protocol will be reduced demand for fossil fuels and a subsequent decline in world oil market price.

In Iran's economy, crude oil and natural gas are the outstanding sources of total government income. In this study, to estimate the impact of response measures by Annex B Countries of the Kyoto Protocol on Iran's economy, a multivariable econometrics model was used. In this model the total private consumption, government expenditure, total individual investment and trade balance were introduced as independent variables and the Gross Domestic Product (GDP) was used as the dependent variable.

4.10.2. Brief Description of Results of Study

Table 4.24 outlines the economic situation of OPEC countries in terms of GDP, GDP per capita, GDP per capita growth rate, inflation rate and the balance of current payments. Table 4.25 shows the share of oil revenue in the export income of OPEC members that indicates the relationship of OPEC countries' economies with oil revenues.

For estimating the impact of response measures on Iran's economy, oil revenue is considered as a exogenous factor which affects all economic indicators. For this purpose the impact of fluctuation on macro-economic indicators was assessed in two following scenarios:

- Scenario Business-as-Usual (BAU): The oil revenues will continued with current pattern,

- Scenario 1: 5% decline in Iran's oil revenues as a result of Kyoto Protocol Annex B response measures,

- Scenario 2: 10% decline in Iran's oil revenues as a result of Kyoto Protocol Annex B response measures.
The results are shown in Figures 4.32 and 4.33.

As indicated in the figures, the reduction in oil revenues may cause a decline in the country's economic indicators like the per capita income, living standard and welfare, which shows that the implementation of the Kyoto Protocol is not consistent with Millennium Development Goals (MDG) in OPEC countries. Therefore, for compensation of the negative impact of response measures on OPEC countries, the financial and technical assistance that emphasized on Article

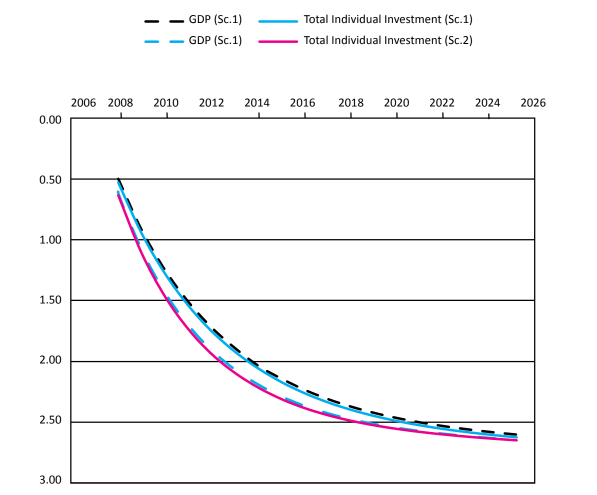


Figure 4.32: Estimate of the Effect of Oil Price Decline on GDP and Individual Investment (%)

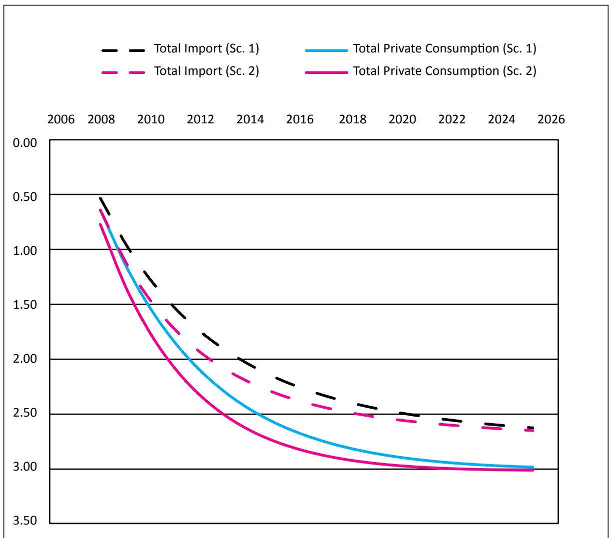


Figure 4.33: Estimate of the Effect of Oil Price Decline on Import and Private Consumption (%)

Table 4.24: The Economic Situation of OPEC Countries

Country	GDP in current price 2004 (Million $)	GDP per capita 2004 ($)	GDP per capita growth rate of 1990-2002 (%)	Inflation rate of 2004 (%)	Balance of current payment 2004 (Million $)
Algeria	84,158	2,623	0.3	5.4	-2,325
Indonesia	255,722	1,187	2.1	6.5	-50
Iran	168,971	2,480	2.2	15.6	2,816
Iraq	23,000	891	-	-	2,988
Kuwait	51,804	19,587	-1.7	1.7	4,561
Libya	29,027	5,013	-	2.1	2,159
Nigeria	71,326	549	-0.3	15.8	-1,016
Qatar	28,451	45,953	-	3.5	585
Saudi Arabia	248,813	10,677	-0.6	2.5	11,991
UAE	103,215	32,235	-	3.4	1,886
Venezuela	106,120	4,050	-1.0	23.7	-3,179
OPEC	1,170,607	2,196	-	-	20,416

Table 4.25: Share of Oil Revenue in Total Export Income of OPEC Members in 2003

Country	Total export (Million $)	Oil export (Million $)	Share oil in total export (%)
Algeria	24105	16476	68
Indonesia	62631	9685	15
Iran	33899	26124	77
Iraq	7587	7519	99
Kuwait	20287	18780	92
Libya	14344	13567	94
Nigeria	24047	22184	92
Qatar	121613	8814	70
Saudi Arabia	92029	84908	92
UAE	56833	25153	44
Venezuela	25800	21838	84
OPEC	374175	255047	68

Source: OPEC Bulletin 2003

4.8 – 4.10 of the Convention and 3.14 of Kyoto Protocol by developed nations is crucial.

4.10.3. Conclusion

As a result of 5% reduction in oil income (Scenario 1) an average decrease of 1.12% per year occurs in GDP which will adversely affects Total Private Consumption, Total Individual Investment and Total Imports by a decrease rate of 2.49, 2.09 and 2.12% per year, respectively.

By considering a 10% reduction in oil income (Scenario 2) the indicators show a lower living standard in the country. In this scenario, an average of 2.33% decrease in GDP occurs which will adversely affect Total Private Consumption, Total Individual Investment and Total Imports by a decrease rate of 2.63, 2.23 and 2.25% per year, respectively. It should be noted that the effect of oil income reduction magnifies when considering the population growth rate and therefore further decrease of per capita income and other welfare indicators.

Chapter 5: Other Information

5.1. Introduction

This chapter contains information on the Research and Systematic Observation as it relates to the Global Climate Observation System (GCOS), Climate Change Education (Article 6 of the Convention) and Technology Needs Assessment (TNA). These issues were not covered in Iran's Initial National Communication (INC) that was submitted to UNFCCC in March 2003. Although a preliminary study on GCOS and TNA were carried out during Phase II of the INC, those studies were not reported, rather during preparation of the SNC these issues were discussed in greater detail, a summary of which is reported herein.

5.2. Global Climate Observation System

5.2.1. General Approach to Systematic Observation

5.2.1.1. Introduction

Iranian Meteorological Organization was established as an independent entity in 1958 and has evolved into the present-day Islamic Republic of Iran Meteorological Organization (IRIMO). The IRIMO is the national lead institution for all external and internal issues and projects regarding weather, climate, water resources and related environmental issues.

Figure 5.1: IRIMO's Synoptic Stations Network

5.2.1.1.1. The National Weather and Climate Monitoring System (National Program)

As is seen in Table 5.1, the total number of IRIMO synoptic stations is 320, and the network has an average density of one synoptic station per 12,200 km^2. Figure 5.1 shows the distribution of these facilities in Iran.

These stations are categorized as the Regional Basic Synoptic Network (RBSN-SYNOP), (RBSN-CLIMAT) and (RBSN-TEMP) which observe 33 meteorological parameters. About 59 of the synoptic stations are located in airports and termed Aeronautical Stations. In these stations in addition to standard synoptic observations, parameters that are normally applied to air traffic control are being observed.

The total number of IRIMO rain gauge stations is 2,738. In addition, the Ministry of Energy, which is responsible for water resources management in Iran, operates a separate rain gauge network consisting of 2,775 stations (1,339 rain gauge stations, 675 evaporation gauge stations and 761 snow gauge stations).

In climatic stations all meteorological parameters are being measured, except the patterns of prevailing pressure (Table 5.1).

IRIMO also operates 30 agro meteorological stations. Crop growth and soil moisture at

Table 5.1: Meteorological Observation Networks

Type of station	No. Of station	Remarks
SYNOPTIC RBSN - SYNOP RBSN- CLIMAT RBSN - TEMP	324 78 78 10	The network gives an average density of a synoptic station per 12,200 km_2.
Upper - air Radiosond Pilot Balloons	16 15 1	
Weather radar	5	
AWS	150	
Agro meteorology	30	
Climatology	253	
Rain Gauge	2,738	
Aeronautical	60	Synoptic Stations within Airports
Evaporation	220	
Marine meteorology VOS Buoys Ship Coastal Station	 2 5 1 13	The Ports and Shipping Organization have three buoys
Satellite receiver	1	Located in Tehran - Mehrabad and installed in 1992
GAW Ozone	1 1	Unactive Active
Others Radiation Station Mountain Station	 49 1	76 Actiongraph

RBSN: Regional Basic Synoptic Network
AWS: Automatic Weather Station
VOS: Voluntary Observatory Ship
GAW: Global Atmospheric Watch
BAPMON: Background Air Pollution Monitoring Network (5).

Sources: IRIMO

four to five levels down to the depth of 70 cm are being measured in these stations as well as climate variables. These procedures are being carried out approximately 20 times a year before and after irrigation, and after rainfall except in winter. In marine meteorological stations the following parameters are measured: height and period of waves, seawater surface temperature, surface current velocity, surface current direction, seawater surface conductivity, wind direction, wind velocity, air pressure, air temperature, directional wave data and CTD profiles.

5.2.1.1.2. MITD Project

The Government approved to grant IRIMO to undertake a major modernization program after 2003 when it launched the extensive and ambitious project known as the Modernization and Information Technology Development (MITD) which seeks to upgrade all technical and human components of the organization to meet the most exacting global standards and provide vastly improved services to the user community including governmental authorities, general public, agriculture and industry. Table 5.2 shows the work plan of the modernization program.

This project addresses all components of the organization, and aims at a significant advance of IRIMO's facilities in all fields:

- Observation,
- Telecommunications and information systems,
- Forecasting and climatology,
- Services to end-users and main sectors of activity (agriculture and fishing, industry),
- Research and training with special emphasis on Numerical Weather Prediction (NWP) oceanographic modeling and pollution.

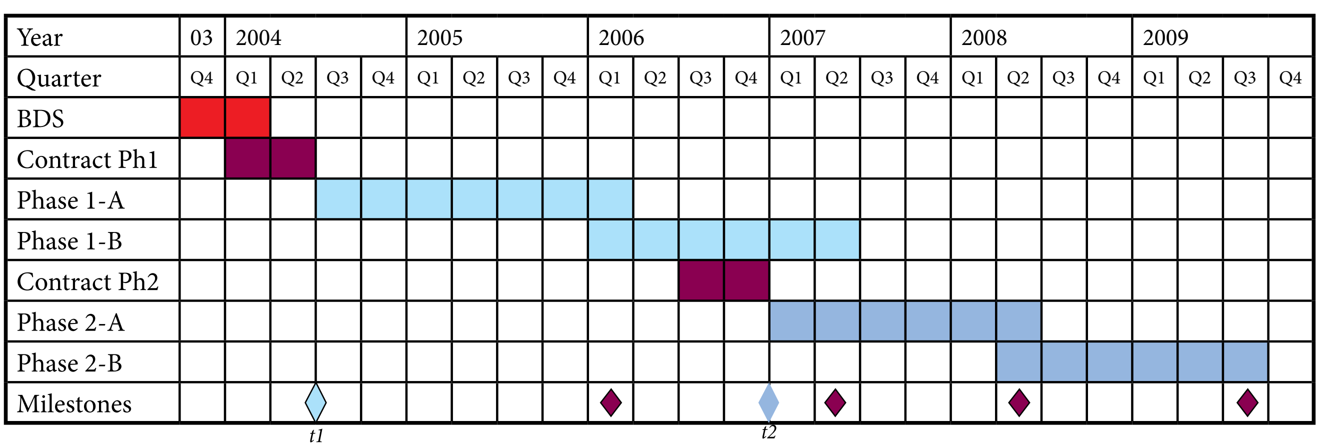
The project covers nearly all fields mentioned in the IRIMO Strategic Guidelines.

After a preliminary phase in summer 2003, IRIMO decided to request a full Basic Design Study (BDS) work from Meteo France International (MFI) in order to obtain a preliminary design study and the technical description of a fully integrated solution that could be implemented during the next national Five Year Development Plan (FYDP).

5.2.1.1.3. IRIMO Marine Station Network Development

One of IRIMO's agenda priorities is the promotion of marine forecasting in the south and north coasts of Iran to insure improved safety for marine travel. To do this it was decided that the available stations and network were to be markedly improved and new stations established to achieve comprehensive marine stations network coverage. Nine coastal and two marine stations are operating now with three coastal and three marine stations scheduled to be installed.

Table 5.2: General MITD Schedule



5.2.1.2. Meteorological and atmospheric observation

There are three main monitoring or observation systems for meteorological and atmospheric observation: Ozone Monitoring Stations, two IRIMO Space Based Sub-Systems and a IRIMO Weather Radar Network, the details of which are listed in Table 5.3.

5.2.1.3. Oceanographic Observations

Iran is surrounded by three main water bodies including the Caspian Sea in the north, Persian Gulf and the Gulf of Oman in the south with a total coastline length in the north and south of the country of more than 3,700 km.

The vastness and complexity of the marine environment both in the northern and southern sectors, from fragile coastal systems running across extensive Exclusive Economic Zones (EEZ) to the high seas, poses considerable challenges for sustainable development. It requires massive and cross-referenced data sets and information along with specialized collection and monitoring systems. As oceanography is a multi-disciplinary field, several different organizations are responsible to collect the data and monitor the marine environment related to their field of expertise. The most important organizations involved in data collection and monitoring of the marine environments are listed in Table 5.4 with other related details:

Of the 22 stations of IRIMO, 11 stations are in the Persian Gulf, seven in the Caspian Sea, two in the Gulf of Oman and two in the Strait of Hormuz.

IRIMO offers all data types including synoptic and climate data to its clients through the Internet as a free public service. Clients can easily connect to the following address and download their request: http://www.weather.ir/farsi/statistics

NCC offers 65 stations that provide tide prediction information for the southerly water bodies at: http://www.iranhydrography.org/

The data of oceanographic mesurments are disseminated by means of hardcopy of cruise

Table 5.3: Specifics of Meteorological and Atmospheric Observation Stations

	Station name	Location	Specification	Type/ cycle	Description
Ozone Monitoring Station	Firoozkooh Station, 1995	52˚ 34´E and 35˚ 43´N, 2987m	Air pollution station	GAW/ 2 per month	Execute rain analysis, not operating as GAW station beacuse of some technical problems and operates as a synoptic station
	Esfahan Station, 1994	51˚ 27E and 32˚ 47N, 1550 m			Data measured in this station is transmitted to World Ozone and Ultraviolet Data Center (WOUDE) in Toronto, Canada
Space Based Sub-System	1992	Receives MeteoSAT 7 in three channels and MeteoSAT 8 (MSG) in twelve channels		Space based/ 1 per hour	Partly unoperational (technical problems), connected to UK, France, Italy, forecasting center
Weather Radar Network	Khuzestan * East-Azarbayjan Tehran Mazandaran Kermanshah				Project started in 2003
*We still have one radar for installation in phase one, it is to be installed in Bushehr. In the second phase IRIMO intends to install six more radars in the country.					

reports and data discs. This information is available only through the chief scientists of the cruises and at present there is no central database for these findings.

