STATE OF ISRAEL
MINISTRY OF THE ENVIRONMENT

Israel National Report on Climate Change 2000

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First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change

Jerusalem, November 2000

State of Israel
Ministry of the Environment

Israel's First National Communication on Climate Change

Submitted under the United Nations Framework Convention on Climate Change

Jerusalem
November 2000

שלום עם הסביבה

המשרד לאיכות הסביבה
وزارة جودة البيئة
Ministry of the Environment

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Production: Publications and
Public Relations Unit

Typesetting, design & publishing:
Studio Kav Graph, Jerusalem
Printed in Israel

Foreword by the Minister of the Environment

On behalf of the Government of Israel, it is both an honor and a privilege to present Israel's First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change.

I would like to begin my message with a quotation from our sages dating back to the first millennium: "When the Holy One Blessed Be He created the first man, He took him and warned him about all the trees in the Garden of Eden, saying: See My works, how beautiful and perfect they are, and all I created - I created for you. Beware lest you spoil and destroy My world, for if you will spoil it, there is no one to repair it after you."

This millennia-old message rings especially true today. In recent years, the resolve to preserve and enhance the world environment for the benefit of present and future generations has led to new initiatives which crystallize the responsibilities of humankind toward the global environment.

Today, at the dawn of the millennium, Israel is determined to join forces with the developed world in protecting the global climate and in taking the necessary steps to cut greenhouse gas emissions. As a party to the Convention since May 1996 and as a signatory to the Kyoto Protocol since December 1998, Israel has demonstrated its commitment to fulfilling its obligations for reducing greenhouse gas emissions into the atmosphere. Its first Communication outlines its initial achievements in developing a national plan of action on climate change. Hopefully, the challenge of implementing and updating the action plan will be undertaken in the coming years with the aim of achieving the goals set out in the Framework Convention for Climate Change.

I am convinced that Israel has the national capability to develop innovative technologies to mitigate the impacts of climate change. I know that the introduction of cleaner fuels and renewable sources of energy, the promotion of energy-conscious building, the upgrading of waste and sewage treatment processes and the advancement of mass transit systems will not only reduce greenhouse gas emissions but will improve our environment, our health and our economic well-being. I have no doubt that our country has both the capacity and the readiness to transfer and share its expertise in such crucial fields as water conservation, afforestation and combating desertification with countries worldwide. However, to fulfill this potential, to transform capacity into practice, both political commitment and economic investment will be necessary.

In a world that is becoming more and more globally interdependent, international cooperation is no longer an option. It is a prerequisite. Israel has been committed to international cooperation since its establishment. Today, it is proud to take its place as a committed member of the world community, ready to contribute to the global effort to mitigate the impacts of climate change.

Dalia Itzik
Minister of the Environment

Introduction from the Director General

At the time of its ratification of the United Nations Framework Convention on Climate Change in 1996, Israel established an Interministerial Committee on Climate Change which includes representatives of government ministries, industries and non-governmental organizations. The committee has overseen the preparation of Israel's national inventory of emissions and removals of greenhouse gases and of its initial reports on mitigation options and action plans for reducing greenhouse gas emissions. It is currently examining recommendations and strategies for reducing greenhouse gas emissions on a voluntary basis.

As a small country, Israel is also a small contributor to global warming. Nevertheless the sensitivity of the country to the impacts of the impending global and regional changes, on the one hand, and its commitment to the protection of the global environment, on the other hand, dictate the integration of national policy with international agreements.

Israel's proposed action plan, which is outlined in the following pages, provides guidelines for activities which will increase economic efficiency, improve the environment and reduce greenhouse gas emissions. Many are based on technological improvement; others on new legislative and economic mechanisms. Optimal implementation of the recommended measures in different sectors will depend on government decisions and incentives. While the price will be high economically, it is anticipated that compliance with international obligations set out in the Kyoto Convention will not only reduce greenhouse gas emissions, but will be advantageous environmentally, economically and internationally, in the form of reduced traffic, energy-efficient buildings, health benefits, and increased competitiveness of Israeli firms and exporters on the international market.

In recent years, we have become increasingly aware of our interconnection with the world, both in terms of the reciprocal impacts of environmental damages and in terms of trade. Our continued economic growth, especially export to developed countries, will be dependent on our ability to comply with stringent standards. I would like Israel to become of the enlightened states of the world in terms of environmental consciousness and in the integration of environmental considerations in economic decisions.

Israel's scarcity of natural resources has led to the development of numerous technologies in such fields as water treatment and recycling, desalination, solar energy, agriculture and afforestation, and combating desertification. Many of the technologies and products developed in Israel are used internationally to monitor air and water pollution, to recycle agricultural and urban waste and to provide clean drinking water to the fast-growing populations of the developing world. As a young country which has invested much to overcome adverse conditions and to promote economic growth, Israel is proud to take its place in the international community and to contribute to the global effort to reduce greenhouse gas emissions and to mitigate the impacts of climate change.

Although many of the actions outlined in this first Communication are still in their infancy, I expect them to be transformed into reality in the near future. As steps are taken to phase out older power stations and phase in power plants operated by natural gas and clean fuels, as renewable energy sources are promoted, as energy conservation becomes the norm, as sewage and solid waste treatment systems are improved, as the tide of vehicular pollution is stemmed, as new economic, legislative and administrative reforms are introduced, Israel will take its rightful place in the world community and in its commitment to mitigate the impacts of climate change.

Yitzhak Goren
Director General
Ministry of the Environment

Acknowledgments

Acknowledgments are due to the directors and staff members of the Ministry of the Environment and to the members of the Interministerial Committee on Climate Change for their essential input. Members include, among others, representatives of the Ministries of the Environment, Finance, Infrastructures, Transport, Industry and Trade, Agriculture, Science, the Jewish National Fund, the Israel Electric Corporation and the Manufacturers Association of Israel.

Special thanks to the Ministry of the Environment and to the following for their contributions to specific chapters. All studies were funded by the Ministry of the Environment.

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1. Executive Summary

Introduction

As a party to the United Nations Framework Convention on Climate Change (UNFCCC) since May 1996 and as a signatory to the Kyoto Protocol since December 1998, Israel is committed to fulfilling its obligations for reducing greenhouse gas emissions into the atmosphere. An interministerial committee on climate change, including representatives of relevant government ministries, industries and non-governmental organizations, was established by government decision made at the time of ratification. The committee is charged with formulating national policy on the reduction of greenhouse gases and preparing reports on national greenhouse gas inventories, policies, measures and future forecasts.

Israel has set its baseline year for compliance with the obligations of the Convention as 1996 due to the unprecedented growth in both population and economy which occurred during the first part of the decade. During this period, nearly one million immigrants arrived in the country, bringing about a sharp increase in energy use and consequently also greenhouse gas emissions.

National Circumstances

- Land and Climate: Long and narrow in shape, Israel is about 470 kilometers in length and 135 kilometers in width at its widest point. Located at the junction of Asia, Africa and Europe, the country makes up for its small size (24,000 km^2) with a varied topography and climate. It is composed of arid zones (45%), plains and valleys (25%), mountain ranges (16%), the Jordan Rift Valley (9%) and the coastal strip (5%).

Israel lies in a transition zone between the hot and arid southern part of West Asia and the relatively cooler and wet northern Mediterranean region. As a result, it is characterized by spatial and temporal variation in temperature and rainfall. The climate of much of the northwestern part of the area is typically Mediterranean, with mild rainy winters, hot, dry summers and short transitional seasons. The southern and eastern parts are much drier, with semi-arid to arid climate. There is considerable interannual variability in rainfall, but average annual rainfall varies from less than 30 millimeters in the southern part to as much as 1000 mm in the north. This marked transition between two climatic types may serve as an important indicator of the sensitivity of the Eastern Mediterranean Basin to regional climate change.

- Demography: Israel's population at the end of 1999 reached 6.2 million residents. Since its establishment in 1948, the country's population has increased more than seven-fold – mainly as a result of large-scale immigration. Since 1990, Israel's population grew by 29.4% with the influx of over 950,000 immigrants in just one decade. More than 90% of the population lives in urban areas.

- Economy: Economic growth was very high (10% annual growth in GDP) in the first 25 years of Israel's existence, reflecting high immigration and accelerated development. In 1990-1996, Israel attained one of the highest GDP growth rates (averaging 6%) in the developed world. This rapid economic growth turned into a slowdown in the second half of the decade – falling to about 2%.

- Agriculture: In the twelve years following its establishment in 1948, the cultivated land area increased from 150,000 to 400,000 hectares, stabilizing at about 430,000 hectares in subsequent years. Over half of all cultivated land is irrigated. The most severe constraint on agriculture is the lack of water. To maximize efficiency of water use, highly mechanized, high-input methods and water-saving irrigation systems are employed. Agriculture accounts for less than 4% of the workforce, less than 2% of GDP and nearly two-thirds of the water used.

- Industry: Industry today continues to grow at a faster rate than any other sector. In the last two decades, the percentage of industrial production which was exported has steadily risen to over 50%, making up 75% of Israel's $21 billion exports of goods. Due to lack of raw materials, industry has concentrated on manufacturing products with a high added value. The highest growth rates are in the high-tech sectors.

- Transport and Communications: In recent years, the development of public transportation has stagnated while the number of motor vehicles has multiplied: from 1,015,000 in 1990 to 1,542,870 by 1996 to 1,730,000 by 1999. The increase in car ownership has not been accompanied by a proportionate increase in road surface. Thus, in 1990 there were 13,199 km in length of roads, going up to 16,115 in 1999. Israeli railroads derive most of their revenues from the transportation of freight, but recent years have seen a gradual increase in railway passengers reaching about 6.4 million in 1998.

- Energy Production: Israel relies almost exclusively on imported fuels, especially oil and coal. Solar energy is used to heat water for residences as per a regulation which mandates installation of such heaters in new houses. Oil shale and natural gas are the only oil fuels to have been discovered in Israel. Wind energy utilization is under development. Further diversification will occur with the introduction of natural gas, either imported or from the recently discovered gas reserves opposite Israel's shoreline.

Special Circumstances

A number of special circumstances dictate the need for mitigating the effects of climate change in Israel including the following:

- Israel's population density and its location at the edge of the desert make it especially vulnerable to climate change. Some 60% of the population resides in a narrow coastal strip along the Mediterranean; 90% of the population is concentrated on 30% of the land area in the Mediterranean region.
- Israel's freshwater resources are limited and are dependent on seasonal rainfall to replenish groundwater and surface sources. Climate change may change the rainfall regime.
- The coastal strip, with its vital infrastructures, natural resources and phreatic aquifer, is very vulnerable to a rise in sea level.
- Technologies for reducing greenhouse gas emissions in different sectors (e.g., electricity generation, transport, waste, agriculture, heating/cooling of buildings, etc.) are expected to carry additional advantages such as emission reductions from other pollutants which damage public health, infrastructure and water sources.

National Greenhouse Gas Inventory

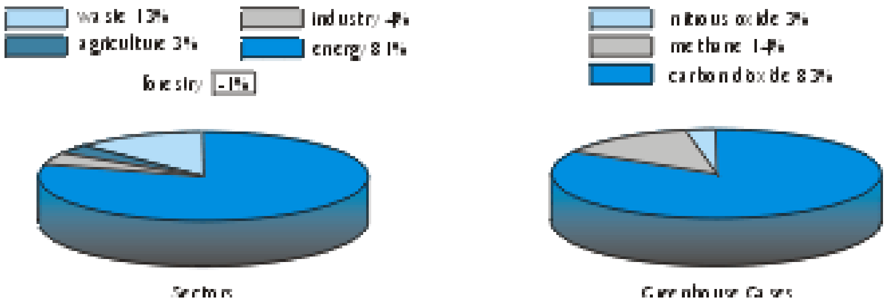
Israel's first inventory of emissions and removals of greenhouse gases was prepared according to the Guidelines of the Intergovernmental Panel on Climate Change and the Revised 1996 Guidelines. It relates to the three main greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as to indirect greenhouse gases which are precursors of tropospheric ozone: carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs). It also relates to sulfur dioxide (SO_2), which although not a direct greenhouse gas, is an aerosol precursor and, as such, has a cooling effect on climate. At this stage, lack of data precluded the inclusion of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

By far the largest source of CO_2 emissions is the oxidation of carbon when fossil fuels are burned to produce energy. Cement production is the most important non-energy industrial process emitting CO_2. The continuous expansion of forests in Israel allows for the removal of CO_2 to form biomass.

Methane is produced through two processes associated with domestic livestock husbandry: enteric fermentation and waste management. Methane is also emitted during the decomposition of landfilled municipal solid waste and the treatment of domestic and industrial wastewater.

The contribution of nitrous oxide emissions from agriculture is dominant. Emissions are attributed to direct emissions from agricultural soils, manure management and animal grazing and indirect emissions from agriculture.

Figure 1.1: Contribution of Sectors and Greenhouse Gases to Total CO_2 Equivalent Emissions



The salient findings of the national inventory may be summarized as follows:

- The contribution of methane emissions from decomposition of solid waste is very significant (27% of all emissions for a time horizon of 20 years and 13% for a time horizon of 100 years). It is second in importance only to the contribution of CO_2 emissions from energy production.
- Coal contributes 39% of all CO_2 emissions in the energy sector, whereas the contribution of residual fuel oil is 27%. Gas/diesel oil and gasoline contribute 14% and 13% respectively.
- Although most forests are composed of conifers and broad-leaved trees, the relatively small area planted with eucalyptuses contributes about 20% of the CO_2 removals.
- Enteric fermentation contributes about 75% of the methane emissions from domestic livestock, mostly from cattle. Manure management contributes 25% of the emissions, mainly due to cattle and poultry manure.
- The contribution of N_2O emissions from agriculture is dominant (62% of all N_2O emissions). In all, N_2O contributes 2% of all emissions for a time horizon of 20 years and 3% for a time horizon of 100 years.

The following table summarizes the emissions and removals of CO_2, CH_4 and N_2O from the different sectors, as estimated for 1996. Methane and nitrous oxide emissions are converted to CO_2 equivalent by means of the Global Warming Potential (GWP) which is a measure of the radiative effects of the different greenhouse gases relative to CO_2. The GWP of methane is 56 for a time horizon of 20 years and 21 for a time horizon of 100 years. The GWP of nitrous oxide is 280 for a time horizon of 20 years and 310 for a time horizon of 100 years.

Table 1.1: Summary of Greenhouse Gas Emissions and Removals (1996) (kilotons)

Sector	CO_2	CH_4	N_2O	CO_2 equivalent (20 yr)	CO_2 equivalent (100 yr)
Energy (Fuel Combustion)	**50,344**	**3.55**	**0.58**	**50,705**	**50,599**
Energy industries	28,466	0.57	0.36	28,599	28,590
Manufacturing industries & construction	6,720	0.23	0.07	6,752	6,746
Transport	11,031	2.18	0.12	11,187	11,114
Commercial/Institutional/Residential	3,520	0.49	0.029	3,555	3,539
Agriculture	607	0.08	0.005	612	610
Industrial Processes	**1,889**		**1.73**	**2,373**	**2,425**
Cement production	1,673			1,673	1,673
Lime production	107			107	107
Soda ash use	17			17	17
Ammonia production	92			92	92
Nitric acid production			1.73	484	536
Agriculture		**42.4**	**3.81**	**3,441**	**2,071**
Domestic livestock		32.4		1,814	680
Manure management		10.0	0.80	784	458
Soil emissions			3.01	843	933
Forestry	**-370**			**-370**	**-370**
Waste		380		21,280	7,980
Municipal Solid Waste Disposal		370		20,720	7,770
Wastewater Treatment		10		560	210
Total	**51,863**	**425.5**	**6.12**	**77,429**	**62,705**

Table 1.2: Summary of Emissions of Precursors of Tropospheric Ozone and Aerosols (1996) (kilotons)

Sector	NO_x	CO	NMVOC	SO_2
Energy	**215**	**832**	**158**	**260**
Energy industries	86	6	2	191
Manufacturing industries	23	1	1	46
Transport	100	824	155	11
Residential	5	1		10
Agriculture	1			3
Industrial processes	**5**	**0.5**	**89**	**19**
Nitric acid production	5			
Ammonia production		0.5		
Road paving with asphalt			86	
Production of polymers			3	
Sulfuric acid production				18
Cement production				1
Total	**220**	**832**	**247**	**279**

Mitigation Options

In recent years, initial attempts have been made in Israel to develop a policy on greenhouse gas reduction. In drawing up its proposed policy, the following conditions which are unique to Israel were taken into account:

- Israel is still evolving and developing and has not yet reached the stability necessary for embarking on a clear course of social, demographic and economic development. Unlike developed countries, its population is expected to continue to grow considerably. The customary baseline year set for emissions in other countries – 1990 – was characterized by unprecedented population and economic growth in Israel.
- The demographic instability makes it difficult to use future scenarios. Uncertainties in future projections and the absence of clear figures regarding future development in all sectors make it necessary to relate to different baseline and target years.
- Uncertainty exists regarding economic development and the future directions of industry. It is anticipated that future industrial growth will be concentrated in the light and technological industries which are not major contributors of greenhouse gas emissions.

- Water desalination, which will carry considerable weight in energy consumption, is still in early stages. There is no precedent for this sector in other countries.
- Advanced sewage and sludge treatment systems are only now being developed and/or upgraded.

Technological Alternatives for Mitigating Climate Change

In 1998, Israel commissioned its first study on options for mitigating greenhouse gas emissions. The paper, prepared by the S. Ne'eman Institute of the Technion – Israel Institute of Technology, was a first step in formulating a national policy on climate change. The document proposes new approaches and innovative technologies for mitigating greenhouse gas emissions.

- Energy Production: In recent years the energy market in Israel has opened itself to private producers in order to promote competition and increase efficiency. In parallel, the energy sector has grown at a rapid rate of 3% per year as a result of accelerated growth in both population and standard of living. Increased awareness of environmental quality and of the adverse impacts of air pollution on public health has promoted a gradual transition to cleaner fuels and encouraged investments in pollution prevention.

Current energy policy calls for increasing the use of natural gas, upgrading the efficiency of the power station system through closure of old oil-fired power plants and their replacement by plants powered by natural gas or "clean" alternative energy, encouraging commercialization of processes and technologies for clean energy production, exploiting alternative energy sources which are available in Israel (wind and solar energy), and reducing loss of energy as a result of long-distance transport. Use of natural gas will release 30% less CO_2 per unit of energy than liquid fuel and 44% less than coal while, at the same time, reducing other pollutant emissions. The switch to natural gas is expected to save the country some 8-10 million tons of CO_2 per year. Alternative sources of energy (wind, sun, biomass, etc.) will reduce CO_2 to near zero levels. New technologies for energy generation and distribution will reduce CO_2 emissions due to more efficient production, transport and supply to the consumer.

- Industry: Energy consumption for climatic comfort constitutes about 50% of total energy consumption in industry. Structural changes and simple measures may reduce this figure by 25-40% (bringing about a savings of 2.5 million tons in 2010). To reach this target, the consultation services offered by the relevant ministries should be expanded, financial allocations should be increased, and green building principles on energy conservation should be integrated into the planning and building process for industrial zones.

Savings from a switch to a "dry" process in the cement industry along with increased use of coal ash in the cement mix may reach 4.2 million tons in 2010, without additional cost to the Israeli economy and with clear supplementary benefits. This activity is already in advanced stages of implementation.

- Domestic and Commercial Energy Consumption: Studies have shown that existing buildings can achieve average energy savings of 35% through an integrated systems approach to energy conservation. In the residential sector, savings will largely be achieved by structural planning, thermal insulation, lighting, energy-saving appliances and efficient heating/cooling equipment. Green lighting in residences and businesses can save 50% of the energy used for lighting, on average. Building regulations should therefore include guidelines and incentives for energy-conscious planning and building. Standards for products, buildings and services that save energy should be developed. To promote awareness and participation of the general public and of different economic sectors, an infrastructure for demonstration and guidance on energy efficiency should be set up.

- Transportation: Without a change in transport policy, greenhouse gas emissions from this sector may double by 2020. Since transport represents a significant part of total emissions of CO_2 in Israel, technical means and transportation control measures should be developed.

Technological improvements in vehicles will be largely dictated by producers in their respective countries. It is anticipated that a 20% rise in vehicle efficiency will take place in the coming decade, without market penetration of vehicles powered by alternative fuel. Israel is currently examining different means of assimilating vehicles powered by alternative energy, most particularly liquefied petroleum gas (LPG). The assimilation of clean vehicles powered by electricity, hydrogen and other alternative fuels should also be examined.

Changes in urban planning conceptions, such as proximity of clean industries and service centers to residential areas or establishment of employment centers outside city centers, should be encouraged.

Special effort should be directed toward traffic control systems which reduce traffic congestion and air pollution. Such systems may include dedicated traffic lanes for multi-passenger vehicles, congestion fees, a public transit system and railroads. Massive government investment is required to develop the railroad infrastructure.

The imposition of a carbon tax will drastically change the transportation system in Israel, but changes in the taxation system are not expected in the short term. Therefore, market failures should be corrected, especially the existing tax system which benefits private car owners. Moreover, the health and environmental impacts of fuels should be internalized in the cost of fuel in order to correct distortions especially with regard to pollution generated by diesel-powered vehicles.

- Waste: All regulated landfills in the country have installed systems for capturing and combusting their gas emissions. It is anticipated that by 2002, most of Israel's waste will reach these regulated landfills. Exploitation of landfill gas-to-energy potential for industrial uses, such as cogeneration, may lead to significant energy savings and economic profitability. This is already in advanced stages of implementation.

Although organic waste is the largest component of household waste, most of the country's solid waste is transported to landfills without fully utilizing its composting potential. An incentive system is proposed to encourage compost use and to advance investments in infrastructures for separation at source, composting and transport.

- Agriculture: The main sources of methane emissions are the gases emitted by livestock and by animal manure. Methane sources may be significantly reduced by proper feed of animals and collection and composting of their waste. Both solutions have added economic and agricultural value. The technological assessment points to a savings of about 200 ktons CO_2 equivalent from improved feed and some 100 ktons CO_2 equivalent from composting of the manure.

The main source of N_2O emissions is agricultural fertilization. Changes in the fertilization regime and in the manner of application may reduce fertilizer quantities, minimize groundwater and river pollution and cut down N_2O emissions by about 400 ktons CO_2 equivalent.

Summary of Recommended Measures

The mitigation measures listed in the following table were assessed according to three scenarios, with the optimistic scenario assuming implementation of the full potential and the pessimistic scenario assuming only partial implementation. Most of these measures do not require significant changes in current processes and practices, some will contribute economic benefits, and nearly all will provide a double dividend in the form of additional advantages, such as significant environmental improvements in air pollution reduction, transport congestion reduction, and improved urban quality. In addition, some measures, such as improved waste treatment, may be implemented within a few years, while others, such as energy-conscious building, improvements in transport and in industry, and introduction of cogeneration and combined cycle energy production, may be gradually implemented over a longer time period.

Table 1.3: Summary of Recommendations on Mitigating Measures

Measure	Expected reduction of emissions (percent of total)			Additional advantages
	Pessimistic scenario	Reasonable scenario	Optimistic scenario	
1. Waste and sewage sludge treatment	8	10	12	Solution of waste problem
2. Switch to natural gas in power stations	3	8	11	Reduction of air pollution
3. Energy production in combined cycle	2	5	7	Use of higher efficiency fuels. Postponement of new power generation plants
4. Cogeneration	2	3	4	Use of higher efficiency fuels. Postponement of new power generation plants
5. Energy-conscious building	3	5	7	Energy savings. Postponement of new power generation plants
6. Transport improvements	2	4	6	Reduction of air pollution. Improvement of urban environment
7. Improvements in industry (without cogeneration)	4	7	10	Improvement of air quality. Postponement of new power generation plants
8. Agricultural changes	0.5	1	2	Reduction of groundwater and air pollution
Total	**24.5**	**43**	**59**	

Forecasts, Economic Impacts and Proposed Policy

Alongside the formulation of technological mitigation options for reducing greenhouse gases, Israel has prepared a preliminary estimation of the economic costs and benefits of emission reduction under different scenarios. On this basis, a national climate change action plan was drafted, within the framework of the Israel Environmental Policy Research Center, which proposes solutions for overcoming legislative, bureaucratic and political impediments by harnessing forces in the economy for the requisite economic and environmental changes.

Emission Reduction Scenarios and Economic Impacts

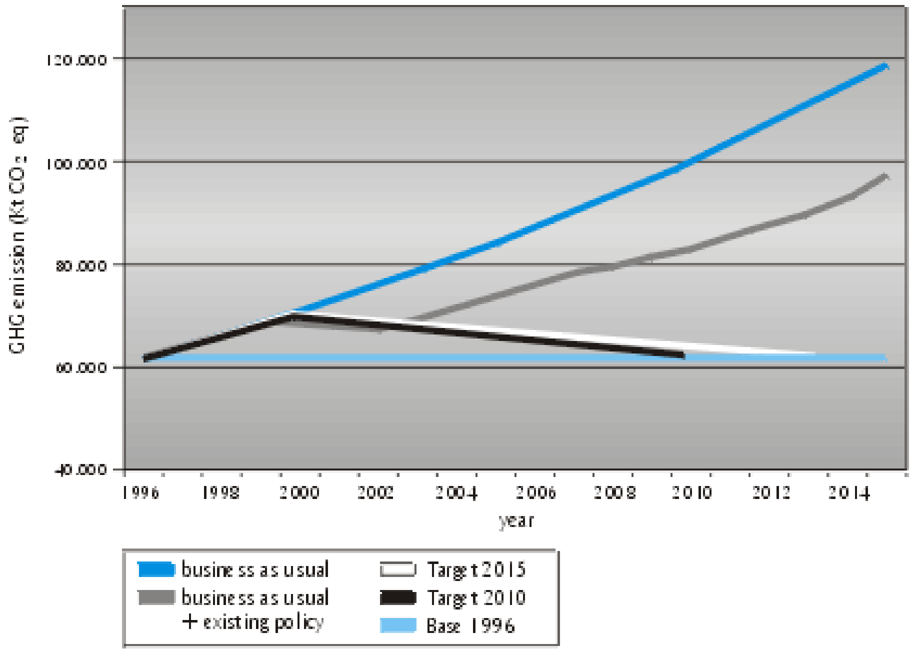
The assessment of the economic costs and benefits of reducing greenhouse gases is based on two target years by which greenhouse emissions should be reduced to 1996 baseline levels: 2010 and 2015. Different scenarios are considered in order to assess the greenhouse gas reductions which will be necessary: a "business as usual" (BAU) scenario, which assumes an annual increase of 3.5% in greenhouse gases, two scenarios which assume that natural gas will gradually be introduced into the energy production sector beginning in 2003 (following a run-in period) and that methane treatment in landfills will become a norm by 2002, and two additional scenarios which do not assume natural gas introduction.

Since both the introduction of natural gas and methane treatment implement existing policy which was not drawn up for the purpose of reducing greenhouse gas emissions, they are considered "sunk costs" – costs which are not included in the economic scenarios of the climate change policy.

Following are the results of the analysis:

- Greenhouse gas emissions in 2010 in a "business as usual" scenario will reach 100,000 ktons CO_2 equivalent.
- Greenhouse gas emissions in 2015 in a "business as usual" scenario will reach 118,000 ktons CO_2 equivalent.
- The difference between the "business as usual" scenario and compliance with an emission level identical to 1996 is 37,900 ktons CO_2 equivalent for 2010 and 56,200 ktons CO_2 equivalent for 2015.
- Transition to natural gas in electricity generation will reduce greenhouse gas emissions by 7,600 ktons and 11,500 ktons for 2010 and 2015, respectively, in relation to the "business as usual" scenario.
- Methane treatment in landfills will reduce greenhouse emissions by 9,700 ktons and 11,500 ktons for 2010 and 2015 respectively, relative to the "business as usual" scenario.
- Without any additional costs to the economy, a switch to electricity generation by natural gas and treatment of methane in landfills can bring about 46% and 38% of the necessary reductions for the years 2010 and 2015, respectively.
- Reduction of the balance (20,600 ktons and 35,900 ktons CO_2 equivalent for the years 2010 and 2015 respectively) should be implemented by means of demand management: a carbon tax and implementation of specific policy measures in different economic sectors.

Figure 1.2: Scenarios of Greenhouse Gas Emissions (Kilotons CO_2 Equivalents)[1]



[1] Assuming 2.5% annual population growth, 1% growth in standard of living

The proposed CO_2 tax for reducing greenhouse gas emissions will reduce the demand for gasoline and electricity to desired levels. The attendant economic impact is estimated at a maximum of 2% of the Gross Domestic Product (GDP) if reduction by 2015 is required, or 1.4% of the GDP if reduction by 2010 is demanded. Additional advantages to achieving greenhouse gas reductions through imposition of a CO_2 tax include a change in the tax structure, a "double dividend," and reductions of pollutants that are damaging to health, infrastructure and water sources.

Vulnerability and Adaptation

In general, most of the impacts of climate change are expected to amplify projected impacts of anthropogenic stresses resulting from accelerated population growth and a higher standard of living; the relative contribution of climate change to the overall impact is not known. Therefore, measures to reduce the overall impact are, by default, adaptations to climate change. Because of the high degree of uncertainty of currently available climate change scenarios for Israel, the following assessments are expected to serve as hypotheses for directing future exploration and research.

- Hydrology: Increased rain intensity combined with a reduction in overall precipitation will increase surface runoff, soil erosion and salinization and will lead to desertification, especially in the Negev. Measures for combating desertification, such as afforestation and rehabilitation and regeneration of natural vegetation, will help adapt to climate change. Water-sensitive urban planning and conservation and rehabilitation of natural vegetation in rural areas will serve as adaptations to potential damages to structures and crops which may result from flash floods.

Water supply may severely decrease, falling to 60% of current levels by 2100, and water quality may deteriorate due to increased sedimentation and salinization and reduced recharge of aquifers and surface reservoirs. Measures already adopted to counter the growing water scarcity in Israel, such as water conservation and generation of additional water sources, will also serve as future adaptations to climate change.

