The First Communication of Malta to the United Nations Framework Conventionon Climate Change

April 2004

MINISTRY FOR RURAL AFFAIRS AND THE ENVIRONMENT

UNIVERSITY OF MALTA

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Foreword

Global climate change is one of the major threats facing humanity in the 21st century. The Government of Malta brought this issue to the agenda of the United Nations General Assembly in 1988. As a result, the international community has taken the first steps towards fashioning a collective strategy to respond to this threat, starting with the 1992 United Nations Framework Convention on Climate Change (UNFCCC).

The first basic commitment of all Parties to the Convention is to share information and experience through the presentation of national communications. In fulfilment of this commitment, Malta presents its first national communication to its partners in the UNFCCC.

In respect of global climate change, as of other global trends, this small island community is destined to undergo external influences over which it has no control. This has been our fate over millennia. Through this experience we have developed the skills of survival and adaptation. From the process of preparing this report, there emerged a picture of a new challenge to these innate skills: the challenge of strengthening our resilience to adverse climatic impacts, notably threats to the fragile water supply on which our lives and our livelihoods depend.

At the same time, the report illustrates a range of win-win opportunities through which, by decreasing the carbon intensity of economic activity, Malta can make its modest but symbolic contribution – commensurate with its capabilities and its responsibilities – to modifying long-term global emission trends.

This communication was presented to and endorsed by the Cabinet, chaired by the Prime Minister, on 15 March 2004. Formal responsibility for its preparation was vested in the Malta Environment and Planning Authority. Its driving force was located in the Department of Physics of the University of Malta, where the process was led by Dr. Charles V. Sammut (Project Manager) and Dr. Alfred Micallef (National Expert). Preparing the report involved consultations with different actors and stakeholders. Its by-products included a wider awareness of the phenomenon of climate change and its relevance to Malta, as well as the beginnings of a national capacity to collect and manage climate-related data and other information. The Government of Malta thanks all those who have contributed to the report and to these outcomes.

The Government of Malta also thanks the Global Environment Facility and the United Nations Development Programme for enabling the preparation of this first communication. It is pleased to signal that facilities for the preparation of its second communication are already in place and looks forward to presenting that to the UNFCCC in due time.

This communication is presented on the eve of Malta's accession to the European Union, a step that will transform its political future. Malta looks forward to working with its partners in the Union to develop a national climate policy that will reflect its new status and benefit from their experience and support. It also looks forward to cooperating with them and other partners in advancing the collective international strategy in the directions indicated by the Convention and its 1997 Kyoto Protocol.

George Pullicino
Minister for Rural Affairs and the Environment
April 2004

Acknowledgements

The Project Team acknowledges the support of numerous individuals, government and non-government officials and organisations, without whose support this project would not have been completed successfully within less than three years. Particular reference is made to the Honourable Dr. Francis Zammit Dimech, former Minister for the Environment, under whose auspices the project started in 2001, and the Honourable Mr. George Pullicino, Minister for Rural Affairs and the Environment, who subsequently assumed responsibility.

The financial support of the Global Environment Facility made this project possible, and the support of the United Nations Development Programme was instrumental in bringing it to completion. The Project Team is particularly indebted to Ms. Andrea Cimborova, GEF Associate, of Slovakia's UNDP Country Office, who provided continuous support and invaluable advice throughout the project.

The assistance of the National Communications Support Programme and the UNFCCC Secretariat is acknowledged, in particular for the review of the National Greenhouse Gas Inventory, ably carried out by Ms. Katarína Mareková of the Slovak Hydrometeorological Institute.

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1.1 Introduction

1.1.1 The country's geography

The Maltese archipelago is centrally located in the Mediterranean Sea and comprises six small islands. The main islands are Malta, Gozo and Comino (figure 1.1) all of which are inhabited, while the islets of Filfa, Cominotto and St.Paul's Islands are uninhabited.

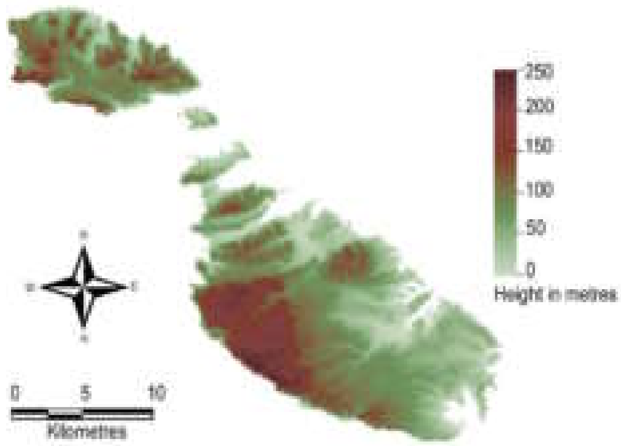

Figure 1.1 The main islands in the Maltese archipelago.

The Maltese islands cover a total area of 320 km^2 with a total coastline perimeter of approximately 140 km. The central position of the landmass is approximately 1,840 km east of the Straits of Gibraltar and about 1,520 km northeast of the Suez Canal. Malta is 93 km south of Sicily and 290 km north of the African Continent.

Malta's land area totals 246 km^2. The general topography of the island can be described as a series of low hills in the northern area with terraced slopes and plains on the southern aspect. There are no mountains or rivers.

Gozo is the second largest island and lies about 6 km northwest of Malta. The total land cover is about 67 km^2 with a coastline perimeter of 43 km. The topography is similar to that of Malta.

1.1.2 Population

With a current population of almost 400,000, Malta has one of the highest national population densities in the world. The present population growth rate is in the region of 0.75%. This small annual increase in the net population is primarily sustained by high life expectancy and a low emigration rate. Furthermore, population density is accentuated by the annual inflow of tourists, which is equivalent to about 30,000 additional residents.

1.1.3 Climate

The climate of the Maltese archipelago is normally described as typically Mediterranean, with moist, mild winters and dry, hot summers. The average annual precipitation is about 530 mm and is mainly restricted to very short periods in the autumn and winter. The air temperature generally ranges between 9.5°C and 33°C, exceptional extremes of 1.4°C and 43.8°C having been recorded. The hottest period of the year runs from mid-July to mid-September and the coldest months are January and February. The sea temperature varies in conformity with the air temperature, with a yearly mean of 20°C. The mean sea temperature is higher than that of the air from September to April, and lower from May to August. Humidity is usually high, rarely falling below 40%, and there is little seasonal variation.

1.1.4 Agriculture and fisheries

Less than 40% (about 13,500 hectares) of the total land area is suitable for agriculture. Irrigated land covers only 700 hectares with the rest, amounting to about 95% of the total agricultural land, receiving an annual average of just over 500 mm of rain.

Agriculture accounts for about 3% of the GDP and employs 2% of the total workforce. The main crop products are potatoes, cauliflower, grapes, wheat, barley, tomatoes, citrus fruits and green peppers. Local animal husbandry is responsible for meeting almost all the country's demand for pork, poultry, eggs and milk.

Fishing plays a very limited role in the Maltese economy. A recent census (NSO, 2002) indicated that, during 2000, there were 1,736 registered fishermen, of whom 1,191 were part-timers. About 990 tonnes of fish were landed by registered fishermen during that year.

1.1.5 Economy

The economy of Malta is highly dependent on foreign trade and services. The only abundant natural resource is limestone, which is used in the construction industry. The most important asset in the Maltese economy remains the human resource. Figure 1.2 illustrates the composition of the Maltese workforce during 2000, with 35% working in the public service.

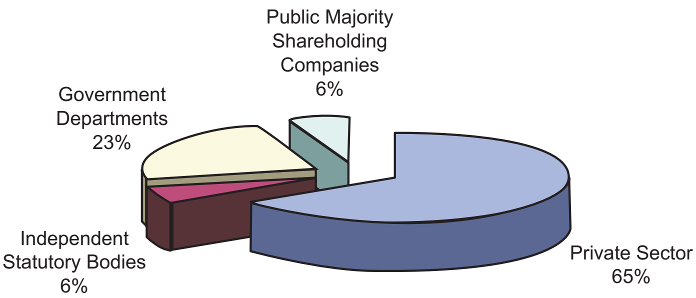

Figure 1.2 Composition of the Maltese workforce during 2000 (NSO, 2001).

1.1.6 Industry

The main industries besides tourism include electronics, ship construction and repairs, food manufacture, textiles, footwear, clothing, beverages and tobacco. Over 180 international firms operate locally and 77% of exports are to the European market. The principal trading partners are Italy, Germany, the United Kingdom and the United States.

1.1.7 Energy

The production of primary energy in Malta is fossil fuel based. Rapid economic growth has led to an increase in national energy consumption from 520 kilotonnes of oil equivalent in 1980 to about 760 kilotonnes in 2000. More than 30% of this increase is attributable to water production and to pressure from the tourism sector

Enemalta Corporation has been entrusted with the generation, distribution and sale of energy in Malta since 1977. Electricity is generated by two inter-linked power stations, one at Marsa on the eastern part of Malta and a more recent plant at Delimara on the southern coast. All urban and rural areas in the Maltese islands are served with electricity supply and the number of registered consumers connected to the system in 2000 was about 200,000. The main user of electrical power is the domestic sector (36%), followed by the commercial sector (30%), the industrial sector (25%) and the water production sector (9%).

1.1.8 Malta's role in setting up the UNFCCC

In the late eighties the international community recognised that exceptional meteorological conditions prevailed in various parts of the globe, including recurring droughts in North America, devastating floods in Bangladesh and abnormally high temperatures in Southern Europe. The scientific community regularly issued reports of global warming as a result of increasing greenhouse gas emissions.

On 22nd August 1988, the Government of Malta requested the inclusion of an item entitled "Declaration Proclaiming Climate as part of the Common Heritage of Mankind" in the provisional agenda of the 43rd session of the UN General Assembly. On 21st September 1988, the General Committee of the General Assembly included an item entitled "Conservation of Climate as part of the Common Heritage of Mankind" and allocated the item for consideration by the Second Committee. On 24th October 1988, Dr. Vincent Tabone, Malta's then Foreign Minister, formally introduced the item at a meeting of the Plenary Session of the UN General Assembly. He explained Malta's view that "there should be global recognition of the fundamental right of every human being to enjoy climate in a state which best sustains life."

Malta then presented a concrete proposal in the form of a draft resolution that was submitted for consideration by the Second Committee. Resolution 43/53 (UNGA, 1988) was unanimously adopted in the plenary meeting of the General Assembly on 6th December 1988. This resolution paved the way for a series of events that led to formulation of the United Nations Framework Convention on Climate Change and eventually to the Kyoto Protocol.

The classification of climate change as a common concern rather than a common heritage of humankind was not intended to protect the climate. Its ultimate aim was to ensure that, by addressing the problem of climate change on a multilateral basis, it would lead the international community towards the formulation of an effective and comprehensive strategy to protect the global climate from change as a result of state activities. This was the basis of the Common Concern concept which was later included in the preamble to the Convention.

1.1.9 National institutions dealing with climate change related issues

The Republic of Malta ratified the United Nations Framework Convention on 17th March 1994 and, as a non-Annex I country, has been committed to preparing its first national communication, as required under Article 12 of the Convention. The main obligation of non-Annex I countries is periodic submission of national communications to the Conference of Parties to the Convention.

The Ministry for Rural Affairs and Environment (MRAE) coordinates activities associated with climate change initiatives. Recently, the Malta Environment and Planning Authority (MEPA) was entrusted with the task of maintaining the national greenhouse gas inventory and subsequent reporting to international bodies, namely the UNFCCC and the EU. A National Board on Climate Change was established to oversee and coordinate initiatives among the different sectors of government and non-governmental organisations.

The MRAE and MEPA have established synergistic links with the Department of Physics at the University of Malta (chiefly with the lead authors in the field of climate change initiatives), which have made possible the compilation of the first extensive and comprehensive national GHG inventory, as well as the first national communication to the UNFCCC.

1.2 Executive summary

1.2.1 The national greenhouse gas inventory

Figure 1.3 summarises the percentage contribution to GHG emissions by sector. Energy, industrial processes, agriculture, land-use change and forestry and waste management were the sectors considered in the compilation of the national GHG inventory. The main contributor of GHG emissions (except CH_4) was the energy sector. For the year 2000, CO_2 emissions by this sector amounted to about 2500 Gg. In the case of methane emissions, waste management and agricultural activities were identified as the main sources. Limited industrial activity made a relatively low contribution of all greenhouse gases. Land-use change and forestry does not constitute a significant source, but was found to be relevant in the determination of CO_2 removal potential. The general emission trends of most greenhouse gases are increasing, particularly that of CO_2.

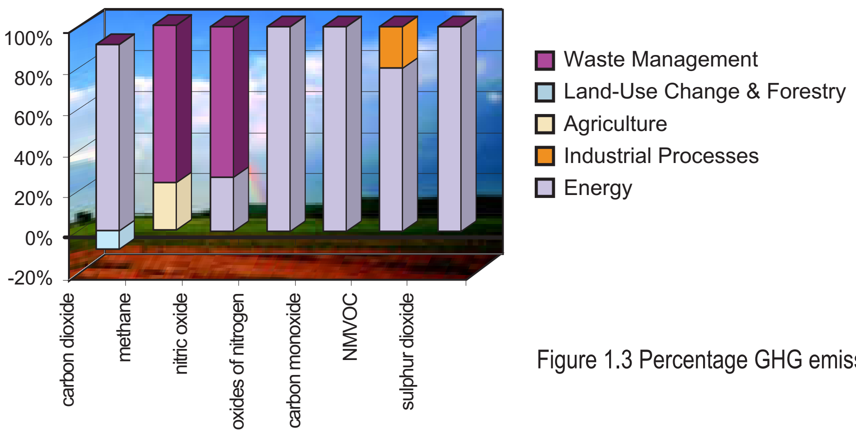

Figure 1.3 Percentage GHG emissions by sector.

Problems encountered during the compilation of the inventory included lack of information on the destination of fuels sold by large private distributors, a lack of information concerning primary energy use in industry and the practice of recording imports by monetary value.

1.2.2 Greenhouse gas abatement analysis and mitigation measures

The search for emission mitigations concentrated on the energy sector, and on transport and waste management, including that of agricultural waste. Although current data on these sectors was reliable, the quality of projections for 2010 varied somewhat. Significant mitigation of GHG emissions is possible without incurring heavy costs. Only the largest cutbacks in the energy sector would require substantial expenditure on the necessary infrastructure.

Efficiency gains in electricity generation may be achieved by replacing the Marsa generators with gas turbines, while improvements in power transmission and distribution and a sustained effort to improve demand-side management could result in further significant mitigation. Changeover to fuels with a lower carbon content, e.g. from heavy fuel oil for steam turbines to gas oil for gas turbines, potentially offers even better results. However, Malta does not yet have the expensive infrastructure to ensure a constant supply of the best fossil fuel (methane) for this purpose. Two combined cycle gas turbines working on natural gas would be capable of bringing 2010 CO_2 emissions down to those for 1990.

The dominance of the private car in the local fleet suggests that an effective mitigation measure would involve restriction of car use. This could result in the elimination of about 20 Gg of CO_2 per year by 2010. Use of unleaded petrol-engines with three-way catalysers would eliminate associated NO_x and reduce CO and NMVOC, but would increase CO_2 emission.

Until sufficient sewage treatment infrastructure is completed by about 2005, no significant mitigation measures can be implemented. Following 2005, aerobic treatment of sewage followed by sludge incineration could achieve significant reduction in methane emission. Partial centralisation of animal manure treatment could yield methane for use as fuel.

With year 2000 solid waste management producing about 14 Gg of methane, there is ample room for improved practice. Composting (aerobic treatment) and combustion of municipal solid waste would yield limited reduction of CO_2 emission compared to that of present practice. If land filling were to be implemented, gas (CH_4) collection and use would result in about 180 Gg of CO_2-equivalent emission per annum.

1.2.3 Vulnerability and adaptation to climate change

There is a 50% probability that the following key climatic changes will occur.

- Temperature will increase by 3°C by 2100.
- Annual total precipitation will decrease by 17% by 2100, with a relative decrease in autumn and an increase in spring.

Climatic changes will affect the environment and, consequently, socioeconomic activities. Expected impacts include:

- deterioration of potable water supplies and quality;
- more frequent extreme weather events;
- changes in soil erosion and an accentuated desertification process;
- threats to public health;
- changes in sea water mass characteristics and effects on fish stocks;
- sea level rise, leading to coastal erosion and inundation;
- reduced biodiversity;
- moderate to moderately high economic vulnerability.

1.2.4 National action plan

Malta is more likely than larger countries to suffer the consequences of climate change but, as with other small states, cannot be considered a main culprit of the change.

The implementation framework should favour multi-sectorial policies (notably energy, transport and agriculture) with a view to integrating environmental considerations within measures aimed at climate change abatement and adaptation strategy.

Malta is committed to honouring obligations in respect of the UNFCCC and the Kyoto Protocol and, as an EU member state, will be obliged to develop the capacity for reporting, monitoring and verifying greenhouse gas emissions. The National Action Plan provides an administrative framework to enable the exploration of various measures proposed in support of greenhouse gas mitigation and adaptation to climate change.

1.2.4.1 Scope and principles of the action plan on climate change

The National Action Plan consists of a set of adaptation and mitigation measures that merit further and detailed investigation with a view to their potential implementation. It recognises that the challenge of climate change must be shared equitably by all sectors and needs to be faced by adopting clear criteria, including:

- commitment to sustainable development;
- disposition to maximise economic efficiency by implementing cost-effective measures;
- policies and measures tailored specifically to all relevant sectors, with the intention of achieving emission reductions across all economic sectors;
- recognition of the specific arrangements and special requirements that pertain to a small island state;
- presentation at international fora of a proposal to allow small island states, and states with a large coastal perimeter to land area ratio, to include marine sinks in their inventory[1];
- generating an impetus for early action by adopting a phased approach that allows for immediate actions while planning for longer term provisions;
- common and coordinated policies and measures to be implemented at EU and wider international levels.

1.2.4.2 Implementation of the action plan

The setting up of a Climate Change Committee, possibly within the National Commission for Sustainable Development, is necessary to work on the formal establishment of a climate change strategy and to oversee the potential implementation of the proposed measures and policies, and others that may be deemed necessary and feasible in the future.

The achievement of policy goals is dependent on the level of cooperation of public and private entities and

[1] This is a reasonable assertion, since coastal regions are considered part of state territory and consequently should be considered for the purpose of providing more realistic net national CO_2 emission values.

individuals, and on awareness of effects of behavioural patterns on climate change. Empowerment of the public with the creation of dedicated structures, inter-sectorial links and trained personnel will facilitate this process and promote the inclusion and integration of greenhouse gas considerations into both public and private decision-making processes. Emphasis should be made on inclusion of the community in the implementation of climate-related actions. Local Councils should have an active role in public awareness and policy implementation.

A final and most crucial component of the action plan highlights the need of an adequate monitoring network for the routine acquisition and analysis of relevant emissions data. Besides being an obligation to which Malta is now committed, such data sets are essential to enable the regular recording of performance in emissions abatement and to provide a basis for sound management and efficient planning. The system will comprise observation networks for collection of data (possibly integrated within a more comprehensive national meteo/ocean/environmental monitoring programme), a common database expert system, and institutional arrangements favouring the setting up of dedicated structures with specific responsibilities.

1.2.4.3 Summary of policies and measures

The suggested policies and measures address mitigation and adaptation. Following is a summary of measures and policies being proposed for further detailed consideration.

Power generation:
- increase in efficiency of electrical generating plant by using combined cycle gas turbines instead of steam turbines;
- switch to natural gas as the main fuel instead of heavy fuel and gas/diesel oil;
- implementation of renewable energy technology;
- use of combined heat and power plant and integration of renewable energy sources;
- reduction of SO_2 emissions by use of low-sulphur fuel;
- power factor correction for major users;
- introduction of modern technology to improve energy efficiency and conservation;
- increase awareness of energy efficient devices by using energy labelling systems.

Transport:
- improvement of traffic management;
- creation of suitable parking schemes and major improvements in public transport to encourage reduction of car use;
- installation of three-way catalysers on unleaded petrol vehicles and enforcement of emission regulations;
- introduction of alternative fuels, principally hydrogen;
- introduction of hybrid and electric traction.

Water resources:
- improvement of demand-side management to limit water consumption;
- use of alternative water sources for activities that can be satisfied by non-potable supplies;
- creation of an awareness campaign on efficient use of water;
- introduction of enforcement measures and revision of water tariffs on the basis of use;
- reduction of water leakage by detection, meter repair/maintenance and pressure management systems;
- curtailment of illegal groundwater extraction, monitoring and assessing the impacts of sea level rise in order to preserve the aquifer;
- adoption of an integrated storm water management plan that comprises a flood mitigation system and improved methods of harnessing storm water;
- use of treated effluent in industry and agriculture outside the groundwater protection zone;
- improvement of irrigation techniques.

Liquid waste management:

- encouragement of on-site treatment of sewage and reuse of treated effluent by major consumers of water;
- reduction of load on the sewerage system by restraining water consumption and eliminating illegal water discharges;
- operation of the sewerage system under aerobic conditions;
- introduction of tariffs for sewage disposal on the basis of water consumption;
- separate treatment of liquid waste resulting from animal husbandry and other problematic (e.g. saline) liquid waste;
- implementation of the provisions of the Sewerage Master Plan for Malta and Gozo in respect of sewage treatment.

Solid waste management:
- capturing and utilisation of methane resulting from treatment of solid waste;
- replacement of existing uncontrolled landfills with engineered landfills;
- upgrade of existing and development of additional recycling facilities;
- separation of waste at source;
- reduction of biodegradable waste by encouraging reduced consumption;
- banning disposal of slaughterhouse and fish-farming residues into landfills and upgrading of the incineration facilities for abattoir waste.

Agriculture:
- adaptation and diversification of crop species through selection of drought tolerant varieties and introduction of salt tolerant crop varieties and by making wider use of greenhouse controlled cultivation;
- reduction of soil erosion through practice of minimum tillage, stubble crop retention, construction of windbreaks and rubble wall maintenance;
- employment of soil improvement techniques, such as the addition of compost, to control salinisation and improve water retention, together with the adoption of xeriscaping for embellishment;
- afforestation of abandoned land by drought tolerant and heat resistant tree species;
- combating inundation, loss/degradation of land and coastal erosion resulting from sea level rise by building/ adapting adequate protective structures;
- protection of special biota, habitats and biodiversity from sea level rise by facilitating natural landward migration of shore zone patterns.

Industry:
- implementation of regulatory instruments;
- development of financial and market based instruments with which Government may stimulate cleaner production methods;
- formulation and adoption of a code of good practice by local industry in relation to environmental issues;
- creation of an awareness campaign on environmental responsibilities aimed at industrialists.

Health:
- preparation and implementation of a hot weather contingency plan;
- formulation of industry specific guidelines for working in hot climatic conditions;
- identification of persons at risk and establishment of communication channels;
- information gathering and analysis (including epidemiological studies) followed by dissemination of the resulting conclusions;
- creation of awareness and education campaigns aimed at sensitising the general public to health risks and protective measures associated with adverse effects of climate change
- enhancement of resources in primary health care and health surveillance in areas where climate change poses the most severe threats to human health.

Cross-sectorial instruments and measures:

- setting up of a national emissions inventory database expert system for Malta to enable efficient and timely reporting and to provide useful information for policy formulation;
- presentation at international fora of a proposal to allow small island states, and states with a large coastal perimeter to land area ratio, to include marine sinks in their inventory;
- benchmark those sectors that are considered to be the major contributors to GHG emissions to corresponding sectors in other regions;
- assessment of the institutional capacity-building requirements across all government agencies
- integration of climate change issues in policy formulation;
- promotion of science and environmental education as part of community planning and development programmes;
- gap analysis of the National Minimum Curriculum in respect of climate change issues;
- ensuring that as many tertiary level courses as possible include environmental aspects and considerations in their curriculum;
- preparation and adoption of a strategy for raising the general awareness of climate change issues;
- development of a network of meteo-marine stations for monitoring hydrological parameters and related indicators that furnish alert systems (such as flood warning) and detect trends of change (such as precipitation forecasts and sea level rise).

Chapter 2

National Greenhouse Gas Emissions Inventory for Malta 1990-2000

2.1 Executive summary

IPCC guidelines (IPCC, 1996a) specify the greenhouse gases to be considered in the national inventory. These are:

- carbon dioxide (CO_2)
- methane (CH_4)
- carbon monoxide (CO)
- non-methane volatile organic carbons (NMVOC)
- nitrous oxide (N_2O)
- oxides of nitrogen (NO_x)
- sulphur dioxide (SO_2).

The sectors considered in the compilation of the national GHG inventory were:

- energy (power generation and transport)
- industrial processes
- agriculture
- land-use change and forestry
- waste management.

The main contributor to GHG (except CH_4) emissions was the energy sector. For the year 2000, CO_2 emissions from this sector amounted to about 2500 Gg. In the case of methane emissions, waste management and agricultural activities were identified as the main sources. Limited industrial activity made a relatively low contribution of all greenhouse gases. Land-use change and forestry does not constitute a significant source but was found to be relevant in the determination of CO_2 removal potential.

Figures 2.1a and 2.1b illustrate emission trends for all greenhouse gases, excepting N_2O which, at an average of about 160 Mg per year, is considered insignificant. The general trend is an increasing one for most gases, CO_2 in particular.

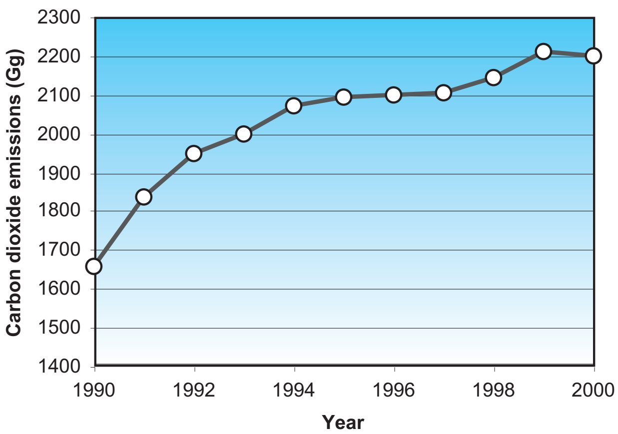

Figure 2.1a CO2 emission trends for 1990-2000.

