Resume

Plan for Energy Improvement in Barcelona

Ajuntament de Barcelona

Presentation Joan Clos

The Mayor of Barcelona

Given the recent revolution in technology, energy is one of the few traditional sectors that have gained in importance as a basic resource required for our society to operate effectively. The degree of quality of life is often related to energy consumption, but the way this consumption has been carried out to date has been detrimental to sustainability.

At an international level, the existing energy model and its negative impact on the environment have led state governments and cities to set up various measures by means of agreements such as those of Johannesburg, Kyoto, Aalborg and Rio de Janeiro. Within this sphere of action, and bearing in mind that 75% of the world's energy is used to sustain complex urban organisations, cities and local institutions play a vital role in energy planning and management, as well as the entities closest to those who demand the energy.

Thanks to its compact nature and its type of energy consumption, Barcelona is one of the European cities of its size with the lowest CO2 emission per capita. However, this satisfactory initial position means that, in order to comply with international commitments, relatively more effort is required to reduce the amount of gas emissions into the atmosphere than for other, more polluting cities.

In spite of this, we are convinced that a change in the energy model is fundamental and have demonstrated our concern in the planning of new large urban areas and infrastructures. For example, in the case of the 22@ District we have endeavoured to establish a model of a diverse, compact city, combining renewed economic activity with residential use, as well as applying sustainable urban development. Similarly, we have incorporated the concepts of bio-urban planning and bio-climactic architecture for the Culture Forum zone and the project "Renewable Barcelona 2004", as well as integrating environmental infrastructures into the dynamics of the city and demonstrating our commitment to the use of solar energy and to a design of sustainable mobility.

Within this action framework, the Plan de Mejora Energética de Barcelona (PMEB) or Barcelona Energy Improvement Plan aims to take another step forward by providing and clarifying a whole series of highly significant data for the future development of a city faced with its current consumption trends. For example, thanks to the measures included in the Plan, Barcelona will become the city that takes most advantage of solar energy in the world.

The PMEB - which has been awarded the European Climate Star 2002 - would not have been possible without the involvement and effort of the public administrations, companies and people participating in the project. To all of them, we give our appreciation and resolve to continue working together in order to bring the Plan's lines of action to fruition.

Presentation Imma Mayol

Fourth Deputy Mayor and Councillor of Public Health and Environment

The intensive use of energy deriving from fossil fuels and nuclear sources is one of the characteristic traits of our current society's consumption patterns. Although the great risks involved in the nuclear production of energy are already well known in terms of the damage to the ecosystem, the use of fossil fuels also has significant repercussions for the environment. As well as being a limited resource, their use leads to localised direct pollution with immediate health effects, as well as having a global impact on aggravating the problems caused by climactic change.

A decisive policy is required on the part of public administrations to reverse current trends in energy consumption, a policy oriented towards promoting the use of clean, renewable sources of energy, to achieving efficiency in the production of final energy and to reducing consumption by introducing technological improvements and the practice of conscientious use.

To this end and for some time now, Barcelona City Council has been carrying out specific actions to promote energy savings and reduce atmospheric pollution, some of them with highly positive results, such as the Thermal Solar By-Law. Notwithstanding this, an overall framework is required to visualise energy policies and place them within a plan of action, such as this Plan de Mejora Energética de Barcelona (PMEB) or Barcelona Energy Improvement Plan. Furthermore, the recent creation of the Local Energy Agency Consortium points to a new commitment to energy improvement in the city, this being an essential instrument to ensure the Plan is promoted effectively.

The PMEB has been put forward as a city programme in which, once the current consumption trends have been analysed, the different administrations involved in energy management will acquire a firm commitment to action, at the same time as the need has become evident for the participation of firms that supply energy, as well as the importance of the role energy users must play at both a company and individual citizen level.

This is an innovative plan, emphasising the importance of the mechanisms of citizen information and participation as essential elements for change, and which aims to foment debate among all the relevant sectors in order to achieve a citizen charter for energy.

Almost all the world is concerned about pollution and the effect this has on the environment, but we still need both an individual and group effort in order to contribute actively to reducing the causes of environmental deterioration. And that is what the PMEB aims to do: to apply various measures - a total of 55 projects - ranging from small modifications in energy use to large changes in energy production and distribution systems, all of them important to reach the horizon of 2010 with a more sustainable concept of energy, as well as greater solidarity among all the people inhabiting the planet and with future generations.

Presentation Isabel Monreal

General Director, Institute for the Diversification and Saving of Energy (IDAE)

As General Director of the Institute for the Diversification and Saving of Energy (IDAE), it gives me great satisfaction to present this "Barcelona Energy Improvement Plan" (PMEB), on which we have co-operated since its beginning, at the start of the year 2001, when the Municipality and the IDAE signed a co-operation agreement on its creation.