- Fires: Delayed winter rains, lower soil moisture, increased evaporation and greater frequency and intensity of heat waves will increase the risk, intensity and frequency of woodland fires. This may offset the high potential for fire resistance and regeneration potential of many Israeli woodland species and may critically damage woodland ecosystems. Controlled livestock grazing or reintroduction of wild mammalian herbivores may serve as adaptive measures to reduce woodland dry matter.

- Natural ecosystems: Since Mediterranean biomes are projected to shift 300-500 km northward and 300-600 m uphill with a 1.5°C warming, the Negev ecosystems may be expected to replace Mediterranean ecosystems in Israel. Climate change, habitat fragmentation and natural limitations on migration may lead to the loss of natural populations or even species.

The ecotone between the desert and non-desert regions of Israel, where peripheral populations of both ecosystems meet, is expected to show the first impacts of climate change. Since peripheral populations may be more resistant to climatic stochasticity than their core populations, they may be more resistant to climate change as well. Adaptations may, therefore, include conservation of ecotones as well as conservation of corridors between biomes, especially along the north-south axis of the country.

Additional impacts may include the following: arrival, establishment and expansion of invasive species which will bring more pathogens, widening of the desert barrier between Europe and Africa for migratory birds travelling through Israel, inundation of coastal ecosystems by sea level rise, degradation of coral reefs in the Red Sea due to increased temperatures and elevated CO_2, forest decline due to invasive pathogens, drought, and high frequency of fires, and increased tree mortality in planted forests. Afforestation with species that survived the severe droughts of recent years is an adaptive measure to prevent further deterioration.

An increase in atmospheric CO_2 (also referred to as CO_2 fertilization) will enhance photosynthesis in some (but not all) plants and allow for more rapid growth. However, although CO_2 may somewhat mitigate the effect of heat and drought, the overall effect of CO_2 enrichment is still poorly understood.

- Agriculture: The impacts of climate change may endanger crops. Drought damages, increase in pests and pathogens and loss of diversity will also impact on agricultural yields. A delayed growing season will reduce Israel's advantage over colder countries in early exports of flowers, fruits and vegetables. Fisheries may be affected by increased salinization, reduced oxygen pressure and frequent algal blooms. New crops and varieties, agrotechnological advances and revised water and investment policies are appropriate general adaptations while delaying seeding time in response to delayed winter rains is a specific adaptation to climate change.

- Infrastructures: Sea level rise will increase erosion along Mediterranean beaches, damage coastal structures, harbors and archaeological sites, decrease hydraulic gradients and reduce the efficiency of power stations and municipal drainage systems. Adaptations include elevating port structures, protecting low coastal areas and beachfront cliffs by breakwaters, raising outlets of power stations, improving drainage systems and introducing water-sensitive urban planning that promotes groundwater recharge.

In the Red Sea, sea level rise will not inundate extensive land areas, but the narrow recreational beaches and transportation lines along the beaches may be affected.

Increased evaporation and decreased flow from the Jordan River to the Dead Sea may accelerate lowering of the water level. This retreat will further decrease ground stability of the exposed coastal lake beds, with the potential to threaten structures and human life.

- Energy: Energy requirements for winter heating and summer cooling of buildings will increase. Designing buildings and urban areas in ways that buffer temperature changes will serve as an adaptation for overall warming and the increased frequency of temperature extremes.

- Human health: Climate change may increase the risk of vector-borne diseases while degradation of municipal and industrial drainage systems will further enhance water-related epidemics such as malaria, cholera, dysentery, West Nile virus and giardiasis. Climate-related morbidity and mortality may increase, especially among the elderly, children, and those suffering from chronic diseases. However, given the level of medical care and standard of living in Israel, it is unlikely that climate-change related extreme events will adversely impact human health.

Research, Surveys and Observation

Climate Change Scenario

The following scenarios, based on the observation of climatic trends within the country and on national and regional climatological research and models, were developed in Israel for the year 2010. It should be noted, however, that these scenarios have a low reliability due to the complexity of climatic factors affecting the region.

Climate changes:

- Mean temperature increase of 1.6-1.8°C
- Reduction in precipitation of (-8)-(-4)%
- Increase in evapotranspiration of 10%
- Delayed winter rains
- Increased rain intensity and shortening of the rainy season
- Greater seasonal temperature variability
- Increased frequency and severity of extreme climate events
- Greater spatial and temporal climatic uncertainty

Related environmental changes:

- Sea level rise of 12-88 cm
- 560 ppmv of atmospheric CO_2 concentration by the year 2040-2065

Research on Mitigation Measures

Specific research on technologies expected to contribute to greenhouse gas mitigation has been conducted in Israel in such areas as solar energy, green building and combating desertification. Israel began its solar energy research soon after its establishment in 1948. Several major developments have resulted from this research: flat solar collectors for domestic use (required in all new buildings), solar ponds and parabolic troughs.

To help overcome the main stumbling blocks to using the sun's energy, two major research centers are carrying out solar energy research: the Weizmann Institute of Science and the Ben-Gurion Solar Energy Research Center. Some of the technologies developed at these and other universities have formed the basis for industrial scale application. In recognition of the importance of the subject, the Chief Scientist of the Ministry of Industry and Trade approved financial support for the formation of an industrial consortium (ConSolar) to develop concentrated solar energy technologies aimed at future commercial applications.

Israel Electric Corporation (IEC) has been involved in solar energy research and development in photovoltaic (PV) and hybrid systems since the mid-1980s, at which time three main research directions were defined: large PV central stations, small grid connected PV systems, and battery linked renewable energy systems applications.

Nearly all of Israel's academic institutions engage in different aspects of research on green building. Research findings are being translated into actual design projects in an effort to apply accumulated expertise to specific problems.

To combat desertification and overcome the effect of minimal rainfall and extreme temperature variation in the desert, Israel has developed and implemented dryland afforestation methods and surface and sub-surface drip irrigation technologies and protocols. Fields of research and development include wastewater treatment and irrigation, floodwater storage, run-off harvesting and agroforestry, dryland crop breeding, and dryland aquaculture.

Education, Public Awareness and International Activities

Environmental education is part of the educational curriculum from kindergarten to high school. As of 1995, Israel has participated in the Global Learning and Observations to Benefit the Environment (GLOBE) project.

At the solar education facility at the Sde Boker campus of Ben-Gurion University of the Negev, several educational and outreach projects have been launched aimed at increasing public awareness of the importance of solar energy. The visitor's program offers both advice and demonstration tours to groups and individuals.

At more specialized levels, conferences are held on climate-change related topics. In 1991, an International Workshop on the Regional Implications of Future Climate Change was held in Israel. More recently, issues of climate change and global warming were incorporated within the framework of the International Conference of the Israel Society for Ecology and Environmental Quality Sciences and the Sde Boker Symposium on Solar Electricity Production.

Demonstration Projects on Energy Conservation

The Department of Infrastructure Resources Management in the Ministry of National Infrastructures provides technical consulting and guidance, promotes education and encourages demonstration projects for energy conservation. Education targeted at professionals includes the establishment of professional advisory services for plants and institutions, workshops for Energy Conservation Officers, and professional literature.

To promote public awareness, the ministry operates an advisory office and a toll-free telephone number for advice on energy conservation. A multimedia station provides advice on energy conservation topics, and leaflets are available on all major home appliances.

International Activities

Israel's experience in overcoming difficult climatic conditions, scarcity of water and limited land resources has become a model for developing countries worldwide. The country has actively shared its accumulated experience and expertise with other states, largely through the services of MASHAV, the Center for International Cooperation. Cooperation revolves around such core issues as water and energy conservation, agriculture and agrotechnology, and combating desertification.

Israel was one of the first countries to sign and ratify the Convention to Combat Desertification and has implemented cooperation and assistance programs in the form of training and demonstration, joint research, and exchange of experts. On the regional level, the working group for the environment in the multilateral peace talks has launched a Desertification Initiative with the participation of teams in Egypt, Israel, Jordan, the Palestinian Authority and Tunisia.

The Jewish National Fund, an afforestation and land development organization, has been active in exchange and training of experts from affected countries. Much of the activity undertaken in the area of sustainable dryland development is in association with the International Arid Lands Consortium, a consortium of USA universities and the US Forest Service.

Because Israel has almost no fuel sources other than its abundant sunshine, it has become a world pioneer in the use of solar energy, both for domestic purposes and for solar power station technologies. Solar water heaters developed in Israel are extensively used within the country and worldwide. An Israeli company was the first to develop and install a fully functional large-scale solar-powered electricity generating plant in South California's Mojave desert.

Today foreign and local companies, in cooperation with Israeli research institutions, are working to demonstrate the commercial feasibility of an advanced solar-power plant capable of generating electricity at competitive prices. An Israeli company has also taken a lead in the design and installation of electricity generating equipment for low temperature heat, mainly geothermal and industrial heat.

2. Introduction

The world community, concerned about the harmful effects of global climate change, reached a landmark agreement at the United Nations Conference on Environment and Development (UNCED) in 1992. At the time, more than 150 countries signed the UN Framework Convention on Climate Change (UNFCCC), whose ultimate objective is to achieve:

> stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner (UNFCCC, 1992).

Two categories of countries were defined in the Convention: developed countries (Annex I countries) and developing countries (all other countries not included in Annex I). According to the Convention and the ensuing Kyoto Protocol, only Annex I countries are committed to reduce their emissions of greenhouse gases according to reduction targets and timetables.

As a party to the UNFCCC since May 1996 and as a signatory to the Kyoto Protocol since December 1998, Israel is committed to fulfilling its obligations for reducing greenhouse gas emissions into the atmosphere. Israel, defined as a developing country under the Convention (and not included in Annex I), is committed to:

1. Develop, update periodically, and publish a national inventory of anthropogenic emissions and removals of greenhouse gases;
2. Formulate and implement a national program containing measures to mitigate climate change.

To meet these obligations, Israel established an interministerial committee on climate change, according to a government decision taken on May 5, 1996, the time of ratification. The committee includes, among others, representatives of relevant government ministries (Environment, Finance, Infrastructures, Transport, Industry and Trade, Agriculture and Science), the Israel Electric Corporation, the Manufacturers Association of Israel, and the Jewish National Fund. It is charged with "formulating national policy on reduction of greenhouse gases and preparing a report on the national inventory of emissions and removals of greenhouse gases in Israel, policies, measures and future forecasts."

Israel's First National Communication to the Conference of the Parties to the UNFCCC presents:

- The national inventory compiled for the year 1996, according to the Guidelines for National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change (IPCC, 1995) and the Revised 1996 Guidelines (IPCC, 1997);
- Israel's mitigation options for reducing emissions in various sectors in Israel – energy supply, industry, transport, agriculture, solid waste and wastewater disposal, and energy in buildings;
- A proposed climate change action plan which focuses on forecasts, policy and economic analysis, and surveys Israel's potential to reduce greenhouse gases;
- A short survey of existing policies and measures;
- A preliminary assessment of vulnerability and adaptation measures to climate change;
- An overview of current research and observation on climate change;
- A short summary of education and awareness programs and of international activities.

Although the baseline year for Annex I countries is 1990, Israel has chosen 1996 as its baseline year due to the demographic and economic reality of the first half of the past decade. This period was characterized by mass immigration into the country which led to a sharp increase in population, energy use and, as a result, also greenhouse gas emissions.

A number of special circumstances dictate the need for mitigating the effects of climate change in a country such as Israel, including the following:

- Israel's population density and its location at the edge of the desert make the country especially vulnerable to climate change. Some 60% of the population resides in a narrow coastal strip along the Mediterranean; 90% of the population is concentrated on 30% of the land area in the Mediterranean region.
- Israel's freshwater resources are limited and are dependent on seasonal rainfall to replenish the sources of the Jordan River and the coastal and mountain aquifers. Climate change may change the rainfall regime.
- The coastal strip, with its vital infrastructures, natural resources and phreatic aquifer, is very vulnerable to a rise in sea level.
- At this stage of the country's development, technologies for reducing greenhouse gas emissions in different sectors (e.g., electricity generation, transport, waste, agriculture, heating/cooling of buildings, etc.) will bring about additional advantages such as emissions reductions from other pollutants which damage public health, infrastructure and water sources.

3. National Circumstances

Table 3.1: Basic Data

Criteria	1996	1997	1998	1999
Population (average) (thousands)	5,685.1	5,828.9	5,970.7	6,122.6
Relevant areas (square kilometers)	24,000	24,000	24,000	24,000
GDP ($US million) (at current prices)	97,380	101,475	100,730	100,841
GDP per capita ($US million) (at current prices)	17,128	17,408	16,870	16,470
Domestic product at basic prices ($US million) (at current prices)	88,225	91,512	90,896	91,110
Share of industry in DP at basic prices (%)	18.4	18.6	18.5	18.7
Share of services in DP at basic prices (%)				
– Finance and business services	18.3	18.4	18.7	20.3
– Public and community services	23.3	22.8	22.5	22.3
– Personal and other services	2.4	2.4	2.5	2.7
– Commerce, restaurants & hotels	11.4	11.2	11.0	11.3
Share of agriculture, forestry and fishing in DP at basic prices (%)	2.1	1.9	2.0	1.7
Share of construction, electricity and water in DP at basic prices (%)	9.1	9.1	8.3	7.4
Share of transport, storage and communication in DP at basic prices (%)	7.6	7.5	7.8	7.9
Land area used for agricultural purposes (square kilometers)	4,300	4,218	4,246	
Urban population as % of total population	90.9	91.2	91.4	91.5
Livestock population – Laying hens (millions)	6.4	6.6	6.2	7.19
– Cattle (thousands)	392	380	388	388
Total forest area (square kilometers)	1186	1235	1261	1280
– Natural forest	350	350	350	350
– Afforested area (total)	836	885	911	930
– Coniferous	543	572	576	581
Thereof: Pines	311	421	435	434
Cypress	29	30	29	31
– Eucalyptus	88	90	91	92
– Other species – total	118	139	159	168
Broadleaves & orchards	76	125	141	144
Natural groves & shrubs	42	14	18	24
Population in absolute poverty (% of families)	18	16	16.6	
Life expectancy at birth (years) – male	76.3	75.9	76.1	
– female	78.9	80.1	80.3	
Literacy rate (based on school enrollment per 1000 for population aged 6-13)		950	963	

Source: Central Bureau of Statistics

Land Resources

Long and narrow in shape, Israel is about 470 kilometers in length and 135 kilometers in width at its widest point. Located at the junction of Asia, Africa and Europe, the country makes up for its small size with a varied topography and climate. Although a small country, just 24,000 km^2 in size, Israel is characterized by fertile plains and arid zones, seashore and desert, mountain ranges and the lowest point on earth – the Dead Sea – all in close proximity. Arid zones comprise 45% of the area of the country. The rest is made up of plains and valleys (25%), mountain ranges (16%), the Jordan Rift Valley (9%) and the coastal strip (5%).

The coastal plain runs parallel to the Mediterranean Sea and is composed of a sandy shoreline, bordered by stretches of fertile farmland extending up to 40 km inland. This area is home to more than half of Israel's population and includes major urban centers, deep-water harbors, most of the country's industry and a large part of its agricultural and tourist facilities.

A mountain belt runs the length of the country and is formed of sedimentary rocks originally deposited as flat layers that were folded in southern and central areas. The hills of the Galilee reach heights ranging from 500 to 1200 m above sea level.

The Negev, comprising over half of Israel's land area, is an arid zone inhabited by only 8% of the population, living mainly in the northern part.

The Jordan Valley and the Arava, running the length of the country in the east, are part of the Syrian-African Rift. The northern stretches are fertile while the southern portion is semi-arid. The Rift Valley includes Lake Kinneret (the Sea of Galilee) which is more than 200 m below sea level and the Dead Sea, with the world's lowest land altitude of 400 m below sea level.

Israel's location at the meeting point of four phytogeographic and zoogeographic zones – the Mediterranean, the Irano-Turasian (steppe), the Saharo-Sindic and the Sudanese – gives the country a rich variety of plant and animal life.

Climate

Israel lies in a transition zone between the hot and arid southern part of West Asia and the relatively cooler and wet northern Mediterranean region. As a result, there is a wide range of spatial and temporal variation in temperature and rainfall. The climate of much of the northwestern part of the area is typically Mediterranean, with mild rainy winters, hot, dry summers and short transitional seasons. The southern and eastern parts are much drier, with semi-arid to arid climate. Throughout the area, summers are completely dry, requiring irrigation for crop production.

Figure. 3.1: Precipitation Map

Israeli Cities

PA Cities

Mean Annual Rainfall

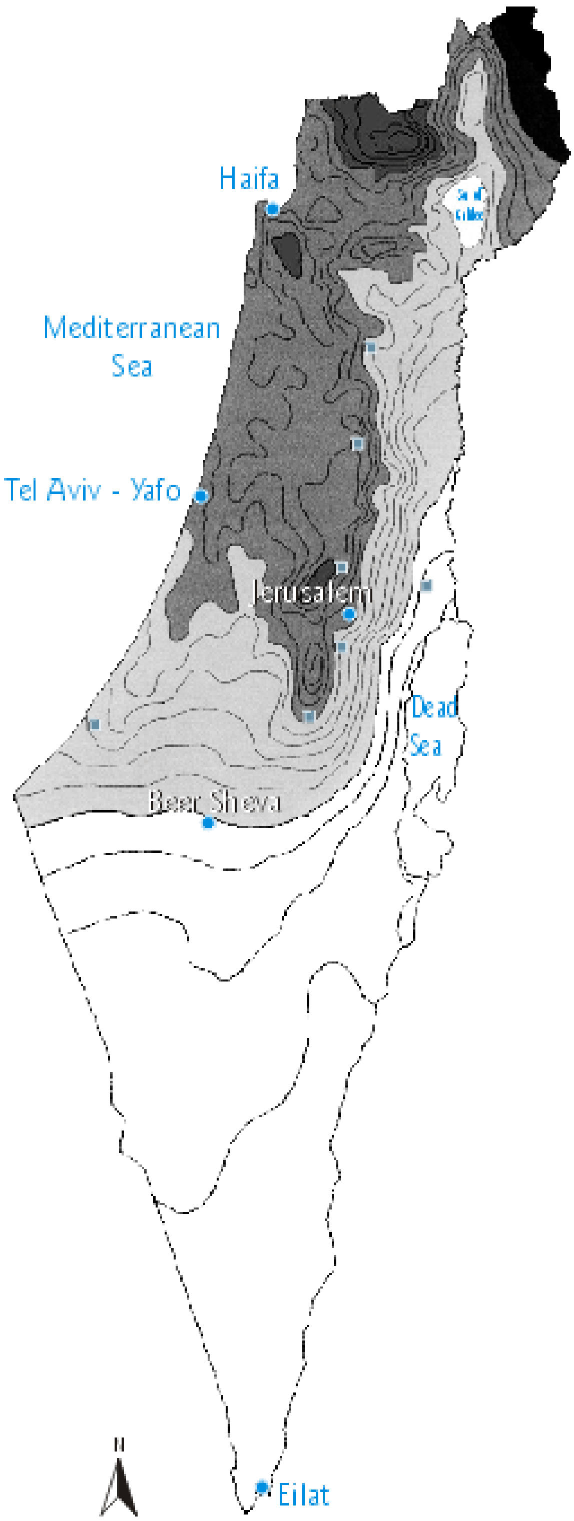
0-200

201-500

501-700

701-950

951-1300



20 0 20 Kilometers

Source: Hebrew University Jerusalem Israel

GIS Unit
Planning Division
Ministry of the Environment
Tel: 02-6553854

Average annual rainfall varies from less than 30 millimeters (mm) in the southern part of Israel to as much as 1000 mm in the north. Rainfall along the Mediterranean coast ranges from 300 mm in the south to 600 mm in the north. More than 60% of the area receives less than 250 mm annually. As is typical of arid and semi-arid climates, there is considerable interannual variability in rainfall. Precipitation in wet years may be almost three times that of dry years.

The yearly mean of rainy days in Israel is 70, 64 and 50 for the northern, central and southern coastal region, respectively (about a quarter of the frequency recorded in the northern coast of the Mediterranean Basin). These winter precipitations largely result from the relatively elevated sea surface temperatures when the mean sea surface temperature in January is about 2.5°C higher than the mean air temperature.

The coastal area belongs to the dry summer subtropical (Mediterranean) climate, although its southern continuation belongs to the semi-arid climate, characterized by potential evaporation and transpiration exceeding precipitation. This marked transition between two climatic types along the coast may serve as an important indicator of the sensitivity of the Eastern Mediterranean Basin to regional climate change.

Summer temperatures are generally high, ranging between 18°C to 32°C, except in the Jordan Valley where summer temperatures may be as high as 45°C. In the winter, temperatures average about 14°C along the Mediterranean coast and about 9°C at higher altitudes. In the Jordan Valley, winter temperatures often exceed 25°C during the day and may drop to 7°C at night. Solar radiation is very high in the summer as is open water evaporation, accounting for as much as 70% of the annual total evaporation.

Demography

Israel's population at the end of 1999 reached 6.2 million residents. Since its establishment in 1948, the country's population has increased more than seven-fold – mainly as a result of large-scale immigration – averaging over 4% per annum. However, this rate has been subject to significant fluctuations corresponding to the volume of immigration. In the three years following independence, the annual growth of the population was over 24%, increasing from about 650,000 at independence to nearly one and a half million at the end of 1952. In subsequent years, average annual rates of growth diminished to 3.5% until the end of the 1950s, 3.2% in the 1960s, 2.4% in the 1970s and 1.8% in the 1980s. Decreased immigration was dramatically reversed at the end of 1989 as a massive wave of immigrants arrived in Israel from the former Soviet-bloc and from Ethiopia. Since 1990, Israel's population grew by 29.4% with the influx of over 950,000 immigrants in just one decade.

Figure 3.2: Population of Israel (thousands)

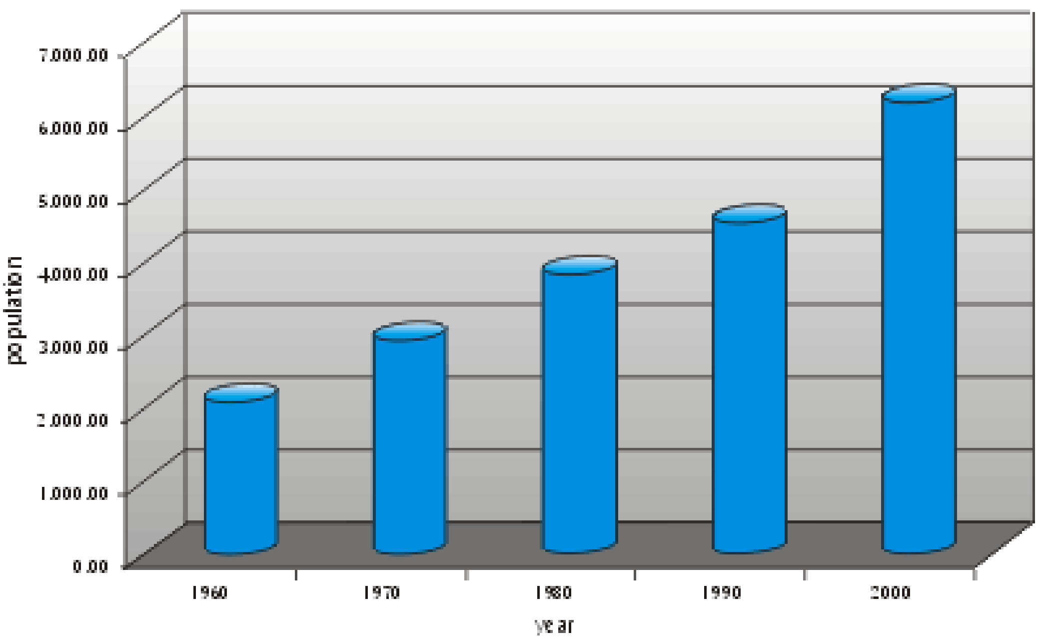
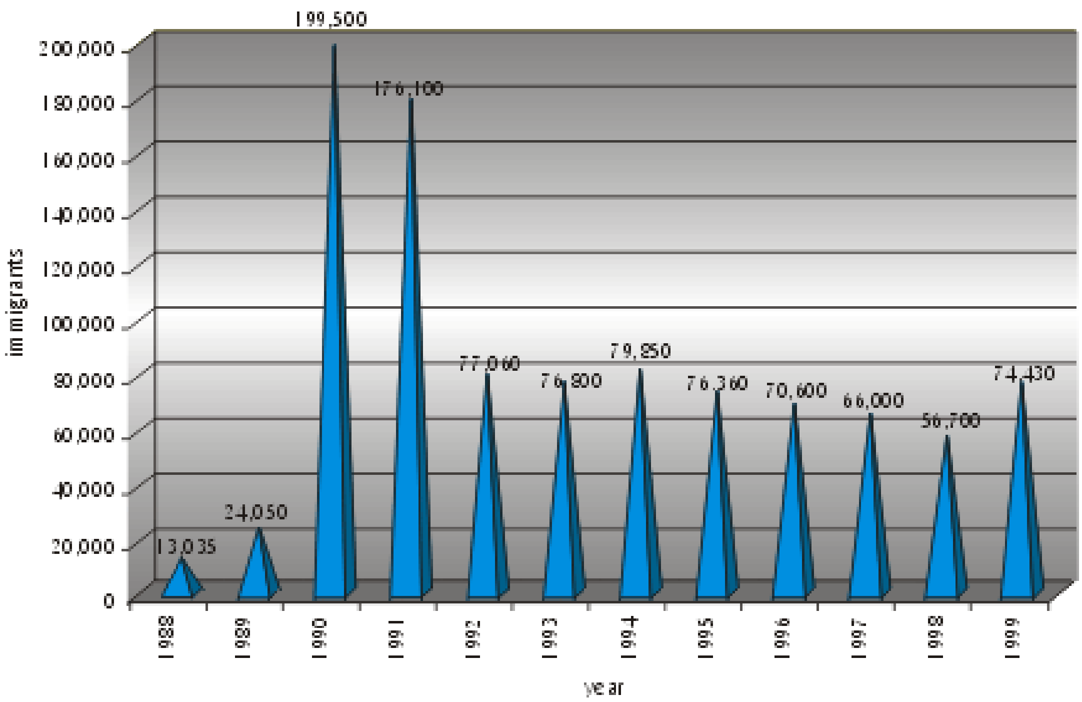


Figure 3.3: Immigrant Arrivals to Israel (per year)



More than 91% of the population lives in some 200 urban centers. The three largest cities are Jerusalem (646,000 inhabitants), Tel Aviv (351,500) and Haifa (269,000). Over 2.6 million people reside in the greater Tel Aviv metropolitan area alone – about 44% of the total population. Just over 5% of Israelis live in unique rural cooperatives – the kibbutz and the moshav. About 3.5% live in other rural localities.

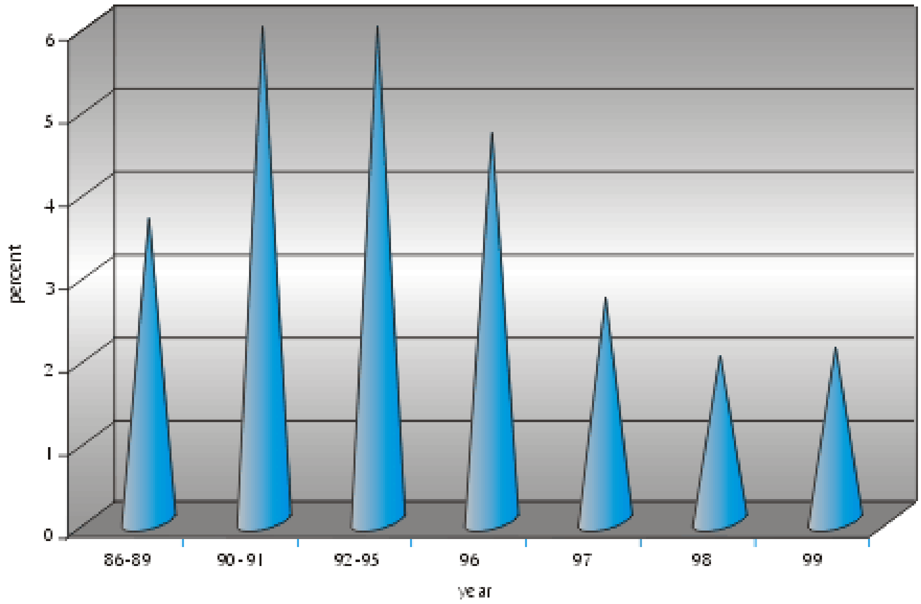
From a sparsely populated country in its early years, Israel has been transformed into a densely populated country. In the area north of Be'er Sheva, Israel has become one of the world's most densely populated countries. Some 92% of the population lives in an area which covers only 40% of the state's land. While average population density at the end of 1999 was 278 per square kilometer, population density reached 6,700 per square kilometer in the Tel Aviv district, as opposed to 1,130 in Jerusalem and only 61 in the southern district.

Economy

Economic growth was very high (10% annual growth in GDP) in the first 25 years of Israel's existence, reflecting high immigration and accelerated development. Between 1973 and 1979 the growth rate decreased to a yearly average of 3.8% and, in the 1980s, it dwindled to 3.1%. In 1990-1996, Israel attained one of the highest GDP growth rates (averaging 6%) in the developed world. This rapid economic growth turned into a slowdown in the second half of the decade – falling to about 2%. The slowdown was accompanied by a sharp increase in unemployment: the unemployment rate, which dropped steadily from 11.2% in 1992 to 6.0% in 1996, changed course and reached 8.9% in 1999.

