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Islamic Republic of Iran

Department of Environment

Initial National Communication to UNFCCC

Islamic Republic of Iran

Initial National Communication
to
United Nations Framework Convention on Climate Change
(UNFCCC)

March 2003

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بسم الله الرحمن الرحیم

In The Name of God

Foreword

Inspired by Article 50 of its Constitution, the Islamic Republic of Iran is strongly bound to protect the environment for present and future generations. To participate in the international effort to mitigate global 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. Since the latter juncture, Iran has actively participated and played a key role in the Conferences of Parties (COPs). As the president of G77 and China during the year 2001, Iran spearheaded efforts at consensus-building during official international negotiations of COP6-II and COP7 of UNFCCC. 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.

Iran's National Climate Change Office was established in January 1998 under the auspices of the Department of Environment. Among other responsibilities, the Office has built national capacity to systematically address climate change issues. 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 for this Communication. A Steering Committee comprising of representatives from relevant ministries and organizations was formed to supervise and review the sectoral and final reports.

The experience of producing Iran's National Communication, being the first of its kind, has been difficult as the necessary capacity and the relevant expertise rarely existed prior to the inception of the process. In addition, in addressing uncertainties and constraints, inadequate data and information, and at times difficulty in locating and accessing data, had somewhat hindered the smooth implementation of the project. However, I am delighted that such barriers were, to some extent, surmounted and that given the inter-institutional coordination, Iran is on track to produce its cross-sectoral Strategies and Action Plan to deal with climate change.

Moreover, with the continued support of GEF, as well as other multilateral and bilateral financial and technical contributions, we shall extend our efforts to keep pace with the urgent need to address global climate change and prepare for the adverse eventualities.

Global climate change is a common threat to the future of humanity, which affects the developing countries disproportionately. The strong linkages between climate change and other issues of global concern necessitate an all encompassing and unflinching global effort. On the other hand, the inextricable linkages between sustainable development and climate change warrants the attention of the global community. We very much hope that the adverse impacts of the global climate change on realising sustainable development could be reversed and that together, we can tackle the political, regulatory, institutional and financial challenges in a spirit of goodwill and joint global action.

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

M. Ebtekar

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First and foremost, our sincere gratitude is extended to the late Professor Taghi Ebtekar who served as the National Project Manager until his demise in March 2001. His substantive scientific contribution and supervision, enthusiasm, and dedication were central to the preparation of Iran's Initial National Communication. He will always be remembered by colleagues at the Climate Change Office for the depth of his humanity and his effusive and affable personality.

We are very grateful to GEF for making this initiative possible, and to UNDP-GEF and the UNDP Country Office in Iran for their cordial support and technical assistance throughout. We also owe special thanks to UNITAR for organizing and delivering three training workshops.

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 (Jahad-e-Keshavarzi), Energy, Interior and Health for technically assisting the project and providing the requisite data. The Meteorological Organization of Iran, the Forest and Rangeland Organization, the Energy Research Institute of Sharif University of Technology and the National Centre for Oceanography deserve a special note of appreciation.

More than 50 specialists, members of scientific faculties at different universities in Iran, several international consultants, and senior experts at different ministries and organizations have cooperated with the 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 document is provided at the end of this report.

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Excecutive Summary

***Tokcheh Mountains, Kashan**; Photography: Kamran SATVAT-MANESH*

Introduction

The Islamic Republic of Iran signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992, at the Rio de Janeiro Earth Summit, along with more than 150 countries. With ratification of the Convention in June 1996, I.R. of Iran became an official UNFCCC member. This document, *Iran's Initial National Communication to the Convention,* has been prepared to meet the country's mandated commitment as a Non-Annex I Party to the Convention. This report has been organized based on available information and the guidelines provided by the Intergovernmental Panel on Climate Change (IPCC). Both the Executive Summary and the main report comprise of five parts namely:

1 National Circumstances
2 Greenhouse Gas Inventory
3 Greenhouse Gas Mitigation Policies
4 Vulnerability and Adaptation Assessment
5 National Proposed Strategies to Address Climate Change.

National Circumstances

The Islamic Republic of Iran lies in western Asia. In the north it is littoral to the Caspian Sea and borders Azerbaijan, Armania and Turkmenistan. It is contiguous with Turkey and Iraq to the west. In the south the country is littoral to the Persian Gulf and the Sea of Oman and abuts Pakistan and Afghanistan to the east. The principal and official language is Farsi (Persian). The population in 1994 (the base year) was about 57.7 million (now estimated at 72.0 million).

The area coverage of different types of climate in Iran is 35.5% hyper-arid, 29.2% arid, 20.1% semi-arid, 5% Mediterranean, and 10% wet (of the cold mountainous type). Thus more than 82% of Iran's territory is located in the arid and semi-arid zone of the world.

Temperature in the country is varied and thus the climate is classified as: 17% extra cold, 47% cold, 22% temperate, and 12% warm. The average rainfall in Iran is about 250 mm, which is less than 1/3 of the average rainfall in the world (860 mm). In addition, this sparse precipitation is also unfavourable with respect to time and location. Another important climatic element is extreme temperature changes that sometimes range from –20°C to +50°C.

Severe drought is also recognized as a feature of Iran's climate. In the last three years, the country has suffered severe desiccation and this lack of rainfall has resulted in extensive losses. It is estimated that damages in the amount of 55,873 billion Rials (approximately USD 7 billion) has been incurred in the water, agriculture, and livestock sectors alone. A total of 4,131.7 billion Rials has been expended to combat the impact of this wide-ranging drought and partially offset its damages.

Iran's gross domestic product amounted to 13,280 billion Rials in 1994-5 (at constant 1982/83 prices). The GDP further increased to 14,605 billion Rials in 1996-7. In 1994/95 the contributions of different sectors namely services, agriculture, oil, and manufacturing and mining to GDP were 42%, 21%, 19% and 18%, respectively.

National Greenhouse Gases Inventory

Iran's Climate Change Office has developed an inventory of both direct greenhouse gases (CO_2, CH_4, N_2O) and indirect greenhouse gases (NO_X, CO, NMVOC) for the base year 1994. The 1996 IPCC Revised Guidelines and default emission factors have been used for preparation of the inventory throughout this report because national emission factors in most sectors were not available. In addition, there is considerable uncertainty in the *Activity Data* for calculation of greenhouse gases (GHGs).

The total CO_2 emission from different sectors in 1994 was about 342,062 Gg, with the energy sector contributing about 84% of the total emission and industries and forests contributing about 7% and 9%, respectively. The total CO_2 equivalent greenhouse gas (GHGs) emission was estimated to be about 417,012 Gg in 1994. The energy sector contributed the greatest volume at 77% and the waste sector the lowest at 2%.

Regarding the contribution of different sectors to CH_4 emission, in 1994, the energy, agriculture, and waste sectors were responsible for about 62%, 25%, and 13% respectively. In fact, the fugitive emissions from oil and gas activities are major contributors to methane emission. Lack of financial resources, required technology, economic constraints in place against Iran, and the impact of the imposed war by Iraq are the outstanding reasons for delays in implementation of the projects leading to alleviation of these emissions.

The per capita annual CO_2 emission in Iran is 5.69 tons. Being an oil producing country, Iran emits large amounts of GHGs in the energy sector, which is associated with exploration and production of fuels and oil products that are mainly consumed in other countries. The comparatively high level of emission/GDP in Iran as a developing country reflects the need for access to more efficient energy technologies to reduce energy intensity.

National GHGs Mitigation Policies

Various measures are proposed for reduction of GHGs. These measures known as Mitigation Scenarios, are evaluated against the Reference or Baseline Scenario (BLS) that incorporates all the government's policy measures in the Third Five Year Development Plan (FYDP). The BLS includes the recovery of flare gases in the oil and gas sectors. Since the execution of the projects which lead to complete recovery of gases may *not* be possible due to technological and financial constraints, the BLS has *also* been defined using the designation *"without"* Recovery of Flare Gases (RFG).

GHGs Emission Trends in Baseline Scenario (BLS)

According to inventory statistics, about 83% of the total GHGs are emitted from the energy and industrial processes sectors that include power plants, oil and gas, transport, agriculture and other energy consuming industries. The remaining volume or some 17% of the total, is generated from non-energy sectors including forest, agriculture, and waste sectors. Relevant indicators forecast that the GHGs emission in energy and industrial processes in the Baseline Scenario "with" recovery of flare gas (RFG) will increase from 337,525 Gg in 1994 to 639,614 Gg in 2010; indicating an annual rise of 5%. However, if the programmes for recovery of flare gas could not be implemented by the government, the total GHGs emissions by 2010 would be 817,449 Gg. The amount of total GHGs emission in all sectors is estimated to witness an upsurge from 417,012 Gg CO_2 equivalent in 1994 to 752,156 Gg CO_2 equivalent in 2010.

GHGs Mitigation Assessment

Iran has high potential for alleviating the amount of GHGs emission. In the energy sector, the principal policies being pursued are clean and efficient power generation, environmentally friendly refineries, improved vehicle and public transport and energy-efficient buildings and appliances. Similarly, in the non-energy sector, reduction strategies include modern farm and livestock management, protection of forestlands and other natural resources, plus control and treatment of wastewater, disposal management and recycling of solid wastes.

Energy Sector

✧ Improving Energy Efficiency

Enhancing energy efficiency has proved to be the most economical option for reducing emission of GHGs. According to a study carried out by Sharif Energy Research Institute (SERI), energy conservation potential is estimated to be 31% in the year 2021. Realization of this potential would have a tremendous effect on the emission of CO_2. By rational use of energy, accompanied with changes in the fuel mix, it would be possible to reduce the average annual growth rate of CO_2 emission from 4.2% to 2.4% in the period 1999-2021.

Energy efficiency mitigation options, include increasing the share of the combined cycle power generation in power plants, defining better standards for energy consumption in domestic and commercial buildings, mandating the use of energy labels for domestic manufacturing of home appliances and improving vehicle technology.

✧ Fuel Switching

By switching from liquid fuels like gas oil or heavy oil to natural gas, the amount of CO_2 emission from thermal power plants will be reduced from 89.4 million tons in 2000, to 83 million tons in 2005, a decline of 7.2%. Increasing the share of natural gas and LPG in the fuel mix consumed by petroleum refineries, in residential and commercial buildings and in the transportation sector through conversion of public vehicle fuels to CNG and LPG are the most important policy recommendations.

✧ Flare Gas Recovery

Flare gas recovery for oil well injection purposes and the development of GTL (Gas-to-Liquid) technologies and petrochemical products such as OCM (Oxidative Coupling of Methane) and DMC (Dimethyl Carbonate) can also make an important contribution to GHGs emission reduction, if the government's plans for flare gas recovery are implemented. This reduction could amount to as much as 200,000 Gg in 2005, and 400,000 Gg in 2010 (see Figure 3.16).

Use of Clean and Renewable Energy Resources

Government has taken positive measures for the development of renewable energy sources. These include solar and wind energy, geothermal, wave and tidal energy, hydrogen energy, hydropower and nuclear energy. Each category has high potential for practical exploitation in Iran. The capacity of hydro, geothermal and nuclear energies in power generation will increase respectively to 7,700 MW, 1,200 MW and 1,000 MW by the end of the third FYDP, i.e. 2004.

Non-energy Sector

The non-energy areas i.e. agriculture, forestry and waste sectors have a rather small share in GHGs emission compared with the energy sector. By implementation of the proposed mitigation policies, GHGs emissions in the non–energy sector will be reduced from 112,542 Gg to 70,424 Gg in 2010. The major mitigation polices in these sectors include increasing ruminant productivity, improving rice cultivation techniques, and management of agriculture residue in the agriculture sector. Afforestation, reforestation of forest, driving livestock from the forests and switching from wood to fossil fuel in the forestry sector are also important policies. Other measures include management of solid waste disposal and recovery of CH_4 from landfill in the waste sector.

Overall Mitigation Assessment

Mitigation policies in the energy sector are crucial to Iran's overall policies. Emission of GHGs can be reduced from 639,614 to 489,822 Gg CO_2 equivalent in 2010 by implementing the policies proposed for the energy sub-sectors. If the government's plans for recovery of flare gas are not put into effect, considering gas injection into oil wells as a mitigation policy, GHGs reduction by 2010 will be about 330,627 Gg CO_2 equivalent. Enhancing energy efficiency, including combined cycle power generation, has proved to be the most economic option for GHGs reduction in energy sector.

At present renewable energy sources represent a low share and high cost in electricity production in Iran. Hence the main options should focus on fuel switching, hydropower, combined cycle, cogeneration and nuclear energy. Once the political obstacles hindering the building of nuclear power plants in Iran are removed, such facilities will become an effective alternative for GHGs mitigation in the country's energy supply industry.

Both fuel switching and energy efficiency improvement methods are recommended for cement and particularly the iron and steel industries. The rate of capital return in implementing energy efficiency and fuel switching, are 70% and 50% for cement and 134% and 182% for the iron and steel industries, respectively. Significant measures have been proposed to reduce the GHGs emissions from the transportation sector in Iran. These procedures constitute a mitigation program package that focuses on improved vehicles, increasing public transport, production of higher quality fuels and promotion of rail transportation for both passengers and cargo.

By implementation of the overall aggregated policies, the amount of GHGs emission will be reduced from 752,150 Gg to 560,791 Gg by the year 2010. In that year, the contribution of power plant and transport sectors to the total GHGs mitigation will be 32% and 20%, respectively; whereas forestry and agriculture sectors will contribute 7% and 6%, respectively. The downward shift in the rate of emission from oil and gas activity in the mitigation program from 18% in 2005 to 5% in 2010, indicates that the government shall have used environmentally sound technologies; whereas in the forestry and land-use sector, the reduction in the mitigation share indicates that more efficient policies should be practiced.

Vulnerability and Adaptation Assessment

Vulnerability and adaptation of the country to climate change are evaluated from two points of view. First, the "*direct*" adverse impacts of climate change are considered. Here, issues such as precipitation and temperature patterns, water resources, sea level rise and coastal zone, agriculture and food production, forestry, drought frequency and intensity, human health, etc. are reviewed. The second perspective includes the "*indirect*" adverse economic impacts that will result from the response measures taken by the developed countries.

Assessment of Direct Adverse Impacts of Climate Change

Temperature and Precipitation

To provide an insight into what will happen if the GHGs emissions issue is not properly managed, six scenarios have been designed. These scenarios were selective combinations of two GCMs (HadCM2 and ECHAM4) models, three emission scenarios, and three different climate sensitivities. Low emission combination resulted in an increase in temperature ranging from 1° to 1.5° C. Changes for the second combination range from 2.5° to 4.1° C and the third combination resulted in an increase in temperature ranging from 5.9° to 7.7° C.

The same patterns were used to portray precipitation variations in the country. The resulting fluctuations appear in the following ranges:

- -11% to 19.1% of the baselines for low emission rate,
- -30.9% to 50% of the baselines for medium emission rate, and
- -58% to 80% of the baselines for high emission rate.

Water Resources

Research on the global warming effects on hydrology and water resources in Iran has been undertaken on several rivers and lake basins by using historical hydro-meteorological data and runoff models in combination with the global warming scenarios. The result of historical runoff data surveys collected at 398 hydrometric stations shows that the Flood Index has changed in 47% of them. In addition, the De Marathon method has been applied to analyse the data related to climatology stations with a long statistical history. The result shows that of the 600 stations studied, 68 indicate climate changes during this decade (1990-2000).

The long-term runoff model applied to 30 basins shows that the temperature rise increases the runoff volume during winter and decreases it during spring as rising temperature melts snowfall into rain and hastens the time of snow melt. It also indicates that temperature increase affects runoff of basins and decreases the amount of runoff variation of rainfall.

Agriculture

The predicted increase in temperature due to global warming may lead to spikelet sterility in rice, loss of pollen viability in maize, reversal of vernalization in wheat and reduced formation of tuber bulking in the potato for the areas near the threshold. The changing climate will affect wheat, which is the main staple crop. The historical data indicates that as a result of drought and reduction of rainfall, wheat production will be sharply reduced.

Losses inflicted by the 1998-1999 droughts on wheat production nationwide are estimated at about 1,050,000 tons of irrigated wheat and 2,543,000 tons of rain-fed wheat. The figures indicate that agricultural areas are highly vulnerable to climate change.

Forestry and Land Use

Climate change has a profound impact on the forestry sector. This includes changing the habitat location of forest species (SPP), especially the less tolerant ones and the extinction of low tolerant SPP. The natural regeneration regime of forest plants is upset and results in the reduction of wood and non-wood production in forests. Forests witness pests and plant disease infestation and an intensification of land erosion, particularly in arid and semi-arid zones. Sea-based mangrove forests are degraded and sometimes destroyed because of the rise in sea level in the Persian Gulf and Sea of Oman.

Environmental conditions for wildlife in forest areas decline sharply as does forage production in rangeland, which can in some cases signal the onset of desertification. Soil erosion is the natural result of destruction of plant cover and all such conditions are exacerbated by high temperature and aridity. One social consequence of this environmental downgrading is population migration because of ecological insufficiency.

Coastal Zones

The northern part of Iran is a centre of agricultural production. The southern region is home to the energy industry and hence oil installations and energy exports. The nation's largest ports for export of goods are also located in the south. These characteristics of both north and south define Iran as being vulnerable to climate change impact.

According to the 10-year hourly recorded data in three sites (Chabahar, Bandar Abbas and Bushehr), the mean sea level in the Persian Gulf and Sea of Oman has been rising at an average value of 4.5 mm/yr which agrees with the IPCC 1995 scenario. The impact of temperature and sea level rise namely: coastal erosion in the north and south; inundation of low lands such as the Miankaleh peninsula and Gorgan Bay; mass bleaching of the coral reef, salt water intrusion caused by flooding and inundation are all outstanding instances of the vulnerability of Iran's northern and southern coastal zones.

From a socio-economic point of view, climate change has a great adverse impact on the availability of fresh water in these regions. Saltwater intrusion both into surface water and groundwater are the most important issues, particularly in the Karun River system, which is the main source of drinking water for the population centres of more than one million people and has been subject to salt water intrusion caused by sea level rise combined with a low river flow.

Health

Climate change will cause direct adverse health effects. Global warming is expected to lead to more cardiovascular, respiratory, and other diseases. In particular, one of the major vector born tropical diseases is Malaria, which is prevalent in different provinces of Iran. The research on the exposure rate to Malaria from 1982 to 1998 indicates that the trend cases of those infected are on the rise.

Energy and Industrial Processes

Reduction in efficiency of thermal power plants, decrease in hydropower production resulting from lower water level in dams, destruction of coastal and offshore oil, gas and petrochemical installations in southern coastal zones caused by severe sea storms are the significant impact of climate change. It is estimated that global warming causes an increase in electricity demand of about 20,000 MW in the next 50 years.

Assessment of the Impact of the Response Measures on Iran's Economy

A summary of the findings of an objective study conducted through a sophisticated General Equilibrium Model called MS-MRT (Multi Sector-Multi Region Trade), developed by Charles River Associates, is used in this report. The model presents a quantification of the impact on the Iranian economy as a result of the policies and measures to be implemented in Annex B countries to meet their Kyoto Protocol targets. The study has been conducted on a scenario basis, with the assumption that the United States is either participating in or withdrawing from the Kyoto Protocol.

Compared to the results obtained when full participation of Annex B countries is assumed, there are significant reductions in the impacts of Kyoto Protocol implementation on crude oil prices and on Iran's economy when the USA withdraws from the Kyoto Protocol. World crude oil prices decrease at a lower percentage, ranging from 2.1% to 4.3% between 2010 and 2030 while they actually increase in the "*Tax Cut Scenario*".

The results from the model show that under the "*No Flexibility Scenario*" and with the US participation, Iran will suffer a loss of USD 6.3 billion in oil revenue and a 3.1% decline in overall social welfare in 2010. The cash compensation required to offset the losses amounts to USD 79 billion. The losses in oil revenue and welfare, however, are reduced significantly to USD 1.2 billion and a 0.7 drop in welfare without the US participation. The cash compensation required to offset losses, therefore, is reduced to USD 20 billion.

Under the "*Tax Cut Scenario*" and with US participation in the Protocol, Iran's losses in oil revenue and welfare will amount to USD 3 billion and 1.76% reduction in social welfare, respectively. Cash compensation required to offset losses, then, amounts to USD 45 billion. Without US participation, however, the losses are reduced to USD 1.6 billion 0.40% in living standards, respectively, and no compensation is required.

Under the "*Flexibility with CDM Scenario*" with US participation, Iran would suffer a loss of USD 4.5 billion in oil revenue and a -2.22% change in welfare. That would require compensation of USD 57 billion. When the US is not participating, the losses in oil revenue and welfare are reduced to USD 0.9 billion and a -0.52% change in social welfare, respectively. The compensation required then amounts to USD 17 billion.

Terms of Trade Impact

There are four important changes in terms of trade that account for spillover effects:

- Imports from adopting Annex B countries will rise in price due to higher energy costs;
- Energy exports will change in price because of changes in demand. In scenarios without reductions in existing taxes on Refined Petroleum Products (RPPs), crude prices will decline because of a drop in demand. But if existing taxes on RPPs are reduced, then the price of crude exports will increase with demand while the price of coal exports will fall with the decline in demand;
- Exports of less energy intensive goods to adopting countries will fall in price because of a drop in demand for all imports by the adopting countries; and
- Exports of energy intensive goods from all countries will rise in price.

These variations in terms of trade will lead to wealth transfers among countries, the largest share in the loss of wealth in this trend will be borne by oil-exporting non-Annex B countries. Annex B countries benefit from the lower price of oil in the world markets, and also receive higher prices for their exports to non-Annex B countries.

Adaptation Policies

Major adaptation policies, combined with proposed mitigation measures, are presented in the national strategies contemplated to address climate change as follows.

Proposed National Strategies to Address Climate Change

The proposed "National Strategies" presented here contain a collection of issues at the national level without identifying their priority and importance. This report presents only a preliminary "*conceptual*" action plan, requiring subsequent extensive studies and effort in order to prepare the "National Action Plan" which can then be incorporated into future national development plans.

In addition, the proposed actions in various disciplines could be categorized in different combined themes like education, public awareness, capacity building, public participation, financing, legislating regulations, investment, etc. In addressing the uncertainties and for preparation of a National Action Plan, the following issues must be assessed:

1 The actions must appraise the on-going national activities and identify gaps, which could improve the understanding of processes that influence and are

influenced by climate change on a national scale. This relates specifically to the impacts on economic development as well as on agriculture, water resources, forests, human health, coastal zones, floods, droughts, and biodiversity.

2 Improving the existing climate observation system by expanding the number of functioning stations nationwide. This would also serve as a positive contribution to the global atmospheric observation system and enhance the development, utilization and accessibility of databases worldwide.

3 Development of early detection systems focusing on changes and fluctuations in climate, especially drought. There is a clear need to establish new facilities and upgrade present capabilities to predict such alterations and shifts and assess the resulting environmental and socio-economic consequences. The areas of immediate concern should concentrate on fresh water supply and water quality changes for drinking and agriculture, food security, human health, burning of forests and range lands, damage to the terra firma in general, sensitive coastal areas and aquatic bio-resources, especially valuable species.

4 Improvement of the existing national mechanisms in building of scientific capacity is a must. Also, the exchange of scientific data and information among national institutions and international organizations is needed. Training of experts and technical staff in the field of research, data acquisition, collection and analysis, and systematic observation related to the atmosphere is another capacity building initiative required. This latter could be initiated through a well-defined national data and information management and exchange system.

For promoting *sustainable development* with climate change considerations, the following policies are recommended:

Energy transformation:

It is necessary to integrate energy resource planning and upgrade the existing research, development, transfer and use of technologies and practices for environmentally sound energy systems. Concerning *supply side management* (SSM), the implementation of policies that would include co-generation and combined cycle power plants, fuel switching, introducing renewable and hydro resources, generating electricity in oil fields (Well-to-Watt) and the recovery of associate gas in oil fields are proposed.

For demand side management (DSM) in industries, transport and agriculture sectors, a host of policies are recommended. These include promoting the efficient use of materials and resources in industries through the expedient of compiling an energy management code of practice and encouraging factories to obtain the ISO 14000 certification.

Incentives are also needed to promote auditing programs, to support the advance of less polluting and more efficient technologies and processes in industries and to develop national energy efficiency and emission standards. New legislature and the introduction of exponential tariffs for high consumption rate consumers are also considered necessary.

Transport system needs a thorough evaluation with the greatest emphasis placed on the most populated cities (such as Tehran). Establishing cost effective, more efficient, less polluting and safer transport systems and rationalizing urban traffic and transportation management are essential. This can be achieved in part by upgrading public transport, compiling a transport code and standardizing parking regulations. Other policy measures include utilization of intelligent traffic lights that would effectively optimise inner-city transport. Improvement of vehicle technology is required, as is the need to upgrade the existing fleet, comprising of vehicles that are heavily used and have surpassed their useful life, in the first step and remove them in the second phase. Retrofitting programs, utilization of catalytic converters for cars, and improvement of fuel quality and fuel pricing are essential in these initiatives.

Water resources:

In this sector there are a wide range of actions needed encompassing monitoring the hydrologic regime, soil moisture and groundwater balance. It is also necessary to develop and apply techniques and methodologies for assessing the potential adverse effects of climate change, through changes in temperature, precipitation and sea level rise, on freshwater resources and the flood risk. In addition, there is a need to develop agriculture and aquaculture activities based on brackish-water use and increasing water use efficiency. Development and implementation of national response strategies utilizing innovative technology and engineering solutions are also recommended.

Agriculture:

In this sector the burning off of agriculture residues needs to be halted and rice cultivation management upgraded. Integrated pest management and decreasing the number of livestock in degraded rangelands are a necessity. Lightweight animals (sheep and goats) should be confined and replaced with crossbred cows. There is also the need to transform the traditional system of animal husbandry through the introduction of intensive systems and increasing feed supply by utilizing agricultural crops. Increased production efficiency of livestock by increasing animal productivity is proposed as well.

Forestry and rangelands rehabilitation:

In this sector the development and silvicultural-based treatment of forest resources are imperatives. Forestation and forest development, balancing of forest harvesting volume with forest growth and expanding forest ecological capacity are also necessary. Forest tree improvement and use of fast growth species for reforestation and forestation and wood farming is another needed measure. The same applies to an increase of wood importing in order to reduce wood utilization from natural forests and to provide the raw materials for wood dependent industries. Another major area for intervention is the abandoned farmlands. They need to be transformed into forestland especially in the north of country. Wood farming and agro-forestry systems also need development. Another major intervention is an urgent requirement for advocacy campaign in implementing the national green movement plan nationwide.

Chapter I

National Circumstances

Imamzadeh Ebrahim (Shazdeh Ebrahim), Kashan; Photography: Behnoush AMIRI

1.1

Governance

With the inception of the Islamic Republic of Iran, the supreme authority in the governance system of the country has been vested in Velayat Faghih (The Supreme Jurisprudent/the Leader). Under his authority are the three branches - 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 270 members who are also elected to a four-year term. A 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 also ensures that legislation is in accordance with the Constitution and Islamic precepts.

With the inception of the Islamic Republic of Iran, the supreme authority in the governance system of the country has been vested in Velayat Faghih.

Table 1.1 Summary of Social, Demographic and Economic Indicators

Social and Demographic Indicators				
Area	1,648,000 sq. km			
Population	57,672,300 (1994-95)			
Population density	36 people per km^2 (1994)			
Population growth rate	2.01% (1994)			
Legal system	Based on the 1979 Constitution which was amended in 1989			
Legislature	Majlis-Shura-ye Islami (Islamic Consultative Assembly- the Parliament) of 270 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.			
Fertility rate Life expectancy	5.5 (1992); 3.2 (1991); Male 67 years (1994); Female 68 years (1994)			
Literacy rate (six years of age and over)	78% (1995)			
Population per physician	2,536 (1991)			
Infant mortality rate	35 per 1,000 (1994)			
Nutrition (per capita daily calorie intake)	3,181 (1990)			
Access to safe drinking water	89% of pop. (1990); 66% of pop. (1980)			
Access to standard sanitation	71% of pop. (1990)			
Economic Indicators				
Distribution of GDP in 1994 at 1982 prices	Agriculture 27.1%; Oil 18.8%; Manufacturing & Mining 23.4%; Services 44.3%			
	1993-94	1994-95	1995-96	1996-97
Oil exports (mbd)*	2.48	2.22	2.5	2.55
Oil output (mbd)	3.91	3.6	3.6	3.6
Oil & gas exports (USD million)	14,333	14,603	15,141	19,271
Non-oil exports (USD million)	3,747	4,831	3,234	3,225
Total exports (USD million)	18,080	19434	18,375	22,496
Imports (USD million)	19,287	12,617	12,678	14,973
Trade balance (USD million)	-1,207	6,817	5,697	7,523
Services (USD million)	-4,508	-3,059	-2,215	-2,625
Current account (USD million)	-4,215	4,956	3,478	5,259
GNP (USD million)	76,700	72,800	90,000	92,000
GDP growth (%)	4.8	1.6	4.5	5.2
Inflation (%)	21.2	31.5	49.7	28.9

Source: *Central Bank of Iran.*
**Million barrels per day*

The Expediency Discernment Council was formally incorporated into the 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. As for the judiciary branch, the leader appoints the head for a five-year term that can be extended once.

1.2

The Geography, Language and Principal Cities

The Islamic Republic of Iran lies in western Asia. It is bordered by the Caspian Sea, Azerbaijan, Armenia and Turkmenistan to the north, 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. The principal and official language is Farsi (Persian), spoken by about 50% of the population. Turkish speaking Azerbaijanis form about 27% of the population and Kurds, Arabs, Baluchis and Turkomans make up less than 25%. The great majority of Persians, Azerbaijanis and Arabs are Shi'ite Muslims while the other ethnic groups are mainly Sunni Muslims. There are also small minorities of Christians (mainly Armenians), Jews and Zoroastrians. The capital city is Tehran and other major cities are Mash-had, Esfahan, Tabriz, Shiraz, etc. (Table 1.2).

Table 1.2 Principal Towns and Estimated Population (1994)

Tehran (The capital)	6,750,043	Karaj	588,287	Kerman	349,626
Mashhad	1,964,489	Zahedan	419,886	Ardebil	329,869
Esfahan	1,220,595	Mehrshahr	413,299	Yazd	306,268
Tabriz	1,166,203	Hamadan	406,070	Qazvin	298,705
Shiraz	1,042,801	Orumiyeh	396,392	Zanjan	280,691
Ahwaz	828,380	Bandar-e-Abbas	383,515	Khorramabad	277,370
Qom	780,453	Arak	378,597	Sanandaj	277,314
Kermanshah	665,636	Rasht	374,475	Islamshar	239,716

Source: *Central Bank of Iran.*

1.3

Population and Human Resources

According to the figures released by the Statistics Center of Iran, the total population grew by 2.01 % in 1994-95 as compared with the previous year, to a total of 57.7 million (Table 1.3), of which 58.6 % are settled in

Table 1.3 Area, Population and Population Density (1994)

Area (sq. km) **Population**	*1,648,000**
1992	*55,427,900*
1993	*56,533,300*
1994-95	*57,672,300*
Population Density (per sq. km)	*36.3*

Source: *Statistics Center of Iran*
** 636,296 sq. miles.*

Table 1.4 Urban and Rural Population
(According to the Iranian year ending 21st of March)

Population	1976/77		1987/88		1991/92		1996/97	
	1,000	% of Total	1,000	% of Total	1,000	% of Total	1,000	% of Total
Urban	15,854	47	27,776	55.1	31,837	57.35	36,818	61.5
Rural	17,854	53	22,602	44.9	23,636	42.65	23,026	38.5
Total	33,708	100	50,648	100	55,837	100	60,055	100

Sources: *Central Bank of Iran / Annual Review.*

Table 1.5 Birth and Death Rates

	1980-85	1985-90	1990-95
Birth rate (per 1,000)	46.1	41.4	35.5
Death rate (per 1,000)	10.4	8.1	6.7

Source: *Central Bank of Iran.*

urban and 41.4 % in rural areas. Table 1.4 shows the percentage of urban and rural population. The birth and death rates are presented in Table1.5.

1.4 Literacy Rate

The overall quality of education has improved. For example, in terms of basic literacy, according to the 1995-96 surveys, the literacy rate was 79.3% in the population above six years of age. The improvement was higher for the age group 6-29 years and registered at 92.8%. The urban literacy figure was 81.9%, compared to 63.7% for rural areas. In 1994, the rate was 84% for males and 72.8% for females nationwide.

1.5 Climate

Generally characterized as arid or semi-arid, Iran's climate is one of great extremes. Summer temperatures of more than 50 ˚C are recorded in some areas. However, in the winter the high altitude of much of the country results in temperatures of –20 ˚C and below. Meteorological and climatic data from 43 stations are used to classify the country in 11 areas on the basis of the variation of the two parameters, i.e., heat and moisture (Farhang and Ghodsinia, 1979). Table 1.6 shows annual averages of temperature, precipitation and evaporation in 11 different areas. The annual average temperatures range from 11 °C in area three to 28 ˚C in area six. More than 82% of Iranian territory is located in the arid and semi-arid regions of the globe. Yearly precipitation varies from 1,800 mm in area one to less than 75 mm in area 11. The rate of evaporation per annum is as low as 700 mm in area one and 4,200 mm in areas five and seven. The national rainfall mean is about 250 mm, which is less than 1/3 of the global average of 860 mm.

There exist extremes with respect to the location and distribution of precipitation. For instance, the mean precipitation is less than 50 mm in the central deserts and the southeastern regions and about 1,600 mm in the northern provinces and high altitude areas found in the west. With respect to duration and distribution, the situation is unfavorable as well because most of the precipitation that occurs in arid and semi-arid regions in the form of showers lasts for only a few days of the year. In addition, the range in fluctuation of rainfall in every region covered by this period

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Table 1.6 Distribution of Temperature, Precipitation, and Evaporation According to the 43 Synoptic Stations' Records

Area	Annual average temperature (°C)	Annual average precipitation (mm)	Annual average evaporation (mm)
1	15-18	700-1800	700-1400
2	Dec-15	200-500	1400-2600
3	Nov-13	300-600	1300-2000
4	Dec-17	450-1200	1600-2800
5	19-25	150-400	3200-4200
6	23-28	80-250	2600-3800
7	18-27	110≥	2800-4200
8	15-17	130-160	2200-3700
9	Dec-18	200-500	1600-2500
10	16-20	100-200	2500-3500
11	19-23	75≥	≥3400

Source: *Meteorological Organization of Iran.*

of statistical survey has been quite high. The land area coverage of climatic regions in Iran is 35.5% hyper-arid, 29.2% arid, 20.1% semi-arid, 5% Mediterranean and 10% wet (of the cold mountainous type).

The low temperature and lower loss of water through evaporation plays the primary role in creating the above types of climate and not the precipitation itself. Moist climate due to rainfall is found in the Alborz and Zagros ranges. The wet climate, due to the amount of precipitation, is found in the Caspian Sea coastal area. Dry and extremely arid climates are found in the low land areas of the central desert region, along the eastern border of the country and, also, in the coastal zone of Persian Gulf and the Sea of Oman. The temperature variations of the country's climate are 17% extra cold, 47% cold, 22% temperate, and 12% warm.

1.6 The Impact of Drought

The country faces shortages of water and challenges caused by drought in different provinces every year. The recent three years of drought has affected almost all provinces in Iran. The latest drought damage assessment notes:

1 Many of the year-round and seasonal rivers have either dried up or their volume dramatically reduced. On average, the flow of surface water of Iranian rivers has decreased by more than 53%.

2 It is estimated that in 2001 there was a reduction of more than 30 billion cubic meters of surface water. There was also a decline in underground water and forecasts of a draw down from underground reservoirs of 15 billion cubic meters.

3 The current cyclical drought has impacted 7.8 million hectares (ha) of farming land directly including 4.1 million ha of dry farming, 2.6 million ha of irrigated farming and 1.1 million ha of dry and irrigated gardens.

4 Urban and rural drinking water is another drought-related challenge. 274 urban and 10,506 rural areas are now suffering from water shortages and distribution difficulties. The phenomenon is estimated to reduce animal feedstock by about 5.5 million tons.

5 Several internationally recognized wetlands have also been desiccated as a consequence of the drought. This has led to the extinction of certain species that sheltered in the now dry areas.

It is estimated that the total damages incurred amount to 55,873 billion Rials (approximately USD 7 billion). This sum relates only to the destruction against drinking water, agricultural water and livestock as shown in Table 1.7.

Table 1.7 Total Estimated Average Damages Caused by the 1998-2001 Drought in Iran*

Agriculture and Livestock				Urban and Rural Drinking Water				Grand Total
1998-1999	1999-2000	2000-2001	Total (Average)	1998-1999	1999-2000	2000-2001	Total	55,873.322
11,481.706	19,946.216	20,789.935	52,217.857	610.046	1,067.318	1,978.101	3,655.465	

* Billion Rials

The country lies in a natural disasters prone zone. Thus, droughts, floods and earthquakes are common.

Drought mitigation costs in the last three years equaled 4,131.7 billion Rials. Committees on drought crisis management have been established in Tehran and in other provincial capitals. The country lies in a natural disasters prone zone. Thus, droughts, floods and earthquakes are common. The rise in the level of the Caspian Sea can also be considered as a natural disaster. In recent years there has been a noticeable rise in the frequency and the impact of floods attributable to climate change and the alarming rate of deforestation. Urban development (e.g. construction of roads, houses and other buildings) has also contributed to flooding through blockage of natural water run-offs.

Table 1.8 Gross Domestic Products by Sector (Rls. billion at constant 1982-83 prices; yearly % change in brackets)

Sectors	1992-93	1993-94	1994-95	1995-96	1996-97
Agriculture	3,352 -7.4	3,536 -5.5	3,606 -2	3,688 -2.3	3,818 -3.5
Oil	2,554 -1.5	2,645 -3.6	2,496 (-5.6)	2,518 -0.9	2,556 -1.5
Mining	72 -6.6	77 -6.4	80 -4.2	84 -5.3	89 -6
Manufacturing	2,002 -6.6	1.992 (-0.5)	2.061 -3.4	2,181 -5.8	2,294 -5.2
Power & water	309 -8.4	339 -9.7	377 -11.3	397 -5.3	421 -6
Construction	549 -8.1	562 -2.4	596 -6.2	624 -4.7	690 -10.6
Trade	1,325 -5.3	1,370 -3.4	1,374 -0.3	1,363 (-0.8)	1,400 -2.7
Transport & communications	1,032 -11.5	1,113 -7.8	1,180 -6	1,106 (-6.3)	1,160 -4.9
Home ownership	1,490 -7.7	1.555 -4.4	1,620 -4.2	1,778 -9.8	1,888 -6.2
Public services	1,003 -8.8	1,194 -19	1,203 -0.8	1,239 -3	1.327 -7.1
GDP including other items at factor cost (after adjustment)	12,478 -5.5	13,071 -4.8	13,280 -1.6	13,884 -4.5	14.605 -5.2

Source: *Central Bank of Iran, Annual Review.*

The latest studies in the country reveal substantial and alarming changes in the frequency, duration and severity of hazardous events like flooding and drought. For example, it was shown that the number of floods rose from 10 between 1921-1931, to 500 between 1981-1991. The effect of El Nino on the country's climate has been studied as well. It has been concluded that El Nino can be held accountable for some of the anomalies observed in the temperature and the precipitation fluctuations nationwide.

Table 1.9 Gross Domestic Products by Economic Sector at Current Prices (1994-95)

Economic Sector	Share in GDP (%)
Agriculture	21.1
Oil	18.9
Manufacturing and mining	18.6
Mining	0.5
Manufacturing	13.7
Electricity, gas and water	1
Construction	3.4
Services	42.2
Trade, restaurants and hotels	15.4
Transportation, storage and communications	6.3
Financial and monetary institutions	0.9
Real estate, specialized and professional services	8.6
Public services	9
Social, personal and household services	1.9
Bank service charges	-0.8
Gross domestic product (at factor cost)	100

Source: *Central Bank of Iran.*

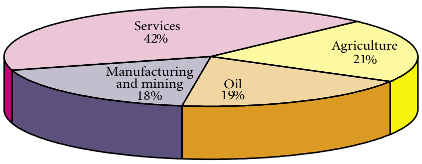
1.7

Economic Profile

After a protracted period of war induced economic stagnation in the 1980s, real GDP growth picked up at the beginning of the 1990s. Soon thereafter, import reduction was imposed for generating large current-account surpluses to meet debt-service obligations. This caused a sharp fall in GDP growth rates from 1992-93 to 1994-95 (Table 1.8).

Iran has been a major oil producer since the first decade of the twentieth century. The production and price increases of the late 1960s and 1970s have dramatically shifted the proportion of export revenue derived from oil.

Figure 1.1 Percent of GDP at Current Prices (1994-95)



The percentage of Iran's GDP by economic sectors (at current prices) is represented in Table 1.9 and Figure 1.1. The state is the recipient of oil revenue and the dominant force in the economy. The state also shoulders a large-scale subsidy program to meet the needs of the poor. Also a significant portion of the state expenditure accommodates reconstruction efforts resulting from the 1980-1988 Iraqi-imposed war.

Table 1.10 Labor Force: Employment by Sector

Sector	1986-87		1991-92	
	Million	% Total	Million	% Total
Economically active:	*11,037*	*85.9*	*13,096*	*88.9*
Agriculture	*3,223*	*25.1*	*3,209*	*21.8*
Manufacturing, mining, construction & public utilities	*1,998*	*15.5*	*3,614*	*24.5*
Services	*4,635*	*36.1*	*5,711*	*38.8*
Other	*1,181*	*9.2*	*562*	*3.8*
Unemployed	*1,819*	*14.1*	*1,640*	*11.1*
Total Work Force	**12,856**	**100**	**14,736**	**100**

Source: *Central Bank of Iran.*

As reflected in Figure 1.1, the agricultural sector accounts for 21% of the GDP. This sector was the first to have been affected by rapid development of services and industry after the revolution. Nevertheless agricultural production has increased and it remains a large nationwide employer, accounting for 21.8% of all jobs in 1991 (Table 1.10). Based on the Human Development Report of 1999, the government is the largest employer in Iran and job creation is the most important objective of the Third Five-Year Development Plan.

High inflation is another characteristic of the economy since the early 1970s. In recent years the depreciation of the exchange rate, the gradual removal of subsidies and reduction of imports have all contributed to rising prices. According to official data, since March 1995, inflation has been dropping steadily and the government continues to control it below 20% per annum.

1.8 Transport

The Ministry of Roads and Transportation estimated that in 1993-94 there was 58,977 km of paved roads in Iran. This represents a 20% increase on the 1985 figures. In addition to the paved-road network, transport in remote areas depends on non-paved roads, of which the Ministry estimates that there is some 45,000 km.

The Ministry of Roads and Transportation estimated that in 1993-94 there was 58,977 km of paved roads in Iran. This represents a 20% increase on the 1985 figures.

By the end of 1994-95, the total number of registered vehicles had risen to 2,239,000, of which 609,000 were vans or heavy vehicles. The bulk of the increase in registration was in private cars. Traffic authorities have recorded 1,630,000 registered passenger cars of which some 80% were privately owned.

Inevitably, this expansion of private vehicular use has led to increases in domestic petrol consumption, severe overcrowding on Iran's roads and serious urban air pollution problems. The government has sought to control these problems by raising the price of petrol. In this connection, the third FYDP has made provisions to eliminate fuel subsidies in order to realize real prices for petroleum products. It should be noted, however, that this measure will still keep Iranian fuel costs several times lower than the international rates.

The railway system has been expanded in the post-war years but remains inadequate. The expansion of the rail system is vital for economic development and the government has allocated significant funding for the expansion of its services under the five-year plans. The present standard-gauge rail network comprises a set of four lines branching from Tehran.

1.9

Energy

Oil:

Iran's proven oil reserves are estimated at 93.7 billion barrels, around 9% of the world's total. The Iranian oil industry is one of the oldest in the region. Average production, which had been over 5 mbd since 1972, fell to 1.5 mbd in 1980. Production recovered partially but remained below 2.5 mbd through 1988, the year of the cease-fire with Iraq.

By 1989, the sector was in need of considerable reconstruction. Iraqi rocket attacks and air raids had damaged production, transport and refining facilities. Consequently, a number of oil-bearing structures suffered as the conflict expanded into the Persian Gulf.