At that time we were laying the bases that will allow this city to advance progressively towards the "sustainable city" model that has been proposed. The Municipality has been committed to the unfolding of this model for some time, with pioneering actions in our country such as its Solar Thermal Ordinance.

Most of the activities that citizens carry out daily in a big city like Barcelona are related to the consumption of energy: transport to their workplaces, the heating of their homes, the household appliances they use, their computers or the lighting of their streets at night.

For this reason the Municipalities, as the public administrations closest to citizens, have a great responsibility in leading municipal actions that increase the awareness of people with respect to the saving of energy, the most energy-efficient technologies and the use of renewable energies.

The challenge that Barcelona is facing is to build the city of tomorrow on the basis of criteria of sustainability, such as those contained in the PMEB. This more sustainable Barcelona of the future cannot be built without the commitment of all to energy efficiency and renewable energies, with each person working within his or her scope of responsibility: in the public administrations, in social organisations or as citizens.

With the translation of this document into Spanish and its dissemination among other Municipalities of our country, the IDAE, as a Corporate Public Entity of the Ministry of Economy, upholds its part of the commitment, promoting and encouraging similar actions.

Lastly, we wish to congratulate the Municipality of Barcelona and the persons who have contributed materially to its achievement, for the result of their work.

CONTENTS

1. Introduction

1.1. Energy

Energy has become the lifeblood of modern industrial societies. Welfare and development indicators are often linked to energy consumption, for example per capita energy consumption or luminosity of the territory in the night sky.

Over 80% of the world's primary energy consumption comes from fossil fuels (Key World Energy Statistics, International Energy Agency, 1999). The consumption and transformation of energy from fossil fuels is one of the ways Mankind wreaks most damage on the environment. In addition, the world's reserves of fossil fuels are limited. Estimates of the remaining life of fossil fuels given current consumption and known reserves are as follows: gas 61.9 years, oil 41 years, coal 230 years.

Both Spain and the EU are highly dependent on imports of fossil fuels. Currently, imported fuels, representing 6% of total community imports by value and 1.2% of the EU's GDP[1], satisfy 50% of the EU's energy needs. If present trends continue, 70% of the EU's energy needs will be met from countries outside the community by 2030[1]. Spain's energy dependence is even greater, given that 74% of the country's energy needs are already met from abroad (source: IDAE "Prospectiva Energética y CO_2. Escenarios 2010" [Energy Prospects and CO_2. Scenario for 2010] IDAE-2000; based on 1999 data). This energy model threatens future economic development in both the EU and its Member States. Hence the Community's objective to cover 12% of its energy demands through renewable sources by 2010. Evidently, this target cannot be reached unless parallel development of renewable energy installations and energy demand reduction measures are taken.

Worldwide primary consumption of energy over the last decade has risen by 0.9% per annum. Energy demand in Spain has grown considerably recently: electricity demand rose 6% and 7% in 1999 and 2000 respectively, whereas the comparable figures for the increase in natural gas consumption were 12% and 14%.

1.2. The Environment

Intensive use of energy from fossil fuel and nuclear sources is currently one of the main causes of environmental deterioration and the risks which that entails. Energy use has both a local and a global impact. The local impact covers air and soil pollution, with consequent effects on human health. The global impact involves climate change and the exhaustion of non-renewable resources.

At the moment, Mankind's main environmental concern is the greenhouse effect and the threat of global warming. Global warming results when greenhouse gases (largely produced by burning fossil fuels) are released into the atmosphere. This emission occurs where the energy used requires the burning of fossil fuels, whether directly (final use: transport, heating) or in transformation of primary energy (electricity generation). According to the IDAE, two thirds of Spanish greenhouse gases emissions are produced by energy transformation and consumption (Source: Prospectiva Energética y CO_2, Escenarios 2010', IDAE, 2000).

The combustion of fossil fuels is not the only source of greenhouse gases – there are others such as methane (produced by anaerobic digestion of organic waste). However, some industrial processes represent the very important sources of such gases.

Concern global planetary warming and the risks of possible climate change have led State governments and city councils to plan ways of reducing emissions of greenhouse gases. This is the reason for a series of international initiatives which have led to environmental protocols and agreements (Kyoto, Aalborg, etc.) aimed at reducing greenhouse gas emissions.

Different kinds of measures need to be taken to reduce gas emissions:

- Fostering the use of renewable and/or clean energy sources
- Greater overall energy efficiency
- Energy saving in final energy consumption based on technological improvements
- Responsible energy use by end consumers

1.3. Cities

Contemporary society is increasingly based on urban settlements, which in turn consume vast amounts of energy. According to estimates made by experts in the field, 75% of the world's energy use goes to maintaining cities' complex organisation.

Cities can be considered as ecosystems. Understanding an ecosystem involves comprehending its internal flows, interrelationships and processes. Thus the flow of energy, materials and information all determine a city's relationship with its surroundings and the environment. This knowledge is vital if one is to grasp the nature of the beast.