The NCC is responsible for tide gauges. At present 10 tide gauges under NCC supervision are operational in Iran's northern and southern waters. These include one tide gauge in the Caspian Sea, two gauges in the Gulf of Oman and seven gauges in the Strait of Hormuz and the Persian Gulf. The GLOSS data center has been provided data from four tide gauges by NCC. In addition, the information is available through the NCC website.

IRIMO is responsible for 22 marine weather stations along the coastal areas of Iran. They have a close relationship with the WMO and NCDC and the data is available through their website[1] . IRIMO is not yet involved in the GOOS program. The organization does however plan to launch a ship for marine weather research by the end of 2010.

At present INCO develops its own facilities and is in the process of deploying three deep-water mooring buoys in the Gulf of Oman and the Caspian Sea. Details are listed in Table 5.4. In summary the marine related organizations in Iran remain largely un-integrated in their oceanographic data collection efforts related to there specific needs as described above.

5.2.1.3.1. Capacity Building

To build the required capacity for oceanographic data collection and management in the country, INCO has undertaken two programs as follow:

- Preparation of instruments for oceanographic data collection and,
- Organizing national and regional workshops and training courses.

5.2.1.3.2. Barriers to Data Exchange

The lack of an integrated oceanographic data collection program in Iran creates obvious limitations and discontinuity in the collected

Table 5.4: Different Oceanographic Data Collection Methods Used by Marine Organizations in Iran

Organization	Space based observing programs	Marine station based observing programs	Marine cruises observing programs	Number of stations	Field
IRIMO	X	X	-	22	*
PMO	-	X	-	3	Physical oceanography, meteorology and sedimentology
NCC	-	X	X	10	Tide gauge, nautical charts
IFO	-	-	X		Hydrochemical, physical and biological data
DOE	-	-	X	5	*
INCO	X	X	X		Oceanography, marine biology, marine chemistry and marine geology
NGO	X	-	X		Large scale maps and charts
ISA	X	-	-		*
GSI	-	-	X		Geochemical and hydrochemistry Atlas of the Iranian water territories
MOE	-	X	X		*

** Not determined.*

1- www.ncdc.noaa.gov

oceanographic data. Accordingly, to fulfill the present gaps in the current oceanographic observation system, the Iranian National Center for Oceanography (INCO) has prepared an integrated program for collection and management of oceanographic data as well as for capacity building.

As mentioned in Section 1.2, different organizations in the country are involved with the compilation of oceanographic data but the exchange and accessibility of information remains very limited due to various problems including:

- Uncoordinated data collecting activities of the marine related organizations in the country,
- Lack of copyright for the organization who has collected the data,
- Non-existence of a dedicated program format for data exchange between the organizations,
- Uncertainty in the accuracy of the collected data,
- The potential benefits of a data exchange program does not satisfy the organizations who own the data,
- Lack of a legal code for the exchange of data that would compel the organizations to comply according to law.

Easy access and dissemination of existing oceanographic archives in the different marine related organizations is the outstanding problem limiting data accessibility in the country. To overcome this insufficiency in 2002, INCO created an integrated program to build up the Iranian marine meta-data directory from all available oceanographic data that was collected by various organizations in the course of their activities.

5.2.1.4. Hydrometeorology Observations

The country's hydro-climate network was established in 1946, coinciding with the establishment of the Independent Irrigation Agency for Dam and Irrigation Affairs. The first measurements were undertaken on the Jajrood, Gholpayegan and Lar rivers. The network has been gradually expanded so that at present it comprises of 2,048 facilities with advanced recording rain gauge stations accounting for about 1/5 of the total of such stations, 526 storage rain gauges, 237 snow survey stations, 567 evaporation monitoring stations, 1,019 hydrometer stations (875 silt recording stations, 880 for water quality), 9,540 observation wells and 8,199 selective resources (5,898 selective wells, 793 springs, 1,508 qanats or subterranean irrigation channels). Tables 5.5 to 5.7 outline the characteristics of the hydrological network.

5.2.1.4.1. Future programs

Future programs for capacity building of GCOS consist of the following items:

- Completion of studies on:
  - Updating relevant data and information,

Table 5.5: Atmospheric Observing Systems for Climate of the Land Surface by the Ministry of Energy

Systems	Climate Parameters (Temp. Precip. Etc.)	Total no. of Stations	Stations Saved in Database	Long-term Data Stations (up to 2005)
Stations useful for national climate monitoring	Temperature	709	120	700
	Cloud amount/height/type		120	700
	Humidity	709	120	700
	Precipitation (liquid)	2294	1840	1500
	Precipitation (Solid)	237	237	250
	Radiation	709	120	700
	Sunshine	709		700
	Wind speed and direction	709	120	700

- Ground water resources data collection,
- Development and completion of observation wells network with up to 16,000 boreholes,
- Drilling 300 exploration wells,
- Drilling 8,500 observation wells,
- Annual review of water resources data and information.

- Continuation of preparing the Water Resources Atlas of Iran on the scale of 1: 250,000,
- Establish GIS system, completion, maintaining and updating water resources data bank,
- Development of flood warning network on watershed basins.

With respect to the costs of the water resources data base information, it is necessary to allocate adequate financial resources for learning advanced technology and also to train manpower to increase the quality and the quantity of data base information. Hence, formulating of national action plans also must address the following issues:

- Establishment of Regional Hydrological Forecasting Center (RHFC),
- Research on land surface climate and water resources,
- Exchange of data and results,
- Establishment of integrating land, water and other relevant information database.

Table 5.6: Terrestrial Observing Systems for Hydrology

Warning systems useful for national climate monitoring	Total no. of Stations	Climatic characterizing of data			Time series No. of stations/platforms		Water quality data processing	Stations Saved in Database	Long-term data stations (up to 2005)
		Fully	Partly	No	30-50y	50-100y	Fully		
River discharge (Streamflow Gauges)	1414	F			367	14	F	1000	1000
Snow depth	237		P				F	237	250
Water quality of rivers	800			N	402	1		1000	1000
Ground water storage	8,199		P		3850			4000	10,000
Ground water level	9,540	F			3000		F		10,000

Table 5.7: Hydrometeorological Stations of the Country

Type of stetions	Normal rain gauge	Hydrometeorological station	Hydrometric station	Sediment sampling station	Snow survey	Storage rain gauge	Recorder rain gauge	Water quality sampling station	Observation wells	Selected resources
Total	3,548	1,134	2,038	1,750	474	1,052	548	1,760	19,080	16,398

5.2.1.4.2. Barriers to Data Collection and Exchange

The record of data and information in the past years indicates that the network not only is defective in design but also has elemental difficulties in primary processing and operation. These three important elements, i.e. network, operation and primary processing of the system are deeply interrelated, with deficiency in each element making it impossible to access accurate and reliable data. These difficulties may be classified in two relevant groups as follows:

- *Data collection*
    - Lack of careful and continuous supervision over data collection,
    - Nonexistence of an appropriate telemetric measurement system for collecting data from base stations,
    - Lack of provision, preservation and uniformity of the hydrometeorology network's measurement equipment (including calibration and repairing),
    - Lack of consistency in support from utility sectors, financial limitations of organization and station vandalism by human or natural factors,
    - Restriction of Iranian meteorology organization due to expensive cost of meteorological data collection.
- *Design and structure of hydroclimatology network*
    - Non-compatability of the station's equipment,
    - Low density of stations,
    - Absence of warning and telemetric systems in the present hydroclimatology networks,
    - Insufficient control stations in the network data (representative basin),
    - Coding and classification of watershed basins are not compatible to international system,
    - The frequent establishment or closing of the stations without any specific criteria,
    - Absence of coordination among the relevant data collecting centers in setting and operation of hydroclimatology installations,
    - Network operation problems,
    - Lack of standard instructions for observing and collecting raw data,
    - Insufficient training for observers and operators towards the importance of their responsibilities,
    - Lack of vehicles for fast access to important stations,
    - Data exchange problems,
    - Lack of uniform format of data collection, data storage and data processing and dissemination.
    - Variations in standardization and quality control of data.

Considering the importance and value of water resources data base information, it is necessary to allocate adequate financial resources for acquiring advanced technology and for training the required manpower. Appropriate actions to increase the quality and the quantity of data base information are necessary.

5.2.1.5. Terrestrial Observations

The terrestrial observations for climate change include measurement of the properties and attributes that control the biophysical and chemical processes affecting climate. These are indicators of climate change. A number of observations in agriculture fall in these categories and there are needs for improved terrestrial observation for most important parameters envisaged in the agricultural related issues.

In Iran, like other developing countries, terrestrial observations, especially in the agricultural sector, are not developed as atmospheric networks. The terrain changes related to climate change, like changes in cultivatable area, soil degradation, land use and land use change, afforestation, deforestation, carbon flux and carbon fixing in the vegetative cover and soil have become increasingly important given the need of UNFCCC for data on terrestrial carbon sources and sinks in the global carbon cycle.

The agricultural observations have been mostly surface based. Moreover, monitoring of the agriculture resource base by traditional methods is generally costly, time consuming, laborious and as a large-scale undertaking practically impossible. Therefore, satellite and space–based observations in conjunction with the in-situ observations and ground checks are practical sources of measurement that have to be developed and used in the country.

The dynamics of the terrestrial ecosystem is largely dependent on interaction between a number of biochemical cycles, particularly the carbon cycle, nutrient cycle and hydrological cycle. Terrestrial ecological systems, in which carbon is retained in the biomass, decomposing organic matter and soil play an important role. Carbon is naturally exchanged between the systems and the atmosphere through photosynthesis, respiration, decomposition and combustion. Human activities change carbon stocks in the pools and exchange between them and the atmosphere through land use and land use change and forestry.

The state of land cover and land use change are important environmental variables identified by the Terrestrial Observation Panel for Climate (TOPC). Accordingly, the status of current networks in Iran can be peresented as follows:

- ***Agricultural soils***

Soil surveys are undertaken to determine physical characteristics, including effective soil depth, which can be exploited by the root zone, infiltration rate, field capacity, bulk density, hydraulic conductivity, relative humidity, texture and soil structure, Organic matter content, chemical properties like soil acidity (pH), salinity, sodicity, SO_4^{2-}, gypsum, Cl^-, CO_3^{2-}, HCO_3^-, saturation percentage, exchangeable sodium, phosphorus, potash, Ca^{2+}, Mg^{2+}, Na^+ N^+, and toxic substances.

Since the start of soil classification in Iran, private firms were engaged in conducting research work, under the supervision of the Soil and Water Research Institute (SWRI). Soil data are stored in the form of maps, tables and reports in the SWRI archives and data banks. Table 5.8 provides the type of survey, mapping scales and the area covered (Source: SWRI).

- ***Carbon pool***

Available information, estimated under different land use and management practices in different parts of the country, has several implications for exploring the potential of agriculture in the wider carbon reduction strategy. The values obtained are however difficult to aggregate and conclude in terms of their policy implications due to the differences in the methodology used. Some steps have been taken in the country to alleviate carbon release from agricultural soils, including a pilot carbon sequestration project described briefly below.

A carbon sequestration project was initiated in 2003 by the Forest, Range and Watershed Management Organization of the Ministry of Jihade-e-Agriculture in the northeastern part of Iran (Khorassan province, Hosseinabad plain)

Table 5.8: Type of Surveys, Mapping Scales and Total Land Areas Covered [SWRI]

Kind of surveys	Area covered (ha)	(%)
Reconnaisance	12,475,280	56
Semi- detailed	9,240,430	41
Detailed	621,900	3
Total	22,337,610	100

Map scale	Area covered (Ha)	%
1:100,000	1,298,100	5.8
1:50,000	16,750,536	75.0
1:20,000	3,304,873	14.8
Others	984,101	4.4
Total	22,337,610	100.0

in an area of about 144,000 ha. The project is assisted and financed by UNDP, through a GEF financial mechanism. The overrididing objective of the project is to enhance carbon sequestration by increasing vegetative cover of the degraded rangelands and enhance local community participation in rehabilitating degraded forest and rangeland.

In addition, other initiatives like conservation tillage is encouraged in the Department of Plant Production of the Ministry of Jihad-e-Agriculture. Recently reduced tillage which is an element in the conservation tillage practices has begun nationwide.

- *Forests, rangelands*

The Forest, Rangeland and Watershed Organization affiliated to the Ministry of Jihad-e-Agriculture is responsible for managing the range, forests and watersheds. Within the organization there are different departments responsible for generating data and information through conducting research, studies and in situ measurements, out of which the following are related to terrestrial observation:

- Assessing the erosion status including the amount of soil erosion intensity and soil erosion categories. To date 10 million hectares (ha) of lands in Markazi, Esfahan, Khorassan and Khuzestan provinces have been studied and classified, and 12 million ha is in the final stage of study,
- Establishing land slide data banks for the country. To date information on 3,935 landslides has been collected and stored in the data bases,
- Establishing flood data base. The objective is to collect data on flood patterns throughout the country. Information on 1,229 floods has been gathered, analyzed and stored in the data bank.

- *Agricultural meteorology*

The Agricultural Metrological Bureau, affiliated to the Metrological Organization, is mandated to establish management and monitor agricultural meteorological stations, observing different field and horticultural phonological processes and biomass measurements. The bureau has a long record of cooperation with the Ministry of Jihad-e-Agriculture and other relevant organizations and universities in providing raw and processed data.

There is a constant two-way flow of data from the agricultural meteorological research stations with the Agricultural Meteorological Bureau, where information is processed and saved in a digital format for easy access by different users.

For the agricultural sector the most important climate variables are temperature, humidity, rainfall, wind, sunshine and evapo-transpiration. There are various levels of sophistication at which the climate variables can be measured. The level of accuracy is determined primarily by the purpose for which the data are collected and on what is technically and practically feasible under prevailing conditions.

There are two types of meteorological stations providing data for agricultural use namely; the agriculture meteorological stations under the Meteorological Organization and those affiliated to the Ministry of Jihad-e-Agriculture. There are 27 stations under the IRIMO and 53 under the Ministry of Jihad-e-Agriculture, 11 meteorological stations under the Forest, Range and Watershed Management Organization of the Ministry of Agriculture, of which eight are functioning.

Organizations responsible for terrestrial observation in the agricultural sector are the Agricultural Planning and Economic Research Institute (APERI); Agricultural Extension, Education and Research Organization; Soil and Water Institute; and the Forest, Rangeland and Watershed Organization.