The price for this impressive growth has been a deficit in the balance of payments, arising from the gap between imports and exports of goods and services. In 1999, imports of goods and services totaled $47.5 billion while exports reached $38.5 billion. In recent years, about 70% of all imports of goods have been production inputs and fuel. As a small economy with a relatively limited domestic market, Israel can only boost growth by expanding exports. Most of the country's resources have been devoted to building up its industrial exports, which have grown from $13 million in 1950 to $21 billion in 1999. Trade is conducted with countries on all five continents. Some 46% of imports and 34% of exports are with the European Union, with which Israel concluded a free trade agreement in 1975. A similar agreement, updated in 1995, was signed with the United States, whose trade with Israel accounts for 22% of imports and 27% of exports.

Figure 3.4: Growth Rate of Gross Domestic Product (%)



Social Services, Health and Education

Government social services include both social spheres and in-cash benefits paid by the National Insurance Institute. The largest spheres of social service activity by government are education and health along with National Insurance Allowances, mostly for pensions and child benefits. Secondary areas of activity are immigrant integration, housing, employment and personal social services. Over the past few decades, the share of government spending has decreased, from about 50% of the GDP in 1980 to the 35-38% range in recent years. However, despite government policy of reducing public expenditure, government expenditures on social services grew in 1995-2000 at an annual rate of 4.6%, on average, reaching 20% of the GDP in 2000 as compared to 18% in 1995 and 15% in 1980.

According to the National Insurance Institute, 16.6% of all families in 1998 had net income below the poverty line (defined as 50% of the net median income, adjusted to family size), with the average net income of a poor family being 75% of the poverty line.

The enrollment rate in the primary education system has long been close to 100%. Almost all three- and four-year olds attend some kind of preschool program, though neither compulsory or free. Kindergarten for five-year-olds is compulsory and school attendance is mandatory from age 6 to 16 and free to age 18. Enrollment in the primary education system reached 694,000 in 1999. Some 535,000 pupils attended post-primary schools, including 238,000 in junior high schools.

Over 165,000 students are enrolled in seven universities and a dozen other institutions of higher learning throughout the country. The percentage of Israel's population which is engaged in scientific and technological research is among the highest in the world, and relative to the size of its labor force, the country is a world leader in the number of published authors in such fields as the natural sciences, engineering, agriculture and medicine.

Israel's extensive medical network and high doctor-patient ratio are reflected in the low infant mortality rate and high life expectancy. The National Health Insurance Law provides a standardized basket of medical services, including hospitalization, for all residents of the country.

Table 3.2: Population, Health and Education

	1960s	1970s	1980s	1990s
Population	2,150,000	3,022,000	3,922,000	5,759,000
Life expectancy:				
Female		73.2	76.0	79.5
Male		69.1	72.6	75.5
Infant mortality (per 1000 live births)	31.3	22.7	15.6	6.3
School population	578,000	824,000	1,201,000	1,766,500
Percentage of the population with 13 years or more of formal schooling	9	11.4	18.7	33.6

Agriculture

In the twelve years following its establishment in 1948, cultivated land area in Israel increased from 150,000 to 400,000 hectares – about a fifth of the land area. Thereafter, cultivation increased far less rapidly, stabilizing at 430,000 hectares. Over half of all cultivated land is irrigated. In the first quarter century of the State's existence, output grew at an average of 6% annually; by the end of the 1980s growth in this sector had slowed to 1%.

The most severe constraint on Israeli farmers is the lack of water. To maximize efficiency of water use, highly mechanized, high-input methods and water-saving irrigation systems are employed. Israel has pioneered drip irrigation and other techniques to increase water efficiency. In order to further stretch the country's water resources, Israel also recycles wastewater for agricultural purposes and develops crop strains which can be grown with brackish water.

Although Israel is a leader in high-yielding agriculture and in the development of scientific methods in all agricultural branches, agriculture accounts for less than 4% of the workforce, less than 2% of GDP and nearly two-thirds of the water used.

Industry

Textiles, diamonds and food processing constituted Israel's industrial base during its first decade of existence. In subsequent decades, the development of chemicals, metallurgical and electronics industries caused a major increase in industrial production. Today, industry continues to grow at a faster rate than any other sector. In the last two decades, the percentage of industrial production which was exported has steadily risen to over 50%, making up 75% of Israel's $21 billion exports of goods.

Due to the lack of raw materials, industry has concentrated on manufacturing products with a high added value. Major industries include medical electronics, agrotechnology, telecommunications, fine chemicals, and computer hardware and software. The highest growth rates are in the high-tech sectors which are skill and capital intensive and require sophisticated production techniques as well as considerable investment in research and development. High-tech sectors accounted for 37% of the industrial product in 1965, 58% in 1985 and 65% in 1997. More than half of the high-tech product is exported (providing 80% of total industrial exports), while more traditional, low-tech firms export some 39% of their product.

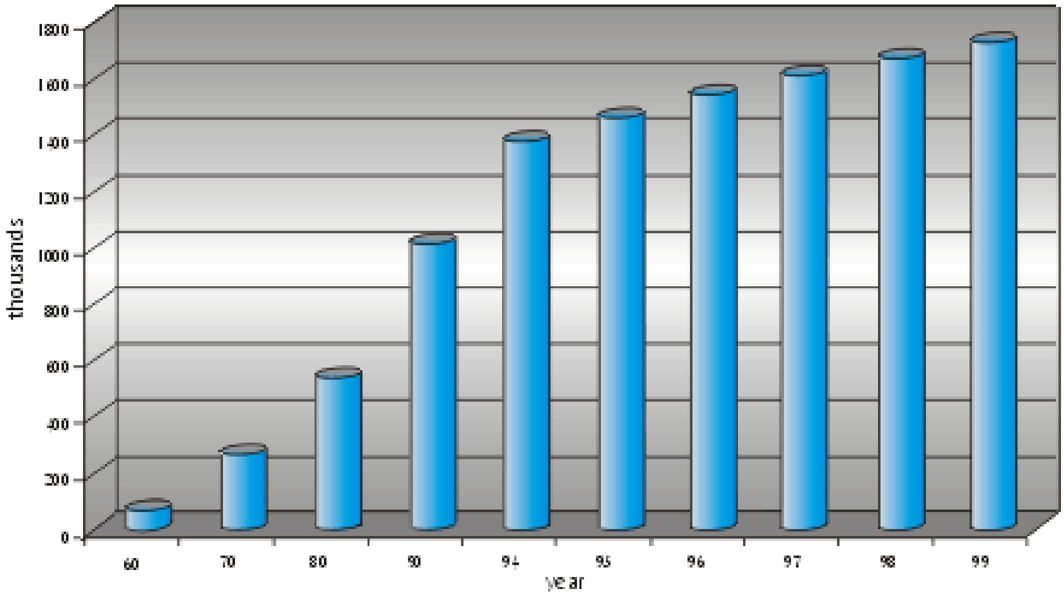
Transport and Communications

Contributing nearly 8% of GDP, the transport and communication sector constitutes some 10% of exports of goods and services.

In recent years, the development of public transportation has stagnated while the number of motor vehicles has continued to multiply: from 70,000 in 1960 to 540,000 in 1980 to 1,015,000 in 1990 to 1,543,000 by 1996 and to1,730,000 by 1999. The increase in car ownership has not been accompanied by a proportionate increase in road surface. Thus, in 1960, there were 6,572 km in length of roads, going up to 11,810 in 1980, 13,199 in 1990, 15,149 in 1996 and 16,115 in 1999.

Israel's railroads derive most of their revenues from the transportation of freight. Inter-city rail travel grew from 1.5 to nearly 4.5 million passengers annually between 1950 and 1960. But by the late 1980s, rail travel had decreased to only 2.5 million passengers annually. Recent years have seen a gradual increase in railway passengers reaching nearly 8.8 million in 1999.

Figure 3.5: Number of Vehicles in Israel (in thousands)



Construction

In the early years of the State, residential building accounted for 84% of total construction output. Subsequently, it fluctuated between 70-75% until 1991 when it rose to 86% to meet renewed immigration. Once considered a leading economic activity, the construction sector contributed just over 6% to the GDP in 1999. While at first almost all construction was the result of government initiative and investment, between 1958 and 1989 its share fell gradually, from 67 to 16%. However, it rose again when the private sector could not meet the demand created by the sudden influx of hundreds of thousands of immigrants. The government's share fell to 34% in 1997.

Energy Production

Israel relies almost exclusively on imported fossil fuels, especially oil. Solar energy, the one local, renewable, environment-friendly source of power, is being used to heat water for residences as per a regulation which mandates installation of such heaters in new houses. Israel is one of the world leaders in development and utilization of solar energy technology. Oil shale and, most recently, natural gas are the only fuels to have been discovered in Israel. Wind energy utilization is under development.

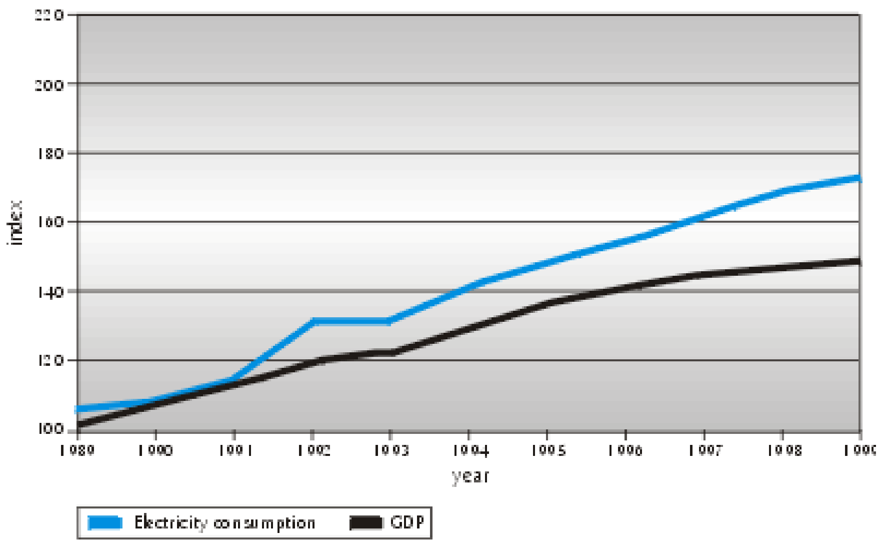
Coal was introduced during the early 1980s to diversify energy resources and has become a major fuel in electricity production. Further diversification is expected with the possible import of natural gas or use of recently discovered gas reserves opposite Israel's shoreline. While the size of the gas reserves and the timetables earmarked for supply in coming years are still unclear, natural gas is expected to replace petroleum-based fuels in the relatively near future.

The installed generating capacity of the Israel Electric Corporation (IEC) now stands at 8,579 MW. Three fuel oil fired plant sites, located in close proximity to the coastal cities of Haifa, Tel Aviv and Ashdod, comprise 2,160 MW of the installed capacity, and two coal fired plant sites, near the coastal cities of Hadera and Ashkelon, comprise 3,740 MW of the installed capacity. The remaining production capacity is in the form of gas oil (diesel fuel) fired gas turbines at various sites around the country and combined cycle sites.

The coal fired and oil fired plants are base loaded, while the gas turbines are primarily used as peaking units. Consequently, coal fired and oil fired plants produced 69.6% and 26.5%, respectively, of the total power generated in 1999, while gas turbines accounted for only 3.9% of the electricity production.

Between 1989 and 1999, electricity production increased from 19.8 to 37.6 billion kWh. Over this same period, peak demand increased from 3,760 to 7,150 MW. The decade witnessed an average annual increase in production and peak demand of 6.6% and an increase in consumption of 6.7%. This data has more significance in view of the recession which prevailed in the economy since the middle of 1996. Over the next five years, IEC plans to add two new 550 MW coal fired units at the Ashkelon site and to add combined cycle capability to gas turbines.

Figure 3.6: Growth in GDP Vs. Growth in Total Electricity Consumption



4. National Greenhouse Gas Inventory

Introduction

According to the Guidelines for National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change and the Revised 1996 Guidelines, Israel's national inventory includes the following sectors: energy, industrial processes, agriculture, land use change and forestry, and waste. It relates to emissions and removals of the three main greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and to indirect greenhouse gases which are precursors of tropospheric ozone: carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs). It also relates to sulfur dioxide (SO_2), which although not a direct greenhouse gas, is an aerosol precursor and, as such, has a cooling effect on climate. At this stage, lack of reliable data precluded the inclusion of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). The inventory will be completed when these data will be obtained. The national inventory will be updated every three years.

Energy Sector

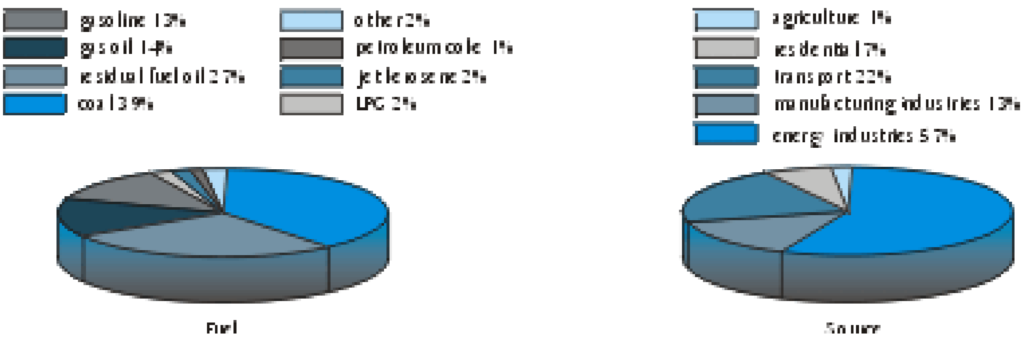
Carbon Dioxide

Israel's inventory is based on the breakdown of CO_2 emissions by the source categories defined by IPCC, as follows: energy industries, manufacturing industries and construction, transport, residential/commercial/institutional sector and agriculture.

By far the largest anthropogenic source of CO_2 emissions is the oxidation of carbon when fossil fuels are burned to produce energy. In 1996, about 50 million tons of CO_2 were emitted by this process.

The energy industries (power plants and oil refineries) are by far the largest source of CO_2 emissions (nearly 60%), followed by transport (over 20%). Coal contributes 39% of the CO_2 emissions in the energy sector, whereas the contribution of residual fuel oil is 27%. Gas/diesel oil and gasoline contribute 14% and 13% respectively.

Figure 4.1: Breakdown of CO_2 Emissions from Fuel Combustion 1996 (by Fuel and Source)



Non-CO_2 Greenhouse Gas Emissions

- Methane: The contribution of fuel combustion to emissions of CH_4 is minor. Methane is produced in small quantities from fuel combustion due to incomplete combustion of hydrocarbons in fuel and its production depends on the combustion temperature.

- Nitrous oxide: As with methane, the contribution of fuel combustion to emission of N_2O is minor. Nitrous oxide is produced directly from the combustion of fossil fuels, and lower combustion temperatures cause higher N_2O emissions.

- Nitrogen oxides: NO_x ($NO+NO_2$) play a role in ozone formation and, as such, are indirect greenhouse gases. Fuel combustion activities, especially energy production and mobile sources, are the most significant anthropogenic source of NO_x. Two different mechanisms contribute to their formation: conversion of chemically bound nitrogen in the fuel and fixation of atmospheric nitrogen in the combustion process. The first mechanism contributes most of the NO_x emitted from coal, whereas the second mechanism is dominant in oil combustion and is the sole mechanism for gaseous fuels.

- Carbon monoxide: CO is also an indirect greenhouse gas. Most CO emissions from fuel combustion come from motor vehicles and small combustion equipment in the residential sector. CO is an intermediate product in the combustion process and its formation is influenced by the facility technology, size, age, maintenance and operation. CO emissions from mobile sources are a function of the efficiency of combustion and post-combustion controls.

- Non-methane volatile organic compounds: NMVOCs (e.g., olefins, ketones, aldehydes) are also indirect greenhouse gases. The main sources of NMVOCs from fuel combustion are mobile sources and the residential sector. Emissions of NMVOCs are due to incomplete combustion, and they are influenced by the same factors as those influencing CO formation. Emissions tend to decrease with increase in plant size and increased efficiency of the combustion process. Emissions from mobile sources are directly related to the amount of hydrocarbons passing unburned through the engine. Emissions due to gasoline evaporation from mobile sources are also accounted for.

- Sulfur dioxide emissions: SO_2 is not a greenhouse gas. However, its presence in the atmosphere has a cooling effect on climate, due to its reaction with photochemically produced oxidants to form sulfate aerosols. The emissions of SO_2 are directly related to the sulfur content of the fuels.

Industrial Processes

Carbon Dioxide

Greenhouse gases are emitted from a large variety of industrial processes not related to energy. The main emission sources are industrial production processes which chemically or physically transform materials.

Cement production is the most important non-energy industrial process emitting CO_2. Carbon dioxide is produced during the production of clinker, an intermediate product from which cement is made. In the cement kiln, calcium carbonate from limestone is calcined to form lime (calcium oxide) and carbon dioxide. In 1996, clinker production was 3.3 million tons, and about 1,700 thousand tons of CO_2 were emitted.

Much smaller quantities of carbon dioxide are emitted from lime and ammonia production. Calcined limestone (quicklime) is formed by heating limestone to decompose the carbonates, a process which releases CO_2. Dolomite may also be processed at high temperature to obtain dolomitic lime and release CO_2. In 1996, 135 thousand tons of quicklime were produced, leading to emissions of over 100 thousand tons of CO_2.

In most instances, anhydrous ammonia is produced by a catalytically assisted reaction of natural gas or other fossil fuels in the presence of steam. Natural gas is used as the feedstock in most plants, while other fuels (e.g., heavy oils) may be used with the partial oxidation process. Hydrogen is chemically separated from the fuel and combined with nitrogen to produce ammonia. The remaining carbon is emitted as CO_2. Production of ammonia was 61 thousand tons in 1996, emitting about 92 thousand tons of CO_2.

Soda ash is used as a raw material in a large number of industries, including glass manufacture, soaps and detergents, pulp and paper production and water treatment. Some 40 thousand tons of soda ash were used, emitting nearly 17 thousand tons of CO_2.

Non-CO_2 Emissions from Industry

The production of nitric acid generates nitrous oxide as a by-product of the high temperature catalytic oxidation of ammonia. Nitric acid is used as a raw material mainly in the manufacture of nitrogenous fertilizers and is produced in three plants in Israel. It is estimated that 1.73 thousand tons of N_2O were emitted during the production of about 277 thousand tons of nitric acid in 1996.

Emissions of SO_2 are attributed to cement production (sulfur in the clay raw material), ammonia production and production of sulfuric acid. NMVOC emissions are attributed to road paving with asphalt, ammonia production and production of various other chemicals. CO emissions are attributed to ammonia production. NO_x emissions are attributed to production of nitric acid.

Agriculture

Methane

Methane is produced through two processes associated with domestic livestock husbandry: enteric fermentation and manure management. Annual methane emissions amount to 42 thousand tons, some 3% and 1.5% of the total CO_2 equivalent emissions for a time horizon of 20 years and 100 years respectively.

About three quarters of the total emissions are contributed by enteric fermentation, of which more than 50% are from dairy cattle and 90% from all cattle. The elevated contribution of dairy cattle is explained by a high emission factor of 150 kg CH_4 /head/yr in Israel. The emission factor takes into account the feed energy requirements for the different physiological functions (i.e., maintenance, feeding, growth, lactation and pregnancy). Its high value is largely due to a record milk production of 30 kg/head/day.

Manure management contributes 25% of the emissions, mainly due to cattle and poultry manure. The contribution of poultry slightly exceeds that of dairy cattle since manure from dairy cattle in Israel is mainly managed in dry systems, which do not favor anaerobic conditions.

Nitrous Oxide

N_2O production in the soil is biogenic and results primarily from the nitrification and denitrification processes. In most agricultural soils, biogenic formation is enhanced by an increase in available mineral nitrogen, which in turn increases nitrification and denitrification rates. Therefore, addition of fertilizer nitrogen directly results in extra N_2O formation. Direct emissions from agricultural soils amount to 1.65 thousand tons N_2O annually; synthetic fertilizers and animal waste contribute 66% and 20% of that amount, respectively.

N_2O is also emitted from two sources related to animal production: manure management and animal grazing. N_2O emissions from different animal waste management systems amount to 0.80 thousand tons annually, of which emissions from solid storage contribute 82%. Waste produced by animals grazing on pasture induces direct soil emissions of 0.40 thousand tons N_2O per year.

Finally emissions are also indirectly induced by agricultural activities through two pathways: volatilization and subsequent atmospheric deposition of NO_x and NH_3 (originating from the application of fertilizers and manure) and nitrogen leaching and runoff. Emissions from the first pathway are estimated at 0.28 thousand tons per year; emissions from the second at 0.68 thousand tons per year. Indirect emissions from agriculture therefore add up to 0.96 thousand tons N_2O annually.

Table 4.1: Total N_2O Emissions from Agriculture

Direct emissions from agricultural soils	1.65 ktons N_2O/yr
Soil emissions from grazing animals	0.40 ktons N_2O/yr
Indirect emissions from agriculture	0.96 ktons N_2O/yr
Total	3.01 ktons N_2O/yr
Animal waste management	0.80 ktons N_2O/yr
Grand total	3.81 ktons N_2O/yr

Waste

Methane

The largest source of methane emissions in Israel is the decomposition of solid waste. In 1996, the total quantity of municipal solid waste was 4 million tons, including domestic, commercial and yard waste. Based on a 20% fraction of degradable organic carbon in the waste, the total methane emissions were estimated at 370 thousand tons. The contribution of methane emissions from decomposition of municipal solid waste is second only to the contribution of CO_2 emissions from energy production (27% of all emissions for a time horizon of 20 years and 13% for a time horizon of 100 years). This relatively high contribution is explained by the large production of solid waste, on the one hand, and the fact that 90% is landfilled, on the other hand (only 10% is recycled and none is incinerated). Waste management practices encourage the development and maintenance of anaerobic conditions within the landfill: the waste is compacted to minimize void space and is covered with a daily to weekly soil layer. On the other hand, there are currently no provisions for collection of generated biogas.

Wastewater can produce methane if treated anaerobically. The main factor which determines the methane generation potential of wastewater is the amount of organic material in the wastewater stream, expressed in terms of Biological Oxygen Demand (BOD). In Israel, the average BOD_5 value (5-day test) of wastewater is 60 g/person/day. This value is higher than the value for domestic wastewater itself and takes into account that about 20% of the industrial wastewater streams are discharged with domestic wastewater. Total annual methane emissions were estimated at 4,000 tons for domestic wastewater and 6,000 tons for industrial wastewater.

Forestry

Vegetation withdraws carbon dioxide from the atmosphere through photosynthesis. In Israel, afforestation programs have been implemented for several decades and are continuing today, causing a net removal of CO_2 from the atmosphere.

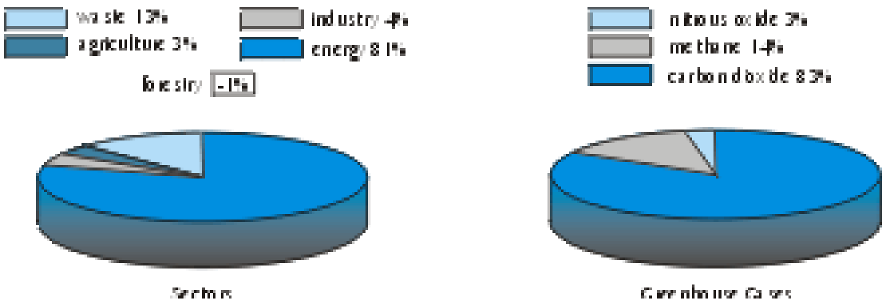
Israel's forest area includes 80,000 hectares of plantations (including 57,000 hectares of conifers, 9,000 hectares of eucalyptus and 14,000 hectares of broad-leaved trees) and about 40,000 hectares of natural woodlands. Although most forests are composed of conifers and broad-leaved trees, the relatively small area planted with eucalyptuses contributes about 20% of the CO_2 removals.

Table 4.2: Calculation of CO_2 Removal by Forests

Forest category		Area (kha)	Growth rate (t dry matter/ ha/yr)	Commercial harvest (kton d.m./yr)	CO_2 removal (kton)
	Conifers	57	4	85	236
Plantations	Eucalyptus	9	7	21	69
	Broad-leaved	14	1	–	17
Natural Woodlands		40	0.8	4	53
Total		120		110	375

Summary of the Inventory

Figure 4.2: Contribution of Sectors and Greenhouse Gases to Total CO_2 Equivalent Emissions



The following table summarizes the emissions and removals of CO_2, CH_4 and N_2O from the different sectors, as estimated for 1996. Methane and nitrous oxide emissions are converted to CO_2 equivalent by means of the Global Warming Potential (GWP) which is a measure of the radiative effects of the different greenhouse gases relative to CO_2. The GWP of methane is 56 for a time horizon of 20 years and 21 for a time horizon of 100 years. The GWP of nitrous oxide is 280 for a time horizon of 20 years and 310 for a time horizon of 100 years.

Emissions from international aviation and sea transport are not included in the national totals.

Table 4.3: Summary of Greenhouse Gas Emissions and Removals (1996) (ktons)

Sector	CO_2	CH_4	N_2O	CO_2 equivalent (20 yr)	CO_2 equivalent (100 yr)
Energy (Fuel Combustion)	**50,344**	**3.55**	**0.58**	**50,705**	**50,599**
Energy industries	28,466	0.57	0.36	28,599	28,590
Manufacturing industries & construction	6,720	0.23	0.07	6,752	6,746
Transport	11,031	2.18	0.12	11,187	11,114
Commercial/Institutional/Residential	3,520	0.49	0.029	3,555	3,539
Agriculture	607	0.08	0.005	612	610
Industrial Processes	**1,889**		**1.73**	**2,373**	**2,425**
Cement production	1,673			1,673	1,673
Lime production	107			107	107
Soda ash use	17			17	17
Ammonia production	92			92	92
Nitric acid production			1.73	484	536

cont.

cont.

Sector	CO_2	CH_4	N_2O	CO_2 equivalent (20 yr)	CO_2 equivalent (100 yr)
Agriculture		**42.4**	**3.81**	**3,441**	**2,071**
Domestic livestock		32.4		1,814	680
Manure management		10.0	0.80	784	458
Soil emissions			3.01	843	933
Forestry	**-370**				**-370**
Waste		**380**		**21,280**	**7,980**
Municipal Solid Waste Disposal		370		20,720	7,770
Wastewater Treatment		10		560	210
Total	**51,863**	**425.95**	**6.12**	**77,429**	**62,705**

Table 4.4: Summary of Emissions of Precursors of Ozone and Aerosols (1996) (ktons)

Sector	NO_x	CO	NMVOC	SO_2
Energy	**215**	**832**	**158**	**260**
Energy industries	86	6	2	191
Manufacturing industries	23	1	1	46
Transport	100	824	155	11
Residential	5	1		10
Agriculture	1			3
Industrial processes	**5**	**0.5**	**89**	**19**
Nitric acid production	5			
Ammonia production		0.5		
Road paving with asphalt			86	
Production of polymers			3	
Sulfuric acid production				18
Cement production				1
Total	**220**	**832**	**247**	**279**

Table 4.5: Summary of Memo Items: International Bunkers (not included in energy totals) (ktons)

Sector	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
International Bunkers	**2,207**	**0.033**	**0.056**	**13.7**	**6.46**	**2.11**	**2.96**
Aviation	1,924	0.014	0.054	8.1	2.72	1.36	0.61
Marine	283	0.019	0.002	5.6	3.74	0.75	2.35

5. Mitigation Options

Introduction

In 1998, a study on options for mitigating greenhouse gas emissions was prepared by the S. Ne'eman Institute of the Technion – Israel Institute of Technology,

In drawing up the proposed policy, the following conditions which are unique to Israel were taken into account:

1. Israel is still evolving and has not yet reached the stability necessary for embarking on a clear path in social, demographic, political and economic fields. Its forecasted population growth remains high. The customary baseline year set for emissions in other countries – 1990 – was characterized by unprecedented population and economic growth in Israel.
2. Israel's demographic instability (along with uncertainties regarding other cardinal issues) makes it difficult to use future scenarios, many of which differ significantly and are difficult to reconcile. As a result of uncertainties in future projections and absence of clear and agreed upon figures on future development in all sectors, different sections of the proposed policy relate to different base and target years.
3. There is uncertainty regarding economic development and future directions of industry. Heavy industries and chemical industries are not a significant segment in Israel. Moreover, projections do not anticipate future growth in these industries but rather in light and high-tech industries, which do not emit large quantities of greenhouse gases in their production processes.
4. Water desalination, which will be an important factor in energy consumption and thus greenhouse gas emission in the future, is still in early stages. There is no precedent for this sector in the policy papers of other countries.
5. Israel does not yet have an advanced solid waste treatment system which includes sludge treatment.

In light of these conditions, Israel's proposals for mitigating greenhouse gas emissions suggest new approaches and innovative technologies. It should be noted that although Israel's baseline year was set at 1996, figures for 1990 are provided for information and comparison purposes.

Recommendations and priorities are based on the following criteria:

1. The relative contribution of the sector to total emissions.
2. The technical probability of a given action to reduce emissions.
3. The public and political feasibility of a recommended action.

4. The relative cost of implementation.
5. The time needed for implementation. Actions that may be implemented in the short range are recommended, but options for future measures are pointed out as well.

Energy Sector

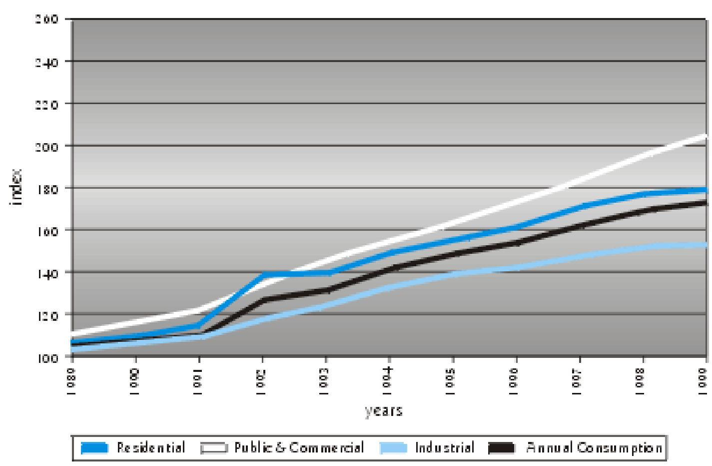
Introduction

By far the largest source of CO_2 emissions is the oxidation of carbon when fossil fuels are burned to produce energy. However, for the purpose of drawing up mitigation measures, emissions were presented in two ways:

1. Emissions resulting from fuel combustion, processes and other activities; and
2. Emissions resulting from electricity consumption (transfer of emissions from energy generation to electricity consumers), processes and activities.