In this context, it is worth noting the City Council's three functions in this field: (1) on matters concerning consumption (acting as a consumer, manager, efficiency booster, urban development regulator and defender of the interests of other consumers); (2) as a party implicated in regulating the quality of services; and (3) as a promoter of new initiatives – particularly those concerning renewable energy sources (including urban waste treatment). In addition to these three functions, the City Council also exercises local legislative powers, although these are necessarily conditioned by the powers enjoyed by higher tiers of government.

1.4. Plan for energy improvement in Barcelona [PEIB]

The city council of Barcelona, to stimulate the knowledge and management between the activities of the city that have environmental impact, charged to Barcelona Regional the development of a Plan for energy improvement in Barcelona [PEIB].

Concern for the environment in Barcelona has led to growing interest in limiting the environmental impact of energy consumption. This interest has manifested itself in various proposals for and agreements on improvements in energy efficiency and the introduction of renewable energy sources. Barcelona is therefore committed to fostering the use of clean, renewable energy sources.

The Energy Plan has the following objectives:

- Reduction in atmospheric emissions.
- Reduction in the consumption of non-renewable energy.

These objectives are conditioned by cultural and technological factors. The strategy for attaining these objectives is to:

- Increase the consumption of clean energy.
- Increase the use of renewable energy sources.
- Reduce energy consumption whilst maintaining goods production, welfare and mobility.

The PEIB is the first approximation to the structured knowledge of energetic sector in the city of Barcelona. It is a tool that can be upgraded with new information and knowledge in order to help in decision making processes, and to upgrade the Plan in the future.

The PEIB covers an analysis of the present situation, as well as the measures to be undertaken in the future. In the analysis of the present situation, containing state of the art of the energy sector, global energy flows and studies by sectors, forecast of the future energy demand based on the trends, as well as the final diagnosis. This part is called: Base Analysis and diagnosis of the Energy flows in Barcelona [BAEB]. Furthermore, within the PEIB, there are the: Action Plan for Energy saving and emissions reduction [APE], with some objectives and strategies for develop Actuations Programs with projects and specific actions, and an analysis of this in the future scenarios.

The PEIB is intended to pave the way for a series of project programmes covering energy, economic and envi-

[1] According to estimates in the: Green Paper, Towards a European strategy for the security of energy supply [COM (2000) 769]

ronmental matters, an Action Plan [APE]. This puts forward practical guidelines which are expressed through various planning instruments: planning regulations, internal City Council initiatives, direct investments (some schemes are already up and running), campaigns fostering private initiatives, co-operation with energy providers, etc., Many of these measures will be put into effect once the PEIB receives final approval. The Action Plan has provided an invaluable source of information regarding qualitative and quantitative aspects of Barcelona's energy system [BAEB]. This has been possible thanks to the development of powerful planning tools. One such tool is GIS [Geographic Information System], which makes it possible to model and contrast consumption behaviour and estimate the impact and efficiency of implementing the Plan proposals.

The PEIB also can be the base for new and futures Action Plans, like the: Action Plan for Infrastructures and Electricity quality improvement [APIE] (actually in development) or other futures actions plans in the city.

Fig 1-1 PEIB structure, links and information fluxes [p18]

2. Diagnosis

2.1. The current situation

The study covers the whole Barcelona Municipality. Each sector is dealt with in detail and 1999 has been taken as the benchmark year. The residential, tertiary, transport and municipal consumption sectors have been studied separately and also analysed in terms of their combined impact. Municipal solid waste has also been studied given that it gives rise to considerable GHG emission but could also provide a valuable source of energy if the right treatment processes are adopted.

The total consumption of final energy in Barcelona-1999 (reference year) was 50.78 PJ[2]. This is equivalent to the share of 40.5% or 20.542 PJ of electricity, 31.5% or 15.97 PJ of oil equivalent, 25,2% or 12.777 PJ of piped gas and 2.9% or 1.484 PJ of liquid petroleum gas.

Fig 2-1 Share of final energy consumption, by energy sources, 1999. Total consumption: 50.78 PJ [p21]

In terms of primary energy sources and bearing in mind the efficiency of energy conversion and distribution processes, this is the equivalent of 92.5 PJ (calculation based on the Catalan power generation mix – the comparable figure for Spain is 89.9 PJ) of which 64% is used to generate 20.54 PJ of electricity. From the above figures, one obtains an overall energy efficiency figure of 54.8%. This relatively low figure is due to the fact that electricity represents a high percentage of final consumption. The high percentage of energy consumption in form of electricity is the result of a process of de-industrialisation in the Barcelona municipality and the growing importance of tertiary sectors in the city's economy.