5.2.2. Meteorological and Atmospheric Observations

5.2.2.1. Data Collection and Processing

5.2.2.1.1. Climate Reporting Stations

The time sequence of most data received from stations are digitized and quality controlled. It should be noted that quality control for climate reporting stations is already fully implemented but in the case of stations that report internationally this process is not yet completed. Regarding five weather related parameters: temperature, precipitation, humidity, pressure, and wind; are fully quality controlled, filling data gaps has been conducted and they are available to users free of charge.

IRIMO has provided climatological regulations for stations that have observations recorded for a period covering 1961 to 1990 .

The collected data available in the database, are not homogeneous. This is primarily a consequence of a lack of metadata of the stations. Although the design of the metadata bank is completed, a high percentage of the collected data has still to be uploaded. Apart from this information time lag, within some specific projects homogenization of data has received greater attention. As an example, homogeneity of some meteorological parameters such as temperature, precipitation, humidity and pressure for the period of 1951-1997 have been surveyed in a project titled "Statistical Detection of Climate Change Over Iran". The methodologies for homogeneity tests are based on recommendations made in WCDMP, No. 32, 1997 on data sets for meteorological land surface observations.

13.7% of the collected data covers a time span commencing in 1951 and ending in 2005. 29% provides information that is less than a decade old.

5.2.2.1.2. Methods for Collection and Exchange of Data (National and International)

There are two general methods for collection and exchange of data at the national and international levels: real time and non-real time. At the national level using the real time method, 30 provincial meteorological offices disseminate the collected data through an automated transmission system on a real time basis.

At the international level, Tehran is serving as an Asian center for collecting synoptic data and also as a Regional Telecommunication Hub (RTH). RTH of Tehran collects observational data from 150 synoptic, 15 upper-air, two pilot ballons, 100 automatic, one marine, and one ozone meteorological station using signal side band (SSB) and telegraph. Microwave communication is used for digital transfer of data from meteorological centers in the region to the main center in Tehran. There are 30 regional sub-centers in provincial meteorological offices, which communicate through microwave transfer to their regional center. RTH of Tehran has an Automated Data Transmission System for collection and dissemination of all observational data in accordance with established schedules.

Tehran is linked to Jeddah and New Delhi as the main regional circuits and to Karachi as the regional circuit. In addition, there are ongoing efforts to establish high-speed links to Moscow.

Concerning the non-real-time method all observed data are registered on coded formats and are regularly distributed to provincial centers in Synop monthly logs, Climatological Return forms and DigiCora forms.

Private users and individuals may access data at the Internet address of IRIMO's website at: www.irimo.ir and www.weather.ir. The organization also offers these data on CDs and digitized formats based on the order placed by the users. At the international level, within Resolution 40 of WMO Congress XII, IRIMO provides additional data on the GTS and upon request made by users for research purposes free of charge.

5.2.2.1.3. Methods for Quality Control

There are two main methods for quality control as follows:

a) Real-time control: Real time data are received, stored, controlled and processed by means of software. Although this software is not able to control the structural disciplines of data parameters, but they meet real-time data requirements of forecasting centers.

b) Non-real-time control: Since research studies need long-term statistical data, quality assurance bears added importance on non-real-time control. In this mode, all parameters are assessed in two steps: first, the data, based on the category of the station, are controlled in provincial centers, and then they pass through another process of quality control. After completion of these processes these data including other products such as yearbooks, metadata, etc., are stored in the database of the meteorological organization.

In quality control processes, the logical compatibility of each parameter to time (status of parameter at the observed time) and location (latitude, longitude and elevation) are checked and then these parameters are compared to each other for further consistency.

5.2.2.1.4. Methods for Data Processing

The data, which have passed quality assurance operations after being stored in the database, are processed in different ways to provide various products and information. IRIMO is equipped with a mainframe computer, which runs the highly regarded OS/390 operating system, at 82 million bps. The computer contains 180 GB secondary memory and 256 MB RAM, equipped with various compilers and security measures.

Data processing operations (including identification of the most appropriate methods and statistical models) have the following characteristics:

1.Test for homogeneity of data (run tests for average and mean values). This test is conducted before data analysis to ensure the random nature of the data stream,

2. Since operation periods of network stations are different, a significant test for mean difference is carried out,

3. Calculation of basic statistical measures such as mean value, variance, standard deviation, coefficient of verification, bias and peak for all time-series,

4. Revision of different statistical models such as Poisson and Negative Binomial Models based on the type of parameter, for example, scarce weather phenomena, number of days of stormy weather, hailstroms and thunderstorms,

5. Using statistical tests such as K2,

6. Evaluation of model parameters by using methods like maximum likelihood and moment methods,

7. Filling data gaps using various interpolation and extrapolation methods, difference and ratio methods.

5.2.2.2. Participation in Global Climate Observing System (GCOS)

5.2.2.2.1. Global Surface Network (GSN) Stations

Iran hosts seven GSN stations that observe major parameters such as temperature, precipitation, cloudiness, dew–point, horizontal and vertical visibility, cloud base height, cloud types, radiation, pressure (QFE, QFF, QNH), wet and dry-bulb temperatures, maximum and minimum temperature, humidity, wind speed and direction, sunshine duration, evaporation

Table 5.9: Participation in the Global Climate Observing System by IRIMO

	GSN	GUAN	GAW
How many stations is the responsibility of the party?	7	1	0
How many of those are operating now?	7	1	0
How many of those are operating to GCOS standards now?	7	1	0
How many are expected to be operating in 2010?	7	1	0
How many are providing data to international data centers now?	7	1	0

Table 5.10: IRIMO's GCOS Network

Station-Name	Station-Num	LONG (DD)	LAT (DD)	Elevation
Tabriz	40706	46°17	05°38	1361
Tehran-Mehrabad	40754	51°19	41°35	1190.80
Mashhad	40745	59°38	16°36	999
Zahedan	40856	60°53	28°29	1370
Shiraz	40848	36°52	32°29	1484
Kerman	40841	58°65	15°30	1753.80
Kermanshah	40766	09°47	21°34	1318.6

and present weather. Table 5.9 describes the status of Iran in GCOS and Table 5.10 indicates the location of these stations as depicted in the map shown in Figure 5.2.

5.2.2.2.2. Global Atmospheric Watch (GAW)

A Global Atmospheric Watch (GAW) station has been observing air pollution and meteorological parameters regularly in Firoozkooh (in the Alborz mountain range 150 km east of Tehran) and sending the data to the world ozone and UV radiation center in Toronto since 1995. It shouldd be noted that the station is not included in the GCOS network because of technical and spare parts issues that originate with the supplier.

5.2.2.2.3. Participation in CBS Lead Center for GCOS

Whilst the GCOS, comprising the GSN and the GUAN, has been in place for many years, dealing with the quality and availability of climate data has been limited to monitoring and analysis centers, in Germany, Japan and the United Kingdom. These centers produce very useful monthly and annual reports, whilst, they have not always led to follow-up communication

Figure 5.2: IRIMO' GSN/GUAN Network

and appropriate remedial action being taken by particular NMHSs.

Consequently, the need for communication of GSN and GUAN monitoring results and related information to NMHSs and appropriate follow-up on these results in order to enhance the performance of the networks has led to the establishment of CBS Lead Centers for GCOS. Establishment of these Lead Centers was recommended at the first CBS/GCOS Expert Meeting on the Coordination of the GSN and GUAN . Such CBS Lead Centers, being part of WMO, have the power to contact WMO member countries regarding their climate data. The GCOS Secretariat has limited powers in this regard, as it is not officially part of WMO.

It is expected that the establishment of the Lead Centers will ultimately lead to improved quality and availability of climate data which will in turn enable enhanced understanding of climate change and variability and provide the basis for further studies on impacts and adaptation strategies.

Since the Islamic Republic of Iran Meteorological Organization (IRIMO) has been selected as Lead Center of the RA II Western Part, it is responsible for monitoring GSN and GUAN Networks of the following Countries:

Afghanistan, Armenia, Azerbaijan, Bahrain, India, Iran, Jordan, Kazakhstan, Kyrgyzstan, Maldives, Nepal, Oman, Pakistan, Qatar, Russia, Saudi Arabia, Sri Lanka, Syria, Tajikistan, Turkey, United Arab Emirates and Yemen.

The Terms of Reference of the CBS Lead Centers for GCOS is shown in the Annex.

5.2.3. Hydrology and Hydrometeorology Observation

The water resources investigations were planned and executed by the deputy for water affairs in the Ministry of Energy in centralized form till the late 70s. Later, the executive body of the water resources investigations was transferred to 15 regional water boards and the Water Resources Survey Bureau (WRSB).

Recently the following organizations have been involved with collecting and producing of hydrological and hydrometeorological data.

- Regional water boards as the main body of data collecting and processing (Ministry of Energy),
- Water Resources Survey Bureau (WRSB) as the headquarters unit and coordinator organization (within the Ministry of Energy),
- Iranian Meteorological Organization (IRIMO).

5.2.4. Oceanographic Observations

5.2.4.1. Establishment of National Oceanographic Data Center (NODC)

Due to the need for a general data collection and information system in Iran, the establishment of the NODC (National Oceanographic Data Center) was facilitated through the Resolution of the 27th Session of UNESCO General Conference. In 1993, draft Resolution 153 was adopted and finally in 1995 the Iranian Oceanographic Data Centre (IRODC) was established in the Iranian National Center for Oceanography (INCO) and was introduced as a node for the International Oceanographic Data and Information Exchange (IODE) in Iran.

IRODC is the only national oceanographic data center in the Persian Gulf and the Gulf of Oman region, tasked with the collection, archiving and maintaining quality control of oceanographic data, as well as its exchange with various international bodies and institutions. In line with this objective, the center has embarked on a program of collecting oceanographic data, metadata and CSR (Cruise Summary Reports) from national and international organizations, which are posted on the INCO website on a regular basis. The physical, chemical and biological data cover the Caspian Sea, the Persian Gulf, and the Gulf of Oman. The hydrological data relate to the Caspian watershed. The data also include meteorological readings from the whole of Iranian territory.

Table 5.11: Participation in the Global Oceanographic Observing Systems

	VOS	SOOP	TIDE GAUGES*	SFC DRIFTERS	SUB-SFC FLOATS	MOORED BUOYS	ASAP
For how many platforms is the party responsible?	-	-	10	-	-	-	-
How many are providing data to international data centers?	-	-	4	-	-	-	-
How many are expected to be operating in 2010?	-	-	13	-	-	3**	-

* The NCC is responsible for the nine permanent tide guages
** It is planned to implement three deep water moorings in the Gulf of Oman and the Caspian Sea until the end of 2010 by INCO

5.2.4.2. Integrated Program for Developing the Iranian Marine Meta-data Directory

The IRODC division of INCO is responsible for the creation and maintanence of the Iranian Oceanographical Metadata. IRODC uses the MEDI tool to automatically generate metadata. The MEDI system provide a tool for metadata management and data discovery for national, regional and global Marine datasets.

The metadata is available through the following web page: http://www.inco.ac.ir/DataCenter

5.2.4.3. Strategy for Data Exchange at National and International Levels

Oceanographic data exchange through the IOC or IODE data centers are currently well known for the many countries it services globally including Iran. INCO, as an IODE focal point in the country has no limitation for exchanging data at the international level. But at the national level the oceanographic data exchange program can not be accomplished due to the many obstacles mentioned above. To initiate an integrated data exchange program at the national level, establishment of the national oceanographic data bank seems to be the first and the fundamental step to take as all of the contributors receive the advantages of their inputs. INCO suggested a national model for collecting and exchanging the oceanographic data based on a distributed model of data centers which will be coordinated by the IRODC. In this line, IRODC aims to collect, manage and distribute the oceanographic data to users and needs to be supported by receiving data from all marine related organizations in the country.

Establishment of the National Marine Data Directory is another important action, which has been taken by INCO to help data dissemination in the country. The marine related organizations have to support the directory by providing their data list to the NODC. In return, they have access to the directory and all the data which the directory can provide. The directory includes only the meta-data, which indicates the data type, the organization who owns data and the condition of data availability. To achieve the best result, all the contributors must follow the FGDS standards for management of their meta-data.

To manage the data exchange programs, it is necessary to establish the data exchange law, which must be approved by the highest authorities and followed up by the marine related organizations. The profits of the data exchange program can guarantee the accomplishment of the data exchange law.

5.2.5. Terrestrial Observation For Agriculture

5.2.5.1. Type of Data and Information Collected and Disseminated by the Agro Meteorological Stations

- ***Weekly agro meteorological information***

Agro meteorological data such as plant phenology and weekly thermal units, are collected and sent to the meteorological offices. As a general procedure, each agro-meteorological research stations in every crop year compiles weekly information, composed of 52 sheets. These metadata, can be accessed at the IRIMO's web site mentioned above.

- ***Ten day period data***

This includes weekly agro-meteorological data and a 10 day information inventory on soil temperature at different depths. The materail collected at the meteorological stations are sent to the meteorological offices for analysis. The information comprises of 36 sheets of 10 day records. The processed data are finally sent to the IRS Meteorological Organization, where they are stored in the data base and can be accessed by users.

- ***Monthly crop bulletin***

The findings of biometric measurements and phonological observations for different crops collected in the individual agricultural meteorological research stations are analyzed and compiled as monthly bulletins. This information is being available at the agro meteorological offices. Recently, this data is being stored at the IRI Meteorological Organization in the form of computerized files, which can be accessed by users.

5.2.5.2. National Plans for Meeting the GCOS Requirements

The Agricultural Planning and Research Institute of the Ministry of Jihad-e Agriculture has undertaken a program for inventory and continuous monitoring of base natural resources at the national scale. It is understood that low resolution, but low cost data may be good enough for studies in large areas, but it is too small for detailed studies of a small area such as the size of Iran. For small area high resolution (20 to 30 m resolution) remote sensing data, such as landsat and spot are readily available. Both landsat and spot covers the visible to near infrared region and is highly suitable for vegetation study. Though some of these data are used for vegetation inventory, due to their high cost there are limitations for their extensive utilization. Recently a MODIS sensor mounted on the Terra satellite has been launched. The medium multi temporal and spacial data are available at very low costs.

For monitoring land use change in the country two monitoring projects were conducted by the Agricultural Planning and Economic Research Institute of the Ministry of Jihad-e-Agriculture. These projects incorporated satellite data from the MODIS sensor of Terra satellite for 2004 (Figure 5.3). The results obtained from processing of the data were compared and variations occurred as the result of land use change and drought were identified. Forest, Range and Watershed Organization conducted a comprehensive project in 2002 for mapping flood occurrence in the country. In this study data (2000) from ETM+ of Landsat were used to prepare the map of floods in different watersheds, which was aggregated at the national level. The primary objective of this mapping exercise was to identify the critical zones prone to flooding and to monitor these areas at regular intervals.