The National Iranian Oil Company (NIOC) launched an intensive drilling program combined with comprehensive reconstruction. Production levels recovered to 3.2 mbd in 1990, and since 1994 have averaged around 3.6 mbd. Table 1.11 presents the production of crude oil and refined products from 1992 to the end of 1996.

Table 1.11 Production of Crude Oil and Refined Products (Million barrel per day)

	1992	1993	1994	1995	1996
Crude oil	3,31	3,425	3,596	3,595	3,596
Total refined products	851.4	911.7	916.9	942	993.8

Source: Central Bank of Iran.

Natural Gas:

In 1994-95, the production of natural gas recorded a 13.4% rise to 54.9 billion cubic meters (Table 1.12). In the year under review, 35.3 b cubic meters of natural gas was consumed domestically and 11.6 billion cubic meters was flared off. About 7.9 billion cubic meters of natural gas was spent for local uses or wasted. Some 0.1 billion cubic meters was exported.

During the same period, the natural gas network was expanded by about 2,571 km, and 188.2 thousand new subscriptions were added to the network. As a result, the total number of functional subscriptions amounted to 2.069 million at the end of 1994-95. Among all the subscribers, Tehran Province ranked first at 31.4% of natural gas consumption.

Table 1.12 Consumption of Natural Gas[1] (Billion cubic meters)

	1993 – 94	1994 – 95	% Change	%
Domestic consumption[2]	36.9	35.3	-4.3	64.3
Flared	11.5	11.6	0.9	21.1
Export	0	0.1	0	0.2
Local uses and waste	0	7.9	0	14.4
Total	48.4	54.9	13.4	100

Source: *Ministry of Oil.*
(1) Excludes gas injected to oil wells.
(2) Includes uses such as household, commercial, industrial, power plants and refineries.

Refineries:

In 1994-95 out of a total capacity of 1.4 mbd of refined products, actual production reached 0.942 mbd. The National Iranian Oil Company (NIOC) is expanding its refining capacity through new facilities at Bandar Abbas and Bandar Asaluyeh, as well as through the renovation and rehabilitation of the existing facilities at Abadan and Arak. In the year 2000, NIOC was operating nine refinery complexes in Iran. Although, as refinery expansion was hindered by financial problems, a number of contracts were signed through international tenders and NIOC managed to increase its refinery capacity to 1.7 mbd by the end of 2000.

Table 1.13 Crude Oil Delivered to Domestic Refineries (Thousand barrels per day)

Refinery	1994 – 95	1998 – 98
Abadan	371	372
Esfahan	347	334
Tehran	229	234
Arak	162	163
Tabriz	97	105
Shiraz	43	53
Lavan	29	29
Kermanshah	22	22
Bandar Abbas	–	226
Total	1,300	1,538

Source: Ministry of Energy.

As shown in Table 1.13, in 1994-95, the crude oil delivered to domestic refineries amounted to 1,300 mbd and the total crude delivered to refineries amounted to 1,538 mbd, indicating an increase of 18.3%.

Domestic Consumption of Oil Products:

In 1994-95, domestic consumption of oil products stood at 1.159 mbd, registering a 3.1% rise in comparison with figures for 1993-94. There was also an increase of domestic oil production. At the same time the import of oil products declined while their exports increased for the same year (Table 1.14).

In 1994-5, the domestic consumption of gasoline and kerosene totalled 197 and 187 thousand barrels per day, indicating 6.5% and 1.1% increase, respectively. The domestic consumption of gas oil and fuel oil grew by 3.7% and 8.2% and amounted to 392 and 265 thousand bpd. The consumption of liquefied petroleum gas (LPG) fell by 5.4 % to 53 thousand bpd. There was a decrease in other oil products consumption by 14.5%. This drop amounted to 65 thousand bpd.

Table 1.14 Domestic Consumption of Oil Products (Thousand Barrels Per Day)

	1993 – 94	1994 - 95	% Change
Domestic Production	1,094	1,188	8.6
Export	124	136	9.7
Import	155	107	-3.1
Total Domestic Consumption	1,125	1,159	3.1

Source: Ministry of Oil.

Electricity:

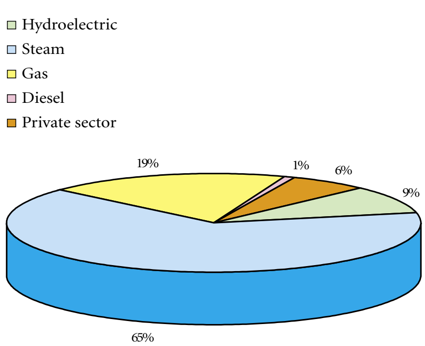
In 1994-95, the production of electricity grew by 7.9% and amounted to 82 billion kWh. Table 1.15 and Figure 1.2 present the production of electricity by type. The Ministry of Energy is the primary authority for power generation. Out of the total electricity generation, 77.1 billion kWh (94.0%) was generated by the power plants affiliated to the Ministry of Energy and the remainder by the private sector. During the year under review, the per capita production of electricity grew by 4.5 % and equalled 1,365 kWh in 1994.

Table 1.15 Production of Electricity[1] (Million kWh)

Electricity production	1993 – 94	1994 – 95	% Change	%
Ministry of Energy:	71,335	77,086	8.1	94
Hydroelectric generators	9,823	7,445	-24.2	9.1
Steam generators	48,166	53,376	10.8	65.1
Gas generators	12,419	15,402	240	18.8
Diesel generators	927	863	-6.9	1
Private sector[2]	4,679	4,933	5	6
Total	76,014	82,019	7.9	100

Source: Ministry of Energy.
1) Includes consumption of the power plants.
2) Includes industries and miscellaneous producers.

Figure 1.2 Production of Electricity by Type (1994-95)



In 1994-95, the consumption of electricity grew by 9.5% compared to 1993-94 and reached 63.6 b kWh (Table 1.16). During this period, 197 m kWh of electricity was exported to Nakhjavan Republic.

Table 1.16 Consumption of Electricity (Million kWh)

Sectors	1993-94	1994-95	% Change	%
Household	22,143	22,473	1.5	35.3
Industrial	15,572	20,470	31.5	32.2
Commercial (General)	14,984	13,747	-8.3	21.6
Agriculture	4,023	5,169	28.5	8.1
Others[1]	1,392	1,766	26.9	2.8
Total	58,114	63,625	9.5	100

Source: Ministry of Energy.
1) Includes electricity for rural areas, religious and charitable institutions and also street lighting.

In terms of the number of subscribers, 629,000 new users were added and the total number of subscribers reached 11.7 m, a 5.7% rise compared to the preceding year. In 1994-1995, the number of new villages connected to the electricity network came to 2,072 raising the total number of villages with electricity to 31,128.

1.10 Energy Conservation Measures in the Third Five -Year Development Plan (FYDP); (2000-2004)

Article 119 of Iran's third FYDP states that the government is to adopt energy conservation and environmental protection measures. Some of the essential features of these measures are:

1 A committee comprised of representatives from the Ministries of Energy and Oil, the Standards Institute, the Department of Environment and other relevant ministries is to define energy conservation standards and technical specifications for equipment, processes and the systems, with which all consumers, producers and importers of these items are required to comply.

2 To define working hours regulations for guilds, corporations, industries and factories in the season of peak electrical consumption.

3 To define energy conservation codes in constructing buildings in the governmental and non-governmental sectors.

4 To encourage compliance, energy prices shall be increased for those governmental and non-governmental buildings whose annual fuel consumption exceeds 5,000 cubic meters of fuel oil equivalent or if their electricity consumption exceeds 5 MWh.

Other significant energy conservation provisions in Iran's third FYDP include:

- Fuel switching from oil products to natural gas;
- Improving fuel quality;
- Gradual rationalization of subsidies with a view to remove them;
- Expansion of public transport;
- Utilizing electricity in pumping underground water;
- Providing subsidies for research and development to enhance energy conservation technologies; and
- Implementing policies that reduce energy intensity.

1.11 Mineral Resources

Iran has considerable mineral resources: in addition to its enormous hydrocarbon reserves. These include iron ore, bauxite, copper, zinc, and chromium deposits that are all found in commercially exploitable quantities.

Table 1.17 Metals Production (1,000Tons)

Metals production	1992	1993	1994	1995	1996
Aluminum (refined)	79.3	91.5	116.2	119.4	80.2
Chromium	102.3	109.8	139.5	N/A	N/A
Copper	105	86.6	117.9	102.2	100.5
Lead	12.4	14.7	18.3	15.9	15.5
Manganese	26.3	37.4	40	N/A	N/A
Zinc	65	70	72.9	145.1	70.6

Source: *Central Bank of Iran.*

Most of the country's minerals were mined only on a small scale until the 1960s, when a systematic survey began to record significant deposits and spurred exploration for new sources. There were some 800 mines being excavated in the Islamic Republic of Iran in 1996. New rail and road facilities provided easy access to major mining areas such as Kerman and Bafq. Table 1.17 reflects metal ore production between 1992-1996.

1.12 Forestry

The forested area in Iran is estimated at some 12.4 million hectares. The forests on the southern coast of the Caspian Sea that is climatically moderate, cover 1.9 million ha. The Arasbaran forests cover 144,000 ha at the border between Iran and the republics of Azerbaijan and Armenia. The remaining woodlands are scattered across the country with a heavy concentration on the Zagross zone (western parts of the country), the central plateau, and the northern shores of the Sea of Oman and the Persian Gulf. These forests are situated in arid and semi-arid zones.

Almost 54% of the country's total land area, i.e. 90 million ha is rangeland. National land use statistics are presented in Table 1.18.

Table 1.18 Land Use (1994-95)

	Area (1,000 ha)	% of total
Land under cultivation	*18,500*	*11.4*
Permanent pasture & meadowland	*143,700*	*88.6*
Total Land Area	**162,200**	**100**

Source: *Forestry Organization of Iran.*

1.13 Agriculture and Livestock

Approximately one-third of the added value in the agriculture sector comes from livestock. Production of major crops and livestock statistics are presented in Tables 1.19 and 1.20, respectively.

Table 1.19 Production of Major Crops (1,000 tons)

Crops	1992	1993	1994	1995	1996
Wheat	10,179	10,732	10,823	11,228	11,200
Barley	3,065	3,058	3,045	2,952	3,000
Rice	2,364	2,281	2,259	2,301	2,300
Cotton seed	330	275	387	523	512
Sugar beet	6,005	5,408	5,295	5,521	4,000
Tea	55	57	56	54	56

Source: *Ministry of Agriculture.*

Table 1.20 Number of Livestock (1,000: estimated

Livestock	1992	1993	1994	1995	1996
Sheep	45,000	47,350	50,285	50,889	51,499
Goats	23,500	25,224	25,757	25,757	25,757
Cattle	6,900	7,300	8,202	8,347	8,492
Camels	140	140	143	143	143
Buffalo	300	440	438	447	456
Horses	250	250	250	250	250

Source: *Central Bank of Iran.*

The forested area in Iran is estimated at some 12.4 million hectares.

1.14

Manufacturing

The main manufacturing industries are petrochemicals, steel, motor vehicles, cement, glass, food processing, textiles and paper. Traditional handicraft products remain important in Iran due to the high value commanded by Iranian carpets internationally. The value of carpet exports totalled USD 2.13 b in 1994-95, representing 44% of non–oil export earnings. Table 1.21 represents Iran's major non–oil export revenues.

Table 1.21 Major Non-Oil Exports (million USD)

Category	1992-93	1993-94	1994-95
Agricultural & traditional goods	**1,995.60**	**2,516.10**	**3,258.60**
Carpets	*1,105.60*	*1,384.00*	*2,132.90*
Fresh & dried fruit & nuts	*577.6*	*674.5*	*628.3*
Leather	*78*	*115*	*134.6*
Caviar	*31.1*	*32.3*	*27.5*
Other	*203.3*	*310.3*	*335.3*
Metal ores	**21.1**	**39**	**55.9**
Industrial goods	**970.9**	**1,191.70**	**1,510.00**
Cast iron & steel	*142.6*	*398.8*	*340.5*
Chemicals	*17.7*	*29.5*	*35.3*
Textiles	*55.6*	*36.5*	*96.1*
Copper bar & sheet	*131.6*	*140.6*	*106.8*
Other	*623.4*	*586.3*	*931.3*
Total	**2,987.60**	**3,746.80**	**4,824.50**

Source: *Central Bank of Iran, Annual Review.*

Chapter II

National Greenhouse Gases Inventory

Rice Cultivation, Guilan*; Photography: IRNA archive*

2.1

Overview

Iran has developed the national inventory of both direct greenhouse gases (CO_2, CH_4, N_2O) and indirect greenhouse gases (NO_X, CO, NMVOC) for the base year 1994. Emissions of HFC's and PFC's have not been included because these gases were substituted for ozone depletion substances under the Montreal Protocol only after the base year 1994.

In this report, the 1996 IPCC Revised Guidelines and default emission factors were used for preparation of the inventory. However, due to the low efficiency in energy production and consumption in Iran, the IPCC default emission factors

Table 2.1 Summary of GHGs Inventory for all Sub-sectors of Iran in 1994 (Gg)

Sources	CO_2	CH_4	N_2O	CO	NO_X	NMVOC
1. Energy	**285,891.30**	**1,559.11**	**8.79**	**2,907.40**	**1,184.39**	**1,091.90**
Fuel Combustion	***254,354.30***	***80.66***	***8.79***	***2,907.40***	***1,184.39***	***1,091.90***
Energy Transformation	*63,197.20*	*7.4*	*2.5*	*323*	*449*	*31.4*
Industry	*48,179.30*	*3.16*	*1.51*	*5.64*	*78.49*	*2.02*
Transport	*58,709.83*	*53.4*	*2.5*	*2,365*	*575*	*1031.8*
Dom./Com. Buildings	*66,512*	*6.11*	*1.65*	*96.85*	*43.55*	*24.49*
Agriculture	*12,689*	*1.11*	*0.35*	*2.68*	*27.95*	*0.81*
Other	*5,067*	*0.7*	*0.12*	*4.9*	*4.8*	*1.4*
Biomass Fuel		*8.7*	*0.16*	*109.4*	*5.6*	
Fugitive Emissions	***31,537***	***1,478.45***	***0***	***0***	***0***	***0***
Oil Activities		*41.87*				
Gas Activities		*491.55*				
Venting & Flaring	*31537*	*930.57*				
Coal Mining		*14.46*				
2. Industry	**24,754**	**1.85**	**2.2**	**79.98**	**6.95**	**1,018.02**
Mineral Production	*10161*			*0.85*	*2.07*	*984.04*
Chemical Industry	*1857*	*1.85*	*2.2*	*10.17*	*3.54*	*14.06*
Metal Production	*12736*			*68.14*	*1.12*	*0.471*
Other				*0.82*	*0.22*	*19.45*
3. Agriculture	**0**	**643.09**	**54.19**	**258.98**	**10.016**	**0**
Enteric Fermentation		*496.77*				
Animal Waste		*19.51*	*21.3*			
Rice Cultivation		*114.49*				
Agricultural Soils			*32.61*			
Agricultural Waste Burning		*12.32*	*0.28*	*258.98*	*10.016*	
4. Forestry	**31416.83**	**6.97**	**0.049**	**61**	**1.73**	**0**
Change in Forest & Wood Stock	*19517.1*					
Forest & Grassland Conversion	*12375.44*	*6.97*	*0.049*	*61*	*1.73*	
Abandonment of Managed Land	*-475.71*					
5. Waste	**0**	**326.71**	**4.64**	**0**	**0**	**0**
Municipal Solid Waste		*297*				
Dom./Com. Waste Water		*3.36*				
Industrial Waste Water		*26.35*				
Human Sewage			*4.64*			
Total GHG's Emissions	**342,062.20**	**2,537.73**	**69.86**	**3,307.40**	**1,203.94**	**2,109.94**
GWP (IPCC – 1996)	**1**	**21**	**310**	**NA**	**NA**	**NA**
Total CO_2 Equivalent	**342,062.20**	**53,292.37**	**21,657.53**	**NA**	**NA**	**NA**

In this report, the 1996 IPCC Revised Guidelines and default emission factors were used for preparation of the inventory.

Figure 2.1 Share of Different Sectors in CO2 Emission in 1994

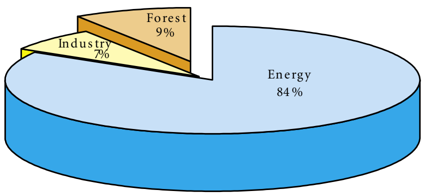


Figure 2.2 Contribution of Different Sectors to total CO_2 Equivalent Emissions in 1994

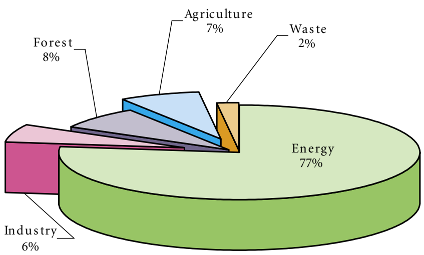
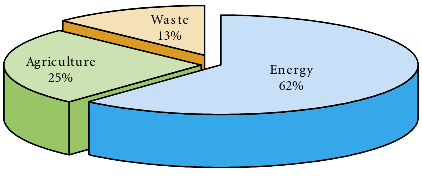


Figure 2.3 Contribution of Different Sectors to total CH_4 Emissions in 1994



show an upper limit. This has led to an over-estimation of emissions in Iran. Based on the preliminary result of this inventory, there are uncertainties vis-à-vis the data gathered on the forestry sector and the flaring of gases in oil and gas fields. Furthermore, Iran's Climate Change Office has experienced extreme difficulties in obtaining the Activity Data required for calculation of emissions. Consequently, extensive work will be needed in the future to improve the quality of the activity data and development of local emission factors.

It should be noted that the forestry sector has had a net emission in 1994. This is due to the assumptions used in defining the areas of logged-over forests under growing stage and natural forests. Indeed, if all of the forests in Iran were assumed to be anthropogenic, then the forests in Iran would have been *net sink* rather than *net source* of emission. The reliability of activity data and emission factors in the forestry sector in Iran should be verified and improved in the future.

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 GHG's inventory in Iran is shown in Table 2.1. As is evident from this table and Figure 2.1, the total CO_2 emission from different sectors in 1994 is about 342,062 Gg, with the energy sector contributing about 84% of the total emission and industries and forests contributing about 7% and 9%, respectively. The total CO_2 equivalent emission is estimated to be about 417,012 Gg in 1994.

As shown in Figure 2.2, the energy sector has the largest share of 77% and the sewage and waste sector has the lowest share of 2%. An important point is that the forestry sector which has a contribution of 8% to CO_2 equivalent has evolved into a source of emission in itself.

Figure 2.3 shows the contribution of different sectors to CH_4 emission in Iran. In 1994, energy, agriculture, and waste sectors were responsible for about 62%, 25%, and 13% of CH_4 emissions, respectively. The fugitive emissions from the oil and gas activities have a large share in methane emission. Lack of financial resources, the required technology, the economic sanctions against Iran, and the impacts of Iraqi-imposed war were the main reasons for the delay in the implementation of the mitigation projects.

Considering the country's population of 60 million in 1994, the per capita annual CO_2 emission was 5.69 tons/capita (Table 2.2). Being an oil producing country, Iran emits large amounts of GHGs in the energy sector. This is associated with exploration and production of fuels and oil products that are mainly consumed by other countries. Table 2.2 and Figure 2.4 show the comparison of CO_2 emission per capita and per GDP for selected countries. It can be seen that, compared to developed countries and some developing countries, Iran has a high level of emission/GDP. This is an indication that the country should secure energy technologies of greater efficiency to reduce the present energy intensity.

Table 2.2 CO_2 Emission per Capita and CO_2 Emission/GDP in Selected Countries (1994)

Country	CO_2 Emission/Capita (tons/ca.)	CO_2 Emission/GDP (tons/USD 1,000)
Malaysia	4.84	2.33
Iran	5.69	3.7
Japan	9.62	0.26
U.S.A	19.42	0.83
Kazakhstan	11.09	4.55
Azerbaijan	4.41	5.56

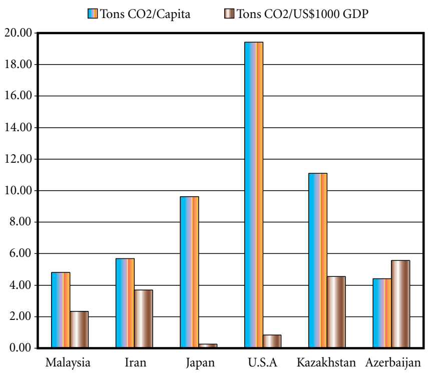
2.2 Energy

The energy sector, in particular oil and gas, plays a very important role in Iran's economy. In 1998, 14% of the GDP and 76% of foreign revenue were generated by oil and gas activities. In the same year, the total amount of primary energy production stood at 5166.7 PJ or 844.2 million barrels of oil equivalent (MBOE). The total amount of end use consumption of energy in the country stood at 3984.7 PJ or 651.2 MBOE, and the electrical energy production was 103,412.4 million KWh.

In 1998, the per capita production of primary energy was 13.64 BOE or 83.5 GJ and the per capita production of electricity has been 1,670.64 KWh. The per capita end use consumption has been 10.52 BOE or 64.4 GJ.

Thus, in 1994 the energy sector including energy transformation, oil and gas activities, combustion in industrial processes, small scale combustion, domestic and commercial buildings, and transportation contribute to over 80% of the total CO_2 emissions in Iran.

Figure 2.4 Comparison of CO_2 Emission per Capita (tons/ca.) and Emission/GDP (tons CO_2/USD 1,000) in Selected Countries (1994)



2.2.1 GHGs Emissions from the Energy Sector

2.2.1.1 CO_2 Emissions

The total CO_2 emissions in the combustion processes is estimated to be around 254,354 Gg. With 26%, the combustion processes from domestic and commercial buildings are the largest contributors to CO_2 emission. Meanwhile, the emission from fuel combustion emitted from energy transformation, transportation and industry were about 25%, 23% and 19%, respectively.

Also, about 31,537 Gg CO_2 is emitted from hot flaring of associated gases in oil and gas fields and petroleum and gas refineries. Therefore, the total CO_2 emissions from Iran's energy sector are about 285,891 Gg. Table 2.3 and Figure 2.5 show the contribution of CO_2 emissions from different energy sectors.

Table 2.3 CO_2 Emissions from Different Energy Sub-sectors (Gg) - 1994

Sources	CO_2 Emissions
Energy Transformation	63,197.20
Industry	48,179.30
Transport	58,709.80
Dom./Com. Building	66,512
Agriculture	12,689
Other	5,067
Sub-total	254,354.33
Hot Flaring	31,537
Total	285,891.33

2.2.1.2 CH_4 Emissions

In the energy sector, methane is emitted in two different forms namely from fuel combustion and from oil and gas activity and coal mining. Emissions of CH_4 from combustion processes are about 80.66 Gg. This is considered negligible when compared with CO_2 emissions in the energy sector. Hence, oil and natural gas are the most important sources contributing to CH_4 emissions.

Based on 1994 figures, the amount of CH_4 resulting from various fugitive sources including oil and gas exploration, venting and flaring of natural gas from the wells, petroleum refineries and solid fuels; was approximately 1,478 Gg. Thus, the total

Figure 2.5 Contribution of Energy Sub-sectors to CO_2 Emissions from Fuel Combustion (Gg) - 1994

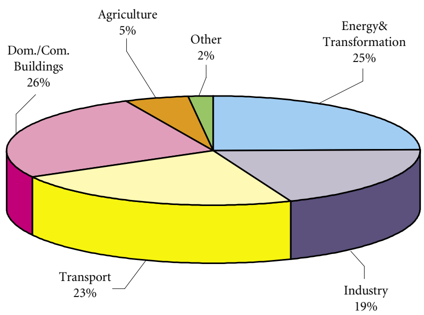
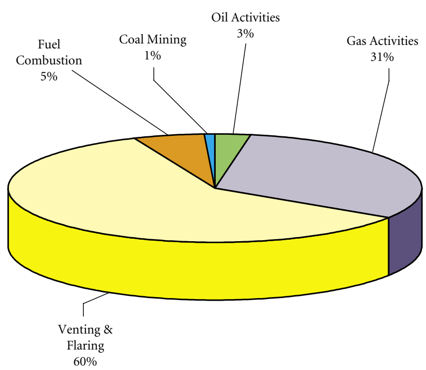


Figure 2.6 Share of the Energy Sub-sectors in CH_4 Emissions (1994)



methane emission from the energy sector is about 1,559 Gg as shown in Table 2.4 and Figure 2.6.

Table 2.4 Methane Emissions from Different Energy Sub-sectors (Gg) - 1994

Sources	CH_4 Emissions
Fugitive Emission	1478.45
Oil Activities	41.87
Gas Activities	491.55
Venting & Flaring	930.57
Coal Mining	14.46
Fuel Combustion	80.66
Total	1559.11

2.2.1.3 N_2O and Indirect GHGs Emissions

In the energy sector, the emissions of N_2O, NO_X and CO are 8.79, 1,114.3 and 2,907 Gg, respectively. Regarding fuelwood and coal, the outcome of the study revealed that fuelwood utilization is the least contributor to the emissions of various greenhouse gases. Absence of coal fired power plants as well as low consumption of fuelwood in the household sub-sector in Iran are the main reasons for the negligible emissions of greenhouse gases by fuelwood.

2.2.2 Summary for the Energy Sector

As illustrated in Table 2.5, in the energy sector, the total amount of CO_2 emission is about 285,891 Gg. Of this amount, almost 31,537 Gg is produced from burning of associated gases in the oil fields and refineries.

Likewise, the total CO_2 equivalent of direct GHGs in the energy sector is about 321,358 Gg. Approximately 89% of this relates to CO_2, and 10% to CO_2 equivalent of CH_4 and 1% to N_2O, respectively. Figure 2.7 shows the contribution of CO_2 equivalent for each direct GHGs category in the energy sector.

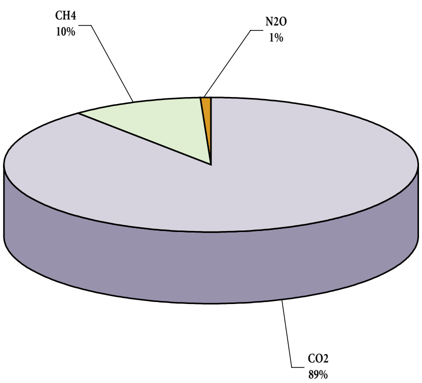
Table 2.5 Total GHGs Emissions for the Energy Sectors (Gg) - 1994

Sources	CO_2	CH_4	N_2O	CO	NO_X	NMVOC
Fuel Combustion	***254,354.33***	***80.66***	***8.79***	***2,907.44***	***1,114.39***	***1,091.90***
Energy Transformation	63,197.20	7.4	2.5	323	449	31.4
Industry	48,179.30	3.16	1.51	5.64	8.49	3.4
Transport	58,709.83	53.4	2.5	2365	575	1,031.80
Dom./Com. Buildings	66,512	6.11	1.65	96.85	43.55	24.49
Agriculture	12,689	1.11	0.35	2.68	27.95	0.81
Other	5,067	0.7	0.12	4.9	4.8	1.4
Biomass Fuel		8.7	0.16	109.4	5.6	
Fugitive Emissions	***31,537***	***1,478.45***	***0***	***0***	***0***	***0***
Oil Activities		41.87				
Gas Activities		491.55				
Venting & Flaring	31,537	930.57				
Coal Mining		14.46				
Total GHG's Emissions	***285,891.33***	***1559.11***	***8.79***	***2,907.44***	***1,114.39***	***1,091.90***
GWP	1	21	310	NA	NA	NA
Total CO_2 Equivalent	***285,891.33***	***32,741.35***	***2,725.52***	***NA***	***NA***	***NA***

2.3

Industrial Processes

Figure 2.7 Contribution of Different Gases to total CO_2 Equivalent Emissions in the Energy Sector (1994)



Almost all the industrial processes classified in the IPCC Guidelines, such as iron and steel, cement, aluminium, pulp and paper, petrochemicals, textile, etc., exist in Iran. Most of these industries are state-owned. The government has plans to privatise many of them in the future.

The activity data and emission in this sector 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 on both direct GHGs (i.e. CO_2, CH_4, N_2O and SF_6) and indirect GHGs (i.e. NO_x, CO, NMVOC and SO_2) have been collected.

In this report, emissions of HFC_s and PFC_s are not accounted for as these gases were substituted in CFCs refrigerating cycles and fire extinguishing systems only after the Montreal Protocol in late 1994. According to the official data, HFC and PFC were neither produced in Iran nor imported to the country before 1994.

In some cases, the emissions of GHGs from various sources in energy, industry and agriculture overlapped. In these 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 $CaCO_3$, 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 Emissions from Industrial Processes

2.3.1.1 CO_2 Emissions

The amount of CO_2 emissions from various industrial processes is depicted in Table 2.6. It is shown that the CO_2 emission from mineral products, metal production and chemical industries are about, 10,161, 12,763 and 1,857 Gg, respectively.

Table 2.6 CO_2 Emissions from Different Sub-sectors for Industrial Processes (Gg)-1994

Emissions Sources	CO_2 Emissions
Mineral Products	10,161
Chemical Industry	1,857
Metal Production	12,736
Total	24,754

Figure 2.8 Share of Different Sub-sectors in CO_2 Emissions for Industrial Processes (1994)

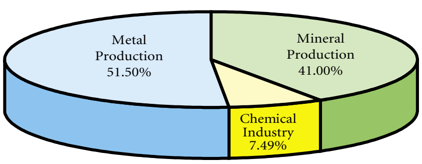
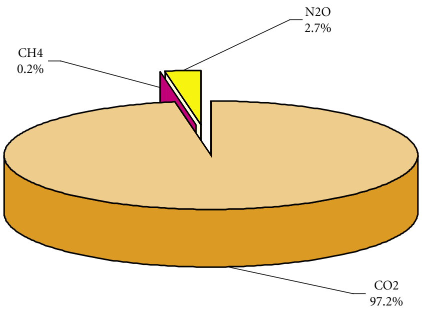


Figure 2.8 compares CO_2 emissions from different industrial sources. It illustrates that metal production has the highest contribution with 51.5%, mineral products emit 41%, and chemical industries have the minimum effect with 7.5%. Total CO_2 emissions from industrial processes were 24,781 Gg in 1994.

Figure 2.9 Contribution to total CO_2 Equivalent Emissions by Gas for Industrial Processes (1994)



2.3.1.2 CH_4 and N_2O Emissions

Emissions of CH_4 from chemical industries such as methanol, dichloroethylene and styrene production is about 1.85 Gg. Emissions of N_2O from nitric acid production is about 2.2 Gg.

2.3.1.3 Indirect GHGs Emissions

Table 2.7 outlines emissions of indirect GHGs from different industrial processes. It shows that the emissions of NO_x, CO, NMVOC and SO_2 are about 6.95, 79.98, 1.018.02 and 29.14 Gg, respectively. Mineral production has a higher share of about 96% of total NMVOC emissions from industrial processes.

Table 2.7 Indirect GHGs Emissions from Industrial Processes (Gg)-1994

Indirect GHGs	Emissions(Gg)
NO_x	6.95
CO	79.98
NMVOC	1,018.02
SO_2	29.14

2.3.2 Summary for Industrial Processes

Table 2.8 summarizes the national emission inventory of both direct and indirect GHGs for different industrial processes. It shows that iron and steel production account for about 50% of CO_2 emissions from industrial processes while mineral production and chemical industry contributions are about 41% and 7.5%, respectively.

The 1996 IPCC's equivalence factors can be used to compute the CO_2 equivalent of direct GHGs. The results are presented in Figure 2.9.

As reflected in Table 2.8 and Figure 2.9, the CO_2 equivalent of N_2O and CH_4 contribute only about 2.9% whereas CO_2 alone contributes to about 97.2% 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 38% whereas iron and steel production contribute to about 49% of the total CO_2 equivalent. Other industries' share was some 13% of the total direct GHG's CO_2 equivalent. The total CO_2 equivalent emissions from direct GHGs is 25,501 Gg. It is to be noted that in 1994, the actual emission of SF_6 was 0.00165 Gg whereas the potential emission of SF_6 was 0.11Gg.

It seems reasonable to adopt measures to reduce CO_2 emissions from cement, iron and steel production.

Table 2.8 Total GHGs Emissions for Industrial Processes (Gg) - 1994

GHGs Sources	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
Mineral Products	10,161	-	-	2.07	0.85	984.04	8.8
Chemical Industries	1,857	1.85	2.198	3.54	10.17	14.06	10.17
Metals Production	12,736	-	-	1.12	68.14	0.471	6.13
Other Production	-	-	-	0.22	0.82	19.45	4.03
Total	24,754	1.85	2.2	6.95	79.98	1,018.02	29.14
GWP-IPCC 96	1	21	310	NA	NA	NA	NA
Total CO_2 Equivalent	24,754	38.85	682	NA	NA	NA	NA

NA = Not Available

2.4
Agriculture Sector

Iran has a traditional agricultural profile. At present, about 50% of the Iranian population is involved in the sector. The major crops in Iran are wheat, barley, rice, cotton, sugar beet, sugar cane and other cash crops. The areas used for agricultural purposes are now 14 m ha (8.48% of the country's land). For livestock, the major domestic animals in Iran are cattle, sheep, goats, poultry and to a lesser extent donkeys and camels.

About 80% of agricultural residues are used by livestock. These are actually the major Iranian feed sources for animal production. It is important to know that most of them are low quality forages. Other use of agricultural residues together with animal manure and green manure are to fertilize the rice paddies.

In Iran, the rice crop is harvested once a year. Since the area of cultivation is variable over the years, the average of cultivated area for the period 1991-94 was used for evaluation of the GHGs emissions.

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 residues are about, 496.78, 19.51, 114.49 and 12.33 Gg, respectively. Therefore, the total CH_4 emitted from the agriculture sector is about 643.1 Gg. Table 2.9 and Figure 2.10 show the CH_4 emissions from different agricultural sub-sectors in 1994.

Table 2.9 CH_4 Emissions from Different Agricultural Sub-sectors (Gg) - 1994

Sources	CH_4 Emissions
Enteric Fermentation	496.78
Manure Management	19.51
Rice Cultivation	114.49
Agricultural Residue Burning	12.33
Total	643.1

2.4.1.2 N_2O Emissions

The amount of direct and indirect N_2O emissions for agricultural soils is about 32.61Gg while N_2O emissions from animals and the burning of the agricultural residues are about 21.33 and 0.28 Gg, respectively. Finally, the total N_2O emission from the agriculture sector is about 54.22 Gg.

2.4.1.3 Indirect GHGs Emissions

Indirect GHGs from the agricultural sector are only emitted from residue burning. In 1994, the amount of CO and NO_X emissions are estimated to be about 258.98 and 10.02 Gg, respectively.

Figure 2.10 Share of CH_4 Emissions from Different Agricultural Sub-sectors

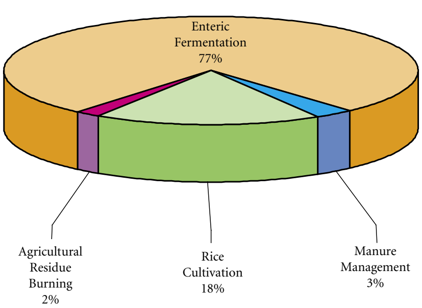


Table 2.10 Total GHGs Emissions for Agricultural Sector (Gg) - 1994

Sources	CH_4	N_2O	NO_x	CO
Enteric fermentation	496.78	NE*	NE*	NE*
Animal wastes	19.51	21.33	NE*	NE*
Rice cultivation	114.495	NE*	NE*	NE*
Agriculture soils	NA**	32.61	NE*	NE*
Agricultural waste burning	12.33	0.28	10.02	258.98
Total	643.115	54.22	10.02	258.98
GWPs	21	310	NA	NA
Total CO_2 Equivalent	13505.42	16808.2	NA	NA

*NE=Not Estimated
** Not Available

2.4.2 Summary for Agriculture Sector

Table 2.10 shows 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% and 45% of the total CO_2 equivalent of GHGs emissions. In 1994, the total amount of CO_2 equivalent is about 30,313 Gg.

2.5 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-geochemical 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 regrow into their natural grassland or forest conditions; and
- Changes in soil carbon.

2.5.1 Natural Resources in Iran

2.5.1.1 Forests in Iran

Nearly 7.5% of Iran is covered with different types of forests with a total area of about 12.4 m ha. According to the existing estimates, annually 165,000 ha of forests in Iran are degraded (qualitatively and quantitatively); 45,000 ha in commercial forests in the north of the country and 120,000 ha in other forests. There are five forest regions in the country, which are summarized below.

Hyrcanian forest

This region is a narrow strip covering the northern slope of the Alborz mountains from Astara in Gilan province to Golidaq in Golestan province and stretching across a distance of about 800 km. The width of this forest varies from 12 km in Ramsar to 70 km in Sari. Precipitation in this region ranges from 600 to 2,000 mm. Forest area equals 1,925,000 ha, and based on the latest inventory in 1987, the volume of the forests stand at approximately 404 m m^3. Average annual growth is estimated at about 2 to 3 m^3/ha. Of these forests, 1.3 m ha, is commercial and 0.625 m ha is protected forest. Some 2 m m^3 of wood are harvested per annum. The total area of reforestation in this region is about 15,326 ha; the total area landscaped is about 1,590.5 ha; and the total tree plantation around villages is 27,743 ha.

Arassbaranian forests

Forests of this region are along the hyrcanian forest in northwest of Iran with an area of about 144,000 ha. Only fuelwood is harvested from this type of forests.

Zagrossian forests (semi-arid zone)

These forests are situated in the west of Iran along the Zagross mountains. The area is equal to 4.8 m ha; growth is about 0.7 m^3 per ha and wood stocks are between 3

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-geochemical cycles because of its role in regulating the concentration of CO_2.

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 worksheets.

to 70 m^3/ha. These forests are severely degraded because of fuelwood harvesting, grazing and other uses.

Area of reforestation in this region is about 9,281 ha; total area landscaped is 9,561.4 ha and tree plantation around villages is 75,978 ha.

Irano-Touranian forests (arid zone)

This region is divided into two categories: mountains with dry forests and flat lands with desert vegetation. Maximum precipitation is 400 mm per year in the mountains and 200 mm on the flats. Forest area in this region is nearly 3.4 m ha. Reforestation area is about 158,000 ha; the area landscaped is 9,862.4 ha and total tree plantation around villages is 70,200 ha.

Gulf-Omanian forests (subtropical zone)

This region is situated in the south of Iran on the northern coast of the Persian Gulf and Sea of Oman with a small portion in the southwest of Iran. Precipitation varies from 413 mm in the southwest to 90 mm in the east. Forest area in this region is 2.08 m ha. The reforestation area is equal to 75,679 ha; the area landscaped is 4,008 ha and tree plantation around villages is 34,684 ha

2.5.1.2 Ranges

Based on the latest inventory, the area of ranges in Iran equals 91,219,428 ha and the amount of annual production of these ranges is 20 m tons of dry forage.

There are three categories of ranges in Iran. These are:

- Good ranges with 14 m ha area,
- Medium ranges with 60 m ha area,
- Poor ranges with 16 m ha area.

About 500,000 ha of rangelands are degraded every year because of unlimited use of these resources by human, livestock grazing, and other natural factors.

2.5.1.3 Deserts

This region is situated in the central plateau with a maximum annual rainfall of about 200 mm. The desert is nearly 43.7 m ha or 26.7 % of total area. Based on

Based on the latest inventory, the area of ranges in Iran equals 91,219,428 ha and the amount of annual production of these ranges is 20 m tons of dry forage.

Table 2.11 Statistics of Land Conversion and Degradation in Iran

Degradation Factors	Area of Degradation per Year (ha)	Percent of Total Resources Area(%)	Percent of Total Area of Country (%)
Forest *	165,000	1.331	0.1
Ranges *	500,000	0.0834	0.455
- Fuel wood combustion	84,000	0.094	0.051
- Change to dry farming	20,000	0.023	0.013
- Range land lease	39,000	0.044	0.024
- Military activity	25,000	0.028	0.016
- Burning of forest and range	20,000	0.023	0.013
- Urban & village enlargement	6,375	0.004	0.004
Farm land degradation	185,000	0.1	0.113
Mines	110,000	0.584	0.07
Total	**1,154,375**	**2.3144**	**0.839**

** Quantitative & Qualitative Conversion.*

scientific estimates, 1% of the total area in Iran is annually degraded to desert land. Table 2.11 shows the statistics of the land conversion and degradation.

2.5.2 GHGs Emissions from the Forestry Sector

2.5.2.1 CO_2 Emissions

Forest and other woody biomass stocks changes

As described earlier, Iran's forests are dispersed in four climatic zones. Forests areas and reforestation activities are changing with a different increase of phytomass in every zone. Therefore, the calculations in this section were performed for four climatic zones under three categories (reforestation, plantation around villages and landscaping). For calculation of wood harvested in all forests, the computation accounted for the total industrial wood harvested from commercial forests (peeler and saw logs, timber and traverse, bolts, fuelwood) and consumption of fuelwood in other forests.

Based on these calculations, the total carbon release and carbon uptake increment are about 5662.4 Kt and 339.6 Kt, respectively. In 1994, the total net CO_2 emission from forest and grassland conversion was about 19,517 Gg

Forest and grassland conversion

The amount of conversion for the commercial forests is 45,000 ha per year and the average biomass formation equals to 183 tdm/ha and biomass after conversion is estimated at about 10 tdm/ha.

According to the above-mentioned data, the amount of CO_2 emissions from off-site and on-site biomass burning and decay of above-ground biomass are about 9,494.16 and 2,881.18 Gg, respectively. The total amount of CO_2 emission is about 12,375.4 Gg in 1994, as shown in Table 2.12.

Table 2.12 CO_2 Emissions from Forest and Grassland Conversion(Gg)-1994

Vegetation type	Immediate Release from Burning	Delayed Emission from Decay	Total
Forest	*9322.87*	*2589.68*	*11912.6*
Grassland	*171.31*	*291.5*	*462.8*
Total	**9,494.16**	**2,881.18**	**12,375.40**

Abandonment of managed land

In the past 20 years the amount of managed areas converted to grassland in Iran has been about 1,037,943 ha. Similar data for forests over the past 20 years is not available. Therefore, the CO_2 uptake is estimated for grassland only, which is about 475.71 Gg in 1994.

Iran's forests are dispersed in four climatic zones. Forests areas and reforestation activities are changing with a different increase of phytomass in every zone.

Soil carbon changes

No clear data is available on land-use classification based on soil type or soil carbon. Therefore, the CO_2 emission estimates were not made.

2.5.2.2 Other GHGs Emissions

For computing the non-CO_2 gases emissions, the amount of carbon released from biomass burned is estimated at 435.63 Kt C. Thus, the amount of total CO_2

Table 2.13 Non-CO_2 GHGs Emission from Biomass Burning

GHGs	Emission (Gg)
CH_4	*6.97*
N_2O	*0.049*
NO_x	*1.73*
CO	*60.9*

equivalent of direct GHGs emissions from biomass burning are about 161.56 Gg. Table 2.13 lists the non-CO_2 GHGs emissions from burning of the cleared forests.

2.5.3 Summary for the Forestry Sector

According to Table 2.14, the land use and forestry sectors in Iran are sources for GHGs emissions with a net total of CO_2 equivalent of about 31,578 Gg. The amount of CO_2 uptake in the land use and forestry sectors is about 1,720.91 Gg. This shows that the programs in the forest harvesting in Iran have not been worked out on a sustainable basis.

Table 2.14 CO_2 Emissions and Uptake in Forestry Sector

Sources	CO_2 Uptake	CO_2 Emission	CH_4	N_2O	CO	NO_x
Change in Woody Biomass Stocks	*1,245.20*	*20,762.13*	-	-	-	-
Forest and Grassland Conversion	-	*12,375.44*	*6.97*	*0.049*	*60.99*	*1.73*
Abandonment of Managed Land	*475.71*	-	-	-	-	-
Total	1,720.91	33,137.57	6.97	0.049	60.99	1.73
GWPs	1	1	21	310	NA	NA
Total CO_2 Equivalent	1,720.91	33,137.57	146.37	15.19	NA	NA

2.6 Sewage and Waste

Construction and exploitation of sewage treatment plants in Iran have developed in recent years. At present, there are 190 proposed projects for construction of sewage treatment plants. Of these projects, 82 are at the preparatory phase (64 projects in first phase stage and 18 projects in second phase), and 108 projects being implemented[2].