With regard to sectoral distribution, 37% of energy consumption is accounted for by industry and tertiary sectors, 33% by transport and 30% by domestic use. Breaking down the transport figure reveals that just 9.6% is accounted for by public transport, approximately 30% by road freight (delivery vans and lorries) and 60% by cars and motorbikes/scooters. Transport accounts for the lion's share of the consumption of liquid fuels, while boilers and industrial processes account for just a small part of the total. Of the liquid fuel used for transport, roughly 54% is petrol and 46% diesel.

Fig. 2-2 Share of final energy consumption by sectors. Total consumption: 50.78 PJ [p21]

The largest source of primary energy in Barcelona after taking into account Catalonia's electricity generation mix, is nuclear energy (49%). The second source is natural gas (23%), followed by liquid fuels (18%). Hydroelectric power (only large schemes of >10MW have been included) accounts for 4% of total energy. Coal represents just 1% of all primary energy. Renewable energy sources (other than hydro-electric power) represent 1% of the total (or 5% if hydro-electric power is included). This compares with 6.3% for renewable energy sources including hydroelectric power (4% without) in Spain. The EU set a target whereby renewable energy sources would contribute 12% of overall demand the year 2010. However, the contribution of renewable energy is declining in relative terms. This is because growth in energy consumption is outstripping the introduction of these new sources.

Fig 2-3 Share of primary energy consumption, by energy sources, 1999. Total consumption: 92.5 PJ [p22]

Placing Barcelona's energy consumption in wider contexts (i.e. Catalonia, Spain and the EU), Barcelona accounts for 25% of Catalonia's population, contributes 33% of the region's GDP and 9.7% of energy consumed. The relationship between GDP and energy consumption is similar if we consider Barcelona in the context of Spain. These data reveal that Barcelona has an economy which is highly tertiary (high GDP, low energy consumption) and that the City possesses an efficient energy system.

In table 2-1 key figures for Barcelona in the context of Catalonia, Spain and the EU are shown. [see table 2-1, p22]

Barcelona's electricity consumption represents 15.5% of total consumption in Catalonia and 3.1% of the figure for Spain. Barcelona's gas consumption represents 2.77% of the total figure for Spain.

Comparison of the city's per capita energy consumption with other cities in the Metropolitan Region and foreign cities of a similar size[3] reveals that Barcelona is one of the most energy-efficient.

Table 2-2 Per capita energy use in cities in the Barcelona Metropolitan Region[3]. [p23]

2.2. Historic trends

Historic energy consumption trends in Barcelona follow economic ones. Total energy consumption over the last ten years (1990 – 1999) has increased by 23.11%, or an average of 2.1% per annum. There was a growth spurt in energy consumption between 1995 and 1999 (an average of 2.94% per annum). Total per capita energy consumption in 1999 was 33.65 GJ whereas the comparable figure for 1990 was 25 GJ. Per capita energy consumption rose by 37.5% during the 1990s.

[2] Total consumption carried out in the city without taking into account energy consumption outside of the city for production and transport of commodities and goods used in the city

[3] Source: "Sistema Municipal d'Indicadors de Sostenibilitat" [municipal sustainable development indicators], Xarxa de ciutats i pobles cap a la sostenibilitat. Diputació de Barcelona. Data for Hospitalet de Llobregat, Manresa, Mataró, Terrassa Rubí and Vilanova i la Geltrú

The ratio of energy use vs. GDP[4] in Barcelona worked out around 1279.5 KJ/€ at 1999 values. A positive feature is that this ratio shows a slight falling trend. The elasticity[5] of average total energy consumption in Barcelona between 1991 and 1999 was 0.78 and 0.98 for the period 1995-1999. The elasticity of electricity consumption between 1991 and 1999 was 0.89 (i.e. higher than the overall figure).

Total energy consumption and consumption of electricity and gas grew to 1992, dipped and then rose again from 1995 onwards.

Table 2-3 Growth in energy consumption in Barcelona [p23]

Fig 2-4 historic trend of final energy consumption in Barcelona [p23]

Figure 2-5 shows trends in the consumption of electricity, oil derivatives and natural gas. The three types of energy show similar trends. Energy consumption between 1993 and 1995 was clearly linked to the state of the economy but petrol and diesel consumption was also affected by the building of city ring roads.

Figure 2-5 Energy consumption trends in Barcelona (electricity, GLP and natural gas) [p24]

2.3. Sectoral studies

The sectoral studies included in this Plan cover 74% of the city's buildings. Although other features of the built environment (i.e. factories, warehouses, car parks and miscellaneous minor uses) have not been studied in depth, they have been taken into account in the city's overall energy consumption. Intensive use of the Geographic Information System (GIS) has been made in analysing energy consumption in buildings. This tool is invaluable for making calculations, analysing data and simulating system behaviour. The sectors studied were: housing; tertiary activities; municipal services; public networks and services; transport; waste.