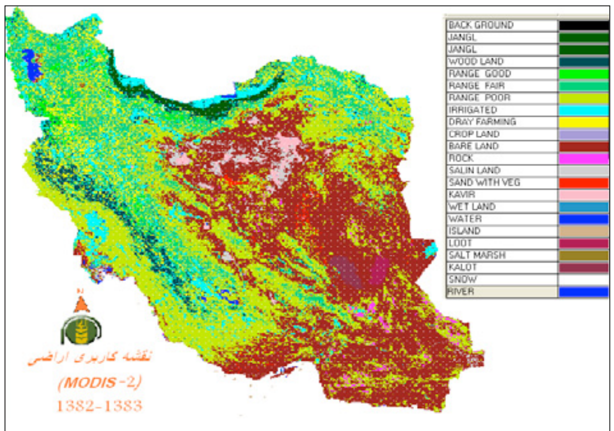


Figure 5.3. Land Cover Map for 2004

5.2.6. Space-based Global Climate Observing Systems

5.2.6.1. National Participation in Observation

In recent years, space technology and its application in remote sensing is becoming more important in Iran. This technology is regarded as a useful tool for tackling the problems in environmental change and decrease in natural resources. Remote sensing and its application could provide better information for the environment. Satellites are important tools for collecting climate data from the earth. They normally operate in either a geostationary or sun-synchronous orbit. Since conventional surface and atmosphere observation stations are normally sparsely distributed, the polar-orbiting (sun-synchronous) satellite systems data may adequately fill-in the gaps of land/water surfaces and observation of the earth's atmosphere. The in-situ data may also be used for calibration of satellite data and hence validate the global/regional data provided by satellites.

The country's participation in observation of atmosphere, land and water to monitor climate change is divided in two sections. The first section includes the MESBAH satellite program and Small Multi Mission Satellite program described briefly below. The second section includes the operation of data receiving stations for climate change observation.

- *MESBAH Satellite Program*

MESBAH is a small LEO telecommunication satellite designed to offer communication between user terminals by means of a satellite. The service is to be implemented over Iran, and it operates in a non real-time store and forward mode. It offers direct point-to-point user telecommunication without the need to pass via a ground station and orbits as an autonomous free flying satellite. MESBAH satellite is scheduled to be set into orbit as a piggyback satellite on the primary launcher payload.

- *Small Multi Mission Satellite Program*

This is an international program in which the Iranian Space Agency (ISA) and five other Asian countries including China, Thailand, Pakistan, Mongolia and South Korea have jointly initiated the design, manufacturing of the platform and payload and launch of the Small Multi Mission Remote Sensing Satellite. Based on the results of the Working Group Meeting and coordination among member countries, a three-axis stabilized small multi-mission satellite was selected to be used by different participants because its economic and the social benefits were considered of optimum advantage.

- *Receiving Stations Programs*

The programs using satellite data to derive operational climate related information include the Iranian Space Agency (ISA) and future receiving stations, Islamic Republic of Iran Meteorological Organization (IRIMO) receiving stations, Iranian National Center for Oceanography receiving station, Geographical Organization receiving station and the Bushehr Remote Sensing Center receiving station

Low Resolution Receiving Station: This is a low spatial resolution receiving station with an antenna 1.8m in diameter which receives AVHRR/3 sensor images of NOAA-16, 17 satellites in five bands of 1.1km resolution daily.

Low to Medium Resolution Receiving Station: This is a low-to-medium spatial resolution receiving station with a 3.65m in diameter antenna which receives MODIS sensor images from the Terra satellite in 36 bands of 250, 500, and 1,000m resolution on a daily basis. The same antenna receives Russian Meteor-3M satellite images from the northern part of the country in four bands of 35m resolution in every 24 hour cycle.

Reception of MODIS data from the existing Terra satellite as well as AVHRR data from NOAA satellite will benefit various applications including meteorology and oceanography.

Future receiving stations program: This is a national program in which the design and manufacturing of a receiving station with an antenna functioning in 8.0-8.4 GHz is being initiated. The receiving station will receive various satellites images.

Meteosat-7 analogue images are received in three bands as visible (VIS 0.7) every half an hour, infrared (IR 11.5) in 3-5km resolution and water vapor (WV 6.4) every half an hour.

GEOS, GMSN (North), GMSS (South) analogue images are received every three hours. These images are used for aviation purposes. Presently we are not able to get these images.

NOAA receiving station that was used to receive AVHRR sensor images of NOAA satellite series in five bands of 1.1km resolution daily until 2002, despite the availability of receiver and antenna, can no longer receive the images due to technical problems.

The receiving station at the Iranian National Center for Oceanography received AVHRR sensor images of the NOAA satellite in five bands of 1.1km resolution every day within the period of 1997 to 2000.

The Geographical Organization Receiving Station receives IRS-1C/1D satellite images provided by PAN sensor in panchromatic band of 5.8m resolution, LISS-III sensor in four bands of 23m resolution, and WIFS sensor in two bands of 188m resolution.

Basir Remote Sensing Center Receiving Station in Yazd receives AVHRR sensor images of NOAA satellite in five bands of 1.1km resolution every day. It will also receive Indian IRS-1C/1D satellite images in the near future.

5.2.6.2. Description of space series, missions, instruments

5.2.6.2.1. MESBAH Satellite Program

The MESBAH satellite is a communication satellite and its mission is to receive, store and send data to points not covered by the current communication network. It receives data from one terminal and sends it to another. If data are not delivered in the first round, they are stored and delivered in the next round based on time multiplexing in the store and forward manner.

5.2.6.2.2. Small Multi Mission Satellite Program (SMMS)

The platform of SMMS will support many kinds of payloads. The payloads include multi-spectral CCD cameras and a hyper-spectrum imager that performs earth observation, Ka-band communication experiment equipment, data collection and storage and forward data transmission (DCS/SAF) and middle ultraviolet backscatter radiometer for space science research.

- ***Multi-Spectral CCD Camera (two units)***

Multi-spectral observation is used to detect the same object in several spectral bands simultaneously. It contains useful information convenient for processing and analyzing. The data will play an important role in the planning of agriculture, forestry, water resource, land, environment, and land resource and local regional economy and accordingly fits the requirements of the earth resource survey and environmental monitoring.

- ***Hyper-spectrum Imager***

The Hyper-spectrum imager affords the requirements for ground object hyper-spectrum imaging. It will play an important role for the environment and disaster monitoring in the Asia-Pacific region and this is an area providing enormous future developments in this field.

Ka-band Communication Experiment The requirement for communication capacity significantly has increased in the region, but the available radio spectrum resources are limited. Ka-band communication has a broad prospect for future telecommunication application in space and terrestrial fields. The sun-synchronous orbit for SMMS is not suitable for telecommunication purposes and it is just for experimental purposes. One Ka-band communication transponder consists of Ka receiving/transmitting antenna, duplexer, receiver, beacon receiver and transmitter, convector and power amplifier.

A single Ka-band transponder can meet the requirements for three kinds of experiments, including Ka-band communication application experiments, ground antenna capture and tracking properties research and Ka-band wave rain-scatter property.

5.2.6.2.3. Data Collection System (DCS)/ Store-and-Forward (SAF) Communication Experiment

. When the satellite flies over an area, the messages sent by DCP can be automatically and continuously picked up. The spacecraft will store the information collected from DCP and transmit the same to the central ground station for processing and providing to decision-makers.

The store-and-forward data transmission could be used to provide not only real-time communication within the same coverage of SMMS but also could delay communication for the users (radio amateurs or government agencies, est.) in different satellite coverages. The store-and-forward data transmission service is used for spreading of space knowledge, targeting specific social benefits and promoting cooperation in this area. Unified DCS/SAF system is adopted in SMMS. It consists of transmitter, antenna, duplexer and switchboard. Its main purpose is to receive the up-link data from ground DCP and messages from amateur radio users, and to send the processed data back to ground station via ultra short wave.

5.2.6.2.4. Middle Ultraviolet Back Scatter Radiometer

The ozone layer is very absorbent of the middle ultraviolet wave band. The middle ultraviolet radiation from low altitude clouds, ground phenomenon reflection and dispersion, thunder and lighting, none of these can be transmitted through the ozone layer. Therefore, the middle ultraviolet background can be accessed equally from space-borne instruments without the disturbance from other elements. This new type of middle ultraviolet backscatter radiometer is composed of an ultraviolet photosensitive tube with a pure metal negative pole and coding Pin-Hole system. It has good efficiency in an ultraviolet radiation environment. It measures the radiation at a wavelength of 250nm to induce the high altitude ozone profile and volume content.

5.2.6.3. Mechanism to Access Data and Products by International Programs in Relation to Climate Change

Data users may purchase data or receive it free of charge from the archive. For instance, the user may be connected to the IRSC web-site, browse the quick look of images, select the appropriate ones and send an order to purchase or receive them free of charge. The raw NOAA-AVHRR data are free, but an operator data handling cost is charged. Some data are also available free of charge to postgraduate students for research purposes through an agreement with universities. The web-site address of the Iranian Space Agency (ISA) is: http://www.isa.ir. At present, the ISA data archive is available to national and international users. The archive contains three sources of information:

-In the form of photograph including Land sat-MSS (1972-73, 1975-77, 1984-85), Land sat-TM (1987-92) and NOAA-AVHRR data (1984-86),

-Through the receiving station as digital images including old NOAA-AVHRR data and NOAA-AVHRR (1996-2007), Terra-MODIS (2002-07) and Land sat-MSS (1972-78),

-Through purchased data in the form of digital images including SPOT-PAN (1986-2000, partial coverage), Land sat-TM (1987-91 and 1998, full coverage), Land sat-ETM (2001, full coverage), IRS-PAN (partial coverage), IRS-LISSIII (partial coverage), RADARSAT (partial coverage), ASTER (partial coverage) and IKONOS (partial coverage).

The Meteorological Organization has archived Meteosat-7 data obtained through the receiving station in the period 2001-03. The web-site address of IRIMO is: http://www.irimo.ir

The Iranian National Center for Oceanography has archived NOAA-AVHRR data received through the receiving station in the period 1997-2000. The web-site address is: http://www.inco-ac.ir

The Geographical Organization has archived IRS-PAN and IRS-WiFS data being received through the receiving station in the period 2002-03. Other archived data includes COSMOS imagery in the year 1990 and also aerial photographs. The web-site address is: http://www.ngo-iran.ir

The National Cartographic Center has archived cartographic maps at scales of 1:250,000, 1:50,000 and 1:25,000 which are used to rectify remotely sensed images by other organizations. The web-site address is :http://www.ncc.org.ir

The Organization of Geological Survey of Iran has archived considerable remote sensing images and data such as Land sat-TM, RADARSAT, aerial photographs and geology maps of the entire country. The web-site address is: http://www.gsi.ir

Use of satellite imagery as a tool for delineation of agricultural land use and land resource inventory plays a key role in climate change analysis. Agricultural, range and forested lands and land use inventory and monitoring using remote sensing data dates back to the early 1990s in the Ministry of Jihad-e Agriculture. It was restricted to small localities due to the limited experience with remote sensing data. However, SPOT, Land sat-TM and Land sat-ETM images are available through the archive and are being used for data interpretation. The web-site address is: http://www.agri-jahad.ir

The archive of the Ministry of Oil located at the Surveying Engineering Section contains limited remote sensing images and data such as SPOT, Land sat-TM, aerial photographs and geology, geochemistry and geophysics maps primarily related to oil and the Zagros mountain areas.

The archive of Ports and Shipping Organization contains aerial photographs and maps of relevance to coastal areas. The web-site address is: http://www.pso.ir

The GIS Center of Tehran Municipality has archived SPOT images (1986, 1992, 1994, 1996, and 1997) and IKONOS (2002) from the greater Tehran area.

There are a number of private companies that provide remote sensing imagery to the user community in the country. These companies are Jazaiery Company which provides SPOT images, Negareh Company which provides RADARSAT images, Kamkar Systems Company which provides IRS images, Remote Sensing Consultants Company which provides COSMOS images, Hezareh-e Sevvom Company which provides a variety of satellites images and Ensan-o Mohit Company which provides ASTER images.

5.2.6.4. Mechanism for Archiving, Quality Assurance and Quality Control

The images received are also analyzed for their quality and then archived. Amongst the multiple daily reception of AVHRR and MODIS images, only the closest ones to mid-day are archived, unless there exists a particular order for another time of the day. For the time being, the quality assurance and quality control are performed in the traditional manner of visual inspection. However, there are some activities in ISA to develop software and standard methods and algorithms for greater quality assurance and quality control, but this upgrade is in its initial stages. They include determining general procedures and instructions for the quality of received and purchased images. For instance, purchased images should not contain more than three missing lines, or more than 25% cloud, or more than 25% snow, and the amount of haze and image sharpness should be at an acceptable level. The resolution should be consistent and not less than the original resolution considered for the image. The image should belong to the same year when ordered or at least to the previous year. If the image is geometrically rectified, only nearest neighbor re-sampling must be applied. The area for which the image is ordered must be inside the image frame, etc. For the images obtained through receiving stations, there is some software that is developed to perform most of the mentioned criteria automatically. In the case of purchased radar images, they must be accompanied with phase data, be in slant range, the resolution must comply with the standard ordered etc.

In addition, in collaboration with universities, AVHRR data are processed to retrieve high quality sea surface temperature (SST) images to use in climate monitoring and research. Substantial data sets now exist of regional SSTs derived from these data. In order to provide accurate SST images, both simultaneous in situ and satellite data are combined to derive coefficients for regional SST formulae. The development of quality control techniques for SST, which took more than a year to develop, test and implement resulted in making due consideration of the work to be continued using MODIS data from the Terra satellite.

5.2.6.5. Major Domains of Applications (Atmosphere, Ocean, Terrestrial)

The application areas include atmosphere, ocean and terrestrial. This section provides a few examples of many applications that present extensive use of satellite data. While not complete, the list includes specific applications within the disciplines such as meteorology, climate, hydrology, oceanography, environmental monitoring, detection and monitoring of natural disasters. The list includes the contribution of the potential user community.

Prognostic charts for 500 (hPa), 1,000 (hPa), vertical velocity, precipitation, relative humidity, vortices, for 24, 48, and 72 hours lead time to be used in weather forecasting (being performed by IRIMO).

In addition, in the major domains of applications (atmosphere, ocean, and terrestrial) some other projects have been implemented or are being implemented so that in the case of need, the proper experience already exists for full and continuous implementation. They include:

- Air pollution monitoring using MODIS images - a case study on Tehran, by Tehran University; Cloud detection using AVHRR images, by Iranian Space Agency and Tehran University; Dust distribution study in the south of Iran, a joint pilot project conducted by the Iranian Space Agency and Tehran University,
- The study of Sea Surface Temperatures (SST) anomalies of the Caspian Sea using AVHRR images as a prediction method in research work on the climate,
- Notably climate change, seasonal change monitoring, and the influence of SST anomalies in calm or stormy seas, etc., by the Iranian Space Agency; thermal structure of the Caspian Sea, Persian Gulf and Oman Sea surface using AVHRR images used as an indicator in research work on fisheries, by the Iranian Space Agency and sediment monitoring.

5.3. Technology Needs Assessment

5.3.1. Introduction

The Islamic Republic of Iran is one of the most natural resource-rich and human resource-rich countries in the Middle East. However, Iran's economy is highly dependent on the production and export of crude oil to finance government spending, and consequently is vulnerable to fluctuations in international oil prices. The country is faced with serious problems in use and managing of resources and hence severe difficulties with respect to energy-related carbon emissions.

Iran possesses the world's third largest known petroleum reserves, following Saudi Arabia and Canada, and the second largest natural gas reserves after Russia.

