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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.

Excel.Chart.5 Excel.Chart.5

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.

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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.

Excel.Chart.5 Excel.Chart.5

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 °C in winter and does not exceed 25.5 °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

0 non shading: roof

3-5

4 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 * * NIS: New Israeli Shekel. 1\$US ~3.8NIS (sqm floor)

** NIS/ kWh/ sqm/ year

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 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

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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.
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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 CO₂ and other greenhouse gases. A significant portion of this energy may be conserved and the CO₂ 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 CO₂ emissions ranges from 0.375 kg CO₂ per kWh cooling in conventional cooling systems to 0.165 kg CO₂ per kWh cooling and 0.114 kg CO₂ 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	savings ratio	Fume vent	60% of the air changes half the time the blower is working
21 Night ventilation	91.60	4.36			
30 air exchanges a night					
5 Improving wall insulation	6.54	1.31			
Increment of 2 cm polyurethane					
4 Improving roof insulation	3.27	0.82			
Increment of 4 cm polyurethane					
7 Double glazing	6.54	0.93			
Green reflective glass outside					
11 Exterior shading	32.73	2.98			
Based on an external shutter					
24 Lighting control On/off according to two lighting control areas	102.30	4.26			
14 Upper window for daylight illumination	36.00	3.93			
Upper window according to specification					
14 Ceiling fan According to specification	26.18	1.87			
18 Solar greenhouse on roof for heating air According to specification	6.55	0.36			
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 CO₂ 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 CO₂ 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 °C in winter and does not exceed 25.5 °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):

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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/m² /Y) Moderate Thermal Comfort Without Measures, $Q_{moderate} = 39$ (kWh/m² /Y)

Pessimistic Improvement Scenario

$Q = 38$ (kWh/m² /Y) Moderate Improvement Scenario

$Q = 34$ (kWh/m² /Y) Optimistic Improvement Scenario

$Q = 26$ (kWh/m² /Y) Reasonable Thermal Comfort Without Measures, $Q_{reas} = 40$ (kWh/m² /Y) Moderate Thermal Comfort Without Measures, $Q_{moderate} = 34$

(kWh/m² /Y) Pessimistic Improvement Scenario

$Q = 29$ (kWh/m² /Y) Moderate Improvement Scenario

$Q = 25$ (kWh/m² /Y) Optimistic Improvement Scenario

Q = 21 (kWh/m² /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 page
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Table 4.6: CO2 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 CO2 emissions savings in the residential sector . S1 and S2 refer to existing buildings and new buildings respectively in table 5.6.

Excel.Chart.5

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:

- 11312Raising the demands of energy conservation standards in buildings
- 11312Including additional design parameters in the building codes, in addition to building insulation and sealing (e.g. having a southern window)
- 11312Expanding the code to include different types of buildings
- 11312Requiring an energy audit to be included in each project
- 11312Determining standards for the optimal and maximal energy consumption level permissible in a building according to sectors
- 11312Green standard of approval a standard for buildings and home electrical appliances that are energy efficient

Construction-related standards or recommendations

- 11312Legislation or recommendations to determine winter sun rights or desired shading in summer
- 11312Legislation or recommendations regarding desired exposure to wind in order to obtain comfort ventilation in summer, or protection from unwanted wind in winter
- 11312Legislation or recommendations regarding sufficient exposure to the sky to obtain daylighting
- 11312Legislation 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:

- 11312Solar terraces will not be included in taxable building area
- 11312External shading products and devices will not be taxed or taxes on them will be reduced
- 11312Building insulation and sealing products and devices will not be taxed or taxes on them will be reduced
- 11312Incentives and encouragement for energy retrofit of existing buildings
- 11312Financial 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:

- 11312Determining the real cost of electricity consumption

Incentives (positive or negative):

- 11312Tax reduction for energy savings in buildings
- 11312Progressive taxation on energy consumption in buildings
- 11312Tax 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		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		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 CO₂ 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 CO₂
 emissions (figure 5.1) .

Figure 5.1: Contribution of vehicle categories to CO₂ emissions 1996

Excel.Chart.5

Figure 5.2 presents the results of a forecast for the increase of CO₂ 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 CO₂ from road transportation will more than double by the year 2020 compared to 1996.

Figure 5.2: CO₂ emission projections by fuel type

Excel.Chart.5

5.2 Mitigation options

The means used or suggested to reduce CO₂ 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 CO₂ .