2.4. Housing

The city's buildings were classified in terms of their energy consumption as a preliminary step to drawing up potential energy-saving measures. The climatic response of buildings is affected by both urban and building layout, as well as the construction systems employed. These factors were used to draw up a classification of building energy consumption characteristics. A dynamic computer simulation was then carried out to study the specific energy consumption features of given types of buildings. The study took into account the most common use to which the buildings were put.

[4] Final energy intensity = final energy consumption / GDP in constant value € (1999)

[5] Elasticity = Δenergy consumption / ΔGDP

The following conclusions can be drawn regarding energy demand[6]:

- Energy demand for heating most of Barcelona's dwellings (83.39%) lies between 31.3 and 36.8 kWh/m² and year.
- Heating demand in buildings in Barcelona's old centre is around 50 kWh/m² and year.
- Energy demand for heating purposes is lower in new buildings (13.9 kWh/m² and year).
- Energy demand for air-conditioning in residential dwellings is currently considerably lower than for heating. Average values for all dwellings other than new build lie between 6.0 and 10.5 kWh/m² and year.
- The demand for air-conditioning in new dwellings stands higher (at 20.3 kWh/m² and year) than is the case in older dwellings. Furthermore, the former consume more energy for air conditioning than for heating.

The following conclusions can be drawn regarding energy consumption[7]:

- Electricity consumption in dwellings lies above 15 kW·h/m² and year. Modern dwellings (built after the introduction of thermal norms) show markedly higher electricity consumption exceeding 33 kW·h/m² and year.
- Solar energy only makes an appreciable contribution in new dwellings affected by Barcelona City Council's Solar Energy bylaw. Even so, useable solar energy contributes 17% of total energy consumption in new buildings, or 30% if only thermal uses are taken into account (heating/air-conditioning).
- Natural Gas is installed in most of Barcelona's dwellings (59%). This is true of all dwelling types with the exception of the buildings in the city's Mediaeval centre.
- The use of other energy sources (mainly fossil fuels) is uncommon and is only found in the oldest dwellings.

Figure 2-6: Energy consumption by source and use. Residential dwellings [p25]

Briefly summarising the situation, one can say that Natural Gas and Electricity represent the two main sources of domestic energy, while LPG (propane and butane) still accounts for a significant share (although both propane and butane are on the wane and confined to older buildings). The contribution of other types of energy such as heating oil or renewable sources to Barcelona's domestic consumption is negligible.

[6] Energy demand is the energy required to provide reasonable comfort in a building (this does not take into account human behaviour but simply focuses on architectural considerations (construction materials, building type, dwelling orientation, etc.)

[7] Energy consumption, unlike energy demand, is affected by human behaviour and the performance of apparatus installed in a dwelling.

Analysing the use to which consumed energy is put, one can say that about 30% is used for heating, as well as for domestic hot water and other household appliances. Energy used for lighting was evaluated separately from that used by household appliances and represents 8% of total consumption. Air-conditioning makes up a small percentage of consumption, given that few dwellings have it installed.

Comments on new dwellings and housing stock.

Industrial construction methods are increasingly employed in new dwellings. However, the house-building industry tends to be very conservative and is loathe to make radical changes based on unproven ideas. Better building skin materials could be used, employing ceramic and non-ceramic components, standardised composite metal panels, light concrete panels reinforced with glass fibre, or conventional reinforced concrete panels, etc. Double-glazed windows are frequently fitted.

The rate of city development indicates some 3.9 million m² of dwelling floor area will be built up to 2010. This represents about 5% of the existing housing stock. There is considerable scope for saving energy by intelligent use of building and planning regulations. Stricter bylaws on the thermal characteristics of buildings could produce a saving of over 100,000 GJ a year.

The heat transfer coefficient U of many building façades fails to meet regulatory standards. This is due to the presence of heat bridges (usually pillars) linking façades and interiors. Simple, cheap measures can be taken to prevent such heat bridges, reducing thermal conductivity from K 1.3-1.4 W/m²·K to below 0.8 W/m²·K. A figure of K=0.8 W/m²·K should be the maximum permitted for the walled parts of new building façades. Although current building trends are better than ones of the past, there is still a great deal of room for improvement, as this study makes clear.

Under the present regulations, the maximum U value for windows and doors is 5.8 W/m²·K. The widespread use of double-glazing makes this standard outdated. Accordingly, the maximum thermal conductivity coefficient should be revised downwards to around K=3.5 W/m²·K.

The maximum permitted U value for roots (currently set at U=0,46 W/m²·K) seems reasonable.

As we have seen, the demand for air-conditioning in new dwellings is not only higher than in existing housing stock but is actually greater than for heating. Air-conditioning in dwellings is not yet standard, but it is becoming increasingly common. This potential growth in electricity consumption should be avoided. Systems for sha-

ding interiors and providing natural ventilation in buildings need to be adopted in order to prevent massive installation of air-conditioning equipment.