In 2006 the GDP was estimated at USD 158.6b (USD 599.2b at Purchasing Power Parity (PPP)), or USD 2,280 per capita (USD 8,700 at PPP). Agriculture accounts for 11.2 percent of the GDP, industry 41.7 % and services 47.1 %. Iran's economy will experience an average annual economic growth rate of about 5.5%, 3.4% and 3% during 2005-2010, 2011-2020 and 2021-2030, respectively. This pattern of ecconomic growth needs to be invested in energy intensive industries like cement, iron, steel and power generation which has previously caused rapid growth in GHGs emission. Therefore, in order to contribute in combating climate change, the transfer of advanced technologhies are crucial, which is now restricted by some countries.

5.3.2. Internationally Existing Climate Friendly Technologies

The majority of GHG mitigation technologies are related to the energy sector as energy production and use is responsible for around 75% of GHG emissions. In general

Fuel Cell Technology in SANA Laboratory

two main strategies are followed by various mitigation technologies, which are energy efficiency improvement and renewable energy sources substitution. Technologies to abate GHG emissions in the energy sector can be categorized based on energy supply, energy transmission and distribution and energy demand sectors. Here, all international mitigation technologies are introduced, considering that only some of these options are suitable for our country as shown in Table 5.12.

Table 5.12: List of Existing International Climate Friendly Technologies

Energy Sub-sectors	Energy Technologies		
Energy Supply	Use of more efficient technologies for conversion of fossil fuels	Combined heat and power generation	
		Fuel cells	
		Gasification of fossil fuels	
		Circulating fluidized bed combustion	
		Combined cycle power plants	
		Associated gas recovery	
	Switching to low- carbon fossil fuels		
	Decarburization of flue gases and fuels and CO_2 capture and sequestering		
	Switching to nuclear energy		
	Switching to renewable sources of energy	Solar energy	PV
			Solar-thermal technologies
			Solar air heating using solar wall technology
		Wind power	
		Hydropower	
		Geothermal energy	
		Biomass energy	Direct combustion
			Biomass co-firing technology
			Biomass conversion into biogas
			Fermentation of biomass to produce ethanol
			Methane fermentation
			Gasification and methanol synthesis
		Waste energy	Refuse buried at landfill sites decomposes to produce a gas (landfill gas)
			Biodiesel fuel
			The use of energy from waste products to generate electric power
Energy Transmission and Distribution	Reduction of power transmission losses		
	Reduction of gas leakage		
	Utilization of excessive pressure in main pipeline		
	Management of steam traps in steam piping		
	Recovery of drain water from steam piping		

Table 5.12: List of Existing International Climate Friendly Technologies (continued)

Energy Sub-sectors	Energy Technologies		
Energy Demand	Transportation	Reduce vehicle energy consumption	
		Switch to alternative/low pollution energy sources	
		Vehicle information and transportation system (VICS)	
		Improve fleet management to increase vehicle load factor	
		Switch to public and non-motorized transport	
		Improve telecommunication systems	
	Residential, Commercial and Institutional	Building equipment	
		Heating	Condensing furnace
			Electric air-source heat pump
			Ground-source heat pump
			Central heating
		Cooling	Efficient air conditioners
		Water Heating	Efficient water heaters
			Air-source heat pump water heater
			Exhaust air heat pump water heater
		Refrigeration	Efficient refrigerators
		Other Appliances	Horizontal axis clothes washer
			Increased clothes washer spin speed
			Heat pump clothes dryer
		Cooking	Biomass stoves
		Lighting	Compact fluorescent lamps
			Halogen IR lamps
			Efficient fluorescent lamps
			Electromagnetic ballasts
			Specular reflective surfaces
			Replacement of kerosene lamps
			Lighting control systems
		Office Equipment	Efficient computers
			Low-power mode for equipment
		Motors	Variable speed drives
			Efficient motors
		Energy Management	Building energy management systems
			Advanced energy management systems
			Micro CHP
		Building thermal integrity	Improved duct sealing
			Proper orientation
			Insulation and sealing
			Energy-efficient windows
	Oil, Gas and Petrochemical	Mitigating pollutants in exhaust gases	
		Modernization of flare facilities	

Table 5.12: List of Existing International Climate Friendly Technologies (continued)

Energy Sub-sectors	Energy Technologies		
Energy Demand	Industry	Heat and Power Recovery	
		Material Substitution and Recycling	Replace metals with plastic
			Replace concrete with wood or plastic
			Lighter materials lower transport-related CO_2
			Use of plant materials as a source of chemical feedstock
		Energy Efficinecy Improvement throygh New Technologies and Processes	Iron & Steel: Smelt reduction, Near net shape casting, Scrap preheating, Dry coke quenching
			Non-Ferrous Metals: Inert anodes, Efficient cell designs
			Chemicals: Membrane separations, Reactive distillation
			Petroleum Refining: Membrane separation, Refinery gas
			Cement: Precalciner kiln, Roller mill, fluidized bed kiln
			Glass: Cullet preheating, Oxyfuel furnace
			Pulp & Paper: Efficient pulping, Efficient drying, Shoe press, Conveyor belt drying
			Food: Efficient drying, Membranes
			All industries: • Use of more efficient motors, pumps, boilers, furnaces, lighting and heating, • Proper ventilation, • Air conditioning
		Fuel Switching	Switching to natural gas
			Waste materials (tires, plastics, used oils and solvents and sewerage sludge)
			Using biomass and biogas
		Energy Management	Benchmarking
			Energy management system
		Process Integration	

5.3.3 Technology Preference According to Country Profile

After reviewing the mitigation technologies for energy supply, transmission and end-use, we now identify the best options, which are suitable for Iran. The Analytic Hierarchy Process (AHP) approach and its software (Expert Choice 2000) is used to identify the priorities of GHG mitigation technologies for existing different sectors, i.e. oil and gas industries, power plants, transportation, commercial and institutional, industry and agriculture. The selected options should meet the environmental objectives and minimum cost as well as social conditions. Six main criteria are considered which are:

1. Environmental benefits (GHG mitigation, other pollutants reduction),

2. Availability of resources,

3. Cost (investment, payback period, investment/ CO_2 tonnage reduction),

4. Conditions for technology transfer (local capacity, localization of manufacturing),

Table 5.13: List of International Existing Climate Friendly Technologies Consistent with Country Condition

Energy Sub-sectors	Energy Technologies		Priority
Oil and Gas Industries	Associated gas recovery		0.059
	Utilization of excessive pressure in main pipeline		0.057
	Process integration (oil & gas)		0.054
	Energy conservation in transmission		0.051
	Fuel upgrading		0.047
	Pre-cleaning of departing gases		0.045
	Flare facilities		0.036
	Reduction of gas leakage		0.029
Power Generation	Cogeneration		0.038
	Small hydro		0.036
	Waste energy		0.036
	Combined cycle		0.035
	Thermal power plant		0.032
	Biogas and biomass gasification		0.03
	Wind power		0.029
	Biomass combustion and power generation		0.028
	Solar thermal heat		0.025
	Nuclear		0.024
	Geothermal		0.023
	CO_2 separation and recovery		0.02
	Photo voltaic (PV)		0.018
	CO_2 capture and storage		0.012
Transmission and Distribution	Energy conservation in transmission		0.051
	Reduction of gas leakage		0.029
	Utilization of excessive pressure in main pipeline		0.057
End Use Technology	Transportation	Vehicle info. & trans. Sys. (VICS)	0.009
		Low fuel consumption technologies	0.009
		Public transportation	0.011
	Residential, Commercial and Institutional	Green lightning	0.019
		Lightning control	0.016
		Energy saving building	0.014
		Central heating	0.01
		Heat pumps	0.013
		Small CHP(Distributed Generation)	0.012
		Central heating	0.01
		High efficiency cook stoves	0.014
		High efficiency home appliances	0.015
		Hot stove waste heat recovery devices	0.015
	Industry	Process integration (industry)	0.018
		High efficiency boilers	0.017
		High efficiency electric motors	0.016
		Compressors	0.013
		Pumps	0.015

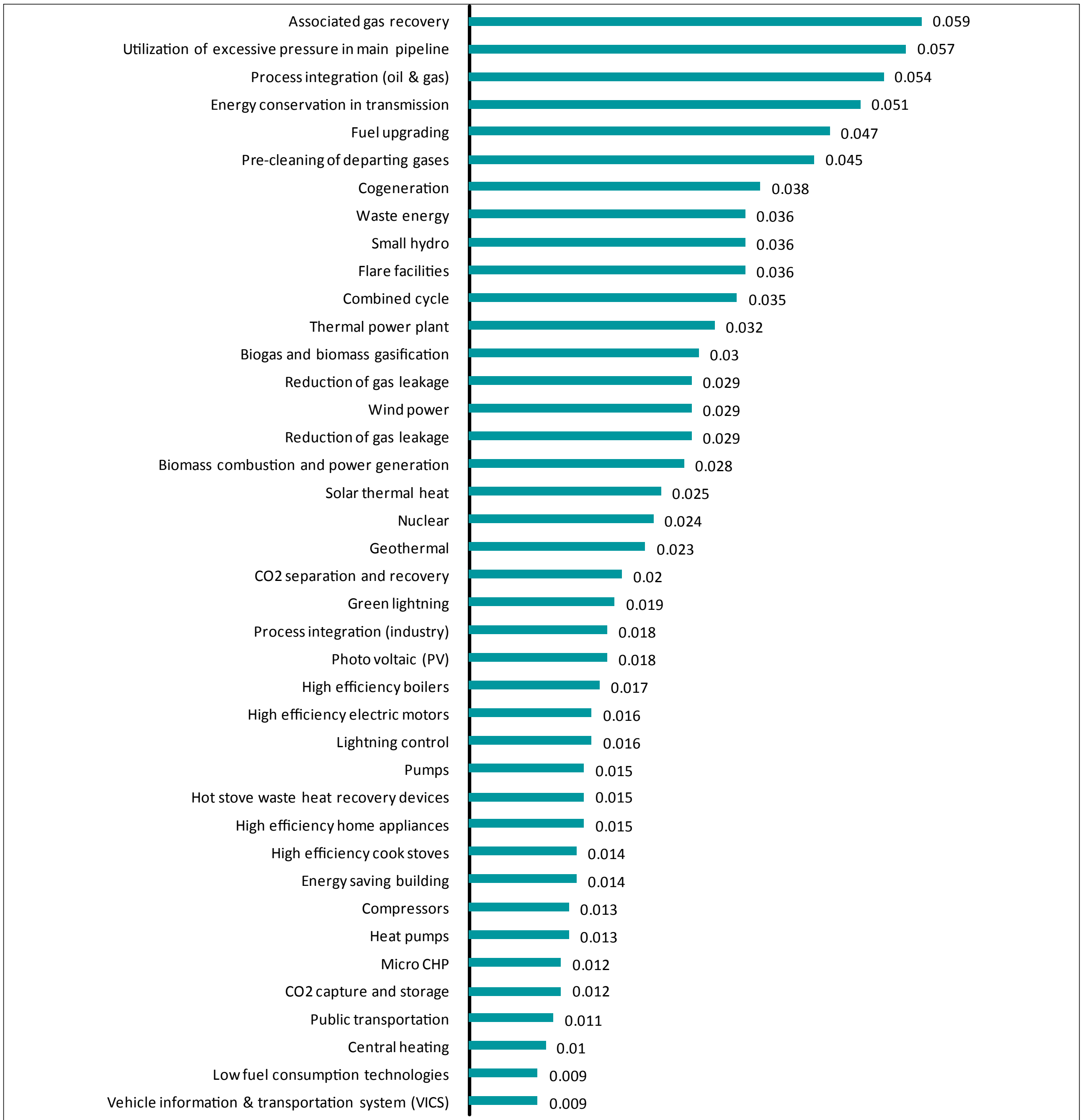


Figure 5.4: The Priority of Mitigation Technologies in Energy Sub-Sectors

5. Economic development (effect on economic growth, job creation),

6. Compatibility with government programs.

Considering the above criteria, 40 effective technologies were proposed for different energy sub-sectors which are shown in Table 5.13.

The results of the hierarchy method for setting priorities on technologies, based on the government's policies, are shown in Figures 5.4 to 5.9. In this study, the criteria are assessed according to the long-term strategies of the Islamic Republic of Iran. The criteria include environment benefits, availability, cost, conditions for technology transfer, economic development and compatibility and are assumed the same for all sub-sectors.

As is shown in Figure 5.4, associated gas recovery and utilization of excessive pressure in the main pipeline are the highest priority, while the vehicle information and transportation system (VICS) and low fuel consumption technologies in the transport sector are the lowest priority. Also Figures 5.5 to 5.9 reflect the priority of sectoral mitigation technologies.

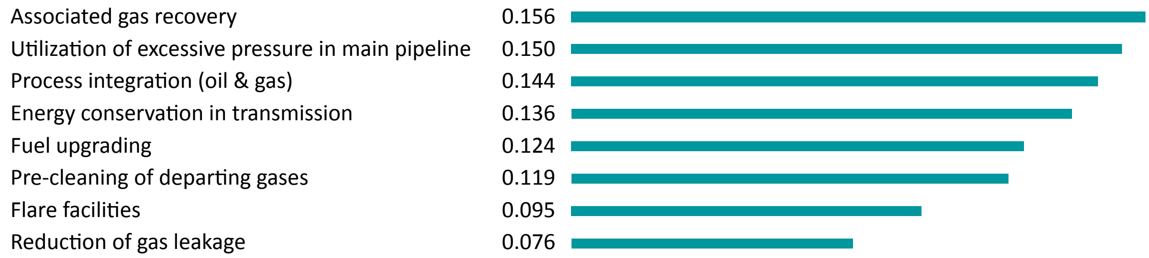


Figure 5.5: Priority Measures for Mitigation GHG Emissions in Oil and Gas Industry and Transmission

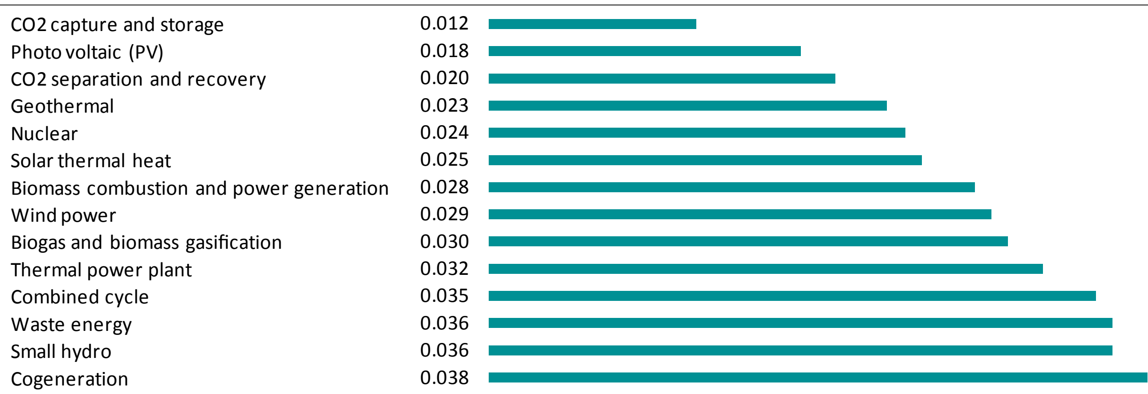


Figure 5.6: Priority Measures for Mitigation GHG Emissions in Power Plants

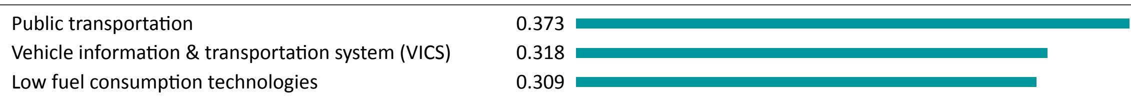


Figure 5.7: Priority Measures for Mitigation GHG Emissions in Transportation

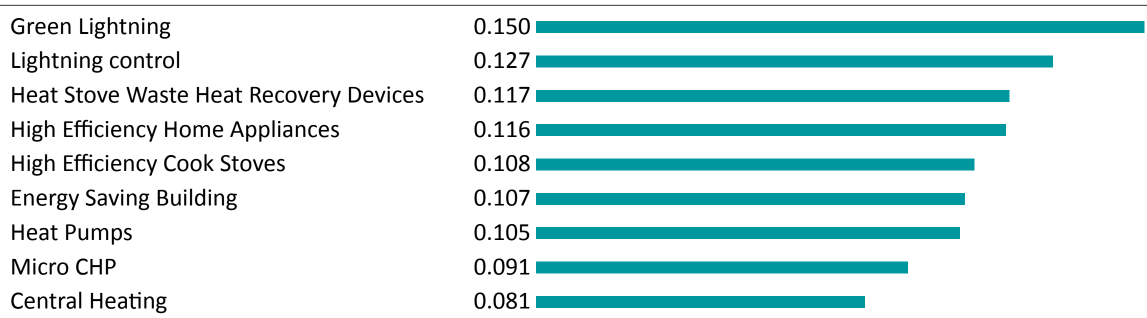


Figure 5.8: Priority Measures for Mitigation GHG Emissions in Residential and Commercial

Figure 5.9: Priority Measures for Mitigation GHG Emissions in Industry

5.4. Research and Education

According to Articles 5 and 6 of the UNFCCC, all countries should promote and facilitate at the national and, as appropriate, subregional and regional levels, and in accordance with national laws and regulations within their respective capacities:

- Development and implementation of educational and public awareness programmes on climate change and its effects,
- Training of scientific, technical and managerial personnel and,
- Development and implementation of education and training programmes, including the strengthening of national institutions and the exchange or secondment of personnel to train experts in this field, in particular for developing countries.

