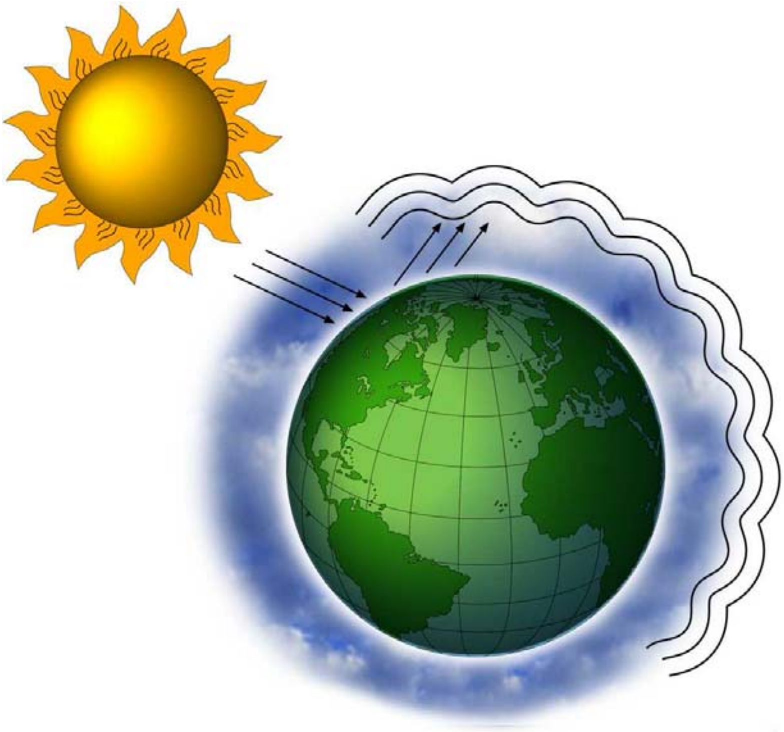
The S. Neaman Institute
For Advanced Studies in science & Technology

Mitigation of Greenhouse Gases Emissions in Israel



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EXECUTIVE SUMMARY

Israel's policy for reduction of greenhouse gas emissions

This policy paper is a first attempt to determine a national policy for the State of Israel to reduce greenhouse gas (GHG) emissions. The paper is based on a thorough breakdown of the sources of GHG emissions and describes the different technical means that may reduce GHG emissions under the special conditions characteristic of Israel.

Conditions in Israel differ considerably in from most developed countries.

1. Israel is still a state that is in a process of evolving and developing. As a result we have not yet reached stability and are not yet on a clear course of development in social, demographic, political and economic fields. Clearly different from other countries, Israel's population is projected to grow considerably (together with uncertainty in the different scenarios of population growth). Furthermore, the customary base year for emissions in other countries' policies, were years in which Israel enjoyed immense population growth and economic activity.
2. The demographic instability (together with uncertainties regarding other cardinal issues) makes it difficult to use future scenarios. The difference between scenarios is immense and difficult to bridge. Uncertainties in future projections and the absence of clear and agreed upon figures regarding future development in all sectors, is one of the main reasons that the different sections of this paper relate to different base and target years.
3. There is uncertainty regarding economic development and the directions industry will take. The heavy and chemical industries that compose a significant element of emissions in other countries, are not a significant segment in Israel. Projections do not point to growth in these industries in Israel, rather in the light and technological industries, which do not emit GHG in large quantities in their production processes.
4. A factor that is expected to carry considerable weight in energy consumption and therefore GHG emissions, water desalination**,** is still in early stages, and there is

currently no formal policy or agreed upon technology for this process. In other developed countries that have prepared similar policy papers there is no precedent for this sector.

5. The climate in Israel demands heating in winter (relatively short) and considerable cooling in the summer. Yet, the climate in Israel is moderate and permits the utilization of climate components (radiation, breeze etc.) to reduce energy consumption.
6. Another element that differs Israel from other countries, is the fact that treatment of waste, including sludge from sewage facilities, there is currently no modern treatment system.

In light of all these reasons, this paper suggests some original and new technological approaches.

The recommendations and priorities in Israel’s national policy for the reduction of GHG emissions were prepared subject to the following criteria:

1. The relative contribution of the sector to total emissions
2. The technical probability of a given action to reduce GHG emissions
3. The public and political acceptability of a recommended action
4. The relative cost
5. Time needed for implementation of a recommended action. The recommendation seeks actions that require a short time but actions requiring a long time and that are significant will be pointed out.

Tables A - F present a summary of the recommendations to reduce GHG emissions. In light of uncertainties in future projections, the tables were prepared based on figures for 1996, a year of which our data are detailed and reliable. We assume that the increase in GHG emissions of each of the sectors will be similar to trends subject of growth in population and GDP, and that the relative contribution of the sectors will be similar to today. It seems to us that this assumption is acceptable to most of the sectors, except the residential and commercial sector, which is projected to consume more energy in the future for comfortable thermal conditions, and will therefore contribute more than it does today to total emissions.

Recommended priorities

1. Waste and sewage sludge

This sector is responsible for over 12% of GHG in Israel (for a time horizon of 100 years. For a time horizon of 20 years methane emissions from waste equals to 24% of total GHG emissions). There are simple measures to reduce emissions caused by activity in this sector.

In an analysis of existing measures we found that the most cost effective measure is to treat the degradable components of waste by composting (investment of 10 US$ in facilities to reduce emission of one ton CO_2 equivalent per year). Incineration of waste is also a very effective means to reduce GHG, but the cost is much higher than composting.

The cessation of burying waste in landfills that produce methane and a shift to more modern measures carry additional advantages; It will save land allocated today for landfills, increase of recycling of materials, production of fertilizers and more. The policy change will be accepted by the public and its implementation depends on government policy.

2. Fuel switch in energy and industrial production processes.

By switching from fossil fuels to natural gas, it is possible to reduce GHG emissions at a rate of 30 - 44%. Switching from oil to gas will reduce Israel CO_2 emissions by 3.2% in a relative low investment. Switching half of the coal operating stations to gas will enable a reduction of an additional 6.6% of the country GHG emissions. Switching from oil to gas in industry will reduce emissions by a few percents (up to 5%).

Considerations other than reduction of GHG emissions exist; source of supply, cost of supply, credibility of supply and existence of emergency reserves**,** considerations that are beyond the scope of this paper. The magnitude of increase in use of natural gas in the future depends, among other things, on the political development in the region and the relations that will be created with neighboring countries.

3. Development of technologies for generation of energy from renewable resources.

In the detailed paper it was suggested several technologies for production of energy from renewable resources, from the use of nuclear power to energy towers, wind power and solar energy. The use of nuclear energy is subject to political considerations, solution to nuclear waste and the availability of safe reactors. The utilization of wind power is well known in the world, but a thorough investigation is required to adapt technologies to Israel. The technologies suggested to produce solar energy (including power towers), are still undergoing development and it is too early to determine their feasibility.

These technologies require further research and demonstration. Though there is uncertainty regarding the success of any one of them, they carry enormous potential. The ability to be less dependent on foreign sources and on the non-replenished resource of fossil fuels, more than justify significant investments in R&D and constant actions to explore these novel methods.

Of all suggested means, the use of wind power can be implemented immediately. In the future, direct and indirect solar energy can be used.

4. Energy production in combined cycles

With gas turbines that operate on liquid fuels or gas it is possible to utilize combined systems in which efficiency is higher by a factor of 1.5 and more than existing systems. Potential reduction of GHG emissions by this method is between 2 and 7.3% of total emissions.

<u>Co-generation of electricity</u>

Systems that use the residual heat resulting from electricity production are limited in Israel because of the small market for heat and steam (as opposed to countries where the climate is cold and in which home heating in the near town provides a stable market). Yet there is a potential to build private energy generation plants in which residual heat and steam may be used for heating and air conditioning. Such plants may be built by the industries (while reducing some 2% of projected emissions) and large public and business buildings (university campuses, hospitals, hotels, office

centers etc.) while reducing emissions by a similar portion to that of the industry sector).
(A thorough and quantitative description is provided in the appendix).
For implementation of this step, appropriate agreements with the Israel Electricity Co. for purchase of electricity is needed.

5. Encouragement of energy conscious buildings

The climate in Israel, in which winter is not very cold and summer is not always warm, it is possible to utilize solar heat and wind to save energy consumption of comfortable thermal conditions. Energy conscious buildings may save 20 - 40% of energy consumption for thermal conditions, which is a significant growing component in energy consumption in buildings. Cost analysis shows that an investment of 0.5 - 3 NIS may provide a savings of one kWh per year.
The investment required for energy savings in buildings is effective because the rate of return on the investment is from one to a few years, more so if electricity prices will include external costs.
There is a need to encourage a process of energy conscious buildings by law, fiscal measures of taxation and credit, and development of awareness among planners, builders and the general public.

6. Transport measures

The transport sector is responsible for some 17% of total greenhouse gas emissions in Israel. This paper provides a set of measures that enable reduction of vehicle kilometer travel and reduction of emissions. These measures must be a component of a policy that develops alternatives of mass transportation and urban planning together with fiscal and administrative measures that limit travel.
It is difficult to project and even asses the efficacy of these measures, but it seems that it is inevitable to deal with this issue, especially due to the projected increase in this sector (doubling emissions by 2020) if the issue is not dealt with.
Decisions about measures in the transport sector should be subject to a variety of national and environmental considerations - to reduce congestion in cities and important transport routes, to reduce air pollution in cities, save land allocated for roads and others.

Summary of policy recommendations

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 Israel
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 fuels with higher efficiency. Postponing of building power generation plants
4. Co-generation	2	3	4	Use of fuels with higher efficiency. Postponing of building power generation plants
5. Energy conscious building	3	5	7	Energy savings and postponing of building power generation plants
6. Improvements in transport	2	4	6	Reduction of air pollution. Improvement of environment in cities
7. Improvements in industry (without co-generation)	4	7	10	Improvement of air quality. Postponing of building power generation plants
8. Agriculture	0.5	1	2	Reduction of underground water and air pollution
Total	**24.5**	**43**	**59**	

Several issues in the policy summary table need to be pointed out.

The detailed measures mentioned in this table are presented in the accompanied paper. They have been assessed subject to three scenarios - the optimistic assumed implementation extracts full potential, while the pessimistic scenario assumed partial implementation.

Most of the measures presented in the summary table are those that do not demand significant changes in current processes and common practice. Some of the measures will contribute direct economic benefits (energy production in co-generation, "green buildings" and some of the measures in the agriculture sector) and some will produce indirect economic advantages like postponing in building new power generation plants. Almost all of the measures discussed produce double dividend as they bring upon additional advantages, some of them very significant environmental improvements such as reduction of air pollution, reduction of transport congestion and improvement of the environment within cities by improving vehicles and transportation systems. Significant components of the measures suggested are actually steps of improving economic and service systems rather than their reduction.

Analysis of required investments within the different sectors is presented in figure A. It is important to point out that investments are one component of the economic factor. For example, investment in measures that reduce GHG emissions in buildings is quite high. Yet the suggested measures carry large energy savings, an element that changes the national economic balance. It is also important to note that many recommended actions produce more than one advantage, environmental and economic, which are not expressed in figure A.

Another consideration for recommending specific measures to reduce GHG is the required time for implementation. It is possible to change the method by which waste is treated within a few years. Other measures require gradual and constant changes such as energy conscious building, improvements in transport and in industry and the introduction of co-generation and combined cycle.

Considerations regarding base and target years

Israel will be committed by current and future decisions concerning the need to reduce global GHG emissions. Past experience regarding the cessation of the use of gases that harm the ozone level has shown to what extent Israel is obliged to fulfill international agreements concerning the environment, as a condition to participate in international trade.

Yet, we must see to it that implementation of international agreements do not burden us with unreasonable costs. In the economic analysis (chapter 8) it is possible to see that implementation based on 1990 as the base year will confront Israel with an unreasonable expense of 6.3% of GNP.

It is essential to point out that during the years between 1990 and 1996 Israel has experienced an unprecedented population growth, absorbing some one million immigrants from the former USSR, and consequently an immense economic growth as well.

The economic analysis demonstrates that if we relate to emissions per capita rather than national emissions, the cost of complying with requirements to reduce emissions will cost only 0.2% of GDP.

We point out that this method of calculation is not unique to Israel. Even Germany, which is richer than Israel, has referred to emissions per capita for a similar reason of population growth.

It is therefore our contention that the base year, as presented in this paper, for Israel's policy to reduce GHG emissions should be 1996.

We recommend implementation in two stages to reduce GHG emissions in Israel. Duration of the first stage of the policy will be the coming 20 years, until the year 2020. During those years it will be possible, as will be shown in the summary table, to reduce 24 to 59 percent of GHG emissions based on the situation in 1996, or to develop the economy at a similar magnitude without increasing GHG emissions. During this period resources must be allocated and pilot plants built to thoroughly examine new systems to produce energy (based on the suggested list and other technologies); new systems to save energy and development of new approaches that will reduce dependence on exterior sources of energy, if by reducing kilometers travel or by more efficient urban planning that will reduce energy consumption.

Further on, the innovative technologies should be implemented.

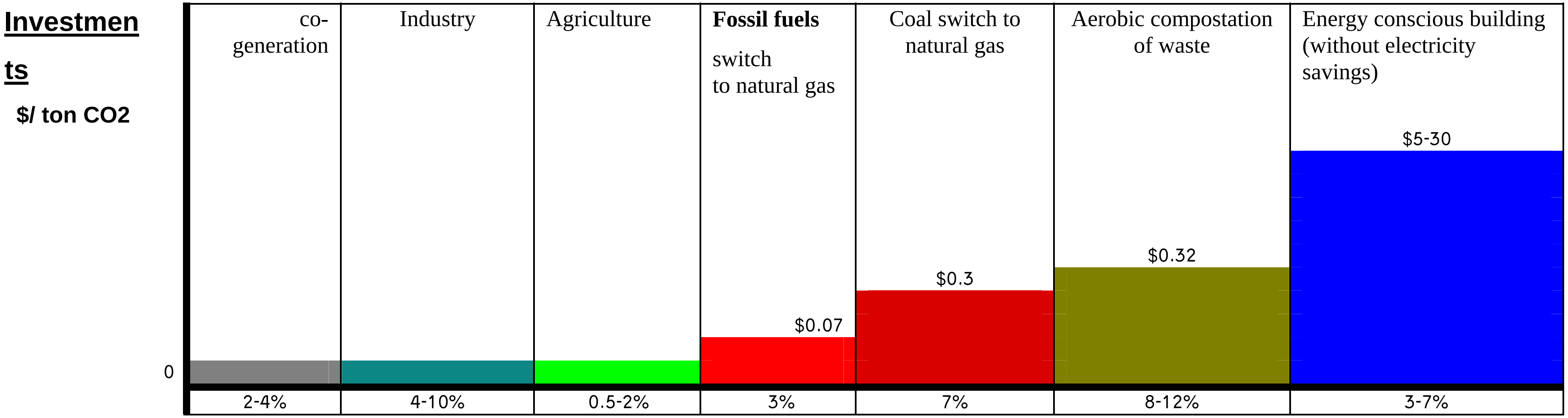


Figure A: Investment Cost of Reduction of CO2 emissions (% of total emissions in 1996)

A. Reduction of emissions in the energy generation sector

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	remarks
1. Switch to natural gas						Requires gas distribution system. Problem of EMERGENCY RESERVES
1A. Switching only plants operating on liquid fuel	Reduction of emissions by 30%. 2 million tons	Existing	10	7.5	3.2	
1B. Switching of 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	420	15.1	6.6	
2. Co-generation	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
3. 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: 5%. In scenario 1B: 5.3%. Total: 7.3%	
4. 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.
5. 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

A1. Alternatives under development

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	remarks
Nuclear energy						
Wind energy (1)	Substitution of 6% of current production technology	Existing	Investment of 850 - 3000 $	6	2.6	
Waste incineration (1)	Substitution of 5% of current production technology	Existing	3000$	5	1	See chapter 7
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 Zaslavsky's report (1998)

(2) All calculations are based on equivalent for 1996.

B. Reduction of emissions in the industry sector

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	remarks
1. Switch to natural gas	maximum potential 3 million tons	Existing	10-42	16	4.8	Requires distribution system
2. Co-generation	Savings of 1.5 million tons	Existing	Savings in most cases	6.4	1.9	Requires agreement with IEC
3. 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
4. Switch to "dry" process in cement production	Savings of 53% in energy consumption. 2.3 million tons	Existing	within the anticipated improvements	12	3.7	Switching to "dry" process has begun; reduction of conventional pollutants

C. Reduction of emissions from energy for buildings

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	remarks
1. Improvements in electricity appliances	No increase in electricity consumption despite increase in use	based on development abroad	no investment			
2. Energy conscious building. (set of measures)	Reduction of emissions of 20 - 40%, 1 - 2 million tons. (Up to 10 million tons in the year 2020)	Existing. Requires adaptation and development.	Investment of 0.5 - 3 NIS 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 significantly
3. Co-generation in public and business complexes	Reduction of energy consumption for heating and cooling of more than 50%.	Existing	Financial savings			

D. Reduction of emissions in the transport sector

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 to reduction of 10% of total GHG.	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 GHG emissions by 3%			
Market Based Mechanism (4)	Reduction of GHG 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 travels 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.

E. Reduction of emissions in the agriculture sector

Alternative	CO_2 reduction ton/year	Technology	Cost $/kW	Percent of sector's emissions	Percent of total emissions	remarks
10% increase in crop coverage	million tons	Existing	Depends on agriculture policy		0.8	Serves other national aims - preserving open space.
10% decrease in crop coverage	Increase emissions by 0.5 million tons					
Minimal tillage, 25% of land	2 million tons during 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		
Improved fertilizer application	1200 tons N_2O, 0.4 million tons CO_2	Existing, requires improvements		0.6		

F. Reduction of emissions from waste and sewage sludge

Alternative	Efficiency of Methane reduction	CO_2 reduction ton/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	8	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

Chapter 1

National inventory of greenhouse gas emissions and removals

This chapter presents a summary of Israel’s emission inventory of the greenhouse gases CO_2 and CH_4 and N_2O for the year 1996. Emissions from international and national aviation and sea transport are not included in the national totals.
The methodology used for estimating emission is based on the IPCC Guidelines for National Greenhouse Gas Emissions Inventories (IPCC, 1995b).
Some of the data presented is a modification of the results presented in Koch and Dayan (1997) and Koch (1998) based on several government sources. The data was modified to facilitate determination of relative contribution to total emissions by the different sectors. In one case (diesel oil used by the industry sector) there is some uncertainty regarding the precision of the data.

Table 1.1 summarizes all emissions by sector in 1996 in Israel. The figures represent emissions resulting from fuel combustion and electricity consumption for each of the sectors, wherever it is applicable. An outstanding case is the energy sector; It burns most of the fuel to produce energy (the respective figure is presented in parenthesis) but consumes only a small amount of electricity (respective figure appears without parenthesis).

Table 1.1: Carbon dioxide, methane and nitrous oxide emissions and removals (in Ktons) per IPCC sector 1996

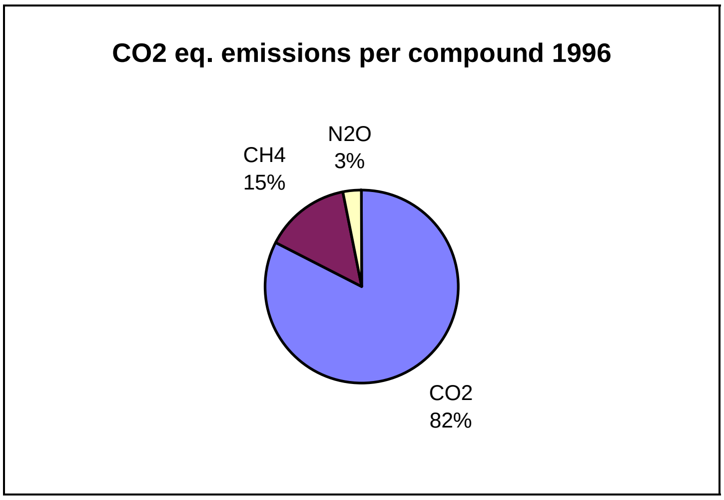
IPPC sector	CO_2 emissions (Ktons)	CH_4 emissions CO_2 eq. (Ktons) for 100 years	N_2O emissions CO_2 eq. (Ktons) for 100 years	
Fuel combustion total	**49,600**		**230**	
Energy production and transformation	*26,500*		*170*	
Industry combustion	*11,000*		*7*	
Transport	*10,300*		*35*	
Commercial and Residential	*1,800*		*15*	
Forestry	**-400**			
Agriculture	**2,500**	**900**	**1,200**	
Industrial processes total			**540**	
Cement	**1,700**			
Solid waste		**7,800**		
Wastewater treatment		**200**		
Total	**53,400**	**8,900**	**1,957**	**64,257**

1.1 Greenhouse gas emissions (CO_2-eq).

To indicate the extent to which the emissions of various greenhouse gases contribute to total radiative forcing, the emissions were calculated in CO_2 gases from anthropogenic sources using the Global Warming Potential (GWP) values for a time horizon of 20 years from IPCC assessment (IPCC, 1996a).

CO_2 is by far the greatest contributor of greenhouse gases, some 51,000 Ktons constituting 82% of the total. CH_4 contributes to the total emission of greenhouse gases, some 8,900 Ktons CO_2 equivalents for a time horizon of 100 years, constituting 30% of the total. N_2O emissions are only some 2000 ktons, which are only 3% of total emissions.

Figure 1.1- Relative CO2- eq. emissions



The current share of CO_2 equivalent emissions for each of the sectors is presented in three manners:

1. CO_2 emissions resulting in fuel combustion and processes (table 1.2).
2. Division of CO_2 emissions resulting from power generation among the sectors, based on electricity consumption by each sector (table 1.3).
3. Combination of the results attained to present CO_2 emissions by sector (table 1.4).

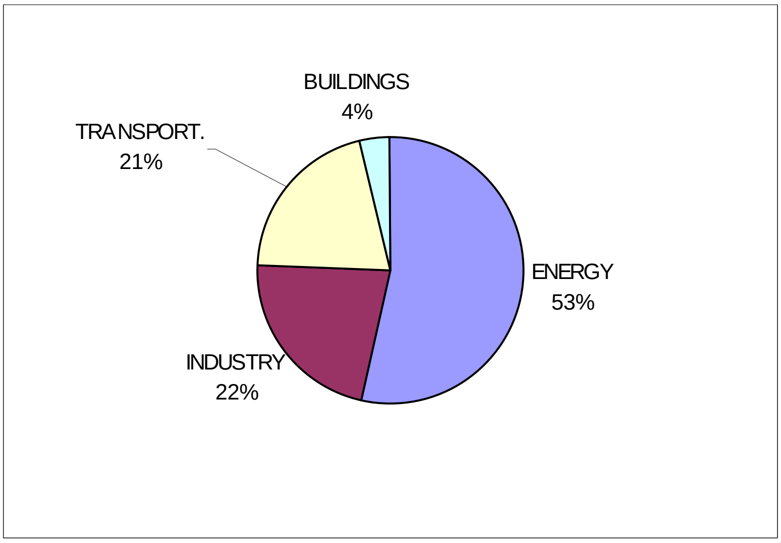
Greenhouse gas emissions by sector is presented in CO_2 equivalent in two manners:

1. Emissions resulting from fuel combustion, processes and other activities .
2. Emissions resulting from electricity consumption (emissions originating from

energy generation is burdened on electricity consumers), processes and other activities.

Emission from fuel combustion point to the energy generation sector as the leading sector with some 27,000 Ktons CO_2 constituting 53% of total emissions. Transportation and industry account for some 13,000 Ktons CO_2 (21% of total) and 11,000 Ktons (22%) respectively.

Figure 1.2 - CO_2 emissions resulting fuel combustion and processes.

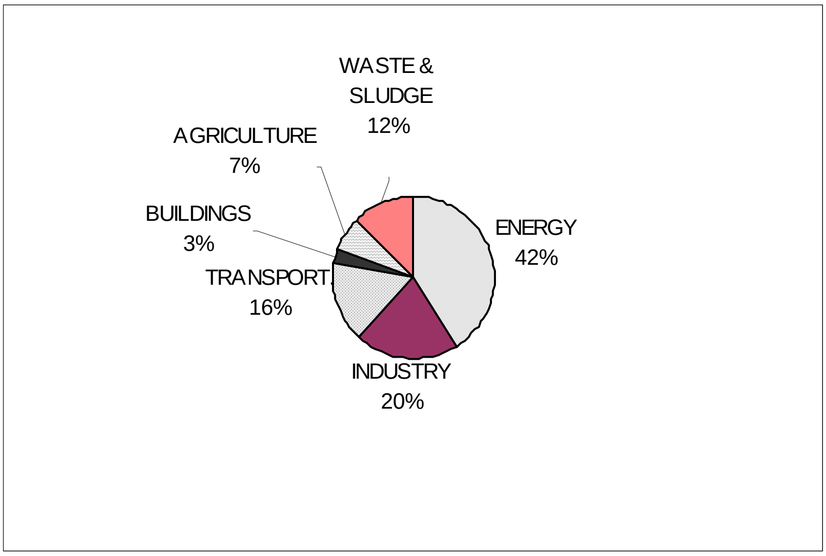


The relative contribution of greenhouse gas emissions by sector resulting from fuel combustion and processes, is changed significantly when electricity consumption by sector is considered. It changes industry's share from 22% to 30% of total emissions, and the residential and commercial sector's share from an insignificant 4% to 26%, thus pointing out the potential to decrease CO_2 by focusing on electricity savings within these two sectors. Transportation retains its large share of emissions - 21% of total.

Solid waste in Israel emits some 8,000 ktons of CO_2 eq. Ktons for a time horizon of 100 years, constituting 13% of total emissions.

The electricity consumption factor has no effect on the share of solid waste, which still contributes 12% as can be seen in figure 1.3.

Figure 1.3- Total contribution to GHG emissions in Israel, 1996



1.2 Carbon dioxide CO_2

By far the largest anthropogenic source of CO_2 emissions is the oxidation of carbon when fossil fuels are burned to produce energy. Combustion of fossil fuels for the production of energy is the leading cause of CO_2 emission - some 53,000 ktons (96%). These emissions are accounted for by the energy generation sector which emits 26,000 ktons (53%), transportation emitting some 13,000 ktons (26%) and industry with some 8,500 ktons CO_2 (17%). Cement production is the most important non-energy industrial process emitting some 1700 Ktons CO_2 (4% of total CO_2 emissions).

Coal contributes about 40% of the $C0_2$ emissions in the energy sector, whereas the contribution of residual fuel oil is 27%. Gas, oil and gasoline contribute each 13%.

Table 1.2 presents the amounts of the various fuels consumed by the sectors, the respective CO_2 emission of each of the fuels and the total CO_2 emissions for each of the sectors.

Table 1.2: Fuel consumption and CO_2 emissions by sectors

Sector	Electricity production		Transportation		Residential and commercial		Industry	
	Fuel consum-ption (1000 tons)	CO_2 emission (1000 tons)	Fuel consum-ption (1000 tons)	CO_2 emission (1000 tons)	Fuel consum-ption (1000 tons)	CO_2 emission (1000 tons)	Fuel consum-ption (1000 tons)	CO_2 emission (1000 tons)
LPG(*)					404	1,194	124	366
Gasoline			2,159	6,657				
Diesel oil	137	435	1,013	2,876	199	632	900**	2,859
Naphtha							769	
Residual fuel oil	2,031	6,252					2,277	7,099
Petroleum Coke							168	675
Tar			267	821				
Coal	8,190	19,882						
Total CO_2 emission (1000 tons)		26,569		10354		1,826		10,999
Percent of total emissions		54		21		4		21

* Liquefied Petroleum Gas (LPG).
**uncertainty about precision of this figure

When CO_2 emissions resulting from power production are passed on to the consumers of electricity, namely we break down the energy sector's share of CO_2 emissions (53% of total emissions) by its consumers, the resulting picture becomes quite different. The power generation sector is responsible for only 3% of all CO_2 emissions resulting from electricity consumption, the residential and commercial sector consumes about 55% of the electricity produced in Israel and is therefore accountable for some 29% of all CO_2 emissions originating from electricity production. The industrial sector consumes 29% of all electricity produced and is, therefore, responsible for some 15% of total CO_2 emitted from power production. The agriculture sector is a small consumer of electricity and is therefore responsible for only 5% of CO_2 emitted due to power generation. Table 1.3 presents the relative electricity consumption for each of the sectors, and the subsequent share of total CO_2

emissions.

Table 1.3: Electricity consumption by sector

	Electricity production	Residential and commercial	Industry	Agriculture
Electricity consumption (million kWh)	1,722*	16,706	8,725	2,902*
Percent of total electricity consumption	5.7	55.6	29	9.6

* The sectorial electricity consumption includes electricity required for water for each of the sectors

Table 1.4 shows all CO_2 emissions by sector due to fuel and electricity consumption (compilation of tables number 1.2 and 1.3). It shows that the industry sector accounts for a third of all CO_2 emissions in Israel, of which about half originates 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 some 88% are a result of electricity consumption. The transport sector accounts for 27% of CO_2 emissions all originating from fuel burning. The agriculture sector accounts for some 5% of the CO_2 emissions originating in fuel combustion and electricity consumption. The power production sector is responsible for 3% of CO_2 emissions as a consumer of electricity. This figure should be treated carefully: the power generation sector may be a small consumer of electricity, but this fact should not conceal the enormous potential within the power production and transmission sector to decrease the amount of CO_2 emitted at the production and the transmission stages.

Table 1.4: Relative contribution of CO_2 emissions by sector due to fuel combustion and electricity consumption

Sector	CO_2 emission resulting from fuel combustion (1000 tons)	Percent of CO_2 emission resulting from fuel combustion	Percent of electricity consumption (percent of total CO_2 emissions)	CO_2 emission resulting from electricity consumption (1000 tons)*	Total CO_2 emissions (1000 tons)	Relative contribution of CO_2 (in %) as a result of 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 each of the sectors' relative electricity consumption

1.3 Methane (CH_4)

The largest source of methane emissions in Israel is the decomposition of solid waste, 370 thousand tons or 20,700 thousand tons CO_2 eq. for a time horizon of 20 years (27% of all greenhouse gas emissions). It is second in importance to the contribution of $C0_2$ emissions from energy production.

Methane emissions originating from agricultural activities produce 42,000 tons, some 3% and 1.5% of the total CO_2 equivalent of methane and CO_2 emissions for the time horizon of 20 years and 100 years respectively. Within the agriculture sector, dairy cattle account for some 50% of all methane emissions.

Methane is emitted from domestic livestock through two processes: 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.

Enteric fermentation contributes about 75% of the methane emissions from domestic livestock, mostly from cattle. Manure management contributes only 25% of the emissions, mainly due to cattle and poultry Manure.

The sources of methane from agricultural activities are presented in table 1.5.

Table 1.5: CH_4 emissions from agricultural activities

Activity	CH_4 emissions			Percent of total
Domestic livestock enteric fermentation and manure management	Enteric fermentation (t/year)	Manure management (t/Year)	Total (1000t)	
Dairy cattle	17,760	3,000	20.8	49
Non – dairy cattle	11,340	1,890	13.2	31
Sheep	2,640	92	2.7	6.4
Goats	450	16	0.5	1
Camels	92	5	0.1	0.2
Horses	18	2	0	0
Mules and asses	10	1	0	0
Swine	113	1,425	1.5	3.5
Poultry	-	3,565	3.6	8.5
Total	32,423	9,996	42.4	

1.4 Nitrous oxide (N_2O)

The inventory of nitrous oxide (N_2O) emission in Israel points to three sources:

1. Agriculture: direct emissions form agriculture soils, emissions related to animal production and emissions indirectly induced by agricultural activities
2. Industrial processes: nitric acid production
3. Fuel combustion

Agriculture accounts for 3,800 tons of N_2O, some 63% of all N_2O emissions as can be seen in table 1.6.
N_2O contributes to the total amount of CO_2 equivalents of greenhouse gases 2% for a time horizon of 20 years, and 3% for a time horizon of 100 years.

Table 1.6: N_2O emissions by IPCC sector

Sector	**N_2O (10^3 tons)**	**CO_2 equivalent (10^3 tons)**	
		20 years	**100 years**
Energy	0.55	1524	171
Industrial processes	1.73	484	536
Agriculture	3.81	1,067	1,181
Total	6.09	1,705	1,888

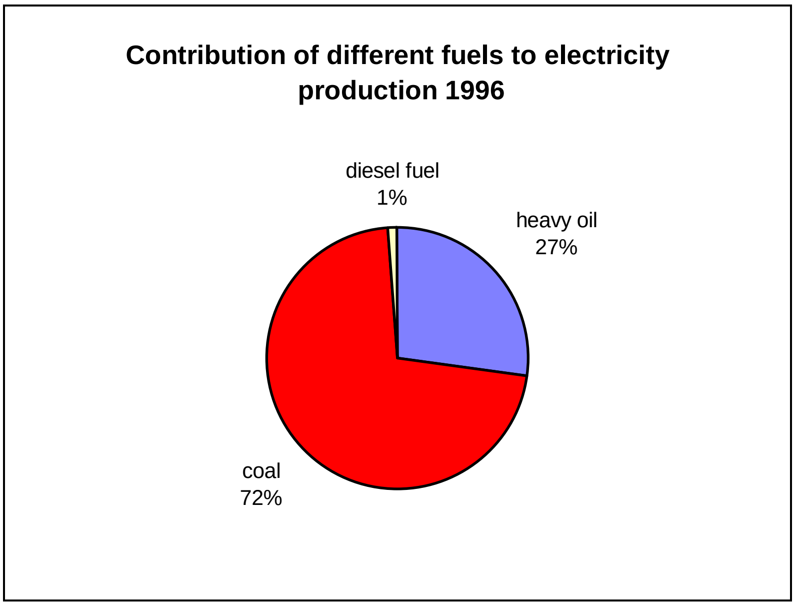
Chapter 2

The Energy Generation Sector

2.1 Introduction

The 1990 CO_2 emissions from power stations in 1990 were estimated at 16.66 million tons. In 1996 this sector emitted some 26 million tons of CO_2 and some 0.2 million tons of CO_2 eq. via N_2O, contributing 43% of Israel's greenhouse gases emissions. By the year 2020 emissions from this sector are expected grow to some 59 million tons of CO_2, an increase of 125% ("business as usual scenario")

Figure 2.1: Contribution of different fuels to electricity production



The increase in demand for electricity in the past decade was an unprecedented 6% per year. In the last five years Israel has experienced an annual increase in electricity demand of 7.7%, but the increase in demand is expected to be less in the coming decade.