Passing the Solar DHW Bylaw was a wise decision. However, effective monitoring is required if it is to be properly applied. The pre-installation of household appliances capable of using water heated by solar panels would help promote use of this energy source.

With regard to installations, boilers and heat pumps should consume as little energy as possible. The recommended figures are:

- for boilers, 89% at full load and 86% on partial load (30%)
- for COP heat pumps, a minimum of 2.5 in cooling mode and 3.5 in heating mode.

The installation of energy-saving lighting should also be fostered in communal areas of residential developments.

The same criteria should also be applied to building refurbishment schemes.

A measure which should be applied immediately is one which requires housing developers to submit energy certificates. This certificate would have to be submitted as part of the procedure for selling the dwelling. A campaign should be undertaken to make citizens aware of the importance of these energy certificates. Companies such as the Municipal Housing Company and REGESA (both of which promote and build publicly-subsidised housing) can blaze the trail by publicising energy certification of their developments.

Barcelona also needs to make improvements to its large stock of older dwellings in order to achieve substantial energy savings. Accordingly, energy efficiency criteria need to be adopted and applied when refurbishment old buildings. The main measures should include improving windows and doors and insulation of façades.

2.5. Tertiary sector

The following energy uses in the tertiary sector were studied: commercial premises, offices, hotels and catering establishments and sports centres. Unlike residential uses, the tertiary sector displays high energy consumption for air conditioning and equipment.

The results support the following conclusions:

Commercial and offices:

- The demand for air-conditioning is greater than for heating.
- Demand for electricity (equipment and lighting) makes up around 50% of total energy consumption.
- ACS demand is minimal (1%)

Hotels and catering establishments:

- The demand is similar for air conditioning and heating, both making up around 50% of total energy consumption.
- DHW demand is considerable, making up around 15 - 21%, depending on the building type.
- Electricity demand makes up about 30% of total demand, except in four and five star hotels where demand rises to 44%.

Electricity consumption is generally high. One can establish a qualitative relationship between the growth of tertiary activities in Barcelona and changes in the sources share of energy consumption. The greater the percentage of tertiary activities in the city's economy, the higher the percentage of total energy consumption accounted for by electricity.

The building types that show the highest energy demand in the tertiary sector are medium-sized to large offices (>500m²) and commercial (both large and small). Four and five star hotels exhibit strong demand for electricity. Accordingly, special measures will need to be taken for these building types.

Figure 2-7 Estimated demand for heating, air conditioning and electricity for the most common building types [p28]

Study of tertiary activities reveals the need to revise thermal norms for the types of buildings used in this sector. One should note that considerable growth of the tertiary sector is envisaged in Barcelona. This plan has assumed that some 2.25 million sqrm of office space will be built between 2000 and 2010. This figure represents an increase of 39% over existing office space. Regulating the sector is therefore both opportune and patently reasonable.

There is a growing trend to use greater window areas in offices. The regulations should therefore fix the ratio of window area and the maximum heat loss/greenhouse effect which glazing produces. The proportion of the façade which is glazed is therefore a prime consideration. The following suggestions could serve as a guideline:

- windows < 33% of the façade: adopt the same criteria used for dwellings
- windows comprising 33% to 66% of the façade: U of glazed area under 2.5, solar factor <30%, K of the walled façade same as the one for dwellings.
- windows >66% of the façade: U of glazed area <2, solar factor <25%, K of the walled façade same as the one for dwellings.

In addition, building services such as lighting and air conditioning need to be rationally grouped zoned and incorporate energy-saving measures (e.g. presence detectors). The zoning of services should take into account building orientation and functional needs. It is therefore worth considering an upgrade to Standard NR-AT 87 regarding the parameters applicable to building exteriors. The definition of a new standard will need to take into account the opportunities presented by a mature property market and its immediate growth prospects, as well as social and technological considerations. As has already been mentioned, thermal standards based on forecast annual energy demand rather than parameters which deal with the building skin in isolation are beginning to emerge in Europe.

Gradual introduction of similar norms needs to be considered to ensure they are accepted by all concerned. The first step in this process could be the one recommended above, i.e. setting new heat transfer coefficients (U) which are 15% - 25% lower than those currently in force. A second stage might be to include limits on energy demand per unit area. This would effectively mean two standards would exist side by side (i.e. one based on total energy consumption and the other on U). The third and final stage would apply demand criteria which were solely based on acceptable standards for a building's installed apparatus and its skin.

A label certifying efficient energy management on the same lines as the "green point" would help promote the scheme. The scheme could also cover equipment maintenance, use of solar energy, energy-saving lighting, presence detectors, temperature set point regulation and the use of energy-saving appliances, etc. In addition the promotion of better energy use and the introduction of more efficient systems (e.g. CHP). Changes in the existing Solar Energy Bylaw could be made to require the solar PV installations in new offices and commercial premises.