5.2.1.1 Means to reduce energy consumption

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

- 11312Decreasing vehicle weight and engine power by light structures materials.
- 11312Improved computerized control systems of vehicle and engine.
- 11312Improved engine design, including direct injection for gasoline engines; direct injection diesel engines with turbo-charging; variable valve timing; optimal inlet port design.
- 11312Improved vehicle design, e.g. reduction of drag coefficient of the vehicle body; improved tires for better interaction with the road surface.
- 11312On-board devices to limit vehicle speed.
- 11312Improved air-conditioning systems.
- 11312Development 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 stretch 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, (CO₂ 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 stretch 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 CO₂. The alternative fuels that have already been used are:

- 11312 Liquefied petroleum gas (LPG)
- 11312 Compressed natural gas (CNG) and liquefied natural gas (LNG)
- 11312 Alcohols: methanol and ethanol
- 11312 Biogas
- 11312 Hydrogen
- 11312 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 CO₂ 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 CO₂ in the total carbon emissions is:

Unknown = 90% of diesel fuel (see Appendix B2)

Unknown = 82% of LPG = Unknown of gasoline (see Appendix B2)

because in both cases the engine operates with stoichiometric mixture.

Carbon content in propane:

Unknown

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 C₃H₈ is needed compared to 1 liter of diesel fuel.

In mass units:

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

Estimation of CO₂ emission is performed according to the method described in detail in the Appendix.

For diesel fuel:

$CO_2\text{mass}(d) = 2.838 * m_f(d) = 2.838 * 1 = 2.84 \text{ kg}$

For LPG:

Unknown

Unknown

Unknown

CO₂ reduction in case of LPG use is:

Unknown

(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

(symbol 187 \f "Symbol" \s 12 » \$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: symbol 187 \f "Symbol" \s 12 » 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 (symbol 187 \f "Symbol" \s 12 » \$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 CO₂

The discussion above was essentially focused on carbon dioxide (CO₂). The main means for reduction emissions of other greenhouse gases from motor vehicles are:

- 11312Reduction of refrigerant leaks from air-conditioning systems or the use of refrigerants with no GWP.
- 11312Reduction of the emissions of N₂O 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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% CO₂ equivalent standards limiting maximal allowed leaks of refrigerants catalytic converter which does not generate N₂O prevention of N₂O 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 N₂O.

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 CO₂ 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 N₂O

up to 2% cost increase of new vehicle (preliminary estimate). Table 5.8. Expected

problems hindering implementation of CO₂ 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:

• 11312 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.

- 11312Reducing the length of trips by changing destinations or residence location.
- 11312Reducing the use of single occupancy vehicle and shifting to high occupancy vehicles' modes including transit and non-motorized modes.
- 11312Reducing 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 greenhouse 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:

- 11312 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
- 11312 High occupancy vehicle priority lane and facilities. As in transit improvements the benefits vary by site and type of facility.
- 11312 Bicycle and pedestrian facilities and programs. The benefits here vary by site and type of facility and program.
- 11312 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.
- 11312 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.
- 11312 Public education and marketing - The benefits are difficult to estimate and vary by site and program.
- 11312 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
11312	Mandatory	Employer Trip Reduction Programs			
· 11312	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·

11312High-occupancy vehicle priority lanes and facilities

· 11312Transit service improvement and expansions

· 11312Bicycle 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·

11312Public education

· 11312Employer-Based Transportation Management Programs

· 11312Measures of the information era

· 11312CBD Auto Restrain Policies

· 11312 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· 11312Congestion pricing and toll program

· 11312Emission and VKT fees

· 11312Fuel taxes

· 11312Parking 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· 11312Mixed use development ordinances and zones

· 11312Pedestrian friendly site design.

· 11312Parking management.

· 11312Growth 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.· 11312Intelligent Transportation Systems (ITS)

· 11312Incident management systems (i.e. special monitoring, motorist information)

- 11312 Congestion management planning and systems
- 11312 Signal Enhancement and Automated Traffic Management Systems
- 11312 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·

11312 Enhanced inspection and maintenance, Reformulated gasoline

- 11312 Stage 2 vapor recovery systems
- 11312 electric vehicles see section 5.1 Chapter 6

The Agricultural Sector

Worldwide, the agricultural sector is responsible for about 20% of the anthropogenic GHG emissions (IPCC 1996). As shown in Fig 1.2 (chapter 1), the fraction of CO₂ emission through agricultural activities is rather small, yet agricultural activities are responsible for a high percentage of CH₄ emission, and are emitting N₂O more than any other human activity. Agriculture activities account for some 1,300 thousand tons of CO₂ (via electricity consumption), 900 thousand tons of CO₂ equivalents (in CH₄) and some 1,200 thousand tons of CO₂ equivalent (N₂O), constituting some 5% of total greenhouse gas emissions.