The total amount of electricity generated by the Israel Electrical Co. (IEC) in 1990 was 20,898 million kWh. The official IEC predictions of future production, including electricity of other producers are 55,760 million kWh in 2010 and 74,794 in 2020. We shall use these numbers as the base for the future predictions of emissions. If we assume the same mix of types of generating stations and fuels we can extrapolate linearly from the current production capacity:

Table 2.1: Current and future electricity production and CO_2 emissions

Year	Production millions kWh	CO_2 emissions million tons
1990	20,898	16.660
2010	55,760	44.213
2020	74,790	59.626

2.2 Mitigation options

It should be noted that this section presents two distinct paths to solve the problem of greenhouse gas emissions from energy production; the first advocates incremental changes (switching fuels) so as to attain a reasonable amount of decrease in emissions. The second points to the great potential that lies in a revolutionary approach to energy production, focusing on the benefits of energy production from renewable sources. It points out the large hurdles that obstruct the development of this approach in the form of external costs and subsidies for only some technologies, placing “clean technologies” at a disadvantage.

Eight options of mitigation of CO_2 have been considered:

1. Increased efficiency of energy production

It was estimated that the efficiency of electricity generators will increase in Europe from the current 40-42% to 60% in the coming 30 years. (Technologies, policies and measures for mitigating climate change, IPCC Technical Paper I, UNEP, 1997, p.5). In Israel the efficiency of electricity generation is lower that 40%, and can be improved in the future when installing new electricity generators.

2. Co-generation.

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 close to the generating stations. The common clients are:

- The chemical industry, which is relatively small in Israel and its demand for low pressure steam is limited.

- Steam for home heating in cities in cold climates. This market in Israeli climate is very limited.

3. Combined cycle.

Utilizing the exhaust gases from steam generators to operate low pressure gas turbines can increase the 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.

4. Decarbonization of flue gas

It has been suggested to recover the carbon and oxygen from CO_2. This proposal assumes that unlimited energy is available from an unknown source. This idea can be relegated to the believers in perpetu mobile.

5. CO_2 storage.

It has been suggested to absorb CO_2 from flue gas and store it underground. This option depends on available non leaking depleted natural gas fields into which CO_2 may be pumped. However, extensive tests of many possible locations in Israel (for the purpose of storage of natural gas, at that time) have proven that all such proposed locations are too leaky for the use as storage of gases.

6. Nuclear reactors

This option is probably the best one for decreasing greenhouse gases. However, it can be realized only if its technology and safeguards can guarantee safe operation and waste deployment and the public resistance to nuclear reactors is overcome.

7. Higher energy fuels

Conversion of fuels for power generating stations from coal and oil to natural gas for economic and environmental reasons will also decrease the CO_2 emissions.

Conversion from fuel oil to natural gas will decrease CO_2 emissions by 30%.

Conversion from coal to natural gas will decrease CO_2 emissions by 44%. The

Electrical Co plans to import natural gas for the next generating station being planned and to convert gradually the coal using power plants to the use of natural gas. Reduction of CO_2 emission as a result of partial conversion to gas is presented in table 2.2. The two scenarios for 2010 and 2020 are a good approximation to the Electric Co. data. Table 2.3 shows the costs of conversion of power plants to gas.

Table 2.2: Projected reduction of CO_2 in 2010 and 2020 resulting from conversion to gas.

	Electricity production (M kWh)		CO_2 emissions (million tons)				
Year	Gas	Current mix	Gas	Current mix	Total	Reduction	Percent of reduction resulting from use of gas
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 on gas and 50% by current mix

Table 2.3: Cost of fuel conversion in power generation stations

Original fuel	Original generating capacity MW	operation hours/ year	fuel use kg/kWh	kg CO_2 to kg fuel	investment cost of conversion to gas $/kW	cost of new station $/kW	Cost $/kg fuel
Heavy FO	2160	8320	237	3.07	10*	1450*	0.12
Light FO	1876	1750*	355	3.06	10*	1000*	0.19
Coal	3700	8250	360	2.47	42	1500	0.04
Nat. Gas	2160**	8320**	200*	2.75	---	420	0.15

* a rough estimate.
** if all heavy fuel turns to gas

Leakage of methane from the transportation lines and the generating plant should be minimized, since the Greenhouse factor for methane is 21 times that of CO_2, which means that a leakage of 7% of the methane used will more than double the CO_2 equivalent emissions.

8. Renewable resources (Solar, wind, hydro, bio mass, waste disposal and geothermal)

A team of experts has recently submitted a report to the Ministry of the Environment by Prof. Dan Zaslavsky. The team analyzed possible alternatives for energy production from renewable resources. This section presents some experts from the document. The report has not yet been approved by all parties concerned and by the Ministry of Environment.

External costs are an essential factor when discussing energy production from renewable sources. There is a wide disagreement on various evaluations of external costs. Representative values are about 2 cents per kWh for energy produced from coal or oil. These values are conservative. A comparison of the costs and benefits of different means of electricity production can be translated into economic values when two conditions exist:

a. The external costs are included in the cost because of environmental damage.

b. The present value of benefit or damage is calculated at a discount rate that approaches zero.

The allowable investments to prevent external costs resulting from fuel combustion for the generation of electricity reach $8000 to $9500 for an average kW generated from oil or coal, and $2700 for an average kW generated from natural gas. These values are based on an interest rate of 5%. At an interest rate of 0% over 30 years, the allowable investment is double, i.e. $16,000 - $19,000 in order to prevent the use of coal or oil, and $5400 in order to prevent environmental damage resulting from the combustion of natural gas.

Electricity subsidies, by a conservative estimate, are 3 cents per kWh. This value is controversial and sensitive, but there is wide agreement that subsidies are a significant component in of energy production costs.

Alternative and renewable energy sources, which do not require fuel import, are at a disadvantage in a competitive market, and cannot penetrate such a market, as long as energy prices are subsidized.

The resulting values of real costs, based on the aforementioned assumptions have been summarized as “permissible investment for an average kW in a non-polluting power station”.

Table 2.4: Permissible investment for an average kW in a non-polluting power

station

Replaced Source	Coal	Oil	Gas
Based on an interest rate of 5%	14800-16160	14800-16160	8752
Based on an interest rate of 0%	28900-31540	2890-31540	17080

These values only refer to the savings in the combustion of fuel in existing power stations, and are conservative.

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 the advantages to Israel in the development of its technologies.

Five technologies are proposed to provide the generation of all Israel's electrical power from renewable resources. The investments in at least three of these are estimated not to exceed an average kW cost of $3,000 to $4000, much lower than the estimated permissible investments in order to prevent the external costs from finite resources.

Two technologies were proposed for immediate application to replace a million and half tons of oil a year. With a complete internalization of the external costs, this potential can be doubled.

The first of these is **wind power**. Wind power potential is over 1.75 billion kWh/year according to a conservative estimate. In comparison, Israel's electricity consumption in 1997 was 30 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: Usage of wind energy may be increased, if the investment in the generators and the transport of energy to the national grid can be decreased. Commercial wind generators are available. For instance: BWC EXCEL is rated at 10 kW and costs $23,000 - $27,000 including the tower About 2500 $/kW). Whisper wind generator offers a 3 kW generator (not including tower) for $5390.

The second is **biomass combustion.** There is some inconsistency in the various data on biomass and waste combustion, and the use of their stored energies in different ways. From an overall view, and based on alternatives for waste treatment, this direction has a high economic potential. Calculations made in a pilot project during the eighties have indicated that the cost is competitive, although it was difficult to meet the subsidized and unrealistic cost of electricity. For example, if the cost for alternative electricity sources increases by 3 cents per kWh, the value of one ton of waste increases by $15 - 20. The potential for waste utilization, including biomass, may reach 5 billion kWh/year. However, it is doubtful that biomass should be grown in Israel for energy purposes.

There are three technologies under development in Israel that could be applied within a relatively short time span. The **“Energy Towers”** technology could lower the price without the internalization of external costs and could provide for very cheap energy storage on a daily and weekly basis. The “Energy Towers” have a potential for supplying Israel’s entire energy consumption. The cost of the expected electricity generation is competitive with the cost of coal combustion and even with that of gas, without internalization of external costs and even without the abolishment of subsidies. The investment for an average kilowatt is estimated to be less than $4000. “Energy Towers” have a built-in storage system of close to 100% efficiency, on a weekly basis, and at a low investment. With the increased use of solar energy, there is a special interest in developing energy-storage systems. “Energy Towers”, as conceived today, may supply this important technology as well, even for other energy sources. Therefore, it should be combined with other solar technologies.

The technology of **concentrating parabolic mirrors** now under development in Israel could be applied if the 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.

The **Solar Tower** technology, under development in Israel, will be ready within a few years. It too can supply between one quarter to one third of Israel’s electricity demand without oil backup, and it too depends on the internalization of external costs.
The two technologies last mentioned, will be worthwhile if the external costs are internalized, or if a technology for energy storage is developed which would enable

the use of the technology 24 hours a day. This could supply any amount of energy required, provided a system for storing the energy is found. Without storage, they would be unable to supply more than one-fourth of the consumption, whatever the actual amount. These two technologies can also be used as an interim solution for enhancing fuel combustion with solar energy. This solution may not be worthwhile to Israel, but it can be exported.

Some technologies may be used as interim solutions by supplementing combustible fuel with solar energy. The development of storage systems that will make solar energy available 24 hours a day is an important and promising development.
Solar energy is utilized in Israel more than in most other countries for home hot water and for large evaporation ponds.

Photovoltaic cells: Examining the current commercial status of solar energy technologies shows that large scale usage for energy production depends on the development of more efficient, cheap photovoltaic converters of solar energy to electricity. Sanyo has announced in May 1998 that it has developed the world's most efficient silicon solar cell that has an efficiency of 17.3%.

Commercial solar cells are small and expensive, for example:

Table 2.5: Examples of several commercial solar cells.

Company	Module Capacity	Module cost	
	watts	$	$/kw
BP Solar	90	595	5945
Soleq SQ	80	449	5612
Siemens SP	75	490	6533
Solarex VLX	53	325	6132
Unisolar US	64	395	6171

These examples are still much better than the 10% efficiencies and $10,000/kw reported in 1973.
The world's largest rooftop photovoltaic plant has been installed on the roof of the New Munich Trade Fair Center. Its peak output is 1 MW.
The most valuable use of solar energy could be for air-conditioning, since solar energy will be available at the warmest time of the day. However, only a few, heavily

subsidized, solar air-conditioning units have been built so far.

Parabolic mirror solar energy concentrators for the production of high temperatures, like the Weitzman Institute Solar Tower, often get headlines but no commercial use. The commercial PSI parabolic concentrator uses 82 mirror facets with a total projection are of 87 sq. m. and delivers 70 kW at best.

There are two possible untapped sources of **hydroelectric power**:

1. From the sources of the Jordan. Only a small hydroelectric generator is presently using this resource. However, this option has been discussed for 40 years and has not been implemented due to water allocation disputes with neighboring countries.

2. Utilizing the height difference of the Mediterranean Sea and the Dead Sea. This option has been investigated in depth many times and is not viable economically currently.

Geothermal sources of energy are limited to a few small thermal springs that are used as tourist attractions and cannot be converted for other uses.

The Electrical Corp. is supporting research on technologies to exploit **wave power** for electricity production. The likelihood of an economic project of this type is low.

2.3 Recommendations

CO_2 reduction ability

Our objective is to reduce CO_2 and CO_2 equivalent emissions to the 1990 level by 2010. It is assumed here that an attempt will be made to reach the targets for 2010 and for 2020.

The 1990 emissions for electricity production were 16.660 million tons CO_2. The 2010 emissions, if no changes are made to decrease the GHG emissions, are expected to be 44.213 million tons CO_2. The 2020 CO_2 emissions if no changes are made to decrease the greenhouse effect will be 59.626 million tons CO_2.

The required reduction in emissions will, therefore, be 27,553 million tons of CO_2 for 2010 and 42,966 million tons for 2020.

Following the discussion of the available options above we recommend two approaches for the reduction in CO_2 emissions. One class do not require excessive investments or changes, the other, pursuing a more revolutionary change and requiring substantial changes in the energy sector pricing mechanisms, technical tradition and decision making criteria.

Class I recommendations

1. Switching the main fuel for power stations from coal and fuel oil to natural gas. The savings in CO_2 emissions for the current mix of fuels are 41.4%. The IEC does not plan to switch the fuel to the coal using power stations in the near future. If only the liquid fuel using power stations are switched to natural gas by 2010, and all future generating stations use natural gas, and the coal using generating stations are switched to natural gas by 2020, the reduction in emissions due to changing the fuel will be 6,464 million tons by 2010 and 24,685 million tons by 2020.

Current projections in IEC for the best case scenario are that natural gas will, at best, account for 50% of the electricity produced.

2. Increased efficiency of new power stations. We assume that the newer power stations will have an efficiency greater by 2% than current power stations and each 1% of efficiency is equivalent to 2.5% in CO_2 emissions (Technologies, policies and measures for mitigating climate change, IPCC Technical Paper I, UNEP, 1997, p.5). for the increase in capacity by 2010 and by 2020 the reductions in emissions will be 1,337 million tons by 2010 and 2,148 by 2020.

3. Reduction of 0.2 million tons a year of CO_2, or more, 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.

The total savings in CO_2 emissions from power stations by 2010 and by 2020 are presented in table 2.6

Table 2.6: CO_2 reductions for 2010 and 2020

Measure	CO_2 reduction ability for 2010. (Mtons CO_2)	CO_2 reduction ability for 2020. (Mtons 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

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 no natural gas is used, the total reductions will be only 1.5 million tons CO_2.

If no natural gas is used by 2020 the total reductions for 2020 will be only 2.5 million tons CO_2.

2.4 Economic considerations

1. Changing of fuels: It is expected that the switch from coal and fuel oil to natural gas will not increase the cost of fuel per generated unit energy. However, considerable capital expenditures will be required. If Sinai natural gas is used, a gas pipeline will be required from the wells to the generating stations. If European suppliers are used liquefaction equipment will be required at the source and evaporation equipment at a local port, with pipelines from the port to the generating stations. Ships capable of carrying liquified natural gas will have to be purchased. In addition, some distillation equipment at the refineries will be idled and an additional fuel oil cracking unit will have to be built in order to correct the imbalance in products due to the loss of market for most of the produced fuel oil. However, advantages other than CO_2 reduction are anticipated, mostly reduction of other air pollutants (SO_2) and saving the cost of

scrubbers.

2. More efficient power stations: If any combined cycle units, that produce process steam, are built, steam pipeline to their process clients will be required.

2.5 Discussion

The greatest reduction in CO_2 emissions will be achieved by switching all fuels used in generating stations to natural gas. New generating stations using low energy fuels with low efficiencies, such as a generating station using shale will only serve to increase the CO_2 emissions, and should be discouraged.

The best technological solution is to switch to non fossil fuel generating stations. There are two such possibilities:

1. Nuclear reactors. These are economical and can be safe if designed and operated properly.

2. Solar, wind and hydrothermal generating stations.

Wind and hydrothermal potential in Israel is less than 2% of the energy demand. Solar energy is the ultimate desirable source of electrical power. It is clean, and renewable. However, its utilization has major hurdles. Solar energy is available only during part of the day, and its use will require massive energy storage devices. The cost is high, and will continue to be expensive, except, perhaps, for solar energy air conditioners, till the reserves of fossil fuels decrease to a point, where the cost of energy from fossil fuels will be similar to solar energy.

Other long term options:

1. The use of combined cycle electrical generators in order to increase the efficiency of the usage of fossil fuels is attractive but limited. The initial cost of these systems are high, but may be justified in the future.

2. The 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.

Since practically most mitigation options are problematical, the best method to minimize CO_2 emissions is to decrease the demand for electricity. This may be achieved by encouraging, through lower taxes, homes designed for energy efficiency, and by setting electricity prices that increase with increased use. Current data of the Ministry of Infrastructure shows that 1995 fuel savings were 19,000 TOE/year. The savings in 2010 may reach 267,000 TOE/year. In electricity savings terms these translate to 24 and 68 million kWh respectively.

<u>Class II recommendations</u>

Table 2.7 below showing alternative energy is not a statistical forecasts, rather a declaration of the essential targets of the Israeli economy, and serve to illustrate what is possible to achieve.

Up to 35,000 GWh per year may be added with savings of more than $30-70 billion from today until the year 2020. There is no doubt that the penetration of alternative sources depends on application processes that take time. This time depends on completing the development of new means at the rate of change of the economic climate and at the rate at which old power stations reach the end of their life cycle. One must also add two appreciable considerations:

a. If the calculations shown here are verified, it will be worthwhile using alternative sources even at the price of preferring existing power stations in order to save on fuel combustion.

b. There are number of steps which would facilitate meeting the targets. Among them are: an economic climate free of distortions, incentives and financial tools, the enactment of regulations, guidance, illustrations and the promotion of research and development at all levels.

We have not included in the tables a list of proposals for the interim period. Basically there are three main proposals.

a. Replacing heavy oil and coal with natural gas.

b. Combining gas turbines with steam-generating power stations (re-powering).

c. Supplementing gas combustion with solar energy at a ratio of 25% and higher.

Table 2.7: Alternative Sources for Electricity Generation

Technology	Status	Expected Date of Application Years	Investment needed until Application $\$10^6$	Estimated Invest. for average net Kw $/Kw	Expected cost of Electricity C/Kwh	Saved Fuel, Assuming Coal Combustion C/KWh	Saved Fuel, Assuming Gas Combustion C/KWh	Additional Allowable Investment <u>Based on the Coal Scenario</u> 0% Savings in $ Billion $\$10^3$ Kw	Additional Allow-able Investment <u>Based on Gas Scenario</u> 0% $\$10^3$ Kw	Potential In Israe MW (GWh per year)	By the Year 2020 MW (GWh per year)
Windmills	Fully commercial	Immediately	10	3250[2]	4-8	2	1.5	19,250[4.8]	8,064[2]	1000< (3504)	750 (2600)
Biomass and waste	Fully commercial	Immediately	5[4]	2860[5]	5.7[6]	2	1.5	19,640 13.7	8,454 5.9	1000< (6000)<	700 (4500)
Parabolic concentrating collectors, solar part only	Fully commercial, with improve. capabilities	One year	5	15000[7]	15<	2	1.5	7499 0.25	3686(-) (-0.06)	not limited, except for backup system	50 (540)
Solar tower of the Weizman Institute, solar part only	Under develop.	6-7 years to complete a demo plant	20	13600[9]	15<	2	1.5	8899 0.3	2288 (-) (-0.08)	not limited, except for backup system	100 (1080)
"Energy Towers", no power limitation	R&D has been completed, a pilot plant about to be constructed	3 years for start of construct. 7-8 y. to complete commercial plant	49	3000	2.5-5[8]	2	1.5	19450 (56)	8314 (23.9)	9000< (80000<)	2900< (24000)
Total								(75)	(31.7)	not limited	4500 (32720)

Notes:

1. Actions for the introduction of wind-power turbines: The completion of a country-wide survey, Enactment of laws and regulations which would require payment for electricity without limitations on the supplier, Setting prices that the Israeli Electric Company will have to abide by.
2. Requiring the preparation of regional plans, Setting main power lines with a governmental investment which would later be charged to the companies, Bids for constructions.
3. Investment per net kW: Based on $1300 per kW, installed, based on a 40% performance coefficient: External cost for coal are only 5 cents per kWh, not including the national economic costs amounting to the addition of 2 cents per kWh of fuel, External cost for gas are only 2 cents per kWh, not including the national economic costs amounting to the addition of 1.5 cents per kWh.
4. Preparation for the utilization of agricultural waste: Preparation of regional plans and the estimate of quantities, Allocation of industrial areas, Investigation, planning, collection, transportation, and storage, Bids.
5. Expected investment based on $2000 per installed Kw, and based on a capacity coefficient of 70%.
6. Fuel cost per kWh, based on $40 per ton, based on 0.15 ton oil equivalence, 5% interest rate for 20 years, 1 cent for operation and maintenance.
7. Installation near industrial zones which require steam may double the energy savings and reduce the actual investment.
8. Costs are dependent mostly on the interest rate which varies between 5.3% and 12%. At the average cost of electricity generation, the following benefits were not taken into account: desalination, the use of “Energy Towers” for pumped storage, for cooling thermal stations, and for increasing the efficiency of gas turbines. Similarly, the potential profits from selling water to fish ponds were not included. These may reduce net electricity prices by as much as 2-3 cents.Solar towers may also be used as an interim solution, supplementing gas turbines with solar energy for up to one third of the power generation. In this case, the formal cost for an average Kw is only one fourth of this number. According to the developers of this technology, in the future, the solar tower will be able to store heat at a cost of $30 per kWh. Deducting such storage up to once a year, will increase the cost of kWh by no more than 1 cent, and is much more attractive than a backup system of natural gas

Chapter 3

The Industry Sector

3.1 Introduction

In 1996 the industrial sector in Israel emitted some 18,500 Ktons CO_2 of which 60% originated from fuel combustion and 40% from electricity consumption. The total electricity consumption by the industry sector in 1990 (according to national statistics) was 5655 million kWh, over one quarter of the total electricity produced. In 1996 industry consumed 8571 million kWh, constituting almost 30% of total electricity produced.

Consumption of electricity by the major industrial segments in 1990 and in 1996 is shown in table 3.1

Table 3.1: Electricity consumption of major industrial segments

Segment	1990 Electricity consumption (million kWh)	1996 Electricity consumption (million kWh)	Average growth %/year
Chemicals	1384	2011	5.5
Food	728	982	4.4
Mining	553	892	7.1
Metal products	499	674	4.1
Non metallic minerals	356	707	10.2
Textile	350	498	5.0
Plastics and rubber	274	517	9.5
Electrical and electronics	273	579	11.4
Metals	234	296	3.5
Paper	108	291	15.4

The factorized average growth rate was 6.381 %

3.2 Projections for the future

The high average growth rate was due to the large immigration from Russia and the high rate of growth of the economy during that period and is not expected to be as large in the coming decade.

Of these segments the food segment is expected to grow proportionally to the population growth. The textile segment is expected to decrease to half its current size. The export oriented chemicals and electrical segments will grow faster than the increase in the population size.

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

1. The oil refineries at Haifa and Ashdod.
The refineries used 663,000 tons of fuel oils for heating and internal electricity generation in 1990. This amounts to 5.8% of the crude oil processed.
If natural gas is imported by 2010, as expected, the refineries will use about the same amount of crude as in 1990, and its electricity and fuel uses will be about the same as in 1990.

2. Users of electrochemical energy for the production of chlorine, caustic and magnesium. These are Electrochemical Industries at Acco, Machteshim near Be'er Sheva, The Bromine Co. at the Dead Sea and the Dead Sea Works.
The Dead Sea Works has started production of magnesium. It can reach production of 50,000 tons by 2010. The electricity usage per kg of magnesium is 18-25 kWh. Assuming that the new Dead Sea Works process is twice as efficient as the older processes, still the electricity use of the magnesium plant alone in 2010 can reach 500,000 MkWh. However, the byproduct of the magnesium plant is chlorine, and the increased production will cause the closure of the chlorine plants, saving about 300,000 MkWh per year.

3. The producers of cement and lime. These are Nesher cement works at 3 locations and lime production by Stone and Lime Co. in many locations and Negev Chemicals in one location.
Lime production in Israel in 1996 was 210,000 tons. It is expected to grow proportionally to the increase in population. The production of a ton of lime generates 0.786 ton of CO_2 from the decomposition of limestone and 0.982 ton of CO_2 from the combustion of fuel, or a total of 1.768 ton of CO_2 per ton of lime.
Cement production in Israel was 2.868 million tons in 1990 and 6.204 million tons in 1995. The average yearly growth rate was 16.4%. The high growth rate was due to the fast growth of the Palestinian market and to the large immigration from Russia. Expansion plans are for 0.7 million tons in 1999 and 0.7 million tons in 2003. It is assumed that most of the Palestinian market will be lost by that time, and the additional increase in production by 2010 will be negligible. The

amount of CO_2 produced per ton of cement clinker, without any mitigation measures is about 0.5 tons by decomposition of carbonates and 0.75 tons from combustion of fuels.

The 1990 electricity use by the largest industrial consumers (according to the Israel Electric Co. statistics) is presented in table 4.2.

Table 3.2: Largest industrial consumers of electricity

Company	Location	Electricity usage (M kWh)
Fertilizers and Chemicals	Haifa	110
Haifa Chemicals	Haifa	82
Periclase	Rotem	48
Electrochemical Industries	Acco	197
Machteshim	Be'er Sheva	121
Haifa Refineries	Haifa	94 *
Bromine Co.	Dead Sea	57
Negev Phosphates	Rotem	74
Petrochemicals Co.	Haifa	106

* Exclusive of own generated electricity.

Most of the electricity usage at Fertilizers and Chemicals was for the ammonia plant compressors. The ammonia plant was closed in 1997. No new ammonia plants are expected to be built in Israel.

Haifa Chemicals has built a plant, similar to its Haifa plant at Rotem, and is expected grow by a similar amount again by 2010.

The petrochemicals plant's production is expected to triple the 1990 rate by 2010.

The other companies in the table above are assumed not grow by more than 25% by 2010.

3.3 Mitigation options

3.3.1 CO_2 originating from fuel combustion

The 1996 CO_2 emissions from the industry sector were estimated at 11 million tons of CO_2 from fuel combustion and 7.7 million tons of CO_2 from electricity consumed, totaling 18.7 million tons CO_2.

Due to the slow down in the economy we project a 3% increase in the consumption of fuels per year from 1996 to 2010. This will bring up 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 industry sector for 1990. However, the last decade was distinguished by fast growth of the industry and we may extrapolate backward at 6.4% a year to 7 million tons of CO_2.

Therefore, the amount to be mitigated is the difference between the amounts of CO_2 expected in 2010 and the amounts of CO_2 in 1990: 8.1 million tons of CO_2 and CO_2 equivalent gases from fuel combustion.

Mitigation options of CO_2 emissions within the industry sector are as follows:

1. Higher energy fuels

Changeover to natural gas from fuel oil is practical only to plants close to the future gas pipelines. The largest user of fuel oil, the refineries, cannot switch to natural gas, since the fuel they use internally is generally the heaviest fuel that cannot be sold externally. If the government will finance a pipeline to Rotem and the Dead Sea, the plants there could switch to natural gas. Conversion from fuel oil to natural gas will decrease CO_2 emission by 30%.

2. 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 to the addition of aggregated ashes to the cement mix.

The savings of energy by switching from the wet to the dry process are 53%. Savings of both energy and CO_2 from decomposition of carbonates can be achieved by the addition of coal ashes, which may be added up to 30% in the final mixture.

The cement plant in Haifa and in Hartuv, both based on the wet process, produce 23% of all cement produced in Israel. The plant in Ramle was switched to the dry process in 1999 and it is anticipated that the other plants will be switched to the dry process as well..

Only minor improvements in the efficiency of lime plants are feasible, due to their relatively small size.

3.3.2 CO_2 originating from electricity consumption

In 1990 electricity consumption by the industry was 5,500 million kWh. CO_2 emissions were 4.55 million tons. In the year 2010 it is projected to be between 11,000 and 13,000 million kWh (according to several projections by the IEC). We will use the middle figure of 12,000 million kWh. Assuming no mitigation measures are implemented in the power generation sector, CO_2 emissions are expected to be 11.8 million tons in the year 2010.

Electricity is consumed by the industrial sector for two purposes; industrial manufacturing processes and air conditioning of space. A large fraction of energy is used by the high tech industry and by other industries for air conditioning purposes.

HVAC (Heating, Ventilation and Air Conditioning) systems consume sizable amounts of energy, which are associated with the production of CO_2 and other greenhouse gases. A significant portion of this energy may be conserved and the CO_2 emission reduced through co-generation. Electric power generation produces large amounts of reject heat. When this power is generated at the power plant, the reject heat is lost; generation of electric power locally, at the site, makes it possible to take advantage of the waste heat for heating and cooling. Co-generation systems may be practical for commercial size HVAC systems such as hotels, hospitals, office buildings and public buildings. 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 co - generation cooling systems and hybrid air conditioning respectively. The technical and quantitative background data for these results are presented in the appendix.

For a thorough discussion of the means and mitigation measures that significantly reduce energy consumption in buildings for heating and air conditioning see chapter 4: Energy savings in buildings.

Energy savings in large buildings can range between 25 - 40%. Assuming that heating and air conditioning account for 50% of energy consumption within the industry sector, implementing energy savings measures may enable a decrease of 2.5 million tons of CO_2 in the year 2010.

3.4 Summary

Our assumed objective is to reduce CO_2 and CO_2 equivalent emissions to the 1990 level by 2010.

The desired total savings in CO_2 equivalent emissions by the industry sector by 2010 are 7.01 million tons of CO_2

1. Cement plants. For 7.6 million tons of cement in 2010, switch to dry process (which has started) and introducing the maximum 30% of coal ashes will decrease CO_2 emissions to a total saving of 4.161 million tons.

2. Switch to natural gas at the Dead Sea and Rotem. For about 250,000 tons of fuel, the savings in CO_2 emissions will be about 100,000 tons.

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

4. **Efficiency improvement** in many plants may add savings of additional 200,000 tons of CO_2.

Table 3.3: Expected reductions in CO_2 emissions:

Industrial activity	million tons of CO_2
Cement plants	4.16
Switching to natural gas	0.1
Refineries	0.8
Other	0.2
Total	5.26

Leaving a deficit of the industry sector of 2.84 million tons.

With respect to reduction of CO_2 emissions from electricity consumption, it is estimated that energy savings for the purpose of comfort thermal conditions within buildings is 25 - 40%. Such a magnitude of savings can be achieved by “green building” as specified in chapter 4 and in cases of large industrial parks, by using more efficient heating and cooling systems as specified in the appendix

A reduction of up to 40% of emissions resulting from electricity consumption by the industry 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.

Chapter 4

The Residential and Commercial Sector

4.1. Development and prediction of electrical energy consumption in buildings

4.1.1 Introduction

The following factors affect energy consumption in buildings: appliances supporting activities in the building, lighting elements and climate control systems for spaces (heating in winter and cooling in summer). In residential buildings appliances include refrigerators, cooking and baking appliances, washers and dryers, dishwashers, telecommunications systems, computers, etc. In non-residential buildings they include mainly computer, printing and photocopying systems. Production and processing equipment found in industrial buildings are not included in the "appliance" category. Most of the equipment and appliances found in buildings run on electricity, with the exception of gas stoves and some heating systems that are based on condensed carbonic gas or liquid fuel. The amount of greenhouse gases emitted directly (in the building vicinity) from the few liquid gas and condensed carbonic gas installations is insignificant compared to the amount emitted from power stations as a result of electrical consumption in buildings. In view of this any reference to energy in buildings in this section is limited only to electrical energy consumption.

When the family economic situation improves, electrical appliances and climate control equipment are used more extensively (relating to both the length of heating and cooling periods and the level of momentary thermal comfort). At the same time the use of heating systems based on liquid fuel or condensed carbonic gas is declining in favor of electrical heating systems. As a result, in order to achieve thermal comfort suited to the rising standard of living, the number of climate control hours in Israeli apartments is on the rise, and the specific energy consumption per person in residential buildings mounts with the improvement in individual living standard. Therefore, if no designed prevention measures are taken the emission of greenhouse gases will continue to increase with the rise in standard of living.

4.1.2 The development of electricity consumption in buildings

With the exception of the hydrological, transportation and industrial sectors, where a relatively large proportion of electricity consumption is an outcome of the processes themselves, in other sectors almost all the consumption is within buildings. In general, data shows that the proportion of electricity consumption within buildings is more than 70% of the total consumption in Israel. The main sectors contributing to consumption within buildings are the residential and commercial-public sectors (in the past few years they have comprised about 60% of total consumption). The commercial-public sector includes offices, malls and commercial centers, schools, hospitals and campuses.

Consumption data from the residential sector was divided into components based on existing information on various installations and appliances found in this sector, and the cumulative electricity consumption. The variation in average annual consumption components per household (in kWh) and the variation in the relative proportion of each component of the total consumption (in percentages) is presented in figure 4.1. There is a significant increase in electricity consumption for each of the components during this period, with the exception of water heating. Total electricity consumption increased by 53%. A similar increase (from 55% to 65%) occurred in electricity consumption for lighting, refrigerators and other domestic appliances. The corresponding rise in electricity consumption for home heating (in winter) was about 110% and for cooling (in summer) about 145%. At the same time electricity consumption for heating water decreased by about 13%. This last figure is especially interesting, since it clearly represents the effect of the expansion in solar water heating system use on the decrease in electricity consumption for the same purpose, despite increases in other sectors. As far as total consumption is concerned, 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 that decreased from about 21% to about 12%. The proportional contribution of climate control rose at a particularly rapid rate during this period, and will continue to do so in the future, because of the under-climate control that still exists in many residential buildings.

In the commercial-public sector no itemized sectioning as described above was done. Nevertheless it is known that the contribution of water heating, refrigerators and other appliances, with the exception of office equipment, is much smaller in most portions of this sector. Lighting, air conditioning in summer, heating in winter and office equipment are the major sources of electricity consumption. According to IEC estimates for 1994 a total of 10,830 thousand sqm were air conditioned and about 10,410 thousand sqm were non-air conditioned in all portions of this sector. The total annual electricity consumption in non-air conditioned areas was only about a third of the consumption in air conditioned areas, with the climate control component accounting for 30% to 50% of the total consumption in air conditioned areas.