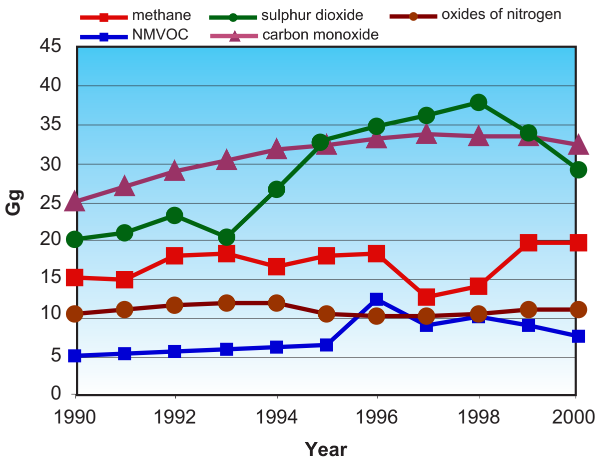

Figure 2.1b GHG emission trends 1990-2000 for CH4, CO, NMVOC and SO2.

Several problems were encountered during the compilation of the inventory. In the energy sector, information about the destination of fuels sold by large private distributors was not available. Similarly, there is a lack of information concerning primary energy use in industry. The practice of recording imports by monetary value has hindered emission calculations.

2.2 Introduction

Partial greenhouse gas (GHG) inventories were drawn up for 1990 and 1994 according to CORINAIR guidelines (EEA, 1996 and 1997), and a synoptic GHG emission inventory was drawn up for 1997. The latter was limited to the energy sector but was in fact drawn up according to IPCC guidelines as required by the UNFCCC. The 1997 Inventory was limited to the energy sector owing to lack of data availability in other sectors. It was motivated by an impression that this sector was the main contributor to GHG emissions, at least as far as CO_2 was concerned. In any case, of the greenhouse gases listed in the IPCC guidelines, year 2002 emissions from the energy sector of CO_2, CO and NO_x fall within 10% of the respective 1997 values. This allows for the absence of CO_2 sinks in the 1997 inventory. On the other hand, CH_4 emissions are 50% higher, while N_2O emissions are almost seven times those reported in the 1997 inventory.

The 1990 and 1994 inventories covered energy as well as the other IPCC sectors but, again, no sinks were included. There are obvious discrepancies between the two. For instance, transport-related NMVOC and CO for 1990 are listed as unchanged in 1994, notwithstanding an increase of 20,000 vehicles registered in the interim period.

Not all of these problems have been overcome in the present GHG Inventory. There is a well-defined methodology available (IPCC, 1996a), use of which is necessary not only for internal consistency but also for inter-country comparison. Contributions from waste and agriculture have been included, together with those from energy and industrial processes.

There is still a marked variation in the quality of the resulting emission estimates for these various sectors. The most obvious cause of this was variable availability of data. Data sets were most complete for the energy and waste sectors. Data on industrial processes, while covering all the likely fields, had internal inconsistencies and were limited to about half the stipulated time span for the GHG Inventory. Some data relating to agriculture were available for 1990-2000. The problem here lay more in the limited reliability of the basic data on animal numbers, in the lack of information on the methods of treatment of animal waste and on the final destination of such waste. Since the agriculture sector is a major producer of CH_4, it is expected that the relevant emission estimates will carry a significant uncertainty. In dealing with emissions from animal waste treatment, it is certain that no fraction of the CH_4 produced is used as an energy source. However, the actual methods of treatment, or more accurately, disposal, are not known. Aspects of this situation improved following publication of the agricultural census (NSO, 2002), which enabled update of the GHG Inventory.

Land-use change and forestry is significant in the consideration of CO_2 sinks. Data for woodland areas are available, as are estimates for dispersed tree numbers. These include the species Ceratonia Siliqua (carob), which has suffered very heavy loss as a result of land development during the last 30 years. There is also information that enables rough estimates to be made for marine CO_2 sinks, which turn out to be significant. These are not included in the final inventory. Also, the emissions from aviation and marine bunkering activities, although listed, do not form part of the inventory.

2.3 GHG emission inventories by sector

2.3.1 Energy

A fair indication of the state of development of the Maltese economy can be obtained from an examination of the link between GDP and energy consumption. In figure 2.2 (MEPA, 2002), it can be seen that a decoupling of GDP and energy use is perceptible after 1995, against the background of a marginal increase in population.

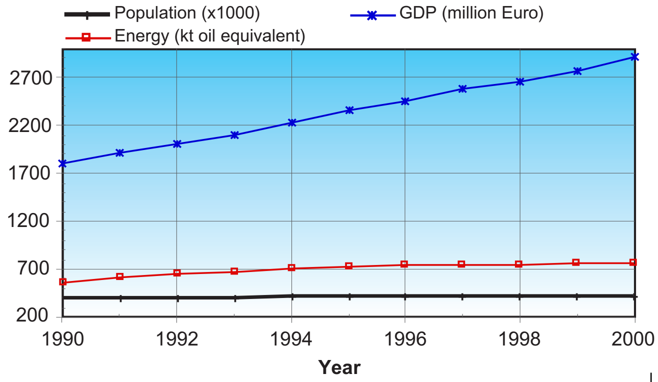

Figure 2.2 Population, energy consumption and GDP trends (MEPA, 2002).

The total population comprises the resident population as well as tourist presences determined by the number of tourist arrivals and by bed-nights. Such an addition amounts to an average of about 30,000 at any given time; equivalent to 8% of the resident population. The figure is large enough to have a significant impact on demand for water and electricity.

Per capita trends in consumption of primary energy, electricity and water shown in figure 2.3 (MEPA, 2002) demonstrate a levelling off after 1995. Whereas primary energy per capita persists at the 1995 level up to year 2000 and water demand drops off perceptibly, consumption of electrical energy resumed its upward trend after 1995.

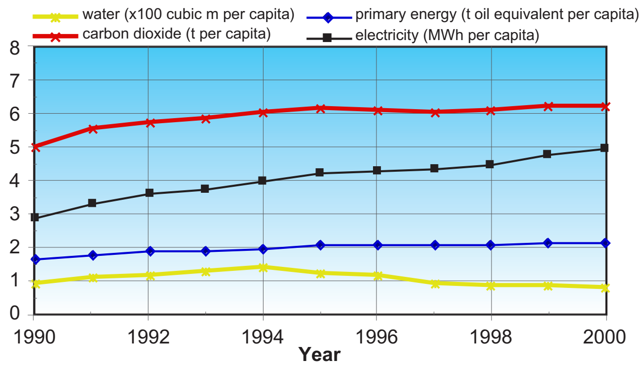

Figure 2.3 Consumption of energy, electricity and water, and resulting CO2 emission per capita (MEPA, 2002).

The CO_2 emissions calculated using a Reference Approach and a detailed Sector Approach show random differences (see table 2.1). The principal source of data was Enemalta Corporation, which had a monopoly on fuel importation over the inventory decade. Data could not be obtained from a small number of private suppliers. This made end-user identification in the detailed Sector Approach impossible, which resulted in the said random differences.

	CO_2 Emissions	
Year	Reference Approach (Gg)	Sector Approach (Gg)
1990	1838	1895
1991	2214	2075
1992	2254	2187
1993	2166	2236
1994	2223	2311
1995	2045	2336
1996	2357	2339
1997	2314	2346
1998	2435	2384
1999	2879	2450

Table 2.1 CO_2 emissions calculated by the Reference and Sector Approaches.

In general IPCC default values for emission factors were used. However, in some cases a number of carefully determined emission factors were used instead of the IPPC values.

The two major contributors of GHG emissions in the energy sector turned out to be electrical power generation and transport. The prominence of the former reflects structural features of energy consumption in Malta. There is no traditional heavy industry processing imported raw materials through use of primary energy, and industrial users consume only small amounts of primary energy. That applies a fortiori to commercial and domestic users. These can avail themselves of an electricity grid that reaches practically all inhabited points on the two main islands.

The other feature that makes the power generating sector such a major contributor to CO_2 emissions is the heavy use of electricity for production of potable water. For about 20 years, Malta has met around half of the demand for potable water by Reverse Osmosis (RO) desalination of seawater. At peak RO use in 1995, water production accounted for 18% of total electricity sales. By the year 2000, this share had dropped to 8%. However, this decline has hardly featured in the national figures for energy consumption (MEPA, 2002).

2.3.1.1 Electricity generation

The general trend in demand for electrical energy during 1990-2000 has been upward, with CO_2 emissions following suit. However, both show changes in rate of increase as various factors came into play during the decade. Figure 2.4 shows CO_2 emissions from electricity generation and transport, and electrical energy generated over the decade.

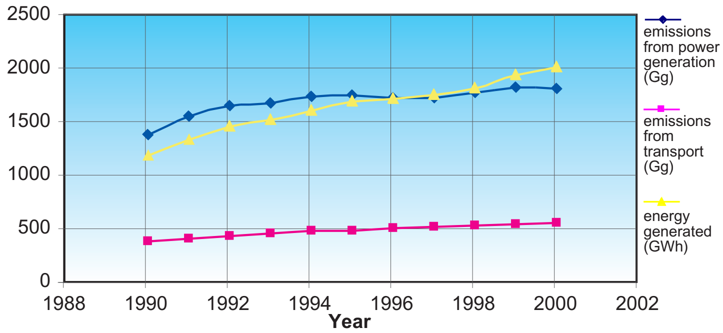

Figure 2.4 CO_2 emissions from electrical power generation and transport, and electrical power generated.

The curves follow a closely similar pattern, with the change in gradient following 1995 being more marked for CO_2 emissions than for generated electrical energy. In fact, between 1990 and 1995 electrical energy production saw an average 5% yearly increase. The rise in demand eased off after 1995 because of the decline in electrical energy use by the Water Services Corporation (WSC), the largest single consumer. From 1994-1995 and 1999-2000, WSC nearly halved its consumption. Despite this absolute cut-back, electrical energy demand had almost resumed its previous rate of increase by 1997 (MEPA, 2002). A look at the large sector consumers of electricity provides a good indication of the source of this resumption (see figure 2.5). While industrial consumption, which includes WSC, shows the 1995 change, the consumption for the commercial and domestic sectors does not. At the same time, a marked narrowing of the gap between winter and summer peak demand for electricity developed, with summer peak demand coinciding with periods when air temperature was in excess of 35°C (Enemalta Corporation, 1996-2000). The main reason was a very rapid rise in the sale and operation of air conditioners.

CO_2 emissions responded to the drop in WSC consumption. In 1995 the remaining coal-fired capacity at Marsa Power Station (MPS) was phased out, principally because of pollution problems at the coal pound and difficulty in the disposal of fly ash. All Marsa boilers were switched to heavy fuel oil (HFO), which has lower carbon content and a higher calorific value than coal. The resulting decline in CO_2 emission is clearly visible; it is more extended than the decline in the rate of increase in demand (see figure 2.4).

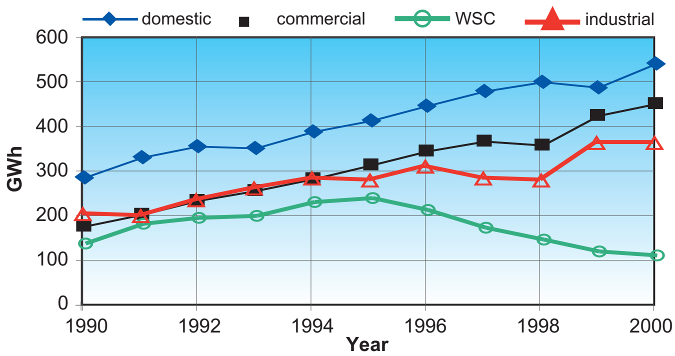

Figure 2.5 Trends in electricity consumption by sector (MEPA, 2002).

Three other gases in the GHG inventory were markedly influenced by the phasing out of coal at MPS. N_2O dropped to about 6 Mg from a previous value of 15 Mg prior to 1995, while NO_x dropped from 6.5 to 4.5 Gg. SO_2 emissions increased sharply when coal, with 0.5% sulphur, was replaced by HFO with 2-3% sulphur (figure 2.6). The higher calorific value of the latter did not quite compensate for its sulphur content.

2.3.1.2 Transport

GHG emissions from transport show a steady increase during 1990-2000, in step with the rise in vehicle numbers. The numbers of private cars during the decade covered by the inventory increased at an annual average rate of 7%. This has been paralleled by a 6% increase in road traffic, suggesting a fairly constant rate of car use. Calculations from fuel sales, adjusted for improved fuel economy, also suggested close to 6% annual increase in traffic (Stafrace, 2002). However, the proportion of diesel vehicles has increased steadily because of better fuel economy and lower fuel price. The premium on purchase price of diesel vehicles has not acted as a deterrent.

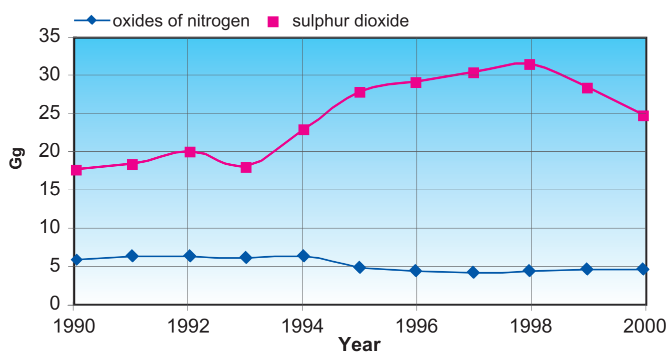

Figure 2.6 Power station NO_x and SO_2 emissions.

CO_2 emissions from transport (figure 2.4) have increased by 40% over the decade and remained about 20% for the total energy sector. CO, NMVOC and NO_x emissions are shown in figure 2.7. CO emissions (mainly resulting from the petrol fleet) dominate this sector. NO_x emissions from energy generation reached parity with CO after 1995 and have maintained that position. Transport generated NMVOC, on the other hand, has been dominant in the energy field.

2.3.2 Industrial processes

Data on the industrial processes sector is scarce. Details of a wide variety of implemented processes are not revealed for commercial reasons. While there is little difficulty in tracing the various types of imported raw materials, it is often impossible to establish quantities because of the practice of recording imports by monetary value.

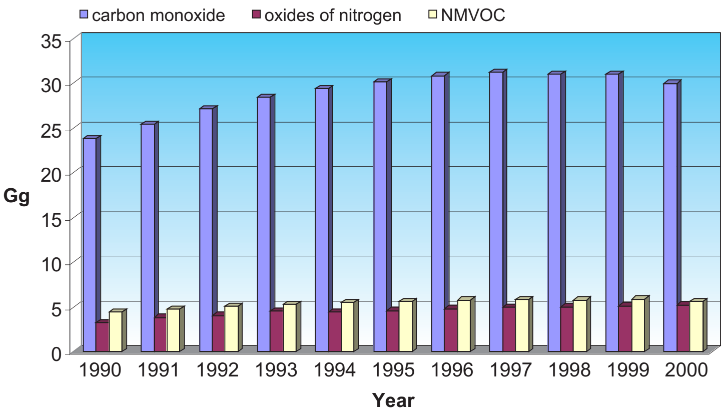

Figure 2.7 Emissions of CO_2, NO_x, and NMVOC from transport.

Some of the difficulties involved are illustrated in dealing with local production and importation of building lime. As far as production is concerned, lime is CO_2-neutral, as the CO_2 produced in breaking down the carbonate ($CaCO_3$) raw material is reabsorbed when the lime is hydrated and used. However, fuel is used in the production of lime. As no information on fuel use is available, the CO_2 that evolved during breakdown of the raw material ($CaCO_3$) was included in the inventory. However, it is estimated that about 0.1 Gg of CO_2 are released if the following assumptions are made:

- fuel used is gas oil;
- the raw material (stone) has to be heated to 900°C;
- 1000 t of lime (CaO) are produced.

This is clearly marginal in GHG inventory terms. On the other hand, the extensive use of imported lime products constitutes a CO_2 sink, the magnitude of which can be roughly determined from the weight of imported lime products. Available data for 1995-2000 suggest weak CO_2 sequestration amounting to about 0.5 Gg, significantly larger than that for CO_2 emissions from local lime manufacture. In the case of CaC_2 production, calculation of the emission factor based on a stoichiometric reaction resulted in overestimate of CO_2 emission.

Fortunately it seems possible to establish that, for most greenhouse gases, the quantities produced are marginal in inventory terms. The one clear exception is NMVOC, where emission is made up in small part by the food processing and beverage industries, but mainly by the manufacture and application of bitumen. The combined emissions (1-3 Gg) from these sources generally amount to a third or less of those from road transport. Industrial use of primary energy could be determined more precisely and GHG emissions from industrial processes more closely monitored.

2.3.3 Agriculture

Agriculture proved a rather difficult sector to handle. Although there is a good body of data on animal numbers, entries for some years and for some species are missing. In some cases there are very large number variations from year to year. From the scattered data available, an attempt was made to produce a consolidated table giving animal numbers during the period 1990-2000 (table 2.2). The major uncertainties are in rabbit numbers over the first half of the decade and in poultry numbers over the whole time span. Fortunately, the contribution of these two categories to GHG emissions is limited. However the impact on total quantities is negligible. Emissions have been estimated according to IPCC revised guidelines (IPCC, 1996a) using default emission factors for an 18.5°C mean annual temperature.

Rabbits, not being considered in IPCC guidelines, presented a problem. Advice had to be sought on the biological proximity of listed species. It transpired that goats offer the closest resemblance in enteric processes. Equivalence was determined by using a body weight ratio of 50:1.

Year	Caprines	Ovines	Bovines	Equines	Poultry	Rabbits	Swines
1990	3429	4623	12891	944	1500000	37642	61607
1991	3429	4623	12891	944	1500000	37642	61607
1992	5300	6000	22000	860	1500000	40000	109000
1993	5300	6200	21500	840	1500000	40000	109000
1994	5000	5600	19800	760	1500000	40000	111000
1995	10169	14773	23049	740	1200000	200000	115120
1996	8436	12327	21894	700	570000	200000	106636
1997	6407	14975	24197	650	570000	200000	73362
1998	5738	12589	15486	640	570000	400000	65572
1999	5110	11839	16902	600	570000	400000	63946
2000	4599	12492	16742	590	570000	400000	64754

Table 2.2 Animal populations, 1990-2000.

All cattle were assumed to be of the dairy type as there are no specific beef herds in Malta. Local beef production is low and is a spin-off from dairy activities, e.g. raising of male heifers and slaughter of less productive dairy cows (NSO, 2002).

Reliable information on the management of animal waste is lacking. There is some direct spreading of animal (mainly bovine) waste on fields but there is also illegal dumping of animal (pig) waste into the domestic sewerage. Under the circumstances, IPCC default emission factors were used to estimate CH_4 emissions. This method is bound to give an upper limit because it assumes complete anaerobic digestion. In any case quantities of CH_4 resulting from manure management amount to only a few tenths of a Gg per year. The inventory therefore reflects both types of emission by the animal population. These could have reached 3-4 Gg of CH_4 per year.

The above reasoning cannot be applied to estimate N_2O emissions as these depend on the specific management method. Only two manure management systems, about which information was available, were considered: liquid system, and solid storage and drylot. In the former case, the only appreciable N_2O contribution came from swine. N_2O emissions from swine manure were not calculated under the solid storage and drylot regimen, since swine manure is not treated in this way. The only contribution came from dairy cattle.

2.3.4 Land-use change and forestry

This sector is of very limited relevance in Malta. The major change in land use over the last forty years has involved the eradication of arable land by building sprawl. The present built-up area amounts to 21% of the total national territory, while arable land covers about 35%. The crop types, mainly vegetables and fruit, do not leave significant residues. This, combined with the restricted woodland areas, produces no source of CO_2 emissions from biomass burning.

The data involving tree types, numbers and areas are adequate for estimation of CO_2 sink capacity. There is a total of about 200 hectares of woodland, made up of 30 hectares at Buskett, 50 hectares at Mizieb and a large number of small areas, generally less than 10 hectares. To these another 22 hectares, represented by small parks in urban settings and by roadside trees, must be added. The resulting sink capacity is small. For the year 2000, CO_2 removal capacity was 112 Gg, when compared to a total emission of 2444 Gg.

As there is no systematic harvesting and fuel wood use, no emissions from this source have been included. The heavy loss of the species Ceratonia Siliqua was the result of planned and unplanned building sprawl. It does not lead to use of the wood, which usually ends up in landfills.

2.3.5 W aste

Waste sector contributions to the GHG inventory have been fairly constant throughout the inventory period, as a result of the comparatively small fluctuations (< 25%) in the quantities of all liquid and solid waste. MSW includes industrial waste of the same composition, which is partly why the amount of MSW appears to be high at 1.7 kg per capita per day. Treatment methods have not changed much either, with MSW going to landfill and no controlled waste incineration. In the case of sewage, the relevant quantity is the fraction of sewage treated at Sant' Antnin Sewage Treatment Plant, rather than the overall volume of liquid waste generated. The untreated fraction, at least 90% of the total, is discharged to sea at a number of points around Malta and Gozo. There cannot be much doubt that in the sewage dumped offshore, some anaerobic action does take place, resulting in evolution of methane, but no attempt at estimation of such emissions has been made.

The three sources of solid and liquid waste generated approximately 13-15 Gg of CH_4 annually, as well as much smaller amounts of N_2O. Combined with the CH_4 production of 3-4 Gg from animal husbandry, total methane emissions could have reached 20 Gg annually. However, the total release of about 0.01 Gg of N_2O is just at the limit of significance, or about half the amount produced by the energy sector.

2.4 Problems associated with data compilation

The GHG Inventory is dominated by the contribution of the energy sector, certainly as far as the three inventory gases CO_2, CO and SO_2 are concerned. The fact that the quality of the final results is not heavily influenced by less significant sectors, with the possible exception of CH_4, comes about because the latter have turned out not to have dominant sources or sinks for greenhouse gases. Even so, there are areas where improvements in the database are required to better the quality of future inventories. In the energy sector, particularly with the impending liberalisation of some market sectors, the destination of fuels sold by large private distributors needs to be known, in order to allow a more complete detailed sector level evaluation of emissions.

Neither of the two major private distributors provided sales data for the purpose of examining the Reference Approach in inventory compilation. The gap could be partly filled with overall importation figures from Enemalta Corporation. Much the same problem exists as far as primary energy use in industry is concerned. There are sectors of industry which use considerable quantities of primary energy in static situations but there is no published information as to quantity. This is exacerbated by the practice of recording imports by monetary value, rather than actual amounts. Furthermore, there is very little information about the split in fuel use between mobile and static devices in the construction industry.

Chapter 3

Greenhouse Gas Abatement Analysis and Mitigation Measures

3.1 Executive summary

The search for emission mitigations naturally concentrated on those areas that emerged from the inventory as major emission sources. These were the energy sector, transport and waste management, including that of agricultural waste. Current data on these areas was reliable. However, the quality of projections for 2010 varied somewhat, depending on the extent of quantitative description. Cost and social acceptability of the proposed measures are not discussed here.

With the present electricity generation arrangements, there are a number of directions in which one can look for possible mitigation measures. Gains in generating efficiency, principally by replacing the Marsa generators by new ones, preferably gas turbines, would produce mitigation proportional to increases in efficiency.

Changeover to fuels with lower carbon content, e.g. from heavy fuel oil for steam turbines to gas oil for gas turbines, offers even better results. However, Malta does not yet have the expensive infrastructure to ensure a constant supply of the best fossil fuel (methane) for this purpose. Two combined cycle gas turbines working on natural gas are capable of bringing 2010 CO_2 emissions down to those for 1990.

Improvements in power transmission and distribution, and a sustained effort to improved demand side management, employing well-tried technology could also result in significant mitigation.

For road transport, dominated by the private car, the most obvious source of mitigation would be restrictions on car use. Curtailment measures on the use of petrol powered cars would eliminate about 20 Gg of CO_2 per year by 2010.

A modern unleaded petrol-engine fleet equipped with three-way catalysers (TWC) would cut down heavily on emissions of CO and NMVOC, but at the cost of an increase in CO_2 emissions. TWC eliminate petrol-derived NO_x without the penalty of other emissions.

Biodiesel offers significant GHG emission advantage, while hydrogen, either in internal combustion engines or in fuel cells, would eliminate car and bus generated GHG. However, the prospects of high penetration of these alternative fuels into the local market by 2010 are rather limited.

The same slow market penetration is likely for pure and hybrid electric traction, where the former can produce CO_2 cutbacks compared to a TWC petrol car, and the latter cutbacks in all vehicle GHG emissions.

As a major user of electrical energy, the Water Services Corporation has already started an energy efficiency drive. Development of this drive would produce worthwhile mitigation in CO_2 emissions. Moreover, demand-side management of water consumption would enhance cuts.

Sewage treatment plants can be a major source of methane emission. In the local case the relatively small fraction of treated sewage will not change until around 2005, by which time the present facility would be upgraded and one or two new plants should come into operation. Following 2005, a choice of aerobic treatment with sludge incineration would achieve major methane emission mitigation. On the other hand, partial centralisation of animal manure treatment could yield methane for use in process heat, electricity generation and even in transport. In each case, conversion of methane into CO_2 would diminish greenhouse impact.

With year 2000 solid waste management producing about 14 Gg of methane, there is ample room for improved practice. Composting (aerobic treatment) and combustion of municipal solid waste would yield limited reduction of CO_2 emission compared to present practice. If land filling were used instead, gas (CH_4) collection and use would result in about 180 Gg of CO_2-equivalent emission per annum.

Finally, this chapter suggests that, with attention to detail, significant mitigation of GHG emissions is possible without incurring heavy costs. Only the largest cutbacks in the energy sector would require substantial expenditure on the necessary infrastructure.

3.2 Energy sector

3.2.1 Introduction

Greenhouse gas reduction potential is strongly dependent on increased efficiency. The overall plant efficiency on the Maltese islands averaged about 27% during 2001, much lower than the 35% prevalent in OECD countries (Watson et al, 1996). Improvement in plant efficiency will result in significant emission reductions of pollutants such as SO_x and NO_x.

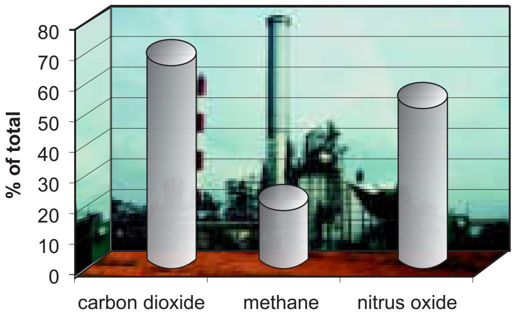

Figure 3.1 Relative contribution of energy generation to total GHG emissions in 2000.