According to the official data, the rate of municipal solid waste (MSW) generated in the country is about 0.8 kg per capita per day. Since the data for emission factors were not available, default values were used. For this purpose, India was chosen as a model since its waste disposal practices and prevailing environmental conditions were considered similar to Iran.

2.6.1 GHGs Emissions from Sewage and Waste

2.6.1.1 CH_4 Emissions

In 1994, the total annual MSW disposed in solid waste disposal sites (SWDS) is estimated at about 6,451 Kt. Thus, based on the assumption of 0.5 for Methane Correction Factor (MCF), the total CH_4 emission from solid waste is about 297 Gg. The amount of CH_4 emission from domestic/commercial and industrial wastewater is about 29.71 Gg, as shown in Table 2.15.

Table 2.15 CH_4 Emissions from Wastewater (Gg)-1994

Sources	CH_4 Emission	Percentage (%)
Municipal Solid Waste	*297*	*91%*
Wastewater	*29.71*	*9%*
Total	326.71	

2- Reported by the Institute of Water & Wastewater Engineering Company (IWWEC), Ministry of Energy.

2.6.1.2 N_2O Emissions

According to the reports issued by the food and nutrition authorities in Iran, the per capita protein consumption is 30.78 kg/yr, thus the total N_2O emission from sewage in 1994 was about 4.64 Gg.

2.6.2 Summary of Emissions from Sewage and Waste

In 1994, the total CO_2 equivalent emission from sewage and waste was about 8,299.3 Gg. Table 2.16 shows that methane is the most emitted GHGs from sewages and waste. The share of N_2O in total CO_2 equivalent emitted from sewage and waste is about 17.33 %.

Table 2.16 Total GHGs Emission from Sewage and Waste (Gg) -1994

Source	CH_4	N_2O
Municipal Solid Waste	*297*	–
Wastewater	*29.71*	–
Human Sewage	–	*4.64*
Total	**326.71**	**4.64**
GWP	**21**	**310**
Total CO_2 Equivalent	**6,860.91**	**1,438.40**

According to the reports issued by the food and nutrition authorities in Iran, the per capita protein consumption is 30.78 kg/yr.

Chapter III

Greenhouse Gases Mitigation Policies

Metro, Tehran; Photography: IRNA archive

3.1 Introduction

Greenhouse gases (GHGs) are the prime cause of global warming and climate change. Higher temperatures associated with climate change and global warming shall adversely affect all economic sectors and certainly the quality of human life. Therefore, mitigation of GHGs is a high priority objective worldwide.

The negative effects of global warming are more evident in semi-desert countries like Iran. Increased utilization of all types of energy, inefficient cooling systems, extra demand for oil, gas, and oil by-products as well as the high-operating costs for maintenance of refineries and power plants are among the main factors leading to great losses of revenue per annum. Like the energy and industry sectors; agriculture, forestry and human life are becoming vulnerable and at high risk.

With respect to GHGs mitigation analysis, various reduction measures are being considered. These measures are evaluated against the Reference or Baseline Scenario (BLS) and incorporated in all the policy measures adapted by government including those introduced under the third Five Year Development Plan (FYDP).

GHGs mitigation initiatives are also developed in accordance with Iran's long-term national priorities with a view to improving the nation's welfare and infrastructure based on a sustainable development paradigm, rising economic growth, and protecting the environment. Implementation of such measures requires inter and intra-ministerial, inter and intra-sectoral, and coordination among all the relevant ministries, governmental agencies, non-governmental organizations and the public. The National Climate Change Office (NCCO), established under the auspices of the Department of Environment, is responsible for such coordination. Table 3.1 presents sectoral mitigation priorities that have been recommended by the NCCO.

These mitigation processes are based on lengthy consultation with experts and research undertaken in the country. On the basis of the evaluation and analyses carried out, the final sectoral priority measures are identified under three scenarios. These scenarios are defined below.

3.1.1 Baseline Scenario (BLS)

This scenario is in line with the government's policies under the third FYDP. The continuation of the BLS program of action is envisaged up to the year 2010. For this purpose, data will be gathered from the 1400 Horizon Program[1]. It is noteworthy that the BLS uses economic indicators of the third FYDP. For example, the annual economic growth rates are estimated as 6% and job creation targets are 700,000 per annum. Many of the environmentally friendly programs and policies aimed at reducing emissions have also been taken into consideration.

Higher temperatures associated with climate change and global warming shall adversely affect all economic sectors and certainly the quality of human life.

3.1.2 BLS without Recovery of Flare Gas (RFG)

This scenario is the same as BLS, referring to the same governmental policies with one exception. The exception here is regarding the oil and gas sector. That is, some of the gas recovery and utilization programs will not be possible due to financial or technological constraints.

1- *The long-term national development plan through 2021.*

3.1.3 Mitigation Scenario

This scenario consists of abatement of GHGs emission programs and policies recommended in this report by the National Climate Change Office to the government. There is, of course, no obligation for the government to implement these recommendations. However, as these recommendations are effective in reducing emissions, they can be instrumental in broadening the awareness of the policymakers and consequently are likely to be adapted by the government.

Table 3.1 Priority Sectors and Measures on GHGs Mitigation

Priority Sectors & Sub-sectors	Measures
Ministry of Energy	*To develop enabling mechanisms to implement energy saving policies and energy efficiency programs*
Energy Generation	*To improve efficiency of fuel utilization at power plants* *To include renewable sources of energy in the energy cycle balance* *To increase the share of natural gas in the energy production balance*
Energy Consumption	*To increase energy saving in industries* *To implement energy saving programs for domestic and industrial uses*
Agriculture	*To increase livestock productivity and optimize livestock population* *To convert less productive land into grasslands and rangelands* *To intensify grain production*
Forestry	*To increase the area covered by forests* *To drive livestock out of the forests*

3.1.4 Signs of Sustainable Development in the Current Government Policies

During its second and third FYDP, the government has taken valuable and effective steps aimed at sustainable development, particularly in reducing undesirable development effects on the environment. Many of these measures have indeed diminished the trend of GHGs emissions. Some important examples are:

- The increase of the share of natural gas in primary energy production from 14% in 1994 to 22% in 2000 (see Table 3.2).
- The increase in the number of domestic/household utilizing of natural gas from 3,200,000 1994 to 5,300,000 in 2000.
- 37% increase in energy efficiency through greater use of electrical energy instead of diesel -pumps for deep-water wells in rural areas and agricultural lands.
- Recovery of associated gases in the oil fields for gas injection into oil wells and greater use of these gases in feeding expansion turbines in generating electricity. Under the third FYDP, the government has planned to recover more than 80% of these associated gases.
- Compile energy consumption standards for domestic and industrial appliances. These standards have already been successfully used for 16 devices, bound to significantly reduce energy use and thus positively affect GHG emission mitigation trends.

During its second and third FYDP, the government has taken valuable and effective steps aimed at sustainable development, particularly in reducing undesirable development effects on the environment.

Table 3.2 Estimated Energy Demand: Share of Natural Gas by Sub-sectors (%)

Sectors	*1994*	*2000*
Power Plants	*59*	*75*
Refineries	*28*	*45*
Industries	*41.7*	*52*
Domestic & Commercial Buildings	*30.39*	*46*

- Capacity increase of combined cycles power generation from 3,000 MW (16%) in 1994 to 5,900 MW (23%) in 2000.
- Capacity increase of hydropower generation from 1,900 MW in 1994 to 2,300 MW in 2000.
- Commission 2,000 CNG powered buses for the public transportation fleet.
- Enforce ECE 15.04 standard for car manufacturing industries in 2000.
- Greater use of railways in freight haulage from 18.98 Mton (11.5 Mton-km) in 1994 to 29 Mton (16.9 Mton-km) in 2000.
- Greater use of railways in passenger transport from 8.36 m people (5.5 trillion person/km) in 1994 to 10.51 m person (6.6 trillion person/km) in 2000.

3.2
CO_2 Emission Trends in Baseline Scenario (BLS)

According to inventory statistics, more than 80% of the total GHGs are emitted from energy and industrial processes that include power plants, oil and gas, transport, agriculture and other energy consuming industries. In order to prepare the BLS, the following plans and strategies have been reviewed:

1 Government's plan for environmental protection and resources conservation,

2 The national strategy for production, consumption and export of all sources of energy including oil and gas, electrical power, and renewable energies incorporating population growth rates and GDP figures. The detailed information and calculation of GHGs emission from different sectors in the BLS are provided in Appendix.

3.2.1 Energy Sector

Iran's high rate of energy consumption resulting from the low costs of energy, improper operational maintenance, and the use of obsolete technologies make the energy sector the main source for greenhouse gas emissions. Hence, high priority is designated to this sector and in formulating a suitable GHGs emission reduction plan. Both long-term and short-term strategies are being developed for the reduction of GHGs emissions in the energy sector and the related industrial processes.

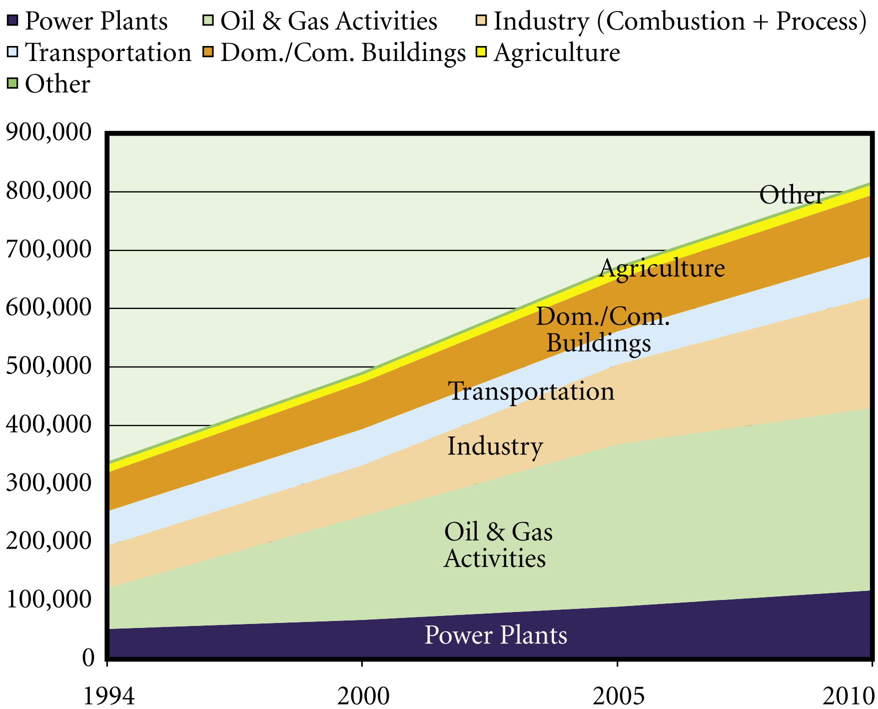
Iran's high rate of energy consumption resulting from the low costs of energy, improper operational maintenance, and the use of obsolete technologies make the energy sector the main source for greenhouse gas emissions.

In the long-term strategies, the "*top down*" approach including clean technology transfer regulation, energy tariffs and guidelines for demand and supply management are to be formulated. Simultaneously, the "*bottom-up*" methods are also used through advocacy programs for a greater use by the public of new energy resources and reducing energy consumption rates. Increased utilization of nuclear energy is also among the government's long-term strategies.

These long-term strategies are in fact proposed by the National Climate Change Office and, in many cases, are consistent with government measures. However, due to insufficient funds or lack of the required technology, the government may not be in a position to implement these strategies. Consequently, international organizations such as the World Bank or the Global Environment Facility, just to name a few, should assist the government in this endeavour.

Over the last three decades, the development of the energy sector in the Islamic Republic of Iran is characterized by the high growth rate of energy demand and

Figure 3.1a GHGs Emission Trends for Energy Sector in Baseline Scenario without RFG in Oil & Gas Activities (Gg-CO_2 equivalent)



rapid expansion of the supply system. Annual consumption per capita has increased from 2.02 BOE/capita in 1967 to 10.29 BOE/capita in 1997. For the period of 1968 to 1997, in real terms, the estimated average annual growth rate of primary energy intensity has risen at 3.8%/y.

The percentage of fossil energy has been also quite high in total energy consumption. Oil and natural gas meet 91% of the domestic energy requirement and have dominated the energy balance of the country. Increased consumption of petroleum products and natural gas in the economic sectors has contributed substantially to the rising emissions of GHGs.

At the same time, air pollution resulting from rising energy consumption and intensive use of petroleum products and natural gas is becoming increasingly severe. Local impact of emissions of CO, SO_2, VOCs and NO_X is seriously hazardous in large cities and industrial centres, especially in the capital city of Tehran. As a positive mitigation measure, it should be mentioned that natural gas has replaced heavy fuels in most domestic and industrial usages thus curtailing both GHGs emissions and local pollution as compared with the situation where natural gas was not used so widely, particularly in urban areas.

Table 3.3, Fig 3.1a and Fig 3.1b show the emission trends of GHGs for the energy sector in accordance with the BLS. In Fig 3.1a, emissions related to oil and gas

Table 3.3 GHGs Emission Trends in Baseline Scenario for Energy Sectors (Gg-CO_2 Equivalent)

Sub-sector		1994	2000	2005	2010
Power Plants		51,914	67,480	89,400	118,080
Oil & Gas Activities	Baseline Sce. without RFG	70,333	177,572	278,766	311,342
	Baseline Sce.	70,333	177,572	100,926	133,507
Industry (Combustion + Process)		72,302	86,292	136,543	190,633
Transportation		58,709	62,583	56,748	70,450
Dom./Com. Buildings		66,512	79,054	89,987	104,152
Agriculture		12,688	13,703	15,758	17,725
Other		5067	5067	5067	5067
Total in Baseline Scenario without RFG		337,525	491,751	672,269	817,449
Total in Baseline Scenario		337,525	491,751	494,429	639,614

CO_2 Emission Trends in Baseline Scenario (BLS)

Figure 3.1b GHGs Emission Trends for Energy Sector in Baseline Scenario (Gg-CO_2 equivalent)

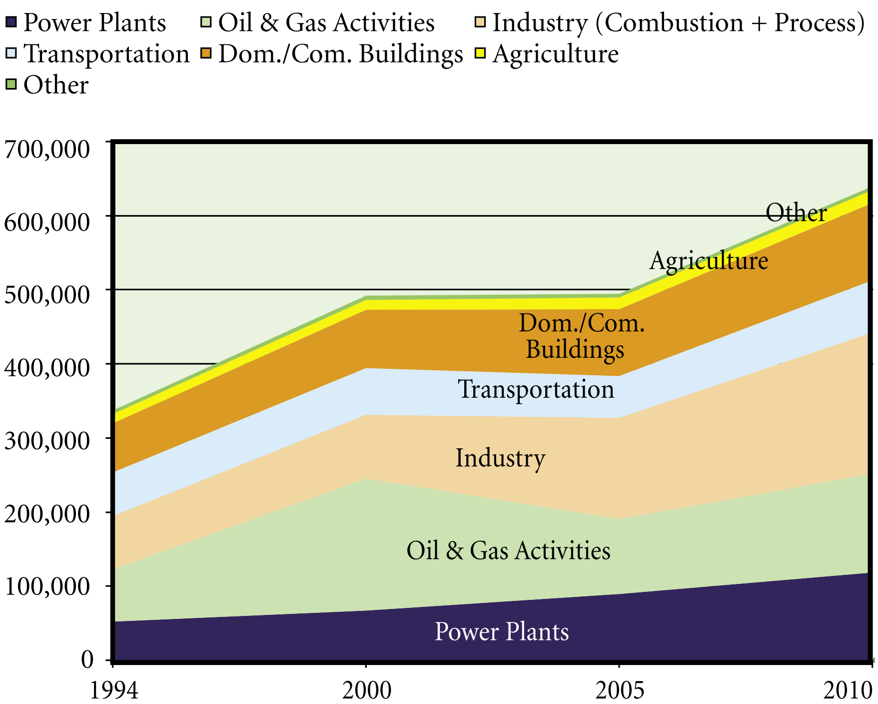
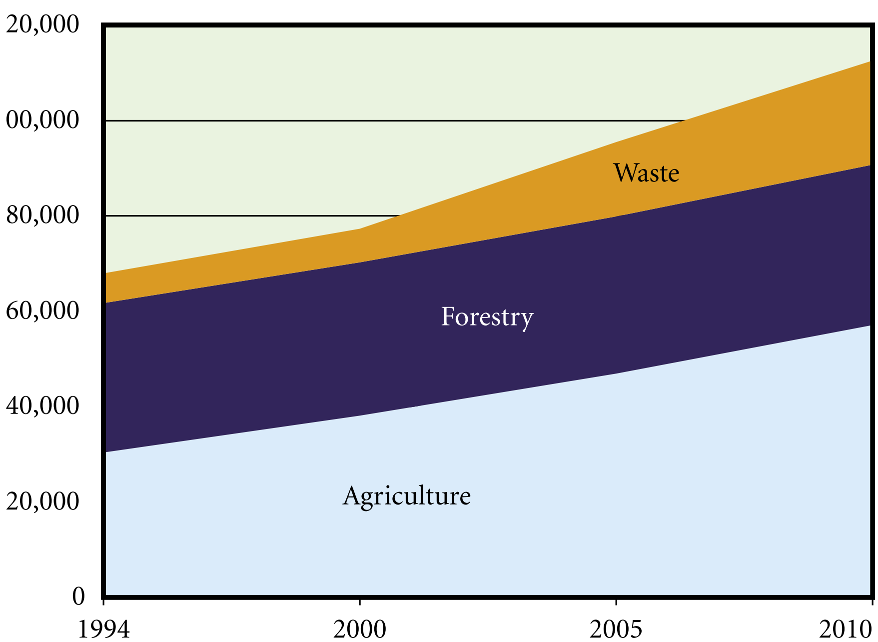


Figure 3.2 GHGs Emission Trends in Baseline Scenario for Non-Energy Sectors (Gg -CO_2 equivalent)



activities have been calculated. In these calculations the government's measures to make greater use of flare gases were not included. Oil and gas activities and the abatement policies are affected as shown in Fig 3.1.b.

3.2.2 Non-energy Sectors

Designing a suitable plan for reducing GHGs emission in the non-energy sector is as important as in the energy sector. Enhanced farming and increased agricultural production along with over-harvesting and rapid destruction of forests have upset the natural carbon cycle. Also there is an increasing rate of solid and liquid waste that emit methane. The pattern of GHGs emission for the non-energy sectors in the BLS is provided in Table 3.4 and Figure 3.2.

3.2.3 Combined GHGs Emission in Baseline Scenario for Energy and Non-energy Sectors

Fig 3.3a and Fig 3.3b show the combined GHGs emission (CO_2 equivalent) trends for energy and non-energy sectors in the BLS. In Fig 3.3a, emissions related to oil and gas activities are calculated *without* inclusion of the government's measures adapted for the recovery of flare gases. Fig 3.3.b shows the trend of GHGs emission *with* inclusion of the abatement policies for flare gases adapted by the government.

Figure 3.3a Overall GHGs Emission Trends in Baseline Scenario without Recovery of Flare Gas (RFG) in Oil & Gas Activities (Gg -CO_2 equivalent)

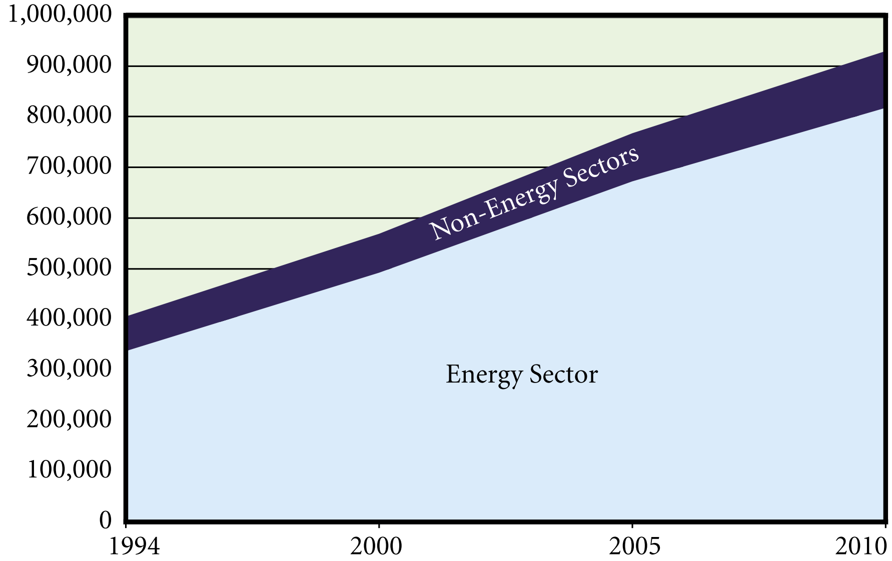


Figure 3.3b Overall GHGs Emission Trends in Baseline Scenario (Gg -CO_2 equivalent)

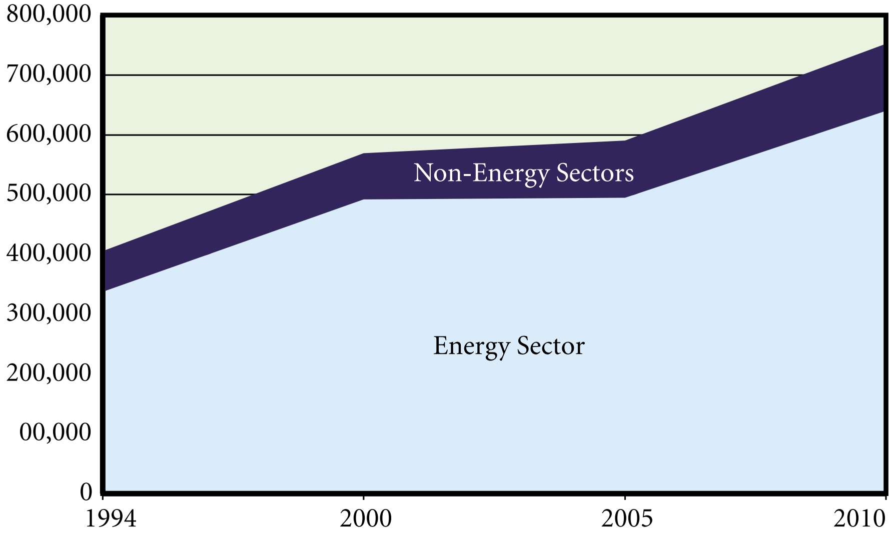


Table 3.4 GHGs Emission Trends in Baseline Scenario for Non-Energy Sectors (Gg-CO_2 Equivalent)

Sub-sector		1994	2000	2005	2010
Agriculture	Agricultural Production	17,457	22,498	27,047	33,034
	Livestock Production	12,859	15,625	19,864	24,027
Sub-total		30,316	38,123	46,911	57,061
Forestry		31,416	32,052	32,909	33,589
Waste	Solid	5,586	6,510	15,110	21,378
	Liquid	608.37	649.362	548.55	513.933
Sub-total		6,194	7,159	15,658	21,892
Total		67,926	77,334	95,478	112,542

3.3 GHGs Mitigation Assessment

Institutions that are directly or indirectly involved in energy-related matters with environmental concerns are briefly described below:

- *SABA or IEEO stands for Iran's Energy Efficiency Organization:* Some of the projects it is involved in are energy use in domestic appliances, expansion turbines, load management in industry, energy consumption labelling and publishing an energy information monthly. Technical booklets and films on energy management are circulated for educating the youth on the energy crisis. A national energy laboratory is also part of the SABA.
- *SANA or INEO stands for Iran's New Energy Organization*: It was established in 1995 to fulfil the following objectives:
    - Develop and upgrade renewable energy sources,
    - Undertake investment and research in the above fields,
    - Design and carry out pilot plants related to new sources of energies,
    - Provide technical assistance to the government and the private sector,
    - Cooperate with international organizations and institutions in R & D schemes,
    - Assist in mitigating environmental problems,
    - Publish technical reports and disseminate information, and
    - Hold general public awareness seminars.

The organization employs more than 70 experienced engineers. Some of the projects implemented to date include: working with photovoltaic cells, lighting of tunnels, solar heating, wind energy, geothermal energy, hydrogen energy, experimenting with hydrogen powered vehicles, water electrolysis and wave energy.

- *SERI stands for Sharif Energy Research Institute*: SERI was established in 1992 at Sharif University of Technology in Tehran. Based on an agreement signed between Japan International Cooperation Agency (JICA) and the Management and Planning Organization (MPO), a research project entitled "The Collaborative Study on the Comprehensive Energy Development Plan" was undertaken.

The above organizations are also involved in data compilation and are in regular contact with the ministries of Energy, Oil, Industries and Mines and Agriculture. They also work and exchange information with the universities as well as the municipalities, traffic departments, water related organizations and the railway authorities.

3.3.1 Tools and Software for GHGs Mitigation Analysis

Sophisticated models for analysis of energy demand and supply systems integrated with the economic and environmental models are available in Iran. The National Climate Change Office of Iran has taken the initiative to synchronize and incorporate the studies conducted by different universities and research centres in this area.

Analysis of the impact of various options for reducing the emission of GHGs indicates that there are many alternatives to lower the level of GHGs.

However, an enormous workload remains to be undertaken in the future. Studies need to be conducted in areas such as the acquisition of reliable activity data, local emission factors and economic and development indicators, just to name a few.

3.3.1.1 Long-Range Energy Alternatives Planning Software (LEAP)

There are many challenges that need to be addressed by policy makers. For example, while there is a need to expand the supply of affordable energy, assessing the environmental impacts of such an expansion has to be simultaneously conducted. Improving energy efficiency and attracting capital investment are among the other issues, which need to be tackled.

In 1997, a new tool called LEAP was designed by Stockholm Environment Institute[1] for conducting an integrated energy-environment analysis. The LEAP is a useful tool for integrated energy policy assessment, formulating energy strategies and undertaking GHGs mitigation assessment. The software is a scenario-based energy-environment-modelling tool. It studies ways of accounting for how energy is consumed, converted and produced, in a given region or economy, and under a range of alternatives (i.e. development, technology and price).

The characteristics of LEAP include comprehensive, integrated systems covering both the energy demand-side and supply-side mitigation options. LEAP provides cost and emission analysis, an associated environmental database containing extensive emission factor data, an easy-to-use menu-driven interface and straightforward data entry screens.

LEAP represents a relatively easy accessed and flexible accounting and modelling framework. As a "*bottom-up*" end-use modelling system, its principal elements are the energy and technology characteristics of end-use sectors and supply sources. The end-use approach enables the incorporation and simulation of several important factors that can have significant effect on future GHGs emissions. LEAP includes factors such as technological improvements and transitions, the limits imposed by saturation of energy-intensive activities and economic sectors.

LEAP contains a full accounting framework of energy, which enables consideration of both demand and supply-side technologies and accounts for total system impacts. For example, a reduction in electricity requirement will lead to a decrease in the operating and fuel costs for the electric plants operating on the margin and a decrease in fuel imports or local energy production requirements. With its links to the Environmental Data Base, LEAP can track the pollution resulting from each stage of the fuel chain, including the reduction in GHGs emission from extraction, processing, distribution and combustion activities that might result from more efficient use of electricity or other fuels.

In this Enabling Activity Project for preparation of Iran's Initial National Communication, extensive efforts were made to collect the required data to run the LEAP software. Despite this attempt, only portions of the data were available and thus complete use of this software remains to be explored in Phase II of the project.

3.3.2 GHGs Abatement Policies

Iran has a high potential for alleviating the amount of GHGs emission. In the energy sector, principal policies are clean and efficient power generation, environmentally friendly refineries, improved vehicles and public transport, and energy-efficient buildings and appliances. Similarly, in the non-energy sector, mitigation strategies include modern farm and livestock management; protection of forestlands

1- *LEAP Training Exercise for GHGs Mitigation Analysis, Stockholm Environment Institute, Boston, MA, U.S.A, 1995.*

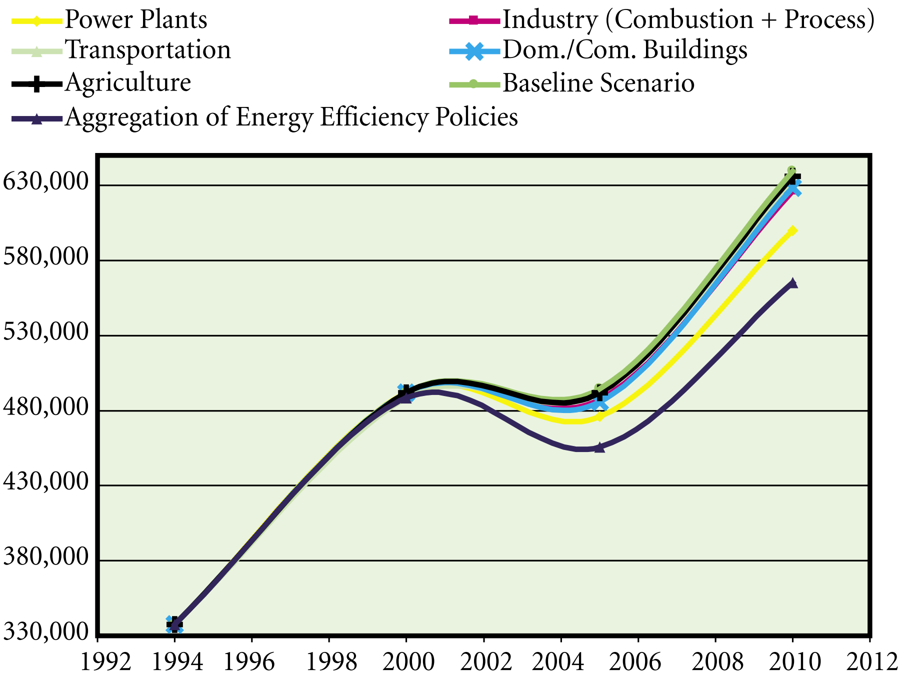
and resources; control and treatment of wastewater; disposal management and recycling of waste.

Some of the primary criteria adopted to screen mitigation measures are listed below:

Table 3.5 Different Policies for Improvement of Vehicle Technology and Their Impact on GHGs Emission Reduction

Policy	*Reduction* kg /veh./yr	(%) Reduction
ECE R83/03 Standard for domestic light-duty vehicles (2015)	1,269	31
ECE R83/03 Standard for imported light-duty vehicles (2005)	1,623	37
EU 2000 Standard for domestic & imported light- duty vehicles (2015)	1,285	32
LPG for taxis with catalyst (2005)	838	15
ECE R49 "Euro 2" standard for imported minibuses (2000)	17,292	45
ECE R49 "Euro 3" standard for domestic & imported minibuses (2005)	9,869	33
ECE R49 "Euro 2" standard with particulate trap for minibuses (2005)	5,500	18
ECE R49 "Euro 2" standard for domestic & imported buses (2000)	39,459	38
CNG buses with catalyst (2000)	76,533	56
ECE R49 "Euro 3" standard for buses with catalyst (2010)	32,616	40
ECE R49 "Euro 2" standard with particulate trap for trucks (2010)	34,120	30
EU 97 standard for motorcycles and mopeds (2003)	100	4

Figure 3.4 Impact of Energy Efficiency on GHGs Baseline Emission in Energy Sector (Gg-CO2 Equivalent)



- Possibilities of integration in the current sectoral and sustainable development programs;
- GHGs mitigation potentials;
- Cost of emissions abatement or cost-effectiveness if implemented;
- Environmental impacts; and
- Ease of application of the selected approach when implemented.

3.3.2.1 Energy Sector

Analysis of the impact of various options for reducing the emission of GHGs indicates that there are many alternatives to lower the level of GHGs. However, it should be noted that the implementation of the policies related to energy efficiency in various sectors, fuel switching and oil and gas activities is dependent on other factors. For example, it is necessary to assess the sufficiency of financial resources and the availability of international cooperation i.e. technology transfer, Clean Development Mechanism (CDM) and supplementary funds.

Improving energy efficiency

Enhancing energy efficiency has proved to be the most economic option for reducing emission of GHGs. Potentials for energy conservation are estimated to be 31% in year 2021[1]. Realization of this potential would have a tremendous impact on the emission of CO_2. Through rational use of energy accompanied by changes in the fuel mix, it would be possible to reduce the average annual growth rate of CO_2 emission from 4.2% to 2.4% in the period 1999-2021. Figure 3.4 shows the trend of GHGs emissions as a result of energy efficiency policies.

Power plants

Owing to the high intensity of energy consumption in power generation units in Iran, utilization of "*pinch technology*" has become very attractive in optimising power plant efficiency. There is potential for 20% reduction of fuel consumption with this technique over a five-year period and the government has approved some projects using pinch technology.

Based on data provided by the Ministry of Energy, per capita electric energy generation in Iran was 1,668 KWh in 1998 and the average annual growth rate is 6.4%. Based on these figures, the total nominal installed capacity of power plants is now 25,000 MW out of which 23,000 MW is generated by thermal power plants. The generation capacity is programmed to reach 39,500 MW by 2005, 32,200 MW of which will be produced by thermal plants (4,800 MW electrical energy will be extracted solely from the steam section of the combined cycles). Therefore, according to the program, in 2005 a conservatively estimated 12,100 MW energy will be produced without CO_2 emission.

Industry

Optimisation of energy consumption in cement and steel industries is being implemented at a projected rate of 2.4% between 2000 and 2005. The same trend is forecast between 2005 and 2010. However, in the case of petrochemical industries, optimisation has been foreseen at 4% between 2000 and 2005, reaching 3% during the period 2005 to 2010. In other industries, this rate is estimated at 2% for the same period.

Domestic and commercial buildings

Starting 2002, new building codes and standards come into effect that legislate optimising energy consumption in residential and commercial buildings. The codes also include the use of suitable and sound building materials and double-glazed windows with adequate insulation.

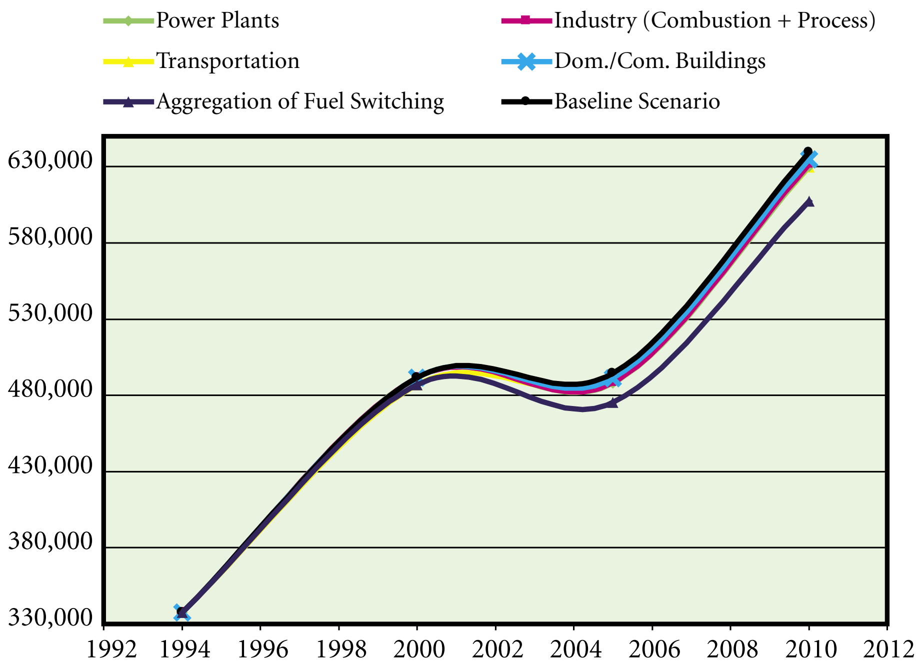
A production program for domestic and industrial appliances with high efficiency and low energy consumption is part of the government legislation for conservation of resources and the environment.

Domestic and industrial appliances

A production program for domestic and industrial appliances with high efficiency and low energy consumption is part of the government legislation for conservation of resources and the environment. This has already been implemented for some 16 domestic and industrial energy-consuming appliances including centrifugal pumps; refrigerators, freezers, air-conditioners, absorptive chillers; as well as electric Samovars, irons, water heaters and radiating heaters.

1- *Sharif Energy Research Institute (SERI) carried out this study.*

Figure 3.5 Impact of Fuel Switching on GHGs Baseline Emission in Energy Sector (Gg-CO_2 Equivalent)



Improvement of vehicle technology

The implementation of standards and policies for reduction of vehicles emissions, compared with the base year 1997, are given in Table 3.5. Since the year of introduction of different standards is different, the total emission reduction in a particular target year cannot be calculated.

Fuel switching

Power plants

In the year 2000, the total heating value of gas oil and heavy oil was equivalent to 5.26 billion m^3 of natural gas. Also in 2005 the amount of natural gas necessary for fuel switching will be 6.9 billion m^3. By switching from liquid fuels like gas oil or heavy oil to natural gas, the amount of CO_2 emission from thermal power plants will be reduced from 89.4 million tons to 83 million tons in 2005, or an abridgement of 7.2%. Figure 3.5 shows the impact of fuel switching on GHGs emission reduction in different energy sub-sectors

Refining processes

To optimise energy consumption, conserve national resources, and also reduce emission of air pollutants, the Ministry of Oil has devised several plans for changing refinery fuels. In general, each refinery unit consumes 5% of its production. Liquid fuels provide a recognizable part of this fuel. In accordance with the said program, over 90% of the fuel consumption in the refineries will be converted to natural gas. For this purpose and also to upgrade the quality of oil products and reduce pollution, the government is investing some 3 billion USD in its third FYDP. If the program targets are reached, about 260 PJ of consumption of oil and gas at the refineries will be provided by natural gas. As a result, emission of about 2,570 Kt of carbon as CO_2 will be reduced. Self-consumption of oil refineries from oil products will reduce to 20 PJ and the corresponding figure for gas refineries will become 4 PJ. Instead, they will consume about 218 PJ and 46 PJ of natural gas, respectively.

At present a 250 KW power plant in Shiraz and also a 1,000 KW power plant in Tehran are under construction.

Flaring gas

One of the most important sources of emission of pollutant materials into the atmosphere is flaring gas at the wellhead. When producing crude oil, associated gas is also produced, which is separated from oil in the reduction steps. Over 30% of this is unutilised and therefore flared. These differently sized fields are found both offshore and onshore. One of the important government programs for using these gases is injecting them into the oil reservoirs, which will both increase reservoir pressure and cease the flaring of associated gases. In addition to the injection that consumes a large amount of the flared gas, transferring it to a pipeline and using it as petrochemical feedstock are alternative programs being considered in the government's plans.

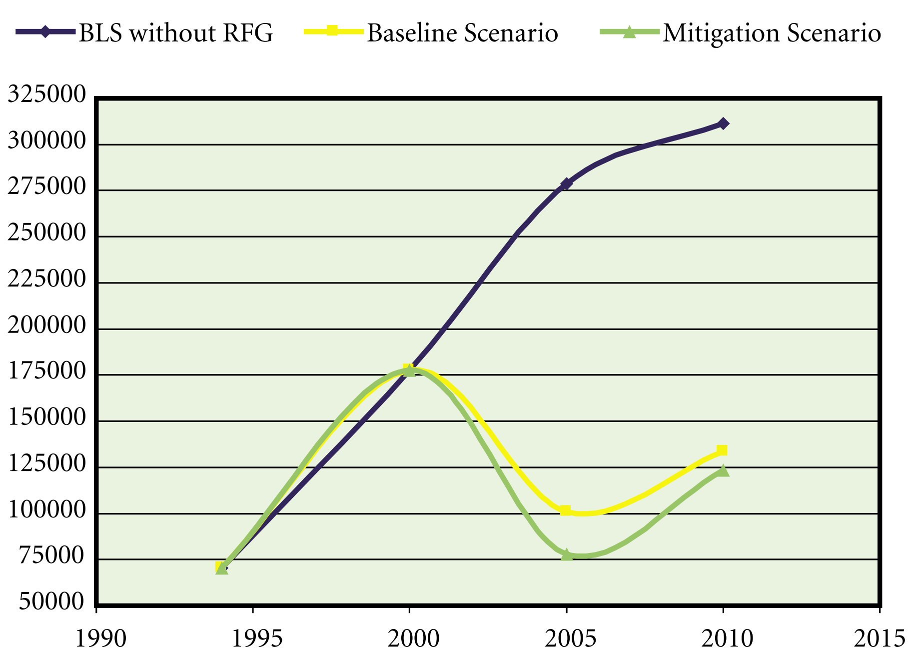
When these plans are implemented, then about 175,270 Kt of CO_2 would be reduced from emission of pollutant gases resulting from flared gases. However, the government is unlikely to fulfil its commitments in collecting the associated gases for injecting into the oil wells owing to the limited allocated budgets and the technologies required.

In spite of all such programs, there would still be minimal of gases that would be flared. Because of the problems associated with distribution of small volumes of gas in offshore and onshore production, setting up the required gathering systems for these gases is not considered as a priority. To make use of these gases, different technologies may be employed:

- GTL (Gas-to-Liquid)
- OCM (Oxidative Coupling of Methane)
- DMC (Dimethyl Carbonate)
- WW (Well-to-Watt); producing electricity at the wellhead.[2]

Regarding the above-mentioned methods, the amount of GHGs emissions in different scenarios is shown in Figure 3.6.

Figure 3.6 GHGs Emission from Oil & Gas Activities in Different Scenarios (Gg-CO_2 equivalent)



Up to now, nuclear energy has been promoted as a research potential in Iran.

Alternative fuels

The primary interest is focused on natural gas and liquefied petroleum gas (LPG) although a rather new fuel, dimety1 ether (DME), seems promising for compression ignition engines.

Fuel conversion of buses and taxis to CNG and LPG with catalysts

Natural gas is to be provided for 8,000 buses nationwide, and it is projected that 1,000 CNG driven buses will be operating in Tehran by 2003. In order to use natural gas in the transport sector with low emission, for example in buses, it is of utmost importance to keep a constant energy content of the gas. To avoid corrosion in pressure vessels and high-pressure tubes, it is also vital that the gas is free of water and sulphur compounds. In winter, in particular, there is also a risk of formation of ice crystals in the gas inlet system if water is present.

The project for LPG-fuelling of taxis in Tehran is underway with over 50,000 taxis running on LPG/petrol dual fuel systems. This measure envisions eventually restricting taxis to LPG use only so that they can add a catalyst to their cars for further reduction of emissions. It is estimated that such action would induce a reduction of 15%, equivalent to 838 kg/year/taxi of GHGs in CO_2 equivalent. There are approximately 100,000 taxis in Iran. Catalysts for LPG fuelled taxis are to be in place before 2003. However, the following factors are to be considered if optimum use of LPG is to be achieved:

- The composition should be 85% by volume propane and 15% by volume butane.
- The content of olefins must be less than 2% by volume in LPG for use as a motor fuel.
- The gas should have the same composition for all seasons.
- The maximum content of sulphur shall be 50 ppm.
- The gas shall be free from oil and water.

Use of clean and renewable energy resources

Solar and wind energy

Generally, the use of solar energy in different regions of Iran is practicable. Establishment of solar power plants especially in Tehran, Yazd, Semnan and Shiraz has been studied. At present a 250 KW power plant in Shiraz and also a 1,000 KW power plant in Tehran are under construction.

A number of different projects including photovoltaic schemes have been implemented as well, or are being constructed. The sum of the power generated from photovoltaic plants is 50 KW, and from solar power plants 1,280 KW. In this regard the required capital investment is about USD 800,000 and 67 billion Rials.

Current studies of wind energy indicate that in Iran the potential for about 6,500 MW of wind energy is available. At present, however, only eight 550 KW turbines, and two 500 KW and 15, 300 KW turbines, are operating, making use of this renewable energy source. Approximately 115 billion Rials have been invested for wind energy projects in the country. Two models of wind power plants with different technologies have been set up and operational in Roudbar.

The sum of the power generated from photovoltaic plants is 50 KW, and from solar power plants 1,280 KW.

Geothermal, wave and tidal energy

Geothermal energy potential is found primarily in five regions in Iran, namely, Sabalan, Damavand, Makou, Khoy and Sahand. Up to now, the geology, hydrology, and geophysics as well as geochemistry of these areas have been studied. Investigations show that the total geothermal energy potential in Iran is 60 million TJ. The Ministry of Energy has begun excavation for a 3,000 m deep cellar in Meshkinshahr in Ardebil province, which is to become a steam cycle power plant in 2005. There is a potential for 1,200 MW of installation capacity.