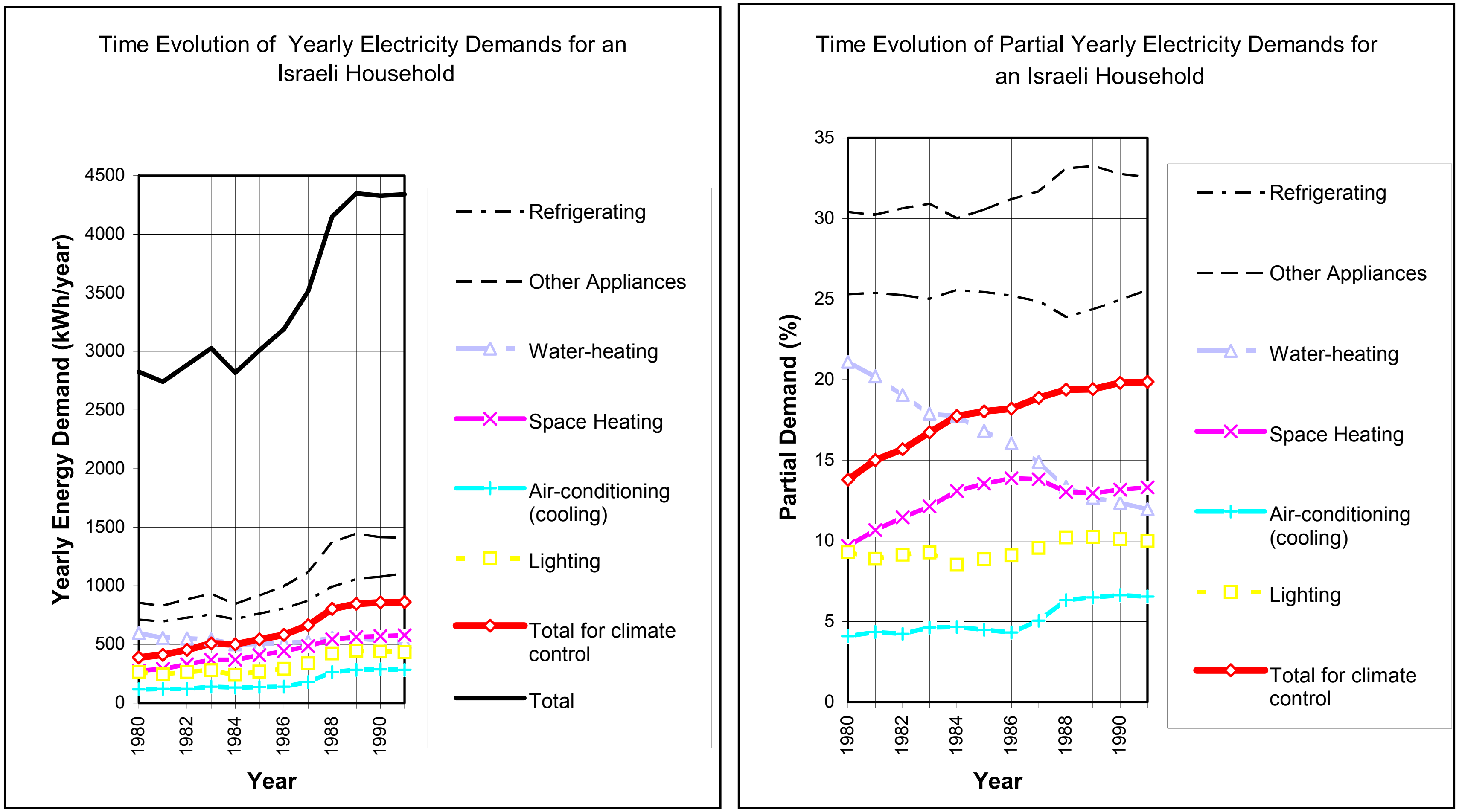


Fig 4.1: The variation of annual consumption components per household (in kWh) and the variation in the proportional part (in percentages) of each of the components of the total consumption.

4.1.3 Forecast of electricity requirements within the next decades

Active efforts to save energy abroad (mainly in Europe), include particularly rapid development of means and mechanisms to improve energy performance of all types of appliances. Local energy-efficiency legislation will eventually stop production of less efficient devices, so that the appliances imported into Israel from abroad will be energy efficient. It would be reasonable to assume that Israeli industry will also utilize the modern developed abroad, even if only out of need to compete with imports in this field. Israeli appliances will essentially become more energy efficient, even if no initiated intervention will take place in this case.

Israeli construction is based on local standards, using a finite variety of materials and technology with which it has experience. It would be reasonable to assume that as the standard of living in Israel rises there will be a greater emphasis on the technological quality of building, only regulated materials and products will be used and there will be better enforcement of design and building regulations. As a result most of the new construction will meet the specified standards, including the thermal insulation code for buildings.

Architectural style and design of buildings are affected by many factors. Standards and regulations, however, have almost no effect on their character, with the exclusion of general layout and building border line that are dictated by municipal building plans. In addition, several architectural characteristics have developed in Israel over the years that originated from lenience in calculating building percentages (such as cantilevered terraces that are not roofed on the same story). Local ordinance is also the source of certain local styles that developed in some municipalities and cause some technical difficulties with the application of the required thermal insulation (such as the requirement for slanted, tiled roofs in certain areas of Haifa, for rigid coverings for exterior walls in Tel-Aviv and stone in Jerusalem). There is no standard, law or regulation in Israel that obligates energy considerations in architectural design. For years there has been a demand in Israel to shorten the project approval procedure. In view of the general democratization of various processes in the country, it is quite probable that in the future there will be a tendency to reduce the level of public involvement in the field of architectural design. As a result, if no initiated actions are taken that will obligate energy saving considerations as early as the design stage, the variety of styles and solutions that are not energy-conscious is liable to grow.

The IEC has prepared a consumption forecast in various sectors for the year 2015 that is based on existing data on electricity consumption and other background data, itemized above. The forecast has been created according to five different development scenarios: "regression" (population of 6 million in 2015), "slowing" (7 million), "stability" (7.5 million), "growth" (8 million) and "boom" (9 million). The forecast takes the rise in standard of living and aspiration to greater living comfort into account on one hand, and the energy improvements in appliances, installations and processes on the other. The forecast also assumes that future construction will be entirely according to standards, so that buildings will be thermally insulated conforming to requirements of existing standards. The forecast, however, does not take into account energy improvements in the building plans themselves, in their thermal insulation beyond the requirements of present standards, and all the more so does not consider the possibility of "energy-conscious architectural design".

The data shows that in the residential sector that as early as the 1990's, the significant energy improvement in appliances cancels out a considerable proportion of the increase in electricity consumption resulting from the rise in standard of living. Moreover, in the 2000's, electricity consumption of Israeli domestic appliances is expected to return to its value at the end of the 1980's, and to its current value in the entire country, despite the significant increase expected in population size. On the other hand, according to the above forecast, as a result of the "life as usual" scenario in relation to architectural design of buildings, the expected electricity consumption for controlling internal climate in Israeli households will not decrease in the 2000's. This is despite certain improvements in the climate systems themselves that have been taken into account. As a result, the proportion of electricity consumption for this purpose is expected to grow in Israeli households from about 20% of the total consumption in the 1990's' to about 50% of it in the 2000's. In the entire country it is expected to comprise even more than half the total consumption in the residential sector.

In the commercial-public sector, the forecast includes reference to the rise in standard of living and to improvements that will occur in conditioning systems and other appliances, but does not take into account improvements in architectural design and climate control procedures. The forecast for specific electricity consumption (kWh/sqm) in offices is a reduction of about 10%, both in air conditioned and non-air conditioned spaces. At the same time an increase in specific consumption by about 125% is predicted for air conditioned spaces in schools, and by about

45% in non-air conditioned spaces, with no changes in other sectors. While the total area of non-air conditioned spaces in this sector are expected to grow by about 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.

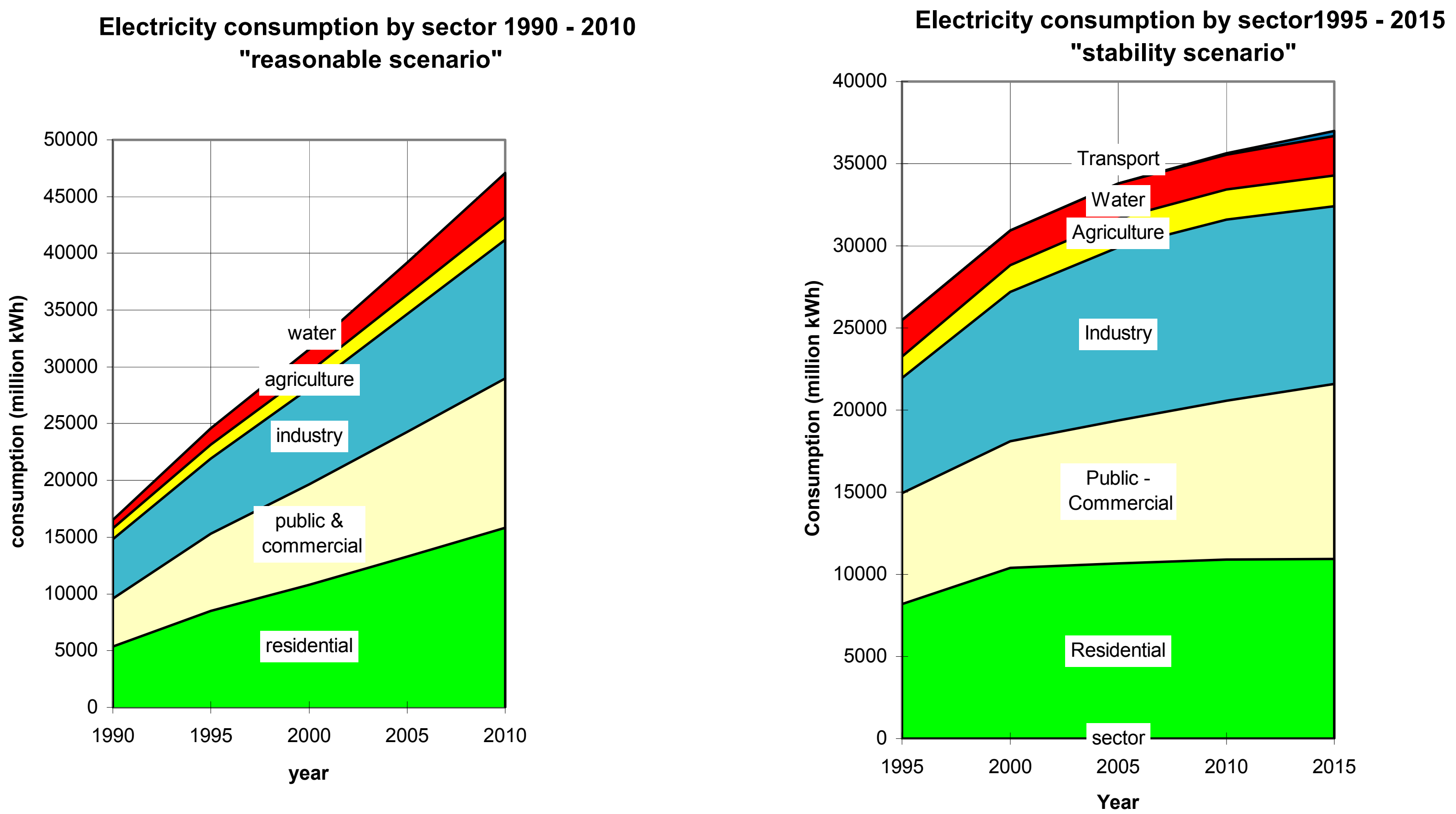


Figure 4.2: Projections of electricity consumption by sector for the years between 1990 and 2015. The two very different projections were prepared by IEC under various assumptions. Among them: "stability scenario" assumes a population of 7.5 million in 2015. "Reasonable scenario" (as opposed to "optimum scenario") assumes that not all of the potential will be utilized by Israel in developing its economy.

4.2 Planning factors affecting energy savings in buildings

It is difficult to provide and analyze of the cost benefit of energy savings within buildings because of the variety of parameters that could be implemented in buildings, of which there is need to implement only some to achieve energy savings. It is possible to decrease energy consumption in buildings by between 25 and 40 percent compared to today, with great variations in implementation of measures and cost. This section provides thorough data regarding the range of effect of various planning parameters. It is our contention that planners should retain significant autonomy in planning, but should seriously consider the potential effect on energy savings and the cost of the different parameters discussed in this section. Some of the means to achieve this are discussed in section 4.4.

4.2.1 Energy savings in buildings by planning parameters

The quantitative range of effects of each of the planning parameters on electricity savings is presented in table 4.1. The data is presented in descending order according to the degree of energy savings. The numbers in parentheses express the maximal possible change in kWh/year per square meter floor, unless otherwise specified. **Figures 4.3 and 4.4 present the maximum effect of each design parameter in the coastal plan and mountain climatic zones**. Thorough data about the range of effect of parameters, in different types of buildings, is presented in appendix A.1 and is based on research carried by Shaviv and Capeluto, 1992).

Several points of clarification regarding table 4.1 and figures 4.3 and 4.4:

1. The figures representing the maximum energy savings for each of the parameters are the results between the worst and the best "energetic conscious" situation that can occur in buildings. The existing situation might be somewhere between the best and the worst cases. The results presented in table 4.1 and figures 4.3 and 4.4 serve as a yardstick to measure the range of effect of the different planning parameters.

2. Implementation of all the parameters as suggested in this section is not a linear function. That is to say that one cannot add the resulting energy savings in case of implementing all parameters. Implementing one parameter will necessarily decrease the impact of another parameter on energy savings.

3. The aim of this section is to point out the benefits of various parameters, so that planners may decide which of them to implement to achieve a required energy savings standard, which currently does not exist.

4. Electricity consumption in houses in Israel is currently below American and European standards (i.e. not all of the apartment are heated at all times). It is assumed that within the coming years, electricity consumption in Israeli houses will increase and reach western standards, specifically for creating comfortable thermal conditions within houses (i. e. air temperature does not fall beneath 17.5^{o}C in winter and does not exceed 25.5^{o}C in summer). Under this assumption, the potential for energy savings in the coming future is larger than at present.

Table 4.1: Range and average effect of energy savings potential of planning parameters in buildings. *The list is arranged according to the expected energy savings in residences (Kwh per sqm floor per year)*

	Residential				Public
	Mountain		Coastal plain		Coastal plain
+ shading: windows in summer (external)	10-12	**11**	18-29	**24**	24
0 non-shading: windows in winter	9-26	**18**	3-25	**14**	
+ insulation: roof	18	**18**	13	**13**	7
+ passive solar energy (southern window & shutter)	5-35	**20**	3-12	**8**	
+ sealing against air infiltration	15-25	**20**	3-15	**9**	
+ insulation: hanging floor	15	**15**	11	**11**	
0 building orientation	5-16	**11**	3-14	**9**	
0 thermal mass	8-15	**12**	5-10	**8**	
+ insulation: walls	5-15	**10**	3-15	**9**	4
+ night ventilation: natural and artificial	5-15	**10**	5-10	**8**	5
- surface area to volume ratio	5-16	**10**	5-8	**7**	
+ comfort ventilation: natural and artificial	5-10	**8**	5-10	**8**	8
- size of windows facing east and west (with shutter)	3-7	**5**	3-17	**10**	
0 color: roof	5-7	**6**	7-10	**9**	
0 solar building orientation	2-15	**9**	2-6	**4**	
0 solar building proportions	1-15	**8**	1-3	**2**	
- size of windows facing north (with shutter)	1-3	**2**	4-8	**6**	
+ shading: roof			3-5	**4**	
0 non shading: roof	3-5	**4**			
+ type of glazing: double versus single	3-5	**4**	2-4	**3**	10
0 color: walls	1-5	**3**	1-5	**3**	
+ non shading: walls	1-5	**3**	1-2	**2**	
0 proportions	1-3	**2**	1-3	**2**	

Legend
+ higher cost
0 identical cost
- lower cost

Table 4.2 shows the cost/savings ratio for design parameters in terms of cost per energy savings (kWh/sqm floor/year)

Table 4.3 provides a comprehensive discussion of additional advantages and limitations for implementing design improvements of climate-conscious and energy-conscious building.

Table 4.2: Cost of design parameters and the potential energy savings in residences.
Design parameters that do not affect building costs have been omitted. The values are based on Shaviv and Capeluto, 1992, for a building with standard insulation and 4 facades. Prices are based on "Heshev" publications, 1998.

	Mountain			Coastal Plain		
Design Parameter Price is based on the describe change (other changes may be applied)	**Savings kWh/year/ sqm***	**Cost NIS*/sqm**	**Cost / Saving****	**Savings kWh/year /sqm***	**Cost NIS/sqm**	**Cost/ Saving****
Passive solar energy (southern window and shutter) Increasing the window and shutter from 5% to 20% and changing the picture window profile from Klil 1700 to Klil 7700	**35**	**38.49**	**1.10***	**12**	**38.49**	**3.21**
Window shading (summer) All windows without shutters versus shutters on all windows	**10**	**30.20**	**3.02**	**24**	**30.20**	**1.26**
	No roof shading					
Roof shading (moderately dark shade) The change: upper roof made of 8 mm cementboard	**4**	**(-)**	**(-)**	**5**	**29.76**	**5.95**
Night ventilation Vent for 20 air changes per hour	**15**	**10**	**0.67**	**10**	**10**	**1.0**
Comfort ventilation 5 ceiling fans	**10**	**15**	**1.5**	**15**	**15**	**1.0**
Air sealing Changing the picture window profile from Klil 1700 to Klil 7700	**25**	**7.07**	**0.28**	**15**	**7.07**	**0.47**
Wall insulation Addition of polystyrene panels Mountain region: 2.5 cm Plain region: 2.0 cm	**13**	**4.89**	**0.38**	**15**	**3.92**	**0.26**

* NIS: New Israeli Shekel. 1$US ~3.8NIS (sqm floor)
** NIS/ kWh/ sqm/ year

Roof insulation Addition of polystyrene panels Mountain region: 3.5 cm Plain region: 3.0 cm	**18**	**7.7**	**0.43**	**13**	**6.6**	**0.51**
Suspended floor insulation Addition of polystyrene panels Mountain region: 3.0 cm Plain region: 2.0 cm	**15**	**6.6**	**0.44**	**10**	**4.4**	**0.44**
Glazing type Single glazing versus insulated double glazing 4+6+4	**5**	**13.6**	**2.72**	**4**	**13.6**	**3.4**

Table 4.3: Advantages and limitations for implementing design improvements.

(+ Higher Cost, **0** Same cost, **-** Lower cost)

Design stage: building geometry

+	Passive solar energy (southern window and shutter)	Very effective design parameter. Suitable construction ensuring sun rights should be stressed. Possible incentive: solariums not included in building area limitations.
+	Shading: windows in summer (external)	The major design parameter in hot climates. Is standard in low-cost residential building, despite expense. In costlier building, such as private houses, there are many that lack shutters. In public buildings, such as offices there is no external shading and internal shading is insufficient.
+	Shading: walls	The energy savings are small, so it is not economic as an addition to the facade, unless it results from suitable construction or is produced by plants.
+	Shading: roof	Necessary only in hot climates, such as the Coastal Plain, and mainly in the Jordan Valley area. More economic than wall shading. Can be implemented with ventilated tiled (light colored) roofs. Shading possible by suitable construction or plants.
0	Non shading: windows in winter	Very important in the cold climate of the mountain region, but also in other climatic regions, except for the Jordan Valley. Solar rights should be guaranteed for each unit by appropriate urban design.
0	Building orientation	Very effective and does not add to construction costs. Appropriate construction that will allow desired building orientation should be stressed. Possible incentive: solariums not included in building area limitations. This incentive will indirectly result in building designs achieving desired building orientation. Requirement to submit analyses of desired and undesired winds in the plans submitted for municipal approval.
0	Solar building orientation	Possible over the entire southern region, from 30 degrees east of south to 30 degrees west of south. In hot climates preferably only until 15 degrees west of south. Suitable construction should be stressed.
0	Proportions	Small effect as long as the building envelope does not vary much and as long as a window can be positioned on the southern facade as recommended.

Table 4.3- II

0	Solar building proportions	Building proportions must ensure that the southern facade is large enough to contain a window positioned as recommended.
-	Envelope area in relation to volume	Very effective. Care should be taken not to create many and unnecessary zig-zags. Proper design also economizes in construction costs.
-	Eastern and western facing window sizes (with shutters)	In hot climates, smaller openings are preferable in these orientations. If the view lies in these directions an effort should be made to design openings as small as possible, particularly those facing west. They should be well shaded and openings provided in other directions that will allow natural lighting, even when shutters are closed. Proper design economizes in construction costs.
-	North facing window size (with shutters)	In the cold mountain climate small openings are preferable.
Design and/or ventilation systems		
+	Nocturnal ventilation: natural and artificial	Extremely important in hot, dry climate. Can be naturally achieved by appropriate urban design or by a fan that produces extensive air exchange. It is usually advisable to add a fan that allows the rate of air exchange to be controlled, even if in most cases natural ventilation can suffice. Fans are low-cost and consume little energy.
+	Comfort ventilation: natural and artificial	Extremely important in hot, humid climates. Can be achieved naturally by appropriate urban design or with a ceiling or portable fan. It is usually advisable to add a fan that can achieve the wind speed necessary for thermal comfort, even if some of the time natural ventilation is sufficient. This is particularly true if there is a combined operation to reduce temperature at night by nocturnal ventilation. Natural comfort ventilation in the daytime will immediately cause temperatures to rise. A fan is inexpensive and consumes little energy. In many cases thermal comfort can be achieved with a fan alone with no need for energy-costly air conditioning.
Construction and materials specifications		
+	Air sealing	This problem existed in the past, mainly with wood frame windows opening on to the wall. Since aluminum has come into use window sealing is good, and cannot be improved. Sealing improvements in existing windows, however, should be encouraged. It should be noted too, that aluminum is a material that consumes very much energy in its production process. Alternative solutions that will allow good sealing without energy-costly production processes should be considered.
+	Insulation: walls	Very effective and inexpensive. The standard should be changed and better insulation required.

Table 4.3- III

+	Insulation: roof	Similar to wall insulation. Standards can be even stricter than in wall insulation.
+	Insulation: suspended floor	Same as roof insulation.
+	Glazing type: double versus single	Double glazing is advisable in the cold mountain climate. When climate is hot, and the window area relatively small, there is no need for double glazing. When window area is large it is advisable. Double glazing also contributes to reducing noise from the environment and so is more advantageous.
0	Thermal mass	Usually desirable. In ordinary Israeli residential building heavy construction is the standard. It is preferable not to switch to light building unless a satisfactory solution for thermal mass is provided. In public building, such as offices, the subject should be examined. Since these buildings are air- conditioned and do not operate throughout the day and night, the rapid reaction of light buildings to air conditioning systems is desirable. Nevertheless, heavy building can save energy and should be extensively examined according to the building's activity hours, internal heat and other factors.
0	Color: walls	Small effect. Different shades can be used as long as they are not particularly dark. Moderately dark shades have an urban advantage over light shades since they do not create glare and brightness problems.
0	Color: roof	In hot climates light shades are desirable. In the cold mountain area climate moderately dark shades are preferable.

Table 4.3- IV

Design: lighting

+	Amplifying natural lighting	In public building the natural lighting parameter is one of the most important design factors for energy savings. Design should aim at achieving maximal natural lighting. Transparent materials that allow visible light to penetrate but block infrared radiation that heats the building in summer should be used. Urban design that ensures daylight rights should be stressed.
+	Lighting control	It is most desirable to stress shutting artificial lighting when natural lighting suffices. Control costs are still high. Simple, convenient control systems should be developed for implementation in construction.
+	Intelligent building systems	Extremely important in public building, but can also be implemented in residential building. Automatic control is still costly. Simple, convenient control systems should be developed for implementation in construction.

4.3 Range of effect of parameters on energy savings in public and commercial buildings

No comprehensive quantitative study similar to the one done on residential buildings was done on commercial-public buildings. The comparison of various planning parameters is based on tests performed on the Department of Energy and Environment building at the Weizmann Institute for Science at Rehovot, that includes offices and laboratories (Shaviv 1998). These results, presented in table 4.5, serve as an example of public buildings that deserves further investigation. The cost of improving the design parameters as suggested was recorded for this example, as specified by the tender for this specific building.

HVAC (Heating, Ventilation and Air Conditioning) systems consume sizable amounts of energy, which are associated with the production of CO_2 and other greenhouse gases. A significant portion of this energy may be conserved and the CO_2 emission reduced through co-generation. Electric power generation produces large amounts of reject heat. When this power is generated at the power plant, the reject heat is lost; generation of electric power locally, at the site, makes it possible to take advantage of the waste heat for heating and cooling. Co-generation systems may be practical for commercial size HVAC systems such as hotels, hospitals, office buildings and public buildings. 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 co-generation cooling systems and hybrid air conditioning respectively. The technical and quantitative background data for these results are presented in appendix A3.

Table 4.4: Description of alternatives and improvements in a public building.

Description	Savings kWh/year/sqm floor	Cost NIS/sqm floor	Cost – savings ratio
Fume vent 60% of the air changes half the time the blower is working	21	91.60	4.36
Night ventilation 30 air exchanges a night	5	6.54	1.31
Improving wall insulation Increment of 2 cm polyurethane	4	3.27	0.82
Improving roof insulation Increment of 4 cm polyurethane	7	6.54	0.93
Double glazing Green reflective glass outside	11	32.73	2.98
Exterior shading Based on an external shutter	24	102.30	4.26
Lighting control On/off according to two lighting control areas	14	36.00	3.93
Upper window for daylight illumination Upper window according to specification	14	26.18	1.87
Ceiling fan According to specification	18	6.55	0.36
Solar greenhouse on roof for heating air According to specification	7	26.18	3.74

Note: The overall improvement should be considered, and not the improvement of each parameter individually. However, the effect of improving each design parameter depends on the degree of improvement of the remaining parameters. One improvement course can indicate a different relative improvement for each parameter when compared to the present results.

The anticipated saving from an ideally built house is 125 kWh/year/sqm floor at a cost of 338 NIS/ sqm floor with a cost saving ratio of 2.7

4.4 Energy efficient buildings - potential energy savings and CO2 emission reduction

4.4.1 Residential electricity consumption scenarios

Predicted electricity consumption levels for the next decades according to the Israel Electricity Company (IEC) forecast, were presented in section 4.1.3. This forecast does not address the fact that in many dwellings, despite being equipped with the adequate heating and cooling equipment, the level of thermal comfort is still very low when compared to accepted comfort levels in Europe and Northern America. With the expected increase in the general standard of living during the next decades the level of thermal comfort will also increase. This implies that, in existing buildings, as well as in new ones, the energy consumption for space heating and cooling (overall space climate control) will increase in comparison to the IEC forecast. These increased values should be used as the base values for estimating the effects of building measures on reducing CO_2 emissions. Table 4.6 presents several scenarios for the year 2020 for existing and new buildings. Figure 4.3 shows the difference in electricity consumption attained for each of the scenarios in the year 2020. Figure 4.4 shows the resulting CO2 emissions based on IEC data for average CO_2 emission for kWh produced.

The value $Q_{reas.}$ in the tables presents the estimated energy consumption for overall space climate control per sqm. of floor area per year in a dwelling with a reasonable level of thermal comfort (air temperature does not fall beneath 17.5^{o}C in winter and does not exceed 25.5^{o}C in summer throughout the day). $Q_{moderate}$ in the tables presents the estimated value for a dwelling with a moderate level of thermal comfort (heating and cooling conditions during climate control hours as above, but the climate control equipment operates for no more than 12 hours a day). These are indicative average values that are based on analyses of many types of dwellings in the various Israeli climatic zones. The values for Q_{reas} are based on hourly simulations for different types of apartment buildings in Israel (Shaviv and Capeluto, 1982). The values for $Q_{moderate}$ are based on hourly simulations for different standards of applying climate control equipment in dwelling units in Israel (Backer and Paziuk, 19??). The differences between existing and new buildings stem from the somewhat improved levels of air-tightness and thermal insulation in the new buildings.

For existing buildings it is assumed that three levels of measures can be taken in order to decrease energy consumption while the comfort level rises to its higher level: (a). Basic measures, that are composed mainly of window stripping and may decrease consumption by approximately 16%. The associated energy consumption level is given in the column indicated by Pessimistic Improvement Scenario. (b). Moderate measures, that in addition take care of proper shading in summer, while permitting solar gains in winter, and may decrease consumption by approximately 24%. The associated energy consumption level is given in the column indicated by Moderate Improvement Scenario. (C). Extensive measures, that in addition take care of thermal insulation improvements, and may decrease consumption by approximately 40%. The combined energy consumption level is given in the column indicated by Optimistic Improvement Scenario.

For new buildings it is also assumed that three levels of measures can be taken: (a). Extensive measures, that are based on a process of Energy Conscious Design. The associated energy consumption level is given in the column indicated by Optimistic Improvement Scenario. These values imply a 48% reduction level. (b). Moderate measures, that utilize only some of the possible measures (e. g. sensible orientation and proper shading with some improved insulation and glazing) and may decrease consumption by approximately 38%. The combined energy consumption level is given in the column indicated by Moderate Improvement Scenario. (C). Basic measures, that include only some proper shading and minor levels of improved insulation and glazing, and may decrease consumption by approximately 28%. The associated energy consumption level is given in the column indicated by Pessimistic Improvement Scenario.

Total floor area figures are based on linear graph prepared by “Israel 2020” (Report phase 1, volume 2 pp: 157):

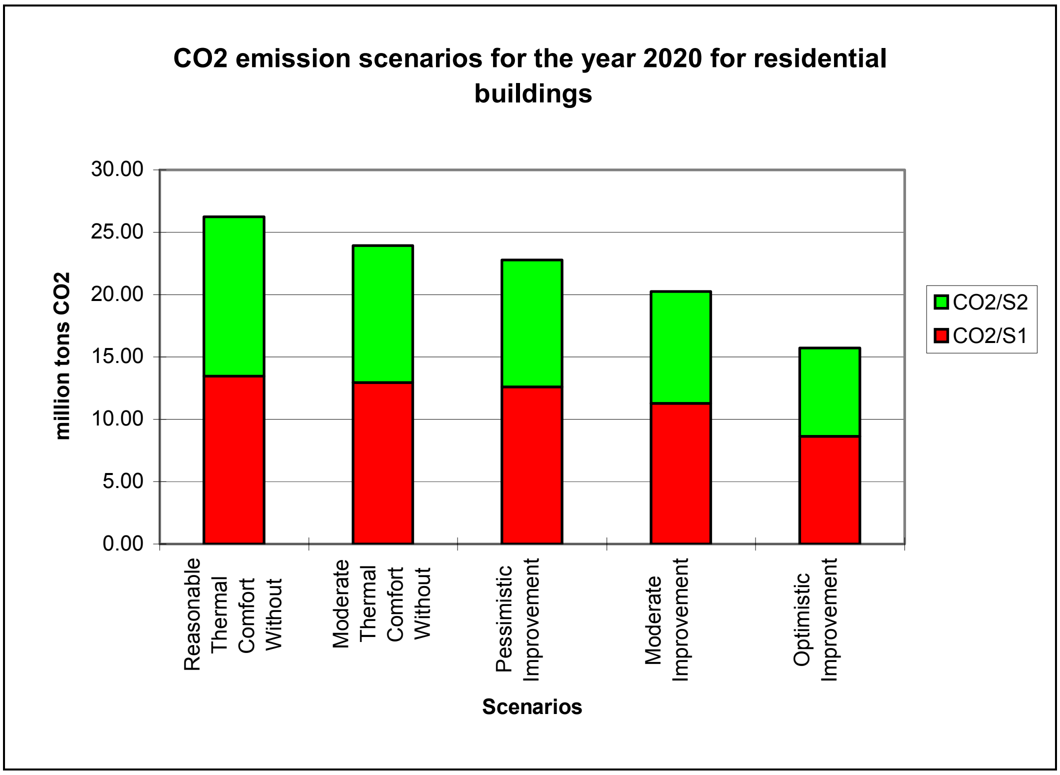
Table 4.5: Residential electricity consumption scenarios for the year 2020 in Israel. *Five scenarios are presented under two categories; "existing buildings" shows consumption of existing and buildings that will be built until 2020 subject to current common practice with several improvements as discussed in section 4.4.1. "New buildings" shows consumption of existing buildings by current common practice and consumption of new buildings by new measures.*

	Scenario	Electricity consumption in existing buildings (million kWh/year)					Electricity consumption in new buildings (million kWh/year)				
Year	existing/ additional floor area (million sqm)	Reasonable Thermal Comfort Without Measures, Q_{reas} = 45 (kWh/m^2/Y)	Moderate Thermal Comfort Without Measures, $Q_{moderate}$ = 39 (kWh/m^2/Y)	Pessimistic Improvement Scenario Q = 38 (kWh/m^2/Y)	Moderate Improvement Scenario Q = 34 (kWh/m^2/Y)	Optimistic Improvement Scenario Q = 26 (kWh/m^2/Y)	Reasonable Thermal Comfort Without Measures, Q_{reas} = 40 (kWh/m^2/Y)	Moderate Thermal Comfort Without Measures, $Q_{moderate}$ = 34 (kWh/m^2/Y)	Pessimistic Improvement Scenario Q = 29 (kWh/m^2/Y)	Moderate Improvement Scenario Q = 25 (kWh/m^2/Y)	Optimistic Improvement Scenario Q = 21 (kWh/m^2/Y)
2000	200	9000	7800	7600	6800	5200	9000	7,800	7,600	6,800	5,200
2020	160	7,200	7,800	7,600	6,800	5,200	6,400	5,440	4,640	4,000	3,360
Total	360	16,200	15,600	15,200	13,600	10,400	15,400	13,240	12,240	10,800	8,560

Table 4.6: CO_2 emission scenarios for residential buildings in the year 2020 (in million tons)

Scenario	Reasonable Thermal Comfort Without measures	Moderate Thermal Comfort Without Measures	Pessimistic Improvement	Moderate Improvement	Optimistic Improvement
CO_2 from existing buildings	13.45	12.95	12.62	11.29	8.63
CO_2 from new buildings	12.78	10.99	10.16	8.96	7.10
Total emission	26.23	23.94	22.78	20.25	15.73

Figure 4.3: Potential CO_2 emissions savings in the residential sector. ***S1 and S2 refer to existing buildings and new buildings respectively in table 5.6.***



4.4.2 Intervention scenarios

The possible 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 a demand from users for energy efficient planning. It is also possible to divide the intervention into incentives, or alternatively to set more stringent standards than those existing today and enforce them. Some of the proposals below are based on the existing experience in other countries, principally the USA and Europe. Special emphasis has been put on planning parameters such as insulation, sealing, shading and passive solar energy that strongly affect the energy consumption of a building.