While calculations of emissions from fuel combustion point to the energy generation sector as the leading sector in terms of CO_2 emissions (over 50% of total emissions), this percentage is significantly changed when electricity consumption by sector is considered. When CO_2 emissions from power production are passed on to electricity consumers, the residential and commercial sector is shown to be responsible for the consumption of about 55% of the electricity and is therefore accountable for some 29% of all CO_2 emissions from electricity production. The industrial sector consumes about 29% of all electricity produced and is therefore responsible for some 15% of the total CO_2 emitted from power production. The agricultural sector is a small consumer of electricity and is therefore responsible for only 5% of CO_2 from power generation.

Figure 5.1: Growth of Electricity Consumption by Sector



The following table presents CO_2 emissions by sector based on fuel and electricity combustion and consumption. It shows that the industrial sector accounts for a third of all CO_2 emissions, of which about half originate in direct fuel combustion and half in electricity consumption. The residential and commercial sector is responsible for another third of all CO_2 emissions, of which 88% are a result of electricity consumption. Although the power production sector is responsible for 3% of CO_2 emissions as a consumer of electricity, the power production and transmission sector has enormous potential to decrease the amount of CO_2 emitted at the production and transmission stages.

Table 5.1: Relative Contribution of CO_2 Emissions from Fuel Combustion and Electricity Consumption

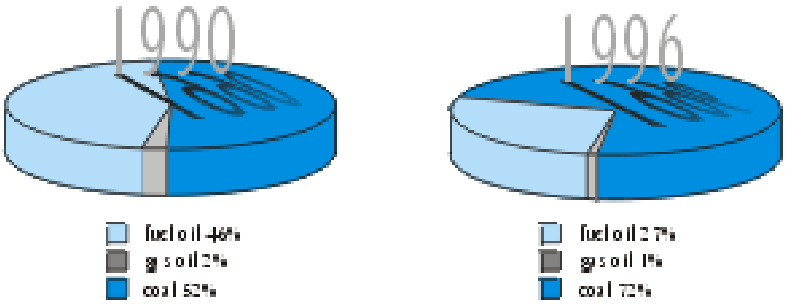
Sector	CO_2 emissions from fuel combustion (1000 tons)	Percent of CO_2 emission from fuel combustion	Percent of electricity consumption (% of total CO_2 emission in parenthesis)	CO_2 emissions from electricity consumption (1000 tons)*	Total CO_2 emissions (1000 tons)	Relative contribution of CO_2 (in %) from fuel and electricity consumption
Energy production	26,569	54	5.7 (3)	1,515	1,515	3
Industry	10,999	21	29 (15.5)	7,705	18,704	37.5
Agriculture			9.7 (5.5)	2,577	2,577	5.5
Residential and commercial	1,826	4	55.6 (30)	14,772	16,544	33
Transport	10,354	21		–	10,354	21
Total	**49,694**	**100**	**100**	**26,569**	**49,694**	**100**

* This column presents greenhouse gas emissions by sector based on the relative electricity consumption in each sector.

Electricity Production

The installed production capacity of the Israel Electric Corporation stood at 8,579 MW in 1999, up from 7,736 MW in 1996 and 5,065 in 1990. CO_2 emissions from power stations in 1990 were estimated at 16.66 million tons. By 1996 CO_2 emissions from power stations increased to 26 million tons. By 2020 CO_2 emissions from this sector are expected to grow to some 59 million tons, an increase of 125% ("business as usual scenario").

Figure 5.2: Annual Electricity Production by Type of Fuel



The increase in demand for electricity in the past decade was an unprecedented 6% per year. In the last five years, an annual increase of 7.7% occurred, but the rate of increase is expected to lessen in the current decade.

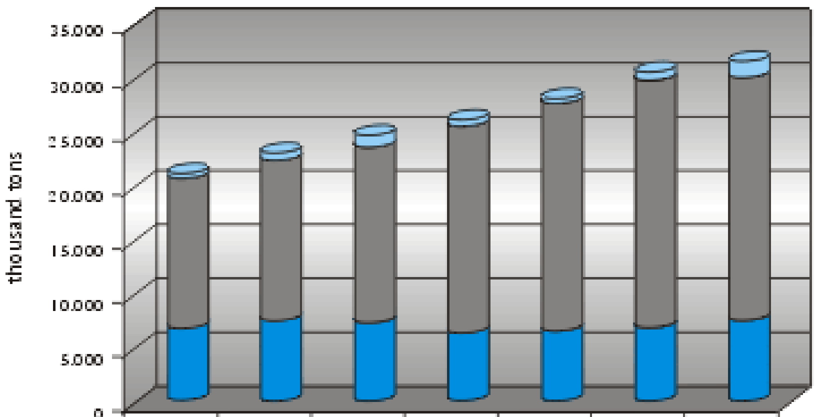
The total amount of electricity generated by the Israel Electric Corporation (IEC) in 1990 was 20,898 million kWh. Official IEC predictions of future production, including electricity by other producers, are 55,760 million kWh in 2010 and 74,794 million kWh in 2020. Assuming the same mix of generating stations and fuels, the following may be extrapolated linearly from current production capacity. However, the following figures do not take into account the shut down of old stations and the introduction of new electricity production technologies which are expected to reduce CO_2 emissions by up to 50% of the quantity noted below.

Table 5.2: Current and Future Electricity Production and CO_2 Emissions

Year	Production million kWh	CO_2 emissions thousand tons
1990	20,898	16,660
1999	37,656	31,228
2010	55,760	44,213
2020	74,790	59,626

To reduce CO_2 and CO_2 equivalent emissions to the 1990 level, the required reduction will therefore be 27,553 thousand tons for 2010 and 42,966 thousand tons for 2020.

Figure 5.3: CO_2 Emissions from Power Plants



	1993	1994	1995	1996	1997	1998	1999
Gas oil	347	679	1.049	415	378	717	1.475
Coal	13.923	14.831	16.257	19.184	21.232	22.795	22.390
Fuel oil	6.687	7.346	7.170	6.304	6.273	6.812	7.363

Two complementary approaches for reducing CO_2 emissions from energy production are recommended: incremental changes (switching fuels) to attain a reasonable decrease in emissions and introduction of renewable sources of energy.

Changes and Improvements in the Current Energy Generation System

- Switch to natural gas: The greatest reduction in CO_2 emissions will be achieved by switching all fuels used in generating stations to natural gas. Conversion from fuel oil to natural gas will decrease CO_2 emissions by 30% while conversion from coal to natural gas will decrease CO_2 emissions by 44%. Reduction of CO_2 emissions as a result of partial conversion to gas is presented in the following table which approximates, to a large extent, estimates of the Israel Electric Corporation (IEC).

The savings in CO_2 emissions for the current mix of fuels are 41.4%. The IEC does not plan to switch coal powered stations to natural gas use in the near future. If only liquid fuel powered stations are switched to natural gas by 2010 and if all future generating stations use natural gas and coal powered stations switch to natural gas by 2020, the reduction in emissions will be 6,464 thousand tons by 2010 and 24,685 thousand tons by 2020.

If coal-generating stations are also switched to natural gas by 2010, the total reductions in CO_2 emissions will be 19.8 million tons CO_2. If only more efficient energy production is introduced and natural gas is not introduced, total reductions will only be 1.5 million tons CO_2. If no natural gas is used by 2020, total reductions for 2020 will only be 2.5 million tons CO_2.

Table 5.3: Projected Reduction of CO_2 in 2010 and 2020 Resulting from Partial Conversion to Gas

Year	Electricity production (million kWh)		CO_2 emissions (thousand tons)				
	Gas	Current mix	Gas	Current mix	Total	Reduction	% of reduction from gas use
2010*	13,940	41,820	6,273	33,874	40,147	6,134	13
2020*	37,395	37,395	16,828	30,290	47,118	14,358	24

* In 2010 25% of electricity production will be from gas and 75% by current mix.
** In 2020 50% of electricity production will be from gas and 50% by current mix.

- Increased efficiency of energy production: It has been estimated that the efficiency of electricity generators will increase in Europe from the current 40-42% to 60% in the coming 30 years. It may be assumed that a similar improvement will take place in Israel as new electricity generators are installed. Based on the projected increase in efficiency, emissions reductions should reach 1,337 thousand tons by 2010 and 2,148 thousand tons by 2020.

- Cogeneration: Utilizing the exhaust gases from gas turbines or steam generators to generate low pressure steam can increase the overall fuel efficiency to about 70%. However, these systems require large scale clients for the low pressure steam near the generating stations. The market for this is very limited in Israel.

- Combined cycle: Utilizing the exhaust gases from steam generators to operate low pressure gas turbines can increase overall fuel efficiency to about 60%. However, the cost of low pressure gas turbines per kW generation capacity is much higher than for high pressure turbines.

- Solar heating and more efficient appliances: Reduction of at least 0.2 million tons a year of CO_2 by 2010 and of 0.4 million tons a year by 2020 will come from increased use of solar heating and more efficient refrigerators and air conditioning systems.

Table 5.4: Total Savings in CO_2 Emissions from Power Stations by 2010 and by 2020

Measure	CO_2 reduction ability for 2010 (million tons CO_2)	CO_2 reduction ability for 2020 (million tons CO_2)
Changing of fuels	6.1	14.4
Efficient new power stations	1.3	2.1
Other	0.2	0.4
Total reduction	7.6	16.9
Desired reduction	27.5	43.0

Other long-term options include the following:

1. Use of combined cycle electrical generators to increase the efficiency of fossil fuel use is attractive but limited. The initial cost of these systems is high, but may be justified in the future.
2. Demand for desalinated water is expected to be considerable by 2010. For desalination the use of flue gas in a low pressure evaporation plant can be economical, and should be encouraged.

The best method to minimize CO_2 emissions is to decrease electricity demand. This may be achieved by encouraging, through lower taxes, homes designed for energy efficiency, and by setting electricity prices that increase with increased use. Data provided by the Ministry of National Infrastructures reveal that in 1995 fuel savings reached 19,000 Tons of Oil Equivalent (TOE) per year. The savings in 2010 may reach 267,000 TOE/year. This translates to 24 and 68 million kWh respectively in terms of electricity savings.

Solutions Based on Innovative Systems

- Nuclear reactors: This option may be optimal for decreasing greenhouse gases, but can only be realized if technological safeguards for safe operation are guaranteed.

- Renewable resources (solar, wind, hydro, biomass, waste disposal and geothermal): Within the framework of a proposed sustainable development policy for the energy sector in Israel, various options for the sustainable use of renewable energy were studied. The alternatives, supported by environmental and economic analysis, take account of both direct costs of electricity production and external costs, one of which is the greenhouse effect. The studies conclude that internalization of external costs in the real cost of electricity will encourage and justify the production of "clean" energy from renewable sources. Moreover, since electricity is currently subsidized, there is economic justification to the development of alternative sources of energy. Advantages to alternative and renewable energy sources include additional economic benefits such as averting the threat of future fuel-price increases, reliability in supply, steady expenditures, improving the balance of payments, and developing Israeli technologies.

Five technologies are proposed to provide electric power generation from renewable resources, two of which may be applied immediately to replace a million and half tons of oil a year. With complete internalization of the external costs, this potential can be doubled.

- Wind Energy: Wind power potential is over 1.75 billion kWh/year. Investment in wind power would make it possible to expand the yield from wind power generation to about one third of all electricity consumption in Israel by the year 2020. Wind energy may be increased if the investment in the generators and the transport of energy to the national grid can be decreased.

- Biomass Combustion: From an overall view and based on alternatives for waste treatment, this direction has a high economic potential. The potential for waste utilization, including biomass, may reach 5 billion kWh/year. However, cultivation of vegetation for energy production is not a realistic possibility in Israel.

- "Energy Towers": This technology, developed in Israel, creates electric power and desalinated water in desert conditions, using air and a spray of water as an energy source. The technology has the potential to respond to all energy consumption needs at a competitive cost.

- Parabolic Mirrors: The technology of concentrating parabolic mirrors, developed in Israel, can be applied if external costs are partially internalized. It can supply between one quarter to one third of Israel's electricity demand, as well as steam to various plants.

- Solar Tower: Solar tower technology, currently under development in Israel, can supply between one quarter to one third of Israel's electricity demand and can be competitive if external costs are internalized.

In conclusion, the best technological solution is to switch to non-fossil fuel generating stations, and specifically to solar energy. Wind potential in Israel is less than 2% of the energy demand. While solar energy is the desirable source of electrical power, its utilization has major hurdles, particularly availability during only part of the day which requires the development of energy storage systems, and high cost.

It is estimated that through use of all the alternative energy sources listed above, up to 35,000 GWh per year may be added with savings of more than $30-$70 billion over the next twenty years. However, the penetration of alternative sources will depend on application processes that take time. These processes can be facilitated through economic instruments, regulations, education and information, demonstration and research and development.

In the interim period, the following steps are recommended:

- Replacing heavy oil and coal with natural gas.
- Combining gas turbines with steam-generating power stations (re-powering).
- Supplementing gas combustion with solar energy at a ratio of 25% and higher.

Table 5.5: Recommendations for Reducing Greenhouse Gas Emissions in Energy Generation

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	Remarks
Switch to natural gas						Requires gas distribution system. Problem of emergency reserves
A. Switching only plants operating on liquid fuel	Reduction of emissions by 30%. 2 million tons.	Existing	10	7.5	3.2	
B. Switching 50% of plants operating on coal	Reduction of emissions by 41.4%. 4.1 million tons	Existing. Simple in plants operating on coal/ heavy fuel	42	15.1	6.6	
Cogeneration	Increase of efficiency from 40% to 60%	Proven and available	Irrelevant	Irrelevant	Irrelevant	Limited market for steam. Effective for water desalination in energy production plants
Combined cycle	Increase of efficiency from 40% to more than 60%. 1.3 million tons in scenario 1A. Additional 3.3 million tons in scenario 1B.	Existing. Easy to implement in gas plants		In scenario 1A: 5%. In scenario 1B: 12.4%. Total: 17.4%	In scenario 1A: 2%. In scenario 1B: 5.3%. Total: 7.3%	
Increase of efficiency in power generation plants	Increased efficiency of 1% per annum	Technology will be developed abroad	*	< 30		Reduction of emissions by 1/3 by 2020
Switching old fuel plants, incl. combined cycle	1.36 million tons	Existing.	*	5	2	Reduction of conventional pollutants

* In conjunction with system replacement and enlargement

Table 5.6: Alternatives Under Development

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	Remarks
Wind energy (1)	Substitution of 6% of current production technology	Existing	Invest-ment of 850–3200	6	2.6	
Waste incineration (1)	Substitution of 5% of current production technology	Existing	3000	5	1	See waste sector
Energy towers (1)	Production of all of Israel's electricity needs	Under development	3000	100	43	
Parabolic mirrors (1)	Production of 25% of Israel's electricity needs	Under development	15000	25	11	Requires energy saving system
Solar tower (1)	Production of 25% of Israel's electricity needs	Under development	13600	25	11	Requires energy saving system

(1) Data from Israel's Sustainable Energy Document (1998)
(2) All calculations are based on equivalent for 1996

Industrial Sector

Introduction

In 1996 the industrial sector in Israel emitted some 18,500 thousand tons of CO_2, of which 60% originated from fuel combustion and 40% from electricity consumption. Total electricity consumption by the industrial sector in 1990 was 5,655 million kWh, over one quarter of the total electricity produced. In 1996 industry consumed 8,571 million kWh, constituting almost 30% of the total electricity produced. The factorized average growth rate was 6.381%.

The high average growth rate was due both to the large-scale immigration and to the high economic growth during this period. Electricity consumption is expected to be more moderate in the coming decade due to slower industrial growth in some sectors and the switch to industries consuming less energy in other sectors.

Mitigation Options

It is estimated that a 3% increase in fuel consumption per year will take place in the years 1996 to 2010. This will increase the unmitigated projection for 2010 to 15.3 million tons of CO_2 from fuel combustion. There are no formal figures for total CO_2 emissions by the industrial sector for 1990, but extrapolation backward at a rate of 6.4% a year suggests the emission of 7 million tons of CO_2 in 1990. Therefore, the amount to be mitigated is the difference between the amounts of CO_2 expected in 2010 and the 1990 amounts: 8.1 million tons of CO_2 and CO_2 equivalent gases from fuel combustion.

The largest industrial users of fuels/and or electricity in Israel are:

1. Oil refineries at Haifa and Ashdod.
2. Users of electrochemical energy for the production of chlorine, caustic soda and magnesium.
3. Producers of cement and lime.

Mitigation options of CO_2 emissions within the industrial sector include the following:

- Switch to natural gas: Changeover to natural gas from fuel oil is practical only for plants near the future gas pipelines. It is anticipated that construction of a gasoline pipeline to the Dead Sea region (Mishor Rotem), where high energy consumption by industry occurs, may decrease CO_2 emissions by 30% through conversion from fuel oil to natural gas. For about 250,000 tons of fuel, the savings in CO_2 emissions will be about 100,000 tons.

- Changing the technology of cement and lime plants: The CO_2 produced by cement plants comes from the decomposition of carbonates (about 69% of the raw material) and from the combustion of fuels. Considerable savings in the use of fuel in cement plants can be achieved by switching from the wet process, used until recently, to a dry process and by adding aggregated ashes to the cement mix. Energy savings from switching from wet to dry process are expected to reach 53%. Savings of both energy and CO_2 from decomposition of carbonates can be achieved by the addition of coal ash, which may be added up to 30% in the final mixture. For an anticipated 7.6 million tons of cement in 2010, a switch to the dry process (which has begun) will bring about savings in CO_2 emissions of about 2.3 million tons.

- Climate control in industrial buildings: In 1996 electricity consumption by industry was 5,500 million kWh, and CO_2 emissions reached 4.55 million tons. In the year 2010, electricity consumption is projected to increase to between 11,000 and 13,000 million kWh (based on an average value of 12,000 million kWh), and CO_2 emissions are expected to reach 11.8 million tons.

The industrial sector consumes electricity for two purposes: industrial manufacturing processes and climate control (heating, air conditioning and ventilation). More than half of the electricity is consumed by high-tech and other industries for HVAC (Heating, Ventilation and Air Conditioning) systems. A significant portion of this energy may be saved and CO_2 emissions may be reduced through cogeneration. The potential to decrease CO_2 emissions ranges from 0.375 kg CO_2 per kWh cooling in conventional cooling systems to 0.165 kg CO_2 per kWh cooling and 0.114 kg CO_2 per kWh cooling in cogeneration cooling systems and hybrid air conditioning, respectively.

Energy savings in large buildings may range between 25-40%. Such savings can be achieved by green building and, in cases of large industrial parks, by using more efficient heating and cooling systems. A reduction of up to 40% of emissions resulting from electricity consumption by the industrial sector in the year 2010 is equal to 4.7 million tons CO_2. With respect to emissions in 1990, the situation would be a deficit of 2.5 million tons CO_2.

- Oil refineries: Since no increase in the capacity of the refineries is expected by 2010, the 3% per year increase assumed for all industry should be deducted. Translated into CO_2 emissions, this equals 800,000 tons.

- Efficiency improvement in industrial plants may save an additional 200,000 tons of CO_2.

Table 5.7: Recommendations for Reducing Greenhouse Gas Emissions in Industry

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	Remarks
Switch to natural gas	30% reduction. Maximum potential-3 million tons	Exists	10-42	16	4.8	Requires distribution system to Mishor Rotem
Switch to dry process in cement production	Savings of over 50% in energy consumption 2.3 million tons	Exists	Within anti-cipated improve-ments	12	3.7	Switch to dry process has begun
Cogeneration in industry	Immediate savings of 1.5 million kWh, 1.2 million tons	Exists	Financial savings	6.4	1.9	Requires agreement with IEC
Energy conscious building	Savings up to 30% of consumption for climate control. 1.2 million tons	Requires adaptation and development	0.5-3	6.4	1.9	Requires legislation

Residential and Commercial Sector

Electricity Consumption in Buildings

About a third of all CO_2 emissions in Israel result from electricity consumption by residential and commercial buildings. The variation in average annual consumption components per household (in kWh) and the variation in the relative proportion of each component of total consumption (in percentages) is presented in the figure on the following page. The figure clearly reveals that between 1980 and 1990, total electricity consumption increased in this sector by 53%. A significant increase in electricity consumption for each of the components was noted, with the exception of water heating, where a decrease of 13% occurred due to expanded use of solar heating systems. An increase of 55% to 65% occurred in electricity consumption for lighting, refrigerators and other domestic appliances. Electricity consumption for home heating (in winter) was about 110% and for cooling (in summer) about 145%. In terms of total consumption, the contribution of indoor climate control in residential buildings increased over this period from about 13% to about 20%, while the contribution of the other components barely changed, except for water heating which decreased from 21% to 12%.

In the commercial/public sector, itemized calculations are not available. Lighting, air conditioning in summer, heating in winter and office equipment are the major sources of electricity consumption in this sector. It is estimated that total annual electricity consumption in non-air conditioned areas is only about a third of that in air conditioned areas, with the climate control component accounting for 30% to 50% of total consumption in air conditioned areas.

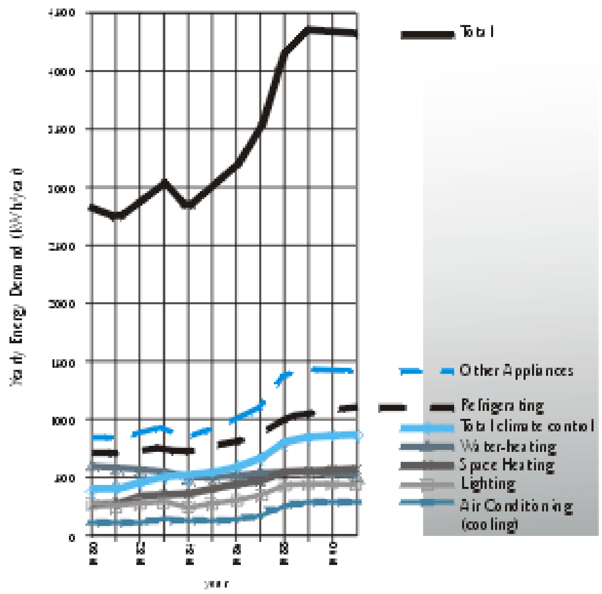
Forecast of Electricity Requirements

The Israel Electric Corporation has prepared a consumption forecast in various sectors for the year 2015 based on five different development scenarios, from "stagnation" (population of 6 million in 2015) to "boom" (9 million). Data show that the growth in electrical appliances will not increase electricity consumption in the home due to the greater efficiency of future appliances. However, the electricity consumption for controlling internal climate in households is expected to grow from about 20% of total consumption in the 1990s to about 50% in 2010. It may well comprise more than half of total consumption in the residential sector.

The forecast for specific electricity consumption (kWh/sq.m) in offices is for a reduction of about 10%, both in air conditioned and non-air conditioned spaces. At the same time a 125% increase in specific consumption is predicted for air conditioned spaces in schools and a 45% increase in non-air conditioned spaces, with no changes in other sectors. While the total area of non-air conditioned spaces in this sector is expected to grow by only 10%, air conditioned spaces are expected to grow by about 140%. Considering these changes, the forecast is for an increase of about 28% in electricity consumption in non-air conditioned spaces in the commercial-public sector, compared to more than 100% in air conditioned spaces.

Figure 5.4: Variations in Household Electricity Consumption Components and in the Proportional Part of Each Component

Time Evolution of Annual Electricity Demands per Household (in kWh)



Time Evolution of Partial Annual Electricity Demands per Household (in percentage)

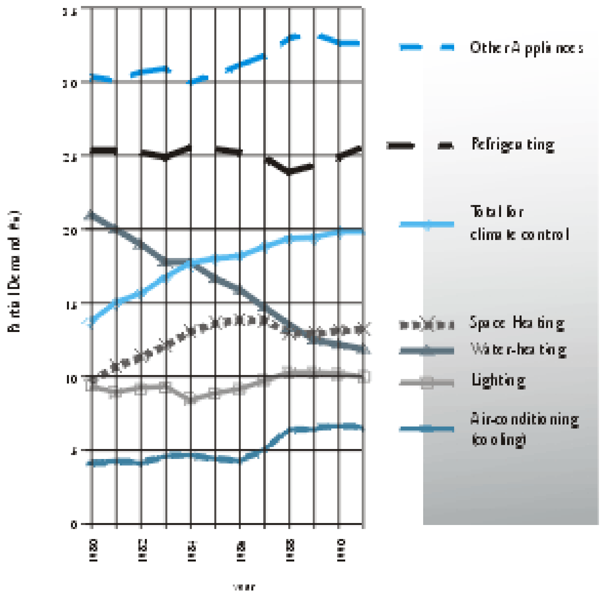
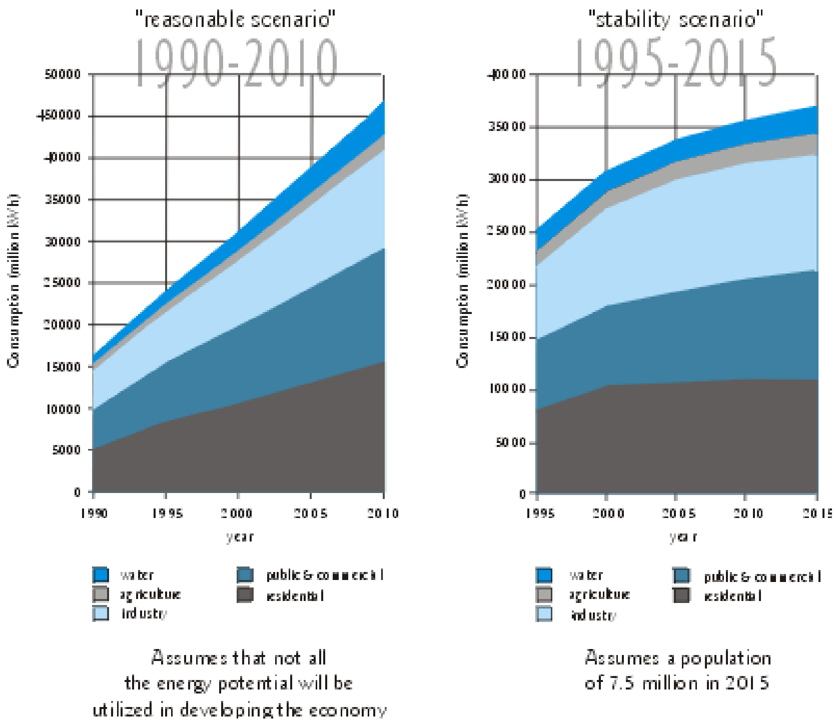


Figure 5.5: Projections of Electricity Consumption by Sector



Residential Electricity Consumption Scenarios

It is estimated that energy consumption in buildings may be decreased by 25-40% by utilizing planning parameters such as window and roof shading, glazing, wall insulation, air sealing, building orientation, passive solar energy (southern window and shutter), and ventilation. Some of the measures do not require additional monetary investments and, in some cases, energy-conscious building will actually save building costs (e.g., reducing the size of windows facing west).

The figure on the following page presents several scenarios for climatic improvement in the year 2020 for existing and new buildings. The term "reasonable comfort" refers to air temperature not below 17.5°C in winter and not above 25.5°C in summer throughout the day. "Moderate comfort" refers to heating and cooling conditions during climate control hours as above, but assumes that climate control equipment operates for no more than 12 hours a day.

For existing buildings, three levels of energy-conscious building were reviewed:

- Basic measures, mostly window shading, that may decrease consumption by approximately 16% (Pessimistic Improvement Scenario).

- Moderate measures, based on shading in summer and increased solar radiation in winter, that may decrease consumption by approximately 24% (Moderate Improvement Scenario).
- Extensive measures, based on a wide gamut of measures, which include, above those mentioned previously, thermal insulation improvements, that may decrease consumption by approximately 40% (Optimistic Improvement Scenario).

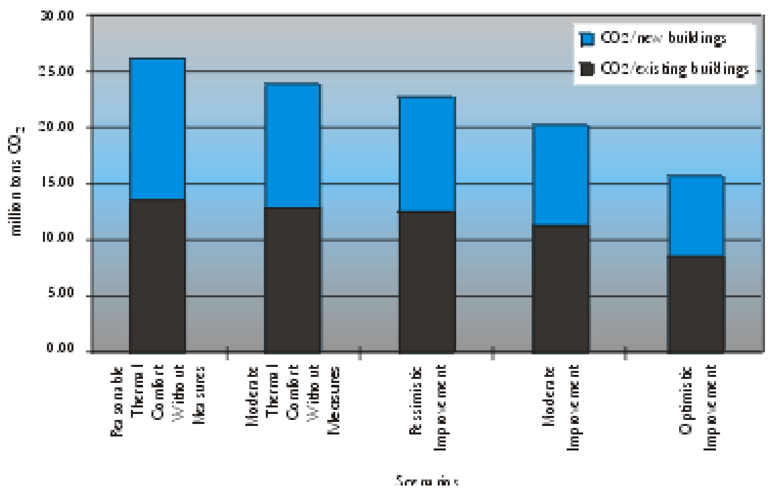
Savings in CO_2 emissions in existing buildings may reach 9 million tons.