Amongst the four sea energies including waves, tides, temperature difference and salt concentration difference, waves and tides are being considered. Establishment of this kind of power plant is highly dependent on the geographical conditions of the site. In this regard, 36 regions along the southern coasts of Iran have been studied. However, the cost of energy produced from tidal fluctuations is considered too high and not a priority at present time.

Hydrogen energy

Hydrogen can be produced, using basic energy resources. It can be simply produced from abundant water. These factors make it the most seriously discussed source of energy. The pilot project of solar hydrogen technology started in Tehran in 1996. It is scheduled to come on-stream by the end of year 2004. To date, the investment in this project stands at 1 billion Rials.

Hydro power units

According to a study conducted by the Ministry of Energy, the total theoretical potential for hydro electricity generation in the country is about 42,000 MW, 20,000 MW of which is considered feasible. Of this total capacity, about 2,000 MW is being utilized and 9,000 MW is under construction. It is expected that in 2005 with the completion of the projects and commissioning of the plants, about 5,300 MW will be utilized by which time the installed capacity of hydropower will be increased to 7,300 MW. This is practically 25% of the projected national electricity demand for 2005.

Nuclear energy

Up to now, nuclear energy has been promoted as a research potential in Iran. Its use in different sections of industry, agriculture, medicine and other services has also been studied. To achieve savings in consumption of fossil fuels, use of nuclear power plants is considered essential. Presently, it is planned that 10% to 20% of the country's electrical energy be nuclear. To date, only the first unit of the Bushehr power plant with a 1,000 MW capacity is being built. Once in operation, the amount of CO_2 emission will be reduced by 3% in the year 2005.

Encouraging farmers to centralize livestock operations will assist them in receiving feeding and genetic recommendations, which will improve animal production and at the same time reduce methane emission.

Comprehensive policies in transport sector

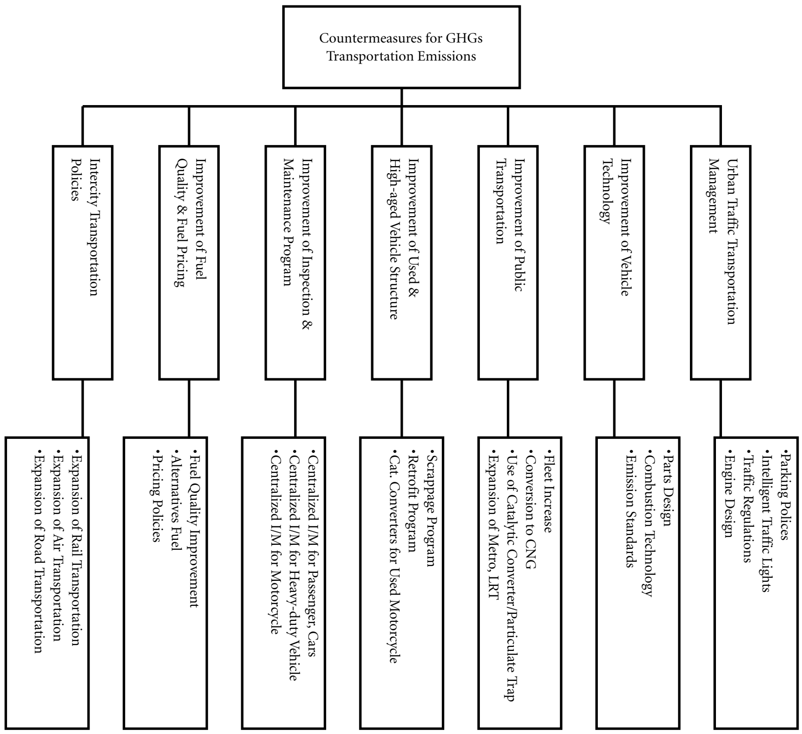
It is possible to mitigate GHGs emissions in the transport sector by improving the following:

- Urban traffic and transportation management
- Vehicle technology
- Public transportation
- Used and aged vehicle structure
- Inspection and maintenance (I/M) programs

- Fuel quality and fuel pricing
- Inter-country and inter-city transportation policies (e.g. land, rail, air)

Detailed studies to be used as working documents for formulation of such policies are available[1]. Figure 3.7 illustrates the above sequences as a flowchart.

Figure 3.7 Fields of Transportation Mitigation Strategies



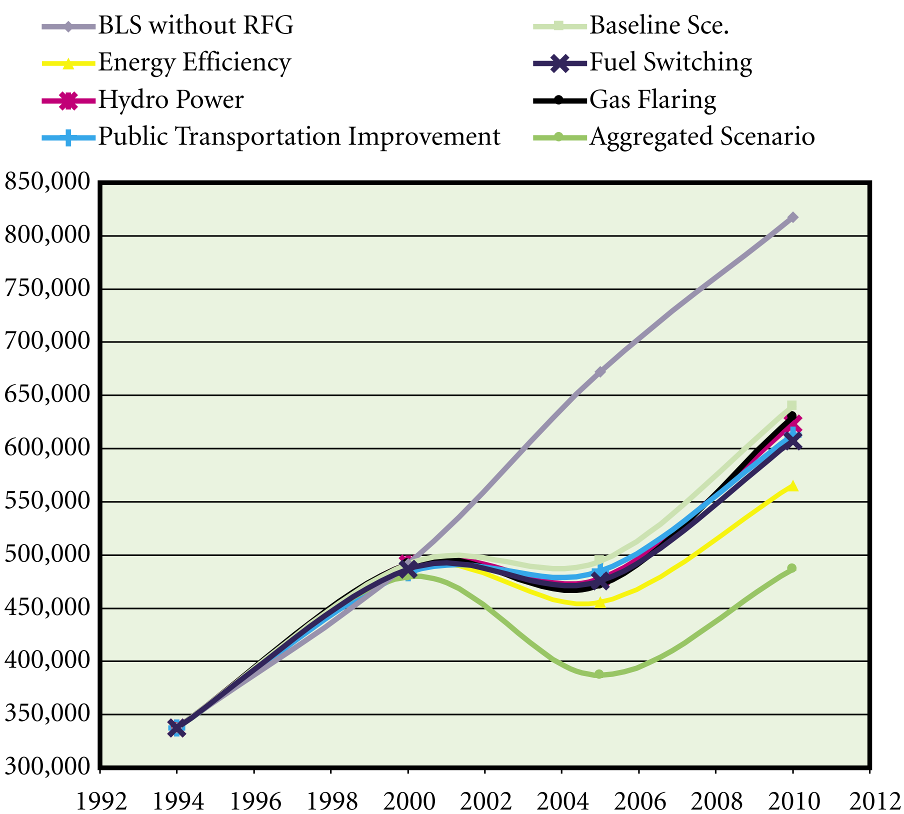
Other mitigation alternatives

The decentralization policies mentioned earlier together with running publicity campaigns, short training courses involving non-governmental organizations (NGOs) and civil society organizations (CSOs), and workshops aimed at increasing public awareness on environmental issues are some of the "*bottom-up*" approaches adopted by the government. There are also other fundamental measures like *"top-down"* government legislation aimed at sustainable development of the country. These include integrated resource planning, energy management guidelines, encouragement for energy auditing and compiling standards. Some *"top-down"* policies such as introducing penalties on consumption tariffs or compulsory code of practice have also been considered by the government.

Some "top-down" policies have also been considered by the government.

1- *Tehran Transport Emission Reduction Project, GEF / World Bank Project, the Municipality of Tehran, 1997.*

Figure 3.8 Different Policies Contributing to GHGs Emission Reduction in Energy Sector (Gg-CO_2 Equivalent)



Impact of integrated policies on GHGs emission reduction in the energy sector

Other relevant policies for the energy sector, which have been described are brought together and reflected in Figure 3.8, which depicts the resulting interaction of implementing these policies.

It is noteworthy that since there are serious financial constraints for the government to implement the recovery programs of flared gases, the possibility of achieving this baseline is unlikely. In short, while the project for collecting and injecting the flare gases into the oil fields is an effective mitigation policy, it requires financial and technological assistance, possibly through international resources such as CDM or similar mechanisms to encourage the government to also allocate the required funding for this highly important mitigation measure.

3.3.2.2 Non-energy Sector Mitigation Policies

Iran's non-energy sector mitigation strategies include modern farm and livestock management, protection of forest resources, control and treatment of wastewater, disposal management and recycling of waste. Designing a suitable plan for reducing GHGs emissions in the non-energy sector is as important as that in the energy sector.

The impact of rising GHGs and the emission of CO_2 due to enhanced farming and agricultural production, over-harvesting and destruction of forests that upsets the natural carbon cycle, and increasing amounts of solid and liquid wastes that emit methane are provided below for the non-energy sector. The pattern of GHGs emissions is given for each of these relevant sectors in accordance to the baseline scenario (BLS).

GHGs mitigation policies in agriculture

The role of livestock population

Stabilizing the number and the breed of livestock, while increasing animal production per head to supply the required human animal protein, can be accomplished through:

- Breeding of animals through a long-term improvement program,

- Enhancement of average daily gain of farm animals,
- Development of feed conversion,
- Reducing internal and external parasites, and prevention of pathogenic diseases,
- Improvement of carcass quality and quantity,
- Synchronization of animals in order to increase their reproduction.

An improvement of 20% in animal production is equivalent to reducing the animal population by the same amount, which in turn will mitigate methane emission.

Methods of livestock manure storage and its decomposition

Management of animal manure will be a problem in the future. The following are expected to mitigate methane production:

- Prevention of manure accumulation by use of manure spreaders in agricultural farms,
- Storage and seasonal use of manure during the year on agricultural land according to technical procedures,
- The use of manure as feed in animal rations,
- The prevention of the use of manure in rural areas as fuel,
- The use of manure in biogas systems,
- Make use of sump tanks with aerators for storage of manure,
- Drying of manure in poultry farms,
- Anti-bacterial deodorant applications for prevention of bacteria growth.

Improvement of feed composition

Changing the feed composition and patterns of feeding can mitigate GHGs by:

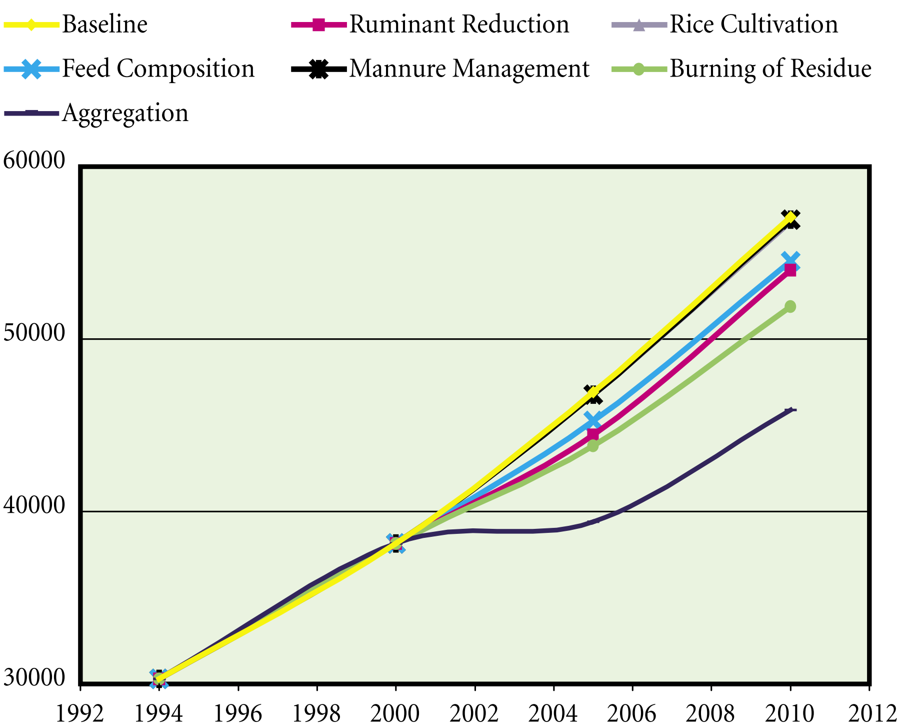
- Using feed formula for reduction of methane production,
- The production of high quality feed material by biotechnological methods for methane reduction,
- Making available feed concentrate for farmers,
- Providing methane inhibitors as feed additives or supplements for control of methane production,
- Providing sources of nitrogen, sulphur and other mineral nutrients in dry season, supplied as urea-molasses blocks left in pastures to increase roughage, digestibility and productivity of livestock and finally reducing methane yield.

Conservation and sustainable management of livestock

Encouraging farmers to centralize livestock operations will assist them in receiving feeding and genetic recommendations, which will improve animal production and at the same time reduce methane emission. Thus educating farmers is important and can provide them with increased knowledge of better use of new technologies.

Mitigation must focus on sustainability using a *"bottom-up"* approach, thus presenting new challenges in relation to livestock production at the grassroots to the farmers themselves. A well-integrated livestock sector has a positive environmental impact. Accordingly, optimising the animal density within every species of livestock is recommended.

Figure 3.9 Contribution of Different Policies to GHGs Reduction in Agricultural Sector (Gg CO_2 - equivalent)



Methane emission reduction in rice fields

Rice is important in agricultural development and for the national economy. More than 50% of Iran's rice crop is produced in the north of the country. Higher air temperature itself will increase rice plant respiration rates and reduce net photosynthesis, hence eventually reducing the plant yield.

Introduction of varieties of high yield rice and improvement of agricultural techniques will increase yield per hectare. Reduction of land under rice cultivation will thus be possible, but this cannot reduce emission by more than 5%.

Preventing the burning of agricultural residue

Rural development plans must in the future take notice of public concern for the environment. Encouraging the management of large industrial farms to refrain from burning agricultural residues is essential and communication between government and farm managers will pave the way for this effort, which by 2010 is expected to mitigate 95% of gases from burning these wastes. Greater involvement of the people and NGOs/CSOs with environmental concerns and advocacy programs to sensitise the general public about the issues will increase the chances of farm managers to follow the governmental policies adapted. Table 3.6 and Figure 3.9 show the impact of different mitigation options on the GHGs emissions reduction (in CO_2 equivalents) for the agriculture sector.

Based on Table 3.6, it is expected that in the years 2005 and 2010 the equivalent of 7,464.7 Gg and 11,193.2 Gg CO_2 will be mitigated, respectively; whereas without these policies, GHGs emission in CO_2 equivalent for the same years will be 46,913 and 57,073 Gg, respectively.

Table 3.6 GHGs Emission Reduction in Various Mitigation Options for Agriculture Sector (CO_2 Equivalent-Gg)

Mitigation Options	2005	2010
Ruminant Number Reduction	*2,457.30*	*3,058.40*
Livestock Manure Management	*142.7*	*256.4*
Feed Composition Management	*1,625.10*	*2,553.60*
Rice Cropping Systems	*132.3*	*135.5*
Management of Agricultural Residue	*3,107.30*	*5,189.30*
Total	**7,464.70**	**11,193.20**

It should be pointed out that the aggregated reduction in GHGs emissions between 2000-2005 and 2005-2010 are 22,475 Gg and 48,563 Gg, respectively.

GHGs mitigation policies in forestry

The following primary activities will be effective in decreasing CO_2:

- Afforestation and forest rehabilitation using native species that absorb more carbon,
- Refrain from over-harvesting, and
- Driving livestock out of the forests.

Other activities include: correct use of land, soil and water resources considering the capacity of the ecological unit; protection of forests and rangelands by silvicultural systems for suitable ecosystems; and combating the trend of desertification.

Afforestation and forest rehabilitation

Continual utilization of forests is possible through protection and development of these valuable resources. Natural resources in fact are considered as the infrastructure of the economy for each nation and are regarded as the most important means of economic and social progress. Consequently, the government has designated forest rehabilitation as one of the top priorities in the third FYDP. An instance of activities in this vital area is the TOOBA project, which is briefly described below.

A summary of the TOOBA project:

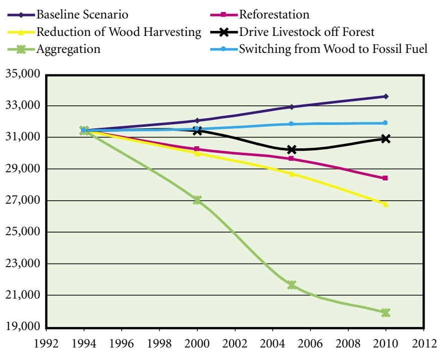
Based upon an agreement between the Ministry of Jahad-e-Keshavarzi (Ministry of Agriculture), Agriculture Bank and the Management and Planning Organization, the TOOBA project was designed and carried out in the year 1999, in two forms:

- Planting fruit species and multi-purpose trees in the degraded national lands located in the northern regions of the country. This project was implemented under the title of 'Management of Forest Resources'. The scheme is an excellent example of involving local people and cooperatives, thus using a "*bottom-up*" approach. The objective was to improve the economics of the related activities, through creating employment and raising production of non-wood products, while protecting and increasing soil fertility. The project can be used as a prototype elsewhere in the country and with greater participation of local cooperatives, NGOs and CSOs.
- Planting, fructifying and multi-purpose species plantation on fertile public lands under the management of the Ministry of Agriculture. Similar activities are undertaken on private holdings, encouraging landowners to perpetuate this initiative with the government providing the required technical and financial support.

Controlling forest utilization and other wood resources and introducing a replacement fuel for wood

Wood and forestry products play a very important role in our daily life. These activities are either legal such as authorized harvesting through forestry projects in the various regions, or there is unauthorized harvesting or the illegal trade of wood from forest areas. There are also other uses that are made of wood in rural

Figure 3.10 Contribution of Different Mitigation Policies to GHGs Reduction in Forestry Sector (Gg CO_2 Equivalent)



areas. For example, there is a variety of harvesting of wood production from the development of tree plantations (wood farming) and other methods of agro-forestry. Given the demand for wood products, there are insufficient resources to meet market needs at present and it is anticipated that the demand will increase in future. Table 3.7 compares the trend of the reforestation and wood harvesting in the baseline and mitigation scenarios.

Driving animals off the northern forest and preventing settlements

The primary causes for the qualitative and quantitative degradation of the northern forests are animal husbandry, farming, cutting the woods for fuel and the implementation of different development projects in the northern area. As reflected in Table 3.7, if mitigation policies are implemented, the forest areas in Iran will be more than doubled by the year 2010. Figure 3.10 shows the impact of different mitigation policies on forestry GHGs reduction (CO_2 equivalent)

GHGs mitigation policies in waste sector

In the third FYDP, the government has planned many projects for solid waste sanitary landfill. Since the landfill increases methane emission, the following approaches are recommended for reducing CH_4 emissions from solid waste landfills:

- The methane generated in landfills can be recovered and used to produce energy;
- The quantity of landfill waste can be reduced through source reductions, recycling, composting and other waste management practices; and
- Changing the landfill sites from anaerobic to semi-aerobic can also mitigate a major part of GHGs. Figure 3.11 shows a landfill gas recovery unit in Shiraz, a city located in the south of Iran.

Urban wastewater treatment plants in Iran are mostly based on aerobic systems that generate a lot of sludge. To prevent CH_4 production during industrial wastewater treatment and sludge disposal, aerobic primary and secondary treatment and land treatment are recommended. Alternatively, anaerobic treatment that produces methane and use of the retained $CH_{4,}$ as an energy source to heat digestion tanks

Table 3.7 Comparisons of the Reforestation, Afforestation and Wood Harvesting Trends in BLS and Mitigation Scenarios

Category		1994		2000		2005		2010	
		BLS	M Sce.	*BLS*	M Sce.	BLS	M Sce.	BLS	M Sce.
Development of Forest Area (ha)	Forest Planting in the North	11,868	11,868	17,255	25,217	51,080	56,483	90,080	101,483
	Forest Planting in other Regions	26,383	26,383	88,000	225,000	376,000	506,000	751,000	881,000
	Tree Planting in Desert Lands	14,181	14,181	30,000	60,000	55,000	110,000	80,000	160,000
	Productive Tree Planting *	0	0	100,000	100,000	100,000	100,000	100,000	100,000
Total		**52,432**	**52,432**	**235,255**	**410,217**	**582,080**	**772,483**	**1,021,080**	**1,242,483**
Wood Harvesting (m^3)	North Forest	4,984	4,984	4,965	4,630	5,432	4,878	5,932	5,116
	Other Regions	14,250	14,250	16,048	14,443	17,718	14,174	19,562	13,693
Total		**19,234**	**19,234**	**21,013**	**19,073**	**23,150**	**19,052**	**25,494**	**18,809**
Impact of Driving off Livestock From Forests	Increasing Wood Production (m^3)	6,800	6,800	151,000	336,690	538,000	1,512,300	301,000	NA
	Area which become Free (ha)	100	100	2,338	5,200	8,300	5,000	3,800	NA

** (TOOBA Project)* *M Sce: Mitigation Scenario* is possible. As a last resort, the gas may be flared and converted to CO_2 that has a lower GWP.

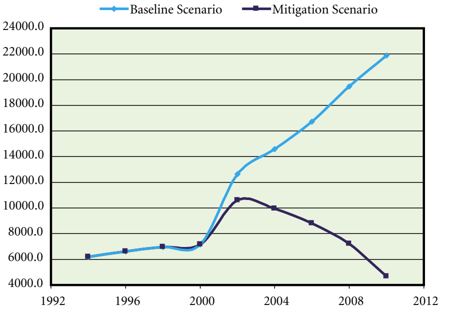
Figure 3.11 Landfill Gas Recovery in Shiraz

The proposed policies in the waste sector can be summarized as:

- Solid waste disposal management;
- Recovery of GHGs to produce energy;
- Recycling and composting;
- Urban wastewater collection and treatment;
- Optimisation of treatment plants;
- Applying new technologies for treatment;
- Recycling and reuse of treated wastewater;
- Storage and treatment of industrial wastewater under aerobic conditions;
- Prevention of CH_4 formation by primary and secondary treatment; and
- Recovery of CH_4's energy and/or flaring of CH_4.

To implement these policies a comprehensive advocacy program is a must. The role NGOs CSOs, as well as the media play in these advocacy programs to enhance their impact and sustainability is also considered essential. Figure 3.12 shows the effect of mitigation policies on methane emissions in the waste sector. It also compares the relative contributions of the energy and non-energy section to GHG emissions.

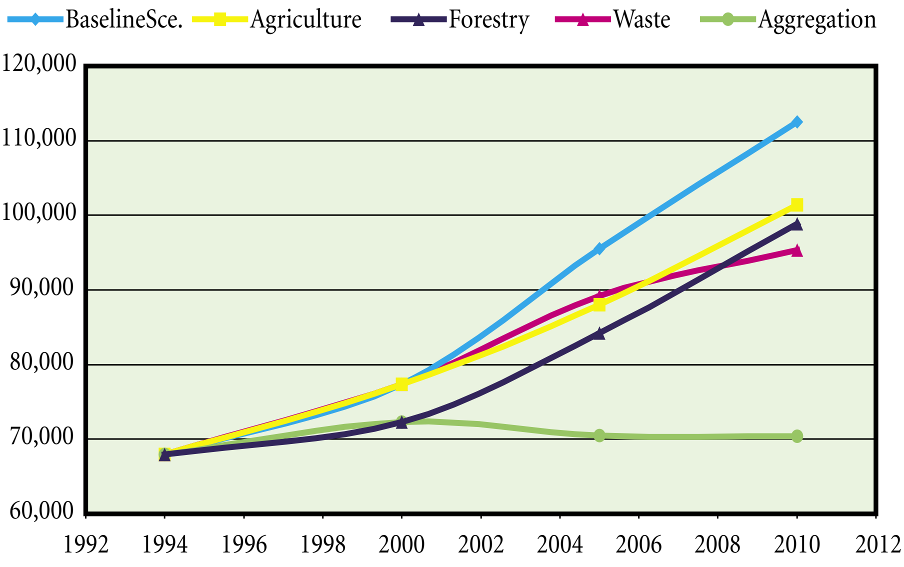
Figure 3.12 GHGs Emission Trends in Different Scenarios for Waste Sector (Gg-CH_4)



Impact of aggregated policies on GHGs reduction in non-energy sectors

The combined effect of aggregated policies on the overall trend of GHGs emissions in the non-energy sectors is shown in Fig 3.13. Figure 3.13 illustrates that if the

Figure 3.13 Contribution of Abatement Policies to GHGs Emission Reduction for Non-energy Sub-sectors (Gg-CO_2 equivalent)



proposed mitigation policies are fully adopted, the total GHGs emissions from non-energy sectors will remain relatively constant up to the year 2010.

Table 3.8 Capital Investment in Different GHGs Mitigation Options for Cement, Iron and Steel Industries

Category	Cement	Iron & Steel*
Average Cost of Conserved Energy (CCE)	*5.15$/Gj- Saved*	*3.85 $/Gj-Saved*
Capital Cost of Energy Efficiency	*334 Million USD*	*664 Million USD*
Capital Cost of Fuel Switching	*240 Million USD*	*164 Million USD*
Net Cost Per CO_2 Reduction for Energy Efficiency	*15,576 USD/Gg*	*-17,963 USD/Gg*
Net Cost Per CO_2 Reduction for Fuel Switching	*39,600 USD/Gg*	*- 43,800 USD/Gg*

** Indicates profitability of these plans, noting that the piping costs are not included.*

3.4 Cost Analysis

It is necessary to estimate the required capital investment per unit of CO_2 equivalent of GHGs mitigated. This makes it possible to review the same from the economic point of view, to prioritise the options and to structure a plan of action. The following calculations are thus necessary:

a. Fixed capital cost of replacing the GHG emitting system;
b. System operating cost, and comparison before and after mitigation;
c. Mitigation costs per unit amount of GHGs reduction ($/Gg) for various policies; and
d. Comparison of options to select the most cost-effective approach.

Sufficient information on the fixed and the variable costs of mitigation policies are not available for many sectors. Therefore, the cost analysis is done only for industry, agriculture and forestry sectors. Table 3.8 and Fig 3.14 show a summary of the cost analysis undertaken for improved efficiency and fuel switching mitigation policies in the cement and iron-steel industries.

Table 3.9 Estimation of Cost for Some Items Needed for GHGs Mitigation in Agriculture Sector (USD)

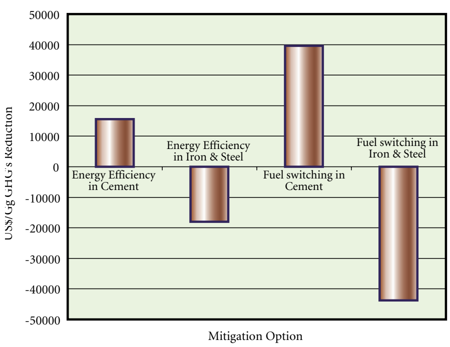
Categories	2005	2010
Training and education	*2,500,000*	*2,500,000*
Establishment of factories [a]	*3,000,000*	-----
Drug & chemical material and semen	*38,867,500*	*38,867,500*
Pasture seeds	*1,000,000*	*1,000,000*
Fuel guarantee in villages [b]	*100,000*	*100,000*
Equipment (car, computer, etc.)	*5,200,000*	-----
Cost of inspection	*1,000,000*	*1,000,000*
Governmental subsidies	*15,000,000*	*15,000,000*
Sub total	*66,667,500*	*58,467,500*
Unpredictable 5%	*3,333,375*	*2,923,375*
Grand total	**70,000,875**	**61,390,875**

a: Cost of material and workers are not included.
b: Cost of fuel is not included.

In the industry sector, applying the methods of emission reduction in cement and steel industries, as examples, is a positive proof for the policy. The rate of capital return through energy efficiency and fuel switching are 70% and 50% for cement and 134% and 182% for the steel industries, respectively. Both of these methods are justifiable and the following priorities are suggested:

- Fuel switching in iron and steel industry;
- Energy efficiency in iron and steel industry;
- Fuel switching in cement industry; and
- Energy efficiency in cement industry.

Figure 3.14 Unit Cost of GHGs Reduction in Different Mitigation Options for Cement, Iron and Steel Industries



Similarly, in the agriculture sector, reduction of GHGs requires training, planning, use of new technology, purchasing the required equipment and developing an investment scheme. The mitigation cost estimates are presented in Table 3.9.

With the implementation of mitigation policies, it is expected that more than 22,474 Gg of CO_2 equivalent in the agricultural sector will be removed between the years 2000 and 2005. In this manner, up to 48,562 Gg CO_2 equivalent reduction is possible between the year 2005 and 2010. Using the data in Table 3.9, the cost of mitigation for each Gg of CO_2 equivalent is determined and shown in Table 3.10.

In the forestry sector, the cost analysis for the three options mentioned earlier were considered and the consequent effect on mitigation of CO_2 is shown in Table 3.11.

Table 3.10 Capital Investment for GHGs Mitigation in Agriculture Sector

Period	GHGs Reduction (Gg)	Capital Investment ($)	Cost per Reduced GHGs ($/Gg)
2000-2005	*22,474*	*70,000,875*	*3,114.75*
2005-2010	*48,563*	*61,380,875*	*1,263.94*
2000-2010	*71,037*	*131,381,750*	*1,849.48*

Table 3.11 Cost Analysis for Forestry Mitigation Options

Mitigation Option	GHGs Emission *Reduction* (Gg CO_2/yr)	Annual Cost (USD 1,000)	Cost of Mitigation (USD/ton)
Reforestation and Forest Rehabilitation	*616.4*	*67,818*	*110*
Reduction of Wood Harvesting & Introducing New Fossil Fuels Instead of Fuel wood	*3250*	*-406,375.30*	*-125.04*
Driving off Livestock from Forests In Northern Forests of Iran	*1517.7*	*-40,585.20*	*-26.74*

3.5 Conclusions

The social and economic consequences of increased GHGs at the local and global levels are so great that they make the control and mitigation of GHGs, particularly in the energy sector, a crucial element for sustainable development.

A significant feature of economic development in Iran is the rapid increase of energy demand. This necessitates the expansion of the energy supply system that is characterized by a high percentage of fossil fuels, especially oil and gas in primary energy consumption and consequent increased emissions of GHGs.

A set of energy models were compiled and applied for studying the development of energy demand and supply balance, identifying the GHGs mitigation options. This has been done through using scenario analyses. The development of the energy sector in the case of BLS was explained earlier and emission of GHGs estimated in that scenario. Controlling emissions in different scenarios were also discussed and various options and their consequences identified.

Emission of GHGs may be reduced from 639,614 to 486,822 Gg CO_2 equivalent in 2010, by implementing mitigation policies in the energy sub-sectors. If the government's plans for recovery of flare gas are not put into effect, considering gas injection into oil wells as a mitigation policy, GHGs reduction by 2010 will be about 330,627 Gg CO_2 equivalent.

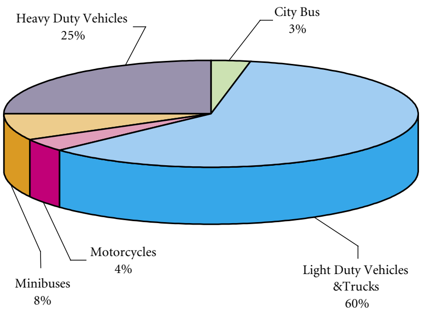
Enhancing energy efficiency, including combined cycle generation, has proved to be the most cost-effective option for reducing emission of GHGs. Potentials of energy conservation are estimated to be 31% in the year 2021. Realization of this potential would have tremendous effect on the reduction of CO_2 emission. Rational utilization of energy will reduce the average annual rate of growth of emission of CO_2 from 4.2% to 2.4% in the period of 1999-2021.

Renewable energy sources have a low share and high price in electricity production in Iran. Therefore, the main options focus on fuel switching, hydropower, combined cycle, and nuclear energy. Once the political obstacles in the way of building nuclear power plants in Iran are removed, these power plants will become an effective alternative for GHGs mitigation in the energy supply industry of Iran. The mitigation benefits of fuel switching and hydropower have been covered. The estimated cost of installation of the additional hydropower plant with an installed capacity of 7,700 MW will be approximately 2.7 billion USD excluding the cost of dams. If the cost of dams were also included, the necessary funding would be approximately 5.5 billion USD.

Iran is a major energy producer in the region and has many programs to reduce environmental damages. Some of them being implemented and the remainder requires proactive investments in the next few years. The main objective is to change the consumption patterns of different sectors and use natural gas instead. Another important option for mitigation is to end the flaring of associated gases. The major plans of the government are to use these flared gases in injection, as petrochemical feedstock and or transfer it by pipeline elsewhere.

The rate of capital return in implementing consumption optimisation and fuel switching, are 70% and 50% for cement and 134% and 182% for steel industries,

Figure 3.15 Share of Different Types of Motor Vehicles in GHGs Emissions in Tehran



respectively. Both fuel switching and energy efficiency improvement methods are recommended for cement and especially for iron-steel industries.

Some mitigation measures were also proposed to reduce the GHGs emissions from the transport sector in Iran. Presented in a program, the recommended steps focused on improvements in vehicles, public transport, fuel quality, and promotion of rail transportation for passengers and cargo. With BLS, an increase of 20% GHGs is predicted in the year 2010 compared with 1994 values. The combined measures, excluding inter-city transportation, will reduce emissions by 40-45%.
A recent international study in Tehran revealing the GHGs emissions inventory from the mobile sector is shown in Figure 3.15.

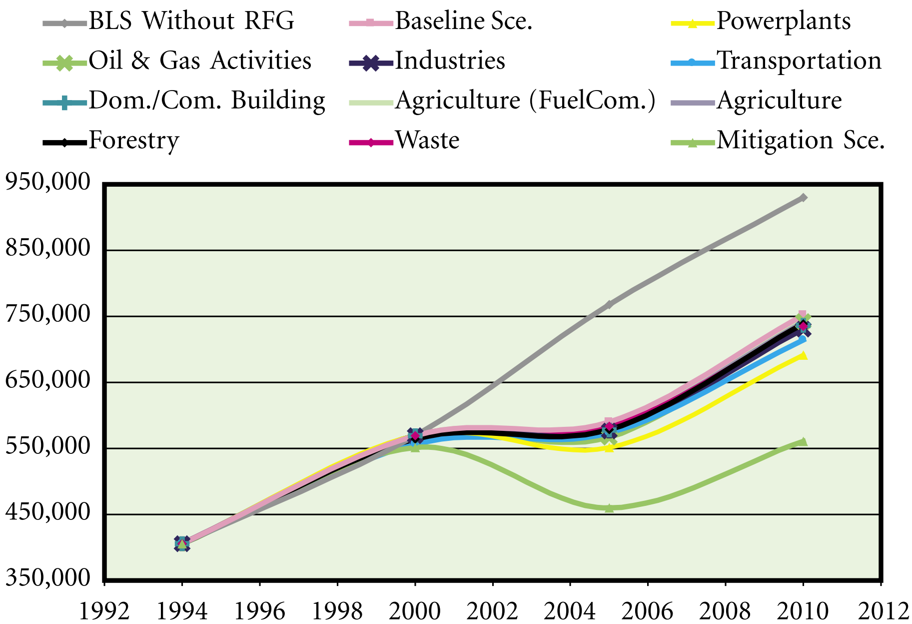
The proportion of light-duty vehicles and trucks is significant and countermeasures are being taken aimed at the reduction of gaseous and harmful particulate substances. For the city of Tehran, the experts estimated an investment cost per ton of local pollutants/CO_2 equivalent of GHGs emissions reduction that is approximately USD 1,000 bringing the total cost to 2 billion USD. For the entire country, the estimated cost is 8 billion USD. This heavy investment would undoubtedly require international partnership both in terms of funding and technical assistance.

The longer-term major development policies of the country targets raising the level of non-oil revenue and reducing dependence on oil income. Equally important is achieving better welfare and greater employment opportunities, particularly for the youth. Improved management of the environment, cost-effective energy

Table 3.12 GHGs Emission Trends in Baseline Scenario for all Sectors (Gg-CO_2 Equivalent)

Sub-sector		1994	2000	2005	2010
Power Plants		*51,914*	*67,480*	*89,400*	*118,080*
Oil & Gas Activities	Without Recovery Plan for Flare Gas	*70,333*	*177,572*	*278,766*	*311,342*
	With Recovery Plan for Flare Gas	*70,333*	*177,572*	*100,926*	*133,507*
Industry (Comb. + Process)		*72,302*	*86,292*	*136,543*	*190,633*
Transportation		*58,709*	*62,583*	*56,748*	*70,450*
Dom./Com. Buildings		*66,512*	*79,054*	*89,987*	*104,152*
Agriculture		*12,688*	*13,703*	*15,758*	*17,725*
Other		*5067*	*5067*	*5067*	*5067*
Sub-total	Without Recovery Plan for Flare Gas	***337,525***	***491,751***	***672,269***	***817,449***
	With Recovery Plan for Flare Gas	***337,525***	***491,751***	***494,429***	***639,614***
Agriculture	Agricultural Production	*17,457*	*22,498*	*27,047*	*33,034*
	Livestock Production	*12,859*	*15,625*	*19,864*	*24,027*
Sub-total		***30,316***	***38,123***	***46,911***	***57,061***
Forestry		***31,416***	***32,052***	***32,909***	***33,589***
Waste	Solid	*5,586*	*6,510*	*15,110*	*21,378*
	Liquid	*608*	*649*	*549*	*514*
Sub-total		***6,194***	***7,159***	***15,658***	***21,892***
Total in BLS	Without Recovery Plan for Flare Gas	**405,451**	**569,085**	**767,747**	**929,991**
	With Recovery Plan for Flare Gas	**405,451**	**569,085**	**589,907**	**752,156**

Figure 3.16 GHGs Emission Trends by Different Sectors in Mitigation Scenario ($Gg\ CO_2$ - Equivalent)



use and economic innovations are the prerequisites of such development policies. In short, to maintain the present 6% overall growth rate is bound to increase GHGs emission at the same rate, as shown in Table 3.12 unless the prerequisites are met.

Instances of technology transfer with which Iran is facing difficulties include liquefied natural gas (LNG), injection of associated gases to oil wells, making use of gas-to-liquid (GTL) techniques and so on. As is seen in Fig 3.16, taking advantage of these technologies can reduce about 200,000 Gg of the CO_2 emissions from oil and gas industries by 2005. The rate of emission of GHGs calculated on a baseline and mitigation scenario, are shown in Fig 3.16.

The agriculture sector had a share of about 7% of the total GHGs emission in the year 1994, which was on the same scale of GHGs emission recorded by the industrial processes plus forestry and rangeland sectors. Mechanized agriculture and introduction of up-to-date technologies to farmers and the rural population are possible indirect GHGs mitigation schemes.

Developed countries' increasing technical cooperation with Iran in line with AIJ programs under the supervision of the FAO is a possibility worth pursuing. Implementing mitigation policies in the agriculture sector has a valuable contribution towards the reduction of GHGs emissions.

In reviewing Figure 3.16, Figure 3.17 and Table 3.12, it can be seen that GHGs emission reduction mitigation policies would have the highest impact on the power plants and oil and gas industries (29% and 18%, respectively) in 2005. The lowest declines will be seen in the agriculture and waste sectors with percentages of 6% and 5%, respectively. These figures, as targets, can be accomplished once the government adopts the proposed flare gases mitigation policy. Should the government be unable to carry out the injection projects due to a lack of financial resources, the proposed mitigation scenario for the oil and gas sectors will remain the outstanding source of emissions in the GHGs mitigation program with 200,698 Gg of reduced emission in 2005.

As shown in the Figure 3.18, depicting contribution of different sectors to GHGs emissions reduction in the year 2010, powerplants and the transport sector will have the largest share in the total GHGs mitigation program with 32% and 20%, respectively; whereas the forestry and agriculture sectors with 7% and 6% will have the smallest shares. The change in the percentage of oil and gas in the mitigation program from 2005 to 2010 indicates that the government shall have

Figure 3.17 Contribution of Different Sectors to GHGs Emission Reduction in 2005(%)

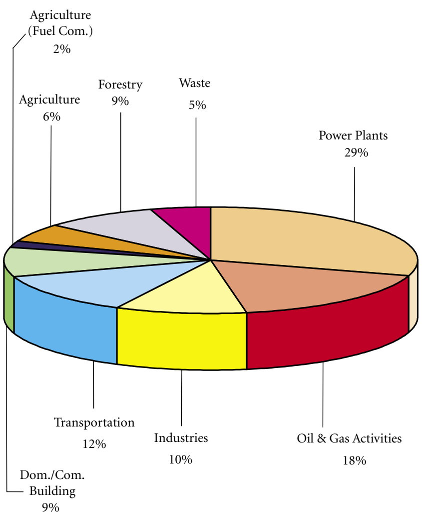
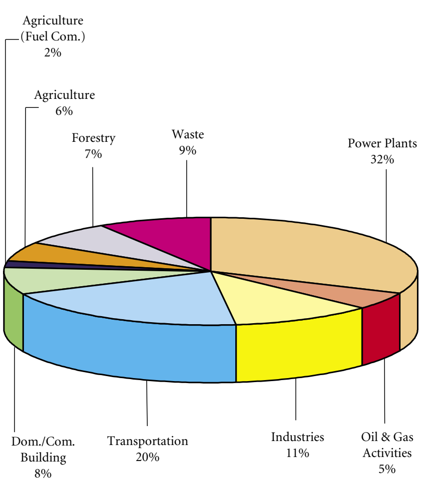


Figure 3.18 Contribution of Different Sectors to GHGs Emission Reduction in 2010 (%)



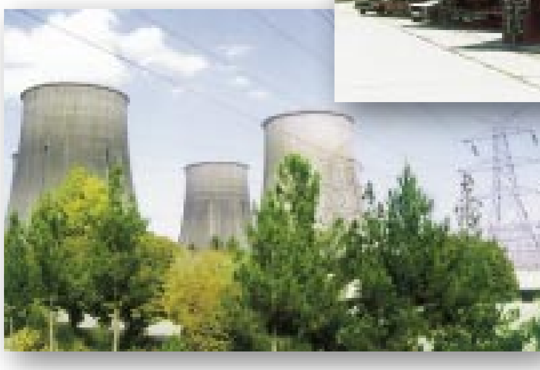
used environmentally sound technologies; whereas in forestry and land-use sector, the reduction in mitigation share shows that more efficient policies should be practiced.

It is noteworthy that the foreign policies of other countries vis-à-vis Iran will impact the achievement of sound environmental management of energy resources. Some such instances are mentioned below:

- Resolve present political tensions that hinder Iran from gaining access to nuclear power generation;
- Facilitate transfer of new and clean technologies and refrain from the transfer of polluting technologies,
- Strengthen regional technical cooperation and organize regional committees;
- Provide financial assistance through international organizations like the GEF and World Bank,
- Define and finance projects to benefit from CDM and AIJ,

Stabilize oil prices in the world markets so that the oil-producing countries can finance the import environmental - friendly advanced technologies.

Blue Sky; *Conversion to CNG*



Pardis (Paradise); *A Power Plant Fueled with Natural Gas*

Chapter IV

Vulnerability and Adaptation (V & A) Assessment

Hamoon Lake, Sistan-o Baluchestan*; Photography: IRNA archive*

In this chapter closer scrutiny is made of the vulnerability of different sectors of Iran to climate change and adaptation measures are assessed. After a brief review of climate change studies in Iran, the susceptibility of water resources, agriculture, forestry, coastal zones, public health, and energy production and consumption to the phenomenon is evaluated. It should be noted that most of these studies are at the preliminary stage and need further investigation.

National acclimatization actions also need to be thoroughly reviewed in the future since sufficient information and data were not available throughout the preparation of this report.

4.1 Climate Change Projection

4.1.1 National Atmospheric Observation Network

The first atmospheric observations in Iran were carried out after World War II by the allied forces to meet their aviation needs. Later in 1947, an independent irrigation agency of the Ministry of Agriculture established synoptic and climatic stations to meet the ministry's own needs. The Civil Aviation Organization was the other institution that constructed a number of meteorological outposts for its own purposes.

In 1954, the Iranian Meteorological Organization, a subsidiary of the Ministry of Road and Transportation was established to avoid parallel tasking. There were 34 synoptic, 107 climate, and 160 rain-gauge stations already functioning when this new establishment was organized. Today 184 synoptic stations, 35 complementary facilities, 250 climate, 2,300 rain gauge, and 12 agricultural research stations are functioning. The current growth in numbers not withstanding, the atmospheric observation network still needs to be enlarged and upgraded to provide adequate coverage for the country's climatic and meteorological condition.

4.1.2 Climate of the Country

Iranian scientists have closely studied the country's climate. The most recent research was undertaken as part of a comprehensive project on national water resources (Khalili et al., 1990)[1]. The modified De Martin method was applied to classify the weather characteristic of the country. Seven different types of climate were identified. Figure 4.1 shows the various zones according to these findings.