4.4.2.1 Intervention at the planning stage

Standards at the building level:

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

Construction-related standards or recommendations

- Legislation or recommendations to determine winter sun rights or desired shading in summer
- Legislation or recommendations regarding desired exposure to wind in order to obtain comfort ventilation in summer, or protection from unwanted wind in winter
- Legislation or recommendations regarding sufficient exposure to the sky to obtain daylighting
- Legislation or recommendations regarding sufficient skylight exposure to obtain nocturnal cooling by long-wave radiation to the sky.

In all these cases it is important to note the desirable street profile regarding building height in relation to street width and the urban texture for various construction densities (Shaviv, Yezioro and Capeluto, 1998).

Incentives:

- Solar terraces will not be included in taxable building area
- External shading products and devices will not be taxed or taxes on them will be reduced
- Building insulation and sealing products and devices will not be taxed or taxes on them will be reduced
- Incentives and encouragement for energy retrofit of existing buildings
- Financial incentive for energy saving initiatives in building, based on economic calculations that include the savings resulting from air pollution reduction, and translating it into tax reductions

4.4.2.2 ***Intervention scenarios at the consumption stage***

Standards:

- Determining the real cost of electricity consumption

Incentives (positive or negative):

- Tax reduction for energy savings in buildings
- Progressive taxation on energy consumption in buildings
- Tax on greenhouse gas emissions above the standard according to sectors

Finally: in order to implement these recommendations, thorough studies to determine the recommended standards and size of incentive must be carried out as a follow-up to the present one, in order that these be economic and just as well as bringing about sizable energy savings in buildings. The studies should examine detailed intervention scenarios for "energy-conscious design" in buildings in various sectors. These scenarios will analyze the various intervention possibilities in a more detailed and exact manner, including consideration of the total real cost (for the individual and the economy) of each alternative, and will determine the justified measure of intervention in Israel in terms of the total economy. Below is a list of necessary studies and precursory actions and an estimate of the time needed for these studies to be executed.

Necessary studies to update and extend standards at the building level:	**Duration**
• Research to determine stricter standards for the insulation level of walls, roofs and suspended floors, according to climatic areas in Israel:	1 year
• Research to determine additional design parameters to be included in the code, besides for insulation and sealing: e.g. area size of southern window, size of necessary openings for ventilation, etc., and determining values according to the various climatic regions:	2 years
• Expanding the code to include various types of buildings:	1 year per building type
• Research to determine how to calculate and prepare an energy audit to be included in each project	
• Research to determine standards for optimal and maximum allowable energy consumption in buildings according to sectors. The green standard of approval will be granted accordingly.	2 years

Studies necessary for preparing standards or recommendations on the urban design level

• Research to determine desirable standards for defining solar rights requirements in winter and desirable shading in summer according to the various climatic areas and the density level required. All this in order to achieve urban tissues that ensures comfortable exterior conditions while saving energy in buildings:	2 years
• Research to determine recommendations for the desired exposure to winds in summer to achieve comfort ventilation, or protection from undesirable winds in winter, as a function of the dominant wind direction:	2 years
• Research to determine recommendations or legislation regarding sufficient skylight exposure to obtain daylighting:	2 years
• Research to determine recommendations relating to sufficient exposure to the sky in order to achieve nocturnal cooling by long-wave radiation:	2 years

Incentives:

• Research to determine specifications for sunspaces (solar terraces) not included in the calculated building area:	1 year
• Preparation of a list of products and construction specifications for	

exterior shading, insulation and sealing for new construction as well as for energy retrofit of existing buildings and determining the tax reduction: 6 months

- Research to determine financial incentives for energy-saving initiatives in buildings, that includes the economic calculations relating to savings resulting from air pollution reduction: 1 year

Chapter 5

The Transport Sector

5.1 Introduction

The transport sector emits some 10 million tons of CO_2, 17% of total GHG emission in Israel in 1996. In 1996 total consumption of gasoline was 2,029,200 tons and 1,013,500 tons of diesel fuel., Passenger cars consumed 69% of the total gasoline. Trucks consume 42% of diesel fuel (tables 5.1 and 5.2 below). Total consumption of gasoline and diesel fuel during the five year period between 1992 - 1996 increased by 27% and 42%, respectively (table 5.3).

Table 5.1: Annual gasoline consumption and CO_2 emissions of various vehicles, Israel, 1996.

vehicle type	number of vehicles	average yearly mileage, km	specific fuel consum. km/liter	yearly fuel consumption, ton	CO_2 emissions, ton
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
motor-cycles	69,011	8,900	21.9	21,034	54,800
others				146,741	382,000
total				2,029,200	5,282,700

Table 5.2: Annual diesel fuel consumption and CO_2 emissions of various vehicles, Israel, 1996.

vehicle type	number of vehicles	annual average mileage, km	specific fuel consumption km/liter	annual fuel consumption, ton	CO_2 emissions, ton
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

Calculations of CO_2 emissions are presented in appendix B2.

Table 5.3: Annual fuel consumption of motor vehicles in Israel, 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

Total CO_2 emissions from motor vehicles in Israel in 1996 was 8,159,000 tons. Passenger cars contributed 45% and trucks accounted for 30% of the total CO_2 emissions (figure 5.1).

Figure 5.1: Contribution of vehicle categories to CO_2 emissions 1996

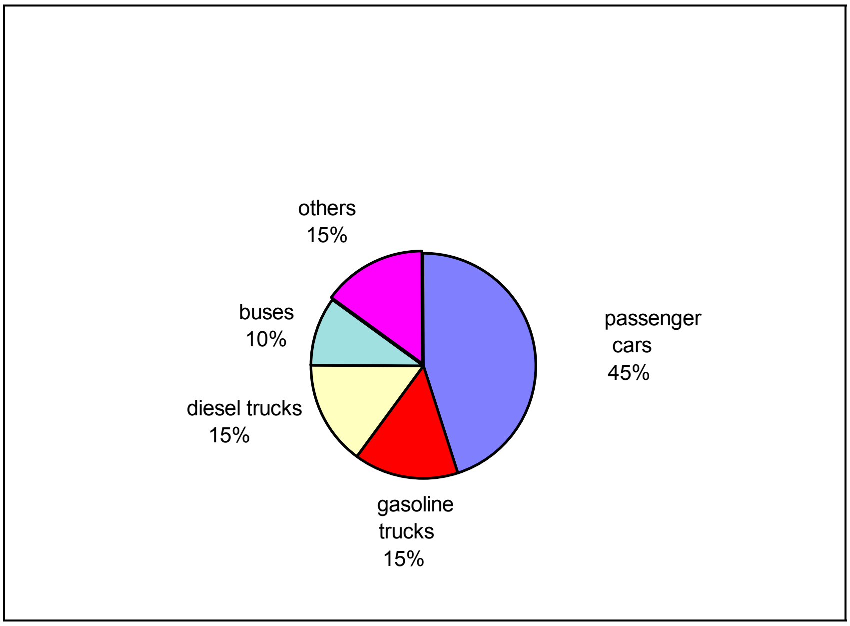
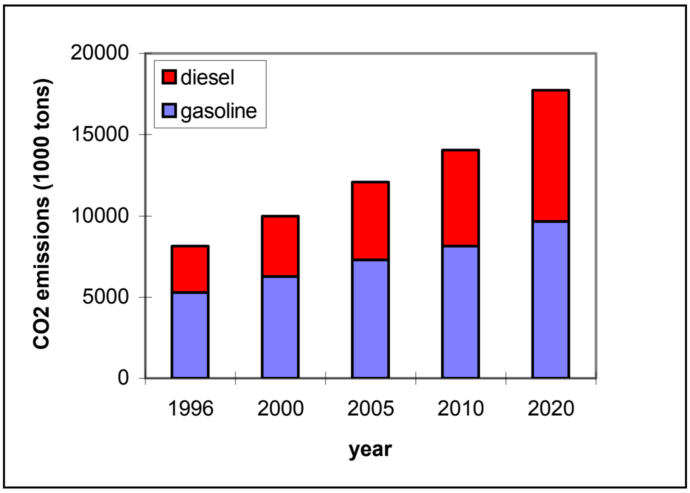


Figure 5.2 presents the results of a forecast for the increase of CO_2 emissions resulting from an increase of gasoline and diesel fuel consumption in Israel until the year 2020, based on a scenario of "business as usual”. According to this projection, increased consumption would be by 83% for gasoline and by 180% for diesel. Thus if no measures will be taken to decrease emission of greenhouse gases, the emission of CO_2 from road transportation will more than double by the year 2020 compared to 1996.

Figure 5.2: CO_2 emission projections by fuel type



5.2 Mitigation options

The means used or suggested to reduce CO_2 can be grouped into three categories:

5.2.1 Technical measures

5.2.2 Transportation control measures: Improvement of transportation effectiveness

and Traffic improvements

5.2.1 Technical measures

The technical means for reducing the emissions of greenhouse gases can be separated to three groups:

1. measures for decreasing fuel consumption
2. use alternative fuels
3. measures to reduce greenhouse gases other than CO_2.

5.2.1.1 Means to reduce energy consumption

The main approaches which can be adopted for reducing energy consumption are:

- Decreasing vehicle weight and engine power by light structures 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.

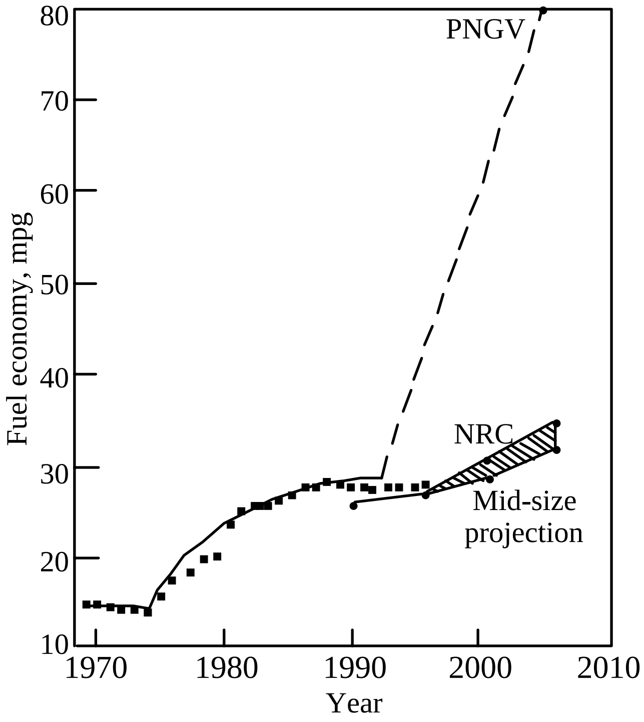
- Improved vehicle design, e.g. reduction of drag coefficient of the vehicle body; improved tires for better interaction with the road surface.
- On-board devices to limit vehicle speed.
- Improved air-conditioning systems.
- Development of hybrid propulsion systems for vehicles and the use of fuel cells (see below discussion on electric vehicles, in the section dealing with alternative fuels).

The expected effects of the means and measures outlined above for reduction of fuel consumption and the necessary actions to encourage their implementation are detailed in Table 5.6. Table 5.7 includes estimates of costs and Table 5.8 outlines the various problems that may arise and obstruct implementation. It is emphasized that education and promotion must be added to all the actions listed in Table 5.6.

Some of the technologies mentioned above are already at advanced development stages. However, based on accepted lifetime of vehicles, their penetration into commercial and practical use in vehicles on the road would take over 10 years for light vehicles, and many more for heavy duty vehicles,(*Technology opportunities to reduce U.S. greenhouse gas emissions. Prepared by National Laboratory directors for the U.S. Department of Energy, October 1997*).

Figure 5.3 describes trends of fuel consumption forecast by the USA National Research Council (NRC), (*C. Amann, The scretch for better passenger car fuel economy: a critical look. Part 1. Automotive Engineering, February 1998*). It shows that a reduction of 20-25% of energy consumption is foreseen by the year 2005 compared to 1990. Similar values of improvement have also been published by German automotive producers and by Volvo, (*CO_2 emissions from transport. European Conference of Ministers of Transport (ECMT), 1997*(. Furthermore, the USA Partnership for New Generation Vehicles (PNGV), which consists of government representatives and the big auto producers set a target of 80 miles per gallon fuel consumption by the year 2004. Moreover, a scheme of hybrid vehicles made of light materials has been selected by the PNGV as a preferred vehicle to attain this target.

Figure 5.3: Trends of fuel consumption of passenger cars in the USA, *(C. Amann, The scretch for better passenger car fuel economy: a critical look. Part 1. Automotive Engineering, February 1998).*



5.2.1.2 Use of alternative fuels

Alternative fuels are important for improved combustion efficiency and for diversifying the energy sources. All the alternative fuels based on petroleum consist of lighter hydrocarbon chains than those of gasoline and diesel fuel, therefore their combustion produces less CO_2. The alternative fuels that have already been used are:

- Liquefied petroleum gas (LPG)
- Compressed natural gas (CNG) and liquefied natural gas (LNG)
- Alcohols: methanol and ethanol
- Biogas
- Hydrogen
- Electricity is often considered as an "alternative fuel" too - for electrical and hybrid

vehicles (EV and HEV), including fuel-cell propulsion.

The expected effects of using the alternative fuels, the necessary actions to encourage their implementation, cost estimates and various problems that may arise are detailed in Tables 5.6 through table 5.8.

5.2.1.2.1 Some aspects of LPG use in public transportation

Public transportation in Israel is based almost entirely on diesel vehicles (mainly buses), therefore comparative analysis of buses conversion to LPG operation is described in detail here.

(a) Comparison of CO_2 emissions by diesel and LPG buses.

The main assumptions that have been used:

- LPG is mainly propane;
- Efficiency of engine operation is equal for both diesel fuel and LPG;
- Average carbon content in diesel fuel is 86%;
- Percentage of carbon associated with CO_2 in the total carbon emissions is:

C'_{CO_2} = 90% of diesel fuel (see Appendix B2)

C'_{CO_2} = 82% of LPG = C'_{CO_2} of gasoline (see Appendix B2) because in both cases the engine operates with stoichiometric mixture.

Carbon content in propane:

$$C_{carb} = \frac{3 * Mc}{Mpropane} = \frac{3*12}{44} = 0.82 = 82\%$$

Heat value of LPG is lower than that of diesel fuel:

LHV_d = 35.7 MJ/l

LHV_{LPG} = 23.6 MJ/l

Therefore, for equal energy supply to the engine:

1.513 liter of C_3H_8 is needed compared to 1liter of diesel fuel.

In mass units:

1 kg of diesel fuel <-> 0.919 kg of LPG.

Estimation of CO_2 emission is performed according to the method described in detail in the Appendix.

For diesel fuel:

$CO_{2mass(d(} = 2.838 * m_{f(d(} = 2.838 * 1 = 2.84$ kg

For LPG:

$$C_{CO_2} = C'_{CO_2} \times Ccarb = 0.82 \times 0.82 = 0.672$$

$$CO_{2_{mass(LPG)}} = C_{CO_2} \times \frac{M_{CO_2}}{M_C} \times m_f = \frac{0.672 \times 44}{12} m_f = 2.464 \times m_f$$

$$CO_{2_{mass(LPG)}} = 2.464 \times 0.919 = 2.26kg$$

CO_2 reduction in case of LPG use is:

$$CO_{2_{mass(d)}} - CO_{2_{mass(LPG)}} / CO_{2_{mass(d)}} = 2.84 - 2.26 / 2.84 = 0.20 = 20\%$$

(b) Cost aspects of conversion of diesel buses to LPG operation

There is only scarce information in the literature about actual or estimated costs of investment and operation of public transportation based on gas engines. All following estimates have been performed based on only two references, (52, 65) and therefore can not aspire to be of high accuracy and reliability.

According to reference (65), the initial cost of a new LPG bus is about 150,000 ECU (≈ $170,000) – 10% more than a conventional diesel bus, (52*).* Therefore, additional investment for bus purchase is about $17,000 per bus.

The cost of a complete LPG filling station for up to 300 buses with overground fuel tanks, including piping, pumps, fuel meter, hoses and nozzles is about 97,000 ECU. Therefore, the additional cost per bus is: ≈ 330 ECU ($370).

Estimation of investment, which is needed for adaptation of a workshop, can be taken from [52]. It is about 14,000,000 S (≈ $1,150,000) for a workshop servicing 150 buses. Therefore, the cost per bus is about $7,700.

Summarizing all mentioned above, the value of additional initial investment per LPG bus is estimated as $25,070. This sum does not includes cost of manpower training,

special national legislation, etc. The total initial investment can be estimated as $26,000/bus (in case of conversion of some hundreds of buses).
It will be possible to estimate operational costs of LPG use in buses only after decision by the Israeli Government about the pricing and taxation of automotive LPG.

5.2.1.3 Means to reduce emissions of greenhouse gases other than CO_2

The discussion above was essentially focused on carbon dioxide (CO_2). The main means for reduction emissions of other greenhouse gases from motor vehicles are:

- 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.

The expected effects of using these means, the necessary actions to encourage their employment, cost estimates and various problems that may arise are detailed in Tables 5.6 through table 5.8.

Table 5.6: Technical means to reduce emissions of greenhouse gases from motor vehicles and their expected effects

measure	expected effect	possible action for implementation
improved engine design improved vehicle design reduced vehicle weight improved engine and vehicle control systems	15 - 30% reduction of greenhouse gases, the effect will be fully realized around year 2015 for light vehicles and later for heavy duty vehicles	taxation according to fuel consumption of vehicles
hybrid vehicle, (HEV)	fuel consumption 3 times better than conventional vehicle, [64] complying with ULEV standards (ultra low emission vehicle)	increasing fuel prices introduction of fuel consumption measurement in annual inspection test
fuel cell vehicle	emissions reduction of up to 100% of greenhouse gases (when hydrogen is used) and other pollutants	encouragement by parking permits, dedicated freeway lanes low electricity prices for EV and HEV
improved air-conditioning systems	50% efficiency improvement (current development for EV), [60], will lead to 5-15% reduction of CO_2 emissions in urban driving, [61, 62[	tax reduction of air-conditioning system according to its power demand
appropriate speed limits	10% reduction of greenhouse gases improved road safety	increasing fuel prices legislation and enforcement of speed limits
alternative fuels: CNG, LPG, methanol (from natural gas)	10-30% reduction of CO_2 emissions, [6, 64, 70], reduced emissions of other pollutants, diversifying of energy sources	subsidizing prices of alternative fuels legislation enforcing use of alternative fuels
alternative fuels: ethanol, methanol, bio-gas and other bio-mass fuels	70% reduction of CO_2 emissions, [60, 70], reduced emissions of other pollutants, diversifying energy sources, encouragement of agricultural development, [70]	encouraging production of bio-mass fuels in Israel encouragement by parking permits, dedicated freeway lanes

hydrogen electricity	reduction of total CO_2 emissions and other pollutants depends on energy sources for production of electricity and hydrogen. Estimates by the Israel Electric Corp., [63], show that operation of EV by electricity from coal-fired power plants will cause rise of CO_2 emissions, but from natural gas - up to 40% decrease. Drastic reduction of emissions of other pollutants.	
reduction of refrigerant leaks from air-conditioning systems	It is possible to decrease emissions of greenhouse gases by 10% CO_2 equivalent	standards limiting maximal allowed leaks of refrigerants
catalytic converter which does not generate N_2O	prevention of N_2O generation in the exhaust gases is equivalent to 10% reduction of emission of greenhouse gases, [70].	tax reduction of catalytic converters which do not generate N_2O.

Table 5.7: Cost estimate of means to reduce emissions of greenhouse gases from motor vehicles.

means	expected cost
improvement of vehicle design and reduction of its weight	5-15% increase of vehicle cost, to be returned to owner by fuel savings.
hybrid vehicle	~ 30% increase of new vehicle cost. The cost difference between hybrid and conventional vehicles will decrease with technology development of hybrid vehicles. The initial investment will be returned to owner by fuel savings. Low to medium government investment will be required for development of charging infrastructure, which will be used in the future as a basis for larger capacities for electric vehicles.
fuel cell vehicle	cost is currently too high, impeding marketing penetration. According to estimates, [64], only cost decrease of fuel cell would enable its introduction into the automotive market.
improvement of air-conditioning system	increase of vehicle cost will be balanced by fuel savings.
speed limits	minor changes in vehicle price. low costs for appropriate legislation.
alternative fuels: methanol, ethanol and other liquid fuels	low to medium investments for development of fueling and maintenance infrastructure for vehicles operated on these fuels, and also for subsidizing their use (whenever necessary(.
alternative fuels: LPG, natural gas, bio-gas, Dimethyl Ether (DME)	medium costs for development of infrastructure and maintenance.
hydrogen electricity	high costs: up to US$ 1,000 per ton of CO_2 reduction, [70].
reduction of leaks from air-conditioning systems	low cost increase (if any) of vehicles. low government investments for preparing maintenance system and program.
catalytic converter which does not produce N_2O	up to 2% cost increase of new vehicle (preliminary estimate).

Table 5.8. Expected problems hindering implementation of CO_2 reduction measures

means	problems
improvement of vehicle design reduction of vehicle weight	technical problem of reducing NO_x emissions from direct injection gasoline engine; technical problem of recycling parts made of light materials: need to maintain safety requirements. political problems: objection of vehicle producers and importers to imposing tax on fuel consumption and/or legislation regarding maximal fuel consumption; public objection to raising fuel prices.
legislation and enforcement of speed limits	political problem: objection of groups of interested parties, e.g. taxi drivers, transporters; objection of organizations such as human rights, esp. in case of no safety problems
alternative fuels	need for special legislation in order to enable use of fuels other than gasoline and diesel oil; standardization: new safety standards are needed, e.g. for EV, HEV and fuel cell vehicles; education, instruction and promotion: to overcome hesitance regarding new fuels and to explain their importance and advantages; education of manpower

5.3 Transportation control measures

Transportation Control Measures (TCMs) are the means available to policy makers to improve air quality. Most TCMs are targeted at reducing Vehicle Kilometer (VKT) of travel by Single Occupancy Vehicle (SOV).

Reducing VKT can be achieved by changing different travel behavior elements:

- Reducing the frequency of trips by reducing the need to travel. Reducing the need to travel involves substitution of travel activities with non-travel activities.
- Reducing the length of trips by changing destinations or residence location.
- Reducing the use of single occupancy vehicle and shifting to high occupancy vehicles' modes including transit and non-motorized modes.
- Reducing the frequency of trips and total VKT by chaining different trips to one trip.

Table 5.9 provides examples for the main TCMs and assessment of their potential impact and ease of implementation. The last column provides a qualitative assessment of their potential impact and ease of implementation together with the author’s estimate for the maximum potential of such measures in reducing greenhouse gas emissions. Given the discussion in appendix B these estimates are no more than an expert's guess, and other experts may have different estimates. We do not have sufficient data and experience to support such estimates. The measures can be implemented at many different levels and scales, therefore the percentages in this column present the maximum potential for an aggressive implementation of such measures.

5.3.1. Packages of TCMs

Some TCMs may complement each other and their combined benefit will be larger than the sum of the individual benefits while other may compete and their combined benefit will be less than the sum of benefits from the individuals' benefits. An example for competing TCMs is HOV lanes and transit improvements. Both measures will attract single occupancy vehicle to shift mode. HOV lanes may even cause some transit users to shift to HOV. An example for complementing TCMs is transit improvements and parking restrictions. The introduction of transit improvements by themselves can not have a significant effect on mode choice as people will always prefer the convenience of the private car. However, with the combination of parking restriction and any other "push" measures on the use of private car like congestion pricing they can be more effective. It is difficult to evaluate the effect of an individual measure, it is further more complicated to evaluate the effect of a package of measures.

5.3.2 Conclusion

There is a wide range of measures available for policy makers to reduce GHG emissions. To be effective TCMs have to be combined into packages of complementary measures. Push and pull measures have to be combined to push people out of their private cars and to pull them to more environmental friendly modes including transit and non-motorized modes, to pull them to reduce the need to travel, pull them to shorten trips and pull them to travel off the peak period.   Pull measures by themselves will not achieve these targets without penalizing the use of private car by measures such as road pricing and parking restrictions.

TCM programs should be developed as part of the overall land use and transportation planning for an area. Such a planning has to derive from clear objectives regarding economic development, mobility, accessibility, air quality and other environmental issues as not all TCMs necessarily affect these different objective in the same direction.   In any case, a combination of various TCM should be designed to support each other. However, while for some TCM like improved transit service it is mostly a cost benefit question, the effect of other TCM should be carefully evaluated before implementation to make sure this effect is going to be in the right direction, toward reducing green house gas emissions both in the short run and in the long run..

A successful implementation of TCM require careful planning and evaluation, education, corporation and commitment of the public and private sectors, political support including constituency that will support the effort, coordination among the many different groups and government offices and continuity over time.

Further research is required to enhance our understanding of people response to various TCM, to understand how these TCM affect the urban and economic development and what the short and long run effects on the transportation system. Further understanding is also required in translating the performance of the transportation system to air pollution concentrations, an area not discussed in this paper.

While many of the measures have to be carefully studied before implementation, few general recommendations can be made. The cost-benefit of these measures have to be studied in order to prioritize them. However, any act in any of the measures should contribute to reduce greenhouse gas emission, though the quantity of the effect is unclear. These measures include, but do not limit others:

- Transit service improvement and expansions. The benefits here are a function of the improvements and are always an issue for debate. According to a report prepared for the U.S. Department of Transportation accepted values for fare elasticity in the U.S. are around -0.3, however, different methods and different type of service and urban areas show fare elasticity vary between -0.04 and -0.87. The evaluation of service improvement is much more site and improvement specific and can not be quantified in general

- High occupancy vehicle priority lane and facilities. As in transit improvements the benefits vary by site and type of facility.
- Bicycle and pedestrian facilities and programs. The benefits here vary by site and type of facility and program.
- Fuel taxes. Fuel taxes are efficient in reducing greenhouse gas emission in the sense that they are targeting the source of greenhouse gas emission directly. According to a survey of the Israel Ministry of Transportation price elasticity of fuel in Israel is 0.17 in the short run and 0.25 in the long run.
  - Emission and VKT tax - Emission tax is even more efficient than fuel tax, the idea here is in addition to the effect of fuel tax to reduce VKT, is to encourage people to by more environmental friendly cars, to replace old cars by new ones, and to encourage purchasing of small vehicles.
- Public education and marketing - The benefits are difficult to estimate and vary by site and program.
- Telecommuting, teleshopping and so. - The effects of these measures on KMT are questionable at the moment. Future effects are not clear.

Table 5.9: Main TCMs and their potential effects

TCM group	Aim	Examples	Effectiveness
Regulatory TCMs	Reduce VKT	Mandatory Employer Trip Reduction Programs Parking Restrictions	Require strong enforcement that in turn require resources. We may know what people will not do, but we do not know which alternative they will choose. Aggressive programs with good enforcement can achieve up to 20% reduction. Politically accepted measures, however, can achieve a maximum of 5% reduction.
Mobility Improvements	Enhance supply of non-single occupancy vehicle (SOV) alternatives	High-occupancy vehicle priority lanes and facilities Transit service improvement and expansions Bicycle and pedestrian facilities and programs	Disagreement regarding the amount of change these measures may cause. Effect on GHG emissions is limited as these measures affect a subset of motorists traveling to and from work. A major new transit infrastructure (e.g., a new metro system) can reduce GHG emissions by up to 8% in the metropolitan area. The introduction of other aggressive restrain measures in addition to such new system can increase this up to 12%.
Travel Demand Management (TDM)	Reduce VKT by modifying traveler behavior	Public education Employer-Based Transportation Management Programs Measures of the information era CBD Auto Restrain Policies Ridesharing	Uncertainty regarding the alternatives the public may choose. Telecommunications will have marginal effect. Auto restrain policies are the most effective, but the affected market is limited. Potential GHG emission at the metropolitan level can be up to 3%

Market Based Mechanism	Charge travelers the full cost of travel including externalities	Congestion pricing and toll program Emission and VKT fees Fuel taxes Parking pricing	Can reduce motor vehicle travel. The magnitude of effect varies depending on how the program is structured. Technical implementation is simple, political, public, institutional and jurisdictional concern are complicated This is one of the most studied TCM. Maximum potential effect on GHG emission reduction with an extensive program can reach 7%. Common figures include up to 6% reduction in auto travel demand for a 10% increase in fuel prices or in car prices, car travel is only little affected by reduction in transit fares, and road use charges can reduce auto travel by up to 8%
Land Use/Growth Management	Shorten the car trip or substitute it with a walk or bike trip or public transportation	Mixed use development ordinances and zones • Pedestrian friendly site design. • Parking management. • Growth management/concurrency requirements.	Uncertainty regarding success in reducing travel. May be more effective in the long run, therefor difficult to evaluate. A good land use development can reduce GHG emission by up to 4%.
Traffic Operation and Flow Improvements	Instead of trying to alter travel demand, attempts to improve the flow of traffic so that it occurs under conditions that are more favorable in terms of emission.	Intelligent Transportation Systems (ITS) Incident management systems (i.e. special monitoring, motorist information) Congestion management planning and systems Signal Enhancement and Automated Traffic Management Systems Traffic surveillance and control systems	may encourage the use of private car by improving the supply and therefore may induce more travel and their overall effect on emission is questionable Such programs can reduce GHG emissions by up to 10% if there is no induced traffic. Induced traffic can easily cancel these reductions and may even cause GHG emissions to increase.
Vehicle Technology	Among other goals, emission reduction	Enhanced inspection and maintenance, Reformulated gasoline Stage 2 vapor recovery systems electric vehicles	see section 5.1

Chapter 6

The Agricultural Sector

Worldwide, the agricultural sector is responsible for about 20% of the anthropogenic GHC emissions (IPCC 1966). As shown in Fig 1.2 (chapter 1), the fraction of CO_2 emission through agricultural activities is rather small, yet agricultural activities are responsible for a high percentage of CH_4 emission, and are emitting N_2O more than any other human activity. Agriculture activities account for some 1,300 thousand tons of CO_2 (via electricity consumption), 900 thousand tons of CO_2 equivalents (in CH_4) and some 1,200 thousand tons of CO_2 equivalent (N2O), constituting some 5% of total greenhouse gas emissions.

6.1 CO_2 Emission and retention.

The different agricultural activities interacting with CO_2 balances are the following:

1. Photosynthetic uptake of CO_2.
2. Release (or uptake) of CO_2 from soil organic matter.
3. Utilization of fuel for agricultural machinery.
4. Utilization of fuel for greenhouse heating.
5. Utilization of fuel for water pumping.

6.1.1 Photosynthetic uptake of CO_2.

The photosynthetic uptake of CO_2 by crops is a significant flux, yet not all of it is relevant to the balance of CO_2 emission. A large fraction of the fixed carbon is left in the soil and is subsequently mineralized and emitted as CO_2. Thus, for example, if we grow cotton, the total biomass is higher than 10 tons/ha as dry matter, or about 5 tons/ha as carbon. Yet, only about 5 tons/ha (i.e. less than 50% of the production) of raw fiber are harvested and taken out from the field. Thus, only the harvested fraction should be taken in account as to the carbon budget.

The CO_2 equivalent of harvested fraction of the crop should be considered as a net removal of CO_2 from the atmosphere, though a part of it will be returned to the air. Thus, the CO_2 equivalent of a vegetable crop will eventually be released as municipal solid waste or as a component of sewage, yet in the CO_2 accounting, these release fluxes are accounted already. Another way of demonstrating this viewpoint is to assume that all agricultural products are to be imported. In this case, only the eventual release of CO_2 from these products is accounted for, and the carbon uptake is not.

It can be assumed that the net average carbon fixing is 5 tons/ha, or 13.3 ton CO_2/ha. Another important principle to be mentioned is that in a semi-arid land such as Israel, agricultural lands do not replace forests or other highly productive eco-systems, but they replace in most cases bare-lands that fix very low levels of carbon. This is contrary to tropical or temperate regions, where the transition of natural eco-systems to farmed lands is leading to an increase in CO_2 release.

Table 6.1: The potential of agricultural soils in Israel (adapted from KKL).

Classification	**Area (ha)**	**Area (%)**
Premium soils	67,219	16.4
Soils with slight limitations	110,101	26.9
Soils with medium limitations	162,25	39.6
Sub-total	339,555	82.9
Soils with severe limitations	69,754	17.1
TOTAL	409,309	100

Total cultivated area in Israel presently is 367,000 ha, 80,780 ha out of which are under irrigation.

Any change, of either increasing or decreasing the cultivated land may be very significant in relation to the CO_2 budget of Israel. A decrease of 10% of the cultivated lands, by abandoning the less profitable lands, will decrease CO_2 fixation by an estimated amount of about 0.5 million ton CO_2/yr. On the other hand, an increase in the area under cultivation, or afforestration of bare lands, could significantly increase fixation of carbon. According to Jenkinson (cited in Paustian et al. 1997), a conversion of abandoned land to forest leads to a sequestration of 520-550 kg C/ha/yr.