6.1 CO₂ Emission and retention.

The different agricultural activities interacting with CO₂ balances are the following:

1. Photosynthetic uptake of CO₂.
2. Release (or uptake) of CO₂ 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 CO₂.

The photosynthetic uptake of CO₂ by crops is a significant flux, yet not all of it is relevant to the balance of CO₂ emission. A large fraction of the fixed carbon is left in the soil and is subsequently mineralized and emitted as CO₂. 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 CO₂ equivalent of harvested fraction of the crop should be considered as a net removal of CO₂ from the atmosphere, though a part of it will be returned to the air. Thus, the CO₂ equivalent of a vegetable crop will eventually be released as municipal solid waste or as a component of sewage, yet in the CO₂ 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 CO₂ 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 CO₂/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 CO₂ 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 CO₂ budget of Israel. A decrease of 10% of the cultivated lands, by abandoning the less profitable lands, will decrease CO₂ fixation by an estimated amount of about 0.5 million ton CO₂ /yr. On the other hand, an increase in the area under cultivation, or afforestation 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 CO₂ from soil organic matter decomposition of soil organic matter.

The storage of CO₂ in the soil is a very significant pool controlling the level of CO₂ 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 CO₂).

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 CO₂. 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 estimated 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 elsewhere (feed additives and genetic improvements) will be adopted in Israel and will reduce specific CH₄ 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 CO₂ 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 husbandry.

6.3 N₂O emission.

Agriculture is the major source of N₂O. Anthropogenic emission of N₂O 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 N₂O (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 N₂O is 1,200 tons. This quantity is equivalent to about 400,000 tons of CO₂.

About 1/3 of N₂O 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 CO₂, assuming a net fixation of 13.3 ton CO₂/ha. A decrease, or increase of 10% in the cultivated (or forested) area, involves a change of about 2.6 million tons CO₂/yr, or about 3.7 of the total CO₂ equivalent emission of the country.

The rate of CO₂ sequestering, 13.3 tons/ha yr, assuming a future market price of 20-30 US\$/ton CO₂, 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 CO₂ 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 CO₂ equivalents). The amounts generated from manure can be cut down drastically (assumed 75% reduction), cutting CO₂ 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 N₂O, or an equivalent emission of 374 thousand tons CO₂/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

Action	CO ₂ equivalent	Additional Advantages
10% increase in crop coverage	10 ³ tons/yr	10 ³ tons/yr
500 in compliance with other national goal	500	10% decrease in crop coverage
-500 Minimal tillage, 25% of land	-500	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 ₂ O	374
Less water pollution		

6.5 Policy steps needed.

1. Farming and forestation should be supported by their contribution to CO₂ 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% CH₄ and 50% CO₂.

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 CO₂.

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

$$C \text{ (ton/y)} = \text{Total MSW} \times \text{fraction landfilled (\%)} \times \text{H}_2\text{O (\%)} \times \text{OM (\%)} \times \text{C (\%)}$$

Total MSW = 4 million tons of waste generated every year

Fraction landfilled (%) = 90%

H₂O = 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 CH₄ emissions to be 370,000 tons. Our calculations show that the estimated CH₄ 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) CO₂ and CH₄ emissions were calculated according to different degradation rates. Calculations of expected CH₄ and CO₂ 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 CH₄, compared with CO₂, is 56 and 21 for 20 and 100 years time horizon, respectively.

Assuming 77% degradation of OM, the total annual CO₂-equivalents release, according to current waste management in Israel, is 17,914,000 and 7,242,000 ton CO₂ eq., for 20 and 100 years time horizon, respectively. This amounts to 24% and 13% from the total of CO₂-eq. emitted in 1996 in Israel.