To accomplish these UNFCCC commitments, the National Climate Change Office (NCCO) of Iran established a research and education working group in 2007. The ultimate objective of this working group is to propose a climate change course program

Traning Wokshop for NGOs

for post graduate study and an organizational chart of a research center for climate change issues in Iran.

5.4.1. Methodology of the Study

Before proposing the climate change course program and organizational chart of a climate change research center in Iran, previous works related to climate change issues implemented in research and educational institutions of Iran were reviewed and collected. To do that, a broad survey was conducted on books, journals, papers, projects, theses, and educational programs relevant to climate change which have been implemented in the following ministries, universities and institutions;

Workshop On Participatory Approach In Climate Mitigation

Table 5.14: Educational Program of Iranian Universities and Institutes

Degree	Title of course
Bachelor level	Meteorology, Hydrology, Sustainable Environment, Protection of Forests, Protection of Soil and Water, Renewable Energy, Pollution of Environment, Geomorphology, Ecology of Seas, Environment Law, etc.
MSc level	Security in Petroleum, Ecosystem of Deserts, Optimizing the Energy in Economy, Water Treatment Plant, Hydrological Models, Hydrometeorology, Remote Sensing, Energy and Environment, Numerical Weather Prediction, Synoptic and Dynamic Meteorology in mid latitudes, Using Satellite Data for Weather Forecasting, Dynamical Aspects of Marine Meteorology and Physical Oceanography, Cloud Physics, etc.
PhD level	Environment Engineering, Energy and Environment, Pollution Protection of Atmosphere, Problems of Water Resources of Iran, Economy of Water Resources, Sustainable Development of Environment, Climatology of Agriculture, General Circulation Models, Microclimatology, Detection of Climate Change, Radioactive and Environments, etc.

– **Ministries**: Ministry of Science, Research and Technology, Ministry of Agricultural Jihad, Ministry of Energy, Ministry of Oil, Ministry of Mines and Industries, Ministry of Roads and Transportation, Ministry of Communication and Information Technology.

– **Universities**: Universities in Tehran such as; Tehran University, Sharif University of Technology, Amir Kabir University, Iran University of Science and Technology, Khajeh Nasir University, Shahid Beheshti University, Tarbiat Modarres University and Azad University. Universities in other provinces such as Esfahan, Shiraz, Mashhad, Gorgan, Mazandaran, Tabriz, Zahedan, Kerman and Shahrekord were also surveyed.

– **Institutions**: The NCCO in the Environmental Research Center of the Department of the Environment; Water Resource Research Center at Ministry of Energy; Sharif Energy Research Institute; Institute of Geophysics of Tehran University; the Institute for Scientific and Applied Environmental Research of the Department of the Environment in Karaj; Environmental Research Institute and the Energy Research Center of Amirkabir University of Technology; Meteorology and Atmospheric Science Research Center affiliated to IRIMO; Desert Research Center and International Research Center for Desert Coexistence of Tehran University at Yazd, Center for Energy and Environment Research Studies of Azad University, Science and Research Branch, Tehran; and Institute for International Energy Studies of the Ministry of Oil, Tehran.

To compare the research and educational climate change activities of Iran with other countries, the priority research and educational activities of developed countries were also collected, the summary of which is presented below.

5.4.2. Results

The climate change activities of five ministries, over 70 universities and 40 research centers were surveyed. The results show that, more than 1,140 journal papers, 600 books, 200 projects and 1,100 theses have been written related to climate change fields in Iran.

In addition, the educational programs of education and research institutions in the area of climate change were surveyed. Results revealed that there are 642 courses at the Bachelor, MSc and PhD levels in engineering, agriculture, human science and natural science fields related to climate change. Table 5.14 shows some courses related to climate change which are taught for different degrees.

5.4.3. Recommendations

Assessing the results of this report reveals that, although a not insignificant body of work related to climate change has emerged in Iran during recent years, most of it focuses on the approaches to mitigation of climate change. Hence there remains a gap in research on development of methods to localize mitigation technologies. Capacity building for develement of local environmental friendly technologies and establishment of a national climate change technology research center is thus more than highly recommended but a clear and urgent necessity. On the other hand, the number of works accomplished in other areas of climate change such as; the scientific basis of climate change and impact and adaptation of climate change is very limited. There is also no dedicated educational program for climate change issues. In this regard, we propose an educational program that contains the courses that cover all three primary aspects of climate change mainly; the scientific base of climate change, the impact of and adaptation to climate change and the mitigation of climate change. Table 5.15 shows the principal items of the proposed climate change courses.

Considering the multidisciplinary nature of climate change issues as discussed above, it is necessary to insure tight-knit coordination among diverse areas of expertise. The NCCO has coordinated all national activities since 1998 by establishing several working groups in different areas of climate change to prepare national communications for UNFCCC. As a

Table 5.15: Proposed Climate Change Courses

Item	Topic	Sub-topics
1	The greenhouse effect and theory of human-induced planetary warming	• The greenhouse effect and planetary temperature • Blackbody radiation; terrestrial and solar radiation • Energy balance model and the natural greenhouse effect
2	The history of earth's climate	• A brief history of planet earth • Paleoclimate • Ice ages and role of the orbital and carbon dioxide
3	Climate trends during the 20th century	• The 20th century record of climate: global, regional, local
4	Climate variability and climate change	• Natural variability: El Nino, etc • Naturally induced changes: solar and volcanoes • Human induced changes: greenhouse gases and aerosols
5	Climate trends during the 20th century: Human or Natural?	• Climate models • Climate sensitivity and feedback • Attribution: Climate of the 20th century and the human impact
6	Projections of the future climate	• Emission scenarios: human factor impact: greenhouse gases and aerosols • Climate of 2100: global impacts • Climate of 2100: regional impacts (by continent) • Uncertainty in the projections (emissions and climate models)
7	Impacts of climate change	• Climate change and world food security: global issues • Climate change and world food security: case study • Climate change and marine ecology; global and case study • Climate change and terrestrial ecology; global and case study • Health and climate change • Climate change and water resources
8	Economy and climate change	• Socio-economic impact of climate change • Climate change and economic diversification • Integration of climate change in development plan
9	Energy, technology and climate change	• Mitigation and adaptation technology • Climate friendly energy technology • Environmental energy planning and policy assessment
10	Climate regimes	• Environmental law • International law • Climate regime and the Kyoto Protocol • Ethics of climate change

result, it has been proposed to the government that NCCO be responsibile for national coordination (see the chart below).

The ultimate objective of this report is to offer a program and an organizational chart to conduct research and education programs of climate change in Iran. Based on the previous works implemented by different institutions and the capabilities of these institutions, the following organization chart is recommended (Figure 5.10).

In this organizational chart, the Department of Environment acts as the head and coordinator, and other institutions are involved in three different aspects of climate change fields namely; the scientific base of climate change, the impact and adaptation of climate change, and the mitigation of climate change.

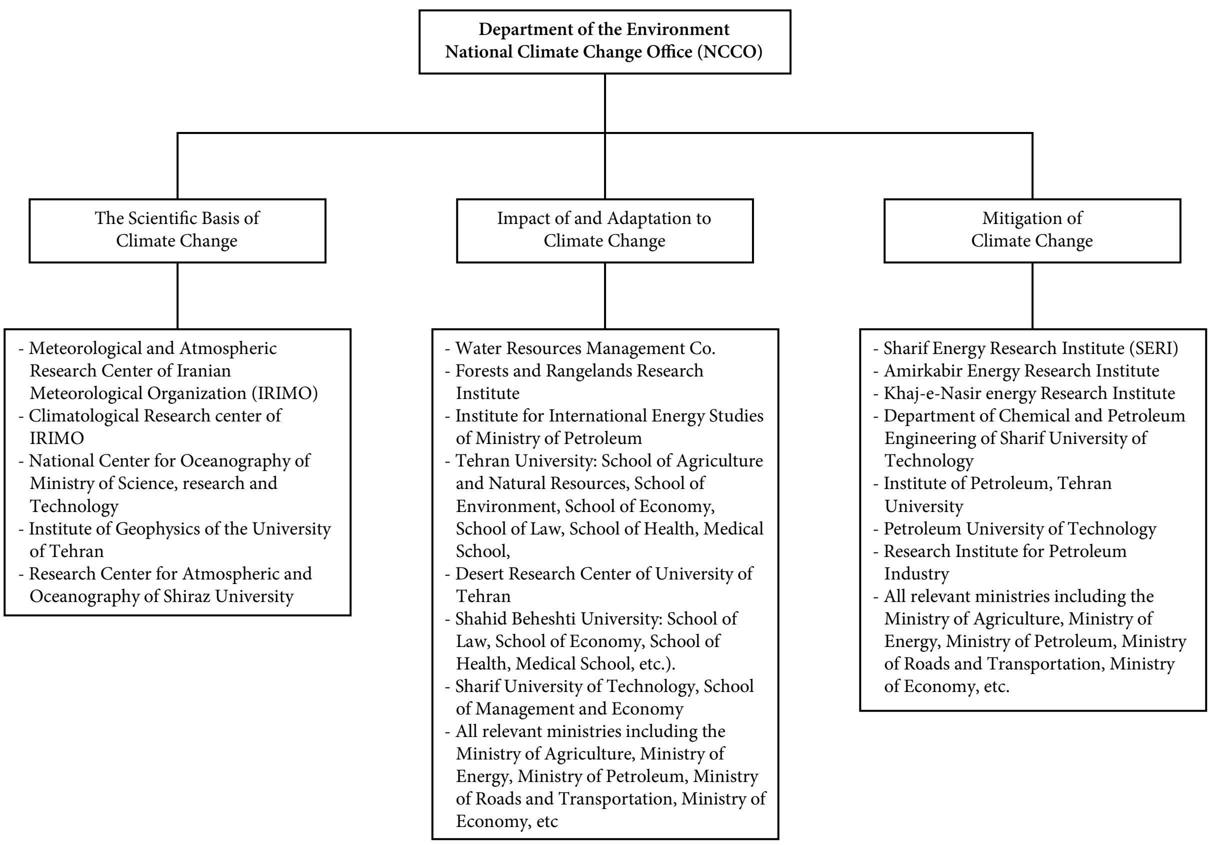


Figure 5.10: Proposed Organizational Chart of Iranian Research Center for Climate Change

Annex: Terms of Reference of the CBS Lead Centers for GCOS

- Monitor and evaluate the performance reports from the GCOS Monitoring and Analysis Centres and the listings of data held by the US NCDC, in conjunction with reference to the WMO weather station network and communication routing catalogues, in order to diagnose the quality, availability, and success or otherwise of communication, of climate data from the GSN and GUAN stations in the GCOS Lead Centre area of responsibility;
- Assist in correcting the anomalies in the routing of GSN data so that JMA and DWD monitoring centres receive the same output (e.g. JMA receives substantially less CLIMAT messages than DWD);
- Assist in improving coordination between various GCOS station lists,
- Co-ordinate activities with other CBS Lead Centres for GCOS as appropriate,
- Liaise with designated GCOS Focal Points in order to address issues identified with the availability and quality of climate data and its communication through the GTS,
- Receive information from GCOS Focal Points on any current and potential problems that might impact data availability and quality,
- Arrange to be included in the communication loop when WMO PRs contact WMO and GCOS regarding changes to GCOS stations (e.g. change from manual to automatic weather stations),
- Maintain the list of GCOS Focal Points in co-operation with the WMO Secretariat.

Lead Centre Areas of Responsibility

Current areas of responsibility and associated responsible NMHSs are:

- RAI northern parts (northern Africa); Moroccan Meteorological Service,
- RA II eastern parts, plus Malaysia, the Philippines, Singapore, Brunei; Japanese Meteorological Agency,
- RA II western parts; Iranian Meteorological Service,
- RA III (South America); Chilean Meteorological Service (MeteoChile),
- RA IV (North and Central America, Caribbean Islands and Hawaiian Islands); US National Climatic Data Centre,
- RA V (Southwest Pacific) less Malaysia, the Philippines, Singapore, Hawaiian Islands; Australian Bureau of Meteorology, National Climate Centre,
- RA VII (Antarctica); British Antarctic Survey.

Additional Lead Centres are planned for:

- RAI (central and southern Africa) ;probably Mozambique Meteorological Service and
- RA VI (Europe); probably Deutsche Wetterdienst, Udo Schneider.

Thus, the future division of areas of responsibility is expected to be:

- R A1a (northern Africa); Moroccan Meteorological Service:

Algeria. Egypt. Libya. Morocco. Mauritania. Sudan. Tunisia. Benin. Burkina Faso. Cape Verde. Cote d'lvoire. Gambia. Guinea. Guinea Bissau. Liberia Mali. Niger. Nigeria. Senegal. Sierra Leone. Togo. Cameroon. Equitorial Guinea,. Republic of Central Africa. Republic of Congo. Gabon. SSo Tome'-et-Principe. Chad and Madagascar.

- RA I b (central and southern Africa - Southern African Development Community [SADC] countries); most likely Mozambique Meteorological Service.