In 2000, at a figure of 1783 Gg, emissions of CO_2 from the energy generation industry accounted for 73% of the emissions from the energy sector (Figure 3.1). In the same year this sector was also responsible for 23% and 56% of the total emissions of CH_4 and N_2O, respectively.

Mitigation measures and policies can be introduced across the whole energy sector by increasing efficiency in fuel conversion, distribution and end use. An effective measure bringing about a significant reduction of GHG would consist of switching to fuels that are more efficiently converted.

As the energy sector in Malta is a public utility, most actions taken to address mitigation will directly affect the public. While some actions may involve only the utility, others necessarily involve the whole population. In order to ensure some degree of success, mitigation measures need to involve all stakeholders.

3.2.2 Increasing the efficiency of power generation

Electrical power generation between 1990 and the present has been achieved by fossil fuel power stations based at Marsa in the central part of Malta and later at Delimara in the south. The older facility at Marsa (MPS A) consisted of five steam turbines and one gas turbine providing 30 MW at 16% and 14% efficiency respectively and was in operation until 1994. MPS B is an open cycle gas turbine (OCGT) introduced at Marsa in 1990, providing 36 MW at about 25% efficiency. The Delimara power station started operating in 1995.

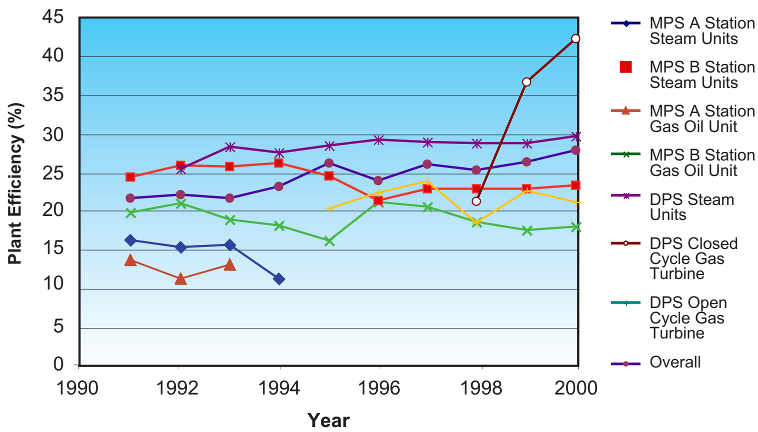

Figure 3.2 Power plant efficiency.

Although efficiency improvement of the energy cycle in existing plants offers an obvious partial solution, certain inherent deficiencies such as plant age and design are not easily circumvented.

The use of combined heat and power production offers a significant increase in fuel utilisation. However, to date the public utilities have had no opportunity to supply heat for use outside of the generating plant. Instead, only some of the generated heat is used to enhance the efficiency of the electricity production process.

Figure 3.2 represents fuel plant generating efficiency at operating power plants. The machines at MPS A were shut down after 1994, since both the gas turbine and the steam generator hardly reached 16% efficiency. The performance of the steam units at MPS B resulted in an efficiency of 19- 20%, while the overall average was 25%, with a specific consumption of about 0.32 kg of fuel per kWh generated. The new plant at Delimara Power Station (DPS) has delivered efficiency levels of as high as 29% with the steam units introduced in 1992.

The 36 MW OCGT, introduced in 1990 at MPS and in 1995 at DPS, operate at different efficiency levels, even though their design is similar, because of different operating conditions. The efficiency of a gas turbine varies with the amount of electricity it generates; the lower the load, the lower the generating efficiency. Thus, the policy at DPS is to run the open cycle gas turbines at base load, i.e. at the rated load, so that when they are called into action, the operating efficiency of these machines is maximised. In contrast, the gas turbine at MPS is mainly used for peak clopping, i.e. loaded only up to specification during peak demand. This means that, here, the turbine normally runs at reduced efficiency levels.

The 110 MW closed cycle gas turbine (CCGT) at DPS offers the best efficiency and the best fuel consumption to power generated ratio. In 2000, 367 GWh were generated at an average efficiency of 38%. Figures for 1998 and 1999 incorporate the start up/commissioning period; hence the lower efficiency figures for these years. In 2001 this plant was not used to its maximum capacity and thus resulted in a lowered efficiency of 34.4%.

The overall efficiency of power generation has increased from about 23% in 1991 to almost 28% in 2000. Reduced use of the CCGT in 2001 has had a significant positive impact. The question remains as to which plant or plants can give the most cost-effective improvement in efficiency.

Some technology options (e.g. combined cycle power) were introduced locally as they became commercially viable. Other new generation high-efficiency technologies based on coal, including pressurised fluidised bed combustion and integrated gasification combined cycles, are as yet not considered in the local context, mainly on account of the ash disposal problem.

The use of natural gas would present several advantages, as will be discussed in the following section. In combined cycle power plants, natural gas has the highest conversion efficiencies of all fossil fuels. This is currently 45% in the short term and 55% in the long term (Watson et al, 1996). Important considerations are high initial capital expenditure for introducing the technology and the possibility of relatively higher fuel costs.

3.2.3 Switching to fuels with lower carbon emission factors

It is possible to use fuels with a lower carbon to hydrogen ratio for power generation. The options include switching power stations from fuel oil to gas oil or from gas oil to natural gas. At 15 t/TJ, natural gas has the lowest carbon emission factor of all fossil fuels (IPCC, 1996b). Residual fuel oil and gas oil have emission factors of 21 and 20 respectively. An added benefit of switching to natural gas would be more efficient energy conversion.

Nine distinct scenarios (Table 3.1) are envisaged and analysed in terms of their relative cost-effectiveness in GHG emission reduction. The gases considered are CO_2, CH_4, NO_x and SO_x. The scenarios start from 1990 levels and include extrapolation of emissions to 2010.

Table 3.2 shows the CO_2 emissions resulting from the nine scenarios. Scenario 7 resulted in the lowest emission. Although the cost of fuel is highly variable when considering current prices, scenarios 2, 4, 6 and 8, which are based on CCGT running on gas oil, would lower the national annual expenditure on fuel by about 1 to 2 million US dollars. According to scenario 7, about 15 000 TJ would be required. Based on a price for natural gas of US$302.37 per tonne (www.autorita.energia.it/gas) and considering only fuel prices, expenditure on fuel would

1	Business-as-usual, based on the patterns of fuel burning in 2000.
2	One CCGT burning gas oil and working on full load for 11months a year.
3	One CCGT burning gas oil and working on full load for 11months a year until 2005, following which use of natural gas is introduced.
4	One CCGT burning gas oil working on full load in daylight hours and half load at night, for eleven months a year.
5	One CCGT burning gas oil working on full load in daylight hours and half load at night for eleven months a year until 2005, following which use of natural gas is introduced.
6	One CCGT burning gas oil until 2005, when a second CCGT is introduced, with only one of the two running fully loaded and the other running on variable load for eleven months a year.
7	Two CCGT burning gas oil until 2005, when natural gas is introduced, with only one of the two running fully loaded and the other running on variable load for eleven months a year
8	One CCGT burning gas oil until 2005, when a second CCGT is introduced, both running on variable load.
9	Two CCGT burning gas oil until 2005, when natural gas is introduced, both running on variable load.

Table 3.1 Future CO_2 emission scenarios.

Year	Scenarios							
	2	3	4	5	6	7	8	9
2002	229	229	167	167	229	229	167	167
2003	228	228	165	165	228	228	165	165
2204	227	227	164	164	227	227	164	164
2005	226	338	163	251	449	648	386	561
2006	225	337	162	250	448	647	385	560
2007	224	336	161	249	447	646	384	559
2008	223	335	161	248	446	645	383	558
2009	223	335	159	247	445	645	383	557
2010	222	334	159	247	445	644	382	557

Table 3.2 Difference in Gg in CO_2 emissions between business-as-usual scenario and the other scenarios.

Year	Scenario				
	1	6	7	8	9
2003	32.1	20.1	20.1	23.4	23.4
2004	32.9	21.0	21.0	27.3	24.3
2005	33.7	10.0	-0.5	13.3	4.1
2006	34.4	10.8	0.3	14.1	4.9
2007	35.1	11.5	1.0	14.8	5.6
2008	35.7	12.2	1.7	15.5	6.3
2009	36.3	12.8	2.3	16.1	6.9
2010	36.9	13.4	2.9	16.7	7.5

Table 3.3 Percentage emissions over 1990 levels for indicated scenario.

increase by US$3 million annually. As a signatory of the Kyoto Protocol, if Malta is obliged to take 1990 as the base year for emission reduction, this would have to result in a CO_2 emission not exceeding 1900 Gg for the entire energy sector. In that case, introduction of natural gas would appear to offer the best solution. This is evident from Table 3.3, which represents the best four scenarios, where scenario 7 is the only one that predicts sufficient reduction in CO_2 emissions.

Nitrogen Oxides (NO_x), Carbon Monoxide (CO) and Non-Methane Volatile Organic Carbons (NMVOC) are indirect greenhouse gases. These gases form ozone which, in the troposphere, acts also as a GHG. Electricity generation is only important as a source of NO_x. Introduction of natural gas will bring about a reduction of NO_x emissions in respect to mid-1990s levels.

Further reductions in NO_x emissions may be achieved by pre-combustion, combustion and post-combustion techniques. Examples of these techniques are water/steam injection in the fuel/air stream, various designs of low NO_x burners, selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR). SCR has already well proven its efficiency achieving reductions of NO_x emissions of over 80% annually. Apart from installation on any new CCGT, refurbishment of the two heat recovery steam generators (HRSG) installed at DPS would allow the implementation of SCR technology within the near future. However, it is noteworthy that, between 1990 and 2000, NO_x emissions from power generation have declined. Conversely, NO_x emissions from the transport sector have increased by approximately 170 Mg yearly.

SO_x emissions from the energy sector in 2000 amounted to 93% of the respective total, hence the significance of this sector. Between 1990 and 1998, SO_x emissions have increased to almost 35 Gg. This is associated with the refurbishment of MPS main boilers from coal burning to residual fuel oil with high sulphur content. In 1998, residual fuel oil of lower sulphur content was introduced. This gave rise to a decline in SO_x emissions. In general, switching to a fuel with lower sulphur content, such as gas oil or natural gas, would further curtail emissions.

The Long Range Transboundary Air Pollution (LRTAP) Convention has two protocols on sulphur. The second defines country-specific emission limits effective from 2004. As a signatory, Malta has to implement an effective programme to curtail SO_x emissions.

Implementation of CCGT is not sufficient to bring about the necessary GHG emission reduction, unless this is accompanied by the introduction of natural gas. One disadvantage with the wider use of natural gas is the additional leakages of CH_4, the main component of natural gas. Nevertheless, there are ways to reduce leakages from distribution systems by up to 80% (Watson et al, 1996).

3.2.4 Improving energy efficiency in the distribution sector

Transmission losses are incurred in both cables and transformers constituting the distribution network. The public utility on the Maltese islands has embarked on a programme of installing power factor (the ratio of the true power, measured in Watt, used in the system to the apparent power measured in VA) correctors in 11 kV and 415 V sub-stations.

However the utility has to generate and distribute what is required by the end user i.e. the apparent power. Residential meters measure only Watt however meters of industrial consumers measure kVA. Thus it would be in the interest of these major consumers to increase the power factor of their plant, hence reducing their costs. The utility would then have the indirect advantage of fewer losses in the system and lower technical specifications in terms of apparent power of its equipment for the same load. The Malta Resources Authority could also adopt a policy requiring plant operators to achieve a power correction factor of at least 0.95 within a reasonable period of time.

The losses from the transmission/distribution network are estimated at 5%. Based on year 2000 figures, the amount of power lost reached 90 GWh, resulting in about 86 Gg of CO_2. Based on a business-as-usual scenario, the electricity generated in 2005 would result in the emission of about 97 Gg of CO_2 and 66 Gg in scenario 7.

3.2.5 Improving end use efficiency

The domestic, commercial and industrial sectors consume roughly equal amounts of electrical energy. Utility investments in energy efficiency can keep utility bills lower because they can be more cost-effective than building new power plants. However, it is envisaged that demand will continue to grow for the near future, thus necessitating further investment in energy generation. Demand side management (DSM) can help delay the requirement for new investments. The utilities can work with customers to reduce the latter's demands for electrical power or to shift these away from periods of high electricity demand. DSM may result in lower electricity bills for the consumer and lower generation costs. Examples of improved utilisation of electrical power include:

- use of energy efficient motors, adjustable speed drives and better pumping or air conditioning system design;
- use of small combined heat and power (CHP) units in large hotels, industrial areas and hospitals;
- use of compact fluorescent lamps and lighting based on appropriate technologies in both large and domestic spaces (fluorescent tube systems with appropriate shades for directional lighting, sulphur lamps, etc.);
- improvements in building design and technology with a view to reduce reliance on space heating and air conditioning, energy for which is derived from combustion processes;
- incentives for the proliferation of alternative energy devices e.g. solar water heaters, photovoltaic panels, etc.

Implementation of the above presents problems, such as:

- lack of knowledge – residences and small/medium sized enterprises may not be informed sufficiently about the opportunities for energy savings;
- relative economic viability – for an enterprise which is not energy intensive, initiatives to reduce energy consumption would not be cost-effective
- limited availability of capital required to invest in improved energy efficiency;
- rapid payback requirements;
- current energy tariff structures.

These problems may be partially resolved by implementation of adequate awareness and education campaigns.

3.3 Transport

3.3.1 Introduction

In a discussion of mitigation of GHG emissions for transport there are a number of projections that must be made, which are related to changes in numbers, composition and use of the vehicle fleet. The degree of difficulty and reliability of these projections depend on the quality and range of information available, as well as on the rapidity of social change.

The local situation is a mixed one. There is a good (and improving) output of data, with occasional lacunae. For instance, despite two household travel surveys carried out by the Planning Authority (PA, 1989) and the Malta Environment and Planning Authority (MEPA, 1998), information on intensity of vehicle use and its evolution is still insufficient.

3.3.2 The vehicle fleet

The components of the vehicle fleet included in the subsequent projections are as follows:

- commercial vehicles, all of which are assumed to have diesel engines (actually about 98% in 2000);
- private cars, having an evolving petrol/diesel ratio, starting from 18% diesel in 2000;
- self-drive hire cars, all assumed to have petrol engines (actually about 99% in 2000).

The future evolution of the private car stock will depend to a large extent on individual wealth. Predictions can be made using a number of indicators such as disposable household income or Gross Domestic Product. The connection of this latter indicator is indirect; moreover it contains factors which are extraneous to disposable income. Nevertheless GDP was used simply because the information available was deemed to be more reliable than that about household income.

The Malta GDP over the decade 1990-2000 is shown in Figure 2.2. A linear extrapolation to 2010 gives growth factors of 1.2 for 2005 and of 1.4 for 2010, close to predictions over the same period for Portugal and Greece, the EU members closest to us in GDP per capita. These incremental factors were applied to the 182,100 private cars registered at end of 2000, resulting in 218,500 in 2005 and 253,000 in 2010.

A different approach was adopted in MEPA (2001). The forcing parameter was taken to be the number of nondrivers per household for a given year, with saturation of vehicle ownership being reached when this number was driven to zero. With 1.45 vehicles per household in 1998, 1.74 vehicles per household were predicted for 2010, which translates into 258,000 registered private cars in that year. This is bound to be an upper limit, as congested roads will persuade people to cut down on the purchase and use of cars.

Projections of disposable household income could serve to substantiate these figures. Estimates of such income over the period 1989-98 (MEPA, 2001) suggest a 4% annual increase, which is flanked by a 5% increase in car ownership. With some tail-off in the rate of the 1990s increase in disposable household income, 2010 would see a private vehicle fleet of 255,000 cars.

In the year 2000, 17.7% of the private car fleet was powered by diesel engines, as against about 13% in 1997. This upward trend is likely to continue, albeit at a reduced rate as diesel and petrol prices converge. A diesel penetration rate of 25% was assumed to hold in 2010.

Two further contributions to the vehicle fleet must be taken into account. The number of self-drive hire cars, assumed to be all petrol-driven, has fluctuated at around 4000-5000 over the last 5 years. Given the seasonal and almost saturated nature of the forcing parameter, i.e. “number of tourists”, this number (5000) was assumed to remain constant over the projection period. As for commercial vehicles, over the last five years these have amounted to about 25% of private vehicles, with over 90% of them having diesel engines. It was assumed that this proportion to private cars is maintained, and that all commercial vehicles are diesel powered.

Year	Fuel type			
	Petrol (passenger car)	Diesel (passenger car)	Diesel (commercial)	Petrol (self-drive hire)
2000	149,900	32,230	43,200	5,000
2005	170,450	48,115	53,600	5,000
2010	191,000	64,000	64,000	5,000

Table 3.4 Evolution of vehicle fleet (2000-2010).

The final projections of numbers and types for the vehicle fleet are shown in Table 3.4. Apart from the evolution of numbers and composition of the vehicle fleet, intensity of vehicle use could influence GHG emissions. Unfortunately, there is an almost complete absence of information on annual vehicle-km. An attempt to derive some information is made in MEPA (2001), through relating fuel use (adjusted for improvements in consumption) to numbers of registered vehicles. The comparison suggests that there was no detectable increase in intensity over the last five years, a conclusion reinforced by the finding that increases in traffic volume match the increase in car numbers. On the other hand, the prediction that trips at the morning rush hour are set to increase at 2% per annum beyond 1998 (ibid.) might imply increased intensity of use. As the basis for this conclusion is rather weak, a constant intensity of use was assumed over the projection period.

Year	Fuel type			
	Petrol (passenger car)	Diesel (passenger car)	Diesel (commercial)	Petrol (self-drive hire)
2000	149,900	32,230	43,200	5,000
2005	161,930	46,190	50,116	4,750
2010	171,900	58,900	64,000	4,500

Table 3.5 Evolution of vehicle fleet and fuel economy (2000-2010).

3.3.3 Mitigation

Before analysing mitigation through improved vehicle efficiency, it is worth considering reduction of vehicle-km, in terms of the "effective number of vehicles". Improvements averaged about 1% per year for petrol cars over 1992-2000, about 0.8% per year for diesel cars and close to 1.3% per year for diesel commercial vehicles. Maintaining these improvements over 2000-2010 would result in the effective number of vehicles decreasing to the values shown in Table 3.5.

3.3.3.1 Restrictions on vehicle use

The most direct, the most effective and possibly the most difficult method to implement socially is the restriction of car use. As increase in intensity of use was assumed, to stabilise car emissions at year 2000 values by 2010, car use has to come down by the percentage number increase. From Table 3.5, it can be seen that only in the case of petrol cars, with rather contained percentage increases (8% by 2005 and 15% by 2010), is there any chance of restrictions of a sufficient magnitude.

A range of policy options designed to secure reduced car use is currently under investigation. The most obvious ones are an increase in fuel prices, a tax on vehicle emissions, time and cost parameters of parking and increasing the appeal of public transport. Such policies would be effective only if used in combination.

With the above restrictions, significant GHG emission quantities would be spared. For example, by 2010, 7.5% of all greenhouse gas contributions of the petrol fleet would be eliminated. For CO_2 alone, this would result in a reduction of 20 Gg of the gas, or about 4% of the whole transport contribution for 2000.

3.3.3.2 Use of catalytic converters

Leaded petrol was phased out in January 2003. Although European motor manufacturers have been fitting catalytic converters to their cars since 1993 and Japanese makers since well before that year (Elsom, 1996), there is no reliable local information on numbers of registered cars with catalytic converters. Local importers of European cars all claim that their cars carried converters. Emissions testing in the Vehicle Roadworthiness Test (VRT) was introduced recently but owners are not obliged to reveal whether their car has a converter. There is a single set of emission criteria with a sliding scale dependent only on the age of the vehicle.

The presence of a modern three-way catalyser (TWC) will have a strong impact on emission of three greenhouse gases; namely, CO, NO_x and NMVOC. As CO and NMVOC are produced almost exclusively (97%) from petrol-powered vehicles, installation of TWC will remove these from circulation. Assuming 0% in 2000, improving to a completely catalysed fleet by 2005, a rather optimistic scenario would eliminate about 80 kt of CO, nearly three times the 2000 transport CO, and 15 kt of NMVOC, 2.7 times the transport NMVOC for 2000. By 2010 the quantities of mitigated CO and NMVOC would be about 170 kt and 32 kt respectively. However, it needs to be emphasised that in these two cases the TWC is removing ozone precursors but increasing CO_2 emissions. The 80 kt CO would convert to nearly 130 kt of CO_2, or about one quarter of transport associated CO_2 emissions for 2000.

The situation with the TWC treatment of NO_x is different. The oxides of nitrogen are broken up into N_2 and O_2, neither of which is a GHG. However, some 20% of transport NO_x comes from diesel engines, which usually have simple oxidation converters that do not act on NO_x (Elsom, 1996). By 2005, 11 kt of NO_x would have been treated without conversion to another GHG. This figure should rise to about 23 kt by 2010. However, recent work indicates that with increasing age, TWC emit increasing quantities of N_2O, a potent GHG (AEA Technology, 1998).

3.3.3.3 Alternative fuels

The alternative fuels that will be considered in this section are biodiesel, liquid petroleum gasoline (LPG), compressed natural gas (CNG) and hydrogen. The first would of course substitute ordinary diesel, the other two would be assumed to be petrol substitutes, while hydrogen can substitute both.

Biodiesel is CO_2 neutral on a vehicle emission basis. If all biodiesel used locally is imported, it still adds CO_2 to the local GHG inventory as the CO_2 that the plant sequestered during growth would have been accounted for in another section of the inventory. However, the amount of CO_2 that biodiesel would generate is half that which would be generated by the amount of mineral diesel that it would displace. If the biodiesel is manufactured locally from originally imported materials (for example, cooking oil), CO_2 would be liberated during the process and would have to be included in the national GHG inventory. NO_x and CO emissions from biodiesel are not significantly different from those of mineral diesel (Hitchcock et al., 1999). Nevertheless, replacement of 2000 t of mineral diesel by biodiesel should bring about a reduction of approximately 1% of CO_2 emissions associated with diesel.

The case for LPG and CNG is quite similar. Such fuels would be imported ready to use. As actual trials have shown that consumption of LPG and CNG is somewhat higher than for petrol in the same vehicle, there is no gain in CO_2 emissions through use of these fuels. As far as CO and NO_x are concerned, a TWC used with these fuels will essentially eliminate both of them, as is the case for unleaded petrol (Hitchcock et al., 1999). Hence, there would be no GHG emission advantage by using these fuels if there is a substantial fraction of TWC in the petrol fleet.

Hydrogen used in internal combustion engines (ICE) or fuel cells will produce no greenhouse gases. Nevertheless, the life cycle for hydrogen will put back some GHG emissions. For instance, at present the cheapest way to produce hydrogen is from the reaction between CH_4 and water, which generates CO_2 as a by product. One kilogramme of hydrogen is required to drive a car 100 km with a fuel cell. In the process, about 70 g/km of CO_2 are produced, without additional GHG, whereas a petrol car consuming 7.3 l/100km produces 250 g/km of CO_2. If the hydrogen is produced by electrolysis powered by a fossil fuel power station, this would result in the generation of 240 g/km. Assuming a methanol source, even lower CO_2 emissions will result – approximately 160 g/km (The Pembina Institute and The David Suzuki Inst., 2000). The only current sources of zero GHG hydrogen are photovoltaic (PV) cells, hydroelectric and nuclear powered electrolysis.

A 0.5% per year market penetration of PV-generated hydrogen as from 2005, would remove 30 Gg CO_2 as well as other small quantities of GHG but less than half that amount of CO_2 if methanol-derived hydrogen is used. Local conditions offer a significant potential for PV-generated hydrogen.

3.3.3.4 Battery electric traction

Electric traction can be viewed from two standpoints:

- pure electric, an autonomous source of motive power;
- hybrid electric, an auxiliary source to take over where the ICE is working under unfavourable conditions.

The end result of the electric traction is to increase the fuel economy of the vehicle by a large factor simply by cutting out the ICE at low speeds. In the case of pure electric traction on-board emissions will drop to zero but there is a transfer of emissions to the power station for batteries charged from mains.

3.4 Potable W ater Production

3.4.1 Introduction

Malta derives its potable water supply through groundwater extraction and desalination by reverse osmosis (RO). The yearly demand is approximately 34 million cubic metres, 51% of which is usually satisfied by groundwater extraction WSC (2001). The four RO plants currently in operation at Lapsi, Cirkewwa, Pembroke and Marsa produce the rest. Desalination of seawater is energy intensive, with average energy consumption per unit volume of 6.24 kWh/m^3. This is more than eight times the specific energy required for groundwater extraction. Hence the general policy adopted by the Water Services Corporation (WSC) is to extract as much groundwater as possible without threatening the aquifer quality. Unfortunately, the quality of the groundwater supply is generally deteriorating due to illegal extraction. This translates into a greater dependence on desalination, and hence increased energy consumption.

During the hydrological year 1999/2000, WSC consumed 131 GWh of electricity, or 8.8% of Enemalta's total sales. This is approximately 36% less than the energy consumed in 1995/1996. This achievement was mainly due to the leakage control exercise carried out by the WSC together with the efficient management of the RO plants and their upgrading.

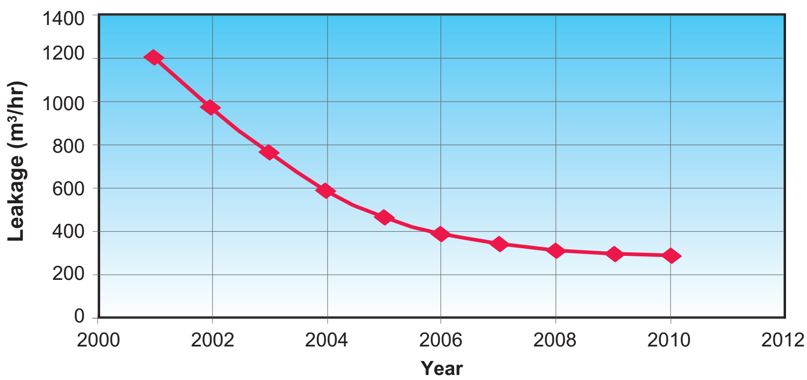

Figure 3.3 Assumed and projected water leakage rates for the period 2001-2010.