For new buildings, it is also assumed that three levels of measures can be taken:

- Extensive measures, based on energy-conscious design, may bring about a 48% reduction level (Optimistic Improvement Scenario).
- Moderate measures, utilizing only some of the possible measures (e.g., sensible orientation and proper shading with some improvement in insulation and glazing) may decrease consumption by approximately 38% (Moderate Improvement Scenario).
- Basic measures, including only some proper shading and minor levels of improved insulation and glazing, may decrease consumption by approximately 28% (Pessimistic Improvement Scenario).

Similar measures may be instituted in public and commercial buildings to attain savings in CO_2 emissions. In addition, cogeneration systems may be practical for commercial size HVAC (Heating, Ventilation and Air Conditioning) systems such as hotels, hospitals, office buildings and public buildings.

Figure 5.6: CO_2 Emission Scenarios for the Year 2020 for Residential Buildings



Recommendations for Energy-Conscious Building

Intervention scenarios to encourage energy-efficient building can be divided into intervention in the design stage, or intervention in the consumption stage that would eventually lead to user demand for energy-efficient planning. It is also possible to divide the intervention into incentives, or alternatively to set more stringent standards and enforce them. Following are different categories of recommendations.

Energy-Conscious Building Standards:

- Increasing the demands for energy conservation standards in buildings;
- Including additional design parameters in building codes beyond building insulation and sealing (e.g., inclusion of a southern window);
- Expanding the building code to include different types of buildings;
- Requiring an energy audit for each project;
- Determining standards for the optimal and maximal energy consumption level permissible in a building according to sectors;
- Granting a green standard of approval (a standard for buildings and home electrical appliances that are energy-efficient).

Planning Recommendations:

- Legislation or recommendations for winter sun rights or summer shading;
- Legislation or recommendations for desired exposure to wind in order to obtain comfort ventilation in summer, or protection from unwanted wind in winter;
- Legislation or recommendations for sufficient exposure to the sky to allow daylighting.

Economic Incentives:

- Solar terraces will not be included in taxable building areas;
- Reduced or no taxation for external shading products and devices;
- Reduced or no taxation for building insulation and sealing products and devices;
- Incentives for energy retrofit of existing buildings;
- Payment level according to the real cost of electricity;
- Progressive electricity rates based on energy consumption.

Research:

- Promotion of research to help develop standards, to determine appropriate municipal planning and to develop economic measures to encourage energy-conscious building.

Table 5.8: Recommendations for Reducing Greenhouse Gas Emissions in Buildings

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	Remarks
Improvements in electricity appliances	No increase in electricity consumption despite increase in use	Based on development abroad	No invest-ment			
Energy conscious building (set of measures)	Reduction of emissions of 20%-40%, 1-2 million tons. (Up to 10 million tons in 2020)	Existing. Requires adaptation and development	Invest-ment of NIS 0.5-3 per savings of one kWh/ year.	6-12 (up to 10 in 2020)	1.6-3.2 (up to 40 in 2020)	Energy consumption for climate control is expected to grow. Requires legislation and incentives.
Cogeneration in public and commercial building complexes	Reduction of energy consumption for heating and cooling of more than 50%	Existing	Financial savings			Legislation and loans are recommended

Transport Sector

Introduction

The transport sector emits some 10 million tons of CO_2, 17% of total greenhouse gas emissions in 1996. In 1996, total consumption of gasoline was 2,029,200 tons and diesel fuel consumption reached 1,013,500 tons. Passenger cars consumed 69% of the total gasoline while trucks consumed 42% of the diesel fuel. Total consumption of gasoline and diesel fuel during the five year period between 1992-1996 increased by 27% and 42%, respectively. Total CO_2 emissions from motor vehicles in 1996 reached 8,159,000 tons. Passenger cars contributed 45% and trucks accounted for 30% of total CO_2 emissions.

Table 5.9: Annual Gasoline Consumption and CO_2 Emissions of Various Vehicles (1996)

Vehicle type	Number of vehicles	Average yearly mileage, km	Specific fuel consumption, km/liter	Yearly fuel consumption, tons	CO_2 emissions, tons
Passenger cars	1,174,166	17,000	10.7	1,399,123	3,642,400
Light trucks	177,540	30,900	8.9	462,302	1,203,500
Motorcycles	69,011	8,900	21.9	21,034	54,800
Others				146,741	382,000
Total				**2,029,200**	**5,282,700**

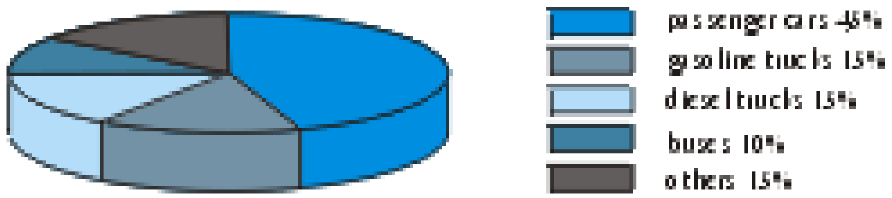
Table 5.10: Annual Diesel Fuel Consumption and CO_2 Emissions of Various Vehicles (1996)

Vehicle type	Number of vehicles	Average yearly mileage, km	Specific fuel consumption, km/liter	Yearly fuel consumption, tons	CO_2 emissions, tons
Trucks	83,130	46,700	7.7	423,510	1,204,900
Buses	11,214	69,400	2.2	297,200	843,500
Taxis	10,000	94,500	9.6	82,690	234,700
Others				210,100	596,200
Total				**1,013,500**	**2,876,300**

Table 5.11: Annual Fuel Consumption of Motor Vehicles (1992-1996)

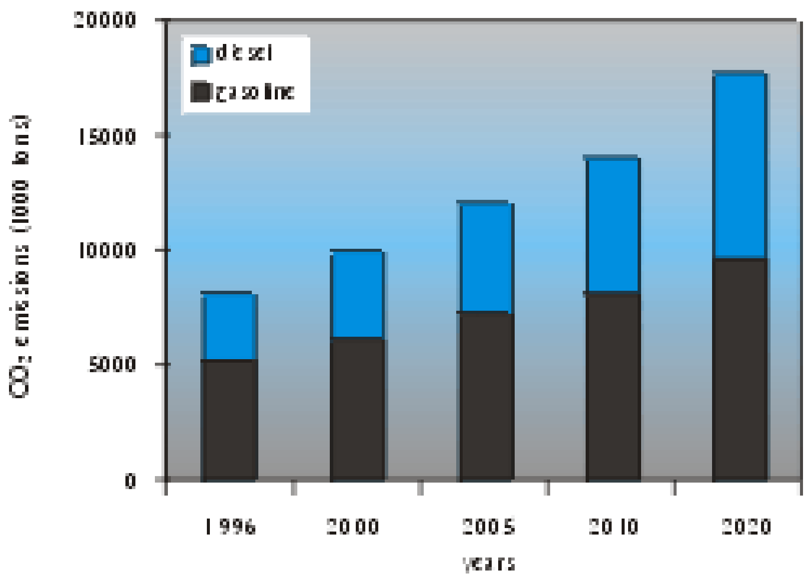
Year	1992	1993	1994	1995	1996
Gasoline, ton	1,598,400	1,719,900	1,834,300	1,970,200	2,029,200
Diesel fuel, ton	712,900	762,600	828,100	933,700	1,013,500

Figure 5.7: Contribution of Vehicle Categories to CO_2 Emissions 1996



The following figure presents the results of a forecast for the increase of CO_2 emissions resulting from an increase in gasoline and diesel fuel consumption until the year 2020, based on a "business as usual" scenario. According to this projection, gasoline consumption would increase by 83% and diesel by 180%. Thus, if no measures are taken to decrease greenhouse gas emissions, CO_2 emissions from road transportation will more than double by 2020 as compared to 1996.

Figure 5.8: CO_2 Emission Projections for Road Transport by Fuel Type



Mitigation Options

Technical Measures

- Means to reduce energy consumption: The main approaches for reducing energy consumption are:

  - Decreasing vehicle weight and engine power by light structure materials.
  - Improved computerized control systems of vehicle and engine.
  - Improved engine design, including direct injection for gasoline engines; direct injection diesel engines with turbo-charging; variable valve timing; optimal inlet port design.
  - Improved vehicle design (e.g., reduction of drag coefficient of the vehicle body; improved tires for better interaction with the road surface).
  - Improved air-conditioning systems.

Some of the technologies mentioned above are already at advanced development stages. However, their penetration into commercial and practical use in vehicles on the road may take over ten years for light vehicles, and many more years for heavy duty vehicles. A reduction of 20-25% in energy consumption is anticipated by the year 2005 as compared to 1990.

- Use of alternative fuels: Alternative fuels are important for improved combustion efficiency and for diversifying energy sources. All the alternative fuels based on petroleum consist of lighter hydrocarbon chains than those of gasoline and diesel fuel so that their combustion produces less CO_2. Alternative fuels already in use include:

  - Liquefied petroleum gas (LPG)
  - Compressed natural gas (CNG) and liquefied natural gas (LNG)
  - Alcohols: methanol and ethanol
  - Biogas
  - Hydrogen
  - Electricity for electrical and hybrid vehicles (EV and HEV), including fuel-cell propulsion

Public transportation in Israel is based almost entirely on diesel vehicles (mainly buses). Therefore, a comparative analysis of bus conversion to LPG operation has been undertaken. Although still preliminary, calculations have shown that a switch from diesel to LPG in buses would reduce CO_2 emissions by 20% at low cost.

- Means to reduce greenhouse gas emissions other than CO_2:
    - Reduction of refrigerant leaks from air-conditioning systems or the use of refrigerants with no GWP.
    - Reduction of the emissions of N_2O by developing catalytic converters which do not generate this gas.

Transportation Control Measures

Transportation control measures are the means available to policy makers to improve air quality. Most of these measures are targeted at reducing vehicle kilometer of travel by a single occupancy vehicle. This can be achieved by changing travel behavior elements as follows:

- Reducing the frequency of trips by reducing the need to travel (e.g., by substituting travel activities with non-travel activities).
- Reducing the length of trips by changing destinations or residence location.
- Reducing the use of the single occupancy vehicle and shifting to high occupancy vehicle modes including mass transit and non-motorized modes.
- Reducing the frequency of trips and total vehicle kilometer of travel by chaining different trips to one trip.

To be effective, transportation control measures must be combined into packages of complementary measures. While many of the measures have to be carefully studied before implementation, the following measures, among others, are expected to contribute to the reduction of greenhouse gas emissions:

- Transit service improvement and expansion.
- High occupancy vehicle priority lanes and facilities.
- Bicycle and pedestrian facilities and programs.
- Fuel taxes.
- Emission and vehicle kilometer traveled tax.
- Public education and marketing.
- Telecommuting, teleshopping, etc.

Table 5.12: Recommendations for Reducing Greenhouse Gas Emissions in Transport

Alternative	Expected efficiency	Technology	Cost	Remarks
Improvements in vehicles	20-25% reduction per km	Developed abroad	Increase of vehicle cost	
Switch to electric vehicle	There will be no reduction of emissions in power plants. Reduction of up to 40% by switching to gas in power stations	Existing	Expensive today	Reduction of air pollution in cities
Switch to gas operating vehicle	Reduction of emissions of CO_2 by 10-30%	Existing	High cost of service and distribution system	Reduction of air pollution in cities
New catalytic converters	Prevention of N_2O emissions equals reduction of 10% of total greenhouse gases	Under development	Additional 2% to vehicle price	
Transport control measures (TCM)				
Regulatory TCMs (1)	Reduction of travel by up to 20%. A more reasonable figure is 5%			Requires regulation and enforcement
Reduction of travel of non-single occupancy vehicle (2)	Reduction of travel in metropolitan areas by up to 8%			Requires regulation and enforcement
Travel Demand Management (TDM) (3)	Reduction of emissions by 3%			
Market Based Mechanism (4)	Reduction of emissions by up to 7%			Requires a central pricing policy
Traffic management (5)	Reduction of up to 10%. Danger of induced traffic			

(1) Measures include parking restrictions, mandatory employer trip reduction programs, closed areas for transport.
(2) Measures include high-occupancy vehicle priority lanes and facilities, transit service improvement and expansions, bicycle and pedestrian facilities and programs.
(3) Public education, employer-based transportation management programs, replacing travel with electronic communications, ridesharing.
(4) Congestion taxes, emission taxes, fuel taxes, parking pricing.
(5) Intelligent transportation systems, congestion management planning and systems, signal enhancement and automated traffic management systems.

Agricultural Sector

Agricultural activities both increase and decrease the release of greenhouse gas emissions. In Israel, the fraction of CO_2 emissions from agricultural activities is small. However, these activities are responsible for a high percentage of CH_4 emissions and emit more N_2O than any other human activity. They account for some 1,300 thousand tons of CO_2 (via electricity consumption), 900 thousand tons of CO_2 equivalent (in CH_4) and some 1,200 thousand tons of CO_2 equivalent (N_2O), constituting some 5% of total greenhouse gas emissions.

Photosynthetic activity of cultivated lands in Israel fixes about 50 million tons of CO_2 yearly, assuming a net fixation of 13.3 tons CO_2/ha. A decrease or increase of 10% in the cultivated (or forested) area involves a change of about 2.6 million tons CO_2/yr, or about 3.7 million tons of the total CO_2 equivalent emission of the country. It is suggested that farming and forestation should be supported for their contribution to CO_2 sequestering.

The carbon storage in the soils is not static. A change in tillage intensity in 25% of the cultivated fields in Israel will reduce energy consumption of the farmer, will increase water efficiency and will lead to the fixation of about 2 million tons of CO_2 over a period of about 10 years, although not continuously.

It is expected that cultivation or forestation of desert soils that contain very low organic matter will lead to significant carbon fixation.

Energy Consumption by Agriculture

With the exception of water pumping, direct agricultural energy consumption is not high, relative to other sectors. It can be assumed that agricultural production will not increase significantly, compared to anticipated changes in other sectors, and that specific energy consumption will be reduced by 10-30%. Means such as more efficient machines, no tillage methods and irrigation with low-pressure water supply should be advanced.

Methane Emissions

Methane generated by agricultural activities amounts to 42,000 tons, 32,000 through enteric fermentation and 10,000 from manure. The amount generated by enteric fermentation can be cut down by 25% through feed additives and genetic improvements. However, since the number of milking cows is expected to increase with the growth of the population, significant change is not anticipated. The amounts generated from manure can be cut down drastically (assumed 75% reduction). Improved manure management will lead to aerobic stabilization, will reduce methane formation, will produce a better agronomical product and will decrease odors. Licenses to operate farm animal operations should demand proper handling of manure.

N_2O Emissions

Agriculture is the major source of N_2O. Anthropogenic emission of N_2O is likely to be most intensive in agricultural systems that have high N input. It is estimated that, on average, 1.25% of the nitrogen applied to soils is converted to N_2O.

The annual application of nitrogenous fertilizers in Israel amounts to 61,000 tons as N, and the application of organic nitrogen, as manure, is some 30,000 tons. Thus, the estimated emission of N_2O is 1,200 tons, or an equivalent emission of 374 thousand tons CO_2/yr.

About 1/3 of the emission of N_2O could be reduced through the use of better agronomic techniques (i.e., optimizing tillage irrigation and drainage, matching N supply with crop demand) and better fertilizers, mostly controlled release fertilizers. These recommendations are easy to implement and carry the additional benefits of minimizing nitrate pollution of water and increasing the profitability of farming.

Table 5.13: Recommendations for Reducing Greenhouse Gas Emissions in Agriculture

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	Remarks
10% increase in crop coverage	Decrease of emissions by 0.5 million tons	Existing	Depends on agriculture policy		0.8	Serves other national aims: preserving open space, green lands
10% decrease in crop coverage	Increase of emissions by 0.5 million tons					
Minimal tillage, 25% of land	2 million tons over 10 years	Existing	Usually saves expenses for farmers		0.3	
Improved feeding to cattle	8000 tons methane, 0.2 million tons CO_2	Existing		0.3		
Improved manure handling	2500 tons methane, 0.1 million tons CO_2	Existing		0.16		Better product, less odors
Improved fertilizer application	1200 tons N_2O, 0.4 million tons CO_2	Existing, requires improvements		0.6		Less water pollution

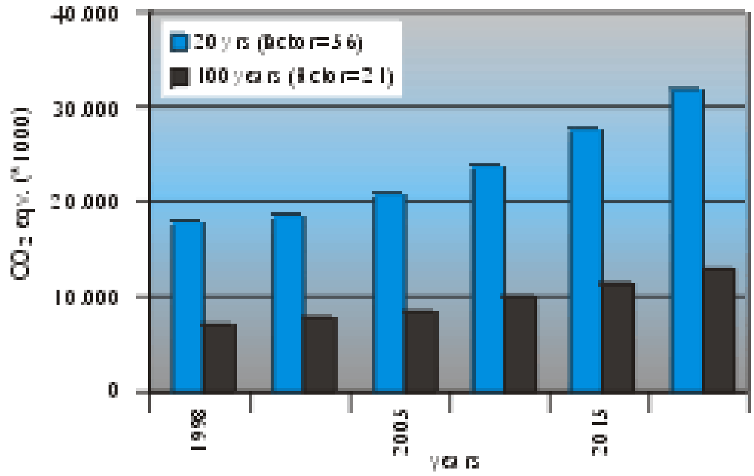
Solid Waste and Sewage Sludge

Waste disposal in landfills creates anaerobic conditions in which the organic material partially degrades to biogas which contains 50% CH_4 and 50% CO_2. Emissions from landfills reach their maximum when landfill gas (LFG) is neither treated, used as a gas source or burned to CO_2.

The global warming potential of CH_4, compared with CO_2, is 56 and 21 for 20 and 100 year time horizons, respectively. Methane production potential in 1996 was 7.8 million tons CO_2 equivalent for a 100 year time horizon, or 12% of the total CO_2 equivalent emitted in 1996.

The following figure presents the forecast for greenhouse gas emissions from waste under a "business as usual" scenario for 20 and 100 year time horizons. The scenario is based on a yearly growth of 2-3% in the amount of municipal solid waste produced, without significant changes in waste management (i.e., landfilling of 90% of the waste).

Figure 5.9: Projections of CO_2 Equivalent Emissions from Waste in the "Business as Usual" Scenario



The potential of sludge generation from municipal wastewater treatment plants is assumed to be 35-40 g dry sludge/capita/day (14.5 kg dry sludge/capita/annum) or 87,000 tons of sludge for a population of 6 million. The carbon content in the dry sludge is about 50%. Therefore, the annual potential of CH_4 formation from wastewater treatment plants is 58,000 tons of methane which are equivalent to 1.2 million tons of CO_2.

In order to estimate annual CH_4 production, it was assumed that all domestic wastewater is treated (not yet a reality in Israel). The total annual potential of methane emissions from solid waste and sewage sludge is 9 million tons CO_2 equivalent.

Alternatives for Solid Waste Management

The following table presents different alternatives for emissions reductions. In practice, all measures are for the emission of CO_2 instead of methane. If all CH_4 produced in landfills is converted to CO_2, emissions will be reduced to 1,670,000 CO_2 equivalent (reduction of 16,230 and 5,564 ktons per year for 20 and 100 year time horizons, respectively). Additional reductions will only be possible with the institution of additional steps such as reduction at source.

Table 5.14: Mitigation Means for Reducing Greenhouse Gases (GHG) by Waste Management

Alternative	GHGs emissions, considerations and assumptions (+ = increase in GHG, – = decrease in GHG)
Landfilling – without LFG treatment	25% of all GHG emissions in Israel, 1996 (CH_4 factor = 56) and 12% (CH_4 factor = 21) – credit for long term carbon storage in the landfill + as a result of transportation to landfill
Landfilling – with LFG flare (assuming 100% efficiency)	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. – credit for long term carbon storage in the landfill + as a result of transportation to landfill
Landfilling – with LFG energy recovery (assuming 100% efficiency)	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. Avoided emissions from conventional energy sources. – credit for long term carbon storage in the landfill + as a result of transportation to landfill
Incineration – without energy recovery	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. + NO_x emissions + as a result of transportation to incineration plant
Incineration – with energy recovery	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. Avoided emissions from conventional energy sources. + NO_x emissions + as a result of transportation to incineration plant
Recycling	*In some products:* Decrease in energy consumption due to lower energy requirements (compared to manufacture from raw products) – Paper recycling increases forest carbon sequestration + as a result of transportation to recycling plant
Aerobic composting	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. – increase in soil carbon storage – increase in yield carbon storage (1 ton dry matter=2 tons CO_2) + as a result of transportation to composting plant + compost machinery emissions
Anaerobic digestion	CH_4 is converted to CO_2, total emissions comprise only 3% of total GHG emissions in 1996. Avoided emission from conventional energy sources – increase in yield carbon storage (1 ton dry matter=2 ton CO_2) + as a result of transportation to AD plant.
Source reduction	Decrease in energy consumption due to lower production Decrease in process emissions Reduced consumption of wood & paper products increases forest carbon storage Avoided transportation emissions

(*) Calculations are per 4 million tons of municipal solid waste

In summary, potential measures for reducing greenhouse gas emissions from solid waste include: extraction of methane gas from landfills (while the table assumes 100% efficiency, a more realistic assumption would be production of 50% of the methane), waste incineration, aerobic composting of waste, anaerobic digestion, recycling and reduction at source.

An analysis of costs clearly shows that the most economic solution to reduce greenhouse gas emissions from municipal solid waste is to compost it ($8 for a reduction of a ton of CO_2) while the most expensive measure is to incinerate it. Sludge may be treated using the same means as organic municipal solid waste (aerobic or anaerobic compostation, incineration).

Table 5.15: Recommendations for Reducing Greenhouse Gas Emissions from Waste

Alternative	Efficiency of methane reduction	CO_2 reduction tons/year	$ investment for reducing CO_2 eq. ton	Percent reduced of sector's emissions	Percent reduced of total emissions	Remarks
Landfilling with gas collection-landfill gas flare	50% of methane will be burnt	4 million tons	10	48	6.5	Difficult to control
Landfilling with gas collection and energy recovery	50% efficiency	4 million tons	24	48	6.5	Credit for energy production
Aerobic composting	Oxidation efficiency 90%	7.2 million tons	9	86	11.1	Need for waste separation
Anaerobic digestion	Oxidation efficiency 100%	8 million tons	39	100	12.9	Credit for energy production
Incineration	Oxidation efficiency 100%	8 million tons	195	100	12.9	Need to control conventional and toxic air pollutants, credit for energy production

Summary of Recommendations

The mitigation measures listed in the following table were assessed according to three scenarios, with the optimistic scenario assuming implementation of the full potential and the pessimistic scenario assuming only partial implementation. Most of these measures do not require significant changes in current processes and practices, some will contribute economic benefits, and nearly all will provide a double dividend in the form of additional advantages, such as significant environmental improvements in air pollution reduction, transport congestion reduction, and improved urban quality. In addition, some measures, such as improved waste treatment, may be implemented within a few years, while others, such as energy-conscious building, improvements in transport and in industry, and introduction of cogeneration and combined cycle energy production, may be gradually implemented over a longer time period.

Table 5.16: Summary of Recommendations
on Mitigating Measures

Measure	Expected reduction of emissions (Percent of total)			Additional advantages
	Pessimistic scenario	Reasonable scenario	Optimistic scenario	
1. Waste and sewage sludge treatment	8	10	12	Solution of waste problem
2. Switch to natural gas in power stations	3	8	11	Reduction of air pollution
3. Energy production in combined cycle	2	5	7	Use of higher efficiency fuels. Postponement of new power generation plants
4. Cogeneration	2	3	4	Use of higher efficiency fuels. Postponement of new power generation plants
5. Energy-conscious building	3	5	7	Energy savings. Postponement of new power generation plants
6. Transport improvements	2	4	6	Reduction of air pollution. Improvement of urban environment
7. Improvements in industry (without cogeneration)	4	7	10	Improvement of air quality. Postponement of new power generation plants
8. Agricultural changes	0.5	1	2	Reduction of groundwater and air pollution
Total	**24.5**	**43**	**59**	

6. Forecasts, Economic Analysis and Proposed Policy

Introduction

Israel's proposed action plan for climate change, drafted within the framework of the Israel Environmental Policy Research Center, responds to the international community's commitment to reduce greenhouse gases. It is anticipated that implementation of profitable technological solutions to reduce emissions will contribute additional benefits to the environment and to the economy – in the form of energy conservation, reduction of air pollutants, more efficient taxes, and increased economic competitiveness in the international arena. Such solutions have not yet been implemented due to legislative, bureaucratic or political obstacles, or due to under-utilization of available knowledge. The proposed action plan, which will be submitted to the government, identifies these weaknesses and proposes solutions to overcome impediments by harnessing forces in the Israeli economy for the requisite economic and environmental change. The plan should serve as part of Israel's building and planning infrastructure for the 21st century.

Emission Reduction Scenarios and Economic Impacts

Israel's proposed mitigation options were accompanied by a preliminary estimation of the economic costs of emission reduction under several scenarios. All scenarios assume that under "business as usual" conditions, an annual increase of 3.5% in greenhouse gases will take place.

The economic assessment is based on the following principles:

1. The base year for greenhouse gas emissions was set as 1996 rather than 1990.
2. The target year for emissions reductions to 1996 levels was examined for two different years: 2010 and 2015.
3. A constant percent of reduction was set for each year from 2000 until the target years.
4. For the first two scenarios, it was assumed that natural gas will gradually be introduced into the energy production sector beginning in 2003 (following a run-in period). For the two other scenarios, this assumption was not taken into account and impacts of energy production without natural gas were examined.
5. It was assumed that methane treatment in landfills will be gradually regulated and that as of 2002, maximum methane treatment will take place.

6. Since the above-mentioned activities – natural gas and methane treatment – implement previous policy which was not targeted at emission reduction, they are considered "sunk costs" which are not included in the economic scenarios of the climate change policy.

Methodology

While Israel's mitigation options examine cost-effective technological substitutes, the proposed action plan is based on a demand management methodology which strives to reduce energy consumption by means of taxes, incentives for removal of market failures, and cost-effective technological and market substitutes.

The demand management methodology is based on five phases:

1. Assessment of the "business as usual" scenario and the necessary greenhouse gas reduction.
2. Assessment of necessary greenhouse gas reduction after implementation of existing policy.
3. Construction of demand curves as a function of fuel and electricity pricing.
4. Simulation of a carbon tax on fuel and electricity at levels that will achieve necessary emission reductions.
5. Calculation of costs and benefits based on the imposition of a carbon tax.

Since this analysis is based on price hikes alone, the results should be viewed as an upper limit which will not be reached if the necessary technological and policy changes are undertaken.

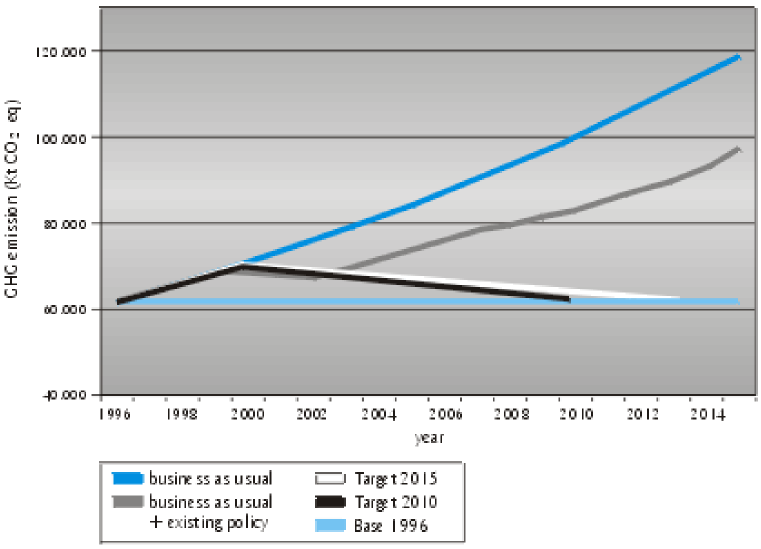
Assumptions

1. Population growth rate of 2.5% per year.
2. Greenhouse gas emissions growth rate of 3.5% per year.
3. Existing policy: switch to natural gas and methane treatment in landfills by 2002 at 75% efficiency.
4. Double dividend (dd) from reducing income taxes and instituting a green carbon tax (29%).
5. Benefits from reducing accompanying pollutants and reducing damages to health, environment and infrastructure, calculated according to a dollar value: sulfur dioxide – $3,510 per ton of pollutant; nitrogen oxides – $2,640 per ton of pollutant; and particulates – $10,642 per ton of pollutant (European Commission, 1998).
6. Seawater desalination and other adaptations to climate change were not analyzed due to uncertainties.

Scenarios of Greenhouse Gas Emissions

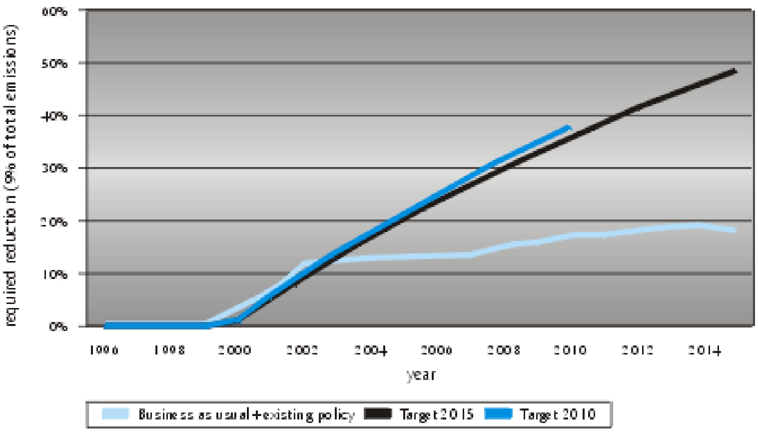
The following figure presents potential scenarios of greenhouse gas emissions and of annual reductions based on a comparison of the "business as usual" scenario and the undertakings for target years 2010 and 2015. The next figure shows the percentage of reduction obtained as a result of introduction of natural gas and methane treatment out of the total emissions in the "business as usual" scenario. These reductions are defined as "sunk costs."