2.6. Municipal Services

Barcelona City Council uses 679 TJ a year in gas and electricity. Local administration's total electricity consumption is 508.1 TJ/year or 2.5% of the municipality's total consumption. Gas consumption is 170.8 TJ/year or approximately 1.34% of the city's total consumption. Although the Council uses much more electricity than gas, its consumption of both is relatively insignificant in the context of the city's total energy demand.

Street lighting makes up the lion's share of the council's electricity consumption (58%). Traffic lights and public schools account for 8% each one whereas Council offices and municipal sports centres account for 6% each.

Schools are important gas consumers (55% of Council consumption), whereas social centres and sports centres respectively account for 11% and 10%. Gas consumption shows a clear seasonal pattern, with winter demand eight times higher than summer demand. Gas is widely used for heating purposes. Proper maintenance of boilers would produce substantial energy savings.

Street lighting makes up the highest proportion of final energy consumption (electricity + gas) by far (43%). Public schools account for 20% of final energy consumption. Sports centres use up 7% of the total. Traffic lights, offices, and social/cultural centres each use up 7% of the final energy consumed by local administration. The above breakdown was obtained from Barcelona City Council databases for 1999. These covered 150,370 points for road lighting and floodlighting, with a total power rating of 26,580 kW. A study of the lightning network reveals that 31,789 points would be changed.

Energy efficiency programmes need to be pursued with regard to municipal consumption and installations. These include: installing LED traffic lights; using high efficiency lamps for street lighting; and employing centralised management programmes to achieve greater efficiency and compliance with standards.

There is considerable potential for savings through renewal of installations and management based on Energy Performance Contracts. Contracting an energy services company would help reduce both energy consumption and bills.

2.7. Networks and public services

Electricity, gas and District heating/cooling networks (DHC) need to be both complementary and compatible if a reliable energy-efficient system is to be obtained.

The natural gas network covers most of Barcelona. Network should continue covering new areas of the city. This trend should be accentuated by the provision of new services which include: DHC, CHP, and other related with high-tech companies activities.

DHC systems represent an opportunity for providing better, more efficient services for District 22@[8] and the Universal Forum of Cultures 2004. These services could later be extended to areas of high energy demand such as Sagrera, the Free Port, and the future area of law courts and related facilities. Solar-based electricity generation (PV) needs to be fostered at the Universal Forum of Cultures 2004 and then applied throughout the rest of the city.

Study of the city's electricity network and forecast demand reveals various shortcomings in the existing system and their attendant risks.

Quality standards need to be set for Barcelona's power supply. Information on compliance with these standards needs to be both exhaustive and regular. The current power network is patchy. Some neighbourhoods are reasonably well-served while others receive a poor service. This is why quality indicators need to be applied to smaller geographical units (rather than simply aggregating electricity provision on a municipal scale). The units adopted might be districts or grid areas of comparable size to ensure that standards were met across the board. The number of micro power cuts is yet another point which needs addressing. One should also note that the number of grid breakdowns in Barcelona (11 per 100 km of grid) is 1.57 times the one reached by UNESA[9] (7 per 100 km). The proportion of grid breakdowns in Barcelona should not exceed the UNESA average.

Rational planning of the electricity grid is urgently required to improve the city's power supply, cut transmission losses and reduce environmental impact. This planning should involve the power supply companies and Barcelona City Council (both of which have responsibilities in this field) as well as external bodies and consultants. The objective is to draw up a proper infrastructure plan for power provision and distribution in the city.

The Plan should include the following (listed in order of priorities):

- Improvements in Barcelona's medium and low voltage distribution network.
- Improvements to the High Voltage network.
- Establishing quality standards and indicators for service provision (TIEPI[10], micro-cuts, TIEU[11]) and effective monitoring mechanisms.
- Setting up an integrated power management and planning system.

The work should be based on the existing state of the network and demand forecasts. Comprehensive information on electricity consumption and loads is required, as is reliable data on network capacity and the true state of the grid. Realistic forecasts of demand will also be needed. The data supplied must provide a proper breakdown of these figures on both a geographic and a sectoral basis. Strategies need to be drawn up to ensure the requisite measures are taken and investments made (to be detailed in the Plan): the creation of new infrastructure; upgrading and extension of existing infrastructure; and any changes required to the same.

The medium-term network strategy should facilitate the connection of micro-generation systems to any point in the grid.