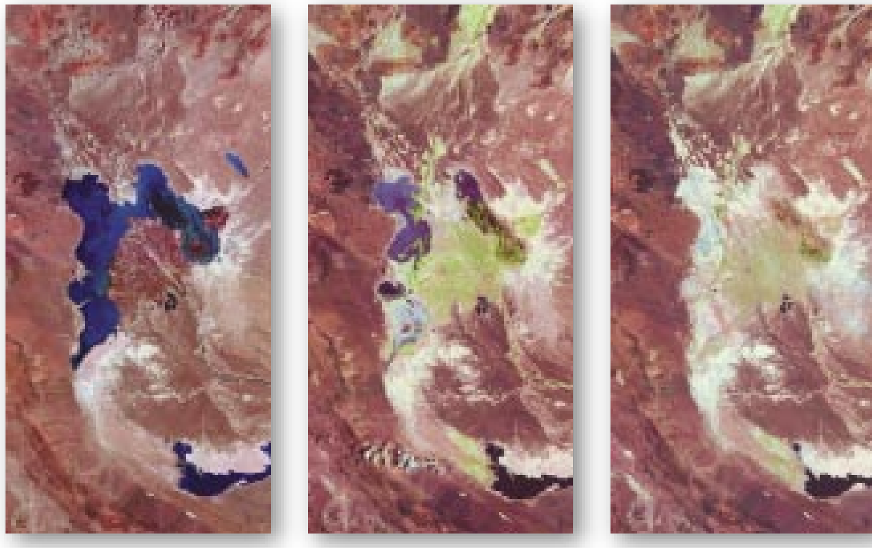
4.1.3 Study of the Long-term Temperature and Precipitation Patterns

Records of minimum, maximum, mean daily temperature and precipitation for the period of 1957-1995 were studied to provide an overall view of the underlying traits defining long-term temperature and precipitation patterns. The other goal of this study was to track any possible impact induced by greenhouse gases. Figures 4.2 and 4.3 indicate the results of these findings.

The first atmospheric observations in Iran were carried out after World War II by the allied forces to meet their aviation needs.

A review of the minimum and maximum temperature patterns along with the mean daily temperature indicate changes introduced by GHGs in most of the major cities. There is also clear evidence of the effective presence of aerosols in some of those cities.

1- *Khalili, A., S. Hajam, and P. Irannejad, 1990.* ***Understanding Iran's Climate, Comprehensive Project on Water Resources in the Country****, Jamab Consulting Engineering Co., The Ministry of Energy.*

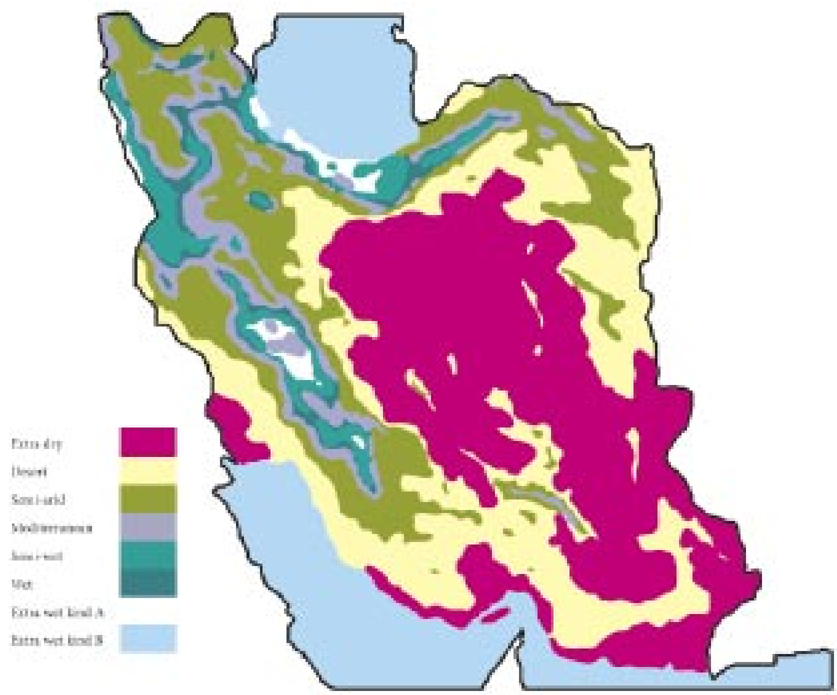


Nature's Rage; *Gradual drying of Hamoon Lake in southeast of Iran*

4.1.4 Climate Change Simulation

For the purpose of V&A model assessment in the Islamic Republic of Iran, a software called MAGICC/SENGEN (version 2.4), developed by the Climate Research Unit at the University of East Anglia in England, has been used. It includes

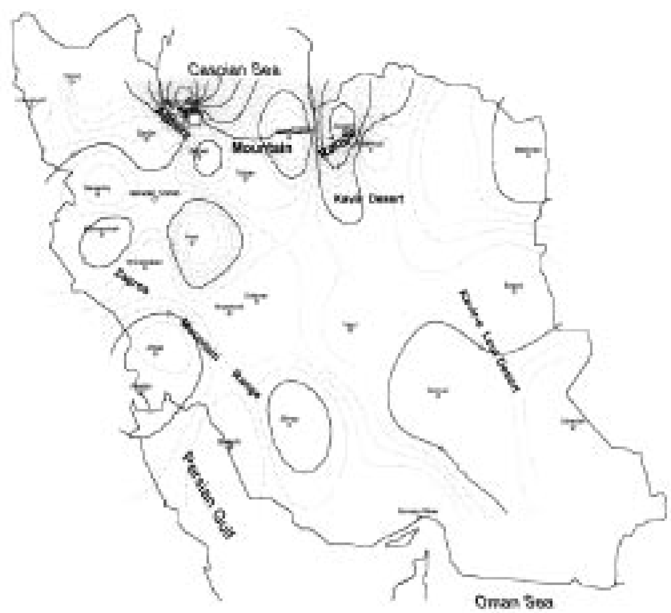
Figure 4.1 Different Climatic Zones as Determined by Khalili et al (1990)



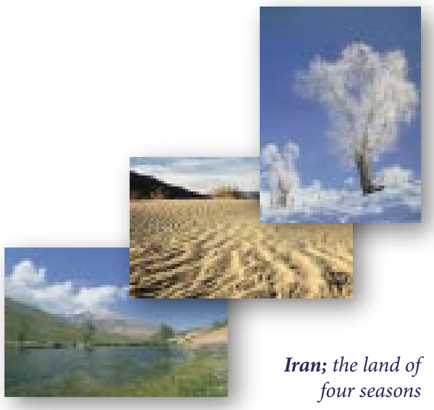
For the purpose of V&A model assessment in the Islamic Republic of Iran, a software called MAGICC/SENGEN, has been used.

Figure 4.2 Map of the Long-term Temperature Records Pattern (°C/y) in the Country

Figure 4.3 Map of the Long-term Precipitation Records Tendency (mm/y) in the Country



Pattern analysis of temperature and precipitation records revealed that the temperature is falling in the northwest; part of the south, and east of the country especially along the Zagros mountain range.



Iran; *the land of four seasons*

a one-dimensional up-welling diffusion model to calculate global temperature and sea level changes using different emission scenarios of greenhouse gases and sulphur dioxide. The software also features a scenario generator, enabling it to forecast possible regional climate change.

4.1.4.1 Choice of Scenario

Considering IPCC recommendations, three scenarios IS92a, IS92c, and IS92e along with three different climate sensitivities, were chosen to project possible future changes in the country's weather.

4.1.4.2 Choice of GCM[1] Patterns

Considering all information available on GCMs, IPCC recommendations, and most importantly the results of long-term meteorological records studies, two patterns HadCM2 and ECHAM4 were chosen to map changes in temperature and precipitation in the country by the year 2100.

4.1.5 Results and Conclusions

Table 4.1 shows the temperature changes as predicted by MAGICC with different combinations of scenarios, climate sensitivities, and SO_2 emission rates by the year 2100. Temperature and precipitation changes were portrayed by means of different combinations of the chosen GCMs, scenarios, and climate sensitivities. Because of the country's geographical condition, it was divided into three sub-regions namely north coast, non-coastal, and south coast.

Pattern analysis of temperature and precipitation records revealed that the temperature is falling in the northwest; part of the south, and east of the country especially along the Zagros mountain range. In contrast, there is an increasing pattern of precipitation in a large part of the country. Study of the temperature indicates that it is too early to conclude that GHGs emission is the main cause of the difficult weather conditions primarily drought related that were experienced during the last two or three years.

To provide an insight into what will happen if the GHGs emissions issue is not dealt with properly, six scenarios have been designed. These scenarios were selective combinations of two GCMs (HadCM2 and ECHAM4), three emission

Table 4.1 Temperature Changes as Predicted by MAGICC with Different Scenario Combinations, Climate Sensitivities and SO_2 Emission Rates

Scenario	Climate Sensitivity	SO_2 emission		
		Full Global	Constant after 1990	Region[1] 2
IS92a	1.5	1.4	1.62	1.54
	2.5	2.03	2.38	2.26
	4.5	2.93	3.45	3.27
IS92c	1.5	0.88	0.8	0.82
	2.5	1.32	1.22	1.25
	4.5	1.98	1.85	1.88
IS92e	1.5	1.74	2.18	2.04
	2.5	2.51	3.19	2.97
	4.5	3.56	4.56	4.24

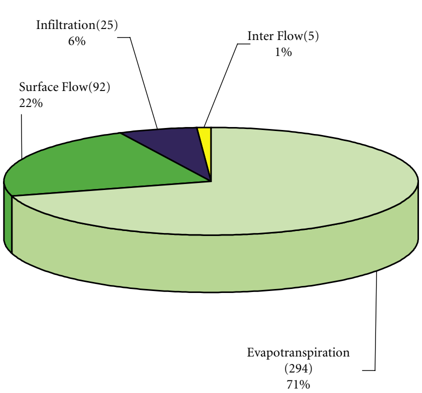
1- *General Circulation Model*

The Heart of Iran's Desert; *Traditional ventilation - cooling for "green life"*

4.2

Vulnerability and Adaptation Study

Figure 4.4 Water Balance and total Precipitation in the Country (billion cubic meters)



scenarios, and three different climate sensitivities. These combinations represent three global GHGs emission conditions:

- Low emission rate;
- Maintaining the present rate; and
- High emission rate.

A low emission combination predicted an increase in temperature ranges from 1°C to 1.5°C. Changes for the second combination range from 4.1°C to 5°C. The third resulted in an increase in temperature scope from 5.9°C to 7.7°C.

The same combinations were used to predict precipitation changes in the country. The consequent possibilities vary according to the following ranges:

- 11% to 19.1% of the baselines for low emission rate;
- 30.9% to 50% of the baselines for medium emission rate; and
- 58% to 80% of the baselines for high emission rate.

4.2.1 Water Resources

Agricultural water usage in Iran is about 81.4 billion cubic meters that accounts for 94% of the total consumption. Of the total about 4.5 billion cubic meters is used as drinking water, which is about 5% of the overall consumption. The industrial sector's water use accounts for only 1 % of the whole.

The required water is primarily extracted from ground water resources that supplies 55% of water used. The rest is sourced from surface water utilizing modern facilities (dams & irrigation networks) and traditional methods, each providing 25% and 20% respectively.

The maximum capacity of the country's dams is 25.4 billion cubic meters, with actual utilization standing at 16.4 billion cubic meters. River water is taken by traditional methods. This accounts for some 20.5 billion cubic meters while exploitation from small water supply plans is about 2 billion cubic meters. Total exploitation of surface water is about 39 billion cubic meters. Water extracted from underground aquifers is about 47.8 billion cubic meters, of which 42.4 billion cubic meters is extracted from deep and shallow wells, 5 billion cubic meters from "*Qanats*" (man–made underground water galleries) and 0.4 billion cubic meters from alluvial springs. Figure 4.4 shows the water balance and Figure 4.5 shows consumption in different sectors of the country.

4.2.1.1 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:

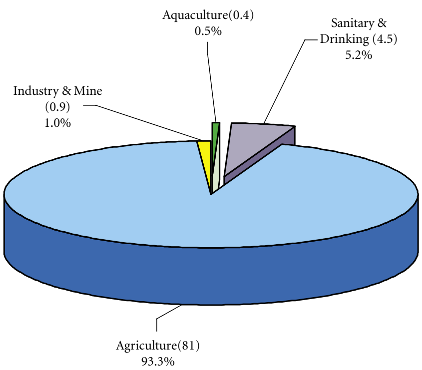
1 Statistical analysis based on the past historical meteorological and hydrological records;

2 Simulation study using climate change scenarios and basin-wide hydrological models; and

3 Simulation based on a macro-hydrological model that combines a general circulation model (GCM) and a hydrological model.

Papers and reports published to date on the impact of climate change on water resources in Iran are divided into three categories. These are: first, researches based on the past climatic and hydrological data; second, studying the impact of

Figure 4.5 Share of Different Sectors in total Water Consumption (Billion cubic meter)



Used for Fishery & Agriculture(45% Surface Water, 55% Ground Water)

Used for Industry (46% Surface Water, 54% Ground Water)

Used for Sanitary & Drinking (32% Surface Water, 68% Ground Water, Alluvial & Karst)

climate change on the water cycle and river flow pattern of river basins; and third, reviewing the operation of dams and reservoirs.

A workshop titled Global Climate Change on Hydrology and Water Resources at the Basin Scale was held at the Ministry of Energy in 2000. In addition, two regional conferences on climate change organized by Iran's Meteorological Organization with the cooperation of the World Meteorological Organization (WMO) were held in Tehran.

Statistical analysis of historical data

The water balance has been studied as a phenomenon of river basin scale by climate models. Impacts assessment at a local level, therefore, inevitably has a higher uncertainty than that estimated globally and nationally.

The rise in sea level

Reviewing fluctuations in the Caspian Sea level reveals that during the period of instrumental observations, its level changed from the elevation of -25.2 below open sea level to-29.1 m, i.e. by nearly 4 m. In view of the majority of researchers, climatic change in the sea basin is the principal factor affecting the level of the Caspian Sea, historically and in the last few decades. This studied opinion is indicated by a clear relationship between components of the water balance and the stage of the sea level.

Data on the Caspian Sea water level related to the years of 1926 until the hydrological year of 1998-1999 were analysed. The results obtained from the surveys indicate that the minimum level of the sea was –28.46 meters in 1977 which has been gradually increasing from that time but in the year 1996-97 a decrease is again observed. These changes come about through the historical fluctuation period of sea water level, climate changes and increased water flows into the Caspian Sea. The process is very complicated and needs a comprehensive survey.

Temperature increase

In general, water demand increases with temperature rise. In addition, a significant part of winter snowfall is converted into water with the increase in temperature. At the same time, when the period of snow melting is decreased, this results in winter flow pattern changes. These phenomena create temporary imbalance in the water demand and supply relationship in some regions. Evapotranspiration accelerates to reduce the average flow and also impacts on water use.

When the period of snow melting is decreased, this results in winter flow pattern changes. These phenomena create temporary imbalance in the water demand and supply relationship in some regions.

The De Marathon method has been applied to analyse data related to climatology stations with a long statistical history. The result shows that from 600 stations studied, 68 indicate climate changes during this decade. Table 4.2 indicates the situation of all the stations studied. The information in this table reveals that the recorded changes in climate patterns from wet to arid in 37 stations, 54% of the total.

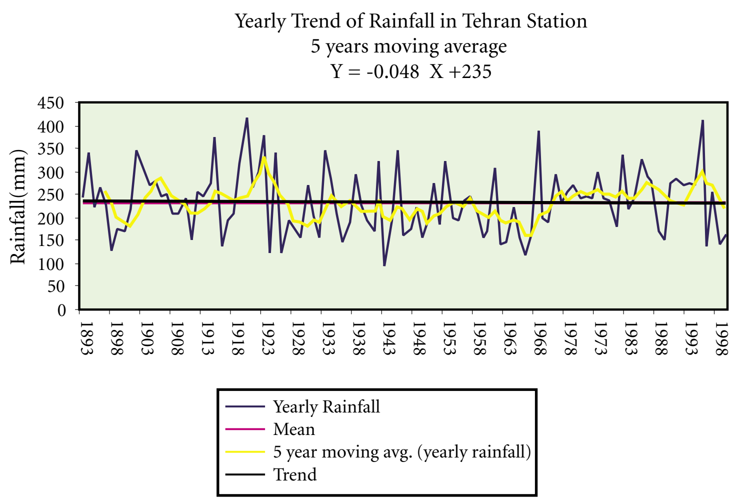
Table 4.2 Changes in the Situation of Climatology Stations

Kind of Study	No. of stations under study	No. of stations with climate change	Stations with undesirable situation	%
De-Marathon	*600*	*68*	*37*	*54*
Singh	*143 stations with long and full information*	*36*	*12*	*35.5*

Changes in rainfall intensity and pattern

Based on long-term meteorological records reviewed in different regions of Iran, precipitation characteristics were compared over the coldest and warmest decades. Analysis of this data demonstrates that the annual amount of precipitation in the coldest decade is slightly greater than that of the warmest decade. This suggests that in the warmest period the need for adjustment of flow intensity and flow pattern by dams and reservoirs increased significantly. Information from two rain gauge stations with more than a 100-year statistical background was also studied. A five-year shift in average rainfall and the pattern of rainfall in Tehran and average rainfall nation wide are shown in Figures 4.6 and 4.7. The results obtained imply a general downward trend in rainfall. The precipitation curve and the five-year shift in average make clear that under these circumstances, the country was on the threshold of drought.

Figure 4.6 Trend of Annual Rainfall in Tehran Station (5-Year Moving Average)



Snow fall

In river basins where the hydrology is snowmelt-dominated, as in the northwest part of the country, the connection between runoff to temperature and potential evaporation is complicated. The change in the seasonal runoff pattern would result from a warmer climate. In this specific case potential evapotranspiration (PET) increases with warmer temperatures.

Due to the increased temperature in the country in recent decades, premature snow melting has occurred. Therefore, warmer temperatures shift the runoff hydrograph from the spring toward the winter.

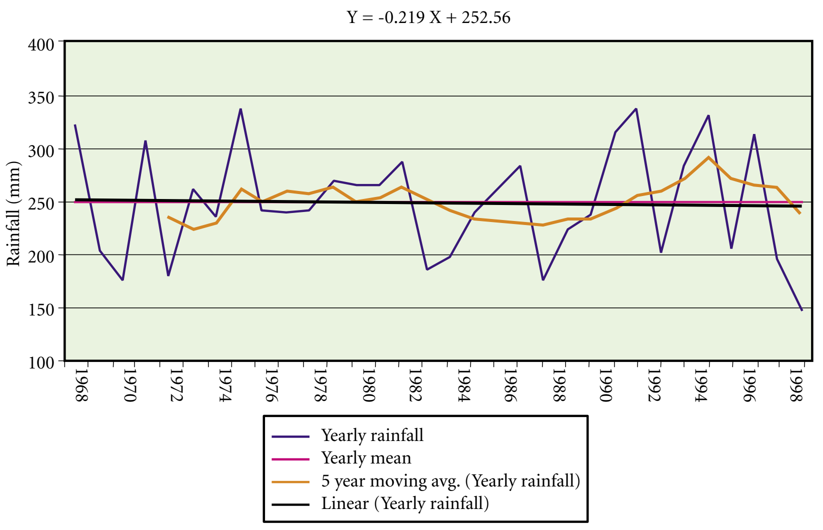
The precipitation curve and the five-year shift in average make clear that under these circumstances, the country was on the threshold of drought.

Run off

From a water-supply perspective, the most important consequences of global warming would be those associated with changes in water supply. A survey of data in the hydrometric stations indicates:

- About 40%-50% of water in the country's rivers is accounted as flood flows.

Figure 4.7 Trend of Annual Rainfall in Iran (5-Year Moving Average)



- The rivers' classical discharge hydrograph curve in drought years indicates the flood discharge for each river is about 20-50 times its yearly mean discharge.
- Floods usually occur after long and intensive precipitation in large basins, where soil humidity increases and the penetration of water decreases. In these conditions high-speed flood flows rapidly arise on the surface of the land rendering absorption into the underground layers impossible.
- A survey was undertaken of the flood index and long-term data related to the hydrometric stations comparing flood prone regions before and after the year 1981. The studies indicate that of the 398 stations reviewed, 213 (or 54% of stations analysed) registered an increase in the flood index.
- The hydrometer station graphs record an increasing pattern at the peak of flood flows despite the decrease of annual mean discharge in the same stations. This phenomenon is an indicator of entering into a period of weather characterized by drought.
- In order to arrive at a harmonious study and determine the changes in the condition of hydrometric information, data of the mean discharge of the stations were tested by means of the Fisher Test and Variance analysis. The results obtained indicate that among 78 stations with more than 30 years of consistently recorded data, only 13 (16%) revealed condition changes. A similar survey on all stations with sufficient information indicates that of 992 stations, 130 (13%) have experienced such fluctuations during the past two years.

Table 4.3 indicates the results of the Fisher Test and Variance analysis on hydrometer stations.

Table 4.3 Results of Fisher & Variance Tests on Hydrometer Stations

Study method	Stations under study	Number of stations with negative change	% of stations with negative changes
Flood index	398	213	53.50%
Variance analysis & Fisher test	78 stations with more than 30 years of data	13	16%
Variance analysis & Fisher test	All stations including data (992)	130	13%

From a water-supply perspective, the most important consequences of global warming would be those associated with changes in water supply.

Groundwater

The study undertaken on groundwater clarifies that the sensitivity of groundwater recharge to a warmer climate in mountainous areas is relatively small and depends on land use. However, this sensitivity in the plain areas dominated by irrigated

The Permeating River; *Zayandeh Rood in Esfahan*

agriculture, is greatly affected by the infiltration of irrigation water, yet greater amounts of it be lost by evapotranspiration. In this instance, groundwater recharge would decrease by about 20% under current land use patterns.

Water supply

A study was conducted on the effects of temperature and annual population growth on drinking water consumption in Tehran. The results indicate that based on the projected population growth figures and assuming two degrees increase in temperature; urban water consumption will increase by 1.718 billion cubic meters in the year 2020. The present consumption amounts to 0.9 billion cubic meters per year.

Projection of future water resources by simulation models

A very preliminary analysis of water resource demand was undertaken while taking into account socio-economic development. This indicates that if annual average temperature increases by 2 °C, the irrigation water demand would increase by up to 30% depending on the difference in the sensitivity of various river basins (assuming the same area under cultivation). Furthermore, the demand for water as a coolant might increase by 1% to 2%.

Hydrological model

Fahmi (1999) developed a Runoff Assessment Model (RAM) for both long- and short-term predictions. This was applied together with the climate change scenarios to assess the impacts of increased temperatures, consequent to the rising level of greenhouse gases. The long-term runoff model used in 30 basins shows that temperature rise increases the runoff volume during winter and decreases it during spring, since rising temperature melts snowfall into rain and hastens the time of snow melt. It also makes clear that temperature increase affects the runoff of basins and decreases the amount of runoff variation of rainfall rather than impacting on flow conditions. Table 4.4 indicates the result of the model for two sample basins.

4.2.1.2 Simulation Study Using a Macro-Hydrological Model Combining a General Circulation Model (GCM) and a Hydrological Model

A study was undertaken using the meteorological findings of different scenarios as input for the hydrological model. The results are shown in Table 4.5.

Table 4.6 defines the classification of the catchments basins of Iran according to the difficulties and complexities of water resources management.

Table 4.4 Variation of Runoff with Respect to the Variation of Temperature and Rainfall in Selected Main Basins

Basin Name	Temp. (T)	Precipitation (P)								
		-40%p	-30%p	-20%p	-10%p	P	+10%p	+20%p	+30%p	+40%p
Aras	*T*	-52.2	-41.2	-28.9	-15.2	0	16.8	35.3	55.4	77.2
	T+1	-53.1	-42.6	-31	-18.1	-3.8	11.9	29.1	47.9	68.2
	T+2	-53.9	-43.9	-32.8	-20.6	-7.2	7.5	23.6	41.1	60
	T+4	-55.3	-46	-35.9	-25	-13	-0.1	14	29.3	45.8
	T+6	-56.4	-47.7	-38.4	-28.4	-17.7	-6.1	6.4	19.8	34.1
Karkheh	*T*	-60.7	-49	-35.1	-18.8	0	21.5	45.7	72.7	102.5
	T+1	-62.3	-51.5	-38.7	-23.9	-6.7	12.9	35	59.6	86.9
	T+2	-63.8	-53.7	-42	-28.3	-12.7	5.2	25.3	47.8	72.6
	T+4	-66.1	-57.4	-47.4	-35.9	-22.7	-7.8	8.9	27.5	48.2
	T+6	-67.9	-60.3	-51.5	-41.7	-30.6	-18	-4.1	11.4	28.6

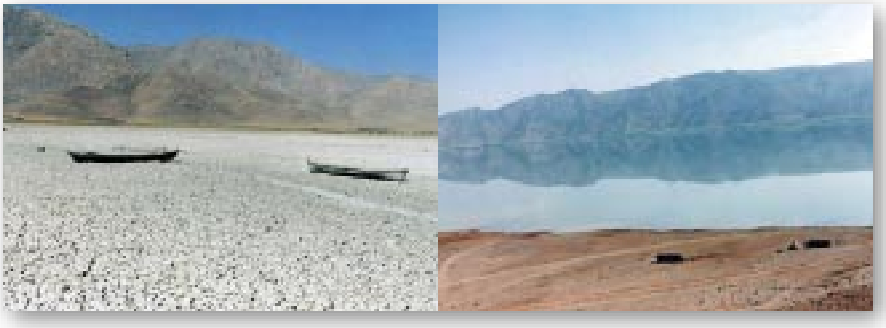
Table 4.5 Results of the General Circulation and Hydrological Models

Models	Sensitivity	North Coast	Non-coastal	South coast
HadCM2+IS92a	*Low*	*West -7.7%*	*Sistan -11.6%*	*West -15.2%*
		East 22.5%	*Khorasan 18.4%*	*East -2%*
HadCM2+IS92a	*Mid*	*West -21.1%*	*Sistan -32%*	*West -9.8.2%*
		East -24.9%	*Khorasan 53.2%*	*East -31.2 %*
HadCM2+IS92a	*High*	*West -37.5%*	*Sistan -57.1%*	*West -21 %*
		East -43.5%	*Khorasan 65%*	*East -58.2 %*
ECHAM4+IS92c	*Low*	*West -12.2%*	*Sistan -19.5%*	*West -2.3 %*
		East -20.7%	*Northwest -8%*	*East 21.2 %*
CHAM4+IS92c	*Mid*	*West -28.7%*	*Sistan 55%*	*West -0.85 %*
		East -47 %	*Northwest -14.8%*	*East 50.3 %*
ECHAM4+IS92c	*High*	*West -48.6%*	*Sistan 78.5%*	*West 10.2 %*
		East -70.7%	*Northwest -26.3%*	*East 40 %*

Impact of global warming on water resources

Research on the effects of global warming on hydrology and water resources in Iran has been conducted on several rivers and lake basins. For this purpose, historical hydro-meteorological data and runoff models were used in combination with various global warming scenarios. The results of the research are summarized below:

- Global warming will reduce snowfall in winter, which causes a significant change in the seasonal pattern of river flows including a decrease in the snowmelt generated flow in spring. This change in seasonal flow pattern may affect various current water uses and the operation of the existing facilities for water resource management.
- Rivers, which are important sources of water supply for the metropolitan areas in the country, are directly or indirectly affected by the changes in precipitation and temperature. In many river basins, snowfall, snowmelt and evaporation may change, resulting in variation in the absolute amount and seasonal pattern of available water resources. In recent years, metropolitan regions in Iran are becoming more and more vulnerable to extreme climatic conditions such as drought. Thus the operation of existing facilities for water resources and newly established plans for more facilities should be reviewed and redesigned. The planning method itself should also be reviewed.



Birds migrate but Aquatic species?! Kaftar Lake; *watery in 1993 and dry in 2000*

- Global warming will affect water quality as well as water quantity. In particular, the progress of eutrophication in lakes and ponds will reduce the quality of water resources, resulting in higher water purification costs.
- Hydrological data and information will experience variations due to climate change. This process comprises the alteration of statistical parameters that indicate the presence of either

Table 4.6 Classification of the Catchment Basins of Iran According to the Difficulties and Complexities of Water Resources Management

Classification index	Catchment basin	Grade	Probability of crisis intensification in the future
Catchment basins with rapid population growth and high exploitation of water resources	*Salt Lake, Zayandeh-Rood, Hari-Rood, Kashaf-Rood, Bakhtegan, Moharloo, Gorgan, Shapoor-Dalki*	*1*	*Very high and difficult to control*
Catchment basins with low population growth and high exploitation of water resources	*Siah-Kouh,Degh-Sorkh, Central Daranjir, KalShour, Abargho, Sirjan, Jazmourian, Minab, Bandar Abbas, Loot, Roodkal, Atrak, Mashkil, Khoaf, Mand*	*2*	*Very high but controllable*
Catchment basins with low population growth and exploitation of water resources, water resources development encounters with major difficulties	*The Persian Gulf coast, south Baleochestan, the Persian Gulf's islands, RiK-e-ta… Zarrin*	*3*	*High but controllable*
Catchment basins with rapid population growth yet adequate water resources development	*The Caspian Sea coast*	*4*	*Low*
Catchment basins with low population growth and more water resources development	*Maroon, Jarahi, Zahreh, Handijan, Hamoon, Hirmand*	*5*	*Lowest*

inconsistency or non-homogeneity in the hydrological data. This event will result in many difficulties related to the safety of hydraulic structures and the operation of the existing facilities for water resources.

- Based on different climate change possibilities as temperature rises, evapotranspiration will increase in most river basins throughout the year. About 2 to 6°C increase in the temperature will increase the annual evapotranspiration by 6% to 12% in 30 basins and the annual runoff will change between 50.2% and 50.3%.
- The runoff distribution model points to a significant increase in peak flow during the flooding runoff in the winter period and a decrease in mean river discharge.
- The plain areas dominated by irrigated agriculture are greatly affected by the decrease of infiltration of irrigation water due to increasing evapotranspiration. In this case, ground water recharge decreases by about 20% under current land use.
- Temperature changes of 1° to 2° C typically have little effect on stream flow.
- Changes in runoff are uniformly more sensitive to changes in precipitation than to change in evapotranspiration.
- The relative change in runoff is always greater than the change in precipitation.
- Runoff is most sensitive to climatic change in arid and semi-arid regions.
- The relative change in runoff excels that of the change in evapotranspiration.
- Many types of non-coastal water-related hazards will result due to climate change, including floods, unexpectedly high lake levels, river and lakeshore erosion, sedimentation, landslides, and ground subsidence. The magnitude and frequency of most of these hazards are largely determined by regional or local geologic conditions and meteorological events. Human activity can have significant intensifying or moderating effects. However, ground subsidence is usually caused by human activity, which is due to the increased extraction of ground water resulting from the greater runoff

In particular, the progress of eutrophication in lakes and ponds will reduce the quality of water resources, resulting in higher water purification costs.

caused by climate change.

4.2.1.3 Adaptation Measures on Climate Change

Although in recent years preliminary investigations have been undertaken on the impact of climate change on water resources, there are still many uncertainties in the analysis. Thus, in order to assess adaptation procedure, further research and investigation should be carried out in the following directions:

- More precise GCMs and climate scenarios should be introduced. The impact studies at the regional and local levels should be carried out using regional climate models and spatially improved GCMs.
- Assessment of the impact of climate change on the types of rainfall such as convective, orographic and frontal rainfall should be made.

However, the following adaptation measures are proposed to minimize the effect of climate change on water resources:

- Water conservation.
- Integrated ground and surface water management.
- Improved water supply.
- Drought controls.
- Improved operation of reservoirs.
- The existing and planned water resources facilities could be reviewed, on the basis of quantitative analysis of the consequences of climate change.
- In the areas suitable for water resources development, structural measures such as dam construction and artificial ground water recharge should be followed.
- In areas unsuitable for water resources development, non-structural measures such as water saving policies, water reuse, etc. along with more efficient use of the existing facilities, should be taken into consideration.
- In order to improve water quality changes due to climate change, expensive treatment technologies will be required.
- To overcome difficulties arising from inconsistency or non-homogeneity in the hydrological data due to climate change, it is necessary to undertake extensive research to identify methods that also serve as solutions.
- Development of simulation systems should be considered to provide comprehensive assessments and management of water resources.
- Low-cost miniature reservoirs for local irrigation and rehabilitation of small tanks should be constructed in dry zones.
- Recycled water should be used for domestic, industrial and recreational purposes.
- Improving water use practices and techniques are required.
- Measures should be made to ensure sound watershed management.
- Reallocation of water to meet growing demands is very important.
- Crops that consume less water should be introduced and the extensive irrigation method such as sprinkling and under-pressure irrigation be employed.
- Water consumption through a range of economic and administrative measures should be decreased gradually.
- Integrated management of ground water and surface water resources are required to preserve water in aquifers and protect it against pollution.

Rationing and a public system of notification of conditions should be implemented for use of water during droughts.

- Improved water supply and treatment efficiency, specifically a program of wastewater treatment and reuse of treated water should be considered.
- Rationing and a public system of notification of conditions should be implemented for use of water during droughts, similar to those in place in the electricity and gas supply industries. This would entail preparation of the relevant legislative tools and making needed institutional arrangements.
- Real-time operation of water reservoirs should be improved.

4.2.2 Agriculture

As mentioned earlier, agriculture plays an important role in the economy of Iran. The country has over 50 million hectares (ha) of arable lands, 130 billion cubic meters of water available annually, 112 million ha of forests and rangeland, abundant aquatic resources and diverse climate. The sector directly supports about 75% of the population's food requirement, about the same percentage of raw material for related industries, 26% of the GDP, 25% of the non-oil export value and 24% of total employment.

The major annual crops include wheat, barley, rice, cotton, sugar cane, sugar beet, oil seeds, fruits and vegetables. Almost 48% of the crops are irrigated. Of this figure 35% is allocated to wheat production. The area under annual crop cultivation is estimated at about 13.5 million ha, 5.9 million ha of which is irrigated while 7.6 million ha support rainfed cultivation. The remaining 8 million ha is kept fallow. The major horticultural crops, produced over an area of about 1.8 million ha, include apples, citrus fruits, grapes, dates, stone fruits, pistachios, almonds, hazelnut, pomegranates, walnuts and tea.

4.2.2.1 Impact of Climate Change on Agricultural Products

Crop production

Major parts of the rainfed land areas are marginal with low yield in addition to being prone to severe degradation. In most of the irrigated area, there is water deficiency and water scarcity. The major climate variables that are potentially of great importance for agricultural production are temperature, solar radiation and atmospheric CO_2 concentration. As concluded by IPCC, most crops[1] are affected by elevated CO_2 concentration. But, the predicted increase in temperature due to global warming may lead to spikelet sterility in rice, loss of pollen viability in maize, reversal of vernalization in wheat and reduced formation in potatoes. The changing climate will also affect wheat, which is the main staple food.

Predicted increase in temperature due to global warming may lead to spikelet sterility in rice, loss of pollen viability in maize, reversal of vernalization in wheat and reduced formation in potatoes.

In the period of 1998-1999, damages due to drought for wheat production in the country are estimated at about 1,050,000 tons of irrigated wheat and 2,543,000 tons of rainfed wheat. The figures indicate that the agricultural areas are very vulnerable to climate change.

At higher temperatures, plant water requirement increases due to higher evapotranspiratation, and this situation further exacerbates the stress on plants, resulting in severe production decrease. This is a particularly significant issue, as crop production in Iran, especially in the south and west, depends directly on spring seasonal rainfall.

1- In Iran, most farmlands are under cultivation with crops such as wheat, barley, rice, vegetables, oil seeds, pulses, maize and sugar cane, grouped as C_3 which at double CO_2 concentration may show a yield increase of about 30% due to higher water efficiency

The sea's food-supply reduction for fish in its northern reaches is partly the result of the loss of aquatic vegetation and increased salinity.

Livestock products

Climate change and the rise in temperature create unfavourable condition for growth and development of livestock production through feed supply reduction. Agricultural crops and their residues supply about 80% and rangelands about 20% of the feed requirements of the livestock nationwide. In the changing climate, animal production in different climatic regions of the country will witness severe changes including:

- In the cold regions of the north and west and a cold semi-arid climate, it is expected that the population of sheep and goats will remain unchanged in the medium-term. Their population will be decreased due to lessened feed production in the long-term.
- In these areas, however, the production of field crops will increase due to the rise in temperature and prolonged growing season. This will result in increased livestock production, especially cattle.
- In the south, southeast and southwest parts of the country, with arid, semi-arid, and desert climatic conditions, feed resources from rangelands and rainfed cultivation will severely decline, but feed from irrigated crops will increase because of the increased area under fodder cultivation and other crops. Therefore, the population of the flock will certainly decrease, but the population of cattle will increase because of the adoption of extensive systems.
- In the western and south-western regions of the country, with semi-arid and mountainous climates, the anticipated climate change may result in variations of the length of the growing season and could lead to an increased grazing capacity of rangelands in the colder parts. But, in the areas of poor and degraded rangelands, the decline in rangeland production may be compensated through controlling abundant surface water and bringing more lands under irrigation.
- In the central regions with arid, semi-arid and desert climates, livestock feed from rangelands will decrease; thus, livestock production will rely mainly on field crop production. In these regions there is not much scope for the development of water resources; therefore, in the mid-term, production will increase due to the intensification of livestock production systems. But, in the long term, livestock production will decrease due to the shortage of feed.

Fisheries resources

There are three basic fisheries resources in the country:

- The Caspian Sea in the north and its fishing industry.
- The Persian Gulf and Sea of Oman in the south characterized by commercial fishing.
- Aquaculture and inland fisheries that comprise a network of semi-intensive and extensive warm and cold aquaculture systems throughout the country.

The Caspian Sea

Marine life in the Caspian Sea has undergone and continues to be affected by the sea level changes of the past three decades. The sea's food-supply reduction for fish in its northern reaches is partly the result of the loss of aquatic vegetation and increased salinity. Decreased springtime inflow from its tributaries has adversely influenced the stocks of semi-migratory freshwater fish and typically migratory species. The combination of these and other changes has meant the ichthyofauna fishes such as *Cyprinus carpio* and *Rutilus caspius* now dominate among the bentophages, as they have escaped the pressure of predation by virtue of their rapid growth.

The Persian Gulf and the Sea of Oman

The Persian Gulf and the Sea of Oman as marine fisheries may be affected by the change in the magnitude, location and duration of up-welling zones and major oceanic currents. These alterations could directly affect the distribution of fish stocks by shifting the location of larvae, juvenile and adult habitats. In addition, the transformations may have secondary effects associated with reduced food resources, altered food networks and community structure, resulting in the exacerbation of existing stress on fish stocks.

Aquaculture and inland fisheries

Although the effect of climate change on aquaculture generally is anticipated to be positive through faster growth and lower winter mortality rate, in Iran aquaculture is negatively affected by climate change. The primary cause is the reduced water inflow to fish farming and inland fisheries and increased temperature in shrimp farming in the southern region.

4.2.2.2 Adaptation Measures on Climate Change

Historically, Iranian agriculture has proven itself adaptive to changing climate. In the central desert of Iran, the type of farming practices and highly efficient use of water resources, especially the use of "*Qanats*" (man-made underground water galleries) for irrigation of crops, are examples of this. Yet uncertainty remains regarding the potential disruptions brought by climate change.

- Technological adaptation

Some of the agricultural losses resulting from the phenomenon can be tolerated and some effects can be alleviated through technological adaptation. New advances introduced to agricultural technology in the country during the last decades, have also encompassed measures to combat the adverse effects of climate change.

- Development of new crop varieties

For most of the crops, especially wheat, barely, sunflower, rice, sugar cane and sugar beet, tolerant, resistant and early maturing varieties are being developed.

- Seasonal changes and sowing dates

In the north-eastern part of the country, with areas where farming is limited by frost, global warming can extend the growing season, allowing plantation of longer maturing annual varieties.

Although the effect of climate change on aquaculture generally is anticipated to be positive through faster growth and lower winter mortality rate, in Iran aquaculture is negatively affected by climate change.

✦ Conservation tillage

The practices listed below have already been adopted in some parts of the country. Development of these measures can be recommended as steps towards adaptation to mitigate the adverse effects of global warming.

- Deep tillage, which can increase plant root depth, is one method to be looked at. One of the reasons for low yield in semi-arid areas of the country is the limited amount of water available to crop roots. The available moisture will be increased if the root depth is increased.
- Minimum tillage will reduce rapid breakdown of soil structure and decomposition of organic matter.
- In most parts of the country and in particular in areas where rainfall is erratic, planting at the right time will yield dramatic crop increases.
- The topographical situation of the country has already proven the usefulness of the construction of small-scale dams as one efficient adaptation measure against the effect of droughts and water deficiency.
- The efficient use of pipes for water conveyance: To minimize the losses incurred in transferring water, existing water conveyance programs through pipes can be better developed by more efficient piping.

✦ Recycling drainage water

- On-farm development including landscaping and land consolidation should be exploited for water use efficiency through reclamation of drainage.

✦ Pressurized irrigation systems

- Programs now underway utilizing pressurized irrigation systems such as drip and sprinkler systems can be accelerated and developed through greater investments.

✦ Leaching of salt affected soils

- This is an important and effective adaptation measure in large agro-industrial complexes in south-western Iran.

✦ Increasing fish yields

- Fish farming facilities have to be further developed to increase the release of fingerlings into the Caspian Sea to offset the consequences of the decline of fish stocks.
- Further development of food organisms, rehabilitation of indigenous fish stocks, and introducing salt tolerant species are also recommended.

4.2.3 Forestry

Iran, with its 164.8 million ha, the Alborz and Zagros mountain ranges and other secondary ranges spread around the country, combined with the Caspian Sea, Persian Gulf and Sea of Oman, give it sharp climatic variety. With a wide range of precipitation rate (e.g. 50mm, to more than 2,000 mm), there is a great biological diversity as witnessed in the country's variegated flora and fauna.

With a wide range of precipitation rate, there is a great biological diversity as witnessed in the country's variegated flora and fauna.

Iran is categorized as a part of the arid and semi-arid regions of the world, which generally have the following characteristics:

- Insufficiency of atmospheric precipitation compared with the annual evaporation rate which is about 15 to 30 times more than its annual

rainfall,
- Short period of rainfall,
- Low relative humidity and limited useful water,
- Great variation of daily temperature,
- Poor or lack of adequate vegetation cover,
- Frequent winds throughout the year,
- Long droughts with destructive effects, and
- Desertification.

The very different ecological and climatic characteristics create a variety of vegetation ecosystems, each of which has been adapted to its own biotic region.

The role of forests, pastures and of land-use-change in absorbing and emitting CO_2 was investigated in the previous chapters with findings given on the various kinds of forests and rangeland as well as their climatic zones. Here, vulnerability of these forest regions to climate change is reviewed and suitable methods for their adaptation are assessed.

4.2.3.1 Methodology

Analogical procedures, expert judgement, field survey, experimentation and modelling are among the different methods used to evaluate the consequences of climate change. This report, given the lack of sufficient information on forestry, relies heavily on expert judgement. Also, field surveys are conducted in parts of these regions to reach, what can at best be considered, as preliminary findings.

4.2.3.2 Impact of Climate Change on Forests, Rangelands and Deserts

Impact on forests

As mentioned earlier, Iran's forests are classified under five categories. Climate change can have the following impacts on these forests:
- Changing the habitats location of forest SPP, especially the less tolerant ones,
- The extinction of low tolerant SPP,
- Transforming the natural regeneration regime of forest plants,
- Reduction of wood and non-wood production in forests,
- Increase of pests and plant diseases in forests,
- Intensification of land erosion, particularly in arid and semi-arid zone,
- Modifications in the hydrological cycle,
- Retrogression of mangrove forests and sometimes their destruction because of the rise in sea level in the Persian Gulf and Sea of Oman,
- Unsuitable environmental conditions for wildlife,
- Increase of the probability of forest fires hazards, particularly in arid and semi-arid areas, due to high temperatures and aridity, and
- The consequent migration of people resulting from degraded ecological conditions.

This report, given the lack of sufficient information on forestry, relies heavily on expert judgement.

These climatic changes have to be considered in the long-term, because accurate consideration is impractical in the short-term. This observation will be more difficult in arid and semi-arid regions located in the Zagros mountain ranges and the central plateau, where climatic conditions are extremely harsh.