Figure 7.1 summarizes the CO₂-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 usual scenario

If all CH₄ produced in landfills is converted to CO₂, by means, which will be described in the next section, the emissions will be reduced to only 1,670,000 CO₂-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, CO₂ emissions from landfills are not counted in, since they do not contribute to the increase in CO₂ abundance in the atmosphere (because the carbon in the CO₂ is of recent biogenic origin). In the present calculations, CO₂ was added in order to be able to compare the different alternatives of waste management and the total effect on CO₂ 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) CO ₂ -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) - 11312CH 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) - 11312CH ₄ conversion to CO ₂ , total emissions comprise only 3% of total GHG emissions in Israel, 1997.
- 11312Avoided 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 - 11312CH₄ conversion to CO₂, total emissions comprise only 3% of total GHG emissions in Israel, 1997.

- + NO_x emissions,
- + Transportation emissions- to incineration plant.

16,230

[5,564]

Incineration

With energy recovery - 11312CH₄ conversion to CO₂, total emissions comprise only 3% of total GHG emissions in Israel, 1997.

- 11312Avoided emissions from conventional energy sources. [according to Enosh (1996) displacement of 468 kWh per ton of waste = 137.6 kg CO₂-eq. per ton waste].

- + No_x 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 - CH₄ conversion to CO₂, total emissions comprise only 3% of total GHG emissions in Israel, 1997.

- increase in soil carbon storage
- 11312Increase in yield carbon storage
(1 ton dry matter=2 ton CO₂)

- + Transportation emissions- to composting plant.
- + compost machinery emissions

16,230

[5,564]

Anaerobic digestion

- CH₄ conversion to CO₂, total emissions comprise only 3% of total GHG emissions in Israel, 1997.

- 11312Avoided emission from conventional energy sources. [according to de Laclos et al (1997) displacement of 173 kWh per ton of waste = 50.1 kg CO₂-eq. per ton waste].

- increase in yield carbon storage (1 ton dry matter=2 ton CO₂)
- + 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
- 11312 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 CH₄ to CO₂ reduces significantly the total CO₂-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 CH₄ 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
(10⁶ \$) size of plant

(t/d) Total investment

(10⁶ \$) costs of reduction

(\$/ ton CO₂ Eq.) payback

investment only

(\$/ ton CO₂ 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 CH₄
Total CO₂ eqv. tpy tpy 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% $\pm$ 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 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 NO_x. 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 benefits 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 business 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 90s was not a normal period; during the first part of the 90s 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.

· 11312 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:

symbol 100 \f "Symbol" \s 12 d = symbol 103 \f "Symbol" \s 12 g = symbol 115 \f "Symbol" \s 12 s = 2.2%

POP₀ = 5.69 million.

GDP₀ = US\$ 88 billion.

CO_{2, 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 (symbol 63 \f "Courier New" \s 12 ? 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 (CO₂ 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 TAC + symbol 63 \f "Courier New" \s 10 ? 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. in 2010 - 6.3% Of 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 inefficient tax is replaces by a more efficient one, namely, the environmental tax with a cost tag (revenue raised) of only \$7.5 million! Only when the inefficiency rate is less than 25% will the abatement cost outweigh the fiscal benefits in 2010.

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

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

Year	CO ₂ (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	91.98	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
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 surplus 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 CO₂ (BAU) CO₂ (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.\$)	(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														

Excel.Chart.5

Excel.Chart.5

Excel.Chart.5

Excel.Chart.5

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TEL AVIV + ISRAEL**

71 Hayarkon Street + Tel Aviv 63903 + Tel: 972-3-519-7365 + Fax: 972-3-510-1035

FACSIMILE TRANSMISSION

To: Hilton Hotel, Jerusalem
ATTN: Reception for Guest Susan Gordon
From: Sharon Regelman, *468*
Science Programs Assistant
Through:
CC:
Subject: Updated Schedule for Climate Change Team

Fax Number: (02) 621-1000
Telephone:
Date: April 7, 2000
Pages: 3 (INCLUDING COVER PAGE)

Susan –

Attached is latest schedule with additional details on meetings and activities scheduled prior to and following the workshop. I have alerted our Travel Office to the change from Abe Haspel to Ray Gene dela Torre through the night of April 14. You may want to confirm the change with the Hilton staff to be on the safe side.