- RA Ha eastern parts, plus Malaysia, the Philippines, Singapore, Brunei and the Japanese Meteorological Agency, China, Mongolia, Japan, Malaysia, the Philippines, Singapore, South Korea, Myanmar, Laos, Thailand, Vietnam, Cambodia, Brunei

- RA II b western parts; Iranian Meteorological Service:

Afghanistan, Armenia, Azerbaijan, Bahrain, India, Iran, Jordan, Kazakhstan, Kyrgyzstan, Maldives, Nepal, Oman, Pakistan, Qatar, Russia, Saudi Arabia, Sri Lanka, Syria, Tajikistan, Turkey, United Arab Emirates, Yemen.

- RA III (South America); Chilean Meteorological Service

- RA IV (North and Central America) plus the Hawaiian Islands; US National Climatic Data Centre

- RA V (Southwest Pacific, including Australia, New Zealand, PNG, Indonesia) less Malaysia, the Philippines, Singapore; Australian Bureau of Meteorology

- RA VI (Europe); contact person/NMHS to be decided

- RA VII (Antarctica); British Antarctic Survey.

Article 50 of Islamic Republic of Iran's
Constitution Law:

Preservation of the Environment

Article 193.b of Islamic Republic of Iran's
5th Five Years Development Plan:

Greenhouse Gases and Air Pollutants Emission Control

National Regulation for
Implementing UN Framework Convention on
Climate Change and Kyoto Protocol

Rules of Procedure for Approval of
Clean Development Mechanism (CDM) Projects
under the Kyoto Protocol
by the Designated National Authority (DNA)
in the Islamic Republic of Iran

Chapter 6: National Strategies to Address Climate Change

6.1. Strategies and Action Plan

In this chapter, goals, strategies and an action plan are presented. At the outset the guiding principles governing the strategies and actions are introduced.

- ***Guiding Principles:***

By guiding principles, we mean the principles whose effects should be internalized throughout the process of decision-making on goal, strategies and action plan definition. This maintains integration and consistency across the planning process. Guiding principles also pinpoint the paradigm opted for. Three guiding principles were identified:

- Sustainable development is the paradigm for the climate change planning process,
- Global and regional cooperation is a necessary part of the management,
- Reinforcement of integrity in development plans and programs.

- ***Sustainable Development (SD) Paradigm:***

Many of the policies and actions that can protect us from the harmful impacts of climate change meet SD compatibility. Comprehensive management of water, sustainable agriculture, optimal fossil fuel consumption and pollution prevention are but a few of them. Fortunately, many of the climate change and SD policies and actions have been considered in our national and provincial development plans. Therefore, pursuing mitigation and adaptation strategies, indeed, proceed on the track of sustainable development.

- ***Global and Regional Cooperation:***

Although developed countries have engendered the outstanding share of climate change poor countries and regions are more vulnerable to its impacts. Nevertheless, all societies are experiencing and will experience its adverse impacts through different channels. In this respect all countries should share in confronting this common problem. The Middle East region wherein we reside will more likely experience a high degree of vulnerability. Hence both regional and international cooperation are of great importance.

In addition to utilization of scientific and technological findings, exchange of traditional knowledge is also an effective means of cooperation in arid and semi arid regions. However, technology transfer for mitigation is of utmost importance.

- ***Reinforcement of Integrity in Development Plans and Programs:***

While provision of a well-defined plan is very important, existence of consistency and homogeneity (integration) among those who implement is more essential. From a participatory viewpoint, since those who implement a plan, should engage in its preparation, more integration is called for. For an effective CCNSAP[1] , a variety of integration techniques should be employed. Substantive, methodological, procedural, institutional and policy integration are, in a sense, pivotal challenges. Therefore, realization of the action plan is bound entirely to development and strengthening of institutional arrangement both at the national and provincial levels.

1- Climate Change National Strategy and Action Plan

6.2. Vision

Our vision of interrelationship of climate change and sustainable development can be stated as:

> Prevention and control of negative socio, economic and environmental impacts of climate change through national integrated management and international and regional cooperation so that incorporation of necessary measures at the national and provincial development policy levels and other related measures, ensures sustainable development of the I.R.Iran.

It is recommended that the vision being incorporated into the following official documents:

- 2025 Development Vision of I.R.Iran,
- Macro Policies of the Country,
- 5th National Development Plan,
- All sector-strategic plans and policies.

6.3. Strategies

To realize the vision, the following strategies have been considered:

- Mitigation of GHGs,
- Adaptation to new climatic conditions,
- Promotion of climate compatible management.

- ***Mitigation of GHGs:***

Reduction of GHGs has twofold benefits for the country. It meets optimization of the fuel consumption on the one hand, and improves the international environmental status of the country on the other hand. This is the area that needs broad cooperation of the developed countries, principally in transfer of technology. Regarding our potentials for green energy, solar, wind and nuclear, Iran is also strongly obliged to reduce GHG emissions. In conjunction with technological improvements, utilization of solar, wind and nuclear energies can reduce the share of fossil fuels that were stated in detail before (see Chapter 3).

- ***Adaptation to New Climatic Condition:***

This strategy embraces all policies and plans which deal with development of the resource-based sectors. The broad outlines of this strategy can be observed in most of the national and provincial and sectoral development plans.

- ***Promotion of Climate Compatible Management:***

Due to the weaknesses of institutional arrangements both in the short and long terms, collaborative management is of great importance to implement the climate change action plan.

6.4. Action Plan

Table 6.1 outlines the action plan that has been originated and developed based on "The National Rules of Procedure for Implementation of the UNFCCC and Kyoto Protocol"; approved by the Cabinet in July 2009. This can be an efficient and effective starting point, but like any other plan needs to be reviewed and upgraded.

Table 6.1: Climate Change National Action Plan

Theme	Action	Strategy	Impact on [1]				Responsible Ministry/Org.	Cooperators
			D	P	S	I		
Establishment of Climate Change (CC) National Committee	Preparation of annual report on GHGs Emission	Mitigation	*				DOE	All members of committee
Members of CC national committee (Mitigation & adaptation)	Preparation of the mitigation policy within the framework of the operational domain	Mitigation	*				All members of committee	Secretariat
	Implementation of the approved programs for a 20 year vision	Mitigation & Adaptation	*		*	*	All members of committee	
	Provide Monitoring & Evaluation report to National Committee	Mitigation & Adaptation	*	*	*	*	All members of committee	Secretariat
Vulnerability & Adaptation	Identification of CC based traumas by sectors and geographical areas	Adaptation			*	*	Relevant ministries and organizations	Secretariat
	Establishment of GIS for vulnerable areas by sectors and integrated	Adaptation			*	*	Relevant ministries and organizations	Secretariat
	Compilation of programme on water consumption optimization in agriculture sector with emphasis on financial and executive mechanisms (to be approved by the Cabinet)	Adaptation	*	*	*	*	Ministry of Agriculture	Ministry of Energy
	Implementation of a few pilot schemes of the above mentioned programme	Adaptation						
	Preparation and approval of mechanisms for insuring those agricultural products which are more vulnerable	Adaptation			*	*	Ministry of Agriculture	Presidency Deputy on Strategic Planning and Supervision
	Complete the network of meteorological stations	Adaptation			*	*	Meteorological Organization	Presidency Deputy on Strategic Planning and Supervision

1)D: Driving Force; P: Pressure; S: State ; I: Impact

Required Capacities			Plan & Budget of	Indicators		First Year(will be filled by members of national committee)			
Individual	Organizational	System		Performance	Outcome	Projects	Spatial Distribution	Technological Requirements (Transfer)	Impact Assessment
	*	*	All members	Annual report	Incorporation into policies	**	**	**	**
*	*	*	All members	Mitigation policies	Approved mitigation policies				
	*	*	All members of committee		Reduction of emission & Adaptation of resource-based sectors				
*	*		All members of committee	M&E report	Modifications wherever needed				
*	*		Relevant ministries and organizations	Sectoral report	Sectoral GIS				
	*	*	Relevant ministries and organizations	Integrated GIS	Decision making support				
	*	*	Ministries of Agriculture and Energy	Programme	Reduction of water consumption				
						**	**	**	**
	*	*	Ministry of Agriculture	Insurance mechanisms					
	*	*	Meteorological Organization	Completion of network	More accurate and precise data				

***This column would be compeleted by organizations.*

Table 6.1: Climate Change National Action Plan (continued)

Theme	Action	Strategy	Impact on [1]				Responsible Ministry/Org.	Cooperators	Required Capacities			Plan & Budget of	Indicators		First Year(will be filled by members of national committee)			
			D	P	S	I			Individual	Organizational	System		Performance	Outcome	Projects	Spatial Distribution	Technological Requirements (Transfer)	Impact Assessment
Forest and rangeland	Preparation and implementation of the programme on identification and rehabilitation of poor rangelands in husbandry hubs of the country	Adaptation	*	*	*	*	Forests, Rangeland and Watershed Organization	Presidency Deputy on Strategic Planning and Supervision		*	*	Forests, Rangeland and Watershed Organization	Approval of the programme	Rehabilitation of rangeland				
	To reduce pressure from rangelands, it is allowed to lease 5% of area of the rangelands to the applicants(individuals and companies) for fodder cultivation	Adaptation			*	*	Forests, Rangeland and Watershed Organization	Presidency Deputy on Strategic Planning and Supervision		*	*	Forests, Rangeland and Watershed Organization	Number and the area of the leased rangeland	Amount of fodder				
	Increase the area of forest by 5% through forestation (Carbon sequestration)	Mitigation	*	*	*	*	Forests, Rangeland and Watershed Organization	Presidency Deputy on Strategic Planning and Supervision		*	*	Forests, Rangeland and Watershed Organization	Site selections	Increase by 5 %				
Water	At least 50% of income from issuance of license for well and water harvest in restricted underground water areas spent for artificial feeding of the aquifers. Annual performance report is presented to National Committee	Adaptation			*	*	Ministry of Energy	Presidency Deputy on Strategic Planning and Supervision		*		Ministry of Energy		Rise of the water level of aquifers	**	**	**	**
	Preparation and implementation of comprehensive programme of identification, conservation and outfitting of drinking water aquifer to be used during drought period	Adaptation	*	*			Ministry of Energy	Ministry of Jihad Agriculture, Interior Ministry		*	*	Ministry of Energy	Selected sites and annual targets	Situation of the selected aquifers				
	Review of comprehensive plan of water resources management with respect to climate change in two years	Adaptation	*	*			Ministry of Energy	Relevant members of National Committee		*	*	Ministry of Energy and pertinent members of national committee	Process of review	Revised plan				
Coastal area	Review regulations and criteria of site selection of regional and urban establishments and facilities coastal areas based on the their vulnerabilities toward the water level rising	Adaptation			*	*	Ministry of Housing and Urbanization	Members of National Committee		*	*	Ministry of Housing and Urbanization and members of national committee	\Process of consultation	Revised regulations and criteria				

Table 6.1: Climate Change National Action Plan (continued)

Theme	Action	Strategy	Impact on [1]				Responsible Ministry/Org.	Cooperators	Required Capacities			Plan & Budget of	Indicators		First Year(will be filled by members of national committee)			
			D	P	S	I			Individual	Organizational	System		Performance	Outcome	Projects	Spatial Distribution	Technological Requirements (Transfer)	Impact Assessment
Health	Identification of all adverse effects and harmful impacts of climate change on public health recognition of the regions prone to breakout of diseases and compilation of the programme to prevent the outbreak and treatment of the diseases	Adaptation			*	*	Ministry of Health and Medical Education	-		*		Ministry of Health and Medical Education	Final report	Implementation	**	**	**	**
Food	Construction of the new granaries and proper warehouses to maintain strategic agricultural products	Adaptation				*	Ministry of Trade	Ministry of Jihad Agriculture Presidency Deputy on Strategic Planning and Supervision		*	*	Ministries of Trade and Jihad Agriculture	Sites, kinds and number of granaries and warehouses	Enough capacity				
Economy	Preparation of strategies for diversification of national economy with emphasis on reduction of vulnerability from CC (in two years)	Adaptation			*	*	Presidency Deputy on Strategic Planning and Supervision	National Committee		*	*	Presidency Deputy on Strategic Planning and Supervision	Strategic Plan	Its approval				
	Compilation and approval of current, medium and long terms hydrocarbons balance for macro planning of economic activities	Mitigation			*		Ministries of Petroleum and Energy	National Committee			*	Ministries of Petroleum and Energy	The report	Using the results in economic activities				
	Identification of the development of value added in the lower-hand gas and oil industries	Mitigation	*	*	*	*	Ministries of Petroleum	Presidency Deputy on Strategic Planning and Supervision			*	Ministries of Petroleum	Report	Industries with more value added				
Education, Research and awareness raising	All educational and research centers under Ministries of Science, Research, and Technology, and Health and Medical Education are bound to allocate 5% of their research fund to the R&D on climate change impacts	Mitigation and adaptation	*	*	*	*	Ministries of Health, Treatment and Medical Education and Science, Research and Technology	Presidency Deputy on Strategic Planning and Supervision		*	*	Ministries of Health, Treatment and Medical education and Science, Research and Technology	Kinds and number of researches	Effectiveness of the results	**	**	**	**
	National Committee is bound to produce 60 hours awareness raising audio and visual products to be broadcast by radio and television	Institutional	*	*	*	*	National Committee	Ministry of Culture and Islamic Guidance		*	*	National Committee	60 hours programme	Effectiveness of the programme				
	All R&D activities of industrial companies which address emission reduction are tax exempt	Mitigation	*	*	*	*	Ministry of Economic and Financial Affairs	-			*	Ministry of Economic and Financial Affairs	Enactment of regulation	Effectiveness of regulation				

Table 6.1: Climate Change National Action Plan (continued)

Theme	Action	Strategy	Impact on [1]				Responsible Ministry/Org.	Cooperators	Required Capacities			Plan & Budget of	Indicators		First Year(will be filled by members of national committee)			
			D	P	S	I			Individual	Organizational	System		Performance	Outcome	Projects	Spatial Distribution	Technological Requirements (Transfer)	Impact Assessment
Education, Research and awareness raising	To formulate general programme of education and awareness raising, all members (ministries and organizations) of National Committee present their programme for their scope of activities	Mitigation and adaptation	*				Members of National Committee	Secretariat		*	*	Members of National Committee	Educational programme	Its effectiveness				
Technological needs	All members of National Committee will submit the reports on technological needs both on mitigation and adaptation in a year. National Committee will integrate the reports and declare technological requirements to GEF through national focal point	Mitigation and adaptation	*	*	*	*	National Committee	Members of national Committee		*	*	Members of National Committee	Lists of technological needs	Provision of technological needs				
	To support construction of renewable resource based power plant, Central Bank will provide low interest rate loan to applicants	Mitigation	*	*	*	*	Central Bank	National Committee		*	*	Central Bank	Number of applications	Number of power plants	**	**	**	**
	All industrial machineries imported through technical and financial capacity of international and regional bodies, as clean technologies, with endorsement of National Committee, exempt from customs tariff	Mitigation	*	*	*	*	Customs	National Committee		*	*	Customs	Kinds and quantity	Their impacts				
CDM	Promotion of CDM projects through removal of existing barriers	Mitigation	*	*	*	*	DOE (national focal point)	National Committee		*	*	Pertinent ones	Number of projects	Their impacts				
	Excluding CDM projects from Economic Commission approval// Import of equipments and machineries for these projects are free	Mitigation	*	*	*	*	DOE (national focal point)	National Committee		*	*	Pertinent ones	Number of projects	Their impacts				
	Annual evaluation report to National Committee	Mitigation	*				DOE (national focal point			*	*		Number of projects and their impacts	Promote international cooperation	**	**	**	**