The following sections present an estimate of the water demand for this decade. Energy consumption and resulting GHG emissions were estimated assuming current specific energy values. Energy saving measures are discussed and translated into reduced emissions.

3.4.2 W ater demand and GHG emissions

Over the past few years, the national system demand varied considerably. It peaked in 1995 and subsequently dropped precipitously due to the management initiatives taken by the WSC. Recent population increase did not result in a corresponding increase in water demand due to an effective leakage control programme. Several factors were taken into account in projecting water demand.

The simple model adopted here considers demand from the domestic, tourism, industrial, commercial and agricultural sectors. Leakage and apparent losses were also incorporated. Population estimates for the domestic and tourism sectors were obtained from McDevitt (1998) and MTA (2002) respectively. In the latter case, an extrapolation from historical data was necessary. It is not envisaged that there will be appreciable changes in the water consumption pattern of farms, government, industry and other commercial entities. In fact the billed consumption fraction of these entities remained approximately constant for the past six years. The leakage rates assumed are shown in Figure 3.3 and vary from 1200 in 2001 to 300 cubic metres per hour in 2010, in line with the WSC estimates (WSC, 2001).

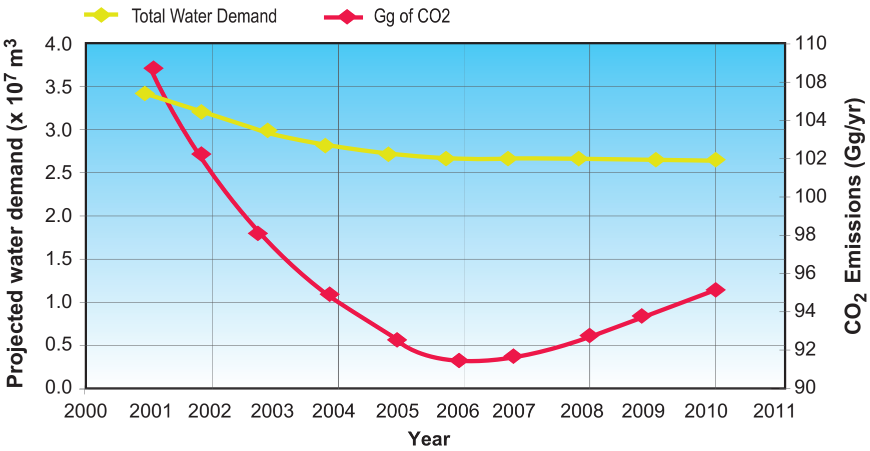

Figure 3.4 Water demand for the period 2001-2010 and corresponding GHG emissions.

Figure 3.4 shows that the projected water demand will continue to decline till 2008 and will then start to increase. If the fraction met by reverse osmosis desalination increases by an assumed 1% per annum, then potable water production will be responsible for approximately 1000 Gg of CO_2 emission during the period 2001–2010. This estimate assumes specific energies of the hydrological year 2000-2001 and fuel use trends by Enemalta in the year 2000. The increasing trend of the RO fraction is already evident in the production data of the hydrological year 2001-2002. Projected GHG emissions for each year are also shown in Figure 3.4.

3.4.3. Mitigation measures

The two main areas where the WSC is investing to reduce energy consumption are inclusion of energy recovery equipment in the RO plants and enhancement of the leakage control programme.

3.4.3.1 Energy recovery in reverse osmosis plants

Malta Desalination Services Ltd. (MDS) is the entity responsible for management of the reverse osmosis (RO) plants. Being one of the largest electricity consumers in Malta, it constantly monitors energy consumption to ensure production at minimum cost. Table 3.6 shows that despite membrane deterioration, specific energy consumption has decreased for the past four years due to efficient management. These values are expected to decrease further with the introduction of energy recovery equipment.

This equipment is being installed in RO trains required to operate as base producers, namely six trains at Pembroke, two trains at Lapsi and one train at Cirkewwa.

Plant	Specific Energy Consumption			
	1997-1998	1998-1999	1999-2000	2000-2001
Lapsi	6.85	6.69	6.55	6.55
Cirkewwa	7.55	7.43	7.14	7.04
Pembroke	6.03	5.84	6.03	5.84
Average	7.22	6.94	6.37	6.24

Table 3.6 Specific energy consumption of RO plants.

3.4.3.2 Leakage control programme

During the past five years, the WSC embarked on an intensive leakage control programme. An Infrastructure Leakage Index (ILI) was established to gauge the effectiveness of this programme (Rizzo, 1999). The current ILI level is approximately equal to 4, with a leakage rate of about 1200 cubic metres per hour. The target is unit ILI level by the end of 2010. This corresponds to a leakage level of 300 cubic metres per hour, which is the current estimate for the unavoidable background leakage in Malta. The progress of the leakage rates between 2001 and 2010 is illustrated in Figure 3.3.

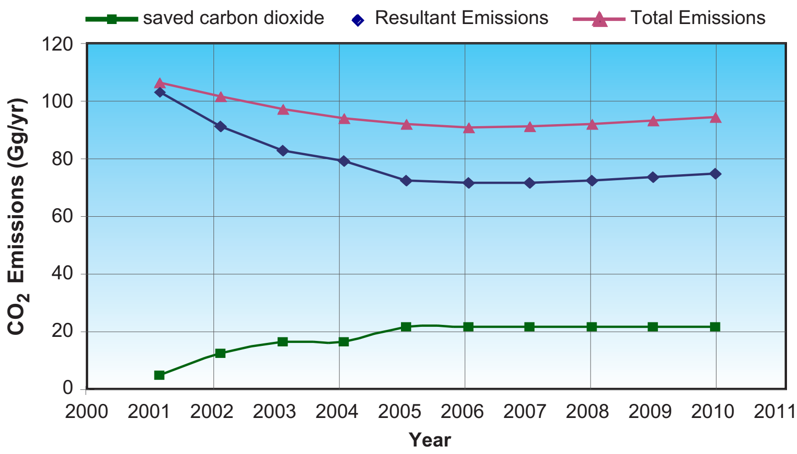

Figure 3.5 CO_2 emissions associated with production of potable water by RO between 2001 and 2010.

3.4.4 GHG emission reduction

Year	Measure
2001	2 Pelton wheels at Pembroke RO plant
2002	4 Pelton wheels at Pembroke RO plant & 1 Pressure Exchanger at Lapsi RO plant
2003	1 Pressure Exchanger at Lapsi RO plant & 1 Pressure Exchanger at Cirkewwa RO plant
2005	Membrane replacement
2005-2010	Routine maintenance

Table 3.7 Energy saving measures for RO plants.

Figure 3.5 shows estimates of the reduction in GHG emissions resulting from energy saving measures already implemented or expected to be implemented by the WSC during the period 2001–2010. These were based on the scenario of Table 3.7 and amount to 180 Gg of CO_2 for the period 2001 to 2010, assuming current fuel use trends.

The estimates of figure 3.5 were based on the following assumptions:

- current specific emission by Enemalta power plants;
- water demand according to figure 3.4;
- 51% of demand being satisfied by RO production.

These three factors, especially the latter two, significantly affect resultant emissions and consequently present a source of significant uncertainty in the projections.

Sewage treatment plant (STP)	Year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Existing SASTP										
Upgraded SASTP										
Gozo										
Malta north										
Malta south										

Table 3.8 Projected developments for sewage treatment infrastructure (2001-2010).

3.5 Sewage treatment and manure management

3.5.1 Introduction

Greenhouse gases, namely CO_2, CH_4 and N_2O are all produced during the treatment of sewage, the resulting sludge and animal manure. GHG emissions in Malta and Gozo from these activities during this decade are quantified and possible mitigation options examined.

Scenario	Sewage sludge treatment		Sewage sludge disposal	
	Aerobic	Anaerobic	Land filling	Incineration
1	x		x	
2		x	x	
3	x	x	x	
4				x

Table 3.9 Sewage handling scenarios following aerobic wastewater treatment.

3.5.2 Projected GHG emissions 2001-2010

3.5.2.1 Emissions from wastewater treatment and sludge handling systems

The present sewerage system leads to sea outfalls at two locations in Malta and three in Gozo. Almost none of the sewage discharged at sea undergoes treatment. The fraction treated at the Sant' Antnin Sewage Treatment Plant (SASTP) is only about 6.4%. Malta is currently in the process of developing and upgrading its sewage treatment infrastructure. This will be the main reason for the expected increase of associated GHG emissions during this decade.

The Sewerage Master Plan drawn up in 1992 envisages the setting up of three new sewage treatment plants (STP), two in Malta and one in Gozo. In addition, upgrading of the supporting sewerage network in the south of Malta will enable SASTP to operate at full capacity.

Table 3.8 shows an envisaged realisation programme covering the period 2001 to 2010 for upgrading of the sewage treatment infrastructure.

The data required to evaluate GHG emissions from wastewater handling consisted of a Population Equivalent (PE), Biological Oxygen Demand (BOD) and Degradable Organic Component (DOC) values for wastewater and sludge.

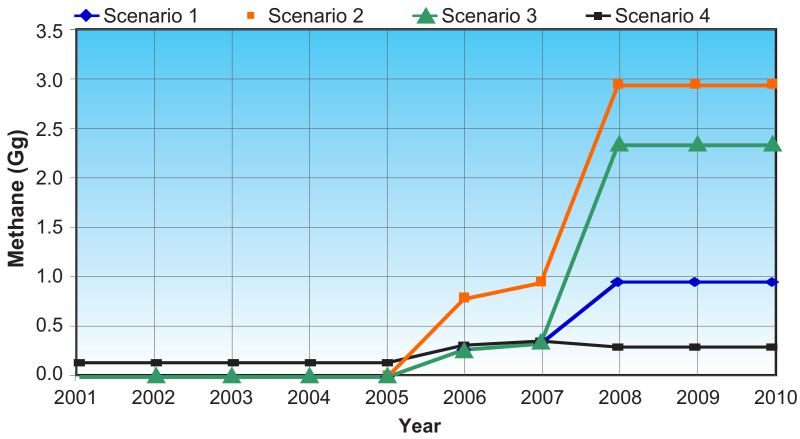

Figure 3.6 Methane emission scenarios based on information from the SMWS (METAP, 1993).

For the period 2005–2010, the fraction of treated wastewater at SASTP was assumed to remain constant. For the subsequent period (2006–2010) the annual PE for each STP includes domestic, tourism and industrial loads. The domestic population was extracted from McDevitt (1998), while tourist population was obtained from MTA (2002) and extrapolated to 2010. Data on industrial loading was extracted from the Sewerage Master Plan for Malta and Gozo (COWI, 1992).

BOD and DOC values were estimated from the specifications of the sewage treatment plants as given in the Sewerage Master Plan.

The proposed plants shall treat wastewater aerobically (COWI, 1992) but discussions on sewage sludge treatment and disposal methods are still ongoing. Table 3.9 lists the four possible scenarios considered for which GHG emissions were estimated.

Scenario 3 assumes both aerobic and anaerobic treatment of sludge, allowing for a mixture of sludge treatment modalities. Moreover, since the application of sewage sludge to agricultural land as soil conditioner is highly unlikely owing to high heavy metal content, landfill disposal and incineration are the two scenarios that have been considered in the calculation of GHG emissions resulting from sewage sludge disposal.
Projected GHG emissions from wastewater treatment and sewage sludge were calculated using the IPCC methodology (IPCC, 1996b). Methane Conversion Factors (MCF) of 1 and 0.2 respectively were assumed for the anaerobic and aerobic processes. The latter value allows for incidental anaerobic conditions that may arise from plant mismanagement.

Figure 3.6 shows the estimated CH_4 emissions resulting from the four scenarios. Emissions during the first four years are negligible since no major developments in the sewage treatment infrastructure are envisaged. These estimates do not account for CH_4 emission from anaerobic activity taking place following discharge of raw sewage into the marine environment, which will continue until all the sewage treatment plants are set up. Population increase does not have a significant impact on these projections.

This analysis confirms that CH_4 emissions from aerobic treatment are significantly smaller than those from anaerobic processes. In fact, the different treatment options are projected to give rise to CH_4 emissions ranging from about 0.3 to 3 Gg per year by 2010.

Emissions resulting from disposing of sewage sludge in landfills were estimated using the IPCC methodology for municipal solid waste (ibid.), assuming a degradable organic carbon value of 0.15 for sewage sludge.

Estimates of emissions from sewage sludge incineration were based on the assumption that this process only yields N_2O (IPCC, 1996b), since CH_4 emissions are not likely to be significant. The resulting N_2O mass was converted to CH_4 equivalent for comparison, assuming an emission factor of 800 kg of N_2O per Gg of sludge. Although this value is typical of a fluidised bed system, there is a high degree of uncertainty since it does not correspond to a specific incinerator design. In addition, direct N_2O emissions from human sewage were estimated to reach about 41 Mg by 2010, a marginal increase over the 2000 figure.

3.5.2.2 Emissions resulting from manure management

In the local context, only cattle and swine play a significant role in the GHG emission scenario. Cattle manure is usually stored in heaps and sold to crop farmers during the months of August and September. Some pig slurry is also used for crop production. About 40% of pig farms have cesspits but most of these have a storage capacity of not more than a few days. On farms with limited storage, slurry is transported out to either crop farms in August and September or to the nearest sewer where it enters the domestic sewerage system. It is estimated that 80% of pig effluent ends up in the sewerage system (Meli, 1993).

This practice is to be discontinued, as all discharges to sewers shall be in line with the Sewer Discharge Control Regulations national legislation of the 1993 Environment Protection Act. Holders of an animal production licence will therefore be required to process and dispose of animal waste produced on their units. However, in Malta units are usually too small to justify the necessary processing equipment and farmers do not have the necessary technical skills to manage such units. In addition, owing to the small scale of the operations, the cost of compliance would exceed the value of the manure produced.

Collection and processing at central units seems to be a more cost-effective solution. These units would process animal waste received from most farms and liquid waste from those farms with their own separation plants. The solid fraction can then either be applied directly as manure in fields overlying non-potable water aquifers, or further processed into slow release compost.

In the past decade, manure management in Malta contributed to an average of 3 to 4 Gg of CH_4 per year. This includes emissions from enteric fermentation and manure management practices outlined above. It is not envisaged that animal numbers will change significantly in this decade. However, CH_4 emission is expected to increase due to the setting up of centralised anaerobic digesters for treatment of animal waste.

3.5.3 Mitigation and abatement measures

3.5.3.1 Wastewater Treatment and Sludge Handling

Although aerobic treatment of wastewater and sludge virtually eliminates methane emissions, it is to be noted that the process requires energy input for aeration, which results in off-site increases in greenhouse gas emissions. On the other hand, the methane generated during anaerobic processes can be captured and used as an energy source to generate electricity. Hence, opting for anaerobic processes will result in a net decrease in GHG emission if it includes energy recovery. Unfortunately, this would not be feasible for small treatment plants, as are two of those envisaged in the coming years.

3.5.3.2 Manure Management

The main strategy for reducing GHG emissions from manure should rely on influencing the choice of manure management methods. These will determine whether the degradation process is predominantly aerobic or anaerobic and hence whether carbon dioxide or methane is evolved. Any methane reduction strategy should therefore seek to avoid uncontrolled releases from anaerobic degradation, either by ensuring aerobic digestion or recovering methane evolved from anaerobic degradation for use in energy generation.

When spreading manure over land, anaerobic degradation can be minimised by avoiding anaerobic soil conditions (e.g. waterlogged soils or compacted soils) and by spreading thinly and evenly. Spreading has the potential to release nitrous oxide. Manure applications should therefore be matched to crop nitrogen requirements in order to avoid excess soil nitrogen and hence nitrous oxides release.

Daily spreading of manure results in the release of 0.1 to 0.5% of its methane potential, compared with releases of 10 to 35% from manure treatment methods most commonly used in the EU. A reliance on daily spreading of manure could therefore significantly reduce methane emissions from these sources. However, a number of disadvantages are associated with the practice:

- increased risk of water pollution during periods of high rainfall;
- application of crop nutrients cannot always be matched to requirements;

- intensification of vehicle movements may result in damage to soil structure;
- access to the land may be restricted at certain times of the year;
- increased labour requirement;
- most areas where manure can be spread overlie potable water aquifers.

Aerobic treatment can be applied to liquid manures through aeration and to solid manures by composting. However, aeration may leave up to 70% of the total organic load (Burton, 1997), which may subsequently degrade anaerobically if the liquid manure is stored. Moreover losses of 4 to 11% of the total nitrogen in the form of nitrous oxide have been reported from the aeration of liquid pig manure (Burton et al., 1993). There is therefore a consequent uncertainty as to the effectiveness of this treatment option.

Composting solid animal manure can reduce GHG emission in two ways: by reducing nitrous oxide and methane emissions during manure storage and application, and by reducing the amount of manufactured fertilisers and the GHG associated with their production and use.

Application of anaerobic digestion (AD) techniques in processing animal manure ensures that most of the carbon is ultimately converted to carbon dioxide before being released to the atmosphere. Utilisation of biogas from AD plants in the production of heat and electricity helps to offset some of the emissions from the energy sector.

3.6 Solid waste management

3.6.1 Introduction

In Malta, the annual solid waste stream consists of about 1.5 million tonnes, most of which is inert construction and demolition waste. In 2001, out of this total amount, about 115 kt of municipal solid waste (MSW) and 125 kt of commercial, industrial and trade waste were deposited on land. The per-capita generation of MSW (including bulky, green and waste from hotels and restaurants) amounted to about 0.6 t (Axiak, 2002). Approximately 30 kt of municipal waste was composted at SASTP.

Waste management during the year 2000 resulted in about 16 Gg of CH_4, 14 Gg of which are attributable to solid waste thus justifying a need for mitigation measures. There are some uncertainties in the estimation of emissions from anaerobic decomposition of the organic content of solid waste. These arise from a lack of information about detailed waste management practices and the portion of organic waste decomposed anaerobically.

For environmental and public health reasons, actions will be undertaken at solid waste disposal sites that will result in reduction of CH_4 emissions. Different options are available to mitigate the effect of greenhouse gas emissions from waste management practices. The options applicable in the local situation will be discussed.

3.6.2 Source reduction and recycling

An environmentally sound and globally holistic viewpoint is to reduce GHG emissions and energy consumption by a frugal use of primary raw material. This practice is therefore important in waste minimisation and resource conservation principles.

For most materials, recycling is the second less GHG-intensive process. Some raw materials are eminently suited to this consideration, such as aluminium and, to a lesser extent, paper production. In the latter case there is the additional benefit of avoiding the felling of trees, thereby maintaining increasing sequestration potential.

An appropriate recommendation in this respect is that, as far as possible, Malta should avoid importing products that give rise to waste. Packaging materials that cannot be recycled locally should be re-exported.

3.6.3 Composting

Composting is a management option for biodegradable waste, mainly food and other green waste. In 2001 SASTP received both mixed waste and waste separated at source. Mixed waste is separated mechanically and the biodegradable fraction is composted. Some of the non-biodegradable material is sent for recycling, the rest being sent to a landfill site (currently at Maghtab, on Malta's eastern coast).

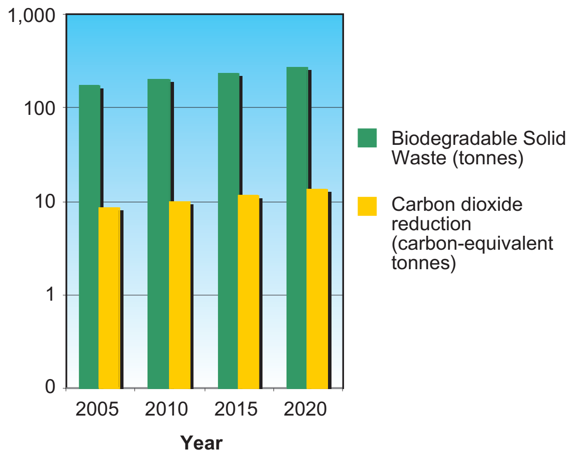

Figure 3.7 Projected biodegradable waste and associated CO_2 reduction potential resulting from waste composting between 2005 and 2010.

In general, the net GHG emissions from composting are lower than those from land filling in the case of food discards, since composting avoids CH_4 emission. However, the converse is true in the case of green waste because land filling is credited with long term carbon storage that results from incomplete decomposition of organic waste. Addition of compost improves the quality of local soils which tend to be poor in organic content owing to intense cultivation, runoff caused by rain and a high content of limestone.

It is estimated that centralised composting of organic materials results in net GHG storage of 0.05 tonnes of carbon-equivalent for every wet tonne of organic input composted and applied to agricultural soil.

Figure 3.7 represents the expected biodegradable fraction (72%) of MSW over the period 2005–2020, assuming a successful waste reduction campaign. Estimates of the resulting CO_2 mitigation potential resulting from composting waste and applying the product to the soil are also presented. It is expected that during 2010 almost 10 tonnes will be saved and that this figure will rise to about 13 tonnes by 2020.

3.6.4 Combustion

Combusting MSW in a waste-to-energy plant as a waste treatment option offers the possibility of partial mitigation of CO_2 emitted by the energy sector, which is currently totally reliant on the burning of fossil fuels. For example, a two-furnace system handling 14 tonnes per hour can generate about 500 kWh of electricity per tonne of waste. This is equivalent to a mitigation of 94 Mg of CO_2 (Grontmij and Ramboll, 1996).

3.6.5 Land filling

The choice of landfill cover and liner systems is also likely to influence the rate of CH_4 generation and collection. Effective covers and controls to keep water and other liquids out of the landfill will make conditions less favourable for degradation of organic waste. Over the long term these improvements may result in a decrease in CH_4 generation and an increase in carbon storage. The SWMS does not mention mining of landfills. This implies that, currently, landfills can be considered to reduce CO_2 emission by virtue of their carbon storage capacity.

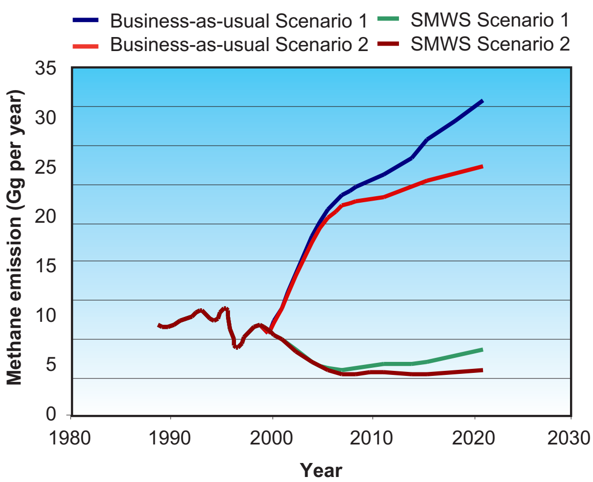

Figure 3.8 Methane emission scenarios based on information from the SMWS (METAP, 1993).

Anaerobic digestion of biodegradable materials deposited in landfills generates CH_4 and CO_2. Of these, CH_4 is considered anthropogenic, whereas CO_2 is not since it would be produced in any case through natural decomposition. Furthermore, the SWMS (ibid.) requires the provision of properly managed and engineered landfills with provision of measures for collecting generated CH_4. This may either be flared or preferably utilised for power generation.

Figure 3.8 compares the methane emission trends according to two scenarios, each considered with and without (business-as-usual) adoption of the Solid Waste Management Strategy (SWMS) (METAP, 1993). The two scenarios are:

Scenario 1: the "worst case" scenario with municipal solid waste growing at 3% per annum and industrial waste generation increasing gradually from the current 3% to 5% in 2009, and thereafter at 0.5% per annum.

Scenario 2: a more optimistic and sustainable scenario with municipal solid waste generation decreasing from the current 3% to 1.5% in 2004, and thereafter remaining constant.

The predicted combined effect of the proposed measures on methane emissions assumes that:

- the uncontrolled Maghtab landfill will be phased out;
- an engineered landfill will be established in 2004;
- the Sant' Antnin composting plant will be upgraded soon;
- all municipal solid waste will be segregated and treated separately.

Chapter 4

Assessing the Vulnerability of the Maltese islands and their Adaptation to Climate Change

4.1 Executive summary

The Third Assessment Report (TAR) (Houghton et al., 2001) issued by the Intergovernmental Panel on Climate Change (IPCC) predicts that by the year 2100, there will be an increase in the global mean temperature ranging from 1.4 to 5.8ϒC. Results from sub-grid-scale scenarios indicate that at the annual rate, local sensitivity of temperature to the enhanced greenhouse effect is about 9% higher than the global sensitivity. A moderate impact of climate change is expected, as summarised in table 4.1.

Parameter	Expected change
Temperature	Sensitivity of temperature to the enhanced greenhouse effect is 9% higher than the global value.There is a 50% probability that the average temperature will increase by 3oC by the end of the century.Seasonal patterns will be retained with an approximately uniform temperature rise
Precipitation	There is a 50% probability of a 17% decrease in annual total precipitation by 2100.Precipitation will decrease in autumn and increase in spring.The predicted range of possible changes lies well within the range of natural climate variability.
Evapotranspiration	Increased evapotranspiration is expected owing to higher temperatures, leading to increased pressure on the water supply.

Table 4.1 Summary of projected climatic changes.

The likely impacts of greenhouse warming were investigated. Environmental and socioeconomic implications of the potential changes in regional weather patterns (meteorological parameters such as temperature, precipitation, moisture and extreme events, as well as sea level rise) were addressed on a national scale. The study has furnished impact assessments and adaptation measures in key areas related to the terrestrial and marine ecosystem, natural water resources, public health, fisheries and agriculture in the Maltese islands.

It is evident that climatic changes affect the environment and consequently, socioeconomic activities. The most important impacts include the deterioration of potable water supplies and quality, more frequent extreme weather events, increase in soil erosion and an accentuated desertification process, threats to public health, changes in sea water mass characteristics and effects on fish stocks, sea level rise, coastal erosion and inundation, and reduced biodiversity. Malta's economic vulnerability to climate change is expected to be moderate to moderately high.

4.2 Introduction

Variations in the earth's climate will be reflected in the Mediterranean region, as well as in the Maltese archipelago where specific climate change effects are influenced by its geographical position and the proximity of the its inland areas to the sea. The changes are uncertain, but it is beyond doubt that there will be an influence on environmental and socioeconomic activities. Potential impacts on a regional scale include drought, deterioration of water quality, floods, increase in soil erosion and desertification, storms, coastal erosion, changes in sea water mass characteristics, sea level rise and biodiversity reduction. The degree of these consequences will in part depend on timeliness of implementation of adaptation measures.