Also in the northern forests, the decreasing rate of precipitation means that some SPP such as *Alnus glutinosa*, *Alnus subcordata*, *Salix*, and *Pterocaria fraxinfolia* and other similar SPP will find it hard to survive. These climatic features will change at high altitudes because of temperature decreases and precipitation increases. Furthermore, the Caspian forests located between the northern slopes of the Alborz mountain ranges and the southern Caspian coastal zone are affected by climate change.

The distribution of tree SPP will change drastically. Some SPPs, with a high resistance to climatic changes will survive in different altitudes with variegated ecological conditions. On the other hand, in the period of 1998-1999, some sensitive SPP such as *Juniperus SPP* that have adapted to specific climatic conditions have already perished under the impact of climate change.

Impact on rangelands

Some of the impacts of climate change on rangelands are described below:

- Reduction of forage production in rangelands,
- Degradation of rangelands and in some cases desertification,
- Soil erosion consequent to destruction of plant coverage,
- Irregularity in hydrologic cycles, reduction of spring water, and drying up of underground water,
- Increase in plant diseases resulting in a destructive effect on the agriculture sector,
- Fires in rangelands,
- Negative effect on regeneration of vegetation cover and animals,
- Extinction of biotic variety as well as incursion of invasive plants, and
- Economical and social consequences including migration.

The decrease of precipitation and increase of temperature in the rangelands will bring about a considerable reduction of forage, which naturally engenders a lowering of stock production too. Vegetation communities consist of various

Table 4.7 Sensitivity of Different Forages to Precipitation Reduction

Kind of Vegetation	Reaction to Precipitation	Production	Continuation of Production	Regeneration
Annual and Seasonal	*High Sensitivity*	*High*	*Low*	*High in Rainy Season*
Perennial	*Low Sensitivity*	*Moderate*	*Moderate*	*High in Rainy Year*
Trees and Bushes	*Non-Sensitivity*	*Low*	*Too High*	*Non-Related to Rain*

species with differing tolerance against climatic changes and this phenomenon will impact according to each species' specific ability for endurance and adaptation.

The decrease of precipitation and increase of temperature in the rangelands will bring about a considerable reduction of forage, which naturally engenders a lowering of stock production too.

In rangelands, the reduction of precipitation, causes the trees, bushes and grasses to become progressively and excessively weak, and provides propitious conditions for pests and plant diseases. Moreover, insufficiency of plant production forces some animals and ruminants to revert to trees for accessing their food needs at the expense of tree bark and the cambium layers. This will create optimum conditions for the invasion of pests and plant diseases, as well as the destruction of vegetation cover. Table 4.7 shows the sensitivity of different forage types to precipitation reduction.

Strategies of production and regeneration of various SPP in arid and semi-regions

A decrease in precipitation will reduce the production rate of rangeland plants. Furthermore, overgrazing of livestock disproportionate to the capacity of the rangelands will intensify degradation and extinction of vulnerable SPP Continuation, recurrence and gradual intensification of these inauspicious conditions will consequently destroy rangelands. Decreased production in rangelands is not the only effect of climate change. The quality of production is also afflicted, which results in lessened nutrition values.

In addition, low rate of rainfall creates inevitable competition for absorbing the necessary but limited water. Overgrazing in such conditions provides an ambient environment for invader plants to occupy rangelands and prevent the regeneration of hardy SPP.

Obviously the shortage of vegetation coverage has a great influence on livestock. Under such unsatisfactory ecological conditions, they are forced to travel long distances to access food and water. These hardships can weaken the stocks and promote diseases that enervate and sometimes kill the animals. The relative dependence of Iranian livestock on rangelands is given below:

- Nomad goats and sheep 80%
- Rural goats and sheep 40-55%
- Native rural cows 25%
- Native normal cows 70%
- Rural camels 80%
- Nomad camels 85%

The figures indicate how different livestock rely on rangelands for providing food and water. The climate change in rangelands is most dangerous for goats and sheep, with total of about 81 million animals, whereas native rural and nomad cows and camels are safer, respectively.

Impact on deserts

Iran's deserts cover approximately 34 million ha in the central plateau and are situated on deposits of the third period of the geological era. This area consists of saline and alkaline soils and is defined by a vulnerable arid and semi-arid climate as well as highly irregular precipitation frequently i.e., half of the annual precipitation falls during a day or even a few hours that cause severe floods.

This dominance of arid and semi-arid regions is one of the essential factors in the trend towards desertification. Consequently, in order to achieve environmental sustainable development precise planning is needed. There are a number of other specific factors that intensify the tendency to desertification. These elements are as follows:

The dominance of arid and semi-arid regions is one of the essential factors in the trend towards desertification.

- Destruction of forests by clearing of trees, livestock overgrazing and a resultant decrease of production potential,
- Destruction of rangelands by cutting bushes, overgrazing and grazing out of season,
- Destruction of farm lands due to incorrect irrigation, employment of inappropriate agricultural machinery, excessive use of chemical fertilizers

and ploughing in the direction of the land's slope,
- Enlargement of urban and rural areas,
- Excessive use of underground water resources, and
- General incorrect exploitation of natural resources.

In addition to the above-mentioned causes of desertification, climate change has the following adverse effects on desert lands:
- Impeding efforts to combat the phenomenon,
- Migration of people from their native habitats,
- Degradation of desert ecosystems,
- Decline of agricultural products including medicinal plants, pistachios, and other nuts, and
- Ecological degradation acting as an inducement for people to smuggle goods and drugs.

Considering all of these facts, acceptance of the universal principles enshrined in the United Nations Convention for Combating Desertification would be of significant benefit for Iran. Some of the principles of this convention are:
- Instituting education, training and public awareness programs in areas which are vulnerable to desertification, and consideration of the social and economical consequences in these areas,
- Combating desertification by coordinating comprehensive activities such as soil conservation, afforestation and reforestation,
- Extension of wide-ranging plans for controlling desertification and integrating them with natural and environmental development plans,
- Extension of broad-based plans against drought and integrating them with practical solutions,
- Programming comprehensive plans to overcome population migrations and controlling the number of environmental refugees,
- Encouraging public participation and environmental training to emphasize the necessity of mitigating limiting desertification as well as the management of the effects that result from climate change, and
- Extension and strengthening of integrated plans to overcome poverty and the creation of new methods for achieving a sustainable livelihood for native inhabitants.

Various experiments indicate that the cumulative impact of destructive factors transform about 1% of Iran's natural resources to desert conditions annually, which in the year 2000 was equivalent to 1.5 million ha.

4.2.3.3 Adaptation Measures

The following adaptation measures are proposed to reduce the adverse effects of climate change on forests, rangelands, and deserts in Iran.

Acceptance of the universal principles enshrined in the United Nations Convention for Combating Desertification would be of significant benefit for Iran.

✦ Forests
- Rehabilitation, development and basic silvicultural treatment of forest resources,
- Afforestation and forest development,
- Balancing the volume of forest harvesting with forest growth and ecological capacity,

- Forest tree improvement and use of fast growing species for reforestation, afforestation and wood farming,
- Increase of wood imports for wood-based industries, in order to reduce its utilization from national forests,
- Transforming abandoned farmlands to forest lands especially in the north of the country,
- Development of wood farming and agro-forestry systems,
- Implementation of the national plan for the green movement nationwide,
- Removal of 4 million animal units from forests in the north of Iran in the course of a five-year plan, and
- Widespread public and NGO participation in these processes.

✦ Rangelands

- Renovation, reseeding, proper use and management of ranges,
- Supporting the more tolerant and productive SPP in rangelands and utilizing them for range rehabilitation and development,
- Balancing rangeland production capacity and animal units that graze on it and implementing a yearly inventory plans in rangelands to estimate forage production,
- Permanent settlement of nomads,
- Implementation of watershed plans, and
- Wide scale participation by the public and NGOs.

✦ Desert land

- Seedling plantation,
- Sowing and seed drilling, and
- Petroleum mulching.

4.2.4 Coastal Zones

As mentioned earlier, the marine environment of Iran includes the coast of the Caspian Sea in the north measuring about 700 km and the Persian Gulf and Sea of Oman in the south with about 1,800 km of coastline. The Persian Gulf islands' coastline amount to about 1,000 km, thus the total Iranian coastline equals some 3,500 km.

The northern coastal zone significantly differs from the south both from the natural and socio-economic points of view. The Caspian Sea is the largest lake in the world. Littoral to it are Azerbaijan, Russia, Kazakhstan, Turkmenistan, and Iran. It accounts for more than 40% of the overall volume of global lacustrine waters. The Persian Gulf is a semi-enclosed sea with high salinity interfacing with the open sea via the northern part of the Indian Ocean through the Strait of Hormuz and Sea of Oman.

4.2.4.1 Coastal Geomorphology

✦ Caspian Sea

The total Iranian coastline equals some 3,500 km.

The southern part of the Caspian coastal zone (The Iranian side) is a narrow coastal plain with an average width of about 50 km, produced by a "*general retreat*" of the sea, which probably once extended as far as the foot of the Alborz mountains. The Alborz range, which overlooks the sea, consists of parallel ranges, increasing in elevation from the north and south. The famous Mount Damavand is in the middle of the Alborz ranges. It is the highest peak in Iran with an altitude of 5,671 meters.

The Iranian Caspian coastline includes two different geomorphologic provinces, one is the central coast with its high dip topography and the other is a low plane in the western and eastern ends of the shoreline. The average slopes of the beaches can be classified in three types including:

- High land slopes with 0.5 percent or more,
- Moderate land slopes with 0.1 to 0.5 and
- Lowland beaches with gentle slopes of less than 0.1 percent. Most of the beaches with high and moderate slopes are sandy and mixed with coarse or medium grade sand easily dispersed by waves.

Persian Gulf and Sea of Oman

The northern coastline of the Persian Gulf (Iranian coastline) is a part of two main geomorphologic provinces, one is the inland-coastal flat area of the Khuzestan province (western part of the coastline) and the other is the wide eastern belt of prominent anticline mountains. The alluvial plains and tidal flats mostly cover the western part of the Iranian coastline in the Persian Gulf. The eastern sector mainly consists of anticline mountains and salt domes.

The geomorphology of the Makran coast (Sea of Oman) can be divided according to three main features (Didehvar, 1997) comprised of:

- Alluvial plains of Dasht-e-Yari: The sediments of this area are mainly of an alluvial and eolian nature. The presence of young alluvial fans, terraces of marine nature, and sand dunes are all geomorphic features indicative of wet and dry conditions that existed during the glacial and interglacial period,
- Marine terraces. These terraces are mainly located in the southern reaches of Dasht-e-Yari and represent geomorphic features characteristic of coastal marine erosion. There are many step-like escarpment and marine caves associated with them, and
- Alluvial terraces of the *Quaternary Age*: These terraces are underlain irregularly by marine sediments mainly marl and sand. The old alluvial terraces consist of dark conglomerates whereas the younger ones consist of light coloured homogeneous fine-grained sediments. The size of the sedimentary grains and particles decreases from north to south indicating their transport by alluvial processes.

Geomorphologic investigations make it appear that the Makran coast was uplifted at the end of the *Tertiary Period* and subsequently was subjected to extreme erosion. The present landforms were formed primarily from *Quaternary Erosion*. The main agents of erosion in this area are water, winds, and salinity, which define the formation of different landforms observed in the region.

14 ecologically sensitive areas have been identified in the region which can be categorized into seven protected areas, two wild life refuges, four international wetlands and one biosphere coastal reserve that fall under special conservation and environmental management.

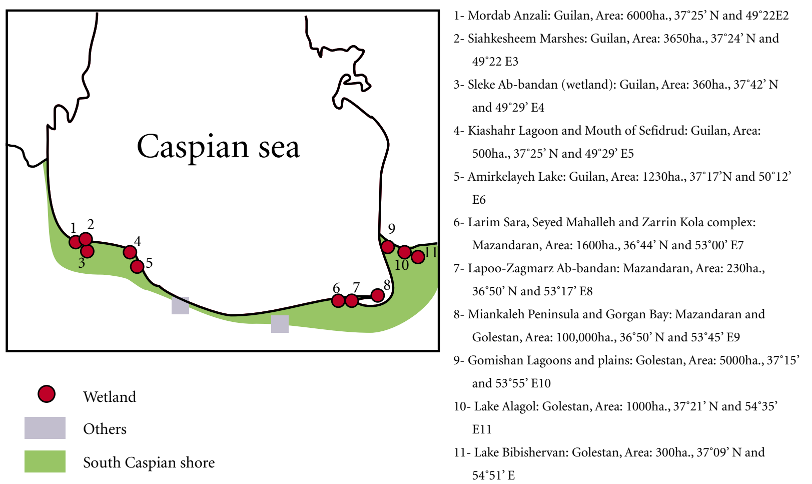
4.2.4.2 Sensitive Ecological Areas

In the south of the Caspian Sea (Iranian side), there are habitats that are ecologically important and contain many valuable species of flora and fauna. These play a major role in marine life cycles and fisheries resources.

The area includes coastal wetlands, estuaries and mud flat zones (NSESD, 1993, Firouz, E. 1974). Moreover, the whole Caspian coastline is a major sanctuary in the migration pattern of migratory birds from the northern hemisphere to the south.

The very long Persian Gulf coastline including its islands, and the Sea of Oman represent a significant variety of environmental conditions from the northwest to the southeast. These include different types of ecologically sensitive regions rich in biodiversity.

Figure 4.8 Sensitive Areas of Southern Caspian



At present, 14 ecologically sensitive areas have been identified in this region which can be categorized into seven protected areas, two wild life refuges, four international wetlands and one biosphere coastal reserve that fall under special conservation and environmental management. These areas include vast inter-tidal mud flat zones, sea-grasses, mangrove forests coral reefs (Sheppard and Wells, 1988) and estuaries.

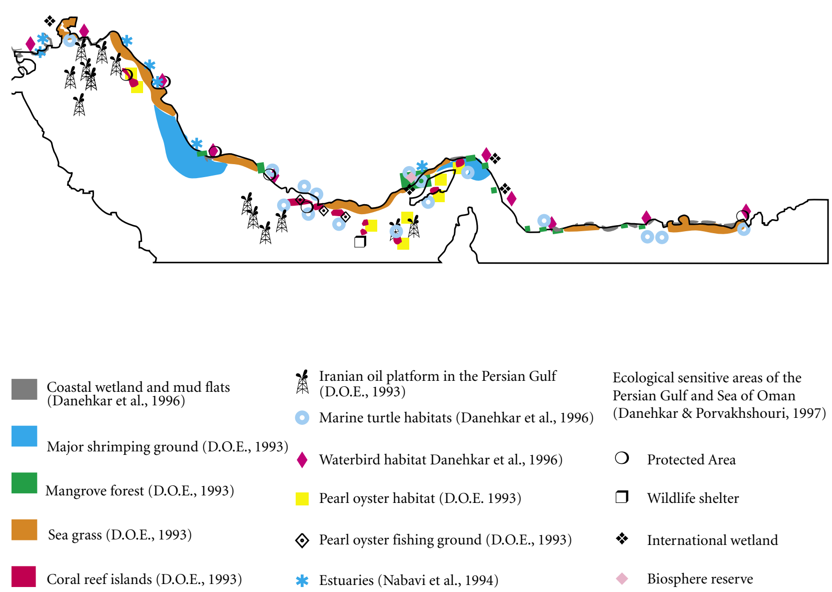
The Persian Gulf and Sea of Oman are in fact a passageway located across the routes of many migratory birds passing from the northern hemisphere to the equatorial regions. Figures 4.8 and 4.9 represent the location of the most important ecologically sensitive areas along the Iranian coastal zones.

The Persian Gulf and Sea of Oman are in fact a passageway located across the routes of many migratory birds passing from the northern hemisphere to the equatorial regions.

4.2.4.3 Socio-economic Conditions of the Coastal Areas

More than 10% of Iran's population lives in the Caspian Sea coastal area. Overall climatic conditions are very mild with an extensive cover of dense forest and vegetation. Land fertility is high and as a result, so is agricultural yield. The

Figure 4.9 Environmental Units, Ecologically Sensitive Areas and Iranian Oil Platforms in the Persian Gulf and Sea of Oman

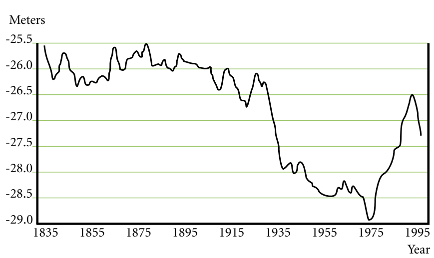


extensive tourist facilities found here, abundance of fresh water and proximity to the capital are the primary regional factors resulting in its high rate of population (Sheikholeslami et al., 1998). The Caspian coastal plain accommodates approximately 6 million people in its 27 towns and cities. The bases of the area's economic activities are agriculture, tourism and fishing.

Conversely, the population of the southern coastal zone is low and scattered along 1,800 km of coastline. There are two important ports in the Persian Gulf (Bandar-Bushehr & Bandar-Abbas) each having a population of more than 100,000. Agricultural activities are limited but oil, gas and petrochemical industries; mining, fishing and trading are the essential areas of economic activities.

Comparatively, the Sea of Oman's coastal area is less developed and generally pristine. Oil and gas are the resources for which the Persian Gulf is best known globally. Availability of natural fresh water is the limiting factor for development in this area. In the past, freshwater was obtained principally from terrestrial sources, such as aquifers. However, the ground water table is lowering and there has been a reduction in surface water availability in recent years. Nowadays, freshwater is provided largely through desalination plants, particularly in the middle and southeast part of the coastal zone as well as on the islands.

Figure 4.10 Caspian Sea Level Fluctuation



4.2.4.4 Climate Change and Sea Level Rise

✦ Caspian Sea level fluctuations

As mentioned in Section 4.2.1.1, the Caspian Sea, like other bodies of closed water bodies, is characterized by large fluctuations in water level (Rodionov, 1994, Kosarev and Yablonskaya, 1994). At present, the sea water level is approximately 27 m below the global mean sea level. Over the last century, tide gauges have recorded abrupt variations over decadal time scales (Figure 4-10). Recent tide gauge measurements recorded between 1978 and 1993 indicate that the water body's level has been rising at an average rate of +12 cm/yr during this 15-year time span, then followed by a drop in water level. Decadal Caspian Sea level changes are currently attributed to changes in river runoff and effective evaporation.

It is obvious that any prediction made for Caspian Sea level fluctuations will be subject to a degree of uncertainty. According to various investigations, the sea level can continue to fall at an average rate of 20 cm/yr, which will lead to a sea level drop of 4 meters in 20 years, or the level can rise at an average rate of +17 cm/yr, which will lead to a sea level rise of 3.4 meters in the next 20 years. Therefore, based on historical observations three scenarios for the next century can be developed:

- Caspian Sea level at 31 meters below the mean water level of the oceans,
- Caspian Sea level at 25 meter below the mean water level of the oceans, and
- Caspian Sea level at 28.5 meter below the mean water level of the oceans.

In any case the Caspian Sea level fluctuations needs to be investigated further.

✦ Persian Gulf and Sea of Oman

In general the relative mean sea level has been rising along the coasts of the Persian Gulf and Sea of Oman at a rate of about 4 cm during the past decade. Unfortunately, the systematic sea level records for this region are of insufficient duration, and date back only 40 years. According to the 10-year hourly-recorded data in three sites (Chabahar, Bandar Abbas and Bushehr), the mean sea level in the two bodies of water has been rising at an average of 4.5 mm/yr. To some extent, the results agree with the IPCC 1995 scenario for the medium sea level rise of 46 cm in the 21st century which is compatible with IPCC 1995 scenarios (20, 50 and 90 cm above present mean sea level for the century).

There are other important elements that should be considered in assessing the possible scenarios in this region. The Sea of Oman is much affected by the storm surges that usually originate from the Indian Ocean. In some cases the amplitude of the sea level rise due to surges, exceeds one meter. This magnitude is in correspondence to present climatic conditions. Perhaps the climate changes do have considerable effect on the size of the surge, which should be analysed and taken into account.

According to the 10-year hourly-recorded data in three sites, the mean sea level in the two bodies of water has been rising at an average of 4.5 mm/yr.

Also in the northern part of the Persian Gulf, tide rise is in the order of four meters, therefore, the dual effect of flooding and spring tides has many hazardous effects on the coastal zone resulting in saltwater intrusion and fish habitat degradation. These effects of climate change should clearly be investigated.

4.2.4.5 Sea Level Rise Impacts on Coastal Zone

The impact of the rise of sea level can be divided into two major categories including the effect on the coastal system and on socio-economic conditions.

✦ Caspian Sea

The impact on the coastal system of the Caspian Sea can be summarized as follows:

- *Coastal erosion*, which is important primarily in the middle, reaches of the Caspian Sea, where the beach types one and two are located. The eroded length of these beaches may reach up to 0.5 kilometres (Saeed Hosseini, M., 1995).
- *Inundation:* Sea level rise gradually inundates the eroded lands and low land beaches, which are mostly located in the east and north-eastern part of the coastline. In some areas the extent of the inundation reaches a few km. The Miankaleh peninsula and Gorgan Bay in the east are the most remarkable examples in this regard.
- *Salt-water intrusion:* The aquifers distributed through the west and central part of the Caspian plain have a proper balance between input and output. Also the high south-north ground water gradient prevents saltwater intrusion in this area. But in the east and northeast part of the Caspian plain characterized by a gentle slope and low groundwater gradient, saltwater intrusion is a major problem when combined with the phenomenon of sea level rise.
- *Drop in sea water level* in the Caspian Sea has significant consequences for the coastal system. Reductions of the coastal wetlands water depth, acceleration of eutrofication, and reduction of fish migration are the most important issues in this context. Significant wetland degradation finally may lead to complete destruction.

Destruction and inundation of agricultural land, damage to and inundation of residential and recreational areas and degradation of coastal infrastructures are the most significant socio-economic impacts in this regard. Official reports indicate that about 2,500 ha of rice paddies in Gilan Province (west coast) have been destroyed due to salt-water intrusion (Saeed Hosseini, M., 1995). The same phenomenon has affected about 1,500 ha of forest area.

In Mazandaran province (east Caspian coast), about 3,500 ha of agricultural land (mostly cotton) have been lost (Ministry of Energy, 1994). Devastation of residential and recreational areas due to the sea level rise is very serious in the Caspian coastal area. Removal and levelling of coastal dunes since 1960 has only served to magnify and speed up the appearance of the consequences. The natural elevated coastal sand dunes that ranged to several meters in height were the natural barrier for coastal protection. Human intervention has undone this natural bulwark.

Official reports indicate that about 2,500 ha of rice paddies in Gilan Province (west coast) have been destroyed due to salt-water intrusion.

✦ Persian Gulf and Sea of Oman

The coastal ecosystem of the Persian Gulf and Sea of Oman, are affected by the rise in sea level in different ways:

- The coral reef seems to be the first victim of global warming in this area. Climate change and increasing sea surface temperature are considered as the outstanding reasons for mass coral bleaching (Sheppard and Wells, 1988). Coral may be placed under additional stress by the projected increases in atmospheric CO_2 concentration.

- Mud flats, coastal plains and the estuaries especially in Khuzestan province are subject to flooding and inundation, which will be followed by salt-water intrusion.
- Land erosion will occur mostly in Bushehr, Hormozgan, and Sistan and Baluchistan provinces according to their geomorphology and landform. Tides, which are supported by surges, will severely erode the cliff-type beaches especially in the Sea of Oman.
- Mangrove forests are also subject to an adverse impact by the upward change in sea level, to their specific morphological features.

From the socio-economic point of view, climate change has a great adverse impact on the availability of fresh water in this region. Salt-water intrusion both into surface and ground water are the most important issues particularly in the Karun River system. This river is the main source of drinking water for a population of more than one million people and has been subject to salt water intrusion caused by sea level rise combined with a low river base flow.

Moreover, intrusion of salt water into the coastal ground water is an emerging problem in this same context. Climate change and its relation with seawater temperature and its impact on the fishing industry are important but poorly understood phenomena.

Mass mortality of fish in the Persian Gulf has been an alarming indication during the past few years, which seems to be the consequence of the adverse impact of seawater temperature changes, general fluctuations in temperature and related dynamic patterns in the Persian Gulf.

4.2.4.6 Adaptation Assessment and Recommendations

For millions of years the Caspian Sea and its coastal area were affected by various natural environmental changes but adapted into the new conditions. Estuaries, lagoons and wetlands shifted, expanded and contracted as the sea level rose or fell and most of the coastal areas were protected by sand dunes against erosion and inundation. But the coastal systems of the Caspian Sea were sharply undermined by human activities and the natural patterns of the coast and its subsystems such as estuaries and wetlands were changed.

Construction of dams on the rivers, parallel with other development activities and transforming the natural pattern of the rivers and estuaries brought many limitations and points of stress into the sea's natural system.

Construction of dams on the rivers, parallel with other development activities and transforming the natural pattern of the rivers and estuaries brought many limitations and points of stress into the sea's natural system. At present most of the estuaries and wetlands have lost their natural adaptation capacity against sea level rise due to human intervention in the coastal areas. Salt-water intrusion into these fragile areas is the most important example, which has had a severe adverse impact on the living resources of these coastal systems. The consequences of the Caspian Sea water level fluctuation in all its diverse patterns on the coastal systems are poorly studied and must be investigated in detail.

Concerning the southern coastal area, certain corals have adapted to warmer or more variable temperature regimes up to 34°C in summer. These include some of the same species, which have been observed to be highly sensitive to temperature variations in other areas. Such acclimatization is clearly seen in the reefs of the Persian Gulf, where temperature fluctuates over relatively wide extremes every year.

All reef development is the result of coral growth out-pacing natural processes of erosion, including bio-eroding organisms and physical processes such as storms. Slower coral growth rates and weaker skeletal structures may shift the balance of many reefs from that of gradually accreting structures to that of incrementally eroding structures. This change will be further accompanied by increasing rates of sea-level rise that needs to be thoroughly and minutely reviewed.

Erosion on beaches is controlled by the effect of sands in decreasing the erosion resulting from tides. If the natural dynamics of beaches are preserved, the effect of coastal erosion will be controlled automatically. This is the case in most parts of the Sea of Oman coastal area where human activities are limited. Mangrove forests have adapted to the sea level rise by shifting with and accommodating the fluctuations.

Residential construction and its consequences around the protected mangrove area of Qeshm Island is limiting the ability of mangrove adaptation and will induce inevitable stresses particularly in the areas with specific morphological features. Adaptation capacity for salt-water intrusion into the estuaries of the northern part of Persian Gulf will be reduced due to changes in river water and sediment flow patterns resulting both from climate change and human interventions. It is important to note that the acclimatization capacities in the Iranian coastal zones are poorly known and must be investigated in depth.

The vastness and complexity of the Iranian coastal regions both in the northern and southern parts, from fragile coastal systems across extensive Exclusive Economic Zones (EEZ) to the high seas, poses considerable challenges for sustainable development. It requires large and crosscutting data sets and information along with specialized collection and monitoring systems. These requirements will include, for example, assessments of environmental assets, threats to ocean and coastal resources and projections for population growth that can be factored into planning and sustainable use thresholds. The efficiency of plans and the future viability and sustainability of the environment and all its resources must be underpinned by data and information systems, which should be extensive, of high quality and easily accessible.

In the case of Iran, as with many other countries around the world, it lacks basic coastline data and information. This is one of the most significant limitations in term of defining a plan of action for the management of the coastal areas. Some recommendations to be considered for further programs are as follows:

In the case of Iran, as with many other countries around the world, it lacks basic coastline data and information.

- Defining a study program to highlight the most important hot spot areas in the coastal zones of Iran.
- Conducting a detailed study of the impact of climate change on the designated hot spots based on the IPCC scenarios and preparing a detailed V&A report based on the above findings.
- Developing the capacity to collect data, store information and develop systems for effective management and timely utilization of

this information for the purpose of development and environmental management.

- Preparing and conducting programs of action in the well-known hot spots mentioned in this report.
- Defining a program at the regional level, particularly for the Caspian Sea to study the issues of transitional importance, which directly affect the Caspian Sea level in collaboration with the littoral states.
- Establishing institutional links between the relevant groups involved in the development and implementation of coastal management projects,
- Identifying funding requirements and modalities for the application of Integrated Coastal Management (ICM).
- Strengthening existing regional initiatives in curricula design through the recognition and incorporation of local situations and the provision of public information.
- Stimulating the development of non-formal education in the country including support for the training of women in subsistence fisheries.
- Supporting training for students as well as the personnel in management positions in the government and private sectors.
- Promoting institutional strengthening to enable delivery of appropriate training for regional personnel.

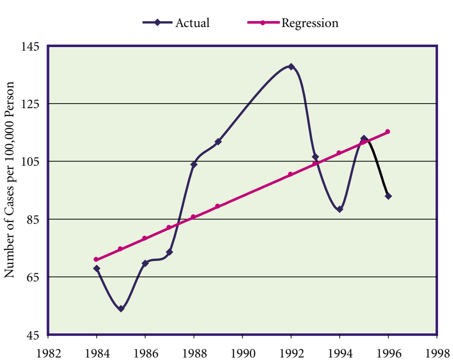
4.2.5 Health

Climate change will engender direct health effects. Global warming is expected to lead to an increased incidence of cardiovascular, respiratory, and other diseases. Injuries, psychological disorders, and deaths would result from a greater intensity and duration of heat waves and perhaps of floods, storms, and other extreme climate events. Indirect effects may be more important in the longer term.

The phenomenon is expected to disturb ecological systems and natural resources, interfere with sanitation and other infrastructure underpinnings and precipitate social and economic dislocations. These trends will expose more people to diseases transmitted by insects, water, and other *"vectors"*. This could also promote infectious diseases such as diarrhoea, malnutrition, hunger, asthma and other allergic disorders.

4.2.5.1 Impact of Climate Change on Disease Exposure Rate

Figure 4.11 Exposure Rate to Malaria between 1984-1996



✢ Malaria

According to a report by World Health Organization (WHO), malaria is one of the most serious and complex health problems facing humanity in the 21st century. Climatic changes of the past have greatly affected the geographical range of this disease. Hence, the seriousness and complexity of malaria as a health problem is likely to be compounded by climate change. A simple simulation model, the Malaria Potential Occurrence Zone (MOZ) model, is formulated to provide insights into the sensitivity of potential malarial transmission resulting from climatic perturbations.

Some entomologists worry that global warming may expand the habitat of the anopheles mosquito that carries the disease. WHO has warned that the result may be anopheles mosquitoes living in places like the southern United States and

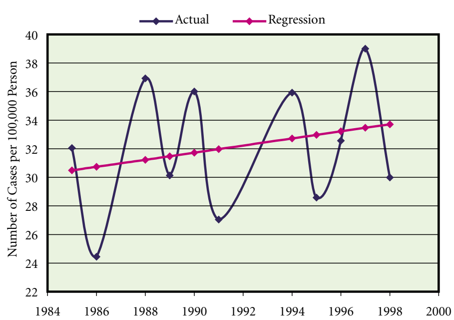
Figure 4.12 Distribution of Malaria in Iran in 1998

southern Europe. It has forecasted an extra 80 million cases of malaria annually by the end of the twentieth century (compared to a current estimated level of 300 million to 500 millions cases each year).

Based on the case history of disease prevalence in Iran, it was concluded that one of the major vector-born tropical diseases found in different provinces is malaria. Figure 4.11 shows the exposure rate to malaria in Iran (1984-1996), which indicates that the patterns of cases per 100,000 people have been increasing.

Fig 4.12 shows the distribution of Malaria in Iran for 1998. The greatest caseload was observed in Sistan & Baluchestan province in southeast of Iran. The average yearly number of cases of malaria in the past five years has been in excess of 24,000. Also the trends of exposure rate and temperature have risen simultaneously.

Figure 4.13 Exposure Rate to Leiashmaniasis between 1984-1998



Leishmaniasis

Leishmaniasis that is transmitted by sand flies is still found in many parts of the world and has caused many deaths. According to WHO it has been estimated that 80 countries are affected by leishmaniasis and that the number of cases is 12 million. More than 400,000 fresh cases are seen per year, and approximately 350 million people are at risk. Fig 4.13 shows the exposure rate to leishmanisis in Iran between 1984 -1998. The incidence of cases per 100,000 persons has been increasing.

Figure 4.14 shows the distribution of leishmaniasis in Iran for 1998. The largest caseload was recorded in Esfahan with 4,707 cases; Shiraz registered 4,293; Khorasan 2,932 cases; other provinces less than 2,000 cases have also been cited.

Figure 4.14 Distribution of Leishmaniasis in Iran (1998)

Cholera

Changes in sea surface temperature could lead to an increase in water-borne infections such as cholera. As waters warm and when nutrient levels increase, the cholera bacteria can become infectious. A warmer climate might increase the incidence of cholera and similar diseases in unprotected areas. In 1996, diarrhoeal diseases, such as cholera and dysentery, killed 2.5 million people out of the 52 million who died worldwide (WHO 1997). Cholera is found in many parts of Iran. The highest caseload was recorded in 1998, during the latest drought. Tehran had 2,209 instances of the malady while 1,041 cases were reported in Khuzestan province, one of the drought-affected areas.

Other Diseases

In addition to cholera, other maladies known to be related to climate change are dengue fever, schistosomiasis, Rift Valley Fever, and viral encephalitis. Fortunately, up to now none of these have ever been reported in Iran due to close monitoring and rural/urban health surveillance.

Mosquitoes are vectors for viruses responsible for a variety of specific encephalitis diseases. As one example viral encephalitis may cause a range of symptoms from headache to aseptic meningitis and even death.

Weather and climate have considerable influence on the concentration of air pollutants such as particles and gases.

Rodents

The United States of America, Latin America, Africa, Europe, Asia, and Australia are at present all facing the same problem with rodent infestation. These opportunists are believed to be the fastest reproducing mammal and they eat everything humans do, thrive on contaminated water and food, and are extremely capable swimmers. One of the reasons for increasing rodent population is warmer temperature as a result of climate change.

Rodents are undesirable for several seasons. They destroy property, spread diseases, and compete with humans for their food. Vector borne diseases are still one of the major health problems and are widely spread in Iran. Tehran and other major Iranian cities have wide-scale plans to control and reduce the reproduction rate of rodents.

4.2.5.2 Interaction of Climate Change and Air Pollution

Weather and climate have considerable influence on the concentration of air pollutants such as particles and gases. The spread of many allergens, particularly pollen in the air, depends on the season of the year.

The range and concentration of these particles and gases are very dependent on prevailing weather conditions, air currents, temperature variation, humidity and precipitation. Large, slowly moving anticyclones may cover an area for several days, or a week or more, and give rise to static conditions that readily allow particles and gases to accumulate.

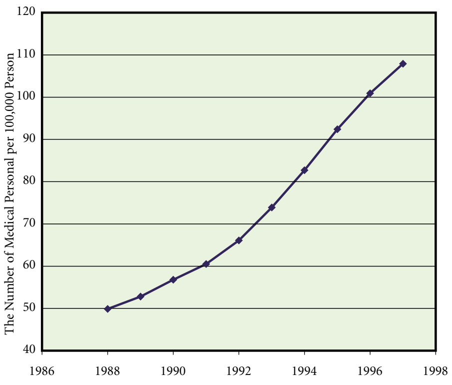
The incidence of asthma has been increasing in many countries in recent decades but the reasons for this are not clear. Acute episodes or attacks of asthma, however, have been linked to the presence in the air of certain dusts, pollen, particles from animal fur, ozone depletion substances, other air pollutants, or a combination of some of these.

Our study of health effects of air pollution in Tehran has shown a correlation between emergency asthma admissions and levels of NO_2 and SO_2. There were 12 days of continuous atmospheric inversion, in autumn 1999 resulting in emergency conditions with the admission of acute respiratory patients in Tehran hospitals increasing by more than 10%. The impact of air pollution in major cities like Tehran on regional climate change needs to be closely investigated.

4.2.5.3 Conclusion

Despite health promotion in Iran, as shown in Figure 4.15 that demonstrates a rise in the number of medical personal (medical doctors and nurses), studies show an increase in the number cases of malaria and leishmaniasis. This may be due to the improvement in case identification in the health system, yet it might also be the result of the increase in the number of new cases related to climate change. A comprehensive review of the situation is essential regarding the latter issue.

Figure 4.15 The Rise in the Number of Professional Medical Personnel in Iran for 1988-1997



4.2.6 Energy Sector

The energy industry in Iran includes the production of oil, natural gas and petroleum products, generation of electricity, and transmission and distribution of electricity and natural gas. The Ministry of Oil and its affiliated organisations and companies (e.g. the National Iranian Oil Company- NIOC and the National Iranian Gas Company- NIGC) and the Ministry of Energy are the two main authorities in the energy sector. The Department of Environment, the Planning and Management

Organisation, the different provincial water authorities/organizations and power companies are among the other main stakeholders in the sector.

4.2.6.1 Power Plants

Climate change impact on electricity production

The most important effects on electricity producing power plants that result from the sea level rise and the changes of ambient temperature are:

Effect of rise in sea level

As mentioned earlier, the rise in sea level, both in the Caspian Sea and Persian Gulf are of major concern to electrical power plants. These plants use the once-through cooling system and located near the sea (e.g. the Neka power plant at the Caspian Sea shore and the Bandar Abbas power plant on the Persian Gulf coast). To prevent physical damage to these facilities, it is necessary that coastal erosion be harnessed by costly structural works (such as concrete sea walls, etc.).

Effect of sea water temperature

For thermal power stations situated near the sea in the north and south of Iran, water temperature is very important for the condenser operation of these steam power plants. It is estimated that an increase of 1°C in water temperature will result in a 3% efficiency drop at a steam power plant. This is primarily because the higher temperature of cooling water affects the condenser vacuum, thereby decreasing the efficiency of the steam turbine. In addition, higher water temperature may cause vibration of the low pressure steam turbine blades and more frequent shut downs of the power plant.

Effect of ambient air temperature

The effectiveness of thermal power plants is also greatly influenced by the ambient temperature. Gas turbine power plants are designed to operate with an average ambient air temperature of 30°C. The output of typical gas plants or combined cycle power plants suffer from temperature rises of even 1°C. It is estimated that increasing the ambient air temperature by 1°C will cause a 2% loss in the power output of a thermal power plant.

Effect of rainfall

The Ministry of Energy plans to produce approximately 11,000 MW of electricity from hydropower plants in Iran by 2008. Most of these hydropower plants will be located in the southern part of the country (Karoun and Karkheh rivers). Changes in the rainfall pattern and occurrence of drought would have an adverse effect on water supplies, thereby limiting the capacity of hydroelectric generation in Iran.

In the present study, the average temperature rise, which would influence electric energy in Iran, is considered to be 0.3 degrees per decade or around 1.5°C in 2050.

Many of the thermal power plants in Iran are located far from the sea or rivers and the water for these power plants is supplied from deep wells. Reduction of rainfall will decrease the level of underground water and the problem of access to these underground water sources will be compounded. Consequently, the total electricity production of power plants will be decreased. This is particularly the case for facilities such as the Shahid Rajaei and Tabriz power plants. Moreover, because of reduction of rainfall, the salt concentration in rivers will rise, which imposes an additional load on demineralisation plants, corrodes water treatment equipment, and results in additional maintenance costs.

✦ Climate change impact on electricity consumption

In the present study, the average temperature rise, which would influence electric energy in Iran, is considered to be 0.3 degrees per decade or around 1.5ºC in 2050 (Scenario IS92a-low sensitive area).

Iran's electricity demand is likely to increase primarily due to space heating and air conditioning. Very hot summers are related to the climate change phenomenon in Iran. High summer loads, associated with cooling systems, will result in greater electricity demand.

In most areas the heating systems are less dependent on electrical energy. Considering the relatively short winters, it is not clear how much the increase in demand for cooling will exceed the reduction in demand for heating in the long term. A net increase of 5% in electrical energy demand due to climate change in Iran is predicted. This will increase the peak demand by around 15% on average in the next 50 years.

Generally, for each 1˚C rise in temperature, a reduction of 2.7% in the net efficiency of thermal power plants is expected. If the rate of growth of consumption of electricity is assumed constant at around 6.5%[1] per year in Iran, then the amount of electrical energy demand without considering the effect of climate change, will be around 460,000 GWh in 2050, which requires an installed capacity of around 120,000 MW. Of this amount, 50,000 GWh (20,000 MW) will be produced by hydropower plants, neglecting the drop in their efficiency due to climate change. Thus, alternative sources to hydropower plants have to considered in macro energy planning.

✦ Adaptation measures in power plants

In Iran, apart from the once-through cooling systems now used in two power plants on the Caspian Sea and Persian Gulf shores, the general trend recommended by experts is toward dry cooling systems. New technologies such as combined cycle and cogeneration with higher efficiencies, which also reduce dependence on cooling water, are proposed. Because of rising household electricity demand due to global warming, additional electrical energy requirement in Iran will be 15,000 MW. If the loss of efficiency of thermal power plants due to higher ambient temperature is also accounted for, an additional 5,000 MW will be required. This means an extra installed capacity of 20,000 MW will be needed within the next 50 years, which requires investment of around USD 7-9 billion for power production, directly or indirectly as a result of climate change.

4.2.6.2 Transportation

Another important consideration in GHGs emissions in the transport sector is the fuel pricing policies in Iran.

✦ Ambient temperature rise

Certain assumptions have been made in an endeavour to quantify the effects of ambient temperature rise in the transportation sector. They were cross-examined with the meteorological information of the past 30 years.

1- Linear growth rate

Assuming that the ambient temperature increases at most by one degree centigrade, the need to operate in-vehicle air conditioning equipment is advanced by approximately five days and prolonged by five days in an average temperature range in urban areas of Iran. This signifies the fact that for this extra 10 days of in-vehicle air conditioning operation, an increase in fuel consumption to provide equivalent vehicle performance characteristics is needed.

A simple calculation shows that this additional load amounts to an extra 5 million liters of petrol annually, in turn producing additional GHGs. Furthermore, the evaporative loss of gasoline is a strong function of ambient temperature which will cause more emissions.

Another important consideration in GHGs emissions in the transport sector is the fuel pricing policies in Iran. An unreasonably low and heavily subsidised price of petrol has resulted in excessive fuel consumption and emission of GHGs and air pollutants. Increased demand for fuel in transportation due to climate change and gradual lifting of subsidized fuel prices will result in an excessive load on transportation costs for families and thus a serious challenge.

✦ Adaptation measures in transportation sector

Since the number of motor vehicles is growing rapidly, while the existing fleet needs retrofitting, the major adaptation policies should focus on fuel economy, air conditioning and control of evaporative loss of petrol. About one fourth of the cars in Iran are equipped with air-conditioning systems. It will be necessary to outfit the remaining three million cars with air-conditioning systems. This will incur an initial cost of some 2.1 billion USD to the nation's economy, taking into account the approximate cost of USD 700 per car.

4.2.6.3 Oil, Gas and Petrochemical Industries

According to the IPCC's classification, the sensitivity of the industry and energy sectors to climate change is given middle or low priority in most countries. Yet in the oil exporting countries based on a thorough study of their social and economic circumstances, these same sectors rank high on the agenda as highly sensitive to climate change for the following reasons:

- The majority of the oil and gas industries in the countries of the Middle East that account for a large share in the world's production and supply of oil and gas, are situated along the shores of the Persian Gulf, the Sea of Oman and the Red Sea. Hence, any climate change and consequential rising of sea level shall have a negative impact on the efficiency of these installations. In Iran, in the upper plateau oil installations and platforms (e.g. Nosrat and Siri in the Behregan area, Norooz in Behregansar area and Forouzan and the Soroush in Lavan area) are vulnerable to large-scale damage from climate change phenomenon.
- In the petrochemical industry sector, major complexes have been constructed along the Persian Gulf, such as Bandar Imam, Razi and the Kharg Island petrochemical complexes. All these facilities are highly vulnerable to climate change.

Sea level rises have resulted in the destabilization of offshore oil platforms.

The intense dependence of Iran's economy on oil revenues increases its being at risk to climate change issue. In Iran, 15% of the national GDP is derived from oil as is

85% of foreign currency income. Other industries rely on oil income for purchasing their equipment and foreign currency needs. This web of interdependence on oil earnings makes Iran's economy vulnerable and extremely sensitive to the climate change issue (see section 4.3 for the impact of response measures in Annex I countries.).

✧ Climate Change Impact on Oil, Gas and Petrochemical Industries

Rising of sea level and it's impact

Sea level rises have resulted in the destabilization of offshore oil platforms. Apart from the damages caused, there are resulting extra costs for dredging, repair and maintenance due to mud build up on these installations. Vast sums are also spent to remedy the degradation of pumping stations and transmission lines resulting from erosion at on-shore and offshore facilities.