Table 6.1: Climate Change National Action Plan (continued)

Theme	Action	Strategy	Impact on [1]				Responsible Ministry/Org.	Cooperators	Required Capacities			Plan & Budget of	Indicators		First Year(will be filled by members of national committee)			
			D	P	S	I			Individual	Organizational	System		Performance	Outcome	Projects	Spatial Distribution	Technological Requirements (Transfer)	Impact Assessment
Regional and international cooperation	All ministries and organizations that cooperate in pertinent bilateral, regional and international agreements and treaties, present periodic performance report, including activities, cooperation opportunities, barriers and recommendations to national committee	Institutional	*				National Committee	All governmental institutions		*	*	All governmental institutions	Number of reports	Kinds of cooperation opportunities, barriers and recommendations to broaden cooperation				
	Propose allocation of loan and facilities for climate change activities by Islamic Development Bank	Institutional	*				Ministry of Economic and Financial Affairs	National Committee		*	*	Ministry of Economic and Financial Affairs	Propose to IDB	Adoption of the proposal				
Monitoring and Evaluation	Preparation and approval of comprehensive programme of monitoring system of climate change including extant and needed capacities and spatial and temporal coverage	Mitigation/ Adaptation	*				Meteorological Organization	National Committee	*	*	*	Meteorological Organization	Approval of comprehensive programme	More accurate and precise data				
	Annual report on activities to strengthen monitoring network concerning whether, water resources, coastal and internal areas	Mitigation/ Adaptation	*				Meteorological Organization	National Committee		*	*	National Committee	Annual Report	Next step				
	Examination and registration of annual fluctuations of Persian Gulf, Oman and Caspian seas water level and its impacts (land use change, ecological and biological change…)	Adaptation	*	*			Port and Shipping Org.	National Committee		*	*	Port and Shipping Org.	Annual Report	Needed measures	**	**	**	**

6.5. Institutional Arrangement for Implementation of Action Plan

The cabinet has approved the "The National Rules of Procedure for Implementation of the UNFCCC and Kyoto Protocol" on climate change in July 2009 that provides a good path for implementation of strategies and the action plan. However, its organizational arrangement is not at a high enough level so that it may not be effectively implemented. A Working Group, led by DOE, has been introduced to undertake responsibility for coordination and implementation of the strategies and action plan under the approved Rules of Procedure. Despite this shortage, it includes many principal policies and actions including:

- Strengthening the institutional arrangements for the implementation of the climate change Rules of Procedure,
- Establishment a systematic approach for preparation of the national GHGs inventory,
- Development of GHGs mitigation policies,
- Provision of adaptation programmes,
- Development of educational and research programs,
- Assessment and acquiring the technologies for mitigation of and adaptation to climate change,
- Enhancement of the national capacity for climate change observation systems,
- Active participation in international and regional cooperation.

It thus brings about both regulations and the organization required for the implementation of the climate change issue by providing the necessary institutional support and coordination. Nevertheless, the rules of procedure have not been yet put into full operation.

Considering the close relationships between mitigation and adaptation policies and actions and the national development policies and action, the twin aspects of institutional arrangement and law require the engagement of a higher level of decision making. Based on the diagram shown in Figure 6.1 below, the High Council for Environment, which is presided over by the President and 10 Ministers and institutions as its members, is sufficient for the political, administrative and technical support of the implementation of the National Rules of Procedure. It also can prop up integration of climate change in the national and provincial development plans. Under supervision of the High Council, a National Committee takes on the responsibility for implementation of strategies and the action plan on climate change. The National Committee consists of the deputies of the following ministries and organization:

- Department of Environment (Head and Coordinator),
- Agricultural Ministry,
- Industries and Mines Ministry,
- Energy Ministry,
- Road and Transportation Ministry (Meteorological Organization),
- Foreign Affairs Ministry,
- Petroleum Ministry,
- Ministry of Science, Higher Education and Technology,
- Presidency Deputy of Strategic Planning and Supervision,
- State Ministry (Ministry of Interior).

The rest of the organizational chart consists of two inter sector layers and a sectoral layer. Integrated working group and five thematic groups carry out coordination and cooperation among sectoral work groups. The inter-sector layer should ensure that policies and projects are moving toward climate change mitigation and adaptation of development activities to the impacts on climate. It also should inform development decision-making processes of the possible climate impacts by province and region. The whole process, especially between development decision-making processes and the proposed body needs a clear-cut division of responsibilities and interaction.

Another important issue pertains to the regional and provincial roles that need to be dealt with at National Committee. It seems that the most appropriate place for undertaking management of climate change impacts at the regional level are the Provincial Development Councils.

From a regulatory point of view, incorporation of climate change considerations into the 5th National Development Plan strengthens the status of CCSAP, the process of the incorporation of the climate change considerations into the 5th National Development Plans currently in progress.

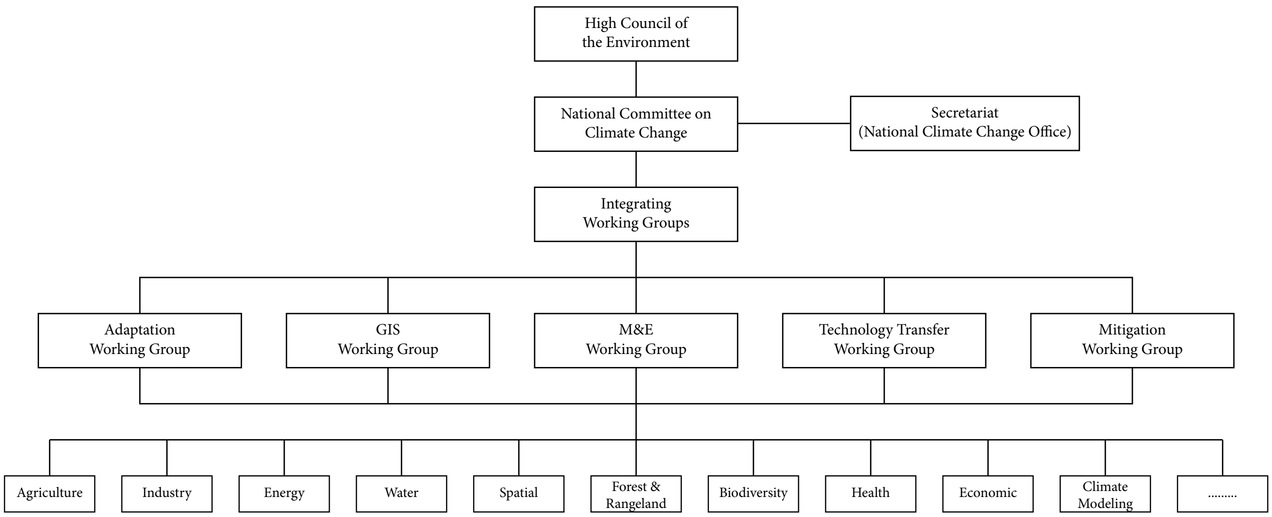


Figure 6.1: Proposed Organizational Chart for Climate Change Integrated Management

Abbreviations & Units

Abbreviation and Units:

Abfa	Stands for Water and Wastewater Company
AD	Activity Data
AEs	Anode Effects
AHP	Analytic Hierarchy Process
APERI	Agricultural Planning and Economic Research Institute
AVHRR	Advanced Very High Resolution Radiometer
BAU	Business As Usual
BDS	Basic Design Study
BLS	Baseline Scenario
BOE	Barrel of Oil Equivalent
C&I	Criteria and Indicators
C_2F_6	Hexafluoroethane
$CaCO_3$	Calcium Carbonate
CBOs	Community Based Organizations
CBS	Commission for Basic Systems
CCD	Charge-Coupled Device
CCNSAP	Climate Change National Strategy and Action Plan
CCSAP	Climate Change Strategy and Action Plan
CDM	Clean Development Mechanism
CEP	Caspian Environment Program
CF_4	Tetrafluoromethane
CFBC	Circulating Fluidized Bed Combustion
CFCs	Chlorofluorocarbons
CH_4	Methane
CHP	Combined Heat & Power
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COP	Conference of Parties
CRED	Centre for Research on the Epidemiology of Disasters

CSL	Caspian Sea Level
CSOs	Civil Society Organizations
CSR	Cruise Summary Reports
CTD	Conductivity Temperature Depth
DCP	Data Collection System
DOC	Degradable Organic Carbon
DOE	Department of Environment
DOM./COM.	Domestic and Commercial Buildings
DWD	The Deutscher Wetterdienst (German weather forecasting service)
ECHAM4	European Center/Hamburg Model 4
EEZ	Exclusive Economic Zones
EF	Emission Factors
ETM	Enhanced Thematic Mapper (LANDSAT)
EU	European Union
FAO	United Nations Food and Agriculture Organization
F_{AW}	Fraction of Animal Wastes
F_{BN}	Fraction of Biological Nitrogen-fixing Crops
F_{CR}	Fraction of Crop Residue
FGDS	Fundamental Geographic Data Set
FOD	First Order Decay
FRWO	Forest, Range and Watershed Management Organization
F_{SN}	Fraction of Synthetic Fertilizer
FYDP	Five-Year Development Plan
GCM	General Circulation Model
GCOS	Global Climate Observation System
GCRMN	Global Coral Reef Monitoring Network
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHGs	Greenhouse Gases
GLOSS	Global Sea Level Observing System
GNP	Gross National Product
GOOS	Global Ocean Observing System

Gov.	Government
GSI	Geological Survey of Iran
GSN	Global Surface Network
GTS	Global Telecommunications Society
GUAN	Global Upper-air Network
GWP	Global Warming Potential
HadCM2	Hadley Center Unified Model 2
HFCs	Hydrofluorocarbons
ICAM	Integrated Coastal Area Management
ICARDA	International Center for Agricultural Research in the Dry Areas
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
IEA	International Energy Agency
IFO	Iranian Fisheries Organization
IKONOS	Stand for a Commercial Earth Observation Satellite
INC	Initial National Communication
INCO	Iranian National Center for Oceanography
IOC	Intergovernmental Oceanographic Commission
IODIE	International Oceanographic Data and Information Exchange
IPCC	Intergovernmental Panel on Climate Change
IRIMO	Islamic Republic of Iran Meteorological Organization
IRODC	Iranian Oceanographic Data Centre
IS92a-e	IPCC Scenario 92a-e
ISA	Iranian Space Agency
ISIPO	Iran Small Industries and Industrial Parks Organization
IWRM	Integrated Water Resources Management
IWWEC	Institute of Water and Wastewater Engineering Company
killed-mio. exp.	Killed Million Exposure
LARS-WG	Lars Weather Generator (A Stochastic Weather Generator for Use in Climate Impact Studies)
LEAP	Long-range Energy Alternative Planning Systems
LEO	Low Earth Orbit (Low Earth Orbit Telecommunication Satellite)

LFCCs	Low Forest Cover Countries
LFG	Landfill Gas
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
M&E	Monitoring and Evaluation
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MBOE	Million Barrels of Oil Equivalent
MCF	Methane Correction Factor
MDG	Millennium Development Goals
MFI	Meteo France International
MITD	Modernization and Information Technology Development Project
MODIS	Moderate Resolution Imaging Spectroradiometer
MOE	Ministry of Energy
MP	Mitigation Policies
MSW	Municipal Solid Waste
Mt.	Mountain
N_2O	Nitrous Oxide
NA	Not Available
NBSAP	National Biodiversity Strategy and Action Plan
NCC	National Cartographic Center
NCCO	National Climate Change Office
NCDC	The National Climatic Data Center
NE	Not Estimated
NG	Natural Gas
NGOs	Non-Governmental Organizations
NH_3	Ammonia
NMHS	National Meteorological and Hydrological Services
NMVOCs	Non-methane Volatile Organic Compounds
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NO_X	Nitrogen Oxides
NSESD	National Strategy for Ecologically Sustainable Development

NWP	Numerical Weather Prediction
ODP	Official Development Plan
OPEC	Organization of Petroleum Exporting Countries
P	Precipitation
PET	Potential Evapotranspiration
PFCs	Perfluorocarbons
PMO	Ports and Maritime Organization
PPP	Purchasing Power Parity
PRECIS	Providing Regional Climates for Impacts Studies
PV	Photo Voltaic
QFE	Atmospheric Pressure (Q) at Field Elevation
QFF	Atmospheric Pressure Converted to Mean Sea Level Elevation
QNH	Atmospheric Pressure (Q) at Nautical Height
R & D	Research and Development
RAM	Runoff Assessment Model
RBSN	Regional Basic Synoptic Network
RCS	Red Crescent Society
RFG	Recovery of Flare Gas
RIFR	Research Institute of Forest and Rangelands
Rls	Rials
ROPME	Regional Organization for the Protection of the Marine Environment
RTH	Regional Telecommunication Hub
SADC	Southern African Development Community
SAF	Store-and-forward
SANA	Stands for Iran's New Energies Organization
SCENGEN	SCENario GENerator
SCHP	Small Combined Heat and Power
SD	Sustainable Development
SEI	Stockholm Environment Institute
SERI	Sharif Energy Research Institute
SF_6	Sulfurhexafluoride
SFM	Sustainable Forest Management

SMMS	Spatial Metadata Management System
SNC	Second National Communication
SO_2	Sulfur Dioxide
SST	Sea Surface Temperature
SWDS	Solid Waste Disposal Site
T	Temperature
TAR	Third Assessment Report
TEMP	Temperature
TNA	Technology Needs Assessment
TPS	Tehran Processes Secretariat
UN	United Nations
UNCBD	United Nation Convention on Biological Diversity
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
V & A	Vulnerability and Adaptation
VICS	Vehicle Information and Transportation System
WCDMP	World Climate Data and Monitoring Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WRSB	Water Resources Survey Bureau

Units:

°C/y	Degree Centigrade Per Year
b	Billion
bcm	Billion Cubic Meters
bm^3	Billion Cubic Meter
BTU	British Thermal Unit
cm	Centimeter
Gg	Giga gram
GHz	Giga Hertz
GW	Gigawatts
ha	Hectare
hPa	HectoPascal
R	Infrared
kg	Kilogram
kg/yr	Kilogram Per Year
km	Kilometer
kt	Kiloton
KWh	Kilowatt Hour
lit/day	Liter Per Day
m	Million
m^2	Square Meter
m^3	Cubic Meters
mbd	Million Barrels Per Day
meters-d	Meters Per Day
million liter p-d	Million Liter Products Per Day
mm/y	Millimeter Per Year
MW	Megawatt
nb -year	Number Per Year
PJ	Peta Joule
PSU	Practical Salinity Unit
Tdm/ha	Ton of Dry Material Per Hectare

Thousand b-d	Thousand Barrel Per Day
TJ	Tera Joule
Ton/ca	Ton Per Capita
TWh	Terawatt Hours
VIS	Visible
WV	Water Vapor

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