Figure. 6.1: Scenarios of Greenhouse Gas Emissions (Kilotons CO_2 Equivalents)[1]



[1] Assuming 2.5% annual population growth, 1% growth in standard of living

Figure 6.2: Potential Scenarios of Emissions Reductions as Percentage of the "Business as Usual" Scenario



On the basis of these figures, the following conclusions may be made:

- Greenhouse gas emissions in 2010 in a "business as usual" scenario will reach 100,000 ktons CO_2 equivalent.
- Greenhouse gas emissions in 2015 in a "business as usual" scenario will reach 118,000 ktons CO_2 equivalent.
- The difference between the "business as usual" scenario and compliance with an emission level identical to 1996 is 37,900 ktons CO_2 equivalent for 2010 and 56,200 ktons CO_2 equivalent for 2015.
- Transition to natural gas in electricity generation will reduce greenhouse gas emissions by 7,600 ktons and 11,500 ktons for 2010 and 2015, respectively, in relation to the "business as usual" scenario.
- Methane treatment in landfills will reduce greenhouse emissions by 9,700 ktons and 11,500 ktons for 2010 and 2015, respectively, relative to the "business as usual" scenario.
- Without any additional costs to the economy, a switch to electricity generation by natural gas and methane treatment in landfills can bring about 46% and 38% of the necessary reductions for the years 2010 and 2015, respectively.
- Reduction of the balance (20,600 ktons and 35,900 ktons CO_2 equivalent for the years 2010 and 2015 respectively) should be implemented by means of demand management: a carbon tax and implementation of specific policy measures in different economic sectors.

Table 6.1: Necessary Reductions
(in ktons CO_2 equivalent)

	Target years	
	2010	2015
Business as Usual Scenario	37,900	56,200
Business as Usual + Existing Policy	20,600	35,900

Results of the Economic Analysis

The results of the economic analysis are summarized in the following figures and tables. As may be seen, the economic cost is presented in terms of "dead weight loss." The attendant economic impact is estimated at a maximum of 2% of the GDP of reduction by 2015 is required, or 1.4% of the GDP if reduction by 2010 is demanded. While reduction costs will clearly increase if natural gas is not introduced, the accompanying benefits from reducing other pollutants and the impacts of the "carbon tax" should be taken into account. The present analysis did not take account of additional benefits which may result from reduced private vehicle use (e.g., time savings and fewer road accidents).

Figure 6.3: Dead Weight Loss (as Percent of GDP) for 2010 and 2015

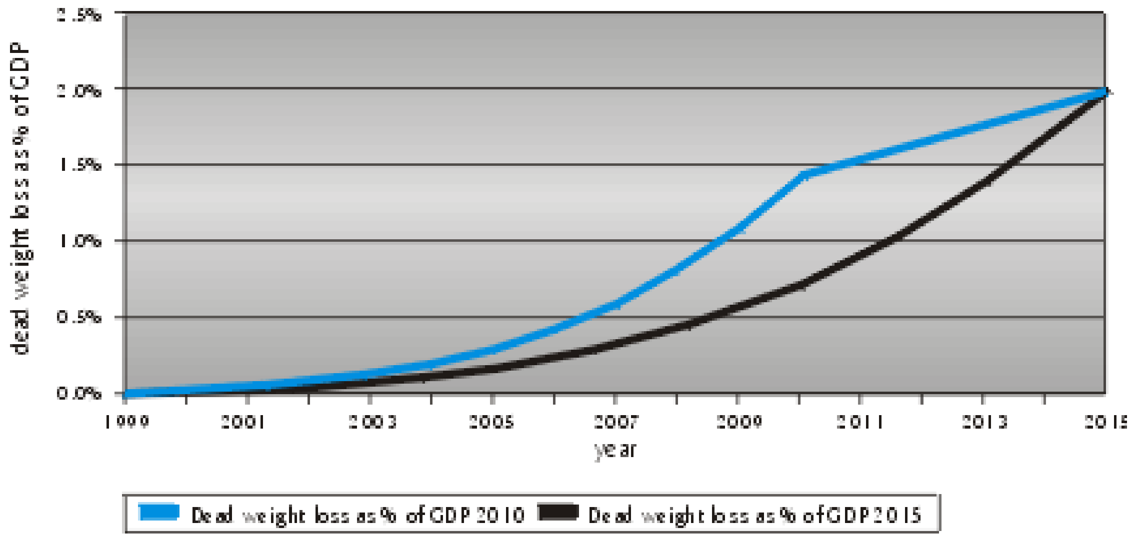


Table 6.2: Summary of Economic Analysis
Based on a Carbon Tax ($ Million)

	Income from tax	Maximum loss to "dead weight loss"	Double Dividend	Benefit from pollution reduction	Maximum addition to "dead weight loss" without switch to natural gas
Scenario 1 – 2010 Target Year	6,641	2,251	1,925.9	560.1	258.48
Scenario 2 – 2015 Target Year	8,256	3,791	2,394	761.4	530.61

Figure 6.4: Economic Cost for Emissions Reductions Not Including Accompanying Benefits (2010)

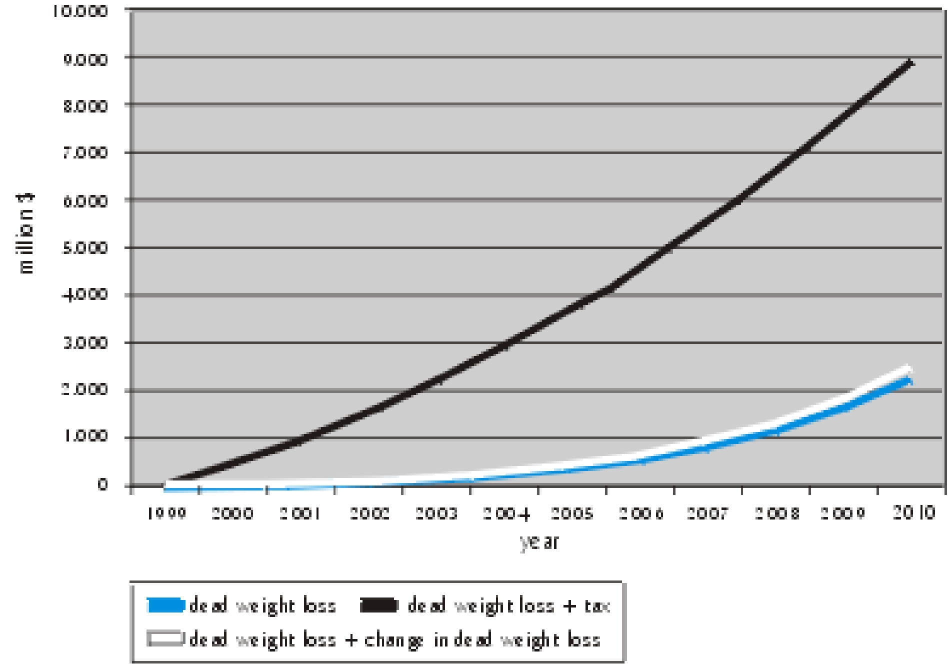


Figure 6.5: Economic Costs for Emissions Reduction Including Accompanying Benefits (2010)

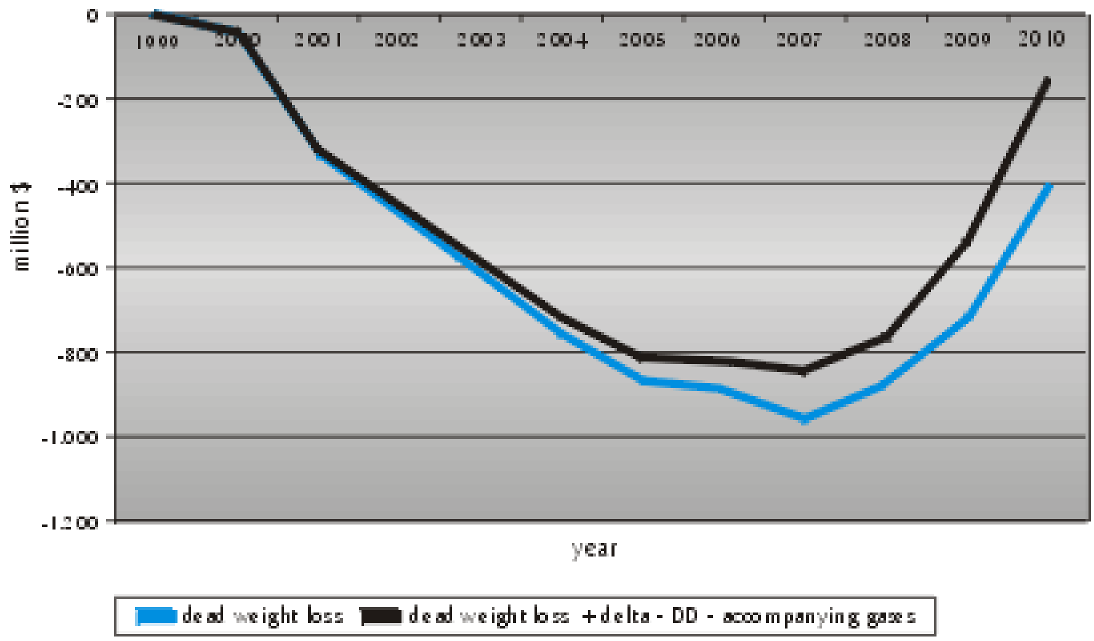


Figure. 6.6: Economic Cost for Emissions Reductions Not Including Accompanying Benefits (2015)

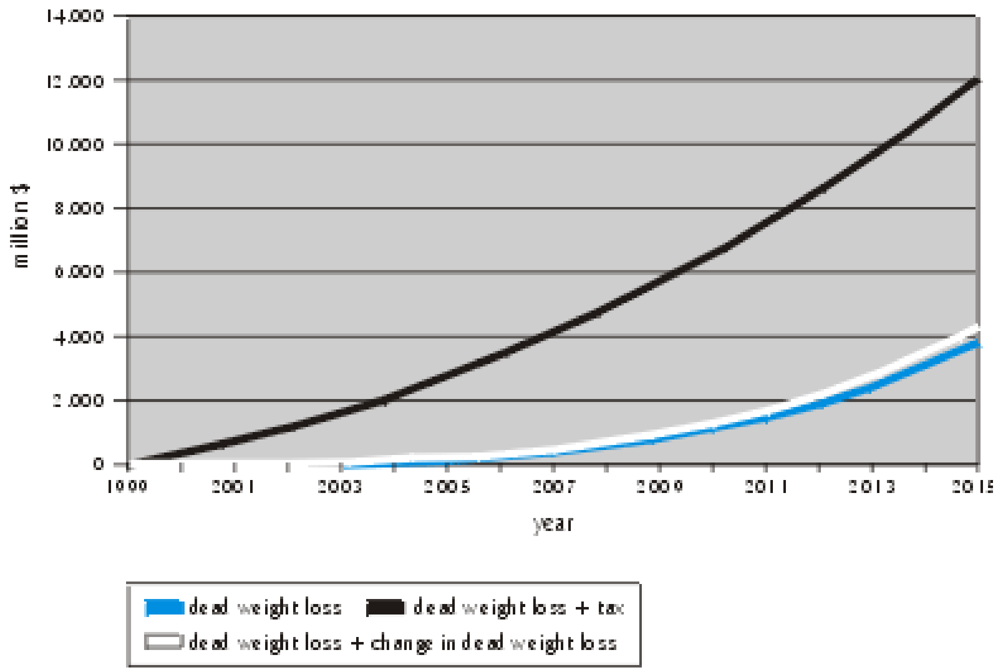
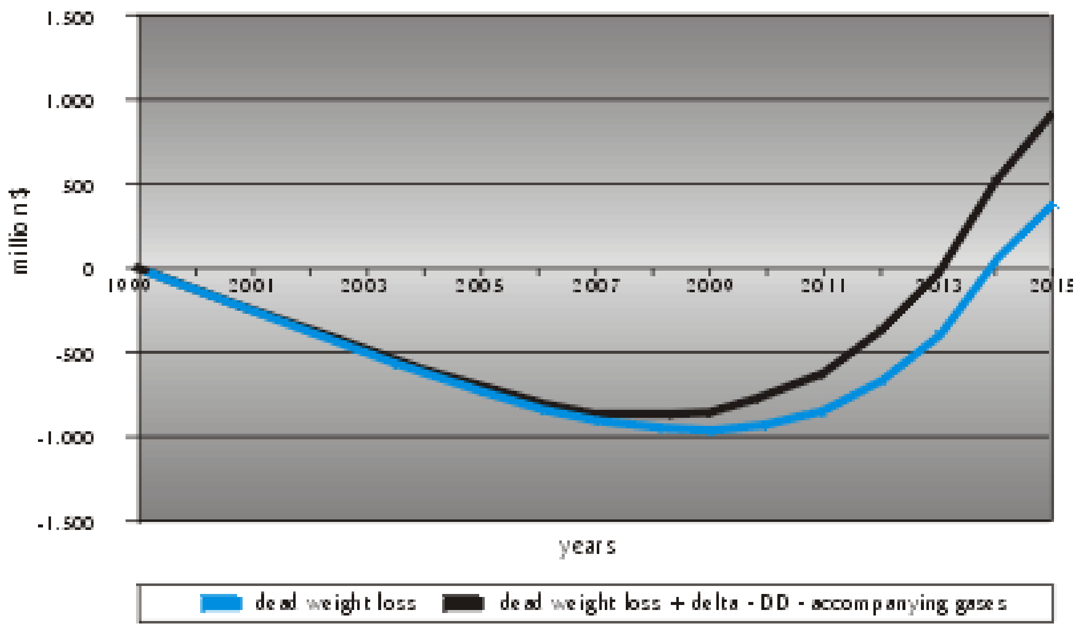


Figure 6.7: Economic Costs for Emissions Reductions Including Accompanying Benefits (2015)



Objectives of Israel's Proposed Action Plan

The primary objectives of Israel's proposed climate change action plan include the following:

- Development of implementation capacity: The action plan is a prerequisite for the development of implementation capacity in national institutions and economic sectors.

- Identification of appropriate policy and technologies: The action plan is intended to identify policy guidelines and measures for reducing emissions. Cost-effective technologies and policy changes are expected to benefit both the environment and the economy.

- Identification of necessary changes in planning and policy: The action plan is intended to identify shortcomings in current policy and to help integrate climate change issues into the national planning process and into relevant plans at all government levels.

- Promotion of awareness among decision makers, economic sectors and the public: The action plan is intended to increase awareness of the potential impacts of climate change on different sectors of the economy, infrastructure, daily life and society in general.

Therefore, the proposed action plan provides guidelines for activities which will increase economic efficiency while reducing emissions. Proposed actions focus on two aspects of market efficiency: technological improvements (discussed in the previous section on mitigation options) and removal of existing economic failures through changes in legislation, research, education and training. Optimal implementation of recommended measures in different sectors will depend on government decisions and on implementation of a macro-economic policy directed at savings in the inputs leading to greenhouse gas emissions.

Although a greenhouse gas reduction policy requires monetary investments in cleaner production technologies and higher prices for certain products, it is anticipated that compliance with international obligations set out in the Kyoto Convention will be advantageous to the economy by providing the following benefits:

- Health and environmental benefits as a result of reduction of additional pollutants including sulfur dioxide, nitrogen oxides and particulates.
- Economic benefits associated with reduction in traffic and increase in energy-efficient buildings. Additional benefits, not taken into account in the economic analysis, include reduction in traffic accidents, savings in time, and savings in parking areas in city centers.
- A double dividend effect in the tax system as a result of a carbon tax.
- Improvement in Israel's international standing, both environmentally and economically.

Summary of Recommendations

Removal of market failures associated with over-regulation:

- Creating competitive conditions in the energy production market by providing the legal framework for small (and "clean") producers to sell electricity to the distribution system. Expanding the privatization process of the electricity-production sector while internalizing the shadow price of electricity production (i.e., charging the true cost including the externality and the peak load pricing component).
- Reducing energy use in buildings and industry through changes in relevant building codes, ordinances and zoning laws in a manner that promotes green building concepts.
- Considering energy requirements of appliances and equipment when issuing import and operation licenses, and marking the energy consumption parameters of electric appliances and equipment.
- Activating cost-effective technological improvements in different market sectors (as per the mitigation options enumerated in the previous chapter) whenever there are economic advantages for doing so.

Government intervention through administration, R&D and education:

- Seeking solutions to reduce transportation congestion including light rail, natural gas and electricity-powered bus transit, high-occupancy vehicle routes, and public transport hubs at city and metropolitan outskirts.
- Advancing an overall metropolitan planning process that emphasizes reduced daily travel between residential, employment and service areas.
- Promoting research and development on "clean" energy production, carbon fixing and resource conservation within existing sectors.
- Creating a framework of training, demonstration and consulting centers to serve the different sectors and ease the integration and adjustment to new technologies and regulations.

Changes to the tax system:

- Imposing a carbon tax that will replace existing taxes. A gradually increasing tax is recommended according to one of the two scenarios that were analyzed (2010 or 2015 target years for achieving 1996 levels of emissions).

Creating a government mechanism to lead, facilitate and monitor the necessary changes:

- Setting up a senior steering team, headed by the directors general of government ministries, to ensure progress and implementation, starting with cabinet approval for the action plan through initiation of recommended regulatory and sectoral changes.

7. Existing Policies and Measures

Environmental Policy

The Ministry of the Environment was established, by government decision, on December 25, 1988. Its policy is based on the following principles, several of which are prerequisites for the reduction of greenhouse gases:

1. Promoting environmental protection and preventing environmental and ecological deterioration based on sustainable development principles.
2. Upgrading environmental protection on the national agenda and assimilating it into the decision making processes of central and local government.
3. Encouraging wise use of environmental resources to promote savings and prevent irreversible damage through planning, technological and economic measures.
4. Basing environmental management on an integrated systems approach.
5. Assimilating the "polluter pays" principle.
6. Preventing, eliminating or reducing environmental problems at source.
7. Implementing the precautionary principle.
8. Promoting public participation through cultivation of environmental values, recruitment of organizations and involvement of local authorities in environmental activities.
9. Impacting public behavior through enforcement and conflict resolution.
10. Promoting environmental justice and equity in different geographic areas and different segments of the population.
11. Promoting regional cooperation.
12. Promoting international cooperation.
13. Developing an integrated database on the state of the environment in Israel.

Over the past decade, standards and regulations have been revised and updated based on evolving research in economics, technology, health and agricultural effects. Monitoring and inspection systems have been set up which provide an up-to-date picture of the state of the environment, allow authorities to predict environmental trends, enable alert and response actions, and contribute to the development of pollution abatement programs. "React and cure" measures have been replaced with "anticipate and prevent" measures.

Environmental Action

The following actions, taken in recent years to improve environmental quality and promote sustainable development, contribute either directly or indirectly toward the reduction of greenhouse gas emissions.

Energy and Industrial Sector

- Near completion of a 24-station national monitoring network, composed of population and transportation stations, regional control centers and a national control center for data storage, analysis and display. The network, which monitors concentrations of sulfur dioxide, nitrogen oxide, ozone, carbon monoxide, particles smaller than 10 μm and hydrocarbons, provides real-time information about air quality throughout the country. The information facilitates enforcement of air quality standards, identifies major sources of air pollution, and informs the general public about air quality levels. While these gases do not directly act as greenhouse gases, they do react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases.
- Reduction of sulfur dioxide emissions from the country's oil fired power plants from 113 thousand tons in 1990 to 55 thousand tons in 1999, mostly through the use of low-sulfur fuel.
- Preparation of personal decrees for air pollution abatement from power plants under the Abatement of Nuisances Law and drafting of regulations for pollution prevention from power generating stations. These decrees and regulations will mandate use of low and very low sulfur fuel, require old power units in Tel Aviv to switch to natural gas by 2003, phase out old oil-powered stations and replace them with combined cycle gas turbines by 2005, obligate use of best available technologies, demand continuous monitoring and reporting, and oblige the reduction of greenhouse gas emissions.
- Preparation of environmental impact assessments for power plants, oil refineries, cement plants and other industrial plants expected to adversely impact the environment.
- Issuance of thirty personal decrees for air pollution abatement to industrial plants.
- Incorporation of environmental conditions including limits on air pollution into the business licenses of industrial plants. According to the Licensing of Businesses Law, these conditions may be enforced through investigation and criminal indictment or through administrative closure if risk to the environment is anticipated. Framework specifications for different industrial sectors have or are being prepared for, *inter alia*, gas turbines, cement plants, dairy farms, oil and coal-fired power plants, and refineries.

- Establishment of a joint forum of the Ministry of the Environment and the Israel Electric Corporation to advance major issues, and appointment of expert teams to determine the potential for alternative energy use.
- Preparation of a Covenant on Implementing Standards on Pollutant Emissions into the Air between the Environment Ministry and the Manufacturers Association. This is the first example in Israel of voluntary compliance by industry of emission standards which have not yet been promulgated. Some 130 industrial plants have signed the Covenant.
- Initiation of interministerial studies on the external costs of air pollution, transport and energy. Transport recommendations call for taking account of such externalities as health effects, accident costs, contribution to the greenhouse effect and energy use. The first interim report of the interministerial team on quantification of the costs of air pollution states that the externalities of air pollutants caused by fuel combustion, electricity generation, transportation and industry must be assessed in order to formulate policy tools which implement a sound environmental policy. The final recommendations will emphasize fiscal measures to improve air quality both in the transport and electricity generation sectors. Moreover, the cost of energy conservation steps will be reviewed, including thermal insulation, home electrical appliances, heating, cooling, cogeneration and alternative energy.
- Preparation of a report by an interministerial team of experts on development and exploitation of alternative energy. The report calls for investments in energy conservation, increased adoption and use of renewable sources of energy, and development and support of technologies utilizing alternative energy. The report notes the country's wide reservoir of knowledge and expertise both in technologies for the utilization of alternative sources of energy and in energy conservation. To promote the subject, the report recommends that Israel must support research, development and demonstration, must internalize externalities in the costs of energy, must undertake legislative, administrative and economic steps to conserve energy, and must encourage fair competition among energy producers.
- Operation of a wind farm with an installed capacity of 6 MW and preparations for the operation of two more farms with an installed capacity of 15 MW.
- Initiation of a project on the economic benefits of environmental investments at the factory level in order to stimulate the adoption of cost-effective, profitable and environmentally-friendly processes and technologies.
- Promotion of ISO 14001 (environmental management systems) and incentives to companies with ISO 14001 accreditation, or in the process of accreditation.

- Legal requirement for all large-scale industrial and institutional consumers of energy to appoint energy conservation officers, to monitor energy consumption and to conduct energy conservation surveys.
- Launching of an ecolabelling system, dubbed the "Green Label," and approval of product standards and labels for energy-efficient products.

Transport

- Improvements in fuel quality including reduction in the sulfur content of diesel for transportation from 0.2% to 0.05%, with plans for a further reduction to 0.015%.
- Introduction of lead-free gasoline and catalytic converters.
- Reduction in benzene content of fuel from 5% to 1%.
- Roadside inspection and enforcement of emission standards with the aid of dedicated mobile air monitoring units.
- Preparation of personal decrees for the prevention of unreasonable air pollution for Israel's two major bus cooperatives which include a timetable for pollution reduction, switch to improved fuels and other measures. Both bus cooperatives have already switched to low-sulfur diesel fuel in major cities.
- Removal of obstacles to the introduction of vehicles powered by liquefied petroleum gas (LPG), especially buses.
- Initiation of two demonstration projects on buses with regard to diesel oxidation catalysts and particulate traps.
- Preparation of an air pollution forecasting model for the Tel Aviv metropolitan area and other cities.
- Inauguration of a "car free day" in Tel Aviv on September 22, 2000 as part of the European Commission's "In town without my car" initiative.

Residential and Commercial Sector

- Promulgation of a 1980 regulation requiring the installation of solar water heaters in new buildings and a 1986 requirement that new residential buildings must also comply with a standard which mandates thermal insulation levels that provide thermal comfort at reasonable energy consumption. This accounts for 80% of all water heating requirements annually and provides a savings to the energy market of 3% of primary energy consumption.
- Formulation and dissemination of environmentally-responsible building guidelines to help incorporate green construction materials and building practices into construction plans in

the public sector. The guidelines deal with all stages of construction and relate to energy use and indoor environment including daylighting.
- Organization of a "Green-Building Seminar" and establishment of an interministerial committee on green building.
- Promotion of green building projects including planning of a green neighborhood in Kfar Saba.
- Preparation of a planning manual on green building in school buildings which relates to the building envelope, building orientation, window shading, energy-efficient use, building materials, etc.

Waste

- Financial and professional aid to over a hundred local authorities for environmentally safe solid waste disposal in regulated landfills.
- Closure of 74 out of 77 unregulated landfills for municipal solid waste and their replacement by a small number of regulated landfills. Stringent conditions for operation of regulated landfills prescribe state-of-the-art technologies for every stage of landfilling from siting to post-closure including sealing and landfill gas collection and use.
- Treatment of over 75% of the country's solid waste in an environmentally sound manner in comparison to treatment of only 10% of the waste in 1993.
- Increase in recycling from 4% of post-consumer municipal solid waste in 1993 to 15% in 1999 (most of which is composted).
- Enactment of a Bottle Deposit Law and a Recycling Law.
- Enactment of a landfill tax which will internalize the externalities of landfilling and help promote other alternatives such as composting, recycling and energy recovery.
- Drafting of recommendations on upgraded standards for wastewater and sludge treatment.
- Government support for a demonstration project on bio-treatment of municipal waste to produce clean energy and compost. The process automatically separates recyclable matter such as metals, plastics and glass from unsorted household waste and transforms the organic fraction of the waste (about 37% of the waste) into biogas and soil conditioning compost.

Agriculture

- Establishment of an interministerial committee on treatment of animal waste in livestock farms, and formulation of guidelines for specific sectors.

- Financial grants to dairy farms for environmental investments in recycling programs for agricultural wastes and pollution prevention systems.
- Introduction of controlled fertilization, using drip irrigation methods and slow-release fertilizers.
- Initiation of surveys and masterplans on treatment of solid and liquid waste originating in livestock farms in different parts of the country, and establishment of regional manure collection and recycling sites.

Land Use and Forestry

- Approval of the National Masterplan on Forests and Afforestation in November 1995 which designates 160,000 hectares for the development and conservation of forested areas – over 15% of Israel's total land area north of Be'er Sheva, where most of the population is concentrated.
- Development of forestry and forest rehabilitation methods for drylands. Agro-technology systems include runoff and rainfall catchment basins, reuse of treated wastewater, utilization of brackish water for salt-tolerant crops and trees, and development of saline-resistant crops. These have allowed for the development of agroforestry and farming in areas with minimal rainfall.
- Preparation of national masterplans – Israel 2020 and the National Masterplan for Building, Development and Conservation – which relate, among other elements, to spatial conflicts within the small land area of the country. These plans are based on the principles of concentrating development in and around urban centers, protecting open space and limiting suburban sprawl, and improving mass transit.
- Preparation of a draft sustainable development strategy for Israel. As part of the process, seven sectorial target groups were established on industry, energy, transport, tourism, urban sector, agriculture and biodiversity. Discussions were conducted in a round table framework with representatives of central government, NGOs, academic experts, professionals, and public and private enterprise, and focused on major issues in each sector, reviews of existing information, forecasts and scenarios, and potential policy directions toward achieving the goals of sustainable development. Energy conservation and promotion of alternative energy were central recommendations of the sustainable energy group.

8. Vulnerability and Adaptation

Introduction

The climate in the Middle East has varied considerably over the past 10,000 years, with changes in precipitation ranging between 15% to 40% of the current average rainfall in southern Israel (Issar, 1995, 1996). The historical high correlation between human settlement and climate change attests to the sensitivity of systems in this area to climate change. Yet, available knowledge does not suffice for distinguishing between sensitivity and adaptability of each of the systems to the climate change projected by the scenarios for Israel. The following is a first attempt to assess how systems in Israel will react to climate change and suggests a number of potential adaptations.

Environmental Impacts

Water

- Surface runoff, flash floods and inundations: Increased rain intensity combined with a reduction in overall precipitation will increase the frequency and intensity of surface run-off events, cause topsoil erosion and loss of water, and result in loss of vegetation and hence higher frequency and intensity of run-off events. Increased surface run-off will exacerbate desertification.

The increased rainfall intensity will also increase surface run-off from urban areas. This, together with the increased run-off from open areas, will generate more frequent and more powerful flash floods that will harm infrastructures and life and will lead to increased water loss.

Increased run-off, coupled with sea level rise and increased rain intensity, may cause flooding and inundations. A decrease in the hydraulic slope between drainage systems (or streams) and sea level will reduce the efficiency of water transfer and increase the probability of flooding. Lack of efficient drainage systems in the coastal plain, an area of low altitude and high population density, may make this area highly vulnerable to projected increases in rain intensity and surface runoff (Gressel *et al.*, 2000).

- Aquifer recharge and surface reservoirs: Reduced infiltration rates caused by increased surface runoff will reduce aquifer recharge. With the added effect of aquifer salinization due to sea level rise and the accelerated use of ground water, climate change is expected to adversely impact water resources.

Although larger annual storage capacity will be required, it is anticipated that average storage volume in surface reservoirs may fall by as much as 25% by 2100 due to lower rainfall and increased evaporation. Water supply will further decrease as a result of increased deposition of sediments in reservoirs and channels due to increased surface runoff and soil erosion.

- Water quality: Increased runoff and soil erosion and degradation will leach more ions, nutrients and suspended particles into the water. Drinking water quality will deteriorate due to an increase in suspended particles, organic matter and pollutants. Eutrophication will further increase the organic load and oxygen demand, leading to a further decrease in water quality.