Take care,

Sharon

STATE OF ISRAEL
MINISTRY OF THE ENVIRONMENT

INTERNATIONAL RELATIONS & SPECIAL PROJECTS

P.O.B. 34033, Jerusalem 95464 Tel: 972 2 6553745/6 Fax: 972 2 6553752

Climate Change Workshop

9-12 April 2000

to be held at the Jerusalem Institute for Israel Studies

Teddy Kollek Hall, 20 Radak Street, Rehavia

Jerusalem

Sunday, 9 April 2000

- 10:00 Pick up delegation from Hilton Hotel, Jerusalem. Proceed to Tel Aviv
- 11:30-13:30 Meeting at the Manufacturers Association of Israel with Yossi Arie, Director, Chemistry, Pharmaceuticals & Environment and reps from Nesher, Israel Chemicals, Machteshim, and Oil Refineries
29 Hamared Street, Beit Hatasia, Tel Aviv (03) 519-8857/8
- 15:00-16:30 Preparatory Meeting at the Ministry of Environment, 5 Canfei Nesharim, Jerusalem
- TBD Return to Hilton Hotel, Jerusalem
- 1930 Informal dinner at Pini's Courtyard or the Botanical Gardens, Jerusalem with Ministry of Environment staff, Mr. Yitzhak Goren, DG; Dr. Miki Haran, Chief Scientist; Ms. Shuli Nezer, Director, Division of Air Quality; Ms. Ronnie Cohen, Division of International Relations
- RON Hilton Hotel, Jerusalem

Monday, 10 April

- 09:00 Pick up delegation at Hilton Hotel Jerusalem. Proceed to Embassy.
- 10:30 Meeting with/pre-briefing for DCM Richard Roth
- 12:30-13:30 Meeting at Israel Union for Environmental Defense, with Director, Danny Fisch, 7 Karlibach (Carlebach) Street, Tel Aviv, (03) 562-4044
- 15:30-17:30 Tour of the Old City of Jerusalem with Mr. Itzik Waknin, Society for the Protection of Nature in Israel, (02) 566-0737 or 050-621-485
- RON Hilton Hotel, Jerusalem

Tuesday, 11 April 2000

- 7:00 Driver and van depart from Embassy with Bill Crane for Jerusalem
- 8:15 Pick up delegation from Hilton Hotel, Jerusalem for Climate Change Workshop, Jerusalem Institute for Israel Studies, 20 Radak Street, Rehavia, Jerusalem
- 8:30-9:00 Registration and coffee
- 9:00-9:20 Opening remarks - Mr Yitzhak Goren, Director General, Ministry of the Environment (MoE)
- 9:20-10:00 Presentation of Neeman Institute document (Technion and Haifa University) - mitigation options
- 10:00-10:45 Presentation of Jerusalem Institute for Israel Studies and Arava Institute document - policy recommendations

10:45-11:00 Coffee Break
 11:00-12:00 Economics and the Kyoto Protocol: Implications of the Flexibility Mechanisms
 12:00-13:00 US Domestic Actions
 13:00-14:00 Discussion lead by Director General, MoE
 14:00 Light lunch
 15:00 Meeting with officials from Ministries of Finance and National Infrastructures DG Yaakov Efrati
 RON Hilton Hotel, Jerusalem

Wednesday, April 12

07:00 Driver and van depart from Embassy with Bill Crane for Jerusalem
 08:15 Pick up delegation from Hilton Hotel, Jerusalem for Climate Change Workshop, Jerusalem Institute for Israel Studies, 20 Radak Street, Rehavia, Jerusalem
 08:30-09:00 Registration and coffee
 09:00-09:20 Opening - Dr Miki Haran, Deputy Director General, Hazardous Substances, MoE - Climate Change Convention and Kyoto Protocol
 09:20-10:00 Presentation of Neeman Institute document - mitigation options
 10:00-10:45 Presentation of Jerusalem Institute for Israel Studies and Arava Institute document - policy recommendations
 10:45-11:00 Coffee break
 11:00-12:00 Economics and the Kyoto Protocol: Implications of the Flexibility Mechanisms
 12:00-01:00 Presentation of US Domestic Actions
 13:00-14:00 Light Lunch
 14:00 Discussion, inter-ministerial committee on Climate Change, headed by Ms. Shuli Nezer, Director, Division of Air Quality, MoE
 TBD Tower of David Museum, Chihuly Exhibit
 RON Hilton Hotel, Jerusalem

Flexibility Mechanisms and Economic Implications of the Kyoto Protocol

Joe Aldy

Council of Economic Advisers

Economic Aspects of Kyoto Protocol

- Binding emissions targets
- Flexibility mechanisms
- Economic analysis of flexibility mechanisms
- Opportunities for non-Annex I countries

Binding Emissions Targets

- 2008 to 2012 commitment period
- Annex B targets are a fraction of 1990/base year emissions
- Targets range from 1990 -8% to 1990 +10%
- U.S. target is 1990 -7%