Although the research and modelling procedures used for assessments have been rapidly evolving and the main climate change effects on the Mediterranean environment can be forecast, data obtained on a Mediterranean spatial scale is still somewhat unreliable for an adequate evaluation and application (EEA, 1999). The region is under the influence of strong transcontinental weather patterns, such as the North Atlantic Oscillation (NAO) in winter in the western basin and the Indian monsoon in summer in the eastern basin (Raicich et al., 2001). It is essential to understand the extent of anthropogenic influence in climate change. This requires analysis of regional data collected over long periods of time.

The identification and understanding of the causes of climate change furnish the basis for an integrated assessment of climate change impacts. Projections of future socioeconomic patterns are used to prepare emission scenarios, which lead to future global climate scenarios. These can be downscaled to regional-scale and local-scale resolutions to provide more detailed and specific assessments. On the basis of these scenarios, adaptation and mitigation measures are proposed and designed. The full process of assessment is, however, beset with uncertainties due to many factors including the inability to predict human-induced stress as well as the inherent limited capability of models to fully represent the complex climate processes. Climate studies do not therefore furnish fixed assessments or exact predictions, but can give estimates expressed as a range of expected outcomes.

During the period 1990–2100, the global mean rise in temperature is estimated to be within the range 1.4–5.8°C (TAR range) (Houghton et al., 2001). This result incorporates uncertainties in the climate sensitivity, emission scenarios, change in atmospheric composition and radiative forcing (Nakienovi and Swart, 2001). This analysis indicates that temperature rises at the extremes of the TAR range are less likely and that the 50th percentile rate of increase in global temperature is larger than that observed over the past century.

While changes in temperature and precipitation patterns are used as indicators of climatic changes, in the coastal zone it is the prediction of sea level rise that has the major impact. Regional sea level changes are expected to differ from the global mean due to hydrological, tectonic and specific characteristics. A detailed forecast of sea level rise in the Mediterranean region is precluded by the lack of climatic historical data series, which, at best, cover only 100 years.

The Physical Oceanography Unit at the International Ocean Institute's Malta Operational Centre at the University of Malta, has recently started to monitor sea level changes. Current trends indicate a 1 cm per year local sea level rise. A sea level rise of 50 cm by 2050 and 100 cm by 2100 was assumed for the assessments and adaptation measures in the Maltese islands.

4.3 Current climate trends

The data used to analyse recent climatic trends concerned rainfall recorded at Valletta (1842–2000), Rabat (1852–2000) and Luqa (1947–2000), temperature at Valletta and Luqa (1927–2000), and atmospheric pressure, number of days with thunderstorms, hail, gusts, mean daily cloud cover and mean daily hours of bright sunshine at Luqa (1947–2000). The longest records are those of rainfall and temperature, spanning over 150 years. Records of other parameters cover a period of about 50 years. Climate data show temporal variations or oscillations due to changing environmental conditions and random processes.

The climate of the Maltese islands is typically Mediterranean, with a mild wet winter invariably followed by a long dry summer. The air temperature generally ranges between 9.5°C and 33°C; exceptional extremes of 1.4°C and 43.8°C having been recorded. The average daily number of sunshine hours ranges from 5.1 in December and January to 11.8 in July.

Statistical analysis of past meteorological data indicates an increase in the mean annual air temperature of about 0.5°C in 77 years (figure 4.1 - overleaf), which is in agreement with the regional value over the Mediterranean during the last century. The maximum local temperature increased by 1.5°C, while the minimum decreased by 0.8°C over the same period. The sea surface temperature around Malta has been taken into account to detect climatic changes. Temperature measurements at 1 m below the surface have been made at sea since 1978, which indicate an increase in mean sea surface temperature of 1.25°C.

Observed extremes in the maximum and minimum temperatures are typical of desert regions. Trends towards these conditions in Malta lead one to conclude that a process of desertification is already occurring. The present

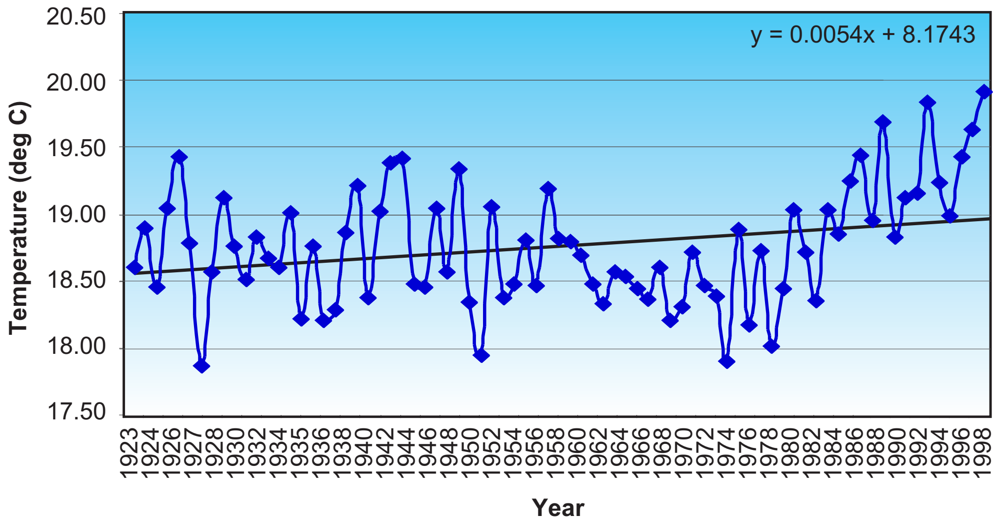

Figure 4.1 Time series of annually averaged monthly mean temperatures at Luqa.

trends suggest that the area of atmospheric subsidence is shifting northwards from the Sahara, thereby enhancing a desert type microclimate.

Rainfall records have been maintained systematically for over 100 years. Annual rainfall is highly variable from year to year. Over the period 1840 to 2000, the highest maximum was 1031 mm (in 1859) and the lowest minimum was of 148.8 mm (in 1977). Both occurrences were recorded in Rabat, Malta. Rainfall is seasonal, with 70% of the annual precipitation occurring from October to March. During the short winters sufficient rain falls for crop irrigation but soil retention does not suffice for the relatively warm and dry spring seasons. The hot, dry summers are followed by warm and showery autumns, normally also with a rainfall deficit. The 30-year average of annual precipitation from 1951 to 1980 was 580 mm, from 1961 to 1990 it was 553 mm and from 1971 to 2000, 568 mm. There are no perennial surface streams in Malta and rain water only flows along the bed of major valleys for a few days after heavy downpours, with about 6% of the total precipitation finding its way directly into the sea via this surface runoff.

Rainfall patterns show a relatively high spatial variability over the Maltese territory and no definite trend in the observed precipitation. Since 1923, there has been little change in rainfall during winter and summer, whereas there has been a decrease of 0.14 mm per year during spring and an increase of 0.8 mm per year during autumn. During the rainy season, the number of days per year with thunderstorms has increased by nine since 1950. The existence of convective rainfall is corroborated by the positive trend in the daily maximum rainfall between 1923 and 2000, since this type of rainfall is of short duration and often heavy. An increase in the daily maximum rainfall is observed notwithstanding the fact that, over a full year, the absolute number of days with rainfall in the range 1–50 mm is decreasing.

Annually averaged observations indicate an overall positive trend in atmospheric pressure implying a reduced frontal activity on a yearly basis and more frequent anti-cyclonic situations which often enhance subsidence, thereby restricting convection, cloud formation and hence rainfall. The recorded decrease in the mean annual cloud cover over Malta amounts to -0.3 oktas since 1965.

The duration of bright sunshine has decreased by an average of 0.6 hours per day since 1923. This decrease is attributed to changes in atmospheric composition, predominantly due to the higher atmospheric loading by suspended particles. The trapping of pollutants and dust in the lower atmosphere is favoured by anti-cyclonic situations that are accompanied by lower level inversions and slack pressure gradients, thereby lacking sufficiently strong air currents that could disperse particles. This would necessarily increase the incidence of haze, especially at low elevations of the sun.

4.4 Future trends of climate change

Future changes for the Maltese islands in important climate parameters due to increasing atmospheric concentrations of the greenhouse gases were estimated as a basis for vulnerability and adaptation assessments to climate change. The expected changes in the seasonal and annual mean temperature and precipitation up to the year 2100 were constructed using the climate scenario generator software MAGICC/SCENGEN (Version 2.4), distributed by the Climatic Research Unit of the University of East Anglia (Wigley et al., 2000 and Hulme et al., 2000). This version of MAGICC/SCENGEN does not take into account the results reported by Houghton et al. (2001) in respect of the new understanding regarding gas cycles, concentration-forcing relationships and climate sensitivity. However, the emission scenarios in MAGICC/SCENGEN were upgraded by those of Nakienovi and Swart (2001), with lower SO_2 emissions. The mid-level no-policy case A1B-AIM emission pattern (ibid.) was adopted as the baseline scenario. Projections were expressed as normalised values for every degree rise in global-mean temperature. These data sets combine the greenhouse gas change patterns from the HadCM2 climate model (Cullen, 1993) with the UIUC-EQ sulphate aerosol results (Yang et al., 2000). These results were utilised in conjunction with baseline climatology from the last 30 years of observations and scaled to account for different sensitivities and different emissions on the basis of the global-mean temperature rise projections by Houghton et al. (2001).

The outcome of these projections indicates that the Maltese islands will suffer a moderate impact from climate change. At the annual level the sensitivity of temperature to the enhanced greenhouse effect is about 9% higher than the global sensitivity. This value could have been overestimated since the special resolution was determined by a 5° latitude/longitude grid box, encapsulating a large portion of Sicilian land mass. This amounts to a 50% probability that the mean annual temperature over the Maltese islands will rise by a further 3°C by the end of the century. Seasonal sensitivities are higher than the global increase throughout the year, except in the period March to May. However, the temperature seasonal pattern is expected to be retained with an approximately uniform warming across all months (refer to figure 4.2).

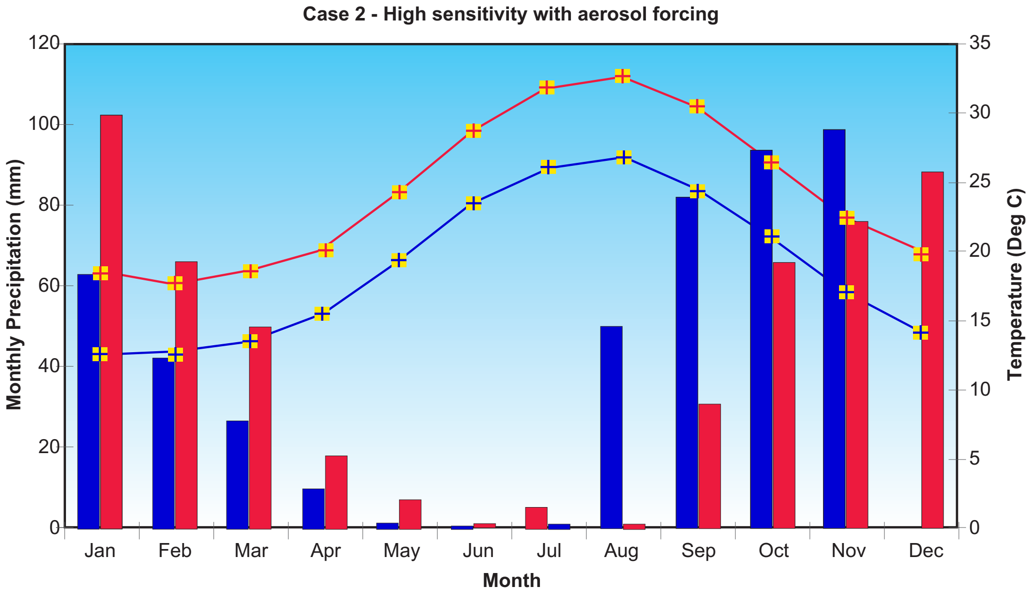

Figure 4.2 Mean temperature and monthly precipitation for the 5o latitude/longitude grid box containing the Maltese islands (37.5oN; 12.5oE). Precipitation values are indicated in the bar chart, whilst the continuous line represents mean temperature. Observed present values (averaged for the period 1971–2000) are indicated in red, while blue corresponds to the scenario constructed using the HadCM2 pattern with aerosol effects, scaled according to the 50th percentile of global-mean temperature change from the IPCC TAR over 1986 to 2100. For reference, the broken curve gives the scaling according to the 95th percentile global-mean temperature change.

The projections for precipitation are less reliable. The scaled precipitation values give an estimated decrease of around 17% (to a best guess with 50% probability) amounting to a reduction of about 60 mm in the annual mean rainfall by 2100. The major decrease in rainfall is expected for autumn, with an increase during winter and little change during the rest of the year. The overall result is that the shift to less rain in autumn will have the greatest impact and will exacerbate dryness due to higher temperatures and the combined effect of enhanced evapotranspiration.

The current observed trends may be the opposite of projections. Most probably, this is because of the high natural variability in precipitation, which masks anthropogenic-induced changes. The mean winter precipitation observed between 1971 and 2001 was 568 mm, with a maximum of 895 mm and a minimum of 304 mm. The standard deviation of the series is 28% of the mean. Thus, the predicted range of possible changes lies well within the range of climate variability.

4.5 Climate impacts on water resources and adaptation measures

The Maltese islands are expected to experience a decrease in the natural water resources due to climate change. The most likely changes in natural processes are the following:

- increased evapotranspiration rates due to an increase in ambient temperature, leading to perturbations in the soil water balance;
- alterations in subsurface water movements;
- sea level rise.

Changes in potential evapotranspiration were estimated using the Penman–Monteith model, based on temperature changes but without allowing for changes in the other parameters. The peak rates expected on the basis of the local rise in temperature by 2100 were estimated to reach values about 7 mm per day. This will impact the soil water balance and ultimately the total water demand for crop irrigation.

The crop water requirement was computed using the FAO crop coefficient approach (Allen et al., 1998) and uses data published in the 1991 agricultural census (CSO, 1991). The model results confirm that temperature changes will accentuate the soil moisture deficit due to the increased evapotranspiration. This is accompanied by alterations in the subsurface water movements through the different soil layers. An accentuated soil water deficit can only be combated by a more conspicuous irrigation demand, thereby putting further pressure on the potable groundwater supplies and thus forcing a shift towards a higher dependence on water production by desalination.

Assuming a sea level rise of one metre and that the majority of galleries will consequently no longer be suitable as a natural water source, groundwater production potential will reduce by about 40%. Even a moderate sea level rise will lead to the deterioration of the groundwater quality due to increased seawater intrusion. Moreover, the expected shift of precipitation patterns towards more frequent events of heavy rainfall, coupled with a consequent increased runoff, will cause deterioration of the aquifer recharge process.

Adaptation measures are necessary to alleviate stress on the natural water resources and to mitigate flood water damage. A concerted effort is necessary to reduce water demand by promoting water efficient devices, use of alternative water sources for activities that can be satisfied by non-potable supplies and careful aquifer monitoring, coupled with carefully drafted conservation policy.

Implementation of a storm water management plan is necessary and should comprise a flood mitigation system. The plan should improve rainwater catchment and storage through the use of more numerous and higher capacity water reservoirs for longer self-sustained irrigation, while averting flood water damage.

Notwithstanding the implementation of adaptation measures, a net negative impact on natural water resources is still expected. It thus seems inevitable that there will be an increased dependence on seawater desalination.

4.6 Terrestrial and marine ecosystems

Maltese ecosystems are divided into three categories:

- marine ecosystems, which can be subdivided into littoral (parts of the rocky or sandy shores that are regularly covered and uncovered by sea water as a result of wave action) and sublittoral (permanently submerged);
- freshwater ecosystems are rare and confined to the valleys and their associated watercourses, temporary rainwater rock pools, subterranean waters and springs;
- terrestrial ecosystems which are classified into three sub-categories, namely, parts of the vegetation succession sequence (steppe, garigue, maquis and woodland), minor and specialised habitats supporting rare and/or endemic species (e.g. sand dunes, saline marshlands, transitional coastal wetlands, maritime fringe) and habitats formed by anthropogenic activity (e.g. disturbed land and afforestation areas).

A reduction in soil water availability due to the expected increased temperature will lead to problems of increased soil salinity and alkalinity, to aridity and an accelerated desertification process. Changes in global and local agricultural patterns are thus expected, resulting in the abandonment of agricultural land and further soil erosion. This situation is exacerbated by the likely increased frequency of extreme events with heavy spells of rainfall. Higher temperatures will also favour the growth of thermophilic (tolerant of hot conditions) and xerophilic (tolerant of dry conditions) plant species, and the decline of hydrophilic (tolerant of wet conditions) species. In conclusion a general shift of flora to a more desert-type assemblage is to be expected. There is still uncertainty on the effects of increased atmospheric CO_2 concentrations and global warming, on plant growth and the response of plant metabolic processes. Some recent studies actually suggest that there could be a shift in the opposite direction, with a greening of the Mediterranean and an extension of the Mediterranean woodland further south and east.

The most obvious effect of sea level rise is the inundation of low-lying coastal areas. Such areas include all sandy beaches and the gently sloping rocky coasts mostly along the northeastern shoreline. Apart from the actual loss of land area, these locations also support rare and localised habitats containing highly specialised organisms. Inundation will thus result in a landward shift of shore zone patterns and the conversion of littoral to sublittoral habitats. As long as the inundation is a slow process, enough sediment is available and if an ecological corridor is accessible, these threatened habitats may shift inwards. However, constructions built recently along shorelines, which may help to reduce inundation, could inhibit this inward migration. Loss of these habitats will result in reduced biodiversity.

An adaptation measure to mitigate inundation of low-lying shores is the designation of building-free zones and construction of protective structures against inundation and coastal erosion. Transplantation of important and/or rare species, and habitat recreation schemes should be considered in vulnerable low-lying coastal areas. Seagrass ecosystems also need to be protected in view of their importance as a special habitat for many marine organisms as well as in combating coastal erosion and in stabilising seabed conditions. Furthermore, their role in CO_2 uptake should not be overlooked.

Other effects of climate change on the marine environment will bring about:

- changes in the physico-chemical parameters, especially changes in sea temperature, localised changes in salinity due to increased runoff and increased turbidity from sediment washout;
- impacts on the important seagrass ecosystems through reduced photosynthesis as a result of increased turbidity;
- increased UV (especially UV-B) radiation, which penetrates well into sea water, can have a negative effect on photosynthesis;
- higher sea temperatures can result in the westward migration of Lessepsian species from the Red Sea and the Levantine basin of the Mediterranean, leading to competition with local species.

In general terms, the ecosystems spread over the Maltese islands will be affected in a number of ways. Most of the bays and the northeastern shores are expected to experience submergence, shifting zone patterns landward. Specialised and rare habitats such as wetlands will be mostly under threat, some of which will be facing complete obliteration. Existing infrastructure may serve to reduce the extent of inundation, but can also restrain the inland transfer of the threatened habitats.

4.7 Agriculture

Changing weather patterns are expected to affect fruit abundance and crop production. The largest effect is expected to be due to the predicted shortening of the rainy season. The greatest damage will result from the combination of long spells of drought and events of intense precipitation leading to soil erosion, soil structural and composition damage, soil water clogging, increased nutrient leaching and direct damage to both crops and infrastructure, such as greenhouses. Soils will be eroded both in quantity and quality.

To mitigate these effects, farmers will have to adopt new techniques in soil and water conservation. Education programs are required to address the impact and mitigation of climatic changes on agriculture. The introduction of more tolerant crop varieties that are less vulnerable to new pests may be necessary. Better adaptation to changes in seasonal climatic patterns and an enhanced reliance and response to improved short-term forecasts for optimisation of crop yields will be necessary.

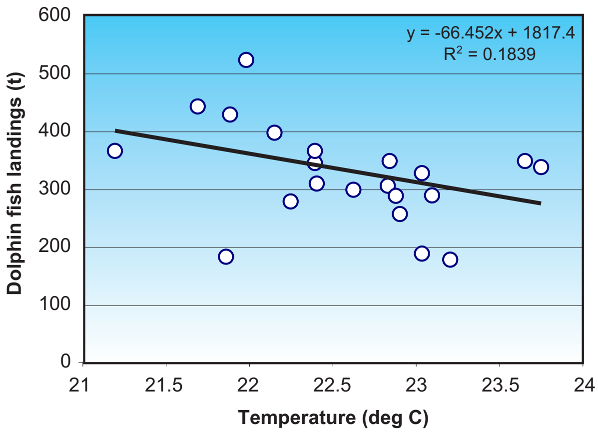

Figure 4.3 Relationship between dolphin fish landings and sea surface temperature (August to December averages over the period 1980 to 2001).

A summary of adaptation measures for the agricultural sector follows:

- reduction of harsh (e.g. rotary) cultivation techniques;
- replacement of artificial inorganic fertilisers by organic matter;
- increased use of organic mulches to provide soil protective cover;
- increased cultivation of perennial crops, e.g. fruit trees;
- improvement in water and alkalinity levels;
- construction of larger reservoirs and improved water conservation practices;
- regular monitoring of soil salinity;
- repair and maintenance of rubble walls;
- farmer education programmes focusing on climate change adaptation strategy.

4.8 Fisheries

Biogeochemical fluxes and cycles are closely linked to the climate system. Human induced alterations in the chemical and biological composition of the ocean (especially in the coastal seas), land and atmosphere have a profound effect on climatic and environmental conditions. In the case of the oceans, warmer and more acidic conditions due to higher surface water CO_2 concentration will suppress sequestration of atmospheric CO_2 by the sea and significantly decrease the productivity and sedimentation of calcite-forming plankton to the deep ocean. The weakening of the ocean thermohaline circulation and the associated alterations in the vertical structures and fluxes of nutrients in the oceans will bring about major shifts in productivity, distribution and diversity of planktonic regimes.

Marine science is not yet able to decipher a priori the response of the pelagic marine ecosystems, their structures, succession, trophodynamics, biodiversity and biogeochemical feedbacks, to these climatic forcings (ESF, 2002). However, it is certain that variations in climate will lead to changes in abundance, distribution and migration patterns of fish species of commercial importance. Temperature, atmospheric pressure, wind and runoff are climate-related parameters, which have been found to be significantly correlated with most of the biological and fish stock indices. However, climate is not the only factor affecting fish stocks.

It is not easy to differentiate between the effects on marine ecosystems of human-induced factors (such as fishing pressure, pollution and river discharge) from those arising as a result of climatic changes. Unlike the depleted stocks of tuna and swordfish, the Mediterranean dolphin fish (better known locally as the lampuka) has not experienced excessive fishing pressure. For many years, this species has been largely targeted by Maltese fishermen, using Fish Aggregating Devices (FAD), between the months of August and December within the framework of an organised management regime and has maintained a relatively constant level of fishing effort. The stock evolution of this species should thus be indicative of climatic influences. Using data covering 1980 to 2001, a slight negative trend in dolphin fish landings has been recorded. This may be related to an increase in the sea surface temperature over this period. Although dolphin fish have a wide temperature tolerance range (21–30°C) they tend to aggregate in the sea surface above the thermocline where they thrive on a variety of other small fish, crustaceans and cephalopods, and are thus susceptible to sea water column temperature variations. The relationship between landings and sea surface temperature is not statistically very significant (figure 4.3), but an indirect effect of temperature on the dolphin fish population cannot be discounted.

An increase in sea surface temperature is normally accompanied by a rise in the thermocline depth and a higher mixed layer temperature. This creates a steeper temperature gradient at the thermocline, a decrease in dissolved oxygen below the thermocline, as well as changes in seawater circulation. Moreover, a greater barrier to nutrient uploading from deeper waters greatly limits nutrient availability to the ecosystem in surface waters leading to evident impacts on the sustenance of the migrating dolphin fish stock. This has a direct impact on the population dynamics of dolphin fish in the region. Growth rate, survival and reproduction, which are directly linked to the abundance of the stock, may be affected, but a gradual shift in the migration pathway of the species in search of more ideal habitats is also a distinct possibility.

Several other species with a high commercial value are landed by Maltese fishermen. However, no analysis on these species is currently possible on a local scale owing to relatively insignificant landings and insufficient catch per unit effort (CPUE) time series data. Nevertheless, the impact of the environment on the marine ecosystem and hence on organisms of interest to fisheries has been widely recognised and climate change is expected to have a significant effect on different species.

The influence of the environment on the biological controls acting on ecosystems could affect fisheries through the impact on the:

- i lower levels of the food chain (i.e. primary production) consequently affecting the upper levels;
- ii upper levels of the food chain (i.e. predatory species) consequently affecting the lower levels; and,
- iii middle levels of the food chain (i.e. fish and other fauna) consequently affecting both the upper and lower levels of the food chain.

Some species are expected to enjoy the positive effects of climate change, such as longer growing seasons, lower natural winter mortality and faster growth rates. Other species may be offset by negative factors such as changes in established reproductive patterns, migration routes and ecosystem relationships.
Climate change is also expected to contribute to changes in the Mediterranean biota creating competition between indigenous and exotic or newly established species, subsequently affecting existing fisheries. Adaptation to climate change in fisheries should focus on environmental considerations in fisheries management. The ecosystem-based fisheries management approach that has started to be implemented on a global scale, actually takes environmental variability into consideration.

4.9 Effects of climate change on public health

International peer reviewed opinion indicates that global warming and correlated environmental changes will affect human health, mostly in adverse ways. The greatest impact is from extreme events, in particular more severe heat waves. Heat waves are likely to intensify and become more frequent. Increased thermal stress will cause deleterious health effects in susceptible subjects, including:

- individuals with impaired cardio-circulatory function;
- the aged;
- the obese;
- the infirm;
- those experiencing high metabolic heat production, e.g. those undertaking heavy manual tasks, emergency services personnel and athletes.

Higher seawater temperatures can also lead to deterioration of seawater quality and increased risk of algal blooms that release toxins. This can be a hazard to public health and a potential threat to marine life, including aquaculture.

A general increase in ambient temperature will also favour the spread of some vector borne diseases such as malaria, which was endemic in Malta in the past, as well as leishmaniasis, cholera and food borne diseases. The proposed adaptation and mitigation measures include:

- better architectural design to minimise heat gains and maximise cool indoor environments;
- rescheduling of work hours and leisure activities;
- preparation of a hot weather contingency plan to safeguard persons at risk;
- improved surveillance programmes against tropical diseases;
- food hygiene.