- Soil: Decreased annual rainfall and lengthened intervals between rains, coupled with increased temperatures and evaporation, will reduce plant productivity and microbial activity, with a concomitant decrease in soil organic matter. This will reduce water-holding capacity and soil permeability. An increase in runoff velocity and intensity will erode the most fertile topsoil, further reducing productivity. Soil salinity – already high – will increase due to higher evapotranspiration and lower leaching effect of the reduced rains. The aggregate effect of these and other processes will lead to desertification in a wide range of lands and habitats, especially in the semi-arid regions of Israel (Imeson and Emmer, 1992; Lavee *et al.*, 1998).

Dry sub-humid and semiarid lands in the Mediterranean basin are prone to desertification when impacted with just minor climatic changes. This vulnerability is demonstrated by the sharp change in soil structure between Mediterranean (dry sub-humid) and desert (semi-arid) ecogeomorphic systems, occurring where annual rainfall is around 300 mm: organic matter rapidly declines, water-holding capacity diminishes and soil erosion occurs more readily. This sharp transition in soil conditions suggests that only a relatively small climatic change is needed to shift the border between desert and non-desert systems in Israel (Lavee *et al.*, 1998).

Ecosystem and Biodiversity Impacts

Through its effect on biodiversity, climate change can alter the composition of species, create new species compositions and even significantly reduce an ecosystem's biodiversity, thus adversely impacting the provision of ecosystem services. Biodiversity in Israel is already impacted by human activity. This makes it especially sensitive to the impacts of climate change and puts at risk the effective provision of goods and services by ecosystems.

- Movement of ranges: Animals are used widely as biological indicators of global climate change since they illustrate the sensitivity of different ecosystems to these changes. In the Mediterranean basin, a northward shift of 300 to 500 km and an upward shift of 300 to 600 m are projected with a 1.5°C warming (Jeftic, 1993).

In Israel, where flora and fauna originate in several different climatic regions, a species will respond by range change depending on its origin. Cold-sensitive species, usually of southern origin, are expected to benefit from warming, while mesic, heat-sensitive species that usually reach their southern limit in Israel, will be adversely affected (Naveh, 1993).

- Loss of biodiversity: The speed and magnitude of climate change may elicit different response by different levels of ecological organization, namely populations, species, communities and ecosystems. Small, isolated populations are usually highly sensitive to environmental changes. Climate change, therefore, is expected to adversely affect populations in the isolated high mountains in the north of Israel (Naveh, 1993), in the coastal plain and on the edge of the desert (Safriel, 1993).

Core populations of a species (in the center of distribution) may also be more vulnerable to climate change than peripheral ones (on the edge of their distribution). This is because peripheral populations face relatively variable and unstable conditions under which selective forces tend to maintain higher genetic diversity (Safriel *et al.*, 1994; Kark *et al.*, 1999). The highest variability, durability and environmental suitability are exhibited by sub-peripheral populations living in the ecotone habitats (areas of natural ecoclimatic transition), and not by extremely peripheral populations, which are usually small and isolated.

Endemic species with narrow ecological niches and species whose distribution has narrowed as a result of anthropogenic disturbance are likely to be highly vulnerable to climate change. Sessile and/or habitat-specific species are more sensitive to climate change than mobile species (which are usually more common and widespread) (Houghton *et al.*, 1990).

The effect of climate change on communities is practically impossible to predict due to the enormous number of factors that determine community assembly. Because Israeli flora and fauna have various origins, the response of species and communities to climate change is expected to differ across lands and habitats.

Sensitive ecosystems in Israel include the coral reefs of the Red Sea, the coastal wetlands, and isolated mountain ecosystems such as the Hermon, Meron and Carmel mountains. The most dramatic changes in ecosystem structure and composition are likely to occur in the semi-arid region of Israel, the non-desert/desert ecotone.

- Migratory birds: All ecosystems of Israel are affected by the flux of migratory birds that use the country as a flyway between Europe and Africa twice a year. Desertification, further exacerbated by climate change, will widen the desert barrier to be crossed by the birds, and will make Israel less hospitable for these migrants (Safriel, 1995).

• Invasive species: Climate change is expected to facilitate the migration and establishment of invasive species in Israel. More frequent *hamsins* (dry hot depressions) may bring invertebrates that migrate with the winds. As an example, five species of rare African migratory butterflies were observed in1998 following a low-pressure cyclone, which carried masses of hot air from Saudi Arabia into Israel (Simon, 1999). A small change in climate may induce significant distribution changes of species moving through the Rift Valley, such as insects, invertebrates and birds. New agricultural pests and human disease vectors may therefore be expected.

The projected rise in sea surface temperatures will also increase the rate of species invasion. Many Red Sea species have already colonized the Mediterranean Sea following migration through the Suez Canal. Some are successfully competing with indigenous Mediterranean species while others, such as the *Rhopilema nomadica* – a jellyfish whose reproduction is temperature-dependent, have proven harmful to humans (Lotan *et al.*, 1992; Lotan *et al.*, 1994). With increased warming, more Red Sea immigrants will colonize, reproduce and persist in the eastern Mediterranean (Agur and Safriel, 1981).

• Desert/non-desert ecotone: Ecotones, areas of transition between adjacent but different environments, serve as repositories of genetic diversity which may be used for rehabilitation or reconstruction of ecosystems of their adjacent ecoclimatic regions if and when these ecosystems lose species due to climate change. Moreover, although ecological changes in response to climate change will occur virtually throughout the country, the desert/non-desert ecotone may provide an early warning of climate change for other parts of Israel.

• Coral reefs: An anticipated rise in background sea temperature will expose corals to an increasingly hostile environment with consequent repeated bleaching (Hoegh-Guldberg and Salvat, 1995; Lough, 1999; Hoegh-Guldberg, 1999a, 1999b; Wilkinson *et al.*, 1999). Coral bleaching in the Red Sea has been observed in recent years, but it is currently unknown whether increased temperature is responsible. Degradation of the coral reef in the Gulf of Eilat by the synergetic effect of pollution and climate change will adversely impact tourism.

• Coastal ecosystems: Extensive coastal development along with accelerated sea level rise may inundate coastal ecosystems and endanger their biodiversity. Most vulnerable are the flat, mostly sandy Mediterranean coastlines, where a 30-cm rise in sea level can flood as much as 60 m of land (Jelgersma and Sestini, 1992). Plant and animal communities will not be able to migrate or expand eastward due to lack of suitable habitats. Aquatic ecosystems within rivers as well as terrestrial ecosystems along the coastline will be endangered by sea level rise and by seawater infiltration of ephemeral river basins (wadis).

• Woodlands: The effect of climate on woodlands in Israel is not regularly monitored . However, based on studies in other Mediterranean countries, it is believed that warming may enhance the activity of invasive pathogens, resulting in increased damage to natural and man-made forests, as well as to crops.

The apparent increase in extreme events has already caused severe damages to forests planted by the Jewish National Fund (JNF), Israel's afforestation agency. The severe droughts of recent years caused high tree mortality throughout the country. The expected increase in extreme weather conditions and higher temperature are expected to increase tree mortality (JNF, 1999a, 1999b).

Most fires in Israel occur in the autumn, when the amount of dry matter is greatest. The highly flammable vegetation becomes thicker and denser with the reduction of mammalian herbivores. Decreased water availability, elevated evapotranspiration, and delayed winter rains may enhance and prolong drought conditions, increasing the probability of fires (Safriel, 1993). Frequent incidences of extreme heat may also contribute to fires.

Because man-made fires have been common in the Middle East for thousands of years, many Mediterranean plants are well adapted to fires, and sometimes can even take advantage of fire effects (Safriel, 1997 and references therein). It is possible, however, that with increased fire frequency these adaptations will not be adequate for restoring woodlands, and rehabilitation efforts following fires will not succeed.

- CO_2 enrichment: The projected increase in atmospheric CO_2 concentration, also referred to as "CO_2 fertilization," is a major component in plant response to climatic change and affects both natural and agricultural ecosystems. The effect is generally positive, but plants diverge in their response to CO_2 enrichment.

The two main positive impacts of increased atmospheric CO_2 are more efficient photosynthesis, leading to improved growth rate, and reduced water loss during CO_2 absorption. CO_2 enrichment also improves plant resistance to soil salinity – a major limiting factor in Israel's drylands. The positive effects of CO_2 enrichment may somewhat counter-balance the adverse effects of water deficit due to decreased precipitation and increased evapotranspiration, and can counteract desertification processes. However, these positive effects may be limited since plant response to the increase in atmospheric CO_2 is not linear. Moreover, some studies have shown that interactions between CO_2 enrichment and other environmental factors may be either positive (under drought conditions, Tubiello *et al.*, 1999) or negative (under heat conditions, Bhattacharya and Geyer, 1993). Thus, the net effect of CO_2 enrichment under climate change is currently unknown, and can only be elucidated through outdoor experiments. Furthermore, the detrimental effect of air pollution on plants may be much stronger than any positive effect of CO_2 enrichment.

Socio-Economic Impacts

- Agriculture: Climate change has broad implications on agriculture. Increased weather fluctuations, especially extreme cold and heat, may endanger both cold- and heat-sensitive crops (Jeftic, 1993). Greater rain intensities and resulting flooding may destroy crops in the coastal plain. The drought effect is expected to intensify, and a shortened winter will further exacerbate this effect. Crops will require more irrigation to account for drought and salinization, but water demand will exceed supply. CO_2 enrichment may reduce the effects of drought and salinization, particularly in the semi-arid region where increased resistance to drought and salinity may be crucial. Finally, Israel's advantage in exporting early crops may be lost when the growing season will be delayed due to the projected delay in winter rains.

The anticipated warming and increased frequency of extreme climatic conditions – mainly excessive heat – will create environmental conditions favorable to the establishment and expansion of pests and pathogens. Drought may also increase crop sensitivity to pests and pathogens, especially in rainfed fields and in drought- and heat-sensitive crops. Climate change induced loss of biodiversity may encompass species that control pests, and progenitors or relatives of cultivated plants that can be used for breeding with their cultivated relatives in order to increase their resistance to pests.

- Fisheries: Fisheries, mainly in the Sea of Galilee, may decline if the projected high water temperatures will reduce water oxygen concentration, change its chemical composition, and increase salinity due to increased evaporation. Eutrophication due to increased surface runoff will promote more frequent algal bloom, which will further reduce oxygen availability and increase fish mortality. The intensified colonization of the Mediterranean Sea by Red Sea species may affect Mediterranean fisheries.

- Mediterranean Sea coasts: Sea level rise may erode coastal structures, adversely affect harbors and other coastal structures (Jeftic, 1993), and lead to collapse of the coastal beach cliff in the central sector of Israel's shoreline (Brachya and Rosen, 1993). Increase in storm frequency and changes in wind directions may enhance coastline erosion and retreat. Israel's heavily populated coastal plain is most vulnerable to coastal erosion (Gressel *et al.*, 2000; Golik and Rosen, 2000). Sea level rise may lead to the loss of valuable lands, buildings and tourist facilities in close proximity to the sandstone coastal cliffs. Vermetid reefs, found in several rocky beaches, are expected to mitigate coastal erosion by decreasing the direct impacts of waves on the shoreline.

- Red Sea coast: Although sea level rise will not extensively inundate the Red Sea coast because of the steep drop of the coastal sea bed, Eilat's narrow recreational beaches and the transportation lines along the beaches may be affected by rising water levels, wave activity and storm conditions.

The Red Sea coral reefs are subtidal, and therefore reduce wave activity less efficiently than the Mediterranean vermetid reefs.

- Dead Sea coast: Reduced water input into the Dead Sea due to anthropogenic causes has led to a continuous lowering of sea level in the Dead Sea. Increased evaporation and decreased precipitation may accelerate this process. Besides its effect on ecosystems, this retreat decreases ground stability. Consequent collapse and formation of hollows along the coastline in this major tourist area may endanger both human life and buildings. It should be noted, however, that increased evapotranspiration may increase the efficiency of salt extraction, aiding the mineral industries.

- Loss of archaeological sites: Underwater sites now covered with sand may be lost or degraded due to coastal erosion and disappearance of sand from the sea floor which will expose the sites to wave attack and oxidation.

- Decrease in hydraulic slope: Sea level rise will decrease the hydraulic slope (water gradient) between water outlets and the seawater table. This will reduce the efficiency of coastal power stations (Brachya and Rosen, 1993; Gressel *et al.*, 2000) and of urban and industrial drainage systems (Jelgersma and Sestini, 1992). More frequent and severe floods during peak water flows will adversely impact such lowland urban areas as the Dan (Tel Aviv) metropolitan area, where intensive urban development has already increased surface runoff.

- Energy: More frequent extreme climatic events and greater seasonal temperature variability will increase energy demands for residential heating in winter and cooling in summer. However, a growing population and higher standards of living are expected to increase requirements at a faster rate so that the effect of climate change on energy requirement may be marginal.

Human Health Impact

- Parasitic diseases: Increased annual and seasonal variability, elevated mean temperature, and extreme weather events may facilitate the spread of existing vectors and the establishment of new invasive ones. Cold-sensitive vectors of human diseases, such as Leishmaniasis, tick-borne diseases and others, which proliferate in summer, are expected to increase with the longer and hotter summers resulting from the projected delay of winter rains.

Reduced efficiency of municipal and industrial drainage system, due to decreased hydraulic slope and greater rain intensities, leading to standing water and swamps, will increase the probability of water-related epidemics (Gressel *et al.*, 2000) such as malaria, cholera, dysentery, West Nile virus fever, giardiasis, bilharzia, etc, mainly in coastal cities. More frequent extreme weather conditions (particularly hot and wet years) might eliminate a climatic barrier to malaria and trigger its recurrence in Israel (Pener *et al.*, 1994). Longer and hotter summers may increase the incidence of cholera, mainly in coastal areas.

- Climate-related diseases: The elderly, children, and people with chronic diseases may suffer more climate-related illnesses (Gressel *et al.*, 2000). Sandstorms and dust storms, which are expected to increase with climate change, will exacerbate respiratory disorders. Climate change may also impact health indirectly, through its combined effect with air pollution.

- Economic costs: Direct and indirect costs of climate change need to be evaluated for all socio-economic systems in Israel. One study, already initiated, aims to come up with a preliminary quantified assessment of the economic costs to society associated with the local impacts of predicted climate change (Shechter and Yehoshua, 2000). Data have been collected on the impact of climate change on agriculture, but wider interdisciplinary research is needed to assess the impact of climate change on land-use and vegetation and the consequential economic costs.

Adaptation

Environmental Adaptations

- Desertification: As a party to the 1996 Convention to Combat Desertification, Israel is committed to combat desertification. Options for combating desertification include: management of rangelands to prevent overgrazing; afforestation in regions of over 90 mm annual rainfall to arrest soil erosion and enhance precipitation at the mesoscale level (Otterman *et al.*, 1990; Sharon, 1993; Perlin and Alpert, 2000); gully management to enhance soil moisture (Lavee *et al.*, 1998), decreased leakage of water, soil and nutrients from desertified lands and increased plant productivity and diversity (Shachak *et al.*, 1998); and implementation of salinity sensitive irrigation practices and breeding of salt- and drought-tolerant crops (e.g., the Biotechnology for Agriculture in Saline Environments project jointly implemented by the Israel Ministry of Agriculture and the University of California at Davis).

- Forest management: The Jewish National Fund (JNF), responsible for afforestation, has begun to plant tree species that proved resistant to the severe droughts of 1998/9 and 1999/2000. Sensitive areas and species have been defined for future care. The JNF and the Israel Meteorological Service initiated a study on the relationship between local climatic conditions and drought damages in Israel's forests in 1999 and 2000. This information will provide quantitative measurement of climatic impact on forestry and allow appropriate planning. Reduction of dry matter – by prescribed and controlled livestock grazing or by reintroduction of mammalian herbivores (Safriel, 1997) – is an adaptation method for the projected increase in fire risk.

Ecosystem Adaptations

- Loss of biodiversity: The following adaptation strategies, also applicable to Israel, were proposed for the projected loss of biodiversity worldwide: prioritizing reserves with local climatic diversity; managing landscape connectivity to facilitate dispersal and migration; and maintaining the natural disturbance patterns that generate resilience (Halprin, 1997). Specific adaptations for Israel are the management of ecotones and of corridors.

- Conservation of ecotones: With climate change, species in the Mediterranean regions of Israel may become extinct, whereas in the desert/non-desert climatic transition zone, at least certain genotypes – probably those resistant to climatic variability – may persist. The latter can migrate to, or be transplanted into the Mediterranean region to restore the species lost there (Safriel *et al.*, 1994). Thus, the immediate conservation of ecotones in Israel may be instrumental in maintaining high genetic diversity and rehabilitating other populations in the future (Naveh, 1993; Kark *et al.*, 1999). More research is needed to determine sensitivity or resistance to climate change among ecotone peripheral populations.

- Conservation of habitat connectivity: Habitat connectivity allows for individuals or propagules to migrate northward and upward as a response to climate change. Maintaining connectivity between ecotones and other ecosystems is recommended worldwide as an adaptation to climate change (Halprin, 1997). North-south cross-Israel corridors, one at each side of the country's major water divide are recommended for conservation. With anticipated climatic and anthropogenically induced changes, these corridors may play a major role in biodiversity conservation in Israel.

Socio-Economic Adaptations

- Agriculture: Israeli agriculture is already impacted by water scarcity and declining economic profitability. New crops and varieties, agrotechnological advances and revised water and investment policies are appropriate adaptations motivated not just by climate change impact. Specific adaptations for climate change impacts include delaying seeding time in response to delayed winter rains, redistribution of lands for agricultural use, and practices for reducing evapotranspiration and consequent loss of soil moisture, such as no-till and straw mulching (Bonfil *et al.*, 1999a, 1999b; Mufradi *et al.*, 1999).

- Human health: Given the level of medical care and standard of life in Israel, it is unlikely that climate-change related extreme events will adversely impact human health. The projected increase in Israel's standard of living is in itself an adaptation to climate change.

The more comfortable and healthy environments of improved urban design provide a possible adaptation to climate change. Improved drainage systems will reduce populations of non-vector mosquitoes and lessen the projected increase in mosquito-borne diseases and epidemics related to flooding. Planting or paving land surfaces in southern cities will reduce the availability of erodible particles and thereby the amount of dust in these desert cities (Tsoar and Erell, 1995; Erell and Tsoar, 1997). This will, in addition, provide an adaptation to the anticipated increase in storm frequency and consequent exacerbation of human respiratory disorders.

- Energy: Energy demands in Israel are rapidly increasing irrespective of climate change, due to population increase and a higher standard of living. However, not enough is currently known about the contribution of climate change to energy requirements through increased seasonal variability and more frequent temperature extremes. The Ministry of National Infrastructures has commissioned a quantitative study on the impact of future climate on energy requirements.

Climate-sensitive housing would provide a more comfortable environment and decrease the energy needs for maintenance, irrespective of climate change. Designing buildings in ways that buffer internal temperature changes will serve as an adaptation for overall warming and increased frequency of temperature extremes. Several measures have been developed by the Blaustein Institute for Desert Research for drylands with low humidity. These include windows with reversible ventilated glazing, earth-sheltered buildings, consideration of the geometry of the building envelope for climate needs such as shading, roof shading and air ventilation, evaporative cooling of public spaces, and design of urban inner courtyards with attention to orientation, geometry, finishing materials and vegetation (see Etzion, Erell and Pearlmutter references) .

Guidelines for urban planning in a hot-humid climate typical of coastal plains have been formulated, but have not yet been applied to local and regional planning and development.

Infrastructure Adaptations

- Water management: The need to collect and save water for drought years will increase with greater temporal uncertainty. Yet, only large-scale solutions may provide sufficient adaptation such as better use of recycled water and use of new water resources.

Better management of aquifer recharge through water-sensitive urban planning may reduce surface runoff and enable aquifer recharge employing relatively inexpensive measures. Since natural vegetation traps soil moisture and reduces surface runoff, conservation of natural and man-made forests may also serve as an adaptation to the projected increase in flash flooding due to climate change.

Israel has used cloud seeding for several decades to enhance rain. This practice may need to be expanded as an adaptation to the projected reduction in precipitation. Employing satellites for determining the potential efficiency of cloud rain generation potential (Rosenfeld and Lensky, 1998) may significantly improve rain enhancement. To assess the applicability of cloud seeding in Israel, further study is needed on the effect of cloud seeding on polluted clouds, particularly cyclonic systems, which are the main sources of rains in Israel. Preliminary assessments show that seeding polluted clouds is highly effective and may reduce or even reverse the negative effect of pollution on rain.

- Flood damage: The effect of floods in Israel has not been evaluated with respect to climate change. Analysis of drainage system efficiency may permit a spatial assessment of sensitivity and adaptation needs. Adaptation to more frequent flooding can be achieved by improving drainage systems and by flood-sensitive urban planning.

- Sea level rise: To obtain direct sea-level measurements for devising reliable scenarios of sea-level rise in Israel, sea level is monitored aerially and by Global Positioning System (GPS) throughout the Mediterranean basin under the Global Sea Level Observing System (MedGLOSS) with a monitoring station at Hadera, Israel (Rosen, 1999). Monitoring across the coast every two years or after storm events, along with more frequent monitoring of winds, waves and currents in order to estimate the sensitivity of different areas to sea-level rise may prepare for appropriate adaptations (Golik and Rosen, 2000).

Damages from sea level rise are estimated at about $1,600 million if no action is taken. These costs could be reduced to approximately $400 million with response strategies such as elevating port structures and offshore structures, protecting low coastal areas and beachfront cliffs with breakwaters and other means, strengthening and repairing existing breakwaters, elevating power station outlets, transporting sands northward (artificial feeding) to refill sands on the northern coast and mitigate the risk of coastal erosion, and designing future offshore islands with higher elevations and greater volume of fill material (Brachya and Rosen, 1993).

These cost estimates do not include the possible impacts of and adaptations to loss of income (tourism, agriculture, industry), loss of lands and drainage-system failures due to reduced water gradient in coastal cities, or the cost of adaptation itself.

The effects of sea level rise may be somewhat moderated by reducing pumping from the coastal aquifer wells to sustainable amounts. A quantitative evaluation of the potential loss of aquifer water due to seawater intrusion, both human-induced and from sea-level rise, has been initiated by the Hydrological Service of Israel.

Lack of Knowledge

Additional research and analysis are necessary in order to understand the potential impacts of climate change in Israel and to prepare appropriate adaptation measures. For example, additional data and analyses are necessary on the following: the impact of climate change on reservoirs and aquifers in order to assess potential impacts on soil, vegetation and natural and agricultural ecosystems; the impact of extreme droughts on natural woodlands in order to assess the vulnerability of different species; the integrated effects of climate change, CO_2 enrichment and human effect on coral reefs; the specific services provided by different ecosystems and individual species; a reliable assessment of sea-level change to allow for management decisions and to identify sensitive beaches in Israel; the sensitivity of different cities to climate change and the implications for future urban development; the overall impact of CO_2 enrichment on wild plants, community structures and crops by means of outdoor experimentation; the net effect of climate change on crop yields and the impact of increased sea surface temperature on oxygen pressure, water quality and fish food organisms in seas, lakes and fishponds; and the extent and potential of climate-related diseases.

Additional information is especially needed in the area of ecosystem response to climate change. Much of the evidence of ecosystem changes to date has come from high latitude (>40°N and S) and high altitude (>3000 m) environments. The sensitivity of local ecosystems in a mid-latitude of 30°N needs to be evaluated – based on knowledge of animal and plant distribution in Israel – in order to identify sensitive landscapes and ecosystems for conservation. Some climate-related studies have provided the basis for such research:

- Analysis of the distribution of trees and shrubs in Israel with respect to climatic factors (O. Farber and R. Kadmon, unpublished data) may provide a quantitative tool for assessing the impact of climate change on the potential distribution of plants.
- A demographic model of a reintroduced species *Equus hemionus* (Asiatic wild ass), correlating annual rainfall and breeding (Saltz *et al.*, 2000) may be used to assess the impact of climate change on the demography of mammalian species in the Negev.
- A survey of current distribution of mammal species to be compared with results of past surveys may detect responses to recent climate change.
- A study has found that changes in the Negev lichen community structure could be used to detect climatic changes as small as 0.8°C (Insarov *et al.*, 1999), but longer-term monitoring is required to verify this claim.
- Available studies of succession processes (the changes in plant and animal community with time) in Israel could be employed to generate predictions for the ecological response to increased frequencies of storms and fires, changes in habitat structures, and sea level rise (Michener *et al.*, 1997).

9. Research, Surveys and Observation

Introduction

General Circulation Models (GCMs) are the state-of-the-art tool for reconstructing changes in climate since the 19th century, for generating scenarios for future climate change, and for deriving impact assessments. In recent years, transient models have come into wider use to generate climatic scenarios. In addition, recent models factor in the effect of sulfate aerosols on solar radiation, which was found to further reduce climatic sensitivity and lower the predicted global warming to 3°C for doubling CO_2.

Climate Change Scenario for Israel

A global-scale scenario cannot be reliably applied to Israel because of the small size of the country, the coarse resolution of current models and the great spatial inaccuracy of global models. When projecting local scenarios from global trends, climatic models tend to display spatial inaccuracy of certain climatic mechanisms, especially precipitation (Wigley, 1992; Mirza *et al.*, 1998). Although incorporating the effect of sulfate aerosols on solar radiation has somewhat improved the models, recent studies show that the effect of urban pollution aerosols also compromises their accuracy. It has been found that these aerosols suppress rain, thereby affecting spatial precipitation patterns and, indirectly, spatial temperature changes (Rosenfeld, 2000; Rosenfeld and Woodley, 2000). The pollution particles act as moisture condensers, increasing the number of water particles and decreasing their size to such an extent that they tend to float in the air instead of colliding, joining and precipitating. These tiny particles can remain liquid even under a supercooled temperature of about -40°C, and are thus no longer available for rain production.

In addition to its direct impact on precipitation, rain suppression changes the spatial heat distribution by suppressing the release of potential energy within water droplets into the upper atmospheric levels. Thus, rain suppression affects upper atmosphere processes unfelt by humans, changing regional water and temperature distribution and the dynamics of depressions and highs.

In order to assess the implications of global climate change for Israel's coastal region, two Israeli researchers developed a GCM-derived scenario, using procedures developed by the Climate Research Unit of the University of East Anglia for the Intergovernmental Panel on Climate Change (Dayan and Koch, 1999). Their results predicted an 80% to 90% sensitivity to the global climate change. That is, for every 1°C change in the global mean, warming of 0.8°C to 0.9°C is anticipated in Israel, with a consequent reduction in precipitation. However, the use of GCM-derived scenarios is problematic in a region highly sensitive to local- and regional-scale effects.

A different method for assessing changes in water balance (namely, precipitation and evapotranspiration) in this region was applied by a group of Israeli scientists (Segal *et al.*, 1994). They constructed a model of winter cyclone movement and overall water balance in the eastern Mediterranean region and found that a rise in temperature will lead to decreased precipitation due to redistribution of rainfall and an increase in evapotranspiration of up to 13% in summer and somewhat more in the winter. These results suggested an overall trend towards greater water deficit.

The scenario presented by Dayan and Koch pertains only to the country's coastline, which is several kilometers wide. Nevertheless, it is consistent with previous models (Palutikof and Wigley, 1996; Segal *et al.*, 1994), and probably applies to a wider area due to the relatively coarse resolution of the model used. Furthermore, since the coastal region is inhabited by 70% of the population, this scenario is valid for most of the Israeli population.

Table 9.1: Sensitivity Values of Temperature and Precipitation for the Coast of Israel

	Temperature (°C change per °C global change)	Precipitation (% change per °C global change)
Annual	0.8-0.9	(-4)-(-2)
Winter	0.8-0.9	(-4)-(-2)
Spring	0.8-0.9	N. Coast (-2)-0 S. Coast: (-7)-(-2)
Summer	0.7-0.9	(-4)-0*
Fall	0.9-1.0	0-3

* Values derived from Palutifof *et al.* (1992) due to insufficient data from the northeastern Mediterranean study.

Based on the IPCC curve describing the projected global temperature change as a function of time for the "business-as-usual" scenario, the predicted annual mean temperature change along the coast is expected to be:

- in 2020: 0.3-0.4°C
- in 2050: 0.7-0.8°C
- in 2100: 1.6-1.8°C

Annual precipitation along the coast is projected to decrease according to (-4)-(-2)% per °C of global change, resulting in the following values:

- in 2020: (-2)-(-1)%
- in 2050: (-4)-(-2)%
- in 2100: (-8)-(-4)%

Sea Level Rise

As in the rest of the world, due to the spatial and temporal variation of sea level, it is impossible to interpolate from global changes to given coasts, without using direct measurements and incorporating local and regional effects. Recent estimates (Nakicenovic *et al.*, 2000) suggest a rise in mean global sea level from 1990 to 2100 of 12 to 88 cm. In the regional scale of the Mediterranean, the anticipated change is 18 cm by 2030, or 50 cm by 2100 (IPCC, 1996).

CO_2 Enrichment Scenario

Climate change is primarily attributed to emission of greenhouse gases, of which CO_2 is predominant. The pre-industrial value of 280 ppmv of atmospheric CO_2 is expected to double between 2040 and 2065; the 1998 figure is approximately 500 ppmv (Special Report on Emissions Scenarios [SRES]; Nakicenovic *et al.*, 2000). Changes in atmospheric CO_2 in Israel are expected to be the same as in other areas.

Observed Climatic Trends in Israel

Temperature

A spatial analysis of temperature changes in Israel during the last forty years shows warming mainly in the center and north (Ben-Gai *et al.*, 1998a, 1999), with a cooling trend in the south and around Hadera (the site of a major power station). Thus, there appears to be a general warming trend, with local exceptions related to anthropogenic factors.

On the other hand, some models and measurements taken in the Mediterranean basin, especially in the eastern Mediterranean, do not show such warming trends (Wigley, 1992). A recent study (Ben-Gai *et al.*, 1999) found no changes in annual mean temperature in Israel between 1964 and 1994 at 40 stations. A cooling trend is also evident from measurements of sea surface temperature (SST) (Kutiel and Bar-Tuv, 1992; Paz *et al.*, 1998b, 2000). Because seawater absorbs large proportions of the incident solar energy, a decrease in SST reduces energy release into the atmosphere and affects heat distribution in the surrounding. Furthermore, reduced evaporation rates due to lowered SST affect precipitation in the coastal region.