Impact of sea storms

Sea storms also damage oil platforms and on-shore petrochemical units. At Bandar Imam petrochemical complex in particular, salt ponds that provide the unit's raw material are regularly impaired. While a rise in sea level could have positive effects on tanker traffic around the ports, yet storm conditions mean a rise in tanker fuel consumption and hence a higher cost for crude oil transportation.

Impact of rising air and water temperature on cooling systems

Air and water temperature increases impede the efficiency of industrial cooling systems like air fans, heat exchangers, cooling towers and air coolers. Consequently, to compensate for this, larger volumes of fluid should be displaced, which in turn, raises overall energy consumption. Likewise, electricity demand in the domestic sector rises due to increased ambient temperature.

As was estimated for power stations, this increase due to climate change will be about 20,000 MW by 2050. The equivalent crude oil needed is approximately 160 million barrels. Some of the main impacts of climate change are summarized below:

- Increased demand for crude oil to compensate for the drop of 2% in efficiency at the country's refineries, assuming a constant annual growth of 6% till 2050, is equivalent to 156 million barrels of oil.
- Output of gas refineries has to be boosted to compensate for the reduced efficiency in cooling systems. In the next 50 years, assuming a 6% annual

Table 4.8 Extra Demand for Oil due to Impact of Climate Change in the next 50 Years

Industry	Thermal Equivalent Crude Oil Needed in 2000-2050 (million barrels)	Base Consumption in 2000	Reduction in Efficiency (%)	Annual Growth till 2050 (%)
Electricity	160	120,000 GWh	2	6.5
Oil (down-stream)	156	1,400,000 b/d	2	6
Gas	122	52.5 b m^3/y	2	6
Petrochemical	12	4.4 b m^3/y NG 49 m tons/y md* 48,800 tons/y LPG	2	6
Total	450	-	-	-

*Middle Distillate

growth in consumption, 19.34 billion m^3 extra gas will be required. The equivalent in crude oil energy output is 122 million barrels.

- The petrochemical industry also suffers from reduced efficiency of cooling systems, corrosion and damages resulting from sea storms at its on-shore units and deteriorating salt ponds in chlor-alkali units and so on, causing at least 2% reduction in efficiency.
- Assuming again a 6% annual growth rate, the level of increased production of sweet and sour gas needed in the next 50 years will be equivalent to 1.62 billion m^3 of gas, or 10.2 million barrels of crude oil equivalent.
- Also, the 2% reduction in efficiency means that if the annual consumption of mid-stage distillation products is 4.4 million tons, 1.36 million barrels of oil equivalent in the next 50 years will be required. In addition, the extra LPG consumption shall be equivalent to 5.43 million barrels.

The extra requirement of equivalent crude oil for industries, associated with climate change in the next 50 years, is shown in Table 4.8.

It is observed that for Iran, global warming through 2050 will require an increase in crude oil production to counter the reduction of efficiency in the oil, gas and petrochemical industries equivalent to 450 million barrels of crude oil. Note that the investment needed for new capacity development of one barrel per day of crude oil, from exploration, geological investigation, extraction and refinery operations is about USD 22,000.

Now, if the total mentioned capacity is extracted from the new fields, then the total capital investment related to climate change in the next 50 years, will be 30 billion USD or an extra annual investment of about 650 million USD.

4.2.6.4 Adaptation Measures on Climate Change

Considering that the country's major oil, gas and petrochemical installations are located on the shores of the Persian Gulf, and that most oil and gas refineries are situated in hot areas, the following measures are recommended for ameliorating the climate change phenomenon:

- Equip the coastal installations with corrosion control systems,
- Increase and outfit the repair, maintenance and monitoring systems,
- Switch from water cooling to air cooling systems,
- Construct shield walls around refineries and coastal platforms, and
- Reinforce oil platforms against sea storms.

The vulnerability of the oil and gas industry and in general the energy sector of the Persian Gulf states including Iran, is a sensitive and important issue, not only for these countries, but for the whole world. This is because the Persian Gulf states have a large share in providing the world's crude oil. Any changes in the oil production of these countries would have significant impact on oil prices worldwide.

It is thus imperative that comprehensive programs, with the cooperation of the UN and the support of GEF, be implemented regarding climate change and exposure to damage criteria in these countries.

Wastewater, sludge and its residual solid by-products produce methane emissions if they are stored or treated under anaerobic conditions.

4.2.7 Waste Sector

Wastewater, sludge and its residual solid by-products produce methane emissions if they are stored or treated under anaerobic conditions. In some cases, methane is collected and used or flared, but in most circumstances the methane produced is released into the atmosphere. The amount emitted depends on the organic loading in the wastewater and the extent to which the organic material degrades under anaerobic conditions.

The most effective technique for reducing these emissions is to implement effective aerobic wastewater treatment systems, although such systems produce other significant greenhouse gases, e.g. CO_2. The primary method for reducing methane emissions from existing landfills is to collect and combust the landfill gas. Diverting organic refuse to other disposal and treatment options and away from landfills can reduce future emissions.

4.2.7.1 Climate Change Impact on Waste

✦ Liquid waste

The following information was gathered and used in estimating the impact of climate change on wastewater in Iran.

- The average amount of per capita consumption of water is 250 lit/day,
- 80% of water used will result in wastewater,
- The average growth rate of overall water consumption is 1.9% annually,
- The average growth rate for water consumption from network distribution is 2.7% annually, and
- The average growth rate for urban wastewater networks is 11.8% annually.

The amount of water evaporated from the surface and transpired from plants increases with air temperature. Consequently, even in areas with significant precipitation, higher evaportranspiration rates may lead to reduced wastewater, implying a possible reduction in renewable water supplies. More annual wastewater caused by increased precipitation is likely at high altitudes. In contrast, some lower altitude basins may experience large reductions in wastewater and increased water shortages as a result of a combination of increased evaporation and decreased precipitation.

The hydrology of arid and semi-arid areas such as Iran is particularly sensitive to climate variations. Relatively small changes in temperature and precipitation in these areas could result in large percentage changes in wastewater by increasing the likelihood and severity of droughts and/or floods.

✦ Solid waste

The influence of climate change on sanitary disposal systems especially on the landfill sites may be summarized as follows:

- Impact on collection, transportation and sanitary landfill systems. When temperature increases, the fermentation and degradation period will be decreased, and frequency of collection and transportation will rise.
- Incorrect collection and transportation results in emissions of odour and various pollutants which will indirectly affect GHG emissions.
- Temperature increase will cause some changes in the solid waste

The hydrology of arid and semi-arid areas such as Iran is particularly sensitive to climate variations.

fermentation process in landfills, hence the amount of gases and leachate will increase significantly.

- In coastal zones because of sea level rise, the efficiency of landfill systems will be reduced. Therefore, recycling will be a good alternative for waste disposal in these areas.

4.2.7.2 Adaptation Measures

Liquid waste

The primary means of adapting to climate change and hydrological variability and meeting the growing demands for water is provided, by

- Collection and treatment of urban and industrial wastewater,
- Application of new technologies such as microbial techniques for wastewater treatment in certain industrial processes,
- Optimisation of the wastewater treatment plants,
- Recycling and reuse of treated wastewater.

If anaerobic treatment is preferred as compared with aerobic treatment, capturing and using the methane produced during treatment would also reduce emissions.

According to the General Circulation Models applied to wastewater treatment plants based on scenarios of a 1.5 to 4.5°C rise in global mean temperature, global mean precipitation will increase by about 3% to 15% which will adversely affect wastewater treatment operations. Furthermore, the rise in temperature results in an increase in thermophilic microorganism growth.

Finally the most important action for reduction of GHG in wastewater treatment plants is upgrading the management of urban and industrial wastewater treatment systems.

Solid waste

The most important adaptation options are:

- Establishing bio-composting plants in order to reduce the amounts of waste transported to landfill sites. The economics of such projects in Iran are feasible if a market exists for compost. This trade often depends on the demand for fertilizer and is generally favourable in areas where organic solid supplements are needed.
- Minimization of waste is a result of efforts to conserve material that may be scarce, strategic, or expensive. Recycling and source separating and reduction of solid waste can reduce the amount of wastes and hence smaller landfill sites will be needed. There are several approaches to waste reduction by:
    - Recycling a potential waste or portion of it on the site where it is generated,
    - Improving the processes and equipment that alter the primary source of waste generation,
    - Improving plant operations such as better housekeeping, improving materials handling and equipment maintenance, automating process equipment, better monitoring and improved waste tracking, and integrating mass balance calculations into process design,
    - Substituting raw materials that introduce fewer hazardous substances

Recycling is usually the step before pollution control.

or smaller quantities of such substances into the production process, and
- Redesigning or reformulating the end products.

Recycling is usually the step before pollution control. However, as there are important economic constraints to recycling, other waste reduction opportunities, which potentially have greater benefits, are highlighted below:

- Development of an engineering design system for sanitary landfills and identifying mathematical models in order to calculate the generation of gases and the amount of leachate. Some of the models for designing a landfill (gases-leachate) are: HELP, PALOS VERDES, SHELDON-ARLETA, SCHOLL CANYON, and EMCON MGM,
- Proper selection of landfill sites, designing the venting systems for gaseous products and leachate collection and treatment systems are good options for reducing the effects of climate change,
- Development of incinerator systems to reduce the quantity of landfill wastes, often combined with energy recovery from the combustion process. Another advantage of incineration is the reduction of leachable wastes from landfills and elimination of long-term odours that might be emitted into the atmosphere surrounding the area. It appears that the landfill option is more suitable in Iran's climatic conditions, however, detailed comparative studies of incinerator systems with landfills has to be undertaken, identifying the advantages and disadvantages,
- Utilization of anaerobic biogas digesters for methane control in various rural (or even municipal) areas due to their economic and sanitary advantages,
- Microbial elimination of methane in landfills as a simple method, and
- Supporting and developing solid waste management program and relevant departments in the country to improve public health.

4.3 Impact Assessment of "Response Measures" by Annex B Countries

Although the developing countries have no emission reduction commitments under the Kyoto Protocol, the potential remains for both direct and indirect impact of policies and measures implemented in industrial countries on developing countries. The so-called *"Response Measures"* that the Annex B countries adopt to reduce their emissions, affect the economics of developing countries. The environmental, social, and economic impacts of climate change are covered primarily in Articles 4.8 and 4.9 and 4.10 of the UNFCCC. In particular, the impact of *"Response Measures"* is dealt with in Article 4.8 of the Convention and Article 3.14 of the Kyoto Protocol. Article 3.14 of the Kyoto Protocol requires *"Annex B countries to implement commitments in such a way as to minimize adverse social, environmental and economic consequences on developing countries that are the Protocol signatories"*.

Since Iran is an oil producing country, articles 4.8(h) and 4.10 of the Convention are particularly relevant to its circumstances. The articles specify that the *"Annex I parties of the Convention, in the implementation of their commitments, shall give full consideration to countries whose economies are highly dependent on income generated from the production, processing and export of fossil fuels"*.

Various studies have been conducted to assess the economic vulnerability of energy exporting developing countries vis-à-vis the *"Response Measures"*. The studies show that oil exporters suffer heavy losses as a result of Kyoto Protocol implementation while *"flexibility mechanisms"* will reduce the economic cost to oil producers.

Estimates of the *"Response Measures"* and their economic impact on developing countries that are heavily dependent on the export of fossil fuels have been made using different models. The IPCC Third Mitigation Assessment Report (TAR) has presented the contribution of Working Group III in its latest 2001 issue. The findings are reflected in Table 4.9:

Table 4.9 Costs of Kyoto Protocol Implementation for Oil Exporting Region/ Countries[a]

Model[b]	Without trading[c]	With Annex-I trading	With "global trading"
G-Cubed	*-25% oil revenue*	*-13% oil revenue*	*-7% oil revenue*
GREEN	*-3% real income*	*"Substantially reduced loss"*	*N/A*
GTEM	*0.2% GDP loss*	*<0.05% GDP loss*	*N/A*
MS-MRT	*1.39% welfare loss*	*1.15% welfare loss*	*0.36% welfare loss*
OPEC Model	*-17% OPEC revenue*	*-10% OPEC revenue*	*-8% OPEC revenue*
CLIMOX	*N/A*	*-10% some oil exporters' revenues*	*N/A*

Source: *IPCC Third Assessment Report; Climate Change 2001, Mitigation, P.64.*

a. The definition of oil exporting country varies: for G-Cubed and the OPEC model, it is the OPEC countries; for GREEN, it is a group of oil exporting countries; for GTEM it is Mexico and Indonesia; for MS-MRT it is OPEC + Mexico; and for CLIMOX it is West Asian and North African oil exporters.

b. The models consider the global economy through 2010 with mitigation according to the Kyoto Protocol targets (usually in the models applied to CO_2 mitigation by 2010 rather than GHG emissions for 2008 to 2012 achieved by imposing a carbon tax or auctioned emission permits with revenues recycled through lump-sum payments to consumers: no co-benefits, such as reductions in local air pollution damages, are taken into account in the results.

c. "Trading" denotes trading in emission permits between countries.

4.3.1 Assessment of Impact on Iran's Economy

A summary of the findings of an objective study conducted through a sophisticated *"General Equilibrium Model"* called MS-MRT (Multi Sector-Multi Region Trade[1]) is presented in this report. The model presents a quantification of the economic impact on the Iranian economy as a result of the policies and measures to be implemented in Annex B countries to meet their Kyoto Protocol targets. The study has been conducted on a scenario basis, with the assumption that the U.S. is either participating in or withdrawing from the Protocol.

4.3.1.1 Methodology

Estimates of adverse effects and required compensation are based on the results from four scenarios:

- Business-as-Usual (BAU),
- Kyoto Protocol with *"no flexible mechanisms"* and *"no tax adjustment"*,
- Kyoto Protocol with *"no flexible mechanisms"* and *"tax adjustments"*, and
- Kyoto Protocol with *"flexible mechanisms"* and *"no tax adjustment"*.

✧ Business-as-Usual (BAU)

In the BAU case, it is assumed that current regulations and taxes persist over the entire model horizon (2000 to 2030). As a result, no international climate change agreements are put in place and, therefore, countries incur no restrictions on their

1- Developed by Charles River Associates greenhouse gas emissions. Countries' emissions and energy consumption are determined by exogenous forecasts. Table 4.10 presents the baseline values for the international price of crude oil, world demand for crude oil, non-OPEC crude oil production and OPEC's share of crude oil production, that are based on the IEA's International Energy Outlook (1998).

Table 4.10 Baseline Projections for the Crude Oil Market

	2010	2020	2030
Baseline world oil price (USD per barrel)	*19.2*	*20.51*	*22.14*
World demand (mbd)	*81*	*97*	*118*
Non-OPEC production (mbd)	*44*	*45*	*46*
OPEC share of world oil production (%)	*46*	*54*	*61*

Kyoto Protocol with "No Flexible Mechanisms" and "No Tax Adjustment"

In this scenario, otherwise known as "No Flexibility," all Annex B countries except Canada and the United States ratify the Kyoto Protocol. No allowance for sinks is granted; banking, permit trading among regions, and CDM are all prohibited in this scenario. The parties are constrained to meet their emissions targets through domestic actions only. In addition, Annex B countries opt not to adjust their pre-existing energy taxes and subsidies.

Kyoto Protocol with "No Flexible Mechanisms" and "Tax Adjustments"

The Kyoto Protocol with no flexible mechanisms and tax adjustments ("tax cut") is considered. Here, some existing energy taxes and all subsidies are replaced by carbon taxes large enough to collect equal net revenues. As in the *"No Flexibility"* scenario, it prohibits flexible mechanisms, and each region must meet its Kyoto obligation through domestic action. Unlike the "No Flexibility" scenario, each country adjusts its pre-existing energy taxes and subsidies.

Kyoto Protocol with "Flexible Mechanisms" and "No Tax Adjustment"

In this scenario, otherwise known as *"Flexibility with CDM,"* the Annex I parties are allowed to use flexible mechanisms, such as permit trading among adopting countries and CDM, to meet their domestic obligation. However, this policy leaves existing energy taxes in place.

To be consistent with the recent EU proposals concerning implementation of the Kyoto Protocol, the Flexibility with CDM Scenario prohibits the sale of "hot air," but hot air can be banked. In addition, there is a supplementary restriction on the purchase of permits: all together, flexible mechanisms are allowed to contribute only 50% of a country's requirement to reduce emissions. This scenario does not allow credits to be taken for sinks.

These possible projections are in line with the Bonn Agreement reached during COP6-Part II meetings, however, they do not take into consideration the use of sinks in the process of reaching developed countries' Kyoto targets and the removal of caps on emissions trading.

The key results with respect to the impact on world crude oil prices under the three policy scenarios *with* and *without* the U.S. participation are presented in Tables 4.11a and 4.11b, respectively.

Table 4.11a World Crude Oil Price under the Three Policy Scenarios *with* Participation of the USA (% change from baseline)

Scenarios	2000	2005	2010	2015	2020	2025	2030
No Flexibility	-0.13	-0.09	-15.32	-16.09	-16.48	-17.66	-18.35
Tax Cut	-0.02	0.06	-7.5	-9.54	-9.63	-9.97	-10.29
Flexibility with CDM	-0.09	-0.16	-10.61	-11.33	-11.13	-11.08	-11.16

Table 4.11b World Crude Oil Price under the Three Policy Scenarios *without* Participation of the US (% change from baseline)

Scenarios	2000	2005	2010	2015	2020	2025	2030
No Flexibility	0.06	0.17	-2.55	-3.02	-3.46	-3.99	-4.31
Tax Cut	0.13	0.29	1.59	1.58	1.47	1.05	0.61
Flexibility with CDM	0.02	0	-2.07	-2.37	-2.75	-3.15	-3.54

Compared to the results obtained when full participation of Annex B countries is assumed, there are significant reductions in the impacts of Kyoto protocol implementation on crude oil prices and on Iran's economy when the USA withdraws from the Kyoto Protocol. World crude oil prices decrease at a smaller percentage, ranging from 2.1 to 4.3 between 2010 and 2030 while they actually increase in the *"Tax Cut Scenario"*.

As shown in Table 4.12a, under *"No Flexibility Scenario"* and *with* US participation, Iran will suffer a loss of 6.3 billion USD in oil revenue and -3.1% change in welfare through 2010. The cash compensation required to offset the losses amounts to 79 billion USD. The losses in oil revenue and welfare, however, are reduced significantly to 1.2 billion USD and a -0.7 change in welfare *without* US participation. The cash compensation required to offset losses, therefore, is reduced to 20 billion USD.

As shown in Table 4.12b, under *"Tax Cut Scenario"* and *with* the U.S. participation, Iran's losses in oil revenue and welfare will amount to 3 billion USD and -1.76%, respectively. Under these conditions the cash compensation required to offset losses amounts to 45 billion USD. Without the U.S. participation, however, the losses are reduced to 1.6 billion USD and -0.40%, respectively, and no compensation is required.

Table 4.12c shows Iran's losses under the "Flexibility with CDM Scenario". *With* the U.S. participation, Iran would suffer a loss of 4.5 billion USD in oil revenue and -2.22% change in welfare. That would require a compensation of 57 billion USD. When the U.S. is not participating, the losses in oil revenue and welfare are reduced to 900 million USD and -0.52%, respectively. The compensation required then amounts to 17 billion USD.

4.3.2 Terms of Trade Impact

Trade is a significant factor in the economic interactions of Annex B and non-Annex B countries. Many non-Annex B countries will face adverse consequences from actions taken by Annex B countries to limit their emissions. These results

Table 4.12a Impact on Iran's Economy of Annex I Three Policy Response Measures Scenarios: "No Flexibility Scenario"

No Flexibility	Revenue losses in 2010 (Billions of 1995 USD)	% change in welfare	Cash compensation (Billions of 1995 USD)
With US	-6.3	-3.1	79
Without US	-1.2	-0.7	20

Table 4.12b Impact on Iran's Economy of Annex I Three Policy Response Measures Scenarios: "Tax Cut Scenario"

TAX cut	Revenue losses in 2010 (Billions of 1995 US D)	% change in welfare	Cash compensation (Billions of 1995 US D)
With US	-3	-1.76	45
Without US	1.6	0.4	0 *

Zero value indicates that no compensation is needed.

Table 4.12c Impact on Iran's Economy of Annex I Three Policy Response Measures Scenarios:" Flexibility with CDM Scenario"

Flexibility with CDM	Revenue losses in 2010 (Billions of 1995 USD)	% change in welfare	Cash compensation (Billions of 1995 USD)
With US	-4.5	-2.22	57
Without US	-0.9	-0.52	17

will be transmitted through changes in the "*Terms-of-Trade*" between Annex B and non-Annex B countries and by changes in the volume of imports and exports.

There are four important changes in "*Terms-of-Trade*" that account for these spillover effects:

- Import prices from adopting Annex B countries will rise due to higher energy costs,
- Energy exports will change in price because of changes in demand. In scenarios without reductions in existing taxes on Refined Petroleum Products (RPPs), crude prices will decline because of a drop in demand. But if existing taxes on RPPs are reduced, then the price of crude exports will increase with demand while the price of coal exports will fall with the decline in demand,
- Export prices of less energy-intensive goods to adopting countries will fall because of a drop in demand for all imports by the adopting countries, and
- Export prices of energy-intensive goods from all countries will raise.

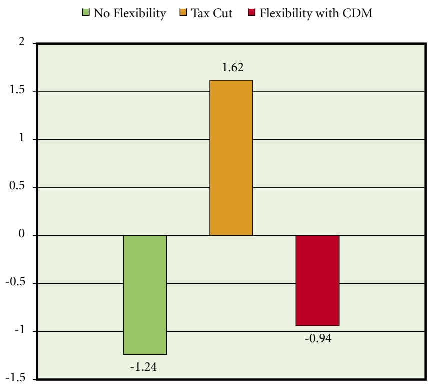
These changes in "Terms-of-Trade" lead to wealth transfers among countries, the largest of which are from oil-exporting non-Annex B countries to all others.

These changes in "*Terms-of-Trade*" lead to wealth transfers among countries, the largest of which are from oil-exporting non-Annex B countries to all others. Annex B countries benefit from the lower price of oil in the world markets, and also receive higher prices for their exports to non-Annex B countries.

4.3.3 Conclusions

To sum up, in general the above results indicate that there are significant reductions in the effects of Kyoto Protocol implementation on crude oil prices and on the Iranian economy compared to the results obtained when full participation of

Figure 4.16 The Impact of Response Measures on Iranian Economy (USD billions)



Annex B countries is assumed. That is, in the scenario where the U.S. withdraws from the Kyoto Protocol, it will increase its demand for oil exports over baseline levels. This causes oil exporting countries to be significantly better off than in the case where the U.S. commits itself to limits.

Unless reductions are made to existing taxes on RPPs, the implementation of the Kyoto Protocol has the most negative effect on oil producing, as well as poorer non-Annex B countries. Removal of subsidies by Annex B countries will reverse the impact on OPEC as a whole to the point that it would be better off under the Kyoto Protocol than in the baseline.

The implementation of *"flexible mechanisms"* in the Kyoto Protocol can result in more efficient choices among oil, gas and coal used globally. Also, it can reduce adverse impacts on oil exporting non-Annex B countries. Eliminating the 50% supplementary constraint and/or allowing credits for sinks would further reduce negative consequences.

Overall, unless reductions are made to existing Annex B taxes on RPPs, GHGs mitigation policies will cause *"Terms-of-Trade"* to deteriorate the most in oil-exporting countries and improve in oil-importing countries, which results in a wealth transfer from oil-exporting countries to oil-importing countries. With *"tax cuts"*, terms of trade would improve in most oil exporting countries. Figure 4.16 shows the impact of Annex-B countries' response measures on Iranian economy.

Chapter V

Proposed National Strategies to Address Climate Change

Kia Deh, Mazandaran*; Photography: Kamran SATVAT-MANESH*

5.1 Introduction

The present «Draft» National Action Plan provides a collection of national issues without prioritising them. It is noteworthy that as the first attempt of such kind, this draft aimed to address climate change issues. It is only a preliminary step and requires extensive subsequent studies and efforts in preparing a comprehensive multi-sectoral *"National Action Plan on Climate Change"*.

In addition, the National Action Plan is expected to amalgamate mitigation initiatives in various disciplines combining different themes like education, public awareness, capacity building, public participation, financing, legislating regulations, investment, etc. However, as mentioned above, once the mitigation initiatives are prioritised and approved by the government, steps would be taken toward finalization of measures under each of the themes and sectors covered under the National Action Plan. At present, this draft edition should be treated as a novice preparatory activity addressing some of the main thematic issues, and at best, a *"conceptual"* action plan for preparation of the Final National Action Plan in the future.

5.2 Addressing the Uncertainties

Climate change and climate variability have a profound influence of varying dimensions on the unique Iranian ecosystem as well as on human health that interacts with socio-economic factors. This is clearly observed in the specific issue of fresh water consumption (potable and non-potable fresh water) and its vital impact on sustainable human development (e.g. agriculture, food production, industry etc.). In addressing the uncertainties involved, the following issues must be assessed:

Assess Ongoing National Activities and Identification of Gaps

Any measures taken must take into account the on-going national activities and identify the gaps that could improve the understanding of those processes influencing and are influenced by climate change on a national scale. Particularly, the following issues should be highlighted:

Impact of drought and desertification on food supply

The combination of agricultural, livestock and aquaculture products are the largest percentage of the national food supply. These include wheat, rice, meat, dairy products, etc. that have a bearing on national food security as well. About 4.4 million ha of annual crops are produced through rain-fed cultivation. This is while most of the dry areas in Iran are located in marginal lands, and are subject to erosion or desertification. About 15% of the 90 million ha of the country's entire rangeland lies in the high productivity or Grade-1 class. The remainder is grouped in Grade-2 and 3 categories with low productivity; while about 50% of the total Animal Units (AU) amounting to about 60 million AU, generally graze directly on rangelands located in arid and semi-arid climatic conditions that are extremely vulnerable to drought. Also, changing the magnitude and frequency of floods related to droughts and particularly the magnitude and frequency of such droughts have a significant impact on the ecosystem, natural resources and socio-economic condition of the country.

Climate change and climate variability have a profound influence of varying dimensions on the unique Iranian ecosystem as well as on human health that interacts with socio-economic factors.

Population movement, migration patterns, and water supply/demand issues

The variability of freshwater, the availability of water, and changes in the quality of fresh drinking water can affect population movement and migration throughout national territories and even migration from neighbouring states into the country. Clearly, these will eventually have a significant impact on national security. The extant and still emerging pattern of high population growth rate and distribution patterns in large cities combined with climate changes and particularly drought has had a magnified mutating influence on the availability and quality of drinking water in most parts of the country. This trend will accelerate in the future.

Health hazards

Human health is adversely affected nationwide by shifting of variables in environmental factors. It may lead to massive illness and mortality and influence the spread of communicable diseases (e.g. malaria, leishmaniasis, etc.) as mentioned in Chapter 4 of this report. This potential will be given increased momentum by climate changes and in particular the magnitude and frequency of drought in most parts of the country. The consequences resulting from the interaction of drought with improper water supply, lack of sanitation control, changes in water quality, lowered food quality, lack of integrated vector control, and waste disposal in most arid, semi-arid and tropical climatic zones in the country, might lead to a disastrous situation.

Coastal-related issues

Degradation of coastal areas has a direct impact on socio-economic conditions and the ecology of these sensitive areas. There is another danger signal. The consequence of the Caspian Sea water level fluctuation (sometimes more than 20 cm per year) reduces coastal autonomous adaptation capacity. The same phenomenon has a negative bearing on the small islands of the Persian Gulf. Any increase in sea level also influences municipal fresh water supplies in the northwest reaches of the Persian Gulf coastal area, through significant saltwater intrusion into the Karoun River, combined with the river's decreased outflows into the Persian Gulf. The quality and quantity of fresh water supply to the coastal ecologically sensitive areas including estuaries, wetlands and mangroves is also of great importance.

Negative impact on bio-resources

The most vulnerable and ecologically sensitive areas and natural bio-resources, including terrestrial flora and fauna (forests, rangelands and deserts), coastal and marine environment, such as wetlands, mangrove forests, estuaries and the coral reef have been adversely affected.

Establishing Atmospheric/Climatic Watch and Observation System

The existing climate observation system needs upgrading and expansion at the national level. In addition, an effective contribution should be made to the global atmospheric monitoring system through contributing to the development, utilization and accessibility of databases listed below:

- Strengthening atmosphere related data collection systematically at the national level both in terrestrial and marine environment,
- Supporting, sharing or transfer of information, tools and technology, such

Human health is adversely affected nationwide by shifting of variables in environmental factors.

as Geographic Information Systems (GIS) and remote sensing, along with the necessary training in their use in resource management,

- Making operational marine focused networks as a means to link the data providers, users, all the stakeholders and data centres at the national level,
- Support relevant national institutions currently dealing with international research and monitoring programs such as GOOS and relevant global observation bodies as a means of gathering basic data and information, and
- Plan a step-by-step studying and monitoring program along the coastal areas for collecting the necessary data and information for integrated management of coastal areas.

The observation system should cover large-scale analyses with macro-climatologic objectives while also focusing on local and micro-climatologic objectives. Alteration of local albedo, humidity, surface temperature and roughness all result from the cultivation of different types of crops and irrigation practices. Large-scale irrigation projects alter atmospheric boundary layer conditions that increase the potential of precipitation. In contrast, overgrazing of large grasslands and large-scale deforestation lead to atmospheric boundary layer modification, which in turn creates a net loss of precipitation.

Major cities can substantially modify the atmospheric boundary layer. Urban areas are normally warmer than the adjacent rural areas. This so-called *"heat island"* effect coupled with increased surface roughness and urban structures alters local winds and atmospheric circulation patterns leading to convergence zones. In turn, clouds and precipitation under certain atmospheric conditions are initiated. Atmospheric particulates and aerosols over and down wind of major cities increase due to fossil fuels combustion. This reduces air quality, visibility and the influences of the local development of clouds and precipitation.

Industrial activities and power plants not only play an important role in increasing aerosols but also in emission of trace gas constituents. Clouds' ingestion of some emitted gases (e.g., sulphur oxides) results in the production of acidic precipitation, which can, at sufficient concentrations, adversely affect structures, vegetation, and water quality. Large cooling ponds and cooling towers cause localized fog, low clouds, and icing under certain weather conditions.

As a consequence, additional local and micro-climatic observation must be made. These are listed below:

- Pattern analysis of the other climatic parameters such as wind velocity, evaporation, cloud cover, etc,
- Micro-meteorological studies for provision of sufficient data and information to the relevant sectors and decision makers allowing them a clear understanding of the changes and the outcome of their planning for the future socio-economic influenced developments in the atmosphere, and
- Given the large variation of national geographical characteristics, micro-climatologically studies are essential for better understanding of present and possible future climate conditions.

This so-called "heat island" effect coupled with increased surface roughness and urban structures alters local winds and atmospheric circulation patterns leading to convergence zones.

Climatic Early Warning Systems

Development of early warning systems concerning changes and fluctuations in climate, especially drought, establishment and improvement of capabilities to predict such changes and assessing the resulting environmental and socio-economic impact. The areas of concern must be sharply focused on fresh water supply and water quality changes for drinking and agriculture, food security, human health, burning of forest and rangeland, damages to sensitive coastal areas and natural terrestrial and aquatic bio-resources, especially commercial valuable and endangered species.

Capacity Building

Improve the existing national mechanism in the building of scientific capabilities, the exchange of scientific data and information among national institutions and international bodies. Training of experts and technical staff in the field of research, data assembly, collection and assessment, and systematic observation related to the atmosphere is also needed. These improvements could be achieved through a well-defined national data and information management and exchange system.

5.3 Promoting Sustainable Development

The need to control atmospheric emissions of GHGs will be increasingly based on efficiency in energy production, transmission, distribution, and consumption.

5.3.1 Energy Development, Efficiency and Consumption

The need to control atmospheric emissions of GHGs will be increasingly based on efficiency in energy production, transmission, distribution, and consumption. Proper measures must be harmonized by correctly utilizing environmentally sound energy systems, particularly new and renewable sources of cost effective energy friendly to the atmosphere, human health, and the environment as a whole.

Strategies and Policies to Reduce Emissions

The high rate of consumption of energy carriers in the country translates as a large share of GHGs emission within the energy sector (78% of the country's total GHGs in 1994). Moreover, concerning the strong dependence of the country's economy on oil and gas activities, high priority should be given to the energy sector for adoption of appropriate strategies and policies for reducing emissions, and to develop a "National Action Plan" to deal with climate change. The measures include:

Alternative sources of energy

Evaluation of on-going national activities in identifying and developing economically viable, cost effective, accessible and environmentally sound energy sources is a must. Iran has high potential in renewable energy resources such as solar, wind and geothermal power. As such, carrying out research and pilot programs in applying the technologies for these energies would be an intelligent approach to increase the share of non-fossil energy in national development. Present studies on geothermal energy in the north and northwest have shown that it will be a prospect in the future for further investment. Two geothermal plant units will be ready for commissioning in Meshkinshahr in north-western Iran by 2004. In promoting the availability of alternative sources of energy including natural gas and the aforementioned sources, it is required particularly to use a bottom-up approach (i.e. through advocacy campaigns by NGOs and CSOs). Also, it is noteworthy that solar energy on a small scale is applicable in most parts of Iran. The same is true for the biogas produced by degradable municipal and agricultural waste especially in rural areas. Promotion of wind energy supply, geothermal and other non-fossil fuel energy is also feasible.

Improvement of the existing institutional, scientific planning and management capacities, particularly increasing usage of efficient and less polluting forms of energy is recommended. In the case of Iran, some remarkable examples could be introduced including:

- *Fuel switching*: Natural gas could substitute oil, as the country holds some 18% of known natural gas reserves worldwide. As exporting natural gas might not be economically sound, replacement of heavy and high carbon fuels with natural gas should be considered a logical policy for reducing GHGs and correct use of energy resources as well. Presently, about 80% of the country's power plants run with gas fuel equipment. The present limitation of gas exploration and future socio-economic development planning should induce the government to make greater exploration and processing of natural gas.
- *Use of electric pumps*: Commonly used diesel engine pumps in the agricultural sector should be abandoned and be replaced by electric ones. It should be noted that diesel motors have an efficiency of about 20% for water pumping and irrigation, whereas integration of electrical pumping equipment into agriculture and the national electric network could raise efficiency to more than 33% and reduce GHGs emission by 65%.
- *Hydropower plants*: The on-going national hydropower plants project capacity both under study or in the implementation phase is estimated to be about 20,000 MW. The national potential capacity of hydropower has been estimated up to 40,000 MW, which should be seen as an appropriate alternative to reduce CO_2 emission.

Environmental Impact Assessment (EIA)

Development of appropriate methodologies for making inter-sectoral and integrated energy, environment and economic policy decisions through EIA need to be considered. Preparation of national guidelines for EIA in the energy development sector should focus on all national specific environmental and socio-economical conditions. This should be twinned with periodic evaluation and modification that is a crucial step to ensure the decision makers' ability to bring national development needs in compliance with long-term integrated energy policy.

Bi-lateral/multi-lateral research and development (R & D) and joint programs and projects

Improvement of the existing R & D, transfer and use of technologies and practices for environmentally sound energy systems, including utilization of new and renewable energy resources as mentioned above are necessary. Progress could be accelerated through bi-lateral or multi-lateral cooperation with international organizations or globally reputed institutions. Identification and implementation of pilot programs/projects, which will clarify and facilitate the subsequent national policy and investment to improve the processes is also recommended.

Commonly used diesel engine pumps in the agricultural sector should be abandoned and be replaced by electric ones.

Energy Efficiency

Improvement of the existing research, development, transfer and use of improved energy-efficient technologies in all relevant sectors such as:

- *Gas injection:* Specific priority should be given to the on-going activities concerning rehabilitation and modernization of oil field extraction and natural gas injection to the oil fields. Oil and gas industries emit 60% of the total methane in the country, equivalent to about 1,500 Gg, in the form of cold flaring and 31,000 Gg of CO_2 as hot flaring. This contributes a large input in GHGs emission. Since CH_4 is a source of energy, implementation of the policies in reducing emission and warming effects, is a rational way of energy conservation that protects both resources and the environment. In oil production processes, a large amount of associated gas, mainly CH_4, is flared. During the third Five-Year Development Plan (FYDP), the government aims to inject gas into oil wells to improve their production capacity. In these procedures, methane as an associated gas could be used for oil well injection. Other reasonable strategies for reducing CH_4 include: liquefying the associated gases (Gas-to-Liquid), oxidative coupling of methane (OCM) and converting CH_4 to DMC (Dimethyl-Carbonate).
- *Generating electricity in oil fields:* There are two efficient options in this regard. First, it is most appropriate to generate electricity utilizing natural gas in the oil fields and then distribute the energy via the electricity network instead of constructing a natural gas pipeline network for power plants. Second, utilizing the pressurized natural gas for electricity generation by expansion turbine (Well-to-Watt) could be a strategy for rational use of energy resources.
- *Co-generation and combined cycle power plants:* Installation of steam turbines onto the gas power stations of the country is associated with increasing their efficiency from 24% to more than 44%, and reducing of GHGs by 35%. The power stations must be equipped with heat regenerative systems (combined heat and power, CHP) as well as gas turbines. Energy consumption and GHGs emission would thus be reduced twofold. This is the result of applying modern combined cycles with heat recovery and supplementary flaring at 90% efficiency.
- *Refining processes:* Considering the high rate of energy consumption in the oil and gas processes in the country, plans for efficient use of energy in the oil industry, particularly fuel switching are necessary. At present, several programs are being carried out for replacement of liquid fuels and enhancing consumption efficiency in the refineries. The government can encourage the oil industry to speed up their plans for improvement by giving them reasonable financial grants in accordance to the amount of saved energy by the corresponding complex.

Systematic monitoring and evaluation (M & E)

Monitoring and evaluation of the current energy supply to identify how the contribution of energy systems that are environmentally sound could be increased in an economically efficient manner. This is particularly true of new and renewable energy systems, taking into account that Iran has high potential for producing solar energy, geothermal and other non-fossil energy fuels. Also, evaluation of

Oil and gas industries emit 60% of the total methane in the country.

the existing national policies and programs including administrative, social and economic measures is considered essential.

✛ Appropriate tariffs

One of the most important measures as a national policy will be to set appropriate tariffs of energy carriers for consumers. Because of the low operating costs for energy carriers in the country that is often combined with very poor technology in industrial equipment, the rate of consumption and losses of energy are very high. In order to reduce the over consumption of energy, the government could take steps towards reducing subsides on energy carriers. This could be done through public awareness and implementing programs for removing the artificial inflationary impact of such subsidies reduction. The government could legislate and introduce exponential tariffs for those customers with excessive energy consumption to alleviate the consequences entailed in cutting subsidies.

✛ Capacity assessment

Assessment of the existing national capacity in energy planning and program management in energy efficiency, as well as for development, introduction, and promotion of new and renewable sources of energy. Determination of the gaps and shortcomings in order to enhance the national capacity in planning and program management in this respect.

✛ Energy strategy

Development of the appropriate national energy efficiency and emission standards, aiming at the development and utilization of technologies that minimize adverse impacts on the environment and reduce GHGs emissions.

✛ Capacity building targeting energy efficiency

Enhancement of research, education and public awareness programs at the local and national levels concerning energy efficiency and environmentally sound energy systems including:

- *Establishment of a National Energy Conservation Research Centre:* Considering the importance of the energy sector in the country's socio-economic structure, the need of such energy efficiency research centres has now become an urgent necessity. This institute could be created as a directive and coordinating body using the existing national capacity in research and education and coordinate with relevant organizations in orienting them to improve their capacity in energy conservation and efficiency research issues.
- *Advocacy campaigns:* Increased public awareness especially in the domestic sector can be an effective tool in reducing consumption of energy carriers. Current energy consumption per square meter of residential buildings in Iran is 2.56 times more than Turkey and Kazakhstan, which is a clear indication of improper energy use in this sector. The government in close cooperation with non-governmental organizations (NGOs) can reduce the consumption rate by efficient use of energy through educational programs such as:
    - ❍ Training of administrators (decision-makers) through management

Because of the low operating costs for energy carriers in the country, the rate of consumption and losses of energy are very high.

and energy efficiency workshops,
- Training of industrial managers by familiarizing them with new and efficient technologies,
- Training of the public through the mass media and with the full cooperation of NGOs and CSOs to campaign for energy efficiency,
- Training of school children, youth, teachers, and particularly women-focused NGOs and CSOs on advantages of energy efficiency, and
- Inclusion of energy efficiency materials in school textbooks. It is worthy to note that initial steps in this regard have already been taken (e.g. energy efficiency as a part of energy section in the science books of third graders).

5.3.2 Transport

The transport sector in Iran plays an essential and positive role in economic and social development. Since the sector is a major source of atmospheric emissions, there is a need for a review of the existing transport systems, and a more effective design and management of traffic and transport systems.

The basic objective of the National Action Plan should be to develop and promote appropriate cost-effective policies or programs, to limit, reduce or control harmful emissions into the atmosphere and other adverse environmental effects of the transport sector including:

Cost-effective transport systems

Evaluation of the existing transport system with more emphasis on the most populated cities (such as Tehran) and establishing cost effective, more efficient, less polluting and safer transport systems. Promotion of an integrated rural and urban mass transit, as well as environmentally sound road networks.

Up-to-date technologies

Design and implementation of compatible programs to access and transfer of safe, efficient, and less polluting transport technologies, including appropriate training.

Data bank linking environment to transport

Strengthen national efforts in collecting, analysing and exchanging relevant information between pertinent national stakeholders on the relation between environment and transport, with particular emphasis on the systematic observation of emissions and the development of a transport database.

Macro/micro transport planning

In accordance with the Third FYDP, evaluate and promote cost effective policies and programs including administrative, social and economic measures at the macro-level. At the micro-level, speed up the use of transportation modes that minimize adverse influence on the atmosphere. Other critical issues are the aged condition of vehicles in the network combined with low fuel prices. Also, inefficiency of inspection and maintenance regulations increases the share of GHGs of the country's transport. In order to reduce these emissions, the government with the cooperation of car manufacturers and the private sector, has carried out various measures in recent years.

At the micro-level, speed up the use of transportation modes that minimize adverse influence on the atmosphere.

Urban traffic and transportation management

The basic strategies in the transport sector concerning adaptation with climate change include urban traffic and transportation management. Mechanisms to integrate transport, urban and regional settlement planning strategies, with a view to reducing the emission and adverse impact on the environment have to be used. This can be accomplished through:

- Compiling a transport code, parking policies, and intelligent traffic lights that would effectively optimise inner city transport,
- Improving vehicle technology and upgrading aged vehicles, and
- Use of catalytic converters, retrofitting or removing old vehicles and improving of fuel quality and pricing.

5.3.3 Industries

Industry in Iran is essential for the production of goods and services and is a major source of employment, income and economic growth. In this section the actions and policies of concern which result in emission reduction are listed as follows:

Enhanced Monitoring and Evaluation (M&E) to minimize emissions

In accordance with national socio-economic development and environment priorities, monitoring, evaluating and, as appropriate, promoting cost-effective policies or programs, including administrative, social and economic measures to minimize industrial emissions into the atmosphere are important components of the future National Action Plan.

Capacity building on efficient and safe production

Encourage industries to increase and strengthen their capacity to develop technologies, products and processes which are safe, less polluting, and make more efficient use of all resources and materials, including energy; cooperate in the development and transfer of such industrial technologies and in the development of capacities to manage and use such technologies.

Application of Environmental Impact Assessment (EIA) in the industrial sector

Formulate and continuously upgrade environmental impact assessments to foster and improve sustainable industrial development.

Efficient use of resources while minimizing waste

Promote efficient use of materials and resources, taking into account the life cycles of products, in order to realize the economic and environmental benefits of using resources more efficiently and producing less waste through:

- *Code of practice*: Compiling an energy management code of practice and distributing it among middle size industries, especially the private sector[1], to be implemented and monitored by the Ministry of Industries and Mines. This policy will attract the contribution of private and government sectors to energy efficiency practice which will be in line with reduction in GHGs emission.
- *Promotion of ISO 14000*: Encouraging factories to obtain the *ISO 14000* certificate. This will enhance better management of resources and

Industry in Iran is essential for the production of goods and services and is a major source of employment, income and economic growth.