4.10 Economic vulnerability

The geographical and economic smallness of the Maltese islands, coupled with their high population density, and their pronounced dependence on tourism and other coastal activities, condition their economic vulnerability to climate change. These characteristics are common to other small island states. The vulnerability to climate change of the Maltese economy was assessed by means of a qualitative analysis of the relative strengths and the likely impact of climatic changes on the production and expenditure sectors of the economy.

The qualitative vulnerability appraisal is expressed in terms of a vulnerability score for the key economic productive activities. The derivation of the vulnerability score is based on the product of the vulnerability score of individual sectors with the weight that the sectors occupy in the economy. Sector vulnerability scores are thus derived as a weighted average of the different impacts and effects. The magnitude of effects is expressed as a score ranging from 0 to 3, as indicated in table 4.2. A similar vulnerability score is estimated for expenditures.

On the basis of these assessments, the overall production vulnerability to climate change of the Maltese economy is estimated at 1.9 in the current scenario and is expected to increase to 2.2 in the future scenario. On the production side, the key effects will be on tourism, agriculture, manufacturing and utilities. The overall expenditure vulnerability to climate change is estimated at 1.8 in the current scenario, rising to 2.2 in the future scenario, with major effects on the expenditure side being on private consumption, particularly on health and housing, public expenditure on health and tourism expenditure. As one would expect, the Maltese economy is especially susceptible to changes in expenditure by tourists. From these figures, and in qualitative terms, Malta's economic vulnerability to climate change is expected to range from just under moderate to moderate-high.

	Current		Future	
	Economic weight (%)	Sector Vulnerability*	Economic weight (%)	Sector Vulnerability*
Production Sector				
Agriculture & Fishing	2.4	2.4	1.0	2.3
Industry	28.4	1.8	23.0	2.7
Distribution	11.1	2.3	9.0	2.3
Transport & Communication	6.4	2.5	10.0	2.5
Financial	19.8	1.4	25.0	1.4
Private Services	11.1	1.4	15.0	1.4
Public Sector (incl. Utilities)	20.8	2.4	17.0	2.7
Production Vulnerability	100	1.9	100.0	2.2
Expenditure Activities				
Private Consumption	33.2	1.7	35	2.2
Public Consumption	10.5	1.5	7	1.5
Investment	10.6	2	12	2
Tourism Exports	11.4	3	17	3
Other Exports	34.3	1.5	29	1.5
Expenditure Vulnerability	100	1.8	100	2.1
* Index of Sector Vulnerability: 0 = None, 1 = Negligible, 2 = Moderate, 3				

Table 4.2 Malta's economic vulnerability to climate change.

It is necessary to focus on "win-win" measures that are, in any case, bound to produce positive results for society and would offer protection against the effects of climate change. Examples of such strategies include efficiency in energy production with an emphasis on renewable sources, promoting energy-efficient buildings, upgrading the road network, improving farming methods, afforestation, wetland creation, beach nourishment, prevention of further over-development of coastal activities and upkeep and maintenance of tourist sites, particularly those of historical importance. If these measures are undertaken in a sufficiently timely manner, the need for more costly measures would be reduced or averted.

Chapter 5

The National Action Plan

5.8 Agriculture

- 5.8.1 Code of good agricultural practice
- 5.8.2 Artificial fertilisers
- 5.8.3 Crop species
- 5.8.4 Soil conditions
- 5.8.5 Sea level rise

5.9 Industry

- 5.9.1 Regulation
- 5.9.2 Financial and market incentives
- 5.9.3 Voluntary negotiated strategies

5.10 Health

5.11 Cross-sectorial instruments

- 5.11.1 National emissions inventory database expert system
- 5.11.2 Sequestration of carbon dioxide
- 5.11.3 Research and development
- 5.11.4 National policy formulation
- 5.11.5 Education
- 5.11.6 Special interest groups
- 5.11.7 Monitoring network
- 5.12 Economic cost-benefit considerations
    - 5.12.1 Economic vulnerability
    - 5.12.2 Cost-benefit evaluation

5.1 Executive summary

Climate change is an unprecedented challenge and critical environmental issue facing all countries, but presenting specifically more acute problems for small island states like Malta. Some climate change impacts are already unavoidable due to the resilient nature of the climate system, and will happen anyway even if emissions are cut down. Averting the worst effects requires a strong will for immediate action to control emissions of greenhouse gases as well as to prepare for adaptation to the impinging impacts. Acting now also means avoiding future excessive burdens and averting irreversible situations.

5.1.1 Key implications of climate change for Malta

Our country is expected to suffer a climatic rise in temperature that exceeds global sensitivity by about 9%. The associated meteo-marine alterations, including lower precipitation, changed seasonal patterns and sea level rise, will certainly have direct implications on socioeconomic activities. The most important impacts include the deterioration of potable water supplies and quality, more frequent extreme weather events, soil degradation, erosion and an accentuated desertification process, threats to public health, changes in sea water mass characteristics and effects on fish stocks, coastal erosion and inundation, and biodiversity reduction. The degree of these consequences will in part depend on the extent to which adaptation measures are implemented on time.

5.1.2 A wider national framework for action

Local greenhouse gas discharges constitute only a tiny portion of global emissions, although rates per capita approach those of developed countries. Malta stands to suffer more from the consequences of climate change but, as other small states, cannot be considered as a main culprit. In the context of global warming, business as usual, as far as adaptation is concerned, is no longer an option for Malta.

The choice of future options needs to be viewed within the more general context of environmental health and sustainable development which dictate parallel and complementary actions, and concomitantly call for awareness and changes in attitudes right across the economy and society. An eventual implementation framework should favour multi-sectorial policies (notably for energy, transport and agriculture) that integrate environmental considerations, for example in respect of air, water, and waste. This offers a solid background and driving force for synergies with measures to adopt climate change abatement and adaptation.

5.1.3 The international context

Malta is moreover committed to honour obligations associated with the United Nations Climate Change Convention and the Kyoto Protocol, to which it is party with non-Annex I status. As an EU candidate country, Malta has already been obliged to develop a capacity for reporting, monitoring and verification of greenhouse gas emissions. As a full member of the EU, Malta will now need to adopt a well-set national strategy for climate change. Primarily, this will have to be achieved by integrating domestic policies and measures that entail climate change considerations into the ongoing restructuring process. Notably, restructuring will be in the energy sector through promotion of greener energy, new technologies and energy efficiency, as well as in other key sectors and through the use of market-based mechanisms suitable to the country.

5.1.4 GHG emission sources, sinks and abatement for Malta

The main greenhouse gas in Malta is carbon dioxide (CO_2), with emissions in 2000 reaching 2400 Gg (5.8 Mg/capita), and mainly arising from the burning of fossil fuel in electricity generation (73 %) and transport (20 %). Improved practices in power generation, such as the elimination of coal in 1995 and the introduction of closed cycle gas turbines burning gas oil, as well as the reduced demand for water production, have eased CO_2 emissions. There is evidence for a levelling-off in CO_2 emissions despite increasing demand for electricity (figure 2.4). Proposals for abatement focus on improving efficiency in power generation and transmission, conversion to gas turbines, use of alternative energy technologies and curbing demand. Emissions from the transport sector can become a more relevant contributor unless the trend in the last decade is suppressed, e.g. by restrictions on car use, use of environment-friendly fuels and alternative traction solutions. Substantial emissions of other greenhouse gases include methane (CH_4), with an overall production of around 19 Gg in 2000 mainly from the waste sector (74 %), including agricultural wastes. Measures such as upgrading the Sant' Antnin composting plant, closing down the uncontrolled landfill at Maghtab and replacing it with an engineered landfill and segregation and separate treatment of all municipal solid waste, are expected to lower methane emissions to levels lower than 7 Gg/year. Anaerobic digestion of sewage sludge and animal waste can furthermore produce methane for energy generation.

CO_2 sequestration arising from land-use change and forestry was 110 Gg in the year 2000. Marine sinks were found to be responsible for the uptake of almost 6% of the CO_2 emission from the energy sector in that year. However, according to IPCC guidelines, the latter contribution cannot be included in the inventory. It would be opportune for small island states and others with a large coastal perimeter to land area ratio to allow for the inclusion of marine sinks in their inventory.

5.1.5 Scope and principles of the Action Plan on climate change

The Action Plan provides an administrative framework for achieving greenhouse gas emission reductions in the most efficient and equitable manner for Malta. At the same time, it complements environmental goals and public health, in full compatibility with economic development and competitiveness, safeguarding sound standards of living and helping to prepare the country for the more ambitious commitments of EU membership. It requires policy goals to be established and related sustainable actions and measures to be taken in all sectors. The Action Plan also considers the potential implications of climate change and proposes adaptation measures to minimise or remove future adverse impacts.

The National Action Plan consists of a set of adaptation and mitigation measures that are to be investigated and analysed further with a view to their potential implementation. The plan recognises that the challenge of climate change must be shared equitably by all sectors and needs to be faced by adopting clear criteria that include:

- a commitment in favour of sustainable development;
- a disposition to maximise economic efficiency by implementing cost-effective measures;
- a broad range of policies and measures tailored specifically to all relevant sectors with the intention of achieving emission reductions across all economic sectors;
- a recognition of the specific arrangements and special requirements that pertain to a small island state;
- generating an impetus for early action by adopting a phased approach that allows for immediate actions while planning for longer term provisions;
- a vigorous and appropriate pursuit of common and coordinated policies and measures implemented at EU and wider international levels.

5.1.6 Implementation of the Action Plan

A national strategy resulting from the Action Plan on climate change should be implemented following due consideration of the policies and measures proposed therein. The setting up of a Climate Change Committee, possibly within the National Commission for Sustainable Development, is necessary to work on the formal establishment of a climate change strategy. As a high-level inter-sectorial group, its role would be to oversee the potential implementation of the proposed and other measures and policies that may be deemed feasible in future.

Furthermore, the achievement of policy goals will require widespread national participation and acceptance, supported by an intensive educational campaign to make all stakeholders, both public and private, aware of the implications of current behavioural patterns, and targeting to catalyse synergies towards the fulfilment of climate change objectives and obligations. Empowerment of the public with the creation of dedicated structures, inter-sectorial links and trained personnel will facilitate this process and promote the inclusion and integration of greenhouse gas considerations into both public and private decision-making processes. Emphasis should be made on inclusion of the community in the implementation of climate-related actions. Local Councils should have an active role in public awareness and policy implementation.

The Action Plan highlights the need for an adequate monitoring network for the routine acquisition and analysis of relevant emissions and meteorological data. It also proposes a common database expert system to centralise and harmonise environmental data. This facilitates reporting according to Malta's international obligations.

5.1.7 Summary of policies and measures

The policies and measures suggested in this action plan are intended to either reduce greenhouse gas emissions, in a direct or indirect manner, or to enable the Maltese islands to adapt to the consequential action of new prevailing climatic circumstances. As most measures depend on popular support, it may not be possible to predict with reasonable confidence the effectiveness of feasibility studies and policy adoption at a national level and the quantification of their potential effectiveness.

Below is a list of measures and policies being proposed as an integral part of the National Action Plan. These address GHG abatement, mitigation and adaptation issues in relation to climate change.

Section

1 Energy

- Increase in efficiency of electrical generating plant by using CCGT instead of steam turbines.
- Switching to natural gas as the main fuel instead of heavy fuel and gas/diesel oil.
- Use of CHP plant and integration of renewable energy sources.
- Reduction of SO_2 emissions by using a low sulphur fuel.
- Power factor correction for major users.
- Introduction of modern technology to improve energy efficiency and conservation.
- Increase of awareness of energy efficient devices by using energy labelling systems.

2 Transport

- Improved traffic management.
- Suitable parking schemes and major improvements in public transport to reduce car use.
- Installation of TWC and enforcement of emission regulations.
- Use of alternative fuels, principally hydrogen.
- Use of hybrid and electric traction.

3 Water resources

- Demand-side management of water resources: curbing abuse to limit the need for potable water production.
- Encouragement of the use of alternative water sources for activities that can be satisfied by non-potable supplies.
- Creation of an educational and awareness campaign on efficient use of water.
- Enforcement measures and possibly a revision of water tariffs on the basis of usage.
- Sustainment of efforts to reduce water losses by way of leakage and repair detection, meter repair/maintenance a and pressure management systems.
- Enhancement of groundwater recharge to improve the groundwater/reverse osmosis water production ratio by curtailing illegal groundwater abstraction.
- Monitoring and assessment of the impacts of sea level rise on the groundwater aquifer.
- Development and finalisation of an integrated storm water management plan that comprises a flood mitigation system and improved methods of harnessing storm water (increasing retention times and conserving infiltration areas to enhance groundwater recharge, improving rainwater catchments and storage through the use of more numerous and higher capacity water reservoirs for irrigation).
- Promotion of the use of suitably treated effluent according to international standards especially in the

industrial and agricultural sectors.

- Use of treated effluent in areas that fall outside the groundwater protection zone.
- Improvement of irrigation techniques and their engineering.
- Development of more energy efficient infrastructures in the water production and water supply sectors and wastewater treatment and disposal, including benchmarking of key parameters to establish feasible targets and assess levels of improvement.
- Encouragement of on-site treatment of sewage and reuse of treated effluent by major consumers.
- Reduction of loads on the sewerage system by restraining water consumption as well as through the elimination of illegal water discharges.
- Ensuring that the sewerage system will operate under aerobic conditions, by providing proper design and maintenance.
- Introduction of tariffs for sewage disposal on the basis of water consumption volumes.
- Implementation of the provisions of the Sewerage Master Plan for Malta and Gozo in respect of sewage treatment.

4 Solid Waste Management

- Ensuring that in cases where waste disposal and treatment lead to the generation of greenhouse gases (especially methane), these gases are not released into the atmosphere.
- Replacement of existing uncontrolled landfills with alternative engineered landfills.
- Upgrading of the Sant' Antnin Composting Plant and development of additional recycling facilities.
- Reduction of the amounts of biodegradable waste directed to the landfills, especially by separating waste at source.

5 Agriculture

- Adaptation and diversification of crop species through selection of drought tolerant varieties, introduction of salt tolerant crop varieties and by making wider use of greenhouse controlled cultivation.
- Improvement of systems for rainwater collection and storage to sustain crop production during dry spells, development of more efficient irrigation systems and use of water demand forecasts and reservoir analysis for the agriculture sector.
- Development of a code of good practice for agriculture that focuses on optimisation of water resources, efficient irrigation techniques, efficient application of fertilisers, on-site composting and utilisation and use of treated effluent.
- Reduction of soil erosion through the practice of minimum tillage, stubble crop retention, construction of windbreaks and rubble wall maintenance.
- Employment of soil improvement techniques, such as the addition of compost, to control salinity and to improve water retention, together with the adoption of xeriscaping for embellishment.
- Afforestation, particularly of abandoned land, with the introduction of drought tolerant and heat resistant tree species.
- Combating inundation, loss/degradation of land and coastal erosion resulting from sea level rise by building/ adapting adequate protective structures.
- Protection of special biota, habitats and biodiversity from sea level rise by facilitating natural landward migration of shore zone patterns.

6 Industry sector

- The implementation of regulatory instruments whereby a public authority sets standards, monitors and enforces compliance to set standards and applies formal legal sanctions in cases of infringement.
- Financial and market based instruments in which Government may stimulate cleaner production methods by encouraging the small cooperative approach.
- Implementation of information based instruments to stimulate adoption of a code of good practice in relation to environmental issues by local industry. Informational measures may include public disclosure of industry's environmental performance and relevant case studies.
- Voluntary programmes that encourage industry to adopt self- and co-regulatory policies in the promotion of

good practice aimed to reduce GHG emissions.
- A sustained sensitisation and awareness campaign among industrialists on environmental responsibilities.

7 Health

- Preparation of a Hot Weather Contingency Plan. A task force should be appointed under the direction of the Civil Protection Department and entrusted with the preparation of the plan.
- Identification and setting up of the required emergency infrastructure to implement the Hot Weather Contingency Plan, possibly with the involvement of Local Councils and NGOs.
- Occupational Health and Safety Authority to prepare, in conjunction with employers' and workers' representatives, general or industry specific guidelines for working in hot climatic conditions.
- Identification of persons at risk.
- Setting up of information gathering, elaboration and dissemination systems, including epidemiological studies.
- Creation of public awareness and educational campaigns focusing on the adverse effects of climate change.
- Direction of more resources to primary health care and health surveillance to areas where climate change risk to human health is highest.

8 Cross-sectorial instruments

- Setting up of a national emissions inventory database expert system for Malta to enable efficient and timely reporting and to provide useful information for policy formulation.
- Presentation of a proposal at international fora to allow small island states, and states with a large coastal perimeter to land area ratio, to include marine sinks in their inventory
- Benchmarking of those sectors that are considered to be the major contributors to GHG emissions to corresponding sectors in other regions.
- Assessment of the institutional capacity building requirements across all government agencies.
- Direct accounting of climate change issues in policy formulation and, more specifically, ensuring that the control of GHG emissions is given full consideration in the adoption and implementation of waste management plans.
- Promotion of science and environmental education as part of community planning and development programmes.
- Gap analysis of the National Minimum Curriculum in respect of climate change issues
- Ensuring that as many tertiary level courses include environmental aspects and considerations in their curriculum.
- Preparation and adoption of a strategy for the promotion of environmental education, emphasising aspects related to climate change.
- Preparation and adoption of a strategy for raising the general awareness of climate change issues.
- Development of a meteorological network to monitor regularly and on a permanent basis the key hydrological parameters and related indicators that identify trends of change (such as for precipitation and sea level rise).
- A quantitative cost-benefit analysis was carried out for these measures. This revealed that measures in energy generation provide the most effective support of 'win-win' strategy.

5.2 Introduction

Malta played a very important international role in the setting up of the UNFCCC, becoming a signatory to the Convention in 1994 and currently holding a non-Annex I status. In recognition of the need to take more concrete actions, the developed countries emission reduction targets at Kyoto in 1997, Malta ratified the Kyoto Protocol in 200l; however, its non-Annex I status poses only limited obligations, namely periodic reporting to the respective bodies.

The European Union aims to significantly reduce greenhouse gas emissions. Following Malta's accession to the EU, it should address common and coordinated policies, strategies and measures aimed at climate change mitigation.

Accession should provide a favourable opportunity to establish and implement a national climate change strategy in the short term. This would direct EU financial assistance towards actions that address Malta's specific problems associated with climate change.

5.3 Scope, principles and framework of the National Action Plan

As a small island state with a population of about 400,000, Malta can hardly be deemed responsible for the significant global increase in greenhouse gases in the atmosphere. Its per capita yearly greenhouse gas emissions in carbon dioxide equivalent is about seven tonnes and therefore less than that of some EU member states.

According to a recent report (EEA, 2001), greenhouse gas emissions in the EU have been decoupled from economic growth and energy use. Figures 2.2 and 2.4 indicate that this trend is also manifest in the case of Malta. Figure 2.2 indicates a decoupling of GDP growth from reliance on fossil fuels for energy generation. Figure 2.4 implies that this results from increased efficiency in energy generation, by virtue of the fact that, while demand continued to increase, CO_2 emission from this sector levelled off after 1995.

Owing to its small size and its being the second most densely populated country in the world, Malta's greenhouse gas abatement strategy has to be considered very carefully within a framework of sustainable development. Abatement measures implemented in Malta will have no significant impact on global greenhouse gas emissions but are bound to impact significantly on the local economy and standards of living. This would result, for example, from putting an added burden on local industry to convert to costly reduced carbon technology. Owing to economies of scale that militate against small nations, such measures will make local industry relatively less competitive. The National Action Plan being presented addresses these issues and proposes a series of actable measures for further consideration.

The goal of the action plan is to provide strategic options and accompanying measures for Malta to address the mitigation of and adaptation to climate change. The plan considers the projected economic and social patterns and scenarios in the short, medium and long term scales, taking account of both national and international driving forces.

The plan presents technically feasible and benefit-evaluated measures. It proposes policy and actions compatible with economic growth and social wellbeing that contribute towards mitigation of greenhouse gas emissions and adequate adaptation to climate change.

The key sectorial issues that are taken into consideration are:

- energy generation and use
- transportation
- water resources
- solid waste management
- industry
- fisheries and agriculture
- public health
- institutional arrangements
- public awareness and education.

A series of policy goals and measures are proposed for each sector. Where possible, institutional, legal and educational initiatives that serve to achieve suggested policies are also put forward. The achievement of the stated goals may have different timeframes and cover the short, medium and long term. Furthermore the achievement of policy goals may require the joint collaboration of all stakeholders. The guiding principles and criteria in the action plan are as follows.

- It is necessary to furnish climate-related components, national sustainable development initiatives and environmental management practice in order to secure a sound and integrated decision- and policy-making process.
- Malta needs to comply with international commitments on climate change.
- The protection of economic development acquires special importance owing to Malta's small size and insularity. Measures proposed should thus not impose burdens that reduce competitiveness.
- A phased approach should be adopted to enable Malta to evaluate its progress, learn from experience and incorporate technological and institutional developments over time. Two phases are suggested.
  - Phase 1 (up to 2010): a foundation-building phase comprising actions and measures (e.g. increase in energy efficiency) that can be implemented with relative ease in the short term, are cost effective and benefit the environment, apart from reducing greenhouse gas emissions.
  - Phase 2 (following 2010): all national policies and actions should take into consideration Malta's obligations in respect of international climate change initiatives and GHG emission targets.

5.4 Energy

5.4.1 Electricity generation

The specific emission from grid generated electricity[1] was 0.88 kg of CO_2 per kWh. This is higher than most of the smaller EU countries (e.g. Portugal 0.76, Denmark 0.82, Ireland 0.81), probably because of lower generation efficiency. Countries such as Luxembourg (0.98) and Greece (0.92) have higher specific emissions, possibly because of significant use of coal and biomass. Specific emissions depend on plant operating conditions and calorific value of the fuel.

The mean generating plant efficiencies[2] are currently 24% for Marsa Power Station (MPS) steam plants, 29% for Delimara Power Station (DPS) steam plants and 39% for DPS Closed Cycle Gas Turbine (CCGT). Although improvement in generating efficiency would lead to a proportional mitigation of GHG emissions, switching to a less carbon intensive fuel such as natural gas would be more effective.

The objectives for both direct GHG and indirect GHG emissions from power production require reduction of emissions, for which the following measures are being proposed.

5.4.2 Increase in overall generating plant efficiency

The MPS generating sets could be replaced with modern generating plant, from which an improvement of at least 4% in GHG emissions is envisaged. This would result in saving about 74 Gg CO_2. Payback time for new and more efficient plant is an important consideration. For example, if the total electricity generated in 2000 at MPS had been generated by the more efficient plant at DPS, US$5.7 million would have been saved on fuel.

Alternatively, similar results may be achieved by partial replacement of plant at MPS and installation of new 100 MW CCGT plant at DPS, which would require a capital expenditure of about LM40 million per generating set.

5.4.3 Fuel switching

Switching MPS and DPS to natural gas, obtained via a submarine pipeline from Sicily provides substantial CO_2 mitigation. At present, this option is under investigation.

[1] Mean CO_2 specific emission for the period October 2001 to September 2002.

[2] Current mean plant efficiencies for the period January 2002 to December 2002.

5.4.4 Industrial use of combined heat and power plants and renewable energy sources

An incentive scheme for industrial establishments to install combined heat and power (CHP) plants can be introduced. Experience in the UK shows that up to a third of CO_2 emissions associated with industry may be reduced by implementation of CHP plants.

The obvious renewable energy sources available locally are solar and wind. Industry can use direct solar water heating without any incentive schemes, as capital costs are fairly low and there is a direct saving of electricity. Photovoltaic (PV) panels and wind energy require incentives, owing to their higher capital cost. The feasibility of local PV panel production should be addressed.

5.4.5 Use of low sulphur heavy fuel oil to reduce SO_2 emissions

The heavy fuel oil currently in use by Enemalta contains 2-3% Sulphur. It is envisaged to reduce this figure to less than 0.3%.

5.4.6 Electricity distribution

The quality of electrical power supply is influenced by both utility and consumer. The total amount of grid losses is about 5% of that generated, associated with 85 Gg CO_2 per annum.

The reactive power at utility substations can be reduced to the required amount by capacitive correction. Enemalta could persuade industrial consumers to improve their power factor by charging on the basis of kVA instead of kW. Power factor improvements are costly and the action plan is therefore proposing further investigation of technology options. If found feasible, this measure should be introduced gradually.

5.4.7 Demand-side management

The proportion of total energy sales in kWh to the industrial, commercial and domestic sectors are approximately equal. Electric motors may account for over 50% of the industrial and commercial consumption, while lighting is important in all sectors. Heating appliances and air conditioners constitute the highest portion of domestic demand. The following measures should curb demand.

- A reduction of 30% in energy consumption by electric motors (efficiency gains and speed controls) is achievable.
- Proper dimensioning of air conditioning units and ducting, accompanied by energy efficiency measures in buildings.
- Use of compact fluorescent lamps with further improvements from newer technologies (sulphur lamps and solid state illumination) can give rise to a 50% reduction in lighting demand.
- Introduction of energy labelling and provision of incentives for the purchase of energy efficient appliances and electrical devices.
- Use of solar water heaters and/or switching to liquid petroleum gas (LPG) for space and water heating in the domestic sector.

To facilitate the implementation of the above measures, fiscal incentives should be considered.

5.5 Transport

Land transport is responsible for 15% of GHG emissions. By the end of the year 2000, the number of registered vehicles reached 246,800, of which 182,100 were passenger cars. Road transport generated about 25% of CO_2, 99% of CO, about 50% of NO_x and 70% of NMVOC.

Reduction and emission control of greenhouse gases can be achieved in various ways, such as improved vehicle maintenance, smoothing and staggering of traffic flows, reduction in traffic volume, introduction of proper infrastructure, use of alternative fuels, implementation of alternative technologies and stringent enforcement of regulations.

The best policy to curtail CO_2 emissions from private passenger cars is to limit their use. This could be encouraged by the introduction of efficient public transport systems and infrastructure, and by driver education.

The following sections propose suitable measures for GHG emission reduction.