6.1.2 Release (or uptake) of CO_2 from soil organic matter ***decomposition of soil organic matter.***

The storage of CO_2 in the soil is a very significant pool controlling the level of CO_2 in the atmosphere. The average level of carbon in Israeli soils (excluding rocky and desert soils) is close to 1%. The potentially cultivated soils in Israel, store, in their reactive top 1 meter layer, an amount in the order of 50 million tons of carbon (or the equivalent of 130 million tons CO_2.

The carbon storage in the soils is not static. Crop residues added to the soil degrade rather fast and the soil gets back to its steady state characteristic carbon level. However, some long-range changes are known to occur, other anticipated. The transition from a land with virgin vegetation to a cultivated one is accompanied by a decrease in the soil organic matter. Rienhorn & Avnimelech (1974) found that this decrease of organic matter in typical Israeli soils amounted to about 14 ton C/ha for the top 30 cm. This process, that took place in the first half of the century, when most fertile lands were changed into farmland, has been terminated. A reverse process is known to take place when cultivated land is brought to a minimum till practice. By doing so one can increase the level of soil organic matter. According to a recent review, (Paustian et al., 1997), organic matter contents can double through this transition. If we assume that this effect will apply only to the top 30 cm of the land, a transition of 25% of cultivated land in Israel to no till (or minimum till) practice, will lead to a fixation of about 750,000 tons C, or 2 million ton CO_2. This is a process that will take time, and can be considered to spread along a 10 years period.

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

6.1. 3-5 Energy consumption by agriculture.

Besides water pumping, direct agricultural energy consumption is not high, relative to other sectors.

It can be assumed that (a) agricultural production will not increase significantly, compare to anticipated changes in other sectors (crops and systems will be changed, but the total area will stay relatively constant) and (b) 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 had been proposed. Energy surplus in pressurized water lines can be recovered, as done already in the Kfar Baruch reservoir.

6.2 Methane emission.

Anthropogenic methane emission is originating mostly from ruminants, animal waste and rice paddies. Israel does not grow rice and its ruminants are limited mostly to milking cows. The total emission by enteric emission was estimeted to be about 32,000 tons equivalent to 1792 (1824) – 672 tons CO2 (for a time horizon of 20 and 100 years, respectively). Methane emission by ruminants can be limited by change of diets and it is assumed that methods developed else where (feed additives and genetic improvements) will be adopted in Israel and will reduce specific CH_4 emission of ruminants by 25% (IPCC 1996). However, it is assumed that the number of milking cows will increase with the increase of the population. Thus, no change is anticipated here.

High potential mitigation is expected in the treatment of animal waste. Presently 3 million tons of animal waste is produced annually. Most of this waste is piled up and is undergoing anaerobic metabolism, producing vast amounts of methane. The methane generated from the manure, calculated according to IPCC data (Koch & Dayan, 1997) is equal to 10,000 ton/yr, or 560 thousand tons or 210 thousand tons CO_2 equivalents (for a time horizon of 20 and 100 years respectively). A proper composing of this material, by frequent turning, will lead to an aerobic stabilization and will reduce methane formation. This treatment has other advantages, since the product is better agronomically and since the transition to aerobic treatment will cut down odor problems (e.g. ducks manure). It is possible to achieve this goal by proper licensing of farm animal’s husbandry.

6.3 N_2O emission.

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 was estimated that

on the average, 1.25% of the nitrogen applied to soils is converted to N_2O (IPCC, 1996).
The annual application of nitrogenous fertilizers in Israel amounts to 61,000 tons, as N and the application of organic nitrogen, as manures is some 30,000 tons. Thus, the estimated emission of N_2O is 1,200 tons. This quantity is equivalent to about 400,000 tons of CO_2.
About 1/3 of N_2O emission could be reduced through the use of better agronomic techniques (i.e. optimize tillage irrigation and drainage, match N supply with crop demand) and through the use of better fertilizers, mostly controlled release fertilizers. It is assumed that Israeli agriculture can easily follow these recommendations. Moreover, these means are effective also to minimize nitrate pollution of water and will increase the profitability of farming.

6.4 Summary

Agricultural activities both increase and decrease release of GHG.
Photosynthetic activity of cultivated lands in Israel are fixing yearly about 50 million tons of CO_2, assuming a net fixation of 13.3 ton 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 of the total CO_2 equivalent emission of the country.
The rate of CO_2 sequestering, 13.3 tons/ha yr, assuming a future market price of 20-30 US$/ton CO_2, implies that farmers are entitled to be credited by 266-400 US$/ha as an external contribution to the environment.
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 along a period of about 10 years. This though is not a continual change.
Methane generated due to 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% (448-168 thousands tons CO_2 equivalents). The amounts generated from manure can be cut down drastically (assumed 75% reduction), cutting CO_2 equivalents emission by 140-53 thousand tons/yr, an operation that has additional agronomic and environmental advantages.

Nitrous oxide emission from fertilizers application is 1218 tons N_2O, or an equivalent emission of 374 thousand tons CO_2/yr. About 33% of this can be reduced, if fertilizers and fertilizer application will be improved.

Table 6.2: Potential mitigation options.

Action	**Amount reduced** 10^3 tons/yr	**CO_2 equivalent** 10^3 tons/yr	**Additional Advantages**
10% increase in crop coverage	500	500	in compliance with other national goal
10% decrease in crop coverage	-500	-500	
Minimal tillage, 25%of land	2,000/10yr	Same	Saving to farmers
Improved feeding to cattle	8 as methane	168-448	
Improved manure handling	2.5 as methane	53-140	Better product, odor control
Improved fertilizer application	1.2 as N_2O	374	Less water pollution

6.5 Policy steps needed.

1. Farming and forestation should be supported by their contribution to CO_2 sequestering (27 – 40 US$/dunam). The extension of farming and development of farming and forestation will serve other national goals (conservation of open space, holding of land etc.).
2. Farmers should be encouraged to change to minimal tillage technology. This can be done by education, subsidies or regulations. Farmers will most probably gain out of this.
3. License to operate farm animals operations should demand proper handling of manure. This will have additional environmental advantages (cutting down odors, reduce water pollution) and raise efficiency of manure.
4. Animal feed industry will be licenced to produce only feeds that cut down methane formation.
5. Licencing of fertilizers application to be demanded (like many European countries). Demand of efficient fertilizer technology.
6. Research is needed to characterize effect of technology on GHG emission from agricultural operations. Most data are from temperate regions and very few reliable figures relevant for our climate and soils. Research and extension needed to develop details of sustainable technology.

Chapter 7

Solid waste and sewage sludge

7.1 The potential of greenhouse gas emissions (GHG) from municipal waste

Disposing of waste in landfill sites creates anaerobic conditions in which the organic material degrades, partially, to biogas which contains 50% CH_4 and 50% CO_2.

The maximum potential of GHG emissions is obtained when waste is landfilled without any treatment of the landfill gas (LFG), without using it as an energy source or without, at least, burning it to CO_2.

In a steady state, it can be assumed that all the waste generated decomposes in landfills according to the following:

C (ton/y) = Total MSW x fraction landfilled (%) x H_2O (%) x OM (%) x C (%)

Total MSW = 4 million tons of waste generated every year

Fraction landfilled (%) = 90%

H_2O = Israeli waste contains 50% water

OM= Israeli waste contains 66% degradable organic materials (including paper & cardboard)

C= organic material contains 50% carbon

Comment- Using the IPCC Guidelines for National Greenhouse Gas Emissions Inventories (IPCC, 1995b), Koch and Dayan (1997) and Koch (1998), estimated annual CH_4 emissions to be 370,000 tons. Our calculations show that the estimated CH_4 emissions would be 304,000 tons. The relatively small difference between these figures is explained by the potentially degradable OM (20% according to IPCC and 16.5% of Israeli MSW (66% 50% * 50%).*

Not all degradable OM actually degrades. The degree of degradation depends on waste composition, water content, temperatures in the landfill etc. According to the IPCC, 77% of OM of the waste will degrade. Since there is high uncertainty with this figure (and no available data from landfills in Israel) CO_2 and CH_4 emissions were calculated according to different degradation rates. Calculations of expected CH4 and CO_2 emissions at different degradation rates (10-100%) are presented in Table 7.1. In all the following calculations and assumptions a 77% degradation rate was used.

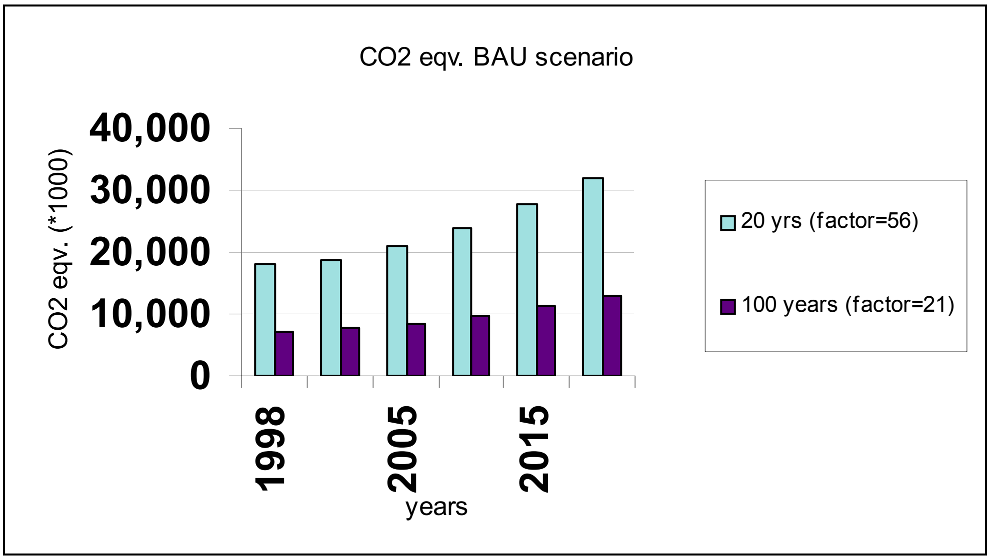
7.2 Emission factor

The global warming potential of CH_4, compared with CO_2, is 56 and 21 for 20 and 100 years time horizon, respectively.

Assuming 77% degradation of OM, the total annual CO_2-equivalents release, according to current waste management in Israel, is 17,914,000 and 7,242,000 ton CO_2–eq., for 20 and 100 years time horizon, respectively. This amounts to 24% and 13% from the total of CO_2-eq. emitted in 1996 in Israel.

Figure 7.1 summarizes the CO_2-eq. for "business as usual" (BAU) scenario for 20 and 100 years time horizon. In this scenario we assume a yearly growth of 2-3% in the amount of MSW produced, without significant changes in waste management, i.e., 90% of the waste is being landfilled and LFG is not collected.

Figure 7.1: CO2 eq. projections in "business as ususal" scenario



If all CH_4 produced in landfills is converted to CO_2, by means, which will be described in the next section, the emissions will be reduced to only 1,670,000 CO_2-eq. (reduction of 16,230 and 5,564 Kton per year for 20 and 100 years time horizon, respectively). This is the minimum amount of GHG due to municipal solid waste, unless steps like source reduction are enforced.

Comment- Usually, CO_2 emissions from landfills are not counted in, since they <u>do not</u> contribute to the increase in CO_2 abundance in the atmosphere (because the carbon in the CO_2 is of recent biogenic origin). In the present calculations, CO_2 was added in order to be able to compare the different alternatives of waste management and the total effect on CO_2 eq. emissions.

7.3 Alternatives for solid waste management in Israel

Each of the following alternatives, described in table 7.1, has a different influence on the amount and composition of GHG emissions.

It should be noted that waste management is only the last stage in the entire life cycle of a product. For example, recycling paper does not only reduce GHG emissions from a landfill, it also increases forest carbon storage.

Table 7.1: GHG mitigation means by waste management

Alternative	GHGs emissions, considerations and assumptions (+ = increase GHG, -= decrease)	CO2-eq. Reduction (Kton/ year)*
Landfilling- Without LFG treatment	Ca. 25% of all GHG emissions in Israel, 1997 (CH_4 factor = 56) [12%, CH_4 factor = 21] - credit for long term carbon storage in the landfill + Transportation emissions 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 Israel, 1997. - credit for long term carbon storage in the landfill + Transportation emissions- to landfill.	16,230 [5,564]
Landfilling- With LFG energy recovery (assuming 100% efficiency)	CH_4 conversion to CO_2, total emissions comprise only 3% of total GHG emissions in Israel, 1997. Avoided emissions from conventional energy sources. *[according to DOE (1993) displacement of 80 kWh per ton of waste =* 23.5 kgCO_2-eq. per ton waste*]*. - credit for long term carbon storage in the landfill + Transportation emissions- to landfill	16,230 [5,564] 94
Incineration Without energy recovery	CH_4 conversion to CO_2, total emissions comprise only 3% of total GHG emissions in Israel, 1997. + NOx emissions, + Transportation emissions- to incineration plant.	16,230 [5,564]

Incineration With energy recovery	CH_4 conversion to CO_2, total emissions comprise only 3% of total GHG emissions in Israel, 1997. Avoided emissions from conventional energy sources. *[according to Enosh (1996) displacement of 468 kWh per ton of waste =* 137.6 kg CO_2-eq. per ton waste*].* + Nox emissions, + Transportation emissions- to incineration plant	16,230 [5,564] 548
Recycling	*In some products:* Decrease in energy consumption due to lower energy requirements (compared to manufacture from virgin inputs) **-** Paper recycling increases forest carbon sequestration **+** Transportation emissions- to recycling plant.	
Aerobic Composting	**-** CH_4 conversion to CO_2, total emissions comprise only 3% of total GHG emissions in Israel, 1997. **-** increase in soil carbon storage Increase in yield carbon storage (1 ton dry matter=2 ton CO_2) **+** Transportation emissions- to composting plant. **+** compost machinery emissions	16,230 [5,564]
Anaerobic digestion	**-** CH4 conversion to CO_2, total emissions comprise only 3% of total GHG emissions in Israel, 1997. Avoided emission from conventional energy sources. *[according to de Laclos et al (1997) displacement of 173 kWh per ton of waste =* 50.1 kg CO_2-eq. per ton waste*].* **-** increase in yield carbon storage (1 ton dry matter=2 ton CO_2) **+** Transportation emissions to AD plant.	16,230 [5,564] 200.4
Source reduction	**-** Decrease in energy consumption due to lower production **-** Decrease in process emissions Less consumption of wood & paper products increases forest carbon storage **-** Avoided transportation emissions.	

(*) Calculations are as per 4 million tons of MSW.

It can be seen that any means that changes CH_4 to CO_2 reduces significantly the total

CO_2-eq. emitted by municipal solid waste. All technologies are practicable and known for many years, nevertheless, the limiting element is the cost of each alternative.

7.4 Cost estimates

Assuming a city producing annually 1 million tons of municipal solid waste (relevant for the Tel Aviv and Dan region in Israel), the estimated CO2- eq. produced is 2,011,000 tpy (factor = 21) or 4,976,000 (factor = 56). If waste is incinerated, composted or if all LFG is extracted and combusted, the amount of CO2- eq. is reduced to 605,000 tpy.

Table 7.2 summarizes the costs related to each alternative. Data refer to CH_4 factor of 21, (i.e. time horizon of 100 years) and in brackets factor of 56 (time horizon of 20 years)

Table 7.2- cost estimations for GHG mitigation from MSW.

Alternative	Investment per plant (10^6 \$)	size of plant (t/d)	Total investment (10^6 \$)	costs of reduction (\$/ ton CO_2 Eq.)	payback investment only (\$/ ton CO_2 Eq.) (15 years)
Landfilling- W LFG flare (100% collection efficiency)	2	400	14	10 (3)	**0.65** (0.21)
Landfilling- W LFG energy recovery (100% collection efficiency)	5	400	34	24 (8)	**1.62** (0.52)
Aerobic Composting	1	250	11	8 (3)	**0.52** (0.17)
Anaerobic Digestion	10	500	274	39 (13)	**2.59 (0.9)**
incineration	50	500	274	195 (63)	**12.98** (4.18)

Comment- Our calculations did not take into account operational and maintenance costs. Estimating these costs is far beyond the scope of this work. Nevertheless- Selling electricity at a price of 0.05\$/kWh is comprised from ca. 0.02\$ for the fuel and 0.03\$ for investment payback. Since waste is fuel substitute, tipping fees at the gate of an incineration plant could be reduced by 9.4\$/ton of waste and at a landfill that recovers energy from LFG by 1.6\$/ton, due to selling electricity.

It can be seen that the most economic solution to reduce GHG emissions from municipal solid waste is to compost it. This option could be implemented within several months, after fulfilling several infrastructure needs. Political opposition is not anticipated, nevertheless, a NIMBY syndrome might prolong the time needed to start constructing such plants.

LFG flares in existing dumps or in new state of the art landfills, will be installed only if strict environmental regulations require them. The economic basis for these regulations could, and should, be based on the potential damage of GHG emitted from landfills.

The extra investment needed to recover energy from the LFG will be covered by income from energy sales.

Incineration is the most expensive way to achieve reduction of GHG emissions from waste management.

7.5 GHG emissions from sewage sludge

The potential of sludge generation from municipal wastewater treatment plants is assumed to be 35-40g dry sludge/ capita/ day (14.5 kg dry sludge/capita/ annum).

The carbon content in the dry sludge is ca. 50%, therefore the annual potential of CH4 formation from wastewater treatment plants in Israel is

CH4 from wastewater treatment plants — 6 million inhabitants

C in dry sludge tpy	CH4 tpy	Total CO2 eqv. tpy
44,000	58,000	1,218,000

In order to estimate annual CH4 production we assume that all domestic wastewater are being treated (this estimation is far beyond the real situation).

The total annual potential of methane emissions from solid waste and sewage sludge are 9 million CO2- eq.

Sludge can be treated using the same means as organic municipal solid waste (aerobic or anaerobic compostation, incineration)

A significant part of the wastewater is not treated in central plants, in addition, part of the sludge produced in wastewater treatment plants is discharged to the Mediterranean sea. These facts lead to the fact that the share of wastewater sludge to the total budget of GHG emission is negligible, and the contribution of methane is insignificant compared with the contribution of solid waste.

Chapter 8

The Economic Costs of GHG Reduction

8.1. Introduction

8.1.1 Background

Controlling GHG gases is costly undertaking, typically characterized by a marginal cost function that rises with the level of abatement. The relevant studies indicate that attaining the Kyoto targets, i.e., 1990 emission levels by 2050, would cost about 2.5% ± 1% of world GDP (Weyant, 1993). Clearly, this figure is high in terms of developed economies' normal GDP growth rates. However, it does not tell us whether this is a price worth paying for reducing GHG, unless we can compare it, say in a cost-benefit framework, with the damages avoided as a result of adopting these abatement measures. Nordhaus (1996), for example, finds that the optimal policy, from a cost vs. benefit perspective, is to invest rather modestly in GHG abatement, to the order of 10% from current levels (which would entail a small, gradual *increase* in global temperatures well into the next century. Using the same framework, but different (higher) benefit estimates, Cline (1992) arrives at a much higher optimal abatement cost level. Typically, the *benefit* estimate side is less amenable to quantification, and is characterized by a high degree of uncertainty.

8.1.2 Objectives

Given the relatively short time-framework and the terms-of-reference of a Policy Paper- we set out in this chapter is to present rough, first approximation estimates of the economic costs of GHG abatement in Israel, motivated by the possibility of Israel's having to comply with at least some of the Kyoto Annex I obligations. These estimates are rough, first approximation for two reasons: The study's framework did not justify, nor allowed us to conduct an in-depth, rigorous analysis of these economic costs. That would clearly involve a longer study, with an extensive and wide-ranging data collection and analysis effort, especially because a good part of these data are either non-existent or difficult to procure. Second, much of these data depends on the sector-by-sector studies undertaken in this Policy Paper study, and they themselves, too, are to a large extent not yet in a position to provide the economist with reliable, comprehensive figures of abatement cost of the alternative abatement technologies and processes. These would in turn provide the building blocks for estimating an over-all, national least-cost abatement function.

In this chapter, therefore, we confine ourselves to estimating an *aggregate*, national-level function, combining parameter estimates from similar studies conducted elsewhere, with Israeli data whenever available, as well as invoking appropriate assumptions based on the situation in Israel. All of this information is analyzed within a framework of a dynamic economic model, which enabled us to project the economic analysis into the year 2010, keeping in mind the precautions and prudence required in interpreting such long-term projections.

The Term of Reference proscribed ignoring damage and benefit estimates, limiting the analysis to cost side, to derive *cost-effective* (i.e., least-cost) solution paths for GHG abatement, for specified targets, say, the reductions mandated by the Kyoto Protocol, or a similar target. That is, we did not attempt to assess the economic desirability of these targets in terms of the damages avoided.

8.1.3 Carbon Taxes and the Double-Dividend Issue

Following the derivation of a cost-effective solution (that is, the sectors and technologies involved in the abatement effort, as well as the *level* of abatement by each sector and its *timing* over the abatement horizon up to the target year), economists have often recommended employing *decentralized market-based incentives*, specifically *emission ("green") taxes* and *tradable emission permits*, as highly efficacious means of achieving these targets. Alternatively, the government can adopt an administrative *command and control* approach through the specification and enforcement of the optimal, cost-effective abatement levels for each industry and each sector in the economy. The economic instrument most often mentioned in connection with GHG abatement is a Carbon tax (Poterba, 1991). With this tax, every emitter of GHG abates until the his marginal abatement cost equals the tax rate. Consequently, the marginal cost of abatement is equal for all emitters -– a precondition for cost effectiveness (i.e., least cost) in achieving the abatement target. In this chapter we incorporate the carbon tax option into our analysis of the Israeli case.

An important feature of the tax, the so-called ‘double dividend hypothesis’ (Bovenberg and de Mooij., 1994), which has made it attractive to governments, is associated with the tax revenues. They could, in, principle, replace or reduce other distortive taxes in the economy, such as taxes on labor (e.g., income tax) and capital (e.g., corporate tax. Obviously, any indirect benefit of this sort should be appropriately subtracted from the cost of abatement.

Another “double-dividend” (or “win-win”) aspect of the carbon tax is that CO2 reduction is often associated with reductions in the emission of *local* pollution gases, such as SO2 and NOx. This may be an important consideration on the national level, since reducing only CO2 may not manifest itself as tangible, direct and immediate benefit to the abating country, while a reduction of these secondary gases confers direct health and materials benefits on the citizens of the abating country. Again, when properly credited to abatement cost, these extra benefit imply lower GHG abatement cost. Indeed a number of studies (summarized in Eckins, 1996), show that, in extreme cases, even a unilateral action on the part of a country in reducing GHG emission without similar actions taken by other emitting countries, could be justified in a cost-benefit framework which takes the above, extra side benefits into account. In fact, it can be shown that under certain assumption, this could also hold true in the case of Israel.

8.2. The Israeli Case: Pertinent Data

8.2.1 Definition

Abatement is defined here in terms of the emission level that would have been reached under a “businesses as usual” (no abatement) policy.

8.2.2 Scenarios to be analyzed

It would be prudent to base the analysis on both *total* pollution and pollution *per capita.* The decade of the 90’s was not a “normal” period; during the first part of the 90’s Israel absorbed a large number of immigrants from the former USSR, with population growing at about 3.4% per annum during 1990-1996. Correspondingly, and in addition to large government expenditures, the GDP grew quite fast, at about 5.7% per annum. Consequently, the overall CO2 equivalent increased by 8.7%

annually. This implies that taking 1990 as the reference year significantly disfavor Israel in terms of the extent of GHG abatement efforts, due to these unprecedented increase in population and the accompanying unusual high level of economic activity. Therefore we propose that the economic analysis examines 2 scenarios:

- Scenario 1: Reducing *total* GHG emissions by 2010 to 1990 levels of total emissions.
- Scenario 2: Reducing total pollution by 2010 to a level where *per capita* emission is set to its corresponding 1990 level.

Thus, although a 0% per-capita GDP growth is assumed, *total* emissions would increase in both scenarios, necessitating appropriate abatement policies.

8.2.3 Parameter Values and Assumptions

Base year: 1996

GDP: US$ 95 billion.

GDP growth rate: 2.2%

Population: 5.69 million.

Population growth rate: 2.2%

Per-capita GDP growth: 0%

Emissions: 77,627 ktons of CO2 equivalent (13.64 tons per capita).

1990 emissions (2010 target): : Total CO2 equivalent 48,100 ktons (10.37 tons per capita at the 1990 population level).

8.2.4 Three Cost Categories

When a carbon tax is employed as a policy tool in abating emissions, two other cost categories should also be taken into account, in addition to emission abatement cost: the *tax payments* (and revenues to the government) and the *loss in the consumer surplus* (a dead-weight welfare loss). If the tax revenues are returned back through government expenditures, say on social goods and services or on a reduction of other distortive taxes (the double dividend argument), we assume that there are no net welfare losses to society. In the analysis that follows, these two other cost items will be estimated explicitly, in addition to the direct abatement cost.

8.3. The Model

A dynamic, economic model framework has been specified the basis for the conducting a consistent, rigorous analysis of the Israeli situation. The model is presented in equations (1)-(13) in the **Appendix C**. The initial conditions, i.e., the levels of the various parameters which drive the equations of the model are those which prevailed in 1996. The terminal year of the analysis is 2010, and the abatement targets are specified for that year. That is, the model is designed to seek the optimal (least-cost) adjustment path for the economy, so that by 2010 the emission targets are achieved.

8.4 Results and Discussion

As noted above, we analyzed two scenarios: Scenario 1 sets to reach 1990 levels by 2010, and Scenario 2 sets 2010 GHG per-capita emissions equal to those in 1990. From Section 2 above, the initial conditions and parameters of the model are as follow:

$\delta = \gamma = \sigma = 2.2\%$

POP0 = 5.69 million.

GDP0 = US$ 88 billion.

CO2, 0 = 77.28 mil. tons.

T = 14 years.

K1 = 48.10 mil. tons.

K2 = 80.08 mil. tons.

Q0 = 16323 tons of oil equivalent.

P0 = $0.05 kWh.

The results are presented in Tables 1 and 2 and Figures 1 and 2 for Scenario 1, and Tables 3 and 4 and Figures 3 and 4 for Scenario 2. Figures 5 and 6 compare the two scenarios. Tables 1 and 3 and Figures 1 and 3 give the results in physical units, while Tables 2 and 4 and Figures 2 and 4 present them in money terms.

Scenario 1: Under the "Business as Usual" (BAU) scenario (the 2nd column in Table 1), GHG emissions will reach 104.80 mil. tons. by 2010. This means that under K1, a reduction of 54% is required. This reduction path is specified in the 3rd column of the table. The difference between the business as usual and the "Kyoto" path is given in the 4th column. It should be noted that on a *per capita* basis, the corresponding cut is from were 10.37 tons per capita in 1990 to 6.23 tons in 2010. The consequences of using this alternative "interpretation" of Kyoto will emerge when we analyze the second scenario.

The monetary equivalent of the three cost categories [total (TAC), average (AAC) and marginal (MAC) abatement cost, consumer surplus (△CS), and tax receipts (TR)] are presented in Table 2 and Figure 2. Total abatement cost increases from US$ 0.75 million in the base year to $6.5 billions in 2010. In terms of GDP (last column in Table 2), it rises from 0.002% in 1997 to 6.3% in 2010. The corresponding tax rate needed to support this path is given in the marginal abatement cost column. Thus, the cost effective tax rises from $0.65 in 1997 to $618 per ton of GHG ($CO_2$ equivalent), an almost 1000% increase! Tax revenues rise from $49 million in 1997 to almost $30 billion in 2010. The change in consumer surplus due to energy prices increases, starts at $0.92 million, climbing up to $976 million in 2010.

Does the figure of $7.52 billion total cost[1] in 2010 - 6.3% 0f GDP - constitute a heavy burden? Most probably yes. It is certainly higher than what similar studies found for other developed economies. But is it justified on socioeconomic grounds? This question, as pointed out above, cannot be answered until this figure is compared with the corresponding benefits (i.e., reduced damages) of the policy. However, we can say something about the "double dividend" benefit issue. Note that tax collection in 2010 is about $30 billion. If these revenues are used to *replace* other distorting taxes (and *not* to increase government expenditure!), and the inefficiency rate associated with these taxes are assumed to be near 0.3 (Bovenberg and de Mooji, 1994). That is, from every dollar raised in the form of, say, income tax, only 70 cents actually reach the treasury, due - in this case - to certain tax distortions in the labor market which are due to the negative incentives of this tax. If this tax leakage value of 0.3 holds, then a fiscal savings (benefit) of about $9.9 billion is achieved because an

[1] TAC + △CS, with TR left out because it is essentially a transfer from consumers and firms to the government, and assumed to be channeled back into the economy.

inefficient tax is replaces by a more efficient one, namely, the environmental tax with a cost tag (revenue raised) of only $7.5 million![2]

Scenario 2: The scenario is based on the premise of achieving 1990 per capita emission levels in 2010, yielding a total emission level of 80.8 mil. Tons in 2010 (Table 3). Clearly, the corresponding reduction in total emissions is much easier to achieve, amounting to only 24% from the BAU case. The cost estimates are likewise lower (Table 4). In terms of GDP, the cost burden reaches only 0.18% in 2010, and the cost effective tax rises up to $27 per ton of GHG in 2010 (vs. $618 in the previous case). Tax revenues are appropriately more modest, rising to only $2.15 billion by 2010.[3] Figures 5 And 6 compare the two scenarios, and reflects the expected higher feasibility of the second scenario.

As a concluding remark to this exercise, we would like to raise again the issue of economic burden. A number of studies have estimated abatement cost to be in the range of 0.5%-2% of GDP. We note that Scenario 1’s target year burden is higher then the upper limit of that range, while scenario 2 is below the lower limit. This suggest that, in addition to the obvious need to construct more elaborate and detailed sector by sector models of the economy, one should explore other scenarios, which could point at alternative policy targets which might bring us close to the Kyoto targets.

[2] Only when the inefficiency rate is less than 25% will the abatement cost outweigh the fiscal benefits in 2010.

[3] The threshold inefficiency rate here is of course lower, about 10%.

Table 8.1- Business as Usual vs. scenario 1 optimal time path.

Year	$CO_2^{\cdot}$ (BAU)	CO_2 (K2)	Reduction
	(Ktons)	(Ktons)	(Ktons)
1996	77.28	77.28	
1997	78.98	75.20	3.78
1998	80.72	73.11	7.61
1999	82.49	71.03	11.46
2000	84.31	68.94	15.37
2001	86.16	66.86	19.30
2002	88.06	64.77	23.29
2003	90.00	62.69	27.31
2004	31.98	60.61	31.37
2005	94.00	58.52	35.48
2006	96.07	56.44	39.63
2007	98.18	54.35	43.83
2008	100.34	52.27	48.07
2009	102.55	50.18	52.37
2010	104.80	48.10	56.70

Table 8.2 - Cost, Tax and percentage of GDP in Scenario 1

Year	TAC	AAC	MAC	CS	TC	TR	PGDP
	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	%
1996							
1997	0.75	0.20	0.65	0.92	1067	48088	0.002
1998	6.84	0.90	2.89	4.70	11.54	211.29	0.01
1999	24.76	2.16	7.18	9.60	34.36	510.00	0.03
2000	63.41	4.13	14.22	12.27	75.68	980.33	0.08
2001	133.48	6.92	24.74	25.08	158.56	1654.12	0.16
2002	228.51	9.81	39.96	51.25	279.76	2587.01	0.28
2003	430.18	15.75	60.97	78.57	508.75	3822.11	0.50
2004	397.48	22.23	89.72	133.84	831.32	5437.93	0.79
2005	1082.48	30.51	128.53	191.49	1273.97	7521.58	1.19
2006	1621.72	40.92	180.23	251.62	1873.34	10,172.18	1.71
2007	2365.88	53.98	249.00	371.44	2737.32	13,533.15	2.45
2008	3374.39	70.20	339.70	496.42	3870.81	17,756.12	3.39
2009	4734.40	90.40	459.91	686.40	5420.80	23,078.28	4.64
2010	6539.39	115.33	617.91	976.00	7515.39	29,721.47	6.30

TAC - Total abatement cost
AAC - Average abatement cost
MAC - Marginal abatement cost
CS - Consumers’ surlus loss
TC-TAC+CS
TR - Government tax receipts
PGDP - Percentage of GDP

Table 8.3- Business as Usual vs. scenario 2 optimal time path

Year	CO_2 (BAU)	CO_2 (K2)	Reduction
	(ktons)	(ktons)	(ktons)
1996	77.28	77.28	
1997	78.98	77.48	1.50
1998	80.72	77.68	3.04
1999	82.49	77.88	4.61
2000	84.31	78.08	6.23
2001	86.16	78.28	7.88
2002	88.06	78.48	9.58
2003	90.00	78.68	11.32
2004	31.98	78.88	13.10
2005	94.00	79.08	14.92
2006	96.07	79.28	16.79
2007	98.18	79.48	18.70
2008	100.34	79.68	20.66
2009	102.55	79.88	22.67
2010	104.80	80.08	24.72

Table 8.4 - Cost, Tax and Percentage of GDP in Scenario 2

Year	TAC	AAC	MAC	CS	TC	TR	PGDP
	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	(Mill.$)	%
1996							
1997	0.05	0.03	0.09	0.10	0.15	7.23	
1998	0.39	0.13	0.39	0.47	0.86	30.30	
1999	1.34	0.29	0.90	1.08	2.42	70.28	0.002
2000	3.29	0.53	1.59	2.45	5.74	123.78	0.006
2001	6.63	0.84	2.69	3.51	10.14	210.82	0.010
2002	11.85	1024	4.01	5.13	16.98	314.73	0.014
2003	19.45	1.72	5.64	7.86	27.31	443.76	0.03
2004	29.99	2.29	7.63	10.71	40.70	601.67	0.04
2005	44.08	2.95	9.97	13.68	57.76	788.70	0.05
2006	62.50	3.72	12.73	16.77	79.27	1009.07	0.08
2007	85.92	4.59	15.94	22.86	108.78	1267.21	0.10
2008	115.28	5.58	19.63	29.20	144.48	1564.14	0.13
2009	151.55	6.69	23.85	35.81	187.36	1904.75	0.16
2010	178.92	7.46	26.84	41.20	220.12	2149.35	0.18

TAC - Total abatement cost
AAC - Average abatement cost
MAC - Marginal abatement cost
CS - Consumers’ surlus loss
TC-TAC+CS
TR - Government tax receipts
PGDP - Percentage of GDP

Figure 1-Business as Usual vs. scenario 1 optimal time path.