Flexibility in Protocol

- “When” Flexibility (Timing)
- “What” Flexibility (Gases and Sinks)
- “Where” Flexibility (International)

“When” Flexibility (Timing)

- Timing of first binding commitment period
- Target specified in terms of 5-year average
- Opportunity for banking allowances to later commitment periods
- Opportunity for banking CDM credits generated between 2000 and 2008

“What” Flexibility (Gases and Sinks)

- Opportunities to trade across 6 kinds of greenhouse gases
- Inclusion of sink activities (such as reforestation)

“Where” Flexibility (International)

- International emissions trading
- Joint implementation (JI)
- Clean Development Mechanism (CDM)

Economic Analysis of Flexibility Mechanisms

- How does emissions trading work?
- Results from economics literature on emissions trading
 - international trading
 - intergas trading
- Results from Administration's economic analysis of Kyoto

How does emissions trading work?

- Establish an aggregate emissions target
- Allocate to private entities emissions allowances
- Allow private entities to buy and sell emissions allowances among themselves
- Private entities provide allowances to cover emissions at end of commitment period

U.S. Experience with Emissions Trading

- Emissions Trading Policy
- Lead Phase-out from Gasoline
- RECLAIM
- Sulfur Dioxide Trading Program

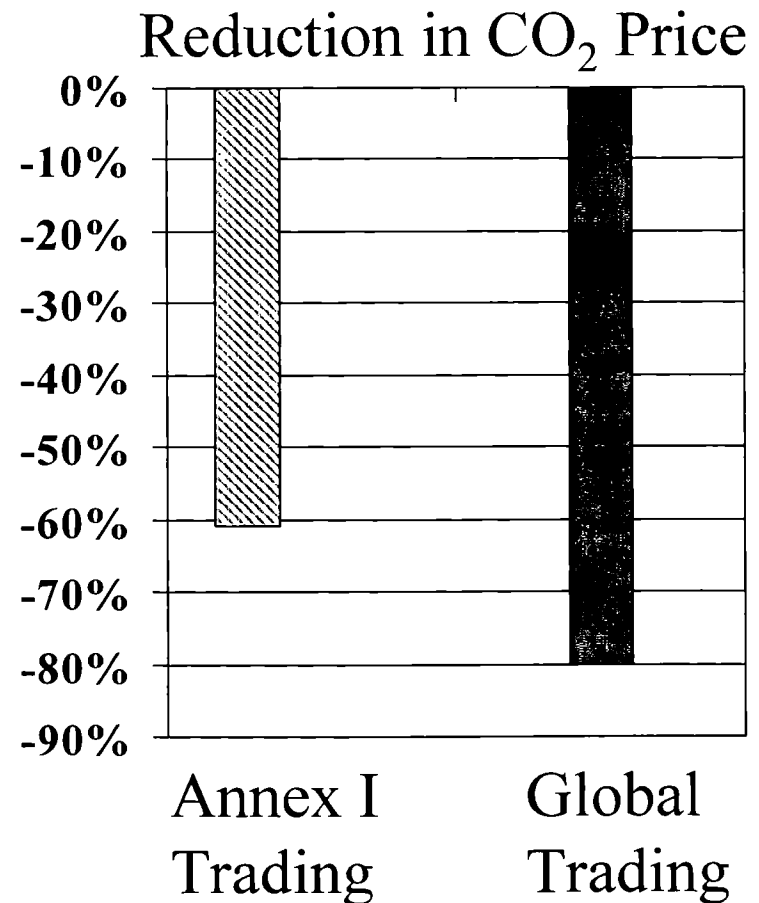
2000 Economic Report of the President:
<http://w3.access.gpo.gov/eop/>

International Emissions Trading Modeling Analyses

- Stanford Energy Modeling Forum
 - Spring 1999 Energy Journal Kyoto Special Issue
- OECD Modeling Workshop
 - <http://www.oecd.org/dev/news/Environment/Modelling.htm>

EMF International Trading Results

- Annex I trading reduces allowance price 60% relative to no trading
- Global trading reduces allowance price 80% relative to no trading



Economic Implications of International Emissions Trading

- U.S. could reduce economic costs by up to 80% with international emissions trading
- The EU and Japan would benefit more than the U.S. from trading
- Non-Annex I countries could adopt emissions targets slightly below BAU and enjoy gains from trade in excess of abatement costs

What explains the large gains from trade?