5.5.1 Emission and fuel taxes

Elsewhere, fuel pricing has been found to be an efficient way of reducing distances driven. However, in the local context, for percentage cutbacks that neutralise the projected increase in petrol car numbers of 8% by 2005 and 15% by 2010, the price of petrol would need to increase by 20% by 2005 and 38% by 2010 as compared to the current price. Such increases are high and a cost-benefit analysis has revealed negligible mitigation benefit but a slight negative impact on competitiveness. Alternatively, abatement may be achieved by introducing a tax on engine emissions. Such measures would provide an incentive towards use of low consumption vehicles. This may be partly offset by an increase in vehicle fuel economy but may result in an increase of vehicle mileage.

5.5.2 Infrastructure

Incentives towards reduced car use can come from changes in availability and cost of parking. A serious transformation of the present (bus) public transport system, including direct linkages which do not go via the Valletta terminus, would also provide a powerful impetus to decreased car use.

Decreased car use will lead to less congested roads and permit higher average speeds, resulting in lower emissions. For petrol cars, with or without catalysers, a speed increase from 20 to 60 km/h will reduce CO emission by 67% and NMVOC by 50%.

5.5.3 Three-way catalytic converters

Three-way catalytic converters (TWC) will impact on CO, NO_x and NMVOC emissions. CO and NMVOC are produced almost exclusively (97%) from petrol vehicles. Hence, a TWC will remove these from circulation. Starting with a completely non-catalysed fleet in 2000, if all cars are fitted with a TWC by 2005 the emission reductions would be about 80 Gg of CO and 15 Gg of NMVOC, about three times the 2000 transport emissions. However, although the TWC removes two ozone precursors it increases CO_2 emissions.

About 20% of transport NO_x comes from diesel engines, which usually have simple oxidation converters. A completely catalysed diesel fleet by 2005 would result in a further reduction of 11 Gg.

Enforcement of regulations related to vehicle emissions will help to attain stipulated targets. In this respect, it would make better enforcement practice to test vehicles for emissions following their third year in use.

5.5.4 Alternative fuels

Bio-diesel, LPG and compressed natural gas (CNG) offer significant reductions in greenhouse gas emissions other than CO_2 over the usual petrol and diesel passenger cars. Hydrogen, generated from electrolysis of water powered by renewable sources, if used in internal combustion engines or in fuel cells, will produce no greenhouse gases.

If all hydrogen had a PV origin, a market penetration factor of 0.5% per year from 2005 would avoid about 30 Gg of CO_2 as well as small quantities of other emissions, but only half that amount of CO_2 if the hydrogen is methanol-derived.

The major disadvantage of these low CO_2 options is that they are unlikely to be economically attractive in the short term.

5.5.5 Battery electric traction and hybrid technologies

Hybrid electric traction, where all charging comes from on-board energy (petrol or diesel), can be considered as increasing the fuel economy of the vehicle. Limited experience with running hybrids suggests that fuel consumption, and so GHG emissions, is essentially halved.

Pure electric traction cuts down CO_2 emission by about 50% and virtually eliminates CO and NMVOC, as power stations have very low emissions of each.

5.6 Water resources

The efficient management of water resources is a key issue for Malta akin to other small island states. Climate change is expected to exacerbate shortage of water supplies, leading to further dependence on non-natural sources and consequently impacting on the energy budget.

Consumption of electricity by the Water Services Corporation (WSC) amounts to 9% of total electricity sales. In addition, sewage treatment places an additional burden on the energy budget and the GHG inventory. An integrated water management strategy is necessary for more effective harnessing of rainwater, to control misuse, reduce demand for potable water and to diversify the utilisation of water supplies by seeking alternative sources for non-potable use. The planned building of three new sewage treatment plants will offer the opportunity to further use this additional source of water in the agricultural and industrial sectors. Furthermore, an energy efficient infrastructure for water production should form part of the integrated water management strategy.

5.6.1 Demand-side management

Assessment of water consumption patterns and identification of components that can be replaced by alternative, naturally occurring sources should form the basis of demand-side management. Introduction of dual water supplies for domestic and community use is one important measure. Non-potable water requirements constitute a significant portion of the overall household consumption. Planning regulations require buildings to have underground cisterns to collect rainfall deposited on the roof area. However, there is no specification as to how such water may be used and in consequence most premises lack the necessary infrastructure. For example, toilet flushing is estimated to constitute around 30% of current potable water demands (Gatt, 1993) and its replacement by cistern water would contribute to a reduction in GHG emissions of up to 0.1 Mg per capita per year.

Management of water resources requires consumer education on feasible practices, awareness of the real cost of water and provision of incentives for installing dual water systems.

5.6.2 Groundwater resources

Groundwater recharge helps to rehabilitate the aquifer and improve the groundwater-to-desalination water ratio. A simulation model is necessary for the scientific assessment and monitoring of the aquifer condition to estimate damage by seawater intrusion due to sea level rise and overextraction, as well as to calculate recharge duration for its sustainable exploitation.

Illegal extraction of groundwater is not yet under adequate control. A voluntary registration scheme for groundwater boreholes was launched some years ago, but there is lack of information on usage. It is now important to identify remaining illegal boreholes, and to monitor extraction.

5.6.3 Storm water

Storms generate significant fluxes of rainwater which need to be properly controlled and directed into improved catchments. This can be achieved by the design and implementation of an integrated storm water collection and control network to harvest rainwater more efficiently, as well as to direct such water to locations which minimise damage and where increased infiltration may occur without adverse effects. Measures should be taken to increase retention times in regions where it can contribute to groundwater recharge.
Non-potable water demand in agriculture can be partially satisfied by the construction of water storage reservoirs in rural areas for more effective storm water collection and use.

5.6.4 Second class water and wastewater

Under the Barcelona Convention and in conformity with the Urban Waste Water Treatment Directive (98/15/EEC and 91/271/EEC), Malta has a firm commitment to treat all sewage prior to its discharge at sea by 2007. Suitably treated effluent is a by-product that offers scope for utilisation in processes where non-potable water supplies are adequate.

Use of treated effluent for irrigation is currently only permitted outside the groundwater protection zone. Improved effluent quality will further encourage use of such water, possibly *in lieu* of groundwater. Industry can also benefit from use of second class water in applications such as for cooling systems and for cleaning purposes. Polishing of the final effluent may be necessary in some cases and the technology required should be investigated.

Comparatively large developments such as hotels and industrial estates should be encouraged to carry out on-site treatment of their sewage. Besides alleviating the burden on the public infrastructure, the treated effluent could be directly reused for non-potable activities.

The sewerage network should be operated under aerobic conditions by ensuring correct gradients and design velocities that would not permit sewage to turn septic prior to treatment. It is also necessary to lower the salinity of the sewage by reducing sea water intrusion and eliminating discharge of brine or sea water. This would improve the quality and increase the potential uses of the treated effluent. Industrial liquid effluent can contain dangerous substances that disrupt the aerobic treatment process and limit subsequent reuse. Legal Notice 139/2002 is partly intended to protect public sewers. Its enforcement should thus ensure the suitability of second-class water by-product for use in agriculture and industry.

In order to reduce sewage volumes and consequent problems of treatment, it is necessary to enforce existing regulations precluding discharge of rainwater into the sewerage system.

Separate billing for disposal of liquid waste, based on water consumption, could have the double benefit of curbing misuse of water and reducing sewage volumes.

5.7 Solid waste management

The minimisation of methane emissions is the main objective of the measures considered under this section. The Solid Waste Management Strategy (SWMS) for Malta (METAP, 1993) established four objectives, namely:

- reduce waste output to break the link between economic growth and waste production;
- recover value from waste;

- adopt an integrated waste management system that uses the best and most economically viable technology/techniques;
- ensure safe waste disposal.

The SWMS does not specifically consider climate change issues, but many of the proposed measures converge with those recommended in this action plan. Compared with other treatment options, source segregation of municipal solid waste followed by recycling and composting of putrescible waste generates the lowest GHG emissions.

A waste management plan for animal manure, as well as a code of good agricultural practice, is necessary. The options for animal manure management are as follows.

a. Composting and application to agricultural land. This can take the form of composting in a central plant, with or without mixing with separately collected degradable waste of municipal or industrial origin. Alternatively, the composting process can take place on the farm. Precautions should be taken to maintain aerobic conditions to ensure insignificant emission of CH_4.

b. Anaerobic treatment and application to agricultural land. Any CH_4 generated in the process should be captured and flared or utilised as a renewable energy source.

The Sewerage Master Plan (COWI, 1992) envisages the building of three new sewage treatment plants which, in addition to the existing plant at Sant' Antnin, will treat all sewage prior to use in agriculture and industry, with any excess being discharged to sea. The treatment of sewage will result in large amounts of sludge (about 11 kt per year, resulting in approximately 3 Gg of methane). Preliminary analysis of sewage sludge indicates that it will probably not be acceptable for application to agricultural land. The management options for sewage sludge are the following.

a. Anaerobic treatment followed by use of stabilised sludge in afforestation projects or as landfill cover. The CH_4 generated (about 3 Gg per year by 2010) may be flared or utilised as a renewable energy source. This will require substantial initial investment.

b. Dewatering and composting (mixed with a bulking agent) followed by use of the product compost in afforestation projects or as landfill cover. This option does not require substantial investment; however, disadvantages include odour emissions and no power generation potential.

c. Drying and incineration followed by land filling of ash residue. The CH_4 generated is negligible. Disadvantages include high running costs incurred in flue gas cleaning and sludge drying.

Other specific actions are being proposed in the following sections.

5.7.1 Engineered landfills

An engineered landfill should be established for the disposal of pre-treated waste such as non-recyclable fractions. It is estimated that this would require an investment cost of about LM5.2 million. Landfill operations should include controlled emplacement of the waste in lined cells, appropriate compaction, daily cover and final capping in order to prevent emissions. Emissions from landfills should remain below 40% of the total methane generation potential.

The old landfills should be phased out. In the meantime, scientific profiling of these sites should be carried out in order to establish the best restoration plan with attention placed on land-use change that might result in GHG emission. The feasibility should be considered of retrofitting landfill gas extraction systems and gas utilisation or flaring as part of the site restoration.

5.7.2 Composting plant

The existing composting facility at Sant' Antnin needs to be upgraded into a composting and recycling complex. This facility would enable the processing of a significant volume of biodegradable waste and would produce high quality compost for local use, as well as the sorting and processing of other dry recyclable material. This measure also envisages the introduction of the separate collection of biodegradable and other recyclable wastes from households and commercial establishments. The capital investment for this upgrade is estimated at LM8 million.

5.7.3 Disposal of biodegradable waste in landfills.

Methane generation from solid waste dumped in landfills is linked to the degradable fraction. If appropriate measures, such as those suggested in section 5.7, are implemented, it is anticipated that by 2020 the fraction of biodegradable municipal waste would be reduced progressively to 35% of that disposed in landfills during 1995. Moreover, all biodegradable waste should be treated prior to disposal in landfills so as to further reduce methane generation.

5.8 Agriculture

The current amount of agricultural land in the Maltese islands is 10,700 hectares and has declined from 38% to 33% of total land area in the last ten years (NSO, 2000). The contribution of the agricultural sector to the economy is only about 2% of GDP. Nonetheless, the farming community constitutes an important component of Malta's social structure and it is necessary to sustain this sector for food security as well as to maintain the rural character of the countryside. There are three major types of agricultural activity on the Maltese islands, namely garden and orchard, dry farming and livestock farming.

The adoption of a new rural development plan, essential for EU Common Agricultural Policy, is a policy development that not only strengthens the role of farmers within the modern concept of multifunctional agriculture, but also recognises the varied needs of rural areas as well as associated environmental requirements. It incorporates a number of measures that aim to consolidate the traditional characteristics of Maltese agriculture through food marketing and processing, as well as improvement and enhancement of the rural environment. Implementation will mainly follow through assistance schemes that encourage increased environmental awareness and responsibility, reduction of soil erosion, an improved landscape quality, an increased biodiversity, the promotion of sustainable farming practices and improved rainwater catchments.

The recommended actions for agriculture are intrinsically linked to the adaptations that this sector will have to adopt to face changes in climate. GHG emissions from this sector are already low and the objective of the proposed measures is to pursue the challenges of adaptation to climate change.

5.8.1 Code of good agricultural practice

The agricultural sector is an important stakeholder in the overall demand for water resources. The water and sewerage operators and regulators are called to work in close collaboration with the competent authority responsible for agriculture to integrate water resource management into a code of good agricultural practice. Issues such as rain water capture and conservation, use of treated effluent and sludge, optimised irrigation techniques, manure management, effective use of fertilisers, as well as improved soil management, are all issues that impact water demand. In particular such a code should comprise:

- promotion of micro-irrigation techniques and application of crop mapping for efficient water resource management;
- a shift to organic farming practice to conserve material and energy resources and reduce pollution and emissions from the production and use of nitrogenous fertilisers;

- optimisation of fertilisers to avoid the presence of excess nitrogen in soils, taking into consideration factors such as the effect of temperature on the decomposition rate of organic matter and accelerated soil processes that determine fertiliser digestion;
- improvement of the soil matrix through the use of compost for additional soil surface permeability;
- aerobic digestion of solid manures by on-site composting and reuse;
- incentives to encourage wider use of second-class water.

5.8.2 Artificial fertilisers

Approximately 80 kg of nitrogen per hectare per year is deposited in agricultural land through the administration of artificial fertilisers. Emission of N_2O is one of the environmental impacts of this application. The Ministry of Agriculture and Fisheries is currently preparing a code of good agricultural practice which includes advice on nitrogen management. It is also entrusted with the implementation of an environmental action programme stipulating maximum levels and acceptable timings for nitrogen and manure application.

5.8.3 Crop species

The response of crops to climatic changes is not easy to assess, and consequently a flexible approach is necessary. There is, however, a significant potential for synergies with other policy priorities such as water resource management, efficient rainwater collection, nutrient management, soil quality, support for rural development, etc. A gradual shift in cultivation trends and practices should be encouraged by exploiting the production of crops that concomitantly sustain profitability to farmers and minimise water requirements. This implies crop diversification to better exploit the seasonal patterns of temperature and precipitation, including a shift to drought tolerant crops, use of more salt tolerant plants in low-lying areas close to the sea and widespread use of cultivation under controlled conditions e.g. greenhouses.

5.8.4 Soil conditions

The current estimate of local CO_2 sequestration by trees is about 5% of emissions from energy generation but it more than balances the emissions from the agricultural sector. Integration of environmental and climate change considerations in agriculture policy should favour an improvement of sequestration budgets.

Adequate protection against soil erosion is needed because of the threat of aridity. Soil conservation techniques must be adopted, such as the addition of soil conditioners e.g. peat, compost, sand vermiculite and manure. Exposure to erosion in agricultural areas is primarily in natural drainage depressions that have been cultivated or where rubble walls have not been maintained. Other than by providing good ground cover, erosion may also be combated by the adoption of various practices such as contour tillage, contour sills, contour banks, absorption banks, grade banks, diversion banks, spreader banks, gully stops, terraces, diversion terraces, grassed waterways, no-till cultivation techniques, retention of crop stubble, growing hedgerows or tree windbreaks and strip or alley cropping.

5.8.5 Sea level rise

The most obvious effect of sea level rise is the inundation of low-lying coastal areas. Most of the bays, sandy beaches and gently sloping rocky coasts, mainly along the northeastern shoreline, are expected to experience various degrees of submergence, shifting shore zone patterns landward, resulting in loss of littoral to sub-littoral habitats. Existing infrastructure may serve to reduce the extent of inundation. As long as inundation is gradual, enough sediment is available and an ecological corridor is accessible, these threatened habitats may migrate inwards. However, constructions built along shorelines over the past decades may inhibit such inward migration, leading to an irreversible loss of biodiversity on the Maltese islands. Among adaptation measures it is necessary to designate building-free zones, which will only permit the construction of protective structures against inundation and coastal erosion. Transplantation of important species and habitat recreation schemes should be considered in vulnerable low-lying coastal areas with important and rare habitats. Sea grass ecosystems also need to be protected in view of their importance as a special habitat for many marine organisms, in combating coastal erosion and in stabilising seabed conditions. Furthermore, their role in CO_2 uptake should not be underestimated.

5.9 Industry

The industrial base in Malta consists of a few large companies and thousands of small, medium and micro manufacturing units amounting to about 3000 enterprises. Manufacture contributes 26% to the GDP and consumes 27% of power generated (Ramboll, 1997).

It is necessary to decouple economic activity from environmental degradation. The minimization of GHG emissions from energy consumption in industry has been considered in section 5.4. Nevertheless, industrial activity should be considered as a key component target to achieve such goals. Specific measures are being proposed in the following sections.

5.9.1 Regulation

It is necessary to incorporate cleaner production principles and objectives into public policies for the manufacturing industry. This should be achieved against emission reduction performance targets through the formulation of industry-specific guidelines and standards.

5.9.2 Financial and market incentives

Grants, loans and favourable tax regimes are key incentives to promote the implementation of cleaner or alternative energy resources and to underpin industry practices that favour both efficiency and environment/climate friendliness. Such measures can be concretely achieved by:

- financial subsidies to stimulate technological development;
- tax incentives and recognition for adoption of environment-friendly technology;
- removal of subsidies on the importation of used, outdated and/or inefficient technology.

5.9.3 Voluntary negotiated strategy

Dissemination of information and technical data relating to GHG emission in industry is necessary. It is also necessary to encourage links with foreign industry for technology transfer on methods for reducing GHG emissions.

Measures for achieving energy efficiency gains within industry are often low-cost or have cost benefits for production. It is also recognised that energy inefficiency is higher in small and medium enterprises and consequently efforts and investment in this category can be more effective. It is necessary to introduce energy performance indicators specific to this category and follow an implementation scheme through voluntary negotiated strategy with industry. This should specify objectives and timeframes, provide an open and transparent system of reporting and monitoring, promote public and private partnerships and be accompanied by appropriate incentives.

5.10 Health

It needs to be highlighted that Malta has a rapidly aging population concentrated in urban areas, where temperatures are generally higher than in suburbs. Such people are at risk during heat waves as their health status depends on cooling devices powered by the domestic electricity supply. The following are some measures that can be implemented in order to avert heat-related morbidity and mortality.

- A task force should be set up to identify persons at risk and to formulate a hot weather contingency plan. The focal point for this task force should be the Civil Protection Department.
- The infrastructure required for implementing the contingency plan should be set up through a collaborative effort involving all stakeholders, notably Local Councils and non-government organisations.
- The Occupational Health and Safety Authority should prepare guidelines for working in hot climatic conditions, following consultation with employers' and workers' representatives.
- It is essential to gather and analyse information reliably and to disseminate it effectively. This information should form the basis of epidemiological studies on the effects of climate change on public health.
- More resources should be directed to primary health care and health surveillance in areas where climate change imposes the more severe threats to human health.
- Public awareness and educational campaigns focusing on adverse effects of climate change are necessary in order to ensure the success of these proposals.

5.11 Cross-sectorial instruments

Cross-sectorial measures are those comprising an across-the-board activity and/or require a combined effort across a number of sectors. Indeed, a commitment to climate change abatement must have a multifaceted approach that embraces all sectors and brings about the necessary synergies.

It is necessary for institutions to have sufficient capacity to coordinate and implement established policies and measures and to secure their acceptance by the public through educational programmes. The following sections describe a number of cross-sectorial policies and measures.

5.11.1 National emissions inventory database expert system

The need for a national emissions inventory database expert system arises from Malta's present obligations associated with its being a signatory to conventions that demand periodic reporting on atmospheric emissions. A concerted effort in trying to develop a common atmospheric emissions database expert system would not only minimise the effort required in periodic reporting to the UNFCCC Secretariat in Bonn, but would do the same in the case of other conventions. Furthermore, the database expert system would ensure consistency in the data submitted to different organisations/institutions associated with the different conventions. The system would also ensure timely reporting to the respective institutions.

Monitoring of emissions and compilation of emissions data will be necessary at key selected source points as well as at arbitrary locations. Such a monitoring system will complement and make use of the structures and arrangements (both for data acquisition and management) proposed for the meteo-marine observation network mentioned elsewhere in this report.

A common database expert system should harmonise data from diverse sources. This harmonisation should be extended to regional and international scales. This would necessitate agreement on methodologies associated with data collation, analysis and storage. Quality control and assurance of data should form an essential part of harmonisation. This would help in establishing reliable trends, consistency over time, comparability among regions and transparency. Furthermore, any gaps in the data would be easily identified well before the submission of reports.

Access to this system could be provided over the Internet and should include not only atmospheric emissions data but also national energy statistics. Implementation of this proposal would respect the public's right to access information related to the environment, increase awareness and provide essential information to industry.

5.11.2 Sequestration of carbon dioxide

CO_2 sequestration arising from land-use change and forestry was 110 Gg in the year 2000. Marine sinks, such as *Posidonia Oceanica* and algae, sequester a further 130 Gg[3]. The latter constitutes almost 6% of the CO_2 emission by the energy sector for that year. However, according to IPCC guidelines, the latter contribution cannot be included in the inventory. It would be opportune for small island states, and states with a large coastal perimeter to land area ratio, to allow for the inclusion of marine sinks in their inventory. As stated earlier, this is a reasonable assertion, since coastal regions are considered part of state territory and consequently should be considered for the purpose of providing more realistic net national CO_2 emission values. Malta should thus take the initiative at international fora to convince other nations of the importance of this particular issue.

5.11.3 Research and development

Malta's active participation in research and development projects should be supported. Such projects should focus on energy saving practices, cleaner fuels and renewable energy technologies that target emission reductions.

The common database system proposed in section 5.11.1 is essential to quantitative benchmarking. In the international and the regional contexts, it is important for Malta to set realistic climate change abatement objectives that do not impinge on the country's competitiveness.

5.11.4 National policy formulation

In the preparation of all future planning and policy instruments, as well as in revisions of existing plans and instruments, it is necessary to integrate climate change issues into the relevant sectorial policies. Inter-sectorial synergy would facilitate this process and promote integration of climate change considerations in decision-making. Greater involvement of the community in implementation of climate-related actions should be encouraged.

Establishment of a Climate Change Committee within the National Commission for Sustainable Development will enhance participation in national policy formulation. Such a committee will have the principal task of providing advice to Government on best practices in matters related to climate change. It should work on the establishment of a climate change strategy and administer the phased implementation of this action plan.

A national climate change policy should establish the obligations of the various stakeholders. Such a policy would cover:

- regulation of national climate change strategy;
- development of strategic partnerships within business and industrial communities;
- development of a voluntary action plan for business and industry;
- promotion of climate change initiatives across society;
- introduction of legislation in connection with renewable energy resources.

5.11.5 Education

To some extent, all climate change initiatives depend on the public's commitment to environmental issues. Healthy attitudes towards the environment stem from effective education targeting a wide cross-section of the population.

Educational programmes should be designed to improve environmental literacy, to empower citizens with knowledge about implications of everyday practices on emissions and consequent effects on climate change, and to promote a positive attitude towards environment friendly practices.

[3] This was calculated assuming 50 meadows each measuring 50 m by 50 m. In the case of algae, two strips, each of 50 km by 10 km, were assumed.

Educational initiatives in support of climate change issues should include:

- emphasis on environmental topics, in particular climate change, in the National Minimum Curriculum;
- use of the media to present topics on climate change in forms that appeal to the lay public;
- introduction of climate change topics in tertiary education courses to ensure that professionals are well versed in climate change obligations and issues;
- identification and utilisation of EU schemes (e.g. Comenius) to promote climate change related activities in schools;
- promotion of science and environmental education as an integral part of continuing professional development programmes in as many disciplines as possible.

5.11.6 Special interest groups

Certain groups of people are more vulnerable to climate change and its consequences. Among these are low-income groups. Their vulnerability is primarily due to the cost of adapting residences to climate change and possibly also because their economic activities are among those that would be most affected by the phenomenon.
No significant adverse effect of the proposed measures of protection against climate change can be identified with respect to any special interest group, provided that indirect costs emanating from the proposed measures, such as increases in Government expenditure, would be shared equitably.

5.11.7 Monitoring network

Regular measurements of key meteorological and marine parameters are essential in tracking climate trends. These are also important to enable reliable weather and marine forecasts, which help to pre-empt and thus limit damage associated with extreme weather events. Efforts should be made to enhance existing measurement facilities and to integrate information being gathered by the Meteorological Office and the University of Malta within a database that should be linked to the national emissions database expert system (section 5.11.1).

5.12 Economic cost-benefit considerations

This section briefly describes the main elements of vulnerability to climate change present in the Maltese economy and the likely implications of ignoring such effects. Chapter 4 of this document sets the scenario against which the costs and benefits of the measures proposed in this plan are subsequently evaluated.

5.12.1 Economic vulnerability

The main characteristics that make the Maltese islands particularly vulnerable to climate change are the following.

a. Malta has one of the smallest populations in the world. Smallness tends to increase vulnerability to climate change (Briguglio, 1995).
b. Malta is one of the most densely populated countries, with over 1,200 inhabitants per square kilometre. This increases vulnerability and hampers adaptation to climate change (Attard *et al.*, 1996).
c. Tourists raise the effective population, especially during the summer months when an increase of about 10% is typical. The tourism sector is highly susceptible to climate change (Bijlsma, *et al.*, 1996).
d. The demography of Malta is similar to that of other developed countries, with very low birth and death rates and an ageing population. This exacerbates sociodemographic vulnerability to climate change and costs of adaptation.

A potential source of economic vulnerability to climate change is the disruption of productive and expenditure activities. GDP in Malta features the minimal and declining share of agriculture, an important but diminishing contribution of industry and an increase in service activities. Permeating all these economic activities is the tourism industry, which is estimated to contribute around 20% to GDP. Within manufacturing, there is a predominance of high technology firms involved mainly in the production of semiconductor chips and medical equipment. The production of food, beverages and tobacco occupies another substantial share of manufacturing sales. It is considered that these two major sectors are relatively vulnerable to climate change.

5.12.2 Cost-benefit evaluation

A number of adverse economic consequences can be envisaged if the effects of climate change are allowed to take hold without any mitigation or adaptation measures. Although a healthier environment is a cause that calls for suppressed emission levels, priority measures should aim for 'win-win' situations that tackle requirements for adaptation within a framework of sustainable development and economic growth.