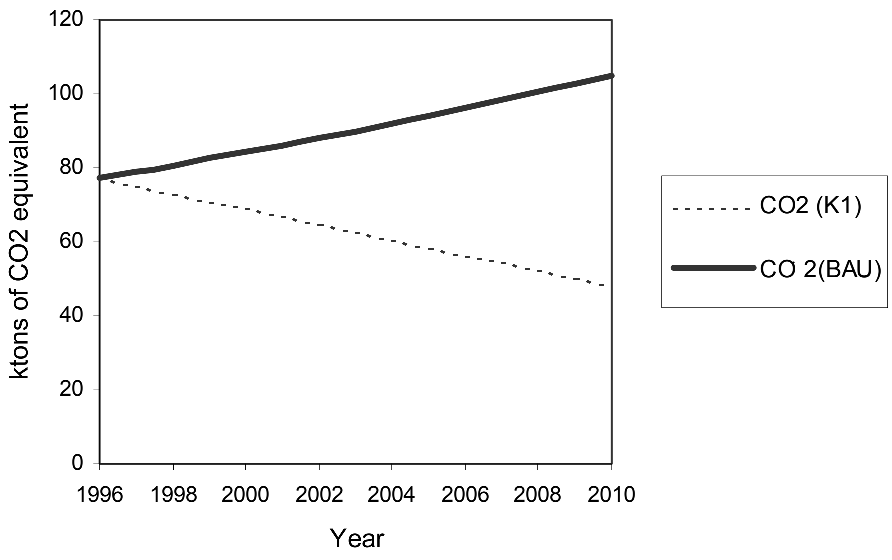
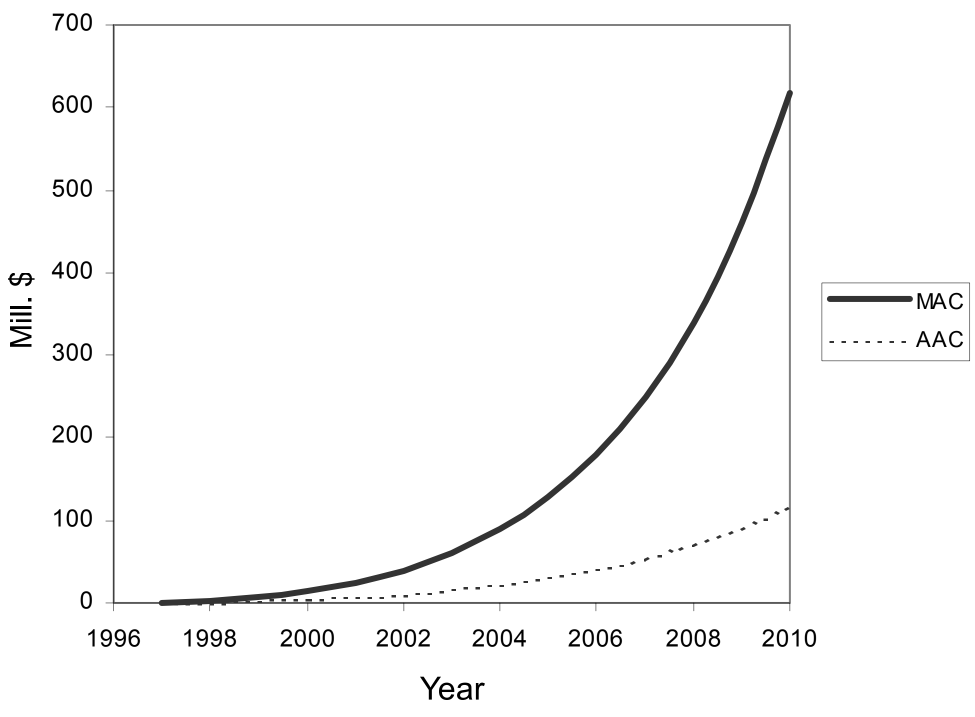


Figure 2- Marginal and Average abatement cost of scenario 1.(in Mill.$)



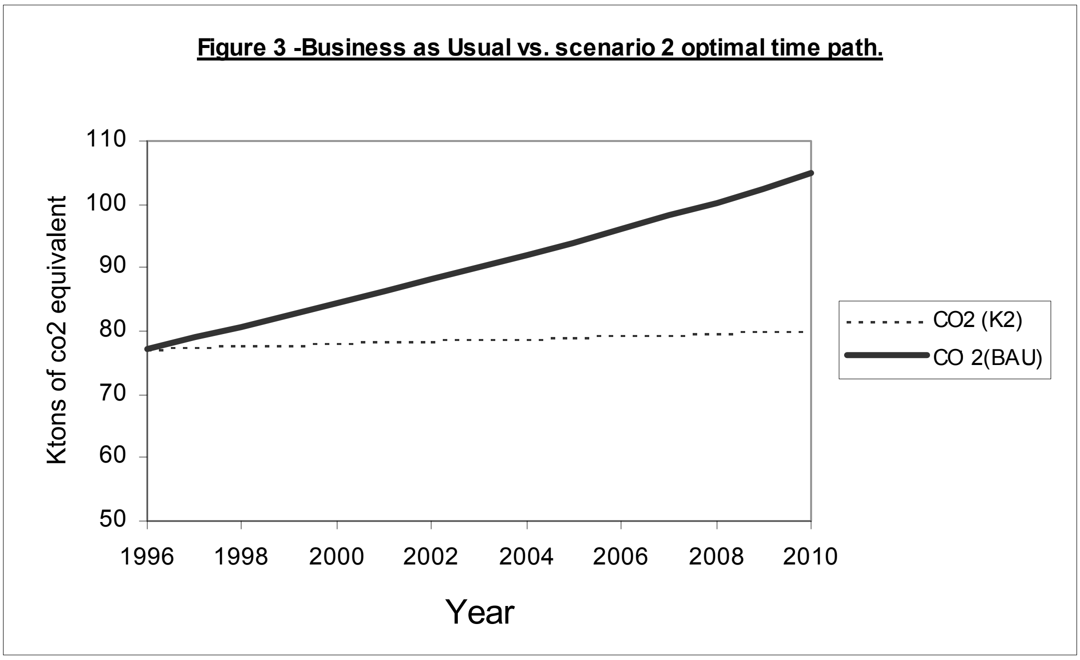


Figure 3 -Business as Usual vs. scenario 2 optimal time path.
Ktons of co2 equivalent
110
100
90
80
70
60
50
1996
1998
2000
2002
2004
2006
2008
2010
Year
CO2 (K2)
CO 2(BAU)

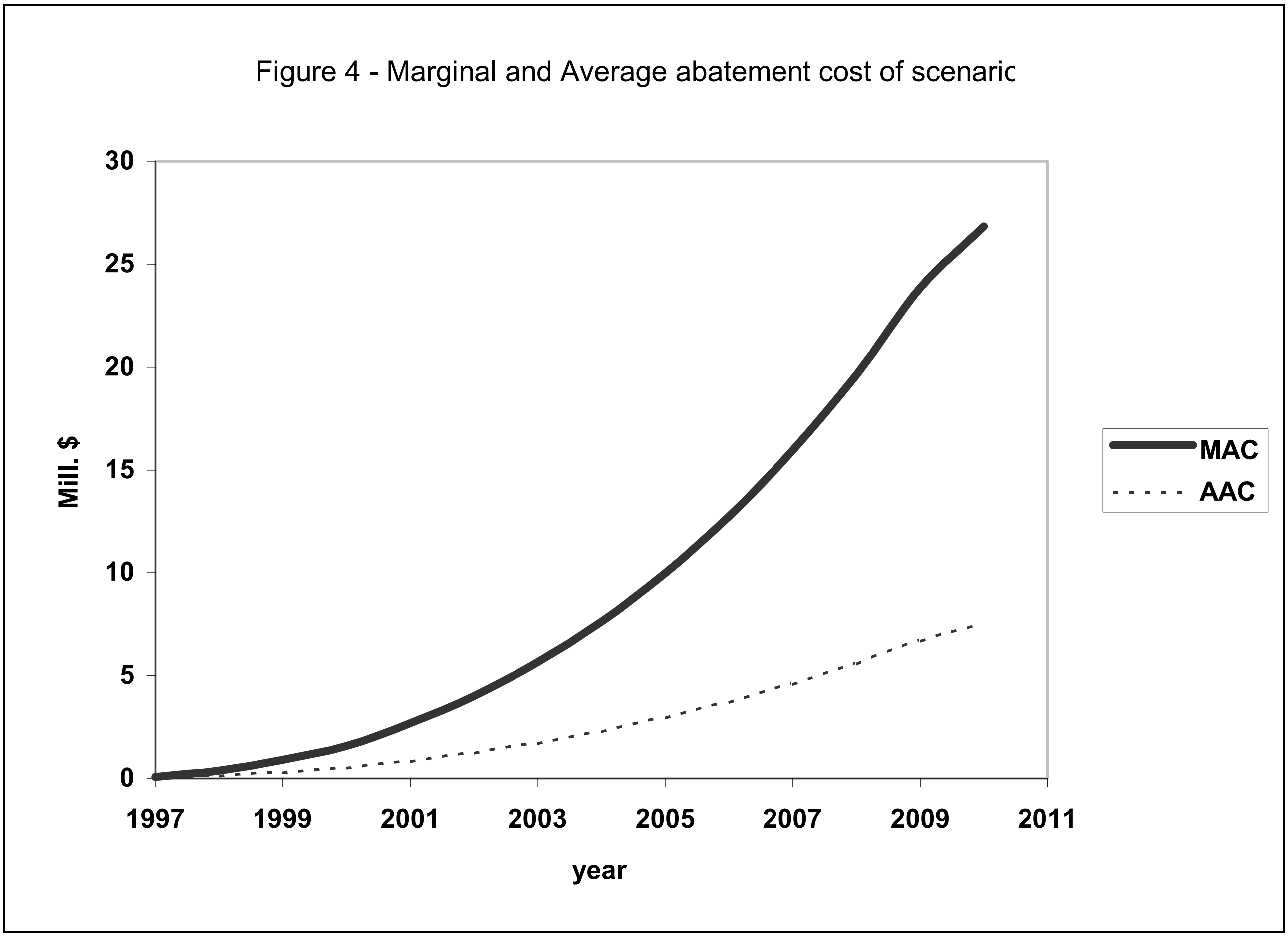
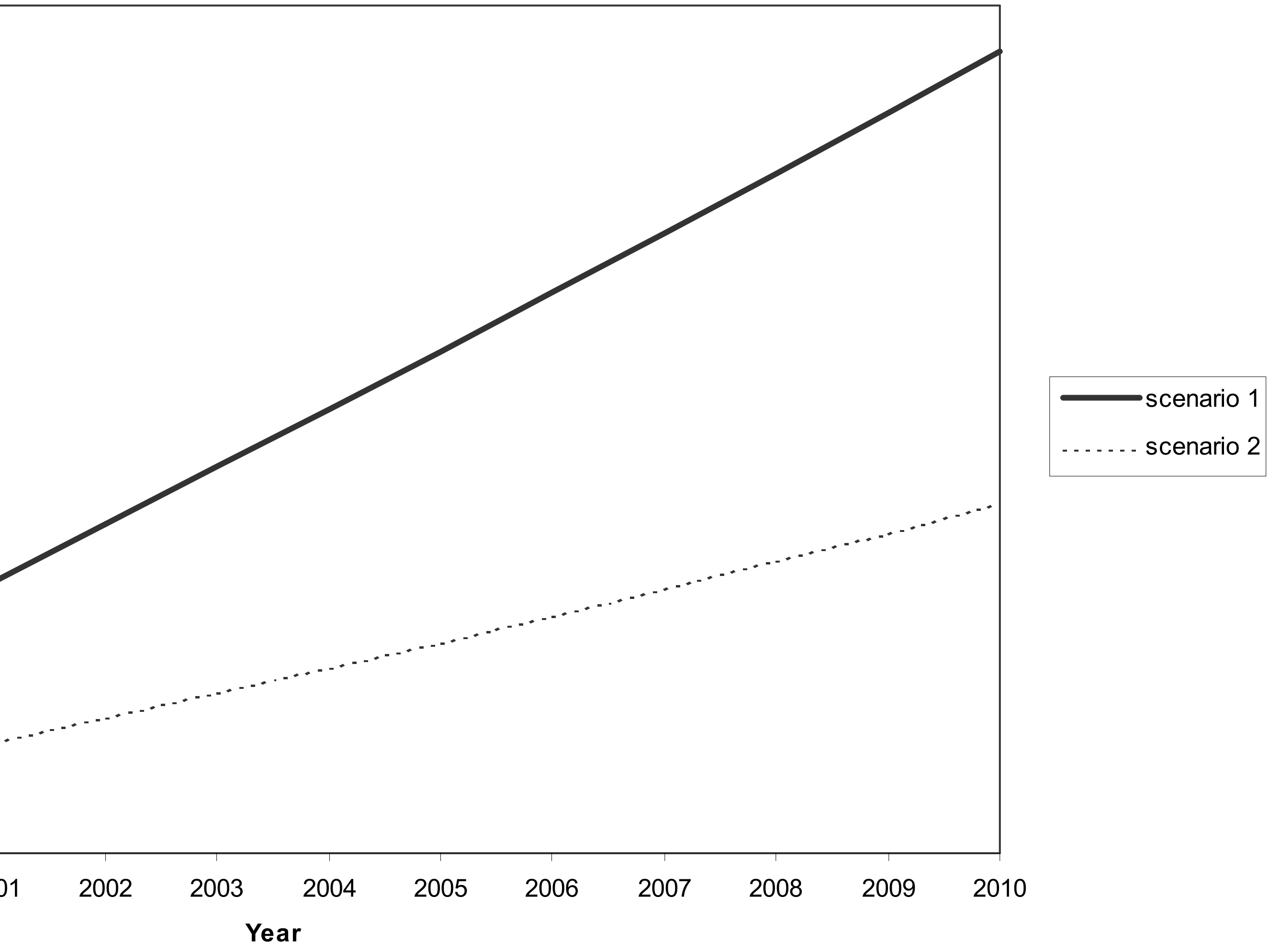
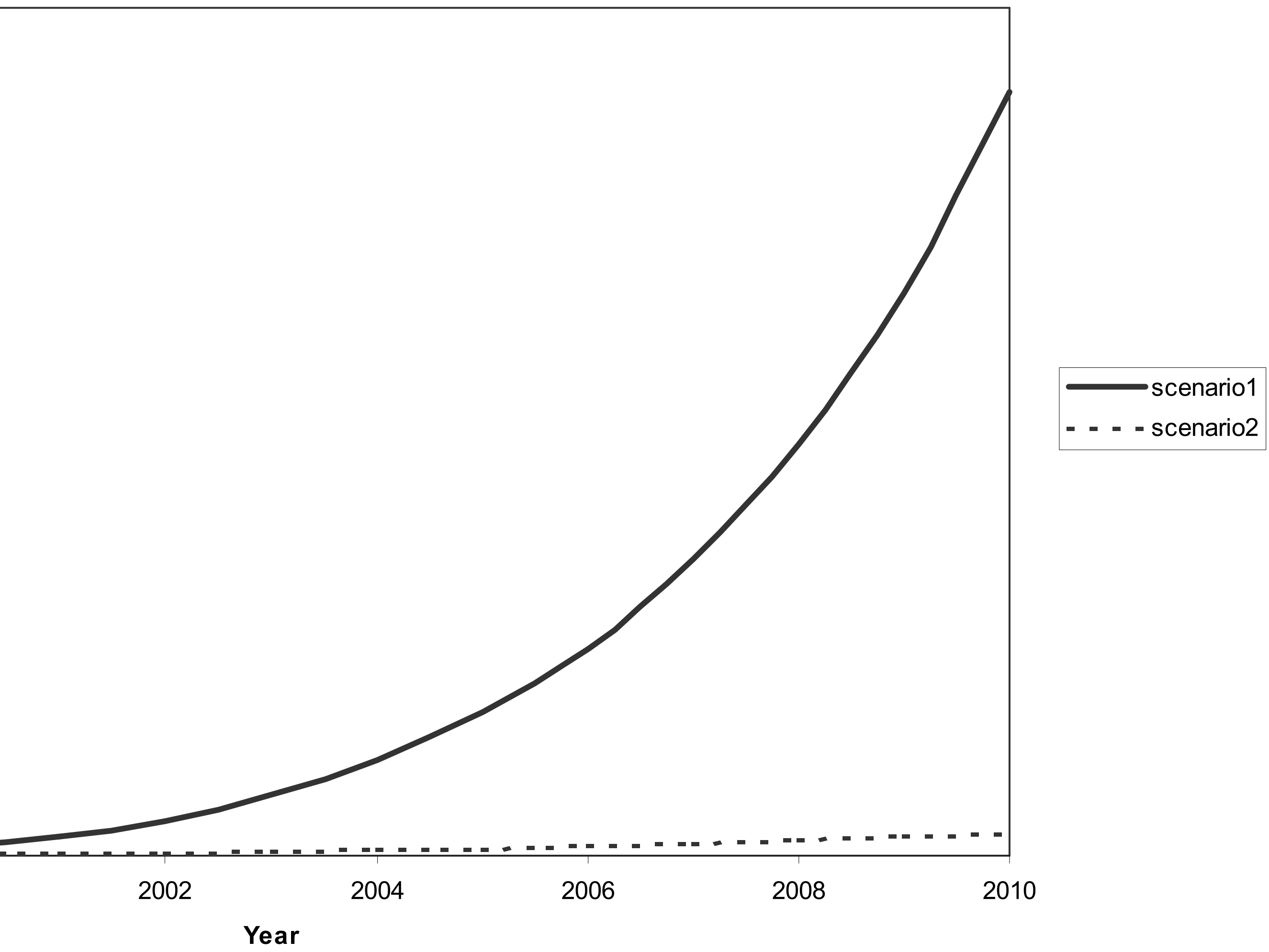


Figure 4 - Marginal and Average abatement cost of scenaric
Mill. $
30
25
20
15
10
5
0
1997
1999
2001
2003
2005
2007
2009
2011
year
MAC
AAC

Figure 5 - Ktons of co2 equivalent



eduction as percentage of GDP Scenarios 1 and 2



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Appendix A

Energy savings in buildings

A.1. Qualitative classification of building parameters

A qualitative classification of the range of effect of design parameters, within the various types of living units in the different climatic zones, points to the more and less significant parameters. Table A.1 provides qualitative data about the degree of importance of each of the design parameters within three climatic regions in Israel.

Table A.1: Comparison of ranges of effect of design parameters on energy saving in buildings.

Region	C				A				B			
	Jerusalem				Tel Aviv				Ramat David			
Apartment type	4 facades roof/ pillar		2 facades middle		4 facades roof/ pillar		2 facades middle		4 facades roof/ pillar		2 facades middle	
Design Parameter \ Insulation Type	S	I	S	I	S	I	S	I	S	I	S	I
Building wall insulation	ν		υ		ν		υ		ν		0	
Building roof insulation	ν				ν				ν			
Floor insulation on pillar story	ν				ν				ν			
Wall color	υ	υ	0	0	0	0	υ	υ	υ	0	0	0
Roof color	υ	υ			ν	υ			υ	ν		
Air infiltration	ν	ν	ν	ν	ν	ν	υ	0	ν	ν	ν	ν
Building ventilation on summer nights	ν	ν	ν	ν	ν	ν	ν	ν	ν	ν	ν	ν
Increasing exterior wall surface	ν	ν	ν	0	ν	υ	υ	υ	ν	υ	0	0
Building orientation	ν	ν	υ	0	ν	ν	υ	0	ν	υ	υ	0
Solar building deviation from south	υ	υ	0	0	υ	υ	0	0	υ	0	0	0
Building proportions	0	0	υ	0	0	0	0	0	0	0	0	0
Solar building proportions	ν	0	υ	0	υ	0	υ	0	0	0	0	0
Wall shading	υ	0	0	0	0	0	0	0	0	0	0	0
Roof shading	υ	0			υ	υ			υ	ν		
Window shading in summer	υ	υ	υ	υ	ν	ν	ν	ν	ν	ν	ν	ν
Non-shading windows in winter	ν	ν	ν	ν	ν	ν	0	0	ν	ν	ν	υ
Increasing solarity level/ external shutter	ν	ν	υ	0	ν	υ	0	0	ν	υ	0	0
Southern windows Size /external shutter	ν	ν	υ	0	υ	υ	υ	υ	0	0	ν	ν
Western windows Size / external shutter	υ	υ	υ	0	0	0	ν	ν	υ	υ	ν	ν
Eastern windows Size / external shutter	υ	υ	υ	0	0	0	ν	ν	υ	υ	ν	ν

Northern windows Size / external shutter	0	0	0	0	0	υ	υ	υ	υ	υ	ν	ν
Southern windows Size / internal shutter	ν	ν	υ	0	υ	υ	ν	ν	0	0	ν	ν
Western windows Size / internal shutter	υ	υ	0	0	υ	ν	ν	ν	ν	ν	υ	ν
Eastern windows Size / internal shutter	υ	υ	0	0	υ	υ	ν	ν	ν	ν	ν	ν
Northern windows Size / internal shutter	υ	υ	0	0	υ	υ	ν	ν	υ	υ	υ	ν

Degrees of Importance

<3 0

S - standard

5-10 υ

I - improved

10-15 ν

>15 ν

The climatic regions:

Zone A: the coastal plain (represented by the Tel Aviv climate); zone B: the inner plain and the valleys (represented by the Ramat David climate) and zone C: the mountain area (represented by the Jerusalem climate).

Region	Temperature (C^0)		Relative Humidity (%)
	January	August	Maximum in summer
Coastal (Tel Aviv)	10.2 - 17.5	24.5 - 29.7	75
Inner plain and the valleys (Ramat David)	6.7 - 16.9	22.2 - 33.1	65
Mountain (Jerusalem)	4.5 - 12.2	18.5 - 30.3	60

Based on table A.1 it is possible to classify the parameters into several qualitative groups carrying specific traits within all or some of the climatic zones or within all or some of the building types:

- Design parameters that have strong effects unrelated to a given climatic zone.

  E.g. Air infiltration and building ventilation on summer nights.

- Design parameters whose effect is strong only in a given climatic zone.

  E.g. Window shading in summer, or variations in window area (particularly those facing west) when they have no external shutter. The effect of these parameters is very significant in the hot-humid Tel Aviv climate, but moderate in the temperate-cool Jerusalem climate.

- Design parameters whose effect is strong regardless of the apartment type and its various design parameters.
  E.g. Window shading in the summer in Tel Aviv, or air infiltration in Jerusalem.

- Design parameters whose effect is strong only in apartments of a certain type and dependent on the values of other design parameters.
  E.g. Non-shading of windows in winter and increasing the solarity level of the apartment, whose effect is very strong, principally in roof apartments.

- Design parameters whose effect is weak to moderate regardless of climate or other design parameter values.
  E.g. Non-solar building proportions, wall shading and color.

A.2. Quantitative classification of the maximal energy savings by design parameter within different climatic regions in Israel

The data is presented in descending order according to the degree of energy savings. The numbers in parentheses express the maximal possible change in kWh/year per square meter floor, unless otherwise specified.

<u>Jerusalem: a roof apartment or on pillars – 4 facades</u>
<u>The standard building</u>

- Parameters with a great effect (over 20 kWh/year per square meter)
  Increasing the southern window surface area, namely the building solarity level. The window is with an external shutter that provides good shading in summer and night insulation in winter (35)
  Air infiltration (33)
  Non-shading of windows in winter (30)
  Roof insulation (23)
  Varying the building exterior wall surface area (21)
  Floor insulation in the first-story apartment on pillars (20).

- Parameters with a large effect (over 10 and up to 20 kWh/year per sqm)
  Insulation of the building walls (17)
  The building orientation(16)
  Solar building proportions (15)
  Building ventilation on summer nights (3.5 degrees C).
  Shading windows in summer (1.5 degrees C).

- Parameters with a moderate effect (more than 3 and up to 10 kWh/year per sqm)
  Solar building deviation from due south (9)
  Wall color (8)
  Roof color (7)
  Varying the surface area of the western window with an interior shutter (7)
  Varying the surface area of the eastern window with an interior shutter (6)
  Double glazing (5% or 10% glazing on main facade) (3-7)
  Wall shading (5)
  Shading of a medium-color roof (4)
  Varying the surface area of the western window with an exterior shutter (4)
  Varying the area of the eastern window with an exterior shutter (3)
  Varying the surface area of the northern window with an interior shutter (3)

- Parameters with a small effect (below 3 kWh/year per sqm)
  Varying the surface area of the northern window with an external shutter that provides good shading in summer and night insulation in winter (1)
  Non-solar building proportions (1).

Jerusalem: roof apartment or on pillars

Improved building

- Parameters with a great effect (over 20 kWh/year per sqm)
Air infiltration (30)
Non-shading of windows in winter (26)
Building ventilation on summer nights (4.8 degrees C)

- Parameters with a large effect (over 10 and up to kWh/year per sqm)
Increasing the southern window surface area, namely the building solarity level (15)
The building orientation (15)
Varying the area of the exterior walls (10).
Shading windows in summer (2 degrees C).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per sqm)
Solar building deviation from due south (5)
Roof color (5)
Varying the surface area of the western window with an interior shutter (5)
Varying the surface area of the eastern window with an interior shutter (4)
Varying the surface area of the western window with an exterior shutter (4)
Double glazing (3-6)
Varying the surface area of the northern window with an interior shutter (3)
Varying the surface area of the eastern window with an exterior shutter (3)
Wall color (3)

- Parameters with a small effect (below 3 kWh/year per sqm)
Shading of a medium-color roof (2)
Wall shading (2)
Non-solar building proportions (1)
Varying the surface area of the northern window with an exterior shutter that provides good shading in summer and night insulation in winter (1)
Solar building proportions (5).

Jerusalem: apartment on an intermediate floor – 2 facades

The standard building

- Parameters with a great effect (over 20 kWh/year per sqm)
Air infiltration (25)
Building ventilation on summer nights (6.9 degrees C).

- Parameters with a large effect (over 10 and up to kWh/year per sqm)
Varying the exterior wall area of the building (15)
Non-shading of windows in winter (13).
Shading windows in summer (1.5 degrees C).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per sqm)
Varying the surface area of the southern window with an interior shutter (7)
Building walls insulation (5)
Building orientation (5)

Varying the surface area of the southern window with an exterior shutter (4)
Non-solar building proportions (4)
Varying the surface area of the western window with an interior shutter (4)
Double glazing (2-5)
Varying the surface area of the eastern window with an interior shutter (3)

- Parameters with a small effect (below 3 kWh/year per sqm)
Varying the surface area of the western window with an exterior shutter (1)
Solar building deviation from due south (2)
Varying the surface area of the northern window with an exterior shutter (1)
Varying the surface area of the eastern window with an exterior shutter (1)
Varying the surface area of the northern window with an exterior shutter (1)
Wall color (1)
Wall shading (.5)
Non-solar building proportions (.5)

Jerusalem: apartment on an intermediate floor – 2 facades

The improved building

- Parameters with a great effect (over 20 kWh/year per square meter)
Building ventilation on summer nights (7.8 degrees C).

- Parameters with a large effect (over 10 and up to kWh/year per square meter)
Air infiltration (20).
Shading windows in summer (1.5 degrees C).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per square meter)
Non-shading of windows in winter (9)

- The effect of all other design parameters is small.

Tel Aviv: roof apartment or on pillars – 4 facades

The standard building

- Parameters with a great effect (over 20 kWh/year per sqm)
Non-shading of windows in winter (24)
Shading of windows in summer (24)
Air infiltration (20)

- Parameters with a large effect (over 10 and up to kWh/year per sqm)
Building walls insulation (19)
Roof insulation (17)
Floor insulation of the story on pillars (13)
The building orientation (13)
Increasing the surface area of the southern window, namely the solarity level of the building (12)
Varying the external wall area of the building (10)

Roof color (10)
Building ventilation on summer nights (2.1 degrees C).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per sqm)
  Varying the surface area of the southern and northern windows with an interior shutter (9)
  Solar building deviation from due south (6)
  Varying the surface area of the northern window with an interior shutter (5)

- Shading of the medium-color roof (5)
  Double glazing (2-5)
  Variation in the area of the eastern window with an interior shutter (3)
  Solar building proportions (3).

- Parameters with a small effect (below 3 kWh/year per sqm)
  Variation in the area of the northern, eastern and western windows with exterior shutters (2)
  Wall color (2)
  Non-solar building proportions (1)
  Wall shading (1).

<u>Tel Aviv: roof apartment or on pillars – 4 facades</u>

<u>The improved building</u>

- Parameters with a great effect (over 20 kWh/year per sqm)
  Shading of windows in summer (29)
  Non-shading of windows in winter (20)
  Air infiltration (20)
  Building ventilation on summer nights (2.9 degrees C).

- Parameters with a large effect (over 10 and up to 20 kWh/year per sqm)
  Varying the surface area of the western window with an interior shutter providing partial shading in summer (13)
  The building orientation (12).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per sqm)
  Varying the external wall area (8)
  Varying the surface area of the eastern window with an interior shutter (8)
  Varying the surface area of the northern window with an interior shutter (7)
  Roof color (7)
  Varying the surface area of the southern window with an exterior shutter (6)
  Solar building deviation from due south (5)
  Shading of the medium-colored roof (4)
  Varying the surface area of the northern window with an exterior shutter (4)
  Double glazing (3-5).

- Parameters with a small effect (below 3 kWh/year per sqm)
  Wall shading (2)
  Size of the eastern and western windows with external shutters (2)
  Solar building proportions (1.5)

Non-solar building proportions (1)
Wall color (1).

<u>Tel Aviv: apartment on an intermediate floor – 2 facades</u>

<u>Standard building</u>

- Parameters with a great effect (over 20 kWh/year per sqm)
  Building ventilation on summer nights (6.3 degrees C).

- Parameters with a big effect (over 10 and up to kWh/year per sqm)
  Window shading in summer (19)
  Varying the surface area of the western window with an interior shutter (19)
  Varying the surface area of the eastern window with an interior shutter (15)
  Varying the surface area of the southern window with an interior shutter (13)
  Varying the surface area of the northern window with an interior shutter (10)
  Varying the surface area of the western and eastern window (10) with an exterior shutter.

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per square meter)
  Variation in the area of the southern window with an exterior shutter (9)
  Variation in the area of the northern window with an exterior shutter (8)
  Exterior building wall area variation (8)
  Building orientation (5)
  Air infiltration (4)
  Wall color (3)
  Wall insulation (3)
  Solar building proportions (3).

- Parameters with a small effect (below 3 kWh/year per sqm)
  Building proportions
  Solar building deviation from due south (2)
  Double glazing (1-2)
  Wall shading (1)
  Increasing the building solarity level (0)
  Non-shading of windows in winter (0).

<u>Tel Aviv: intermediate floor apartment – 2 facades</u>

<u>Improved building</u>

- Parameters with a great effect (over 20 kWh/year per sqm)
  Building ventilation on summer nights (6.4 degrees C).

- Parameters with a large effect (over 10 and up to kWh/year per sqm)
  Varying the surface area of the western window with an interior shutter (19)
  Shading windows in summer (18)
  Varying the surface area of the eastern window with an interior shutter (15)
  Varying the surface area of the southern window with an interior shutter (14)

Varying the surface area of the northern window with an interior shutter (11)
Varying the surface area of the western window with exterior shutter (12)
Varying the surface area of the eastern window with an exterior shutter (10).

- Parameters with a moderate effect (over 3 and up to 10 kWh/year per square meter)
  Varying the surface area of the southern window with an exterior shutter (14)
  Varying the surface area of the northern window with an exterior shutter (9)
  Variation in the exterior wall area of the building (7)
  Wall color (3).

- Parameters with a small effect (below 3 kWh/year per sqm)
  Building orientation (2)
  Air infiltration (2)
  Building proportions (2)
  Solar building deviation from due south (2)
  Double glazing (1-2)
  Wall shading (1)
  Increasing the building solarity level (0)
  Non-shading of windows in winter (0).

A3. Energy Efficiency in HVAC Systems for Commercial-Size Buildings

HVAC (Heating, Ventilation and Air Conditioning) systems consume sizable amounts of energy, which are associated with the production of CO_2 and other greenhouse gases. A significant portion of this energy may be conserved and the CO_2 emission reduced through Co-Generation. Electric power generation produces large amounts of reject heat. When this power is generated at the power plant, the reject heat is lost; generation of electric power locally, at the site, makes it possible to take advantage of the waste heat for heating and cooling. Co-generation systems may be practical for commercial size HVAC systems such as hotels, hospitals, office buildings and public buildings. This article explains the principles of co-generation, estimate the reduction in CO_2 emission and give some typical examples.

Figure 1 describes a conventional-type air-conditioning system employing a vapor-compression chiller with a typical COP (coefficient of performance) of 3.5. The electric power for the chiller is produced at a coal-fired power plant as shown, with a typical efficiency of 40%. 1.0 Ton of coal delivered to the power plant, with a typical caloric value of 6,000 kcal/kg, produces 6,977 kWh of heat which is converted to 2,791 kWh of electric power and 4,186 kWh of waste heat at about 40^{o}C. The associated emission of CO_2 is 3.667 Tons. The chiller employs this electric power to produce 9,768 kWh of cooling (typically by producing chilled water at about 7^{o}C, suitable for both sensible cooling and dehumidification) and rejects 12,559 kWh of waste heat at ambient temperature. The resulting CO_2 production is thus 0.375 kg per kWh of cooling.