- Variations in emissions targets
- Variations in projected economic growth across countries
- Variations in pre-existing energy prices
- Extent of coal in energy system

What are the differences between trading, JI, and CDM?

- International emissions trading and JI occurs between countries with targets
- CDM occurs in a country without a target
- JI and CDM are project-oriented
- Trading is broader and can include projects as well as policies

Administration's Illustrative Modeling Analysis

- Second Generation Model
 - Long-run economic model (CGE)
 - models international emissions trading
 - modified to model trading across 6 gases
- Various Trading Scenarios
- Evaluate effects on energy prices, typical household, economy

<http://www.whitehouse.gov/WH/New/html/kyoto.pdf>

2010 Economic Effects of an Illustrative Trading Scenario

- Efficient trading among Annex I and large developing countries
- Allowance price: \$23/ton
- Direct resource cost to U.S.: \$12 billion/yr
- Energy price increase: 5%
- Average household energy expenditures would increase about \$110/yr

Limitations to Modeling Analysis

- Less detail in global CGE than a country-specific macro model
- Modeling does not account for:
 - Carbon sinks
 - Electricity restructuring
 - Government R&D programs
 - Ancillary air quality benefits

Opportunities for Non-Annex I Countries

- Potential economic gains from trading
- Trading requires emissions target
- Alternative target formulations consistent with a country's economic development objectives

Alternative Target Formulations

- Basic Principles on Targets
- Kyoto Protocol Annex B Targets
- Overview of Emissions Growth Targets
- Overview of Indexing Emissions Targets

Basic Principles on Targets

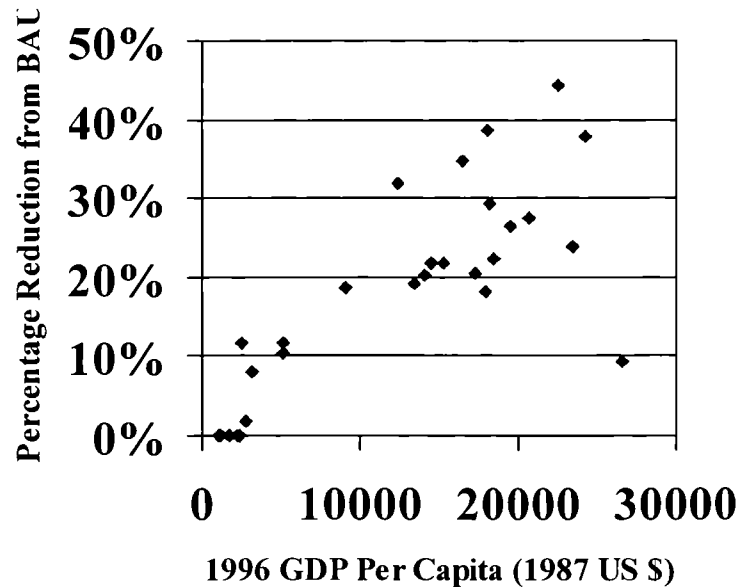
- Targets Should Be Consistent with Economic Development
- Targets Should Provide Climate Benefits
- Targets Should be of a Form that Allows Participation in International Emissions Trading

Kyoto Protocol Annex B Targets

- | Percentage of Base
Year Emissions | Annex B Targets |
|--|---|
| • Include Sources and
Sinks of 6 Types of
Greenhouse Gases | <ul style="list-style-type: none">• US 1990-7%• EU 1990-8%• Japan 1990-6%• Russia 1990• Australia 1990+8% |
| • 5-Year Average | |