1- *In Iran, at present, the majority of industries are state-owned* materials including energy carriers. Environmental evaluation and energy auditing is one of the key controls in ISO14000, that will ultimately meet the objectives of energy efficiency practice in relevant sectors.

- *Energy audit program*: Energy auditing particularly in large and energy-intensive industries like iron and steel, aluminium, chemical, petrochemical, textile and paper industries can make a considerable contribution in the reduction of GHGs emission. With this in mind, the government should introduce certain public and private research establishments to the industry whose duties would be annual auditing of these factories and providing the government with reporting in order to enable it to carry out the necessary measures in relevant factories. At the same time, it would be necessary and useful to carry out energy auditing in the field of energy management and energy saving, with the support of the government for small industries and the private sector as well.

✦ Efficient technologies

Support the promotion of less polluting and more efficient technologies and processes in industries, taking into account the area-specific accessible potentials for energy, particularly safe and renewable sources of energy, with a view to limiting industrial pollution and adverse impacts on the atmosphere.

5.3.4 Waste Management

To reduce CH_4 emissions from solid and liquid wastes, the recommendations are listed below.

5.3.4.1 Solid Waste

In order to reduce GHG emissions from sanitary landfill sites, the following options should be considered:

✦ Waste minimization and source separation:

Recycling of the feasible portion of waste at the site of origin and improving process technology and equipment that alter the primary source of waste generation. Upgrading plant operations inclusive of better housekeeping; improved materials handling and equipment maintenance. Increased automation of process equipment, better monitoring and improved waste tracking is essential. Integrating mass balance calculations into the design process and substituting raw materials that introduce fewer hazardous substances or smaller quantities of such substances into the production process is also valuable. Finally, end products need redesigning or reformulating.

✦ Sanitary landfills

Engineering plant design of sanitary landfills to control gases and leachate. CH_4 could be collected and used for generating energy and electricity. Also, changing the landfill sites from anaerobic to semi-aerobic which results in reduced CH_4 emission, improving the leachate quality and offering increased biodegradation and higher cost-effectiveness.

Energy audit program: Energy auditing particularly in large and energy-intensive industries like iron and steel, aluminium, chemical, petrochemical, textile and paper industries can make a considerable contribution in the reduction of GHGs emission.

Usage of anaerobic biogas digesters
Such digesters are for methane control in rural areas due to the economic and sanitary advantages of this system.

Incinerator plants
Development of incinerator plants for hazardous wastes is a must. Incineration of these materials will decrease the quantities of buried wastes often combined with energy recovery from the combustion process.

Methane elimination
Microbial elimination of methane in landfills as a simple method.

Solid waste management program
Supporting and developing solid waste management program with relevant departments in the country, considering the public health in order to improve the human environment, along with establishment of relevant data and information management and exchange systems. Under this program, establishment of a research centre to study sanitary collection, transportation and disposal of wastes is recommended. Public awareness and training programs at various levels, to be conducted by the centre, is a basic pre-requisite in reducing the solid waste quantity, thereby reducing GHG emissions.

5.3.4.2 Liquid Waste
For liquid waste, the major actions for reduction of GHG's include:

- Collection and treatment of urban and industrial wastewater,
- Application of new technologies such as microbial techniques for wastewater treatment in certain industrial processes,
- Optimisation of wastewater treatment plants, and
- Recycling and reuse of treated wastewater.

If anaerobic is preferred to aerobic treatment, capturing and use of the produced methane is recommended. Strengthening the urban and industrial wastewater treatment management system, including the use of mathematical models for design and operation of wastewater plants is effective. Establishment of data and information management and exchange systems is also a logical suggestion.

5.3.5 Water Resources
The country's renewable water resources are about 130 billion cubic meters but given the population growth rate, per capita water resources are consistently decreasing. In the last two decades, the spatial distribution of the national water resources does not follow the population distribution pattern and expansion of population centres. Therefore, the need for investment on inter and intra–basin water transport would be increased accordingly.

The country's renewable water resources are about 130 billion cubic meters but given the population growth rate, per capita water resources are consistently decreasing.

At present the highest water consumption rate, 81.4 billion cubic meters per year or 94% of the total water use, is allocated to the agricultural sector. There is uncertainty with respect to the prediction of climate change at the global level. This incertitude is magnified at the national and local levels. Higher temperatures and decreased precipitation have led to decreased water supplies and increased water demands along with severe deterioration in the quality of freshwater bodies. The combination of these factors is putting strains on the already fragile balance between water supply and demand in most parts of the country.

The most important national activities are summarized below:

✢ Monitoring the hydrologic regime, formulating strategies and undertake climate change impact assessment

Such a regime would include soil moisture, groundwater balance, transpiration of water-quality, and related climate factors, especially in all water basins and areas most likely to suffer from the adverse effects of climate change and where the localities vulnerable to these effects need to be defined. Developing and applying response strategies, techniques and methodologies for assessing the potential adverse effects of climate change, through changes in ground water levels, temperature, precipitation and sea level rises, on freshwater resources and flood risk are proposed. Also, it seems appropriate to conduct case studies and establish linkages between climate change and the current occurrences of droughts and floods in certain regions. Further strategies include:

- Development of agriculture and aquaculture activities based on brackish-water use and increasing water use efficiency,
- Development and implementation of national response strategies utilizing innovative technology and engineering solutions for installation of flood and drought warning systems,
- Construction of water resources facilities such as dams, aqueducts, well fields, levees, banks and drainage channels,
- Non-construction measures including water conservation, integrated ground and surface water management and improved water supply,
- Drought control, improved operation of reservoirs, water saving policy, and water recycling and reuse, and
- Increasing the research activities under way within the national priorities.

5.3.6 Terrestrial and Marine Resource Development and Land Use

5.3.6.1 Agriculture

The National Action Plan in the agriculture sector aims to integrate climate change concerns into the national planning process and programs by enhancing policy options, building national capacity, improving national awareness, and establishing priority policies and measures to mitigate and adapt to the impact of climate change.

Iran as an integrated part of the globe is facing the consequences of climate change. Deforestation and land use change, overgrazing of rangeland, excessive use of manure and chemical fertilizers, all are contributing to the emission of GHGs which are directly related to climate change issues. Strategies and policies have to be diverted to sustainable and wise use of natural resources.

The National Action Plan in the agriculture sector aims to integrate climate change concerns into the national planning process and programs.

The United Nations Conference on Environment, Agenda 21, has placed capacity building and human resources development for sustainable management of natural resources and the related policies, in particular in the area of the Food and Agriculture Organization's (FAO) mandate. For mitigating the adverse effect of climate change, all countries have to take an integrated approach. International assistance has to be taken strongly into account. The following strategies in agriculture are viewed as the national contribution to global strategies:

Crop production

Resource inventory and agro-ecological zoning

A strategy at the national level must be applied for comprehensive inventory, monitoring and evaluation of the state of the resources. Agro-ecological zoning in particular helps to assess the land use potential for resource allocation and preventing undesirable land use change due to climate change.

Water quality control and irrigation schemes

Irrigated agriculture in Iran is the source of cereal production and export crops. Salinity and water logging threats are considerable in most irrigated lands. Mono cropping encourages insect, pest and diseases (e.g. schistosomiasis), while intensive fertilizer use is causing nitrate build-up in ground water and posing a risk to human health.

Incremental water use efficiency

Proactive involvement of farmers in irrigation design, providing improved training for water users and framing water-pricing policies that minimize water consumption are key concern in strategic climate change mitigation planning.

Water quality management

To prevent non-agricultural activities from degrading the quality of water for farming and vice versa, applying cost-effective water quality monitoring programs and regulations is needed. This would minimize water pollution by agriculture, agro-industries and urban users.

Disaster preparedness strategy

Long-term strategies for the areas of the country encountering scarce water resources; development of land and water use policies and plans to improve the reliability of supply, and applying measures to prevent over extraction from aquifers and to improve preparedness during drought/flood disasters are among the main priority areas.

Non-promotion of dry land farming

About 4.4 million ha of annual crops are rain-fed. Most dry lands in Iran are located at marginal lands, prone to erosion and subjected to desertification. Another threat is the expansion of agriculture onto rangelands, deforestation for fuelwood, declining crop yield due to soil degradation and expansion of salt affected lands. One strategy option is to discourage cultivation of rain-fed marginal lands and to improve the productivity of limited rainfall through enhanced cropping and pastoral systems. De-stocking could control damages caused by overgrazing and improving feed resources.

Land consolidation measures

Land fragmentation is vital and this issue has serious problems in agriculture. In Iran, individual farmers have a number of small parcels scattered over a large area.

A strategy at the national level must be applied for comprehensive inventory, monitoring and evaluation of the state of the resources.

This inhibits good farm management practice. Scattered and small plots are prime causes of low yield and production. Land consolidation and unification strategies have to be given special priority. The aim would be to check the fragmentation of properties and lands and establish uniform farms of an efficient size. This will facilitate cultivation of crops, ease of machinery movement, and permit sufficient and controlled application of irrigation water.

Water resources strategies

Strategies for best utilizing water resources and watershed management are also essential. This would include modification of current physical structures. Construction of cost effective small-scale reservoir dams to counteract adverse effect of climate change on water resources is one such measure. These types of dams are cost effective and less prone to environmental degradation. Lining of existing irrigation canals carries a heavy investment but is a necessity in order to upgrade the traditional earth canals now in use. This would considerably improve irrigation conveyance efficiency. Using pipes as water conduits would also increase efficiency and ultimately compensate for a portion of water deficiency. Leaching salt affected soils is another strategy in the planning process to provide drainage networks in salt affected soil and leach salts in irrigated lands. Reuse of drainage water to increase irrigation efficiency should also be put in place and water used for irrigation can be recycled. Treating water discharges from city and industrial effluents is also needed. Avoiding pollution of water by agricultural chemical and manure is another requirement.

Improving resource efficiency and diversification

The development of crop variety or species to counteract the effect of temperature rise due to climate change is a must. New heat resistant crops and diversified farming systems must be developed. Diversification can more easily minimize environmental and socio-economic risks. New schemes have to be developed by research, extension and training centres for monitoring and pre-warning systems for assessing pest outbreak have to be in place, as do methods for making adjustments for seasonal changes and sowing dates. Increasing research work on conservation tillage including deep tillage and minimum tillage is also important. Diversification and mixed cropping systems accompanied by improved management techniques help to promote maximum efficiency in the use of natural resources. This helps to facilitate waste management and recycling, and reduce the need for external input. Use of urea-coated fertilizer causes a significant reduction in both NH_3 loss and N_2O emission by slow release.

Integrated biological pest management

Use of appropriate techniques for controlling pests in a merged manner that enhances rather than destroys the natural biological control of pests is another concern. In order to prevent over use of chemicals for controlling pests, weeds and diseases, biological control must be encouraged. Use of natural enemies, parasites or predators to control pests is already being implemented underway in the country. Various techniques are used to augment the number of existing natural enemies.

The development of crop variety or species to counteract the effect of temperature rise due to climate change is a must.

✦ Livestock production

Greater use of intensive livestock production
The relevant activities include decreasing the number of livestock in degraded rangelands, replacing lightweight animal (sheep and goats) with crossbred cows. Also entailed is replacement of the traditional system of animal husbandry by intensive systems and increasing feed supply through agricultural crops.

Prevent burning of agricultural residues
Through training programs, stable mulching green manures and mechanical pest control are alternatives for crop residue burning.

Enhanced rice cultivation management
Mid-term drainage is considered to be a good practice for removing excess water from paddy fields.

Establishing biogas plants
To upgrade management of livestock residues, farmers should be encouraged to establish small-scale biogas plants. This will improve manure quality and at the same time by extraction of gas for cooking and heating purposes, the atmospheric harm done by burning of animal wastes can be reduced.

Improving livestock production efficiency
Virtually all efforts that improve animal productivity will reduce methane emission and nitrogen use efficiency. The composition of livestock diet can greatly influence digestibility and nitrogen use efficiency

5.3.6.2 Fishery Resources

✦ Comprehensive fisheries management program

Planning, preparation and implementation of long-term core research studies for each resource is called for. Research programs on the physiological and ecological effects of climate change on commercially important species of fish need to be conducted. Another necessity is preparing and implementing schemes for a comprehensive fisheries management program. Strengthening statistical services in support of this research is required.

5.3.6.3 Forest, Natural Rangeland and Desert

✦ Rehabilitation and silvicultural based treatment of forest resources

Forestation and forest development (e.g. transforming abandoned farmland to forestland especially in the north of country), balancing of forest harvesting volume with forest growth, and forest ecological capacities are the pillars of rehabilitation efforts. Forest tree improvement and use of fast growth species for reforestation and forestation and wood farming are also important. Other main areas of intervention are the development of wood farming and agro-forestry systems. Putting in place the national green movement plan nationwide is another bottom up approach and its achievement could be enhanced through greater involvement of NGOs and CSOs. Removal of 4 million surplus animal units from forests in the north of Iran over the course of a five-year plan.

Forestation and forest development, balancing of forest harvesting volume with forest growth, and forest ecological capacities are the pillars of rehabilitation efforts.

✦ Greater wood import

Increase wood importing in order to reduce wood utilization from the limited natural forests and to provide the needed inputs of wood dependent industries.

✦ Range renovation, range reseeding, proper use and range management

Support the high tolerant and production plant species in rangelands and use them for range rehabilitation and development. Balancing of range production capacity and animal units that graze on it and implement yearly inventory plans in rangelands for estimation of annual forage production are another measures to enhance range management. These initiatives together with permanent settlement of nomads are expected to minimize range degradation.

✦ Desert management and combating desertification

Seedling plantation, sowing and seed drilling, preparing petroleum mulching plans, programming for combating desertification, designing and implementing landscape management, and encouraging public participation and joint ventures with international organizations are the other activities required to upgrade the Iranian rangelands.

(Notes)

[1] In Iran, at present, the majority of industries are state-owned

Abbreviations & Units, References and Contributors

Abbreviations

App.	Appendix
AIJ	Activity Implemented Jointly
AU	Animal Units
BAU	Business As Usual
BLS	Base Line Scenario
BOE	Barrel of Oil Equivalent
CCE	Cost of Conserved Energy
CDM	Clean Development Mechanism
CFCs	Chlorofluorocarbons
CF_4	Tetrafluoromethane
C_2F_6	Hexafluoroethane
CH_4	Methane
CHP	Combined Heat & Power
CNG	Compressed Natural Gas
COP	Conference of Parties
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSL	Caspian Sea Level
CSOs	Civil Society Organizations
DMC	Di-Methyl Carbonate
DME	Di-Methyl Ether
DOE	Department of Environment
DOC	Degradable Organic Carbon
DOM./COM.	Domestic and Commercial Buildings
DSM	Demand Side Management
ECHAM4	European Centre/Hamburg Model 4
EEZ	Exclusive Economic Zones
EIA	Environmental Impact Assessment
ESM	Energy Supply Model
EU	European Union
FAO	United Nations Food and Agriculture Organization
FYDP	Five-Year Development Plan
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHGs	Greenhouse Gases
GNP	Gross National Product
GOOS	Global Ocean Observing System
Gov.	Government
GTL	Gas-to-Liquid
GWP	Global Warming Potential
HadCM2	Hadley Centre Unified Model 2
HELP	Hydraulic Evaluation of Landfill Performance

HFCs	Hydrofluorocarbons
ICM	Integrated Coastal Management
IEA	International Energy Agency
IEEO	Iran's Energy Efficiency Organization
INEO	Iran's New Energies Organization
IPCC	Intergovernmental Panel on Climate Change
IS92a-e	IPCC Scenario 92a-e
IWWEC	Institute of Water & Wastewater Engineering Company
LEAP	Long-range Energy Alternative Planning Systems
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRT	Light Rail Track
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MADE	Model for Analysis of Demand for Energy
MBOE	Million Barrels of Oil Equivalent
MCF	Methane Correction Factor
MOZ	Malaria Potential Occurrence Zone
MPO	Management and Planning Organization
MS-MRT	Multi Sector-Multi Region Trade
MSW	Municipal Solid Waste
N/A	Not Available
NCCO	National Climate Change Office
NE	Not Estimated
NGOs	Non-Governmental Organizations
NH_3	Ammonia
NIOC	National Iranian Oil Company
NO_X	Nitrogen Oxides
NSESD	National Strategy for Ecologically Sustainable Development
N_2O	Nitrous Oxide
OCM	Oxidative Coupling of Methane
OCM	Optimal Control Model
OPEC	Organization of Petroleum Exporting Countries
P	Precipitation
PBO	Plan and Budget Organization
PET	Potential Evapotranspiration
PFC	Perfluorocarbons
R & D	Research & Development
RAM	Runoff Assessment Model
RES	Reference Energy System
RFG	Recovery of Flare Gas
Rls	Rials
RPP	Refined Petroleum Products
SABA	Stands for Iran's Energy Efficiency Organization
SANA	Stands for Iran's New Energies Organization
SE	Southeast
SERI	Sharif Energy Research Institute

SCENGEN	SCENario GENerator
SEI	Stockholm Environment Institute
SF_6	Sulfurhexafluoride
SPP	Species
SSM	Supply Side Management
SWDS	Solid Waste Disposal Site
T	Temperature
TAR	Third Assessment Report
TCF	Trillion Cubic Foot
TEL	Tetra Ethyl Lead
TOOBA	A Tree Plantation Project at Slope Lands
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USSR	Union of Soviet Socialist Republics
V & A	Vulnerability and Adaptation
VOCs	Volatile Organic Compounds
WHO	World Health Organization
WMO	World Meteorological Organization
WW	Well-to-Watt

Units

mbd	Million barrels per day
cm	Centimetre
MW	Megawatt
°C/y	Degree centigrade per year
mm/y	Millimetre per year
lit/day	Litre per day
ha	Hectare
km	Kilometre
m^2	Square meter
Tdm/ha	Ton of dry material per hectare
Ton/ca	Ton per capita
PJ	Peta Joule
KWh	Kilowatt hour
Gg	Giga gram
b	Billion
m	Million
kt	Kiloton
kg	Kilogram
m^3	Cubic meters
TJ	Tera Joule

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Appendix

Assessment of GHGs Emission Trends in Baseline Scenario for all Sub-sectors

Abadan Refinery; Photography: IRNA archive

App. 1
Power Plants

This appendix presents the findings of studies of greenhouse gas emission from the existing power plants in Iran as well as the ones that are going to be installed and put in operation during the next decade.

Among the GHGs emitted from fossil fuel power plants, CO_2 is the most important one. Therefore, only CO_2 emissions have been considered.

Types of Power Plants

Electricity is mainly produced in Iran from thermal power plants and hydroelectric power plants. Obviously, for evaluation of the amount of CO_2 emissions, only thermal power plants have been considered. The capacity of steam, gas turbine, combined cycle, and diesel power plants is shown in Table App. 1

Table App. 1 Share of Different Power Plants in Power Generation (MW)

Type of Power Plants	1994	2000	2005*	2010*
Thermal Power Plant	18507	23000	32000	52800
Hydropower Plant	1950	2000	7300	7300
Total	20457	25000	39300	60100

* Estimates.

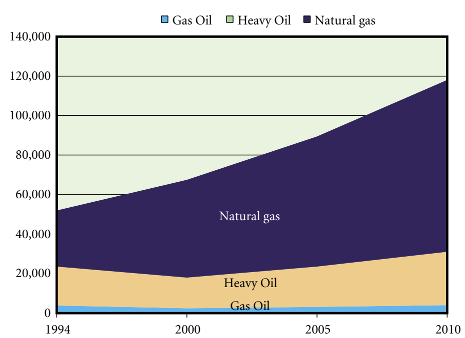
Types of Fuel Used in Thermal Power Plants in Iran

The fuels used in thermal power plants in Iran are natural gas, heavy oil and gas oil. Pulverized coal fired power plants have not received attention due to abundance of the liquid and gaseous fuels in Iran (Table App. 2), although feasibility studies in this regard are being carried out by the Ministry of Energy.

Table App. 2 Share of Different Fuel Types in Thermal Power Plants in Baseline Scenario

Fuel Type (PJ)	1994	2000	2005	2010
Gas Oil	49.1	31.05	39.75	51.25
Heavy Oil	265.81	200.6	265.8	350
Natural Gas	496.21	890	1180	1560
Total	801.12	1120.65	1485	1962

Figure App. 1 CO2 Emission Trends for Thermal Power Plants in Baseline Scenario (Gg CO2)



App. 1.1 Power Plants GHGs Emission Trends in Baseline Scenario

To obtain the total amount of CO_2, the annual consumption of gas oil, heavy oil and natural gas in steam, gas turbine, combined cycle and diesel power plants are considered. The amount of CO_2 has been calculated in tons per tera joules (10^{12} J) of produced energy for each power plant separately, and summed up to obtain the total amount of CO_2.

According to the existing data issued by the Ministry of Energy, per capita electric energy generation in Iran was 1,668 kWh in 1998 and the average annual growth rate is 6.4%. Based on these data, the total nominal installed capacity of power plants is now 25,000 MW out of which 23,000 MW is thermal and 2,000 MW is from hydro-power plants. This is expected to reach 39,500 MW by 2005, of which 32,200 MW will be thermal and 7,300 MW from hydropower plants (4,800 MW electrical energy will be produced solely from the steam section of the combined cycles). Therefore, according to the program, in 2005 at least 12,100 MW hydropower will be produced with no CO_2 emission. Figure App. 1 shows the CO_2 emission trend for thermal power plants in the Baseline Scenario.

App.2

Oil and Gas Production and Refining

The increasing consumption of oil and gas has been considered as an important issue since the last century, and is becoming uncontrollable in developing countries. On the other hand, maintaining the recently achieved higher standards of living means the continuation of this trend, which is associated with high emission of CO_2. Iran is a developing country with a very large young population. Thus the volume of energy consumption will rise rapidly in the future. Hence, a program for optimisation of energy use and reduction of pollutants must be put in action. In line with global policies to alleviate GHGs and global warming, Iran is taking appropriate action to minimize environmental pollutants.

Fossil Energies' Situation of Iran

Iran is one of the important energy producers of the region, with more 93 b barrels of proven oil reserves and producing almost 3.6 mbd. The natural gas reserves are over 810 TCF. Estimations have thus been carried out on the amount of production and refining of oil and gas during the period 2000 to 2005, shown in Table App. 3.

Table App. 3 Oil and Gas Production and Refining in 1994-2005 (PJ)

Category	1994	2000	2005
Crude Oil Production	*8567*	*9000*	*8700*
Domestic Consumption of Oil Products	*2780*	*3300*	*3500*
Gas Production	*1425*	*4800*	*8000*
Gas (import-export)	*-409*	*200*	*200*

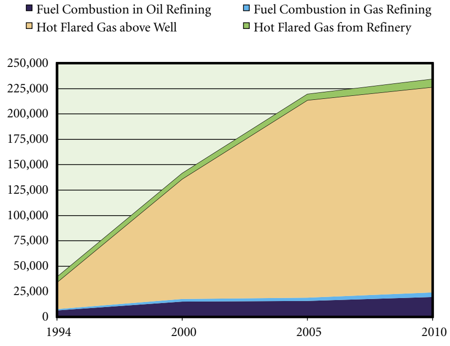
App. 2.1 Oil and Gas GHGs Emission Trend in Baseline Scenario

With respect to the emission of methane from oil and gas sectors, the amount of oil and gas production, oil and gas refining and also distribution should be taken into consideration. According to the forecasts and growth rate of activities assumed in the third FYDP, the amounts of CO_2 and GHG equivalent emissions from oil and gas activities in the baseline scenario (BLS), *without* recovery of flare gas (RFG), are calculated and shown in Table App. 4, Table App. 5 and Figure App. 2.

Table App. 4 CO_2 Emission Trends for Oil and Gas Activities in the BLS without RFG (Gg)

Year	Combustion		Hot Flaring		Total
	Oil Refining	*Gas Refining*	Well	Refinery	
1994	*6,395*	*1,363*	*26,235*	*5,302*	***39,295***
2000	*15,000*	*2,559*	*118,283*	*5,580*	***141,422***
2005	*15,664*	*3,289*	*194,528*	*6,032*	***219,513***
2010	*19,580*	*4,604*	*202,309*	*7,842*	***234,335***

Figure App. 2. CO2 Emission Trends for Oil & Gas Activities in Baseline Scenario without RFG(Gg CO2)



Thus, according to the present trend and disregarding the plans of the Ministry of Oil for optimising the usage of energy sources and minimizing environmental damage, emission curves of CO_2 equivalent for 1994, 2000 and 2010 are shown in Figure App. 3. The baseline scenario based on the government policies is illustrated for all sectors. However, the oil and gas sectors for which the government lacks sufficient funds to implement the desired policies are illustrated according to the scenario *without* the mitigation option of flared gas.

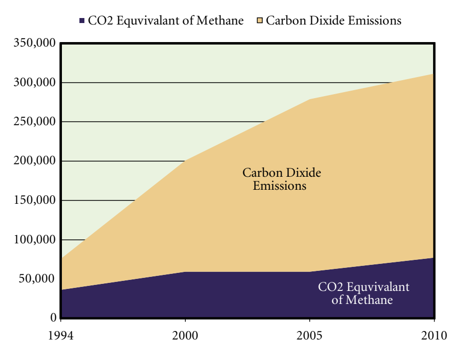
Table App. 5 GHGs Emission Trends for Oil & Gas Activities in the BLS Without RFG (Gg)

Year	CH_4	CO_2	Total (CO_2 Equiv.)
1994	1,478	39,295	70333
2000	1,721	141,422	177563
2005	2,821	219,513	278754
2010	3,667	234,335	311,342

App.3
Industry

As a result of using aged technology and because of negligible proportion of fuel cost in the price of finished products, Iran's industries suffer from a high rate of energy consumption. In 1994, some 25% of the total pollution was associated with the industry sector. On the other hand, with an increasing young population, the need for industrial development is keenly felt, so that the minimum annual growth rate has been estimated to be 6% in the third FYDP.

Figure App. 3 GHG's Emission Trends for Oil & Gas Activities in Baseline Scenario without RFG (Gg)



App. 3.1 GHGs Emission Trends from Industries in the Baseline Scenario

Based on the development policies of major industries in the third FYDP, which most likely shall continue in the fourth FYDP; the rate of GHGs emission caused by industrial processes, will be as shown in Table App. 6 and Figure App. 4.

As can be seen, despite the government's policy to promote the private sector, that is, switching from a state economy to a free market economy; the rates of emission will rise at a slower rate because of new technologies being available in the private sector.

Implementing the necessary measures to reduce energy consumption in industries is effective in conserving national resources as well as reducing GHGs. Studies are being carried out on energy consumption optimisation, and altering fuels in the cement, iron-steel and petrochemical industries; known for their high GHGs emissions and fuel consumption.

Figure App. 4 CO2 Emission Trends in Baseline Scenario for Industries (Combustion + Process) (Gg)

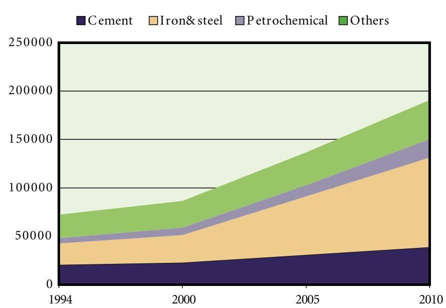


Table App. 6 CO_2 Emission Trends for Industries in Baseline Scenario (Combustion+Process) (Gg)

Year	Cement	Iron-steel	*Petrochemical*	Others	Total
1994	20,445	22,280	5,200	24,377	**72,302**
2000	22,648	28,440	7,678	27,526	**86,292**
2005	30,642	60,450	11,517	33,934	**136,543**
2010	38,636	92,460	19,195	40,342	**190,633**

App. 4

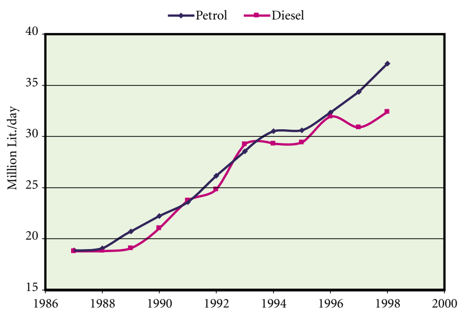
Transport

Use of different fossil fuels in the transportation sector is contributing significantly to the emissions of GHGs in Iran. The government has endeavoured to combat the rapidly increasing rate of fossil fuels consumption in transportation.

A glance at the growth trends of petrol and diesel fuel consumption, shown in Figure App. 5, signifies the ever-growing use of such energy sources in Iran's transportation sector. It is worth mentioning that between the years 1987-1998, the average annual growth rate of petrol consumption was 6.4%. It should be noted that, more than 98% of petrol in Iran is consumed in the transportation sector.

Furthermore, private transportation is strongly relied upon in Iran. For instance, in Tehran, approximately 61% of daily inner-city trips are made by different modes of public transportation and the remaining 39% by private motor vehicles. The ratio of the number of motor vehicles to population in Iran is around 1:20, [World Bank Report]. Despite this, the 39% share indicates a high rate of private vehicle use. Hence, development of public transport is a progression towards mitigation.

Figure App. 5 Petrol & Diesel Fuel Consumption Growth Trends in Transport Sector



App. 4.1 Transport GHGs Emissions Trend in the Baseline Scenario

Emission patterns in the transport sector for GHGs in the BLS is shown in Figure App. 6, indicating how the planned activities influence the growth trend. The need to increase the public transportation fleet, improve petrol quality due to non-availability of tetra-ethyl-lead (TEL), and conversion of the public transport fleet to CNG fuel, have been taken into consideration.

App. 5

Buildings, Agriculture and other Energy Sub-sectors

With the aim of attaining higher levels of social welfare and improving people's quality of life, the government, in its third FYDP has arranged specific programs for the construction sector. Annual growth rates of 5.5% in the third FYDP and 6% in the fourth FYDP are foreseen for this sector. Conditions have been prepared in the second FYDP for constructing dams and irrigation networks. Also, the principal government's policy has been to reduce the share of oil in GDP to diminish dependence on oil, and to reduce the import of agricultural products. Thereupon, progressive trends of 6% and 5% in the third and fourth FYDPs will be expected, respectively.

At the same time, the government's policy is based on the replacement of liquid fuels with natural gas, LPG fuels and electricity in buildings and the agriculture

Figure App. 6 GHGs Emission Trends in Baseline Scenario (Gg) in Transport Sector

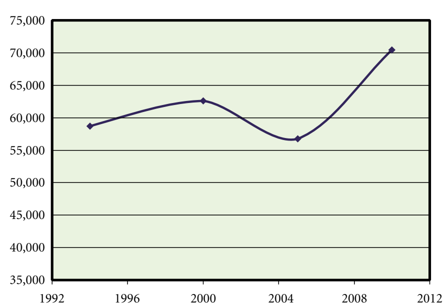
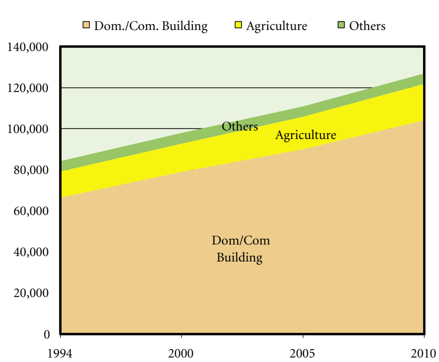


Table App. 7 Rising Rate of Energy Carriers Consumption in Domestic/Commercial Buildings & Agriculture Sectors (%)

Type of Carriers	1995	1996	1997	1998	1999	Average
Dom./Com. Building						
Oil Products	-7.37	6.48	2.92	-7.81	-8.12	**-2.78**
Natural Gas	13.85	12.97	28.69	-10.03	11.36	**11.37**
Electricity	2.79	2.62	8.38	6.99	3.83	**5.92**
Agriculture						
Oil Products	-4.02	5.84	-12.9	14.28	-12.34	**-1.82**
Electricity	4.5	6.09	4.85	12.86	18.24	**9.31**

sectors. As shown in Table App. 7, the average consumption rate of energy carriers for the period 1994-1998, indicates this trend. Figure App. 7 shows the trend of GHGs emission for these sectors in the period 1994-2010.

Figure App. 7 CO2 Emission Trends in BLS (Gg)



App. 6

Agriculture Sector

Iran's climate is mostly arid or semi-arid. It has vast regions of deserts with extreme aridity. All areas experience large fluctuations in rainfall. The native plants and animals could adapt themselves to a small variation in rainfall, but are most vulnerable to droughts that have occurred in the past several years. The climate in Iran greatly limits the portion of the land in the country suitable for livestock production and agricultural crops.

Future of Agricultural Products and Livestock

To provide policy makers and planners with information to formulate strategies to cope with climate change, it is necessary to draw up a clear picture of what is going to happen in the future. For this purpose, the BLS and the corresponding trends are seen as simulating changes in agricultural scenarios.

Livestock has always formed the major portion of the agricultural sector in Iran, which also affects climate change. Based on 1994 statistics, the number of animal population and the number of each kind of ruminant and non-ruminant, have been forecast for the years of 2000, 2005 and 2010 as shown in Table App. 8.

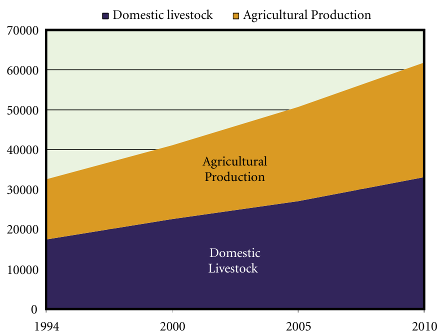
To overcome the problem in securing the natural food supply, several courses of action have been planned including increase of vegetation area and increase of yield level per hectare. Considering the year 1994 as the base, the amount of grains, peas and beans, oil seeds, potatoes and sugar beet production have been predicted for the years 2000, 2005 and 2010 shown in Table App. 9.

Table App. 8 Estimation[a] of Animal Population[b] in Iran

Livestock Species	2000	2005	2010
Ruminant			
Sheep	*48,731*	*60,728*	*75,679*
Goats	*24,503*	*30,389*	*37,689*
Camels	*85*	*85*	*85*
Buffalo	*271*	*316*	*361*
Native cattle	*4,654*	*4,892*	*5,141*
Cross-bred cattle	*820*	*1,285*	*2,150*
Exotic cattle	*397*	*501*	*631*
Non-ruminant			
Horses	*132*	*132*	*132*
Donkeys	*1,174*	*1,174*	*1,174*
Mules	*115*	*115*	*115*
Poultry			
Domestic fowl	*46,647*	*46,647*	*46,647*
Layer	*38,017*	*42769*	*48,115*
Breeder	*4,232*	*4,542*	*4,851*
Broiler	*473,935*	*506,675*	*539,414*

a: Source: Iran's Statistics Center.
b: Thousand heads.

Figure App. 8 GHGs Emission Trends of Agriculture Sector in Baseline Scenario (Gg CO2 Equ.)



About 75%-80% of livestock feed in Iran has traditionally been agricultural residue like straw, sugar cane by-product, and maize stalk. Most of these are categorized as low quality feeds and therefore action must be taken to improve the quantity and quality of the feeds.

Table App. 9 Estimation of Agricultural Products from 2000 to 2010

Products (tons)	2000	2005	2010
Wheat	*12,366,133*	*14,952,500*	*17,518,800*
Barley	*3,365,333*	*5,372,000*	*7,379,000*
Maize	*967,000*	*2,040,500*	*3,114,000*
Rice	*2,904,600*	*3,342,250*	*3,779,900*
Peas & Beans	*608,000*	*749,750*	*891,500*
Oil Seeds	*362,333*	*758,250*	*1,154,167*
Potatoes	*3,566,933*	*4,515,000*	*4,563,067*
Sugar Beet	*5,220,000*	*6,969,250*	*8,718,500*

App. 6.1 Agriculture GHGs Emission Trends in Baseline Scenario

Using the mentioned data in Tables App. 8 and App. 9, and default emission factors given by IPCC, GHGs emission by animal, manure management, soils, etc. are calculated for 2000, 2005, 2010, and presented in Table App. 10. Based on forecasts, the GHGs emission trends associated with agricultural production and domestic livestock are shown in Figure App. 8. Obviously, if recent droughts continue these rates of production of crops and emission rates will change.

Table App. 10 GHGs Emission Trends from Agriculture Sector in Baseline Scenario (Gg)

Year	1994		2000		2005		2010	
GHGs Emission Sources	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Enteric Fermentation	*496.8*	*NE*	*620.7*	*NE*	*753.7*	*NE*	*933.55*	*NA*
Animal Waste	*19.51*	*21.33*	*28.42*	*28.65*	*33.06*	*34*	*39.26*	*40.7*
Rice Cultivation	*114.5*	*NE*	*123*	*NE*	*126*	*NE*	*129*	*NE*
Agriculture Soils	*NA*	*32.61*	*NA*	*40.61*	*NA*	*53.5*	*NA*	*66.37*
Agriculture Waste Burning	*12.32*	*0.28*	*16.04*	*0.375*	*20.85*	*0.63*	*25.66*	*0.66*
Total	**643.1**	**54.22**	**788.12**	**69.635**	**933.56**	**88.09**	**1,127.47**	**107.73**
Total CO_2 Equivalent (Gg)	**13,505**	**16,808**	**16,551**	**21,587**	**19,605**	**27,308**	**23,677**	**33,396**

App. 7

Forestry and Land Use Change

The forests, pastures and soil play a very important role in the natural carbon cycle, both as the absorbing sink and emitting source of CO_2 gas. The gross flow of carbon and CO_2 is considerable across the world. Annually, the earth's plant life absorbs about 14% of the total CO_2 present in the atmosphere. Without human interference, this huge flow of CO_2 from atmosphere to soil biosphere is balanced by the return process of respiration.

Land use changes, forest conversion and over utilization of these resources create an imbalance in the flow of CO_2 and amount of carbon reserved in the soil and in the living and dead plant coverage. For example, cutting and burning of forest trees for expanding farmland will increase the CO_2 return flow and decrease the photosynthesis process. As a result, the carbon cycle in the converted lands will reach a new balance (photosynthesis of farm plants against their respiration and decomposition of the organism in-situ, and utilization of the agricultural products that are consumed elsewhere). Under such conditions, the total carbon reserves of the globe will be decreased and in contrast, the amount of carbon in the atmosphere will increase which in turn will intensify the greenhouse effect and global warming. This is because the forests absorb and reserve more carbon compared to annual farm crops and grazing pastures. In the moderate regions the imbalance between deforestation and plant growth, is much less than in tropical regions. However, this has a large effect on earth's CO_2 cycle and the increase of CO_2 balance in the atmosphere.

App. 7.1 Forestry GHGs Emission Trends in Baseline Scenario

On a global scale, Iran has limited forests and pastures covered with plants. Variation in their amount will in any case affect the total balances of absorption and emission of GHGs. In the inventory section, the effects of forests, pastures, and their changes on GHGs emission and uptake for 1994 have been discussed and the findings are reviewed as follows.

Changes in Forests and other Woody Biomass Stocks

- Increase of forest area:
    - Afforestation
    - Development of arboriculture (tree plantation in the rural areas)
    - Establishing parks and green areas

The above-mentioned activities cause absorption of about 340 Kt C.

- Utilization of forest and wood resources:
    - Legal and illegal harvesting and utilizing (industrial and fuelwood for energy uses).

These activities in forest utilization cause emission of about 5,662 kt C. Because of limited afforestation and excessive utilization of wood resources, a total amount of 19,517.1 Gg of CO_2 will be emitted. Obviously, in the above calculation, the effect of natural forests for absorption of the CO_2 has not been calculated and only the annual changes of these resources is set forth.

Table App. 11 Reforestation, Afforestation and Wood Harvesting Trends in Baseline Scenario

Category		1994	2000	2005	2010
Development of the Forest Area (ha)	Forest Planting and Rehabilitation in the North	11,868	17,255	51,080	90,080
	Forest Planting & Restoring in the other Regions	26,383	88,000	376,000	751,000
	Tree Planting in Desert Lands	14,181	30,000	55,000	80,000
	Productive Tree Planting (TOOBA Project)	0	100,000	100,000	100,000
Total		52,432	235,255	582,080	1,021,080
Wood Harvesting (m3)	North Forest	4,984	4,965	5,432	5,932
	Other Region	14,250	16,048	17,718	19,562
Total		19,234	21,013	23,150	25,494
Impact of Livestock Exiting from the Forest	Increasing of Wood Production (m3)	6,800	151,000	538,000	301,000
	Area which Become Free (ha)	100	2,338	8,300	3,800
CO_2 Emission (Gg)		**31,416**	**32,052**	**32,909**	**33,589**

- Conversion of forest and rangeland

This comprises the conversion of forest and pastures, farmlands or other managed lands that alter the carbon resources in the following ways:

  - On-site and off-site burning of phytomass through forest and rangeland conversion releases about 2,590 kt of carbon.
  - Through decay and decomposition of biomass due to land conversion, about 786 kt of carbon is released.

Thus, the total amount of carbon emission from the above cases is equal to 3,375.1 kt equivalent to emission of 12,375 Gg CO_2. In addition, estimation of emissions of other gases will be CO, 61 Gg; CH_4, 7 Gg: N_2O, 0.05 Gg and NO_x, 1.7 Gg.

Abandonment of managed land

When managed lands like farmlands, orchards, reforestation areas, man-made pastures and forages are abandoned, they will return to their original state. Consequently, the biomass in such areas will increase, causing the absorption of CO_2 gas. The total amount of carbon absorbed is about 130 kt C; equivalent to 475.7 (Gg CO_2). Table App. 11 shows the trend of reforestation, wood harvesting and its impact on CO_2 emission in baseline scenario.

App. 8
Waste Sector

Based on the inventory, the total methane emission from waste was nearly 296 Gg/yr. The estimate of GHGs emissions from waste in the period between 1994 and 2010 for BLS is reported. The estimation methods are based on information in documents published by the Iran Management and Planning Organization (IMPO). The most important information consists of:

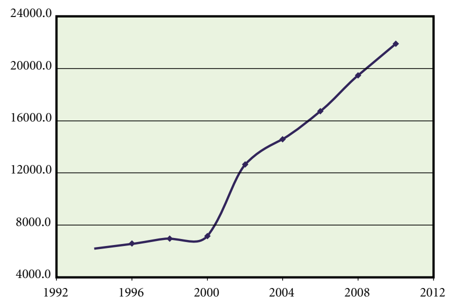
- The average growth rate of the population is 1.7% per annum.
- The average amount of per capita consumption of water is 250 lit/day.
- 80% percent of water used will turn into wastewater.
- The average growth rate of water consumption is 1.9% per annum.
- The average growth rate for water consumption from network distribution is 2.7% per annum.
- The average growth rate for the urban wastewater network is 11.8% per annum.
- Municipal solid waste generation rate in Iran is about 0.8 kg/capita/day.
- Methane correction factor (MCF) and the fraction of carbon released as methane are 0.5.
- Fraction of DOC in MSW and fraction of DOC that actually degrades are 0.18 and 0.77, respectively.

App. 8.1 GHGs Emission Trends in Baseline Scenario in the Waste Sector

Assuming that the population growth rate is linear, the total annual MSW, net annual CH_4 emissions and other parameters have been calculated.

Since the amounts of GHGs emissions are related to population growth and the amounts of wastewater produced, the relevant data should be acquired. According to the National Census Report, the population of Iran in 1994 was 57,978,000.

Figure App. 9 GHGs Emission Trends in Baseline Scenarios for Waste Sector (Gg-CH4)



With the average annual growth rate of 1.7%, the population in 2010 will reach 73,601,000 with 67.2% living in urban and the rest in rural areas.

According to the IMPO, the average annual water reserves, from all resources in Iran is about 87.5× 10^9 m^3, 90% of which is consumed for agriculture and the rest for urban use. Based on government information in 1999, there are a total number of 612 cities in Iran, of which 95% are projected to have collection and treatment of wastewater systems. For these projects about 1,190 km of network and 76,000 transfer branches will be established each year. The cities are classified as:

1 First group cities such as: Tehran, Esfahan, Ahvaz, Arak, Shiraz, Mash-had, Bandar-Abbass and Tabriz which already have current plans for wastewater treatment.

2 Second group of cities such as: cities in the north of Iran, and also Bushehr in the south, and Kerman in the southeast of Iran, which will have plans for wastewater treatment before 2010.

3 Third group cities: They are small cities without any such planning.

The amount of CH_4 emission from wastewater treatment systems between 1994 and 2010 is estimated by using the mentioned data and the policies that have been planned by the Iranian government, as depicted in Figure App. 9.