Benefits deriving from the measures proposed in this plan have to be viewed against the costs of implementation in order to quantify their cost-effectiveness and feasibility. A cost-benefit analysis typically entails the quantitative estimation of the additional benefits and costs that are associated with the implementation of a specific measure over its useful life. Such estimates are adjusted for the degree of uncertainty and the resulting net benefits are brought to present values using appropriate discounting techniques (see, for example, Gramlich, 1990). This approach is not ideal for assessing climate change measures, where the quantitative evaluation of costs and benefits is complicated by a long time horizon and a considerable degree of uncertainty. A qualitative approach was adopted, based on IPCC guidelines (Carter *et al.*, 1994) and UNEP guidelines (Feenstra *et al.*, 1998). This approach takes into account the uncertainties that typically bias the effectiveness of the measures, the actual need for the measures and their implementation costs, focusing on the extent to which measures are likely to produce benefits additional to those associated with climate change, as well as on their ease of implementation.

The methodology entails a qualitative evaluation of the costs and benefits associated with a measure on the basis of a Likert scale, taking into account the effect of uncertainties. The qualitative evaluations are derived on the basis of consultations with other members of the project team.

A given measure within the action plan is classified in terms of its effects on climate change, mitigation and adaptation. Each measure's benefits are categorised into those associated directly with climate change or with other issues, so as to assess its potential for the creation of 'win-win' situations. In each type of benefit, a description of its nature is provided by means of two numerical values. The first is associated with the degree of effectiveness that the measure is likely to achieve in relation to the benefit being considered. The second is the likelihood with which such a degree of effectiveness is likely to be achieved. Both numerical values range from 0 ("inexistent"), up to 5 ("high").

The costs associated with a given measure are likewise divided into two categories, namely direct and indirect.

Sectors	Gg of CO_2 emission (2000)	Sector weighting
Energy generation	1427	34%
Transport	496	15%
Water resources	357	12%
Waste management	90	7%
Agriculture	5	5%
Industry	58	6%
Health	11	10%
Cross-sectorial instruments	n/a	10%
Total	2444	100%

Table 5.1 Sector weight for cost-benefit analysis.

Direct costs are those associated with the actual implementation of the measure. Indirect costs of the measure are second-round effects that would impact negatively on society and the economy. The direct costs are evaluated in terms of initial outlays and annual running costs. Both are evaluated on a six-point scale starting from 0 ("inexistent") and rising in steps of LM2 million up to 5 for costs in excess of LM8 million. For the purpose of cost amortisation, the lifespan of a measure is assessed on a three-level scale with the lowermost level (1) associated with a span of up to 5 years, level 2 with a 6 to 10 year span and level 3 for periods in excess of 10 years. Indirect costs are described in terms of their nature and evaluated, in terms of their impact and degree of certainty, on the same lines as the method adopted for the benefits.

An overall benefit assessment of a measure is derived by scaling the effectiveness factor by the likelihood separately for both direct and indirect benefits. The final score for the given measure is the average of the two resulting products. A similar approach is adopted to obtain an overall cost assessment. The net benefit of a measure is

Rank	Measure	Sector	Weighted net benefit
1	1.6 Use of technology to improve energy efficiency and conservation.	Energy	1.14
2	1.2 Use of natural gas as main fuel instead of heavy fuel and gas/diesel oil.	Energy	1.00
3	1.1 Use of CCGT instead of steam turbines to improve efficiency.	Energy	0.74
4	1.3 Use of CHP plant and integration of renewable energy sources.	Energy	0.57
5	1.4 Use of a low sulphur fuel.	Energy	0.51
6	1.7 Use of energy labelling to improve public awareness.	Energy	0.46
7	3.1 Curbing of abusive water use and introduction of alternative non-potable supplies.	Water	0.35
8	3.10 Implementation of provisions of Sewerage Master Plan.	Water	0.30
9	7.2 Identification of persons with health risk and implement education campaign.	Health	0.30
10	3.4 Storm water harnessing.	Water	0.29
11	3.8 On-site treatment of sewage and use of treated effluent by heavy consumers.	Water	0.27
12	7.3 Preparation and implementation of occupational health measures.	Health	0.27
13	2.3 Installation of TWC and enforcement of emission regulations.	Transport	0.27
14	3.5 Increased use of treated effluent.	Water	0.26
15	7.1 Preparation of hot weather contingency plan and setting up of relative emergency infrastructure.	Health	0.25
16	3.6 Improvement of irrigation techniques and their engineering.	Water	0.25
Note: The reference numbers of the measures correspond to those appearing in the appendix.			

Table 5.2i Relative ranking of the proposed measures.

Rank	Measure	Sector	Weighted net benefit
17	7.4 Focus on primary health care and health surveillance.	Health	0.25
18	3.9 Curbing of illegal storm water discharges to sewage system.	Water	0.24
19	8.3 Promotion of science and environmental education.	Cross-sect-orial	0.20
20	5.3 Control of soil erosion.	Agriculture	0.19
21	5.4 Implementation of soil improvement techniques and afforestation.	Agriculture	0.19
22	3.2 Sustainment of efforts to detect and repair leakages.	Water	0.17
23	3.7 Improvement of energy efficiency in water production and wastewater treatment.	Water	0.17
24	5.2 Improvement of rainwater collection and storage, and of irrigation systems.	Agriculture	0.15
25	8.1 Setting up of a national emissions database.	Cross-sectorial	0.15
26	4.4 Reduction of disposal of biodegradable waste in landfills, especially by separation at source.	Waste	0.14
27	4.5 Banning of the dumping of waste from healthcare facilities, fish-farming, etc. in landfills.	Waste	0.14
28	6.2 Introduction of incentives to use clean technology and disincentives to discourage polluting technologies.	Industry	0.13
29	4.1 Prevention of the release into the atmosphere of greenhouse gases from waste.	Waste	0.12
30	4.2 Closing down and restoration of existing uncontrolled landfills.	Waste	0.12
31	4.3 Upgrading of Sant' Antnin plant to reduce amount of biodegradable waste going to landfill.	Waste	0.12
32	6.1 Regulation of emissions.	Industry	0.10
33	6.3 Information-driven networking and training towards clean industrial technology.	Industry	0.10
34	5.1 Adaptation and diversification of crop species.	Agriculture	0.09
35	6.4 Introduction of voluntary programmes for self-regulation and co-regulation.	Industry	0.09
36	2.2 Improvement of public transport and management of parking practices.	Transport	0.09
Note: The numbers preceding the measures correspond to those in the appendix.			

Table 5.2ii Relative ranking of the proposed measures.

Rank	Measure	Sector	Weighted net benefit
37	3.3 Protection and regeneration of groundwater resources.	Water	0.09
38	8.2 Consideration of climate change issues in policy-making and in environmental impact assessments.	Cross-sectorial	0.08
39	5.6 Facilitation of natural landward migration of shore zone patterns.	Agriculture	0.05
40	5.5 Erection of protective structures against sea inundation.	Agriculture	0.02
41	1.5 Adjustment of power factors for major users.	Energy	0.00
42	8.4 Implementation of economic instruments.	Cross-sectorial	0.00
43	2.1 Increase of fuel price.	Transport	-0.11
44	2.5 Use of hybrid and electric traction.	Transport	-0.23
45	2.4 Use of alternative fuels, principally hydrogen.	Transport	-0.32
Note: The numbers preceding the measures correspond to those in the appendix.			

Table 5.2iii Relative ranking of the proposed measures.

obtained by deducting the overall cost from the overall benefit, a procedure which is justified by the fact that the cost and benefit measures are derived through similar approaches. This would result in identification of measures with positive and negative net benefits.

In making comparisons between the net benefits of measures, the possibility is also considered that they may have different impacts on climate change issues when they are applied to different sectors. For instance, energy production and transport are likely to have stronger effects than agriculture and health. For this reason, it is appropriate to apply different weightings to the net benefits of measures depending on the sector. The weighting scheme shown in table 5.1 was derived by apportioning a 10% weight to cross-sectorial and health measures and a flat 5% weight to the other sectors. The remaining weights are apportioned in line with the share of each sector in year 2000 CO_2 emissions.

The appendix gives details of calculations based on this methodology. The results are displayed in table 5.2 in order of relative ranking of the proposed measures.

Measures with the highest weighted net benefits are primarily associated with energy production. This reflects the high relevance of energy generation to overall emissions in Malta, together with the fact that the proposed measures feature a number of important benefits that are not strictly associated with climate change, but are also related to pollution and human health. Apart from making a marked improvement to the emissions scenario, such measures are thus more likely to create ‘win-win’ situations for the Maltese economy and society.

The water production and health sectors also feature a number of measures with important net weighted benefits. Such measures, together with those related to the agricultural sector and waste management, feature a number of adaptation approaches rather than ones aimed strictly at mitigation. This reflects the relatively high scores attributed to adaptation measures in small islands such as the Maltese archipelago, where climate change effects are typically attributable to activities in other countries rather than to its own. In particular, adaptation measures associated with the health sector are among those with the most significant net benefits.

In spite of the relatively high emissions by the transport sector, measures associated with this sector score relatively low in terms of their weighted net benefits. This reflects the generally large economic costs and the low degree of certainty on benefits associated with these measures, especially when they concern changes in fuel prices or use of alternative fuels. In fact, these are the only measures featuring a negative net benefit. A notable exception to this is the installation of TWC and the enforcement of emission regulations.

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Appendix

Cost-Benefit Analysis

Measure	Nature (Adaptation-/Mitigation)	Benefits					
		Climate Change			Other		
		Nature	Effectiveness*	Degree of Certainty	Nature	Effectiveness*	Degree of Certainty
1. Energy generation							
1.1 Use of CCGT instead of steam turbines to improve efficiency.	Mitigation.	Reduction in GHG emissions.	2	4	Savings in fuel bill.	2	4
1.2 Use of natural gas as main fuel instead of heavy fuel and gas/diesel oil.	Mitigation.	Reduction in GHG emissions.	5	4	Savings in fuel bill.	3	3
1.3 Use of CHP plant and integration of renewable energy sources.	Mitigation.	Reduction in GHG emissions.	3	2	Savings in fuel bill.	3	2
1.4 Use of a low sulphur fuel.	Mitigation.	Reduction in GHG emissions.	3	3	None.	0	0
1.5 Adjustment of power factors for major users.	Mitigation.	Reduction in GHG emissions.	3	3	None.	0	0
1.6 Use of technology to improve energy efficiency and conservation.	Mitigation.	Reduction in GHG emissions.	4	4	Savings in fuel bill.	4	4
1.7 Use of energy labelling to improve public awareness.	Mitigation.	Reduction in GHG emissions.	2	1	Savings in fuel bill.	2	1
2. Transport							
2.1 Increase of fuel price.	Mitigation.	Reduction in GHG emissions.	3	2	None.	0	0
2.2 Improvement of public transport and management of parking practices.	Mitigation.	Reduction in GHG emissions.	2	2	Time saving from reduced congestion.	1	1
2.3 Installation of TWC and enforcement of emission regulations.	Mitigation.	Reduction in GHG emissions.	4	3	None.	0	0
2.4 Use of alternative fuels, principally hydrogen.	Mitigation.	Reduction in GHG emissions.	4	4	None.	0	0
2.5 Use of hybrid and electric traction.	Mitigation.	Reduction in GHG emissions.	4	2	None.	0	0

3. Water resources							
3.1 Curbing of abusive water use and introduction of alternative non-potable supplies.	Adaptation and mitigation.	Reduced greenhouse gas emissions and reduced dependence on water resources.	4	2	Reduced costs of water production, lower cost of living and improved business competitiveness.	4	4
3.2 Sustainment of efforts to detect and repair leakages.	Adaptation and mitigation.	Reduced greenhouse gas emissions and reduced dependence on water resources.	5	3	None.	0	0
3.3 Protection and regeneration of groundwater resources.	Mitigation.	Reduced greenhouse gas emissions.	4	2	Reduced costs of water production.	3	2
3.4 Storm-water harnessing.	Adaptation and mitigation.	Reduced greenhouse gas emissions and exploitation of more intense precipitation.	4	2	Reduced exploitation of groundwater and costs of water production.	4	3
3.5 Increased use of treated effluent.	Adaptation and mitigation.	Reduced greenhouse gas emissions and reduced dependence on primary water resources.	4	3	Reduced costs of water production; reduced costs for industry, business and agriculture; and reduced impact on environment and human health.	4	4

Measure	Nature (Adaptation/-Mitigation)	Benefits					
		Climate Change			Other		
		Nature	Effectiveness*	Degree of Certainty	Nature	Effectiveness*	Degree of Certainty
3. Water Resources (contd).							
3.6 Improvement of irrigation techniques and their engineering.	Adaptation and mitigation.	Reduced greenhouse gas emissions and reduced dependence on primary water resources.	1	3	Reduced costs for agriculture.	1	3
3.7 Improvement of energy efficiency in water production and wastewater treatment.	Mitigation.	Reduced greenhouse gas emissions.	4	4	Reduced costs of water production.	1	1
3.8 On-site treatment of sewage and use of treated effluent by heavy consumers.	Mitigation.	Reduced greenhouse gas emissions.	4	2	Reduced overflows from infrastructure.	2	2
3.9 Curbing of illegal storm water discharges to sewage system.	Mitigation.	Reduced greenhouse gas emissions.	2	2	Reduced overflows from infrastructure.	3	2
3.10 Implementation of provisions of Sewerage Master Plan.	Mitigation.	Reduced greenhouse gas emissions.	3	3	Increased infrastructural efficiency.	3	3
4. Waste Management							
4.1 Prevention of release into atmosphere of greenhouse gases from waste.	Mitigation.	Reduced greenhouse gas emissions.	4	3	Reduced air pollution, alternative energy source.	3	4
4.2 Closing down and restoration of existing uncontrolled landfills.	Mitigation.	Reduced greenhouse gas emissions.	3	3	Reduced impact on environment and human health.	3	3

4.3 Upgrading of Sant' Antnin plant to reduce biodegradable waste going to landfill.	Mitigation.	Reduced greenhouse gas emissions.	3	3	Production of compost.	3	4
4.4 Reduction of disposal of biodegradable waste in landfills, especially by separation at source.	Mitigation.	Reduced greenhouse gas emissions.	2	4	Reduced impact on environment and on human health.	3	3
4.5 Banning of the dumping of waste from healthcare facilities, fish farming and related waste into landfills, and upgrading of incineration facilities at hospital and civil abattoir.	Mitigation.	Reduced greenhouse gas emissions.	2	4	Reduction of impact on environment and human health.	3	3
5. Agriculture							
5.1 Adaptation and diversification of crop species.	Adaptation.	Reduction of dependence on rainwater.	3	1	Improved competitiveness and operations of agriculture.	2	1
5.2 Improvement of rainwater collection and storage, and of irrigation systems.	Adaptation	Reduction of dependence on rainwater	2	4	Improved competitiveness and operations of agriculture.	2	3
5.3 Control of soil erosion.	Mitigation and adaptation.	Favours GHG entrapment and reduces negative effects of climate change.	4	3	Improved competitiveness and operations of agriculture and improved environment.	4	4
5.4 Implementation of soil improvement techniques and afforestation.	Mitigation and adaptation.	Favours GHG entrapment and reduces negative effects of climate change.	4	3	Improved competitiveness and operations of agriculture and improved environment.	4	4

Measure	Nature (Adaptation/-Mitigation)	Benefits					
		Climate Change			Other		
		Nature	Effectiveness*	Degree of Certainty	Nature	Effectiveness*	Degree of Certainty
5. Agriculture (contd.)							
5.5 Erection of protective structures against sea inundation.	Adaptation.	Protects land and its resources.	4	3	None.	0	0
5.6 Facilitation of natural landward migration of shore zone patterns.	Adaptation.	Restores amenities.	3	3	None.	0	0
6. Industry							
6.1 Regulation of emissions.	Mitigation.	Reduced greenhouse gas emissions.	4	3	Reduced pollution.	4	4
6.2 Introduction of incentives to use clean technology and disincentives to discourage polluting technology.	Mitigation.	Reduced greenhouse gas emissions.	3	2	Reduced pollution, lower national energy bill.	4	2
6.3 Promotion of information-driven networking and training towards clean industrial technology.	Mitigation and adaptation.	Promotion of awareness, exploitation of synergies and prevention of problems.	3	2	Setting up of skills base that could be exploited internationally.	3	1
6.4 Introduction of voluntary programmes for self-regulation and co-regulation.	Mitigation and adaptation.	Reduced greenhouse gas emissions	2	1	Reduced pollution, lower national energy bill and increased business competitiveness.	3	1

7. Health							
7.1 Preparation of hot weather contingency plan and setting up of relative emergency infrastructure.	Adaptation.	Protection of population against health risks of temperature increases especially heat waves.	4	4	Increased preparedness for national emergencies.	2	2
7.2 Identification of persons with health risks and implementation of education campaign.	Adaptation.	As in 7.1 with special emphasis on the more vulnerable population sector.	4	4	Improved health for vulnerable persons.	3	2
7.3 Preparation and implementation of occupational health measures.	Adaptation.	As in 7.1 with special emphasis on workers.	3	3	Improved efficiency in the workplace.	3	3
7.4 Focus on primary health care and health surveillance	Adaptation.	Protection of population against risks of infectious diseases.	4	2	Improved health for population.	3	2
8. Cross-sectorial instruments							
8.1 Setting of up a national emissions database.	Mitigation and adaptation.	Promotion of awareness, exploitation of synergies; and prevention of problems.	4	3	None.	0	0

Measure	Nature (Adaptation/-Mitigation)	Benefits					
		Climate Change			Other		
		Nature	Effectiveness*	Degree of Certainty	Nature	Effectiveness*	Degree of Certainty
8. Cross-sectorial instruments							
8.2 Consideration of climate change issues in policy-making and in environmental impact assessments.	Adaptation and mitigation.	Promotion of awareness and exploitation of sectoral synergies.	4	4	Promotion of policy awareness on environment issues in general.	1	2
8.3 Promotion of science and environmental education.	Mitigation and adaptation.	Promotion of awareness and prevention of problems.	4	2	Promotion of policy awareness on environment issues in general.	1	2
8.4 Implementation of economic instruments.	Mitigation and adaptation.	Change in human behaviour.	4	1	Reduced pollution and better health.	4	1

*		**		***	
5 = High		5 = Lm 8 million+		3 = 10+ years	
4 = Medium/High		4 = Lm 6 - 8 million		2 = 6 - 10 years	
3 = Medium		3 = Lm 4 - 6 million		1 = 0 - 5 years	
2 = Medium/Low		2 = Lm 2 - 4 million			
1 = Low		1 = Lm 0 - 2 million			
0 = Inexistent		0 = Inexistent			

Measure	Costs						Overall Benefit Assessment*	Overall Cost Assessment*	Net Benefit Assessment*
	Direct			Indirect					
	Initial**	Lifespan***	Running (per annum)**	Nature	Importance*	Degree of Certainty			
1. Energy Generation									
1.1 Use of CCGT instead of steam turbines to improve efficiency.	5	3	0	None.	0	0	3.0	0.8	2.2
1.2 Use of natural gas as main fuel instead of heavy fuel and gas/diesel oil.	5	3	0	None.	0	0	3.8	0.8	2.9
1.3 Use of CHP plant and integration of renewable energy sources.	5	3	0	None.	0	0	2.5	0.8	1.7
1.4 Use of a low sulphur fuel.	0	Indefinite.	0	None.	0	0	1.5	0.0	1.5
1.5 Adjustment of power factors for major users.	0	Indefinite.	0	Higher costs to business.	3	3	1.5	1.5	0.0
1.6 Use of technology to improve energy efficiency and conservation.	4	3	0	None.	0	0	4.0	0.7	3.3
1.7 Use of energy labelling to improve public awareness.	1	3	0	None.	0	0	1.5	0.2	1.3
2. Transport									
2.1 Increase of fuel price.	0	Indefinite.	0	Higher cost of living and reduced business competitiveness.	4	4	1.3	2.0	-0.8
2.2 Improvement of public transport and management of parking practices.	1	3	0	Increased costs of parking and public transport.	2	1	1.5	0.9	0.6
2.3 Installation of TWC and enforcement of emission regulations.	1	Indefinite.	0	None.	0	0	1.8	0.0	1.8

Measure	Costs						Overall Benefit Assessment*	Overall Cost Assessment*	Net Benefit Assessment*
	Direct			Indirect					
	Initial**	Lifespan***	Running (per annum)**	Nature	Importance*	Degree of Certainty			
2. Transport (contd.)									
2.4 Use of alternative fuels, principally hydrogen.	2	3	4	Higher cost of living and reduced business competitiveness.	4	3	2.0	4.1	-2.1
2.5 Use of hybrid and electric traction.	3	3	2	Higher cost of living and reduced business competitiveness.	3	3	1.5	3.0	-1.5
3. Water Resources									
3.1 Curbing abusive water use and introduction of alternative non-potable supplies.	5	20	1	None.	0	0	3.5	0.6	2.9
3.2 Sustaining efforts to detect and repair leakage.	3	Indefinite.	2	None.	0	0	2.0	0.6	1.4
3.3 Protection and regeneration of groundwater resources.	5	Indefinite.	1	Higher costs to agriculture.	4	3	2.8	2.1	0.7
3.4 Storm water harnessing.	5	Indefinite.	3	None.	0	0	3.3	0.9	2.4
3.5 Increased use of treated effluent.	5	20	3	None.	0	0	3.8	1.6	2.1
3.6 Improvement of irrigation techniques and their engineering.	1	Indefinite.	0	None.	0	0	2.0	0.0	2.0
3.7 Improvement of energy efficiency in water production and wastewater treatment.	4	20	2	None.	0	0	2.5	1.1	1.4
3.8 On-site treatment of sewage and use of treated effluent by heavy consumers.	5	Indefinite.	1	None.	0	0	2.5	0.3	2.2
3.9 Curbing of illegal storm water discharges to sewage system.	1	Indefinite.	1	None.	0	0	2.3	0.3	2.0
3.10 Implementation of provisions of Sewerage Master Plan.	4	Indefinite.	2	None	0	0	3.0	0.6	2.4

4. Waste Management									
4.1 Prevention of release into atmosphere of greenhouse gases from waste.	Cost sunk as part of measure 4.3	Indefinite.	Cost sunk as part of measure 4.3.	Carried over from measure 4.3.	3	4	3.5	1.8	1.8
4.2 Closing down and restoration of existing uncontrolled landfills.	1	Indefinite.	Negligible.	More pressure on other landfills.	2	3	3.0	1.3	1.8
4.3 Upgrading of Sant' Antnin plant to reduce amount of biodegradable waste going to landfills.	5	20	1	Social costs related to site and increased costs of waste separation and treatment.	2	3	3.3	1.6	1.7
4.4 Reduction of biodegradable waste dumped in landfills, especially by separation at source.	1	20	1	Additional costs of managing waste for agriculture, fisheries and other sectors.	2	1	3.0	1.0	2.0
4.5 Banning dumping of waste from healthcare facilities, fish-farming and related waste into landfills and upgrading of incineration facilities at hospital and at civil abattoir.	2	20	1	Additional costs for healthcare and abattoir waste.	2	1	3.0	1.0	2.0
5. Agriculture									
5.1 Adaptation and diversification of crop species.	Negligible.	Indefinite.	0	None.	0	0	1.9	0.0	1.9
5.2 Improvement of rainwater collection and storage, and of irrigation systems.	Negligible, if supported by RDP.	Indefinite.	0	None.	0	0	2.9	0.0	2.9
5.3 Control of soil erosion.	Negligible, if supported by RDP.	Indefinite.	0	None.	0	0	3.7	0.0	3.7
5.4 Implementation of soil improvement techniques and of afforestation.	Negligible, if supported by RDP.	Indefinite.	0	None.	0	0	3.7	0.0	3.7

Measure	Costs						Overall Benefit Assessment*	Overall Cost Assessment*	Net Benefit Assessment*
	Direct			Indirect					
	Initial**	Lifespan***	Running (per annum)**	Nature	Importance*	Degree of Certainty			
5. Agriculture									
5.5 Erection of protective structures against sea inundation.	3	20	1	Landscape deterioration.	2	1	1.8	1.3	0.4
5.6 Facilitation of natural landward migration of shore zone patterns.	1	Indefinite.	2	None.	0	0	1.5	0.6	0.9
6. Industry									
6.1 Regulation of emissions.	2	Indefinite.	2	Increased costs to industry.	4	2	3.8	2.1	1.7
6.2 Introduction of incentives to use clean technology and disincentives to discourage polluting technology.	2	Indefinite.	2	None.	0	0	2.8	0.6	2.2
6.3 Promotion of information-driven networking and training towards clean industrial technology.	2	Indefinite.	2	None.	0	0	2.3	0.6	1.7
6.4 Introduction of voluntary programmes for self-regulation and co-regulation.	1	Indefinite.	1	None.	0	0	1.8	0.3	1.5
7. Health									
7.1 Preparation of Hot Weather Contingency Plan and setting up of relative emergency infrastructure.	1	20	1	None.	0	0	3.0	0.5	2.5
7.2 Identification of persons with health risks and implementation of education campaign.	1	Indefinite.	1	None.	0	0	3.3	0.3	3.0
7.3 Preparation and implementation of occupational health measures.	2	Indefinite.	1	None.	0	0	3.0	0.3	2.7
7.4 Focus on primary health care and health surveillance.	1	Indefinite.	1	None.	0	0	2.8	0.3	2.5
8. Cross-sectorial instruments									
8.1 Setting up of a national emissions database.	1	Indefinite.	1	None.	0	0	1.8	0.3	1.5

8. Cross-sectorial Instruments (contd.)									
8.2 Consideration of climate change issues in policy-making and in environmental impact assessments.	0	Indefinite.	0	Higher costs for development projects to become climate-change compliant.	4	4	2.8	2.0	0.8
8.3 Promotion of science and environmental education.	1	Indefinite.	1	None.	0	0	2.3	0.3	2.0
8.4 Implementation of economic instruments.	1	Indefinite.	1	Increased cost of living and reduced business competitiveness.	5	4	2.5	2.6	0.0

*		**		***	
5 =	High	5 =	Lm 8 million+	3 =	10+ years
4 =	Medium/High	4 =	Lm 6 - 8 million	2 =	6 - 10 years
3 =	Medium	3 =	Lm 4 - 6 million	1 =	0 - 5 years
2 =	Medium/Low	2 =	Lm 2 - 4 million		
1 =	Low	1 =	Lm 0 - 2 million		
0 =	Inexistent	0 =	Inexistent		

The First Communication of Malta to the United Nations Framework Conventionon Climate Change

MINISTRY FOR RURAL AFFAIRS AND THE ENVIRONMENT

UNIVERSITY OF MALTA