Figures 2 and 3 describe two conventional-type heating systems. Figure 2 shows an oil-fired furnace or steam boiler employing light oil with a typical caloric value of 10,000 kcal/kg, at a combustion efficiency of 85%. 1.0 Ton of oil delivered to the furnace produces 9,884 kWh of heating, and 1,744 kWh of waste heat through the stack. The associated emission of CO_2 is 3.106 Tons. Figure 3 shows a different type, more energy-efficient heating system based on a vapor-compression heat pump with a typical COP of 4.0. The required electric power is generated at a coal-fired power plant under identical conditions to those of Figure 1. For the same input, the heat pump produces 11,164 kWh of heating at about 45^{o}C. The resulting CO_2 productions are thus 0.314 kg and 0.328 kg per kWh of heating, respectively, for the furnace (Figure 2) and the heat pump (Figure 3).

Figure 4 describes a co-generation HVAC system which can reduce significantly both the energy requirements and the CO_2 emission by generating the electric power locally and utilizing the reject heat. A diesel engine employing 1.0 Ton Diesel fuel with a typical caloric value of 10,000 kcal/kg, generates 4,070 kWh of electric power and 7,558 kWh of reject heat at a typical conversion efficiency of 35%. The associated emission of CO_2 is 3.106 Tons. The electric power drives a vapor compression chiller to produce 14,245 kWh of cooling at a COP of 3.5. In the winter, one may use the same electric power to drive a heat pump for heating, as in the system of Figure 3. The reject heat may be employed for heating in the winter or for cooling in the summer. by employing an absorption chiller at a typical COP of 0.6, additional cooling in the amount of 4,535 kWh may be produced from the waste heat. The data in Figure 4 shows that the total amount of CO_2 production for the cooling system shown may is 0.165 kg per kWh of cooling, a significant reduction from the value of 0.375 kg per kWh of cooling associated with the conventional system of Figure 1. The energy requirements are reduced as well.

A different system of co-generation in HVAC may be considered which separates the sensible and latent loads in air conditioning and uses desiccants to take care of the latter. Figure 5 illustrates a conventional situation where a vapor compression chiller with a typical COP of 3.5 employs 100 kW of electric power from the Utility to produce 350 kW of cooling at about 7^oC, suitable for both sensible cooling and dehumidification. The air conditioned space has a typical load profile requiring 40% latent and 60% sensible cooling. This system is essentially the same as the one of Figure 1 and as we have seen, the resulting CO_2 production is 0.375 kg per kWh of cooling.

The situation may be improved by employing the hybrid system described in Figure 6. The sensible and latent loads are separated out, and the vapor compression chiller is now responsible for the sensible part only. It is therefore sufficient for the chiller to produce the required 210 kW of cooling at a higher 15 ^oC, resulting in a higher COP of 4.0. The latent load of 140 kW is handled by a desiccant - a hygroscopic material which removes the humidity from the air and must be regenerated (dried) before it can be used again. This is done in co-generation mode by driving the chiller with a Diesel engine (directly or indirectly) and using the engine waste heat for desiccant regeneration. The total resulting CO_2 production is 0.114 kg per kWh of cooling, a significant reduction from the system of Figure 5. Energy requirements are reduced as well.

Figure 1 Conventional Cooling System

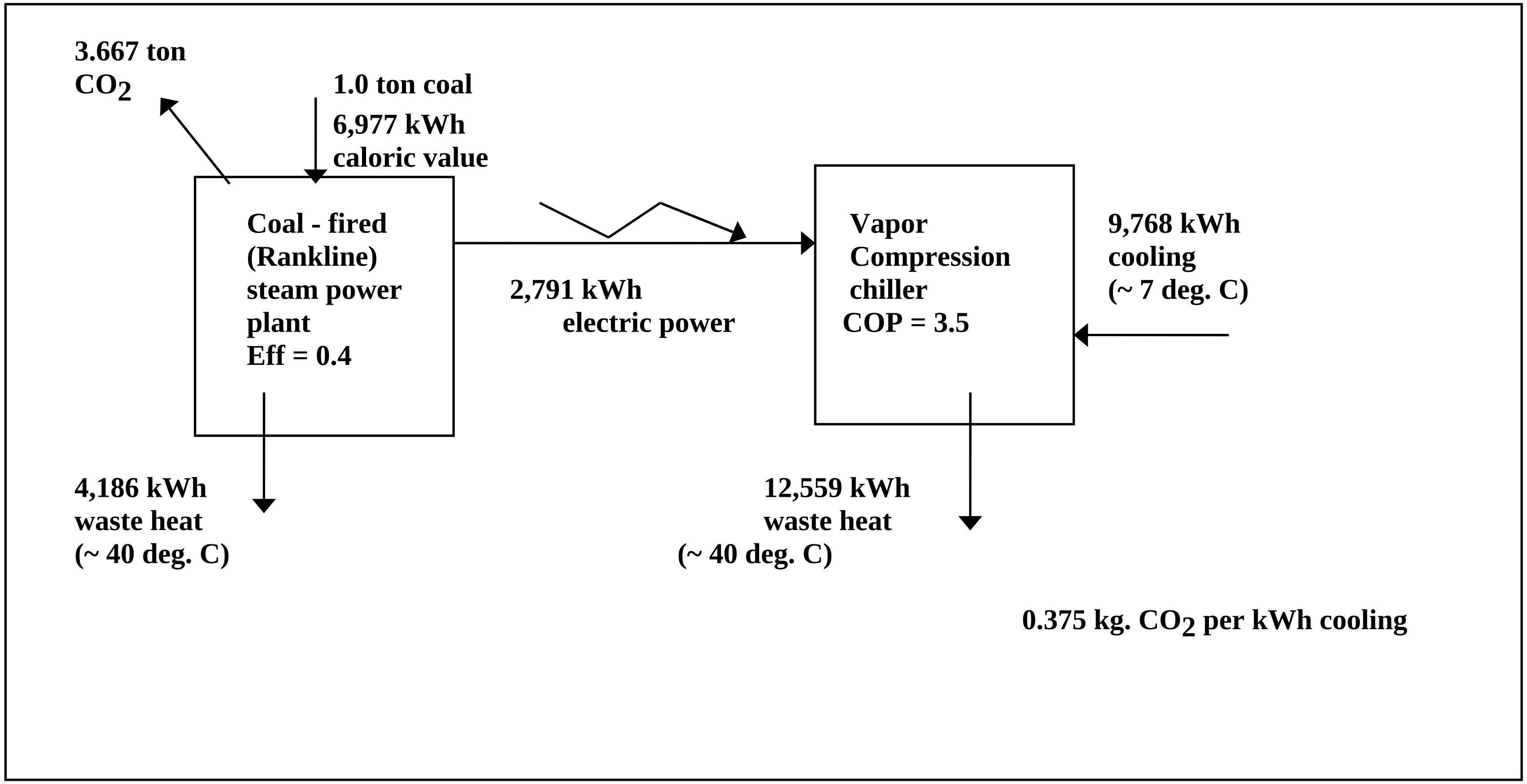


Figure 2: Conventional Heating System

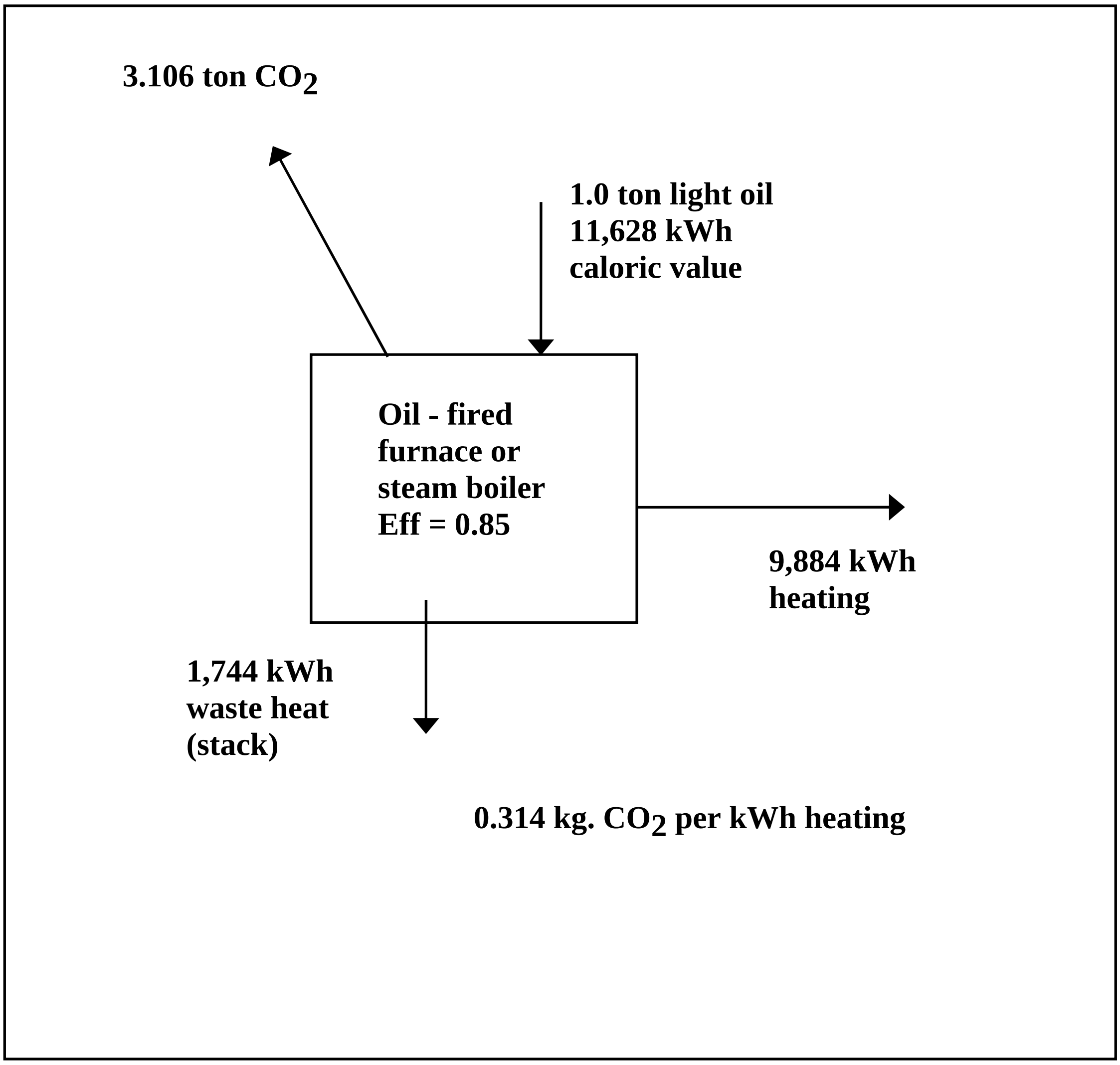


Figure 3: Conventional Heating System

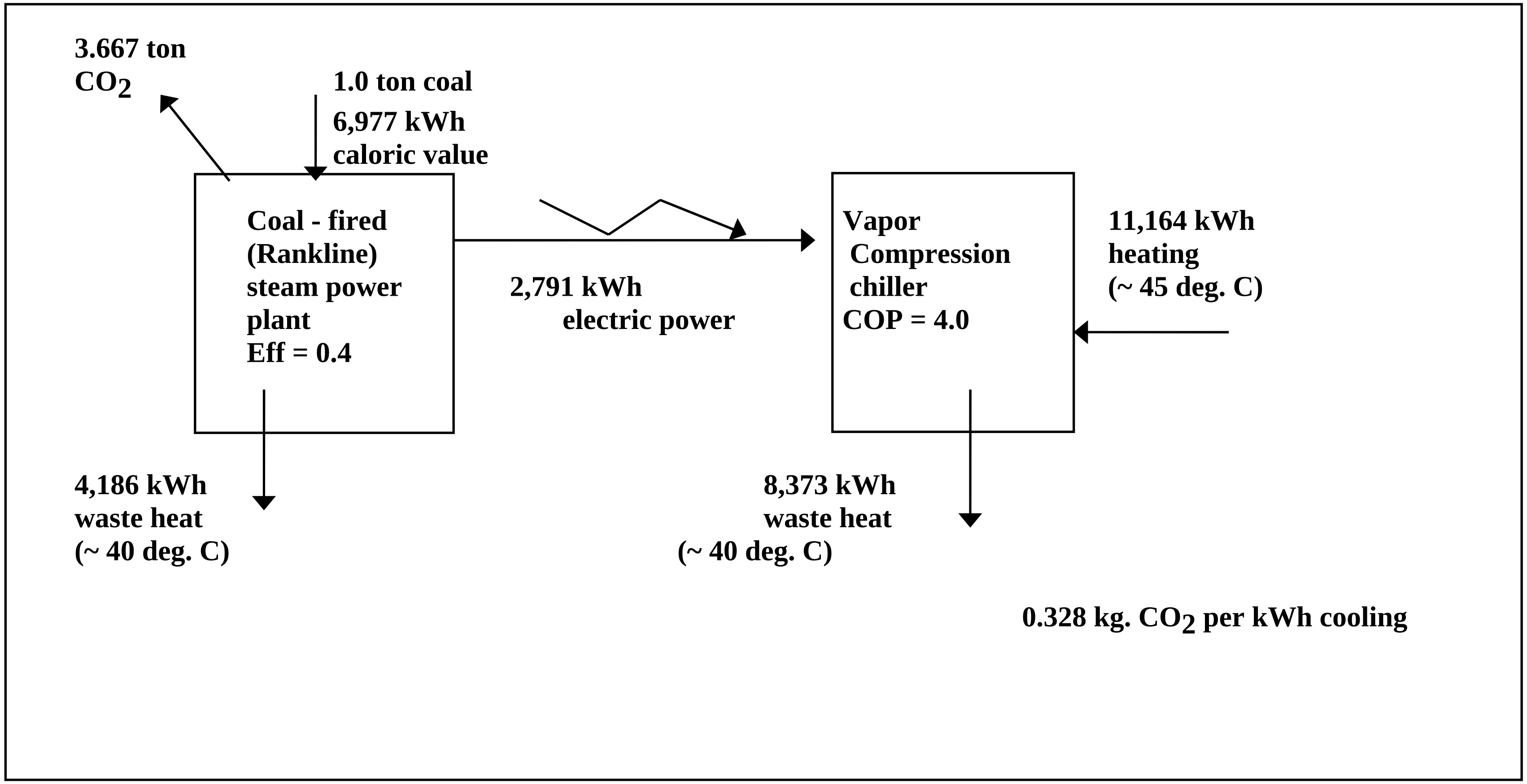


Figure 4: **Co - Generation Cooling Systems**

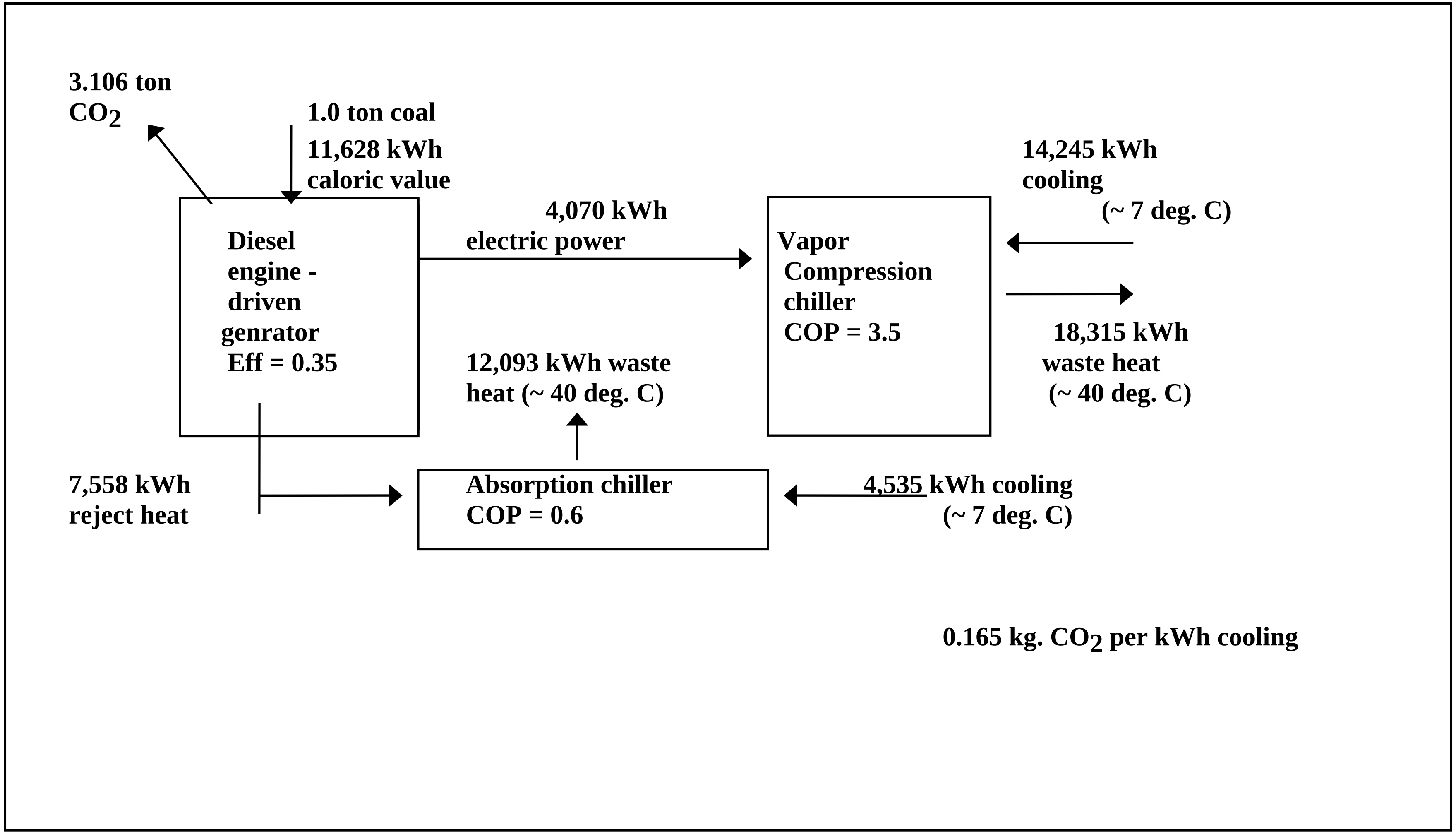


Figure 5: **Conventional Air Conditioning**

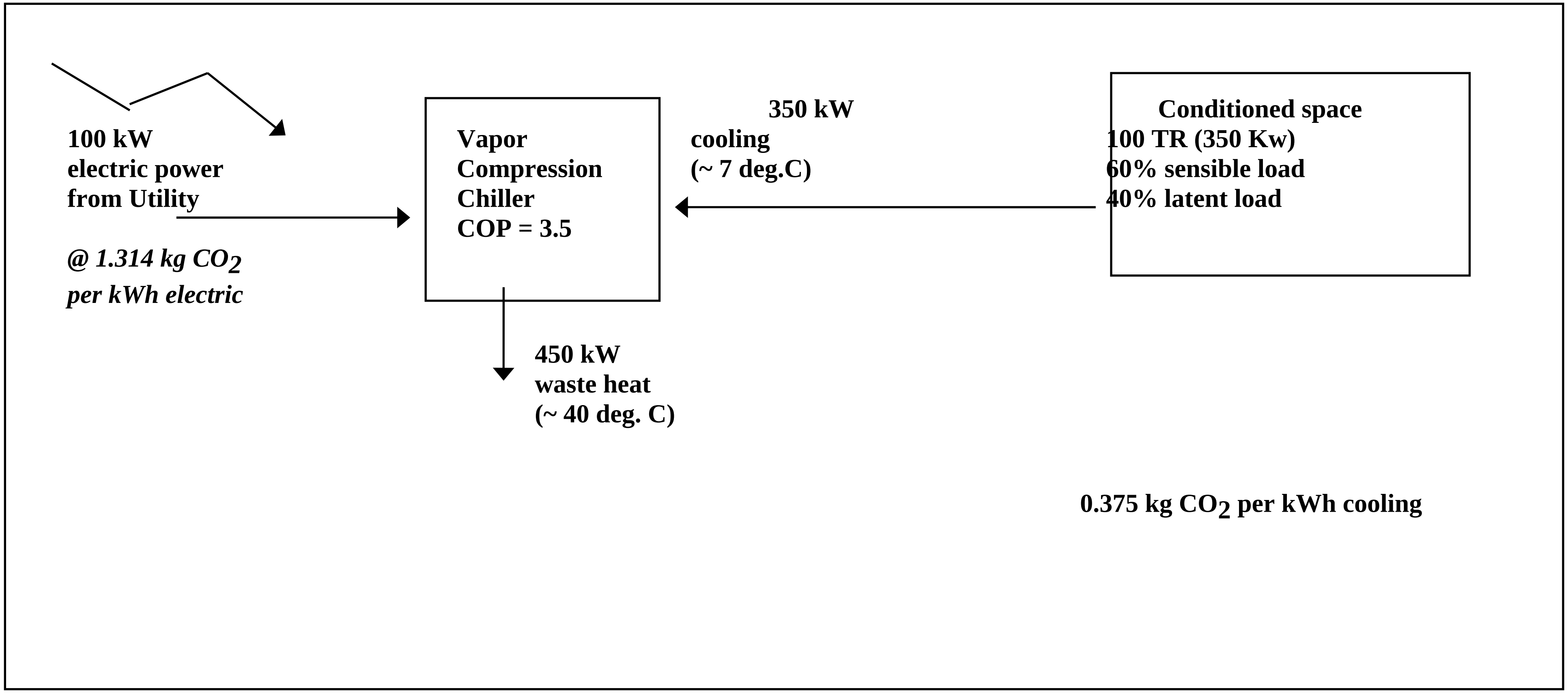
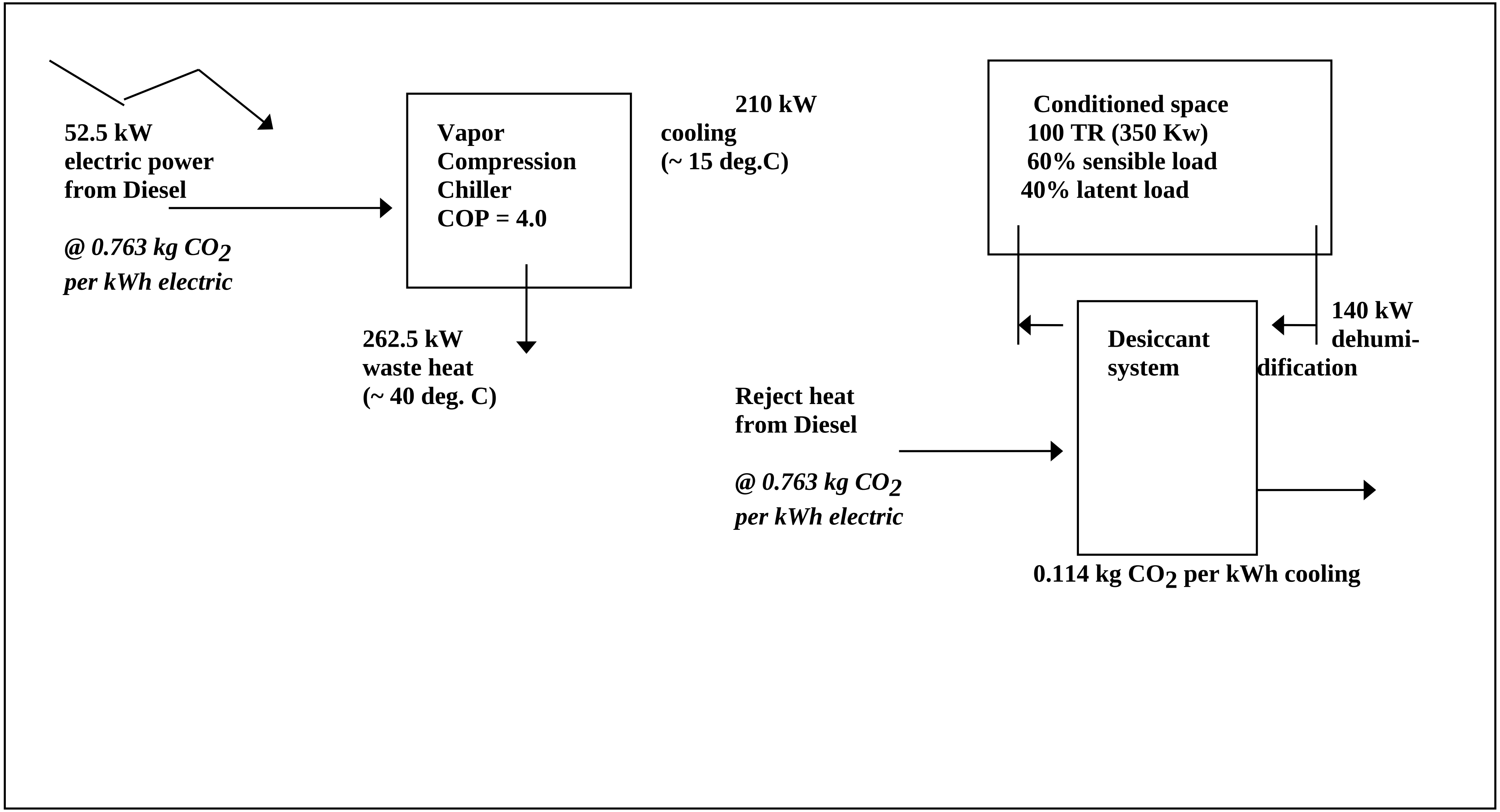


Figure 6: <u>Hybrid Air Conditioning</u>



Appendix B

B1. Considerations in the decision making process about Transportation Control Measures (TCMs)

In order for an authority to choose a TCM to implement it needs to know:

- How travelers will respond to a given TCM?
- What greenhouse gas emission reduction effect can be expected from a given TCM?
- What are the expected benefits from such reductions?
- Which of all TCMs are the most cost-effective and easy to implement?

Unfortunately, the available tools and information necessary to perform evaluation and answer these questions are limited, and the error associated with such tools is often larger than the effect to be measured.

The actual nature and magnitude of the impact of transportation on global warming are subjects of considerable disagreement, and the benefit of CO2 reduction are difficult or impossible to quantify (Cambridge Systematics, 1997)

TCMs should not be assessed exclusively on the basis of their potential to reduce emissions/greenhouse gas effect and the associated agency costs to implement and operate. In the U.S. it has been shown that TCMs frequently are stated to be cost-ineffective when only emission reduction impacts are considered, and it is not unusual for TCMs to have benefit-cost ratios of up to ten when other relevant impacts are included as part of the evaluation process (Cambridge Systematics, 1983 and Apogee Research, 1994).

Other than their air quality impacts TCMs should be evaluated on their effect on:

- direct cost of the implementation of the TCM including new facilities, new services (like extended transit service) and operating and administration costs.
- change in maintenance and operating cost due to shift in demand and/or supply
- saving in vehicle operating and maintenance expenses
- land use and changes in land values
- indirect costs

- Reduce congestion
- Noise and aesthetics
- travel time differences (some users may improve their travel time while other may increase their travel time)
- social and community impacts
- economic impacts
- noise impacts
- safety impacts
- land use and economic development
- energy consumption

A lot has been written about the problem of cost benefit analysis of transportation project and how to consider some of these many factors in the analysis. A TCM can be viewed as a transportation project in this sense, except that the problems are more difficult because our understanding of the consequences of such measure lags behind our understanding of the consequences of new transportation infrastructures projects. Our inability to correctly evaluate the benefits from TCM complicated our ability to prioritize them.

While the long-term benefits of large scale program like the U.S. federal motor vehicle emissions control program on carbon monoxide and ozone levels can be seen by examining several years' worth of air quality monitoring data (Shiftan et. al 1996), it has proven to be considerably more difficult to statistically relate changes in air quality to the implementation of specific fuels, vehicle inspection/maintenance, or transportation management programs. While there are many efforts to evaluate the air quality benefits of TCMs most of these efforts rely on some assumption of participation rate. However, our understanding of peoples' response to TCM and the long run effect of such measures if far from being satisfactory for the purpose of evaluating the benefits of such measure. This view is shared by many recent researchers. For example, Knapp et. Al (1995) in a study for the U.S. Federal Highway Administration investigated issues related to the evaluation and monitoring of TCM impacts and concluded that none of the methods available can evaluate all the TCMs. They also argue that this fact, and the difficulties with TCM participation rate estimation and TCM program evaluation, limits the ability to evaluate the regional impacts of TCMs. In a more recent study, that represent the state of the art and the practice in this area Envair/Cabmridge Systematics (1998) conclude that achieving the goal of relating the effects of specific transportation control measures and other mobile source air quality control measures to changes in ambient air quality levels remains elusive.

Previous papers have extensively listed potential TCMs. These include the efforts by Salamon (***), Comsis (1993) and Shiftan and Suhrbier (1997). TCMs can be classified in different ways.   The two main classifications are regulatory versus voluntary, and the "push" versus "pull". Regulatory TCMs represents traditional "command-and-control" type actions that involve passage of a law or regulation to require a change in behavior. Voluntary TCMs induce such a change through some process of providing alternative choices or restricting existing alternatives. The later is the "push" and "pull" classification. Pull TCMs represent TCMs that induce a change through providing new alternatives or improving existing more environmental alternatives. Push TCMs represent TCMs that make the use of single occupancy vehicle less attractive by restrictions and charges. Most of the TCMs are targeted at reducing VKT.

Few TCMs are targeted at specific areas through other means like vehicle technology and traffic operation. Some of the TCMs are useful for the short run like traffic improvement and ridesharing programs, while some are strategies for the long run like land use/growth management policies. Another possible classification concerning the action taken is the authority level making the decision. Some TCMs like parking restrictions and physical measures will usually be initiated by local authorities, while pricing and taxation will usually be carried at the state level.

While the classifications discussed above overlay in the sense that a TCM can belong to any combination of these dimensions an effort was made to classify the wide range of TCMs to seven main groups according to the type of action they involve as follows:

1. Regulatory TCMs
2. Mobility Improvements

3. Travel Demand Management
4. Market Based Mechanism
5. Land Use and Growth Management
6. Traffic Operation and Flow Improvements
7. Vehicle Technology

Within this classification regulatory TCMs are kept separate because of their different nature but each of the TCMs in this group can be placed in one of the other groups. Mobility Improvements are aimed at shifting mode away from single occupancy vehicle. Travel demand management, market based mechanism and land use measures can all be viewed as one block aiming to reduce VKT. It is possible to include market based mechanism and land use measures under the general group of travel demand management but they are kept separated because of the wide range of options they represent. Traffic operation and flow improvements aim more at the supply side. Vehicle technology aim at changing technology instead of changing behavior.

Some TCMs may complement each other and their combined benefit will be larger than the sum of the individual benefits while other may compete and their combined benefit will be less than the sum of benefits from the individuals' benefits. An example for competing TCMs is HOV lanes and transit improvements. Both measures will attract single occupancy vehicle to shift mode. HOV lanes may even cause some transit users to shift to HOV. An example for complementing TCMs is transit improvements and parking restrictions. The introduction of transit improvements by themselves can not have a significant effect on mode choice as people will always prefer the convenience of the private car. However, with the combination of parking restriction and any other "push" measures on the use of private car like congestion pricing they can be more effective. It is difficult to evaluate the effect of an individual measure, it is further more complicated to evaluate the effect of a package of measures.

In Europe a current effort is taking place under the European Commissions' Directorate General VII project DANTE: Design to Avoid the Need to Travel in Europe. As part of this project Marshall and Banister (1997) reviewed the level of implementation of 64 different TCMs in seven European countries. Marshall and Banister also focused on the implementation of particular packages of measures by means of case studies in three cities. For example, the city of Enschede in the Netherlands implemented a variety of TCMs including restrictions on car use in the city center, extending and improving cycle network, and raising awareness about car use. Measures included:

- closure of streets in the city center for cars
- reduction in the number of parking spaces
- extension of bicycles path including paths to bypass bus stops and intersections
- advanced stop lanes at traffic lights to make cars wait behind cyclists
- cycle priority by detection loops and green lights for cyclist in all directions twice during a complete cycle
- guarded bicycle parking
- press releases and information stands at local events
- information packages (leaflet about negative effects of car and information about other alternatives)
- reduced fare by public transport
- discounts at shops when traveling by bicycle

The results show that the measures were successful in reducing car travel to the city center and increase bicycle mode share by Enschede residents but not by visitors from beyond Enschede.

In the U.S. a number of metropolitan areas are required by the federal Clean Air Act to begin implementing TCM during the next several years. Many states and metropolitan planning organizations have therefore factored the influence of these travel control measures into their long-range forecasts of regional travel demand. In assessing and synthesizing these forecasts, the Department of Transportation found that they predict annual growth in motor vehicle travel on a national basis to be about 10 percent lower that what might otherwise be expected (TRB, 1997).

While our estimate of the effects of TCM is always questionable, it is clear that a good policy program to reduce VKT should be based on packages of various TCM combining push and pull measures and target both the short and long run. A comprehensive land use transportation plan should be established, with growth management and mix of land uses that will minimize travel. This type of land use will be better served by transit and therefore investments in transit will be more effective. For a TCM package to be effective it has some form of road pricing and other effective restricting measures like parking availability.
Many cities attempted to implement integrated transport policies, using a combination of measures to reduce traffic and encourage the use of more energy-efficient means of transport. Usually, these attempts are hard to assess because it is difficult to judge what would have occurred if the policies had not been implemented. In terms of the maximum possible reduction it is interesting to observe the experience in Singapore. Since the early 1970s, Singapore adopted a variety of TCM including road pricing using an area licensing scheme and other auto and usage taxes. Ang (1992) estimated that the impact of this combination of measures reduced gasoline consumption on the island by 42%. This reduction can be considered the maximum possible effect by combination of measures in a politically supportive environment and limited dense and congested area. It is unlikely that these level of impacts can be achieved in Israel.