Progressivity of Annex B Targets

**Emissions Reduction vs.
Per Capita GDP**

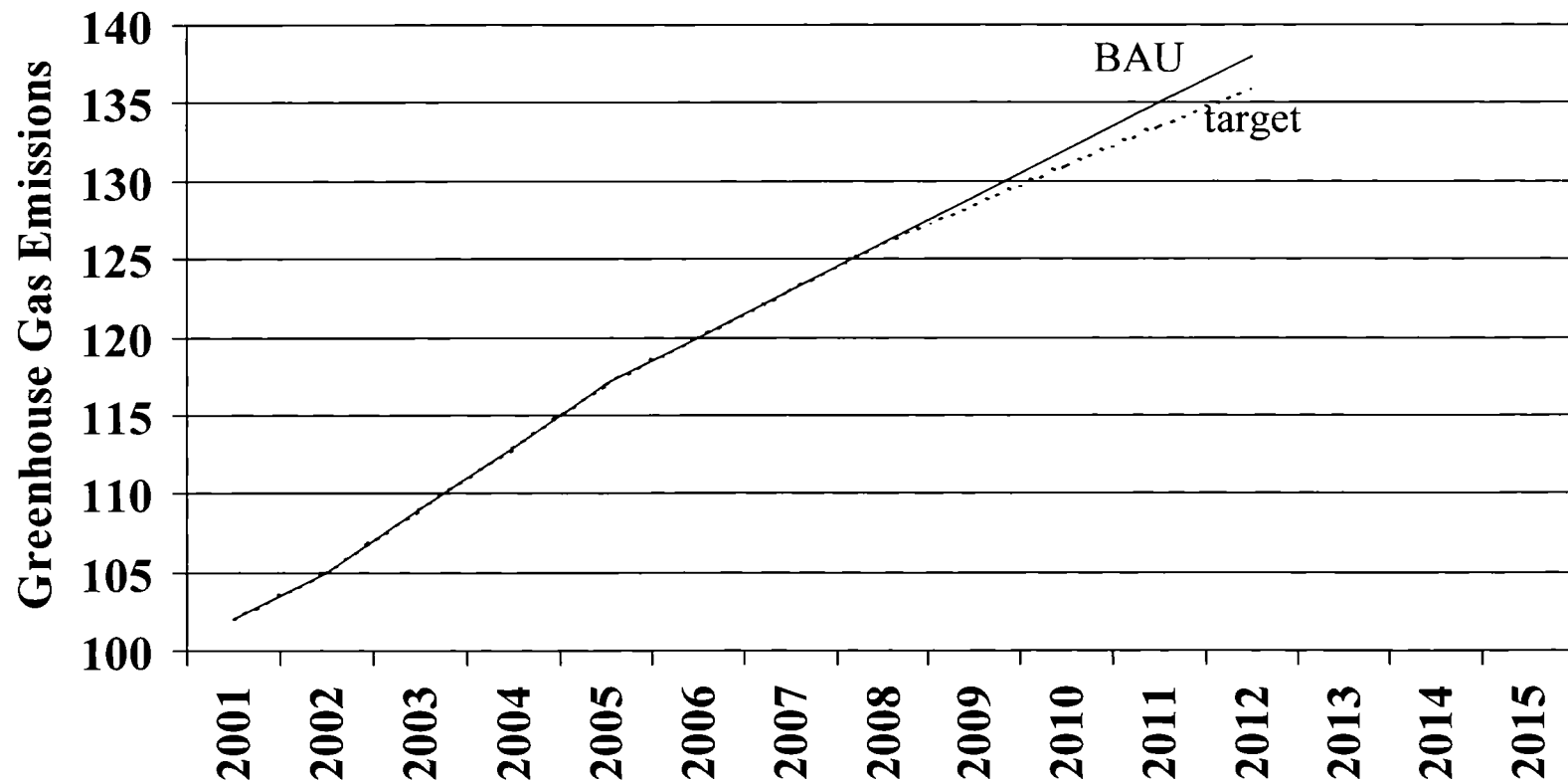


- Annex B targets, when evaluated relative to projected 2010 business as usual emissions, follow a pattern of progressivity

Emissions Growth Targets

- Target would allow for emissions to grow above current levels
- Target should result in deflection off of the business as usual emissions path
- Stringency of target evaluated in terms of reduction from business as usual

Illustration of an Emissions Growth Target



Indexing Emissions Targets

- Uncertainty in forecasting emissions
 - Some are concerned about inadvertently stringent targets
 - Others are concerned about inadvertently lax targets
- These risks could be mitigated by indexing a target to relevant economic indicators

An Example of Indexing

U.S. labor contracts are often indexed to the Consumer Price Index (one measure of inflation). For every percentage increase in the CPI, the contract specifies a given increase in wages -- a cost-of-living adjustment. Since wages change with the CPI, the uncertainty in real wages is reduced.

Principles for Indexing

- Reasonable forecast of emissions from indexing variables (such as the relationship between GDP and emissions)
- No perverse incentives from indexing
- Predetermined targets

Samples of Indexing Targets

- For every percentage point that GDP turns out to be higher (or lower) in 2007 than forecast, the emissions target is raised (or lowered) by X%
- A carbon-to-GDP ratio could be used as the basis for the emissions target