Precipitation

Several Israeli studies have detected a decrease in precipitation in recent decades, primarily in the center and north of the country (Steinberger and Gazit-Yaari, 1996; Ben-Gai *et al.*, 1998a). Others detected an overall trend of decrease in precipitation over the last decades (Paz *et al.*, 1998b; Alpert *et al.*, 2000). This may be explained by a decrease in the arrival frequency of mid-latitude cyclones to the east Mediterranean. Some researchers ascribe the changes in precipitation to intra-seasonal changes in rain distribution (Paz *et al.*, 1998b, 2000). Others have found that changes in annual rainfall varied distinctly between regions, and only the coastal region showed a constant decline (Sharon, 1993). This suggests that specific regional factors might play an important role in the local climatic trend.

Rainfall measurements at different stations in the Mediterranean basin show similar declines in most regions of the basin. High correlation between changes in vegetation and changes in sea level during the last 10,000 years in the Middle East suggests that the trend of decreasing precipitation in the Middle East may be attributed to global warming (Issar, 1995).

A recent study of the yearly distribution of rains found a delay in winter rains during the years 1976-2000 (Kutiel, 2000). The length of the period during which the cumulative amount of rainfall reached 20% and 50% of the annual rainfall was extended by 6 days and 4 days per decade, respectively, due to lower rainfall in October and November. This observation contrasts with former reports of increased rains in October (Steinberger and Gazit-Yaari, 1996). A delay in winter rains, with no extension of the rainy period, may explain the decrease in Israel's total annual rainfall.

Other studies demonstrate an increase in overall precipitation in Israel's southern coastline and the northern Negev (Otterman *et al.*, 1990; Ben-Gai *et al.*, 1993; Sharon, 1993; Sharon and Angert, 1998). This is attributed to land-use changes: afforestation, intensive agriculture under irrigation, and grazing restrictions. It is suggested that land-use changes have caused a decrease in surface albedo and an increase in convection during daytime, conditions that enhance diurnal rains in October (Otterman *et al.*, 1990). Other researchers have found that October rains have increased throughout the country (Steinberger and Gazit-Yaari, 1996). The long-term effect of these local processes on precipitation, and possibly on desertification, is unknown. Some suggest that land-use changes may merely delay an inevitable drying process due to global warming while others claim that they could prevent it.

Increase in Extreme Weather Events

The temporal and spatial distribution of rains in the Mediterranean basin is highly changeable, with rainfall varying greatly both from year to year and within the year (Kutiel, 2000). It is anticipated that greater variability due to climate change will likely be as important or more important than changes in mean climate conditions for determining climate change impacts and vulnerability (IPCC, 1996).

Analysis of spatial and temporal long-term trends in climate in Israel has revealed increased seasonal variability due to a decrease in the maximal and minimal temperatures in the cool season, and an increase in the maximal and minimal temperatures in the warm season (Ben-Gai *et al.*, 1999). These two opposite tendencies, observed at 40 stations over 31 years (1964 to1994), may explain the absence of change in mean temperature. However, analysis of the same data did show increased temperatures in the center and in the north.

Another study by the same researchers of the frequency distribution pattern of maximal and minimal temperatures found increased seasonal variability as well as increased frequency of extreme temperature events, demonstrated by the upper and lower tail of the temperature distributions (Ben-Gai *et al.*, 1998a, 1999).

A recent analysis has shown that high intensity rains increased in frequency, with fewer rains of moderate and weak intensity (Alpert *et al.*, 2000). This supports a prevailing notion of an increased incidence of extreme weather, particularly in the last decade. The high incidence of extreme weather events in Israel during the 1990s is borne out by observations.

Incidence of extreme weather events in Israel in the 1990s:

- 1991/2: Wettest year recorded in Israel in over a century, with annual mean precipitation above 200% in most areas.
- 1995, 1998: While most spring and fall *hamsins* (hot, dry cyclones) occur in May-June and in September-October, respectively, the first ever recorded *hamsin* as late as July (accompanied by a severe forest fire in the Judean mountains) and as early as April (causing severe agricultural damage) occurred in 1995 and 1998, respectively.
- 1998: Hottest summer ever recorded in Israel.
- 1999: First *hamsin* ever recorded in December, accompanied by severe forest fires on Mt. Carmel.
- 1998/9 and 1999/2000: Two consecutive years of extreme drought and the longest drought ever recorded in the south (leading to wide mortality of trees in the Jewish National Fund afforestation projects).
- 2000: Heaviest snow in the northern Negev.

- 2000: Hottest July in Israel in the last 50 years, with a mean temperature 4°C higher than average. Hottest recorded temperature (41°C) in Jerusalem since 1888.

Evapotranspiration

A trend of decreasing evapotranspiration was measured in the eastern Mediterranean (Paz *et al.*, 2000), probably due to the observed lowering of SST. However, with the anticipated increase in overall temperature and probable increase in SST, the increase of 1.5°C in the Mediterranean basin anticipated in Israel around 2100, is expected to increase evapotranspiration rates by 10% (Jeftic, 1993).

Evaluation of Models and Observations

As shown above, the observed trends in Israel and the region do not always support a scenario of warming and drying. The discrepancies between model predictions and actual observations may be only partly due to the complexity of modeling climate change in this region. Positioned at the meeting point between subtropical highs and mid-latitude depressions, Mediterranean climate is determined by the combined effects of both global and mesoscale circulation patterns (Dayan and Koch, 1999). Spatial climatic models are very sensitive in this area; minor changes in parameters can significantly influence the results.

The models may be even less reliable in projecting precipitation changes. Israel is located at 30° to 32°N latitude; GCMs predict increased precipitation in latitudes above 35°N and decreased precipitation in latitudes below 35°N (Wigley 1992). It might be expected that local and regional processes would affect precipitation, reducing the reliability of such coarse-resolution models. In fact, winter cyclones – the major source of rain in the eastern Mediterranean – are largely responsible for the inaccuracy of the model in this region. Cyclones develop at the contact area between the subtropical and the middle latitude climate systems, where slight climatic changes affect both their generation and their paths.

In addition, the models do not incorporate the effect of urban pollution aerosols on rain production in the eastern Mediterranean. Both locally generated pollution and pollution originating from Europe may affect temperature and precipitation distribution on regional and local scales and greatly reduce the spatial accuracy of scenarios.

Integrated Scenario for Climate Change in Israel

Based on the climate change scenario of Dayan and Koch (1999) and evaluation of observations and models, the following scenario for Israel is currently considered to be most likely:

- Increase in the mean temperature as follows:
  - 0.3-0.4°C by 2020
  - 0.7-0.8°C by 2050
  - 1.6-1.8°C by 2100
- Decrease in precipitation as follows:
  - -2 to -1% by 2020
  - -4 to -2% by 2050
  - -8 to -4% by 2100
- A 10% increase in evapotranspiration with an increased temperature of 1.5°C anticipated around 2100;
- Delayed winter rains;
- Increased climatic variations and frequency of extreme events, expressed in the following increases: seasonal variability in temperature, climatic uncertainty due to increase in spatial and temporal uncertainty, frequency and severity of extreme weather events, and frequency of high intensity rainstorms.

The impact, vulnerability and adaptation assessments presented in the previous chapter are based on this integrated scenario. Since time horizons are not available for most of the climate changes in Israel, the information is based on a qualitative evaluation of anticipated trends and effects.

Research on Mitigation Technologies

The main government bodies which fund research studies in Israel include the Ministries of the Environment, Agriculture, National Infrastructures, Science, and Industry and Trade. The Environment, Infrastructures and Agriculture Ministries fund practical research intended to solve specific problems. The Ministry of Industry funds research whose aim is to develop technologies or final products, some of which are related to the environment. It also runs programs for the development of generic technology, in which consortia of academic and industrial researchers work together on pre-competitive research and development in different areas, one of which is high-temperature solar energy. The Ministry of Science promotes the development of new generic technologies in priority areas in order to bridge the gap between basic research and applied industrial research. Several non-governmental organizations are also active in environmental research. The Jewish National Fund, for example, is renowned for its afforestation strategies and methods for combating desertification.

While the quality of environmental research conducted in Israel is very high, government investment in this sector constitutes a very small portion of general investment in civilian research and development. Investment lags far behind government investment in environmental research in other countries.

The Chief Scientist's Office in the Ministry of the Environment is responsible for coordinating environmental surveys and research on the national level. In recent years, the Chief Scientist's Office has spearheaded several innovative, future-oriented projects designed to promote sustainable development – especially sustainable urban development, green building, and implementation of Environmental Management Systems (ISO 14000) in the industrial, services and municipal sectors.

Each year, the Chief Scientist issues a call for papers on subjects which are of special relevance to the Ministry of the Environment. Some of the priorities in recent years have been related, indirectly or directly, to the reduction of greenhouse gas emissions. These include, among others: collection and treatment of methane in landfills; treatment and use of municipal and industrial sludge; microclimatic considerations in the urban environment; mapping the potential for climatic green construction in Israel; water-sensitive urban planning; economic aspects of investments in prevention of environmental damages and conservation of resources; and impact of fuel quality on vehicle emissions (diesel and gasoline).

Solar and Alternative Energy Research

Due to the lack of natural fuel resources in Israel, the country has pioneered several developments in the field of alternative energy. Israel began its solar energy research soon after its establishment in 1948. Several major developments have resulted from this research: flat solar collectors for domestic use (required in all new buildings), solar ponds and a parabolic trough technology.

Solar heating is used for two main applications: domestic water heating in more than 50% of the homes in Israel and evaporation ponds in the Dead Sea for sodium chloride production and for crystallization of sodium chloride and carnallite. The latter requires the evaporation of about 120 million tons of water a year, which would have necessitated at least 5 million tons of fuel, had non-solar evaporators been used. Today, solar energy accounts for about 3% of the gross energy consumption.

The Israel Electric Corporation (IEC) has been involved in solar energy research and in the development of photovoltaic (PV) and hybrid systems since the mid-1980s, at which time three main research directions were defined: large PV central stations, small grid connected PV systems, and battery linked renewable energy systems applications.

An experimental system based on a 3.8 KW dual axis tracker, carrying 75 m^2 of M- 55 flat plate Siemens solar modules, has been put into service at the Ben-Gurion National Solar Energy Center. The system has provided field experience and practical know-how in large grid connected dual axis trackers, carrying PV modules.

The "solar house" which IEC outfitted in Mitzpe Adi in 1996 represented small grid connected PV systems which could find application on available free space atop residential buildings, small commercial centers, and public buildings. Excess energy is sold to the grid, while a shortage of energy can be covered by drawing from the grid.

Battery linked renewable energy systems are suitable in remote areas which are not connected to the national electric grid. IEC has been involved in this type of research in renewable energy projects in developing countries within the framework of cooperation with the European Union in the field of reverse osmosis water desalination units powered by solar and wind energy.

Additional alternative energy sources include the "energy tower," developed at the Technion – Israel Institute of Technology, and wind energy, a subject which has been investigated by the IEC since 1980.

Weizmann Institute Solar Tower

The Solar Tower at the Weizmann Institute of Science in Rehovot focuses on the utilization of concentrated solar energy. The 3000-kilowatt facility enables technologies to be tested on a large scale. Major features include a field of 64 computer-controlled mirrors, or heliostats, each measuring seven by eight meters, which track the movement of the sun and are controlled by a computer that calculates the sun's position relative to the earth for every second of the year. The light collected in the field is redirected to a receiving tower at the field's southern edge. This 54-meter-high receiving tower contains five separate experimental stations. Light can be reflected toward any or all of these stations, allowing several experiments to be carried out simultaneously. The directions of research include high-temperature solar thermal conversion; solar-driven chemistry for energy storage and synthetic fuel production; advanced optics for high concentration; solar-pumped lasers; split-spectrum multiple conversion systems; and solar enrichment of fuels.

The thermal solar research at the Weizmann Institute has focused on technologies that can provide heat at high temperatures that are compatible with the operation of gas-turbine power generation systems. In order to achieve this goal, a breakthrough in three different technologies was achieved:

- Large scale non-imaging optical concentrators;
- Beam down tower technology that will place all heavy machinery on ground level;
- High-temperature high-pressure volumetric receivers that can absorb the concentrated solar light and convert it to heat.

Figure. 9.1: Experimental Tower Reflector Installed on Solar Tower

Ben-Gurion National Solar Energy Center

The National Solar Energy Center at Ben-Gurion University of the Negev provides another testing ground for an array of solar-thermal facilities. All facilities at the site are monitored by a computerized system which collects and compiles performance and solar radiation data. The Center is active in solar radiation studies, photovoltaic research, solar-thermal research and advanced parabolic troughs research. The overall research direction aims at improving the efficiency and cost-effectiveness of solar power generation on a large scale. Alongside research, component and system testing play a significant role in the Center's activities as well as the design or testing of solar energy systems for neighboring kibbutzim and other settlements.

Of special interest is the use of a 25 m diameter parabolic dish to generate electric power by concentrating solar energy onto a relatively small area of photovoltaic cells, investigation of new materials as potential low-cost replacements for silicon, outdoor photovoltaic testing for the testing and characterization of solar cells, meteorological studies to identify suitable sites for solar power stations and to identify the most efficient type of solar technology for each site, and further development of parabolic trough solar electricity generating technology.

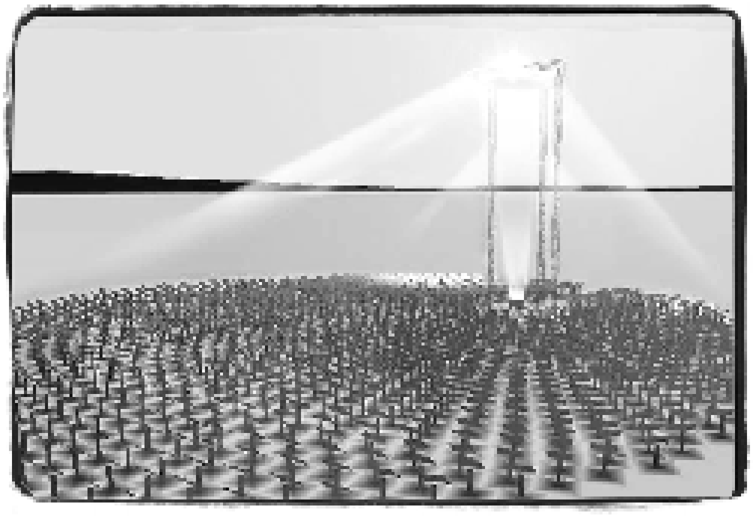
Figure. 9.2: Parabolic Dish at Ben-Gurion National Solar Energy Center

Commercial Applications

Some of the technologies developed at the Weizmann Institute and at other universities in the country have formed the basis for industrial scale application. In recognition of the importance of the subject, the Chief Scientist's Office of the Ministry of Industry and Trade approved financial support for the formation of an industrial consortium (ConSolar) to develop concentrated solar energy technologies aimed at future commercial applications. The consortium, established in 1995, is composed of four industries and three academic research institutes. Its technological objectives include the following:

- Central solar multi-megawatt power stations based on a unique concept whereby a tower mounted hyperbolic mirror reflects the initially produced solar beams issuing from a heliostat field downwards to an advanced secondary concentrator onto a proprietary collector capable of converting it to high temperature air to power a gas turbine or combined cycle configuration. The new system is implemented in a pilot solar plant, the first of its kind in the world, which uses solar energy for directly powering gas turbines in order to produce electricity. The pilot plant, located at the Weizmann Institute of Science, is being set up as a collaboration between Boeing Co. in the USA and ConSolar's respective members (Ormat, Rotem, El-Op and the Weizmann Institute). The use of such technologies as special optics and an innovative air receiver should lead to the development and marketing of commercial solar powered electricity generation stations. The overall investment of the Israeli industries and the Israel government in the basic technologies and in the program was $20 million in addition to $15 million in infrastructure. The budget of the US/Israel Science and Technology Commission, which approved the proposal for a commercial solar power conversion system whose components will be integrated with a 250 kW gas turbine, is $5 million, equally shared by both governments.

Figure. 9.3: Computer Simulation of Solar Thermal Demonstration Plant



- A light Unmanned Airborne Vehicle using a concentrated sunlight photovoltaic system and electrical battery storage to power its electrical propulsion system. This solar electricity generating and storage system will be adapted for use in space applications and as a terrestrial electricity generator.
- High powered solar-pumped lasers for industrial and space applications.
- Small solar thermal electric power plant based on concentrated sunlight, a solar receiver and a Brayton engine. The system will be a hybrid power plant, operating mainly on solar energy with fuel topping or using fuel only during no-sun hours.
- Concentrated photovoltaic power system to replace large areas of high-priced solar cells with inexpensive optics and a small number of advanced solar cells.

Several Israeli companies have pioneered technologies that influence the international renewable energy industry. For example, Solor Photovoltaic Systems, a division of Chromagen Solar Energy Systems, has developed a solar energy system that can simultaneously supply electric power and hot water for residential applications. This versatile Multi-Solar System uses photovoltaic cell technology and batteries in combination with flat solar panels to supply hot water, lighting and heating for domestic and industrial purposes.

Ormat, another Israeli company, has become world leader in the design and installation of electricity generating equipment for low temperature heat, mainly geothermal and industrial waste heat. It has installed clean power generating plants in 21 countries including New Zealand, Japan, Iceland and Italy.

Solel Solar Systems Ltd. is developing products and services for the deployment of solar thermal technologies ranging from household water heaters to utility-scale power stations, as well as a range of other commercial and industrial solar applications. The company acquired the intellectual know-how of Luz Industries Israel which installed and operated the world's largest solar thermal power plants in California's Mojave Desert, where nine power plants generate about 350 MW of clean electricity for approximately half a million residents. Solel has recently inaugurated a Thermal Energy Center in its industrial production plant where solar panels are producing 50 kilowatts of power for the building's air conditioning system and will eventually supply heat and electricity too. The project demonstrates the application of energy systems – cogeneration of solar electricity, solar heating and cooling – in a commercial/industrial environment.

Green Building

Nearly all of Israel's academic institutions engage in research on green building. Some prominent examples include the National Building Research Institute in the Technion – Israel Institute of Technology and the Desert Architecture Unit of Ben-Gurion University's Desert Research Institute. In these and other institutions, research findings are being translated into actual projects in an effort to apply accumulated expertise to specific problems.

A bio-climatic laboratory, sponsored by the Ministry of National Infrastructures, was recently inaugurated at the Faculty of Architecture and Urban Planning of the Technion – Israel Institute of Technology. It is equipped with physical demonstrators, as well as computerized simulators, which enable the study and demonstration of such subjects as energy loss in buildings, shading solutions, and natural and artificial lighting. A heliodon, a device that simulates the sun's position throughout the year, simulates solar radiation at different times of the day in each season. Finally, computer workstations, equipped with computer aided architectural design software, enable architectural design of single dwelling as well as high-rise buildings aimed at achieving thermal comfort and efficient lighting with minimal energy consumption. The software, which was developed at the lab, also provides design solutions for such topics as shading between buildings, solar rights in urban regions, design of sunshades, and solar daylight illumination on selected planes in the designed buildings.

The International Center for Desert Studies in Sde Boker is a notable example of the application of such green building principles as energy efficiency and conservation through natural and innovative techniques for heating, cooling and lighting. Another is the Environmental Sciences Building at the Weizmann Institute of Science. This green building, inaugurated in 1996, was planned by architects in conjunction with expects on climatic-energetic building. Energy savings were mostly achieved through the construction of large shaded windows, use of natural lighting, and sophisticated ventilation methods.

The Ministry of National Infrastructures supports several projects that promote energy and climate-conscious design in buildings. Thus, for example, data accumulated during a recent study on daylight illuminance in Israel has been translated into a designer's manual for efficient utilization of natural illuminance. In another area, the ministry is sponsoring a research project on urban planning in hot and humid climates with the goal of producing a manual on this subject as well. In addition, a task force composed of experts in climate-conscious design is being established to provide consultation services in urban development projects.

Combating Desertification

Since about 95% of Israel is a dryland, the country has developed a productive and efficient agricultural system and recycles more than 70% of its effluents – one of the highest rates in the world.

To combat desertification, Israel has developed and implemented dryland afforestation methods and computerized surface and sub-surface drip irrigation technologies and protocols. Research and development are carried out on wastewater treatment and irrigation, floodwater storage, run-off harvesting and agroforestry, dryland crop breeding, and dryland aquaculture.

The Jewish National Fund (JNF) has been instrumental in afforesting the land of Israel since 1901. Its afforestation branch has been especially active in developing afforestation practices for semi-arid and arid regions. The savannization project, initiated in 1987, is aimed at preventing desertification and increasing productivity and biodiversity without resource enrichment. By manipulating the patchiness at various sites in the Negev desert and utilizing water harvesting techniques, rainfall and runoff are redirected, and relatively highly-productive patches are created within the desert landscape. The JNF supports and manages several agricultural research centers in Israel's drylands.

10. Education, Public Awareness and International Activity

Formal Education

In Israel, environmental education is part of the educational curriculum from kindergarten to high school. Environmental Education Centers, set up in local authorities throughout the country, play an important part in incorporating environmental education concepts into the school curriculum and promoting environmental awareness among all sectors of the population. As of 1995, Israel has participated in the Global Learning and Observations to Benefit the Environment (GLOBE) project, a worldwide network of students, teachers and scientists working together to study and understand the global environment. The three-year program is implemented in 50 elementary, junior and senior high schools throughout the country. Students study and take part in scientific observations in a number of areas, including atmosphere and climate.

To assimilate energy conservation principles, students are exposed to the subject at different grade levels. An energy conservation curriculum program is included in the Education Ministry's program for fifth to seventh grade. At the junior level, a prize-bearing drawing competition is organized and at the senior high school level, a national energy conservation contest is conducted. To supplement formal education, articles in children's magazines are published, and features are aired on educational television.

In recent years, a new prize bearing competition for secondary schools focusing on the environment has been launched. Two prize categories are awarded: one for an outstanding research project on the environment prepared by an 11th or 12th grader and one to a high school that promotes environmental studies.

Another initiative has seen the participation of hundreds of middle and high school students in a competition to design a model environmental city for the 21st century. Submissions in the form of computer presentations, calendars, videos and architectural models demonstrated ideas ranging from underground transportation systems and infrastructures to sludge treatment and compost systems. Nearly all the presentations emphasized energy efficiency in residential heating and cooling and non-polluting transportation models.

At the university level, courses and programs on environmental subjects are added each year, assuring a pool of professionals and researchers capable of environmental problem-solving and able to influence policy and decision making at all levels. Today, all of Israel's institutes of higher learning offer a variety of options for environmental degrees at all levels.

At the solar education facility at the Sde Boker campus of Ben-Gurion University of the Negev, several educational and outreach projects have been launched aimed at increasing public awareness of the importance of solar energy. The visitor's program offers demonstration tours as well as advice to individuals and groups on solar energy.

At more specialized levels, conferences are held in Israel on climate-change related topics. In 1991, an International Workshop on the Regional Implications of Future Climate Change was held under the auspices of the Ministry of the Environment and the Israel Academy of Sciences and Humanities. An International Conference of the Israel Society for Ecology and Environmental Quality Sciences is held every two years, with sessions devoted to climate change and global warming among other subjects. In addition, a Sde Boker Symposium on Solar Electricity Production is organized every 18 months.

Special Events and Consciousness Raising

Special events are an important part of the effort to increase public awareness. The presentation of environmental awards to outstanding individuals, local authorities and industries for their environmental activities is an important part of annual events. Such events are accompanied by school competitions, youth marches, photography and art contests, cleanup campaigns, workshops and environmental exhibitions.

More and more emphasis is being placed on informal education on the community level – from environmental courses and lectures to recycling libraries which collect industrial waste products and transfer them to schools or artists for reuse. Community centers play a particularly important role in encouraging environmental activism on the local level. Industry too has shown greater readiness to work on behalf of the environment and new lines of communication have been opened between the industrial sector and the community. Israel's youth movements have also taken an active part in raising environmental awareness.

Each year some 200,000 students participate in tree planting ceremonies organized by the Education and Youth Division of the Jewish National Fund. Five Field and Forest Educational Youth Centers serve as focal points for education on forests and afforestation. Some 50,000 people participate in annual tree planting ceremonies on the occasion of Tu Bishvat (Arbor Day), and thousands more participate in mass happenings organized in forests throughout the country on holidays.

To promote awareness in the industrial sector, publications, conferences and workshops are organized on such subjects as the economic benefits of environmental investments at the factory level, green building, and implementation of ISO 14000. Guidelines and information on environmentally-responsible behavior on the individual and corporate levels are provided on the Internet site of the Ministry of the Environment.

Demonstration Projects on Energy Conservation

Energy conservation is probably the most effective method of reducing energy-related environmental effects. To meet its goal of continuously improving energy intensity, the Department of Infrastructure Resources Management in the Ministry of National Infrastructures provides technical consulting and guidance, promotes education and encourages demonstration projects for energy conservation. Recent energy conservation projects include energy conservation in the water pumping sector and a zinc-air energy system for powering electric vehicles; demonstration projects focus on solar energy for domestic use, hospitals and industry, cogeneration, municipal waste treatment for energy supply, and energy conservation measures in building envelopes and office building systems. The ministry is also promoting such projects as municipal and industrial sewage treatment for energy supply, an electric train feasibility study, traffic flow control improvement, and demonstrations of resources management in office buildings and urban neighborhoods.

Education targeted at professionals includes the establishment of advisory services for plants and institutions, workshops for Energy Conservation Officers, and professional literature on subjects such as air conditioning, steam boilers and water pumping. Reports on energy conservation demonstration projects are made available to all potential users.

To promote public awareness, the ministry operates an advisory office and a toll-free telephone number for advice on energy conservation. A multimedia station provides advice in Hebrew on energy conservation topics. An English version will be developed in the future. Leaflets are available to the public on all major home appliances.

The ministry estimates that energy conservation legislation, information and demonstration have saved some 12,778,000 Tons of Oil Equivalent (TOE) between 1977 and 1995, thereby preventing CO_2 emissions of about three times this amount. These activities saved Israel about $2.9 billion. If these activities will be continued and expanded, an additional 6 million TOE may be saved by the year 2010.

International Activities

International activities are carried out within the framework of international and regional organizations, foremost among which are the United Nations Environment Programme, affiliated United Nations organizations and independent organizations. Several bilateral agreements for environmental cooperation have been concluded with countries throughout the world, many of which specifically relate to combating desertification, solar energy and water conservation, and effluent reuse.

Israel's experience in overcoming difficult climatic conditions, scarcity of water and limited land resources has become a model for developing countries worldwide. The country has actively shared its accumulated experience and expertise with other states, largely through the services of MASHAV, the Center for International Cooperation. Founded over 40 years ago as part of Israel's Ministry of Foreign Affairs, MASHAV has brought tens of thousands of people, representing 130 countries/authorities, to Israel to take part in advanced study courses. Cooperation largely revolves around such core issues as water conservation, agriculture and agrotechnology, combating desertification, augmenting water sources, energy and environmental protection.

Since 1995, the Ministry of National Infrastructures, in cooperation with the Ministry of Foreign Affairs, has offered a one-month international course on energy management and conservation. Participants, mainly from developing countries, learn about available technologies and methods to utilize and conserve energy, taking into account such considerations as economy, environment, public awareness, government aid and incentives. To date, more than 150 graduates are dispersed over 40 countries on all continents.

Combating Desertification

Israel was one of the first countries to sign and ratify the Convention to Combat Desertification. Cooperation and assistance activities, carried out by government, academic and non-governmental organizations, take the form of training and demonstration projects in Israel and in developing countries, joint research and development programs, exchange of experts and public outreach. In 1999 alone, Israel carried out nearly 60 training and consulting activities, and Israeli scientists performed more than 15 joint research projects on issues related to desertification in African, Asian, Latin American and Middle Eastern countries. MASHAV initiated 22 courses in Israel in areas related to desertification with the participation of experts and trainees from different countries.

In line with its accumulated experience and its commitments under the Convention, Israel is completing the establishment of an International Center for Combating Desertification in Sde

Boker in the Negev desert. Within this initiative, the Albert Katz International School for Desert Studies was inaugurated in 1999 which offers an international M.Sc. program.

On the regional level, the working group for the environment in the multilateral peace talks has earmarked desertification as one of the priority areas for regional cooperation. During its first phase, the so-called Desertification Initiative supported teams in Egypt, Israel, Jordan, the Palestinian Authority and Tunisia in their efforts to control natural resource degradation. The first phase focused on four critical subject areas: germplasm for arid lands, economic forestry and orchards, rangeland management and marginal water and saline soils. In 1999, partner countries expressed their interest in moving the Initiative into a second phase and agreed to focus on such priority areas as management of treated wastewater and biosolids, development of watersheds using water harvesting techniques and suitable plant resources and policy options for reversing natural resource degradation.

Solar Energy

Because Israel has almost no fuel sources other than its abundant sunshine, it has become a world pioneer in the use of solar energy, both for domestic use and in technologies for solar power stations. Solar water heaters developed in Israel are extensively used both within the country and worldwide, and a large-scale solar-powered electricity generating plant was developed and installed in South California's Mojave desert by an Israeli company.

Israel's solar energy developments continue to gain international recognition and both foreign and local companies, in cooperation with Israeli research institutions, are investigating the commercial feasibility of an advanced solar power plant capable of generating electricity at competitive prices.

In addition to entering the international solar energy market, Israeli companies have taken a lead in the design and installation of electricity generating equipment for low temperature heat, mainly geothermal and industrial heat.

Afforestation

The Jewish National Fund is actively involved in exchange and training of experts from desertified countries. Much of the activity undertaken in the area of sustainable dryland development is in association with the International Arid Lands Consortium (IALC), a consortium of several American universities and the US Forest Service.

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