B2. CALCULATIONS OF CO_2 EMISSION ESTIMATES

Estimate of CO_2 emission from gasoline vehicles

1 The carbon content in the gasoline was calculated on the basis of fuel consumption in Israel.

The gasoline consumption in 1996: 2,029,200 ton

Fuel (gasoline) density: 0.75 kg/litre

Number of passenger cars in Israel in 1996: 1,174,166

Average mileage in 1996: 17,000 km

Average fuel consumption of passenger cars: 10.7 km/litre.

Total fuel (gasoline) consumption of passenger cars:

$$Q = \frac{17,000 \times 0.75}{10.7 \times 1,000} \times 1,174,166 = 1,399,123 \;\; ton$$

Average carbon content in the gasoline: 86%

Carbon content: C_{mass} = 1,203,246 ton

2 The total emissions of the following substances, from passenger cars in Israel, 1996, were estimated by [5]:

CO_{mass}: 417,000 ton

CO_{2mass} : 3,830,000 ton

HC_{mass}: 57,000 ton of $H_{1,85}C$ (as measured by FID)

3 The carbon content (C) in these emissions was calculated by the molecular weight:

$$C'_{mass} = \frac{M_C}{M_{CO}} \times CO_{mass} + \frac{M_C}{M_{CO_2}} \times CO_{2mass} + \frac{M_C}{M_{HC}} \times HC_{mass} =$$
$$= \frac{12 \times 417{,}000}{28} + \frac{12 \times 3{,}830{,}000}{44} + \frac{12 \times 57{,}000}{13.85} =$$
$$= 178{,}714 + 1{,}044{,}546 + 49{,}386 \cong 1{,}273{,}000 \text{ ton}$$

4 The relative difference between the two estimates of carbon contents in emissions of passenger cars:

$$\delta = \frac{C'_{mass} - C_{mass}}{C_{mass}} = 5.8\%$$

This rather low value is an indication of the validity of the two different estimates.

5 The percentage of CO_2 in the carbon balance of the fuel, C_{CO_2}, is calculated on the basis of the data according to (3). The percentage of carbon associated with CO_2 in the total carbon emissions, C'_{CO_2}, is given by:

$$C'_{CO_2} = \frac{1{,}044{,}546}{1{,}273{,}000} \times 100 = 82\%$$

Taking 86% carbon content in the average gasoline, as above:

$$C_{CO_2} = C'_{CO_2} \times 0.86 = 0.71$$

6 The amount of CO_2 emissions are calculated by:

$$CO_{2_{mass}} = C_{CO_2} \times \frac{M_{CO_2}}{M_C} \times m_f = \frac{0.71 \times 44}{12} = 2.603 \times m_f$$

where m_f is the annual gasoline consumption.

The total fuel consumption of the various gasoline vehicles categories in Israel are listed in Table 1. The above equations were used to calculate the total CO_2 emissions, and the results appear in Table 1 too.

The estimate of total CO_2 emissions from passenger cars in Israel, 1996, calculated on the basis of fuel consumption, is (from Table 1) 3,642,400 ton. The estimate based on the emission coefficients, cf. (2) above, is 3,830,000 ton. The relative difference is: $\varepsilon \cong 5\%$

Estimate of CO_2 emissions from diesel vehicles

The calculation of CO_2 emissions from diesel vehicles is based on the assumption that C'_{CO_2} = 90%. Therefore:

$$C_{CO_{2(d)}} = 0.9 \times 0.86 = 0.774$$

$$CO_{2_{mass(d)}} = \frac{0.774 \times M_{CO_2}}{M_C} \times m_{f(d)} = 2.838 \times m_{f(d)}$$

where $m_{f(d)}$ is the annual diesel fuel consumption.

The results of CO_2 emissions which appear in Table 2, are based on the values of $m_{f(d)}$ in this Table, and calculated by the above equation.

Comparison of CO_2 emissions by diesel and LPG buses

Public transportation in Israel is based almost entirely on diesel vehicles (mainly buses), therefore comparative analysis of buses conversion to LPG operation is described in detail here.

The main assumptions that have been used:

- LPG is mainly propane;
- Efficiency of engine operation is equal for both diesel fuel and LPG;
- Average carbon content in diesel fuel is 86%;
- Percentage of carbon associated with CO_2 in the total carbon emissions is:

  C'_{CO_2} = 90% of diesel fuel

C'_{CO_2} = 82% of LPG = C'_{CO_2} of gasoline because in both cases the engine operates with stoichiometric mixture.

Carbon content in propane:

$$C_{carb} = \frac{3 * Mc}{Mpropane} = \frac{3*12}{44} = 0.82 = 82\%$$

Heat value of LPG is lower than that of diesel fuel:

LHV_d = 35.7 MJ/l
LHV_{LPG} = 23.6 MJ/l

Therefore, for equal energy supply to the engine:

1.513 liter of C_3H_8 is needed compared to 1liter of diesel fuel.

In mass units:

1 kg of diesel fuel <-> 0.919 kg of LPG.

Estimation of CO_2 emission is performed according to the method described in detail in the Appendix.

For diesel fuel:

$CO_{2mass(d(}$ = 2.838 * $m_{f(d(}$ = 2.838 * 1 = 2.84 kg

For LPG:

$$C_{CO_2} = C'_{CO_2} \times Ccarb = 0.82 \times 0.82 = 0.672$$

$$CO_{2_{mass(LPG)}} = C_{CO_2} \times \frac{M_{CO_2}}{M_C} \times m_f = \frac{0.672 \times 44}{12} m_f = 2.464 \times m_f$$

$$CO_{2_{mass(LPG)}} = 2.464 \times 0.919 = 2.26 kg$$

CO_2 reduction in case of LPG use is:

$$CO_{2_{mass(d)}} - CO_{2_{mass(LPG)}} / CO_{2_{mass(d)}} = 2.84 - 2.26 / 2.84 = 0.20 = 20\%$$

Cost aspects of conversion of diesel buses to LPG operation

There is only scarce information in the literature about actual or estimated costs of investment and operation of public transportation based on gas engines. All following estimates have been performed based on only two references, [1,2], and therefore can not aspire to be of high accuracy and reliability.

According to reference [1], the initial cost of a new LPG bus is about 150,000 ECU (≈ $170,000) – 10% more than a conventional diesel bus, [2]. Therefore, additional investment for bus purchase is about $17,000 per bus.

The cost of a complete LPG filling station for up to 300 buses with overground fuel tanks, including piping, pumps, fuel meter, hoses and nozzles is about 97,000 ECU, [1]. Therefore, the additional cost per bus is: ≈ 330 ECU ($370).

Estimation of investment, which is needed for adaptation of a workshop, can be taken from [2]. It is about 14,000,000 S (≈ $1,150,000) for a workshop servicing 150 buses. Therefore, the cost per bus is about $7,700.

Summarizing all mentioned above, the value of additional initial investment per LPG bus is estimated as $25,070. This sum does not includes cost of manpower training, special national legislation, etc. The total initial investment can be estimated as $26,000/bus (in case of conversion of some hundreds of buses).

It will be possible to estimate operational costs of LPG use in buses only after decision by the Israeli Government about the pricing and taxation of automotive LPG.

References

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Appendix C: A Dynamic Model of the Economy

(1) $GDP_t = (1+\delta)^t \, GDP_0$

(2) $POP_t = (1+\gamma)^t \, POP_0$

(3) $CO_2 = (1+\sigma)^t \, CO_{2,0}$

(4) $\overline{CO_2}_{,T} = K$

(5) $\overline{CO_2}_{,t} = \left(\frac{\overline{CO_{2,T}}}{T} - \frac{CO_{2,0}}{T} \right) t + CO_{2,0}$

(6) $A_t = CO_{2,t} - \overline{CO}_{2,t}$

(7) $TAC_t = 83 \left[\frac{A^3{}_t}{\left(CO_{2,t} - A_t \right)^2} \right]$

(8) $AAC_t = \frac{TAC_t}{A_t}$

(9) $MAC_t = \frac{166\, A_t^{\,3}}{\left(CO_{2,t} - A_t \right)^3} + \frac{249\, A_t^{\,2}}{\left(CO_{2,t} - A_t \right)^2}$

(10) $TR_t = MC_t \bullet \overline{CO}_{2,t}$

(11) $\Delta CS_t = \frac{\Delta Q_t \bullet \Delta P_t}{2}$

(12) $TC_t = TAC_t + \Delta CS$

(13) $PGDP_t = \frac{TC_t}{GDP_t}$

Where: GDPt = Gross domestic product in year t.

δ = Annual GDP growth rate.

POPt = Population in year t.

γ = Annual population growth rate.

CO2,t = Emission in year t.

σ = Emission growth rate.

K = Terminal year emission level.

T = Number of planning periods.

TACt = Total abatement cost, year t.

AACt = Average abatement cost, year t.

MACt = Marginal abatement cost, year t.

TRt - Emission tax revenues in year t.

ΔCSt = Change in consumer surplus in year t.

ΔQt = Change in energy consumption in year t.

ΔPt = Change in unit energy price in year t.

TCt = Total cost in year t.

PGDPt = Total cost as a percentage of GDP.

Eqs. (1) - (3) specify GDP at year t for a given economic growth rate, δ; population at year t for a given population growth rate, γ, and GHG emission level at year t for a given annual pollution growth rate, σ, respectively. Together, eqs. (1)-(3) determine how the economy evolves over time without any intervention. Although one can a sensitivity analysis with different parameter values, in the present analysis a zero growth rate in GDP per capita was assumed, which implies that the GDP growth rate equals the population growth rate. Specifically, a growth rate of 2.2% was used, based on various predictions (Bank Hapoalim, 1998). We also assumed that the annual increase in the GHG emissions will follow the annual growth rate of the economy, i.e., 2.2% per annum; a reasonable first-approximation assumption.

Eq. (4) fixes the terminal condition. As detailed above, we analyzed two scenarios: the first one sets the emission level in 2010 at the 19990 level, i.e., the total emission in 2010 of GHG-equivalent gases should reach 48.10 million tons. The second scenario sets emission levels to their *per capita* 1990 level, implying an aggregate emission level of 80.08 million tons.

Eq. (5) describes the path of emission level over the planning period, noting that it specifies moving from base to target year in equal annual reduction steps. The annual abatement effort is proscribed in eq. (6), which states that annual abatement should be the difference between the emission levels in the “business as usual” case and those specified for the scenario under examination.

Goulder and Mathai (1998) have recently proposed the functional form given by eq. (7) for estimating abatement costs:

$$TAC_t = M\left(\frac{A_t^{\alpha_1}}{\left(CO_{2,0} - A_{t.}\right)^{\alpha_2}}\right)$$

Where: TAC_t = Total abatement cost in year t.

$CO2$ = Emission in year t (business as usual, baseline scenario)

A_t = Abatement effort (in CO_2 equivalent units) in year t

M, α_1 and α_2 are parameters.

This form has the desirable property that marginal abatement cost tends to infinity as abatement approaches 100% of the baseline emission. Furthermore, the parameters M, α_1 and α_2 are chosen so that the following requirements are satisfied: (1) A 25% pollution reduction in 2020 should entail a cost in the range of 0.5% to 4% of global GDP [based on EPRI (1994), extrapolated to the global economy]; (2) The discounted (at 5%) value of global abatement costs required in order to attain a CO2 concentration of 550 ppvm by 2200 is roughly $600 billion (Manne and Richels, 1997). It has been shown (Goulder and Mathai, 1998) that the parameter values that best meet these requirements are M=83, α_1=3 and α_2=2. Inserting these values into eq. (7), gives the total cost estimate, from which average [eq. (8)] and marginal [eq. (9)] cost can be derived.

Assuming a carbon tax mechanism is used to reach the desired abatement levels, eq. (10) determines the tax revenues in year t. Therefore, multiplying total emission in year t by the marginal abatement cost (which, by assumption, is equal the tax rate) gives the tax revenues for that year.

As explained above, abatement cost is not the only cost imposed upon the economy. The reduction in energy consumption due to the shift in the energy supply function (and consequently the rise in energy prices, by the amount of the tax) causes a decrease in consumer surplus. Knowledge of the price elasticity of demand for energy (ε) enables the economist to estimate this welfare loss to society [eq. (11)]. There are a handful of studies which attempted to econometrically estimate this elasticity. We have decided to use in this study a value of ε = -0.5, which is appropriate for the medium-run (Poterba, 1991), with short-run and long-run elasticities -0.11 and -0.82, respectively. Using Poterba's estimate of the effect of a tax on the price of energy supply, we have calculated the loss in consumer surplus by approximating a linear function in the range of the price change range (i.e., estimating the area of a triangle instead of an integral of the area under the function).

Eq. (12) sums abatement cost and consumer surplus loss, giving the grand total cost for the given scenario, and eq. (13) presents this cost figure as a percentage of the GDP in year t.

Appendix D: Essentials of policies to reduce GHG emissions in other countries

D1: The Dutch strategy to reduce GHG emissions

Reduction strategies

The main instruments the Netherlands government has decided to aplly in order to achieve a CO_2 emission reduction are:

- standards and regulations
- financial and fiscal incentives
- long term (negotiated) agreements between government and industrial and non - industrial sectors
- the environmental action plan of the energy distribution companies, partly financesd by a surcharge on gas and electricity prices
- public awareness
- research and development

Initial targets that will provide reduction of CO_2 emissions include:

- Increase of energy efficiency by 33% from 1996 to 2020.
- Increase the share of renewable energy by 3% untill 2000and by 10% untill 2020.
- Increase combined heat and power capacity to 8000MW in 2000.

The energy sector is to achieve the goals of higher efficiency by heat distribution plans and new, more efficient plants via investment plans of power generators. It is to achieve an increase of ;average efficiency from 40 % in 1990 to 43% in 2000.
Also it is expected to add 10% wood in 2 coal - fired plants in 2000 subject to an agreement between the government and the energy sector, decreasing 0.4 Mton of CO_2 emission.
In 1990 the largest sources of Co2 in the Netherlands were energy transformation (30%) and industry (29%). Transport and residential sectors contributed 16% and 13% respectively. Since 1990 various policy measures haver been implemented aiming at the target for 2000. Yet CO_2 emissions increased by 2.8% from 12990 to

1994 and preliminary figures for 1996 sugest a significant increase of 3.9%. Therefore the Dutch government has decided on additional measures to those mentioned above, that will ensure the achievement of the targets set.

Co-generation

By the year 2000 co-generation will make an important contribution to energy efficiency - some 8000MW (40% of total capacity. Given various conditions it is expected that co-generation will produce 14,000Mw in the year 2020. The largest autonomous growth will be in industrial co-generation.

Renewable energy

Implementing the Renewable energy action programme will enable the Netherlands to achieve the target of 10% renewable energy by 2020. The programme consisits of the following steps:

- broadening the range of fiscal instruments (see fiscal incentives), a low 6% VAT tariff on renewable - based electricity and a refund of the regulatory energy tax afora renewable enerfy users (30 million NLG)
- providing extra R&D budgets (raised to 95 million NLG) and participation in European research
- demonstration and introduction pjrojects
- suport to the distribution sector
- setting up a Renewable Energy Project Bureau
- providing adequate payments for delilvery of electricity generated from renewable resources by private operators to the public sector
- a mandated minimum portion of renewable energy in total electricity supply to captive consumers from 2001 and onwards, if the above mentioned measures do not achieve the required results.

Regulatory Energy Tax

A tax on natural gas, electricity and oil consumption which raises the prices for small scale energy consumption by 15% to 20%. The tax is paid by all consumers except the greenhouse horticulture sector which is exempt from the tax on natural gas. Since the tax is intended to induce energy conservation, revenues are recycled back into the economy through relief in other raxes. Use of renewable energy is exempted from this tax.

Fiscal incentives

Inveastments in energy conservation and in renewable energy are encouraged through a number of provisions in the corporate income tax. These include an energy investment tax credit, free depriciation of cetrain kinds of energy and environment related investments, ‘VAMIL scheme’ (22 million NLG in 1995 to 35 million in 2000) allows the discretionary depriciation of environmentally - friendly investments, ‘Green investment’ (12.5 million NLG in 1996 to 15 million in 2000) is a tax concession which allows private individuals to invest in projects which foster environmental protection, including nature and woodland conservation, EIA (energy investment deduction) starttiong in 1997 witah a budget of 125 million NLG.

Budgets and fiscal incentives

The Dutch government has allocated 204 million NLG for energy conservation programmes and 93 million NLG for renewable enrgy projects.

The industry sector is to achieve its targets of 20% efficiency improvement in 2000 via energy saving. This will be done by an increase of combined heat and power, energy management (good housekeeping and monitoring) and new technologies, all subject to long term agreements that account for 90% of energy use by industry, fiscal incentives and R,D&D. For the light industry manufacturing industry the long term agreements is not a viable strategy and theregore targets will be achieved by setting standards in environmental licences, namely, a regulatory approach.

These will be attained via:

- standards and regulations
- regulationmg energy tax for small scale energy consumption
- CO_2 reduction plan - funding fromn 750 mln budget
- other financial/fiscal incentives:

⇒free depreciation

⇒green investments

- energy investment tax credit
- environmentqaql action ploan
- public awarenmess campaigns
- research and development and demonstration

The strategy in the **transport sector**, aimed at reducing CO_2 emissions by 10% by the year 2010 relative to 1986, consists of three tracks:

1. measures addressing the sources (technical measures such as inproving fuel efficiency of cars), although the potential of the Dutch market to influence this issue alone is small. These include mainly subsidies for energy saving in traffic and transport and programmes on more quiet , cleaner and efficient transport in urban areas and wide scale introduction of econometers, board computers and cruise controlls in cars.
2. policy on mobility. Various measures and programmes are implemented with the aim of reducing the number of vehicle - km travelled.
3. measures addressing driving behavior such as increase in fuel prices, stricter control of speed limits, stimulation of more efficient driving and purchase behavior, and stimulation of other transport modes as alternatives for long distance trips.

Speed limit has achieved a reduction of 1.5% CO_2 emission of total road transport.

Possible measures on the optimal fuel mix (petrol, diesel and LPG) and others, including the introduction of econometers, are currently under review. As of July 1997 excise duties on motor fuels has been increased while the fixed tax for car owners has been decreased in particular for small cars.

The residential and service sector has already taken several steps to save energy consumption, which will further persued. These include: improving insulation and insulation standards, intensifying the Energy Performance Standard (setting limits to the allowable energy use for heating and hot water in homes and other buildings), demonstration and fiscal incentives for very energy efficient buildings.
Special attention is attributed to the relationship of bew building with energy infrastructure in locations whire the dimand for new swellings is to be met in the short term.

The Dutch assume that quality improvements in new construction wil lead to market trends to upgrade existing buildings, including their energy efficiency. These will be achieved by LTAs (long term agreements) with rental agencies in the social housing sector and with relevant organizations for renting and maintaining office buildings. The inprovements in energy efficiency targets are 30% in the year 2000 relative to 1989.
Energy efficient heating systems and appliances, levies, public education and labeling are and will be a means of inducing energy conscious (purchasing) behaviour. Subject to the Environmental Action Plans (MAP) the energy distribution companies (gas and electricity) are organized in a body which is to achieve specific targets in terms of CO2 reduction for small scale end users of energy. According to the Energy Saving Appliances Act labelling has been introduced for refrigerators, freezers, washing machines and tumble dryers; minimum efficiency standards have been introduced for refrigerators, freezers and central heating boilers. Similar minimum efficiency standards will be introduced for a wide range of appliances and applications, either via regulations or voluntary agreements.

D2: The German strategy to reduce GHG emissions

In 1990 Germany emitted 1,014,155 million tons of CO_2. In 1996 the amount of emitted gas fell to 910,000 million tons
CO_2 emissions in Germany decreased by 10.3 % between 1990 and 1996. The decrease, which was continuous between 1990 and 1995 (minus 11.8 %), was interrupted by a temperature-related increase of CO_2 emissions during the unusually cold winters of 1995/1996 and 1996/1997.
Germany's aim is to reduce CO_2 emissions by the year 2005 by 25 % compared to emissions in 1990.

From 1990 to 1996, the ratio of energy-related CO_2 emissions to gross domestic product (GDP) decreased by about 19 % in Germany. This indicates further severance of the link between economic growth and CO_2 emissions. Between 1990 and 1996, per-capita CO_2 emissions were reduced by 13.3 %.

Two studies aimed at assessing the possibility of achieving CO_2 emissions, agree in their finding that a 15-17 % reduction of energy-related CO_2 emissions will be achieved by the year 2005 with the set of measures already adopted by the Federal Government. In accordance with these findings, the authors suggest that additional measures are required to attain the Federal Government's CO_2 reduction objective.

With respect to recommendation of additional measures, it should be noted that the underlying studies were unable to take account of some important measures that are now showing their effect. These measures include:

- reduced subsidies for the use of domestic hard coal in power generation Whether this will help reduce CO_2 emissions by the year 2005 - and if so, to what extent - depends on what substitute energies are used in future. It is not possible at present to provide precise data on the extent of any relevant CO_2 reductions that may now be occurring.
- the concept for continuation of employment-promoting investments; one of this concept's important aims is to support the construction industry (about 5.5 million tonnes of CO_2 reductions by the year 2005).

- the amendment of the motor vehicle tax, which is expected to accelerate replacements of motor vehicles on the road.
- subsidies for owners of energy-efficient homes (*Niedrigenergiehäuser*), and use of energy-efficient technologies in the framework of subsidies for housing construction (in each case, about 0.4 million tonnes of CO_2 reductions by the year 2005).

  Finally, it is necessary to take into account the CO_2 reduction potentials that will result from the Federal Government's activities in the area of waste management. The contribution of waste management measures is estimated at 15 - 24 million tonnes of CO_2 reductions by the year 2005.

- Refinement of German industry's declaration on global warming prevention. Inclusion of additional associations, taking into account the relevant monitoring data (additional reductions of 10-20 million tonnes of CO_2.
- Promotion of the use of renewable energies (5 - 7 million tonnes of CO_2.
- Amendment of the Thermal Insulation Ordinance (*Wärmeschutzverordnung*) and of the Ordinance on Heating Systems (*Heizungsanlagen-Verordnung*), with the ultimate aim of an Energy Saving Ordinance; better enforcement of regulations for existing buildings (conditional provisions of the Thermal Insulation Ordinance and the Ordinance on Heating Systems, or of the future Energy Saving Ordinance), including information campaigns with continuation and expansion of existing funding programmes for overcoming barriers to investment (especially in the eastern German *Länder*) and for initiating additional early measures, depending on the rapidity and extent of implementation, 16 - 24 million tonnes of CO_2.
- Greater use of combined heat and power generation systems by industry and local authorities (cooperation between companies and local authorities in the heat/power generation sector) (30 - 60 million tonnes of CO_2).
- Training programmes, counselling and public awareness campaigns (4 - 8 million tonnes of CO_2)
- Increased efforts to inform the public about and raise awareness of energy-efficient driving (3 - 5 million tonnes of CO_2)

  In addition, Germany is considering the introduction of route-based tolls for trucks, for reasons that include a fair allocation of route costs, traffic prevention and shifting transports to more environmentally compatible modes of transport.

  A central element of Germany’s concept with regard to further decreases in motor-vehicle fuel consumption is the German Automobile Industry's (VDA) voluntary commitment from 1995.

D3: The Japanes strategy to reduce GHG emissions

1. *Introduction of More Efficient Thermal Electric Power Generation*
Until now, countermeasures for improving efficiency have also been promoted for economic reasons, and the efficiency has been improved by increasing the capacity of power-generating facilities, raising the temperatures and pressures used to produce steam, and introducing combined-cycle systems. As a result, the combined heat efficiency of thermal power plants (gross) improved from about 24% in the mid-1950s to about 37% in the mid-1960s, and now to about 39% in the mid-1990s.

Countermeasures for coal-fired power plants
Compared with other fossil fuels, coal emits high amounts of carbon dioxide per unit energy and is therefore in particular need of efficiency-improving measures. One of the effective ways to control carbon dioxide emissions from coal-fired plants is to introduce ultra-super-critical (USC) technology, pressurized fluidized-bed combustion (PFBC) technology, or integrated coal-gas combined cycle (IGCC) technology every time a new facility is built or an old facility is replaced. In addition, the Japan Development Bank has established a system of lowinterest financing for the construction of high-efficiency coal-fired thermal power plants.

Countermeasures for LNG power plants
Because LNG emits less carbon dioxide per unit energy them those of other fossil fuels, its aggressive use in power generation is another effective way to combat global warming. Current combined-cycle systems (which combine the use of gas and steam turbines) have achieved a heat efficiency in excess of 48% (with a gas-turbine intake temperature in the 1,300^{0}C class). Furthermore, technical development is currently being pursued with the aim of achieving a heat efficiency of 50% or higher by further raising the gas-turbine intake temperature. In addition, the Japan Development Bank has established a system of lowinterest financing for the construction of' high-efficiency LNG-fired thermal power plants.

Development of Efficient Energy Supply Systems
High-efficiency energy supply systems currently under technical development include: more efficient power generation and electrothermal supply systems that improve overall efficiency, energy storage systems that boost the efficiency of facility operations; and systems that make use of dispersed energy sources.
Work on these various technologies is being conducted on:

1. Superconducting Technologies
Practical superconducting technologies are being developed to enable the expansion of power-source capacities, and to alleviate problems (such as locating power-line construction sites and suffering increased power loss during transmission) that are encountered as power plants are built further away from the areas where the energy is consumed. Research and development is also being carried out on superconducting generators, total systems, and refrigeration systems.

2. Distributed Electrical Energy Storage System
Studied are being conducted on ways of controlling carbon dioxide emissions throughout the entire power supply and consumption system by improving the efficiency of power storage technologies. Specifically: developing power storage

systems that use the high-performance characteristics of lithium batteries; reassessing low-efficiency storage systems such as pumped-water power generation plants located in the mountains far from where the power is consumed; establishing power storage plants that use NaS batteries and other technologies that can be located close to consumers; and encouraging consumers to install their own highefficiency storage systems.

Introduction of energy sources that produce little or no carbon d ioxide emissions

1. Nuclear Power

Development and Use of Nuclear Power Premised on the Assurance of Safety

Nuclear power has already been one of Japan's main sources of electricity, accounting for 29.4% of total power output in fiscal 1995.

2. Hydroelectric Power

Given Japan's steep, mountainous topography, hydroelectric power is Japan's greatest domestic energy resources, and also has the advantage of not emitting carbon dioxide. In fiscal 1996, Japan possessed a hydroelectric power-generating capacity of approximately 44.4 million kW, representing about 19.0% of' total capacity

3. Geothermal Power

Japan's wealth of volcanic activity makes geothermal power another valuable source of clean energy that does not produce carbon dioxide, sulfur oxide, or nitrogen oxide. As of fiscal 1996, Japan had a geothermal power-generating capacity of 530,000 kW, accounting for 0.2% of total capacity

Efforts are currently being made to develop the following technologies-. investigative technologies that will reduce the risks associated with finding new geothermal power resources; technologies that enable the use of such potential energy sources that have not yet been exploited as medium-hot water and hot dry rocks, and deep geothermal resource survey and extraction technologies that will have an immediate effect in expanding the production capacities of existing geothermal sites. In these and other ways, the amount of electricity generated by geothermal means is expected to expand.

4. Development and Dissemination of New Energy Sources

The expansion and dissemination of solar power and other new energy sources is being made in various fields on the basis of the Basic Guideline for New Energy Introduction and as part of the New Sunshine Project.

4.1 Solar and Solar-thermal Power Generation

As of the end of March 1996, Japan had a solar power generating capacity of about 39,000 kW . Cost is the main obstacle to further dissemination. Efforts are therefore being made to lower costs and to offer incentives for the initial introduction of solar power.

To promote the introduction of solar power generating systems, the government offers large-scale assistance for residential solar systems and supports the introduction of such systems in public facilities. It has also compiled a manual to encourage regional public organizations to introduce solar power systems, and is conducting research concerning various applications for solar power, including noise barrier walls and other road-related facilities, and beverage vending machines. Also, efforts are being made to raise public awareness of the purchasing system for surplus electricity that power companies have established through the use of special time-of-day residential lighting contracts; to use the purchasing system more fully; and to improve the practicality of solar power generation systems that are built into construction materials.

4.2 Wind Power Generation

Research has been conducted on 100 kW wind-activated power plants, and the technology for small and midsize wind-activated power plants has essentially been established. Applications, however, are still limited to testing and research, isolated islands, and demonstrations, with a total generating capacity of about 9,500 kW as of the end of March 1996.

Japan's unique climatic and geographical conditions offer limited potential for wind power generation.

4.3 Waste Power Generation

Improvement in generating efficiency would permit an expansion of waste-generated power output capacity, making waste a more viable alternative to fossil fuels. Four types of technology currently hold promise as practical ways to improve generating efficiency: (1) high-temperature, high-pressure waste power generation; (2) super refuse power generation (waste power generation combined with gas turbine); (3) refuse derived fuel (RDF) power generation; and (4) steam spray type waste power generation (conventional type of waste power generation). Japan aims to introduce these technologies to expand the nation's total waste-fired generating capacity to about 2 million kW by the year 2000 and to about 4 million kW by the year 2010.

As part of its efforts to establish more waste-fired power generating facilities, the central government provides support to regional public organizations for the construction, expansion and renovation of facilities, as well as for the construction of plants that convert waste into solid fuel.

4.4 Fuel Cells

Field tests are currently being conducted on phosphoric acid fuel cells and molten carbonate fuel cells with the aim of developing new technologies, improving equipment, and enhancing performance. Although phosphoric acid fuel cells are not yet in full-fledged use, they are currently generating 30,000 kW in Japan, which is more than in any other country.

4.5 Ocean Energy

Various kinds of wave power-genetation technologies are being developed, including: floating oscillating-water-column systems; shore-fixed systems; pendulum systems; and wave-energy-absotption breakwater systems that convert the energy of the waves into the flow of air. Approximately 1,000 wave-activated generators are currently used on navigational buoys etc. in Japan.

Regarding ocean-thermal-convetsion power-generation systems, closed cycle technologies are being developed that use ammonia and other media. Although demonstration operations have been completed at a pilot plant, it seems unlikely that a power plant based solely on this technology will be economically feasible. As for open-cycle systems that use seawater as the direct working fluid, basic research has been conducted in an effort to improve condenser performance.

4.6 Biomass Energy

Most of the current work focuses on technologies for producing ethanol and other alcohols by using microorganisms and enzymes and on separating and concentrating biomass fuel by means of a membrane process.

4.7 Hydrogen Energy

Elemental technical development is being pursued on the use of hydrogen energy, an extremely clean secondary energy source that generates no car-bon dioxide when burned.

Measures *to Support the Dissemination of New and* Renewable Energy Supply Systems

Various financial, tax, and systemic support measures have been formulated that 1) promote cogeneration, solar power, and other new energy technologies that are already basically established but not yet adequately disseminated because of their high costs; 2) promote the installation of facilities that level energy demand; and 3) promote the regional introduction of new energy systems.

The national government plans to quickly establish the market autonomy of solar power generation by providing large-scale assistance over a concentrated period of time with the aim of greatly reducing costs through the effects of mass production. Also, efforts are being made to promote the use of the power companies' surplus power purchasing menus, which make use of optional time-of-day fighting contract, and studies are being pursued to promote the practical application of solar power generating systems that are built into construction materials.

(1) Financial and Tax Measures

The Japan Development Bank and other lending institutions offer low-interest, long-term financing to operators who install solar, wind, cogeneration and other new energy systems.

Similarly, a program of tax incentives that promotes investment in the structural improvement of energy supply systems has been established to encourage the installation of such facilities as: solar power generation f'acilities, wind power generation facilities; equipment that uses geothermal heat;, equipment that uses solar heat; fuel cells; waste power generation equipment; and gas turbines used in combined-cycle generation systems. In addition, tax reductions on fixed assets are available for certain types of facilities that utilize localized energy sources such as solar and wind power. Subsidies are also available to regional public organizations tfiat adopt a positive stance toward introducing new energy systems in an extensive and concentrated manner. Also, an interest subsidy system has been adopted for local development and use of new and renewable energy promoted by local public organizations and/or private organizations.

(2) Deregulation and Other Systemic Measures

Japanese electric power companies are subject to regulations based on the Electricity Utilities Industry Law, including a requirement to receive government approval for the construction plans of structures used for electric power generation. In 1990, however, these regulations were relaxed for solar, wind and fuel-cell power generation plants with regard to such requirements as notification of construction plans and appointment of main engineers.

Progress has been made on establishing guidelines for technical requirements for interconnecting commercial electric power systems with power generating facilities. In October 1995, an overall review of the guideiii'les was conducted and requirements were clarified to ensure a higher degree of transparency and fairness.

In February 1994, a purchasing menu was established for surplus electricity produced by such dispersed sources as solar, wind, waste, and cogeneration power-generation facilities.

Measures to Control Demand (Including *Load Leveling)*

Demand-side management (DSM), which sets different electricity usage fees depending on the time of day, has been introduced to accommodate the difference between daytime and nighttime energy demand. In addition, energy storage systems such as pumped storage generators and thermal storage tanks are being used, and studies are being conducted on a new power storage system adjacent to the area where the power is consumed such as seawater-pumped-storage generators and compressed-air-storage gas turbine generators. Technologies being researched for future use include super heat-pump energy collection systems that store waste heat and other forms of heat at high densities, and dispersed-type power storage batteries.

Other activities aimed at leveling out power loads include: the implementation of interest subsidies, low-interest loans, and tax incentives (through a program that promotes investment in the structural improvement of energy supply systems) for thermal-storage air conditioning systems and gas air conditioning systems-, and the testing of load-centralized control systems that permit the energy supplier to directly control the equipment of energy consumers.

Improving the *Efficiency of* Petroleum Refining

Progress is being made in introducing heat recovery systems and advanced energy-efficient equipment designed to improve the operating efficiency of present refineries. New oil refining technologies, including new high-performance catalysts, are being developed, and systematically introduced whenever existing facilities are renovated. Studies are also being conducted on replacing railway tank cars and tank trucks with pipelines in order to improve the long-term efficiency of the distribution system for petroleum products, reduce energy consumption, and control carbon dioxide emissions.