2.8. Transport

This study reveals that transport is one of the largest energy users and polluters. In this context, public transport is both energy efficient and environmentally friendly. Public transport consumes 8.9% of total energy used for transport yet accounts for 48% of all journeys. Private cars, motorbikes, trucks and vans account for 91.1% of energy used for transport purposes and account for 51.9% of journeys (without commodity transport –only private cars and motorbikes- account for 60,5% of total energy used in transport). The underground is the most efficient form of transport in Barcelona, employing 3.86% of energy and making up 21.7% of journeys. Public transport use needs to be determinedly promoted and more space should be given over to pedestrians and cyclists and less to motorists. Public transport should incorporate new technologies and systems (e.g. energy-saving braking on underground trains and natural gas-powered buses).

Private vehicles: private cars, motorbikes, scooters, trucks and vans; represent an inefficient use of energy, made worse by the fact that vehicle occupation averages just 1.1 passengers per car. Furthermore, private vehicles are responsible for 92% of NOx emissions, 99% of CO, 98% of VOC and 95% of CO_2 in the area inside Barcelona's ring roads. Energy saving policies and transport planning and management need to take this enormous environmental cost into account.

In order to promote the introduction of new technologies, users/owners of private vehicles employing clean technologies (compressed air, hybrid vehicles, electric and fuel cell vehicles) should enjoy special advantages, such as: use of bus lanes, free parking or tax breaks. New technology and management systems should play a big role in facilitating the distribution of goods and reducing environmental and traffic impacts. In this context, it should be noted that Barcelona is increasingly becoming an inter-modal freight centre (particularly in the Port and Free Port areas).

The estimate of energy saving arising from Infrastructure Plan for transport measures was based on the following assumptions: 33,971,280 journey per annum by public transport between 2001 and 2005 and an average journey distance of 6.5 kilometres. This is equivalent to 220.8 Mvkm which, taking the figures for 2005, would represent 17,090,951 litres of petrol and 3,011,629 litres of diesel. The energy equivalent of this fuel is 683,732 GJ or 6.8% of private vehicle fuel consumption. These figures do not take inter-modal transport into account. Measures for the period 2005-2010 would result in public transport absorbing 25,039,840 journeys

[8] District in process of deep transformation foreseen to be high-tech activity site

[9] Spanish association of electric industry

[10] In Spanish: Service interruption of installed power

[11] In Spanish: Equivalent service interruption of installed power by consumer

a year which, based on the same average journey distance and consumption figures for 2010, would represent 11,323,597 litres of petrol and 2,140,215 litres de diesel (i.e. 458,279 GJ).

The annual energy saving in the first period would be some 532,748 GJ (2005 figure). A further annual energy saving of 294,953 GJ (2010 figure) would be obtained in the second period. Total annual energy savings in 2010 would therefore be the sum of these two figures, i.e. 827,701 GJ.

The energy savings are shown in table 2-4.

Table 2-4 Annual energy savings (in GJ) arising from Infrastructure Plan measures [p32]

2.9. Environmental impact evaluation

Evaluation of the Plan's impact has been limited to atmospheric emissions. This is the most relevant impact given that most energy use is associated with combustion of fossil fuels. The environmental consequences of using nuclear fuels have not been analysed here. This is because there is no clear methodology for comparing the effects of using fossil fuels (the greenhouse effect, and local/primary Contamination gases) with the risks associated with nuclear power and wastes.

Given that the city's main source of energy is nuclear, followed by natural gas (the least polluting of fossil fuels), it is not surprising that Barcelona produces relatively low emissions of greenhouse gases. The production of radioactive wastes and the risks of a nuclear accident are the other side of the coin and should be borne in mind. Coal has almost disappeared from the scene and the other liquid fuels are little used. There is little scope for reducing global emissions of greenhouse gases and pollutants by substituting traditional energy sources. The strategy therefore has to focus on fostering the use of renewable sources and reducing consumption through improved energy efficiency.

The emission of greenhouse gases arising from energy use and waste treatment in 1999 was equivalent to 4,732,360 metric tonnes of CO_2. This is equivalent to 3.14 tonnes of CO_2 per capita, given the Catalan electricity generation mix or 4.4 tonnes of CO_2 equivalent employing the Spanish mix. Barcelona has one of the lowest emissions per capita among European cities (and in the West in general). These low emissions of CO_2 equivalent are explained by: a mild climate; an electricity generation mix which uses a relatively low proportion of fossil fuels; a very compact densely populated city and concentrated functions; and the widespread use of natural gas.

Fig 2-8 Emissions of CO_2 equivalent per capita[12], the figures for 1997 are from different sources [p33]

Fig 2-9 Trends in emission of greenhouse gases in Barcelona (based on the Catalan electricity generation mix) [p33]

Fig 2-10 Trends in emission of greenhouse gases expressed in per capita terms [p34]

The breakdown of greenhouse gases (GHG) by sector leads one to the conclusion that 26% of these come from the Garraf USW Disposal, 25% from transport, 19% from housing, 8% from the tertiary sector, and 7% from USW treated at the St. Adrià energy recovery plant. The remaining 15% comes from other activities (such as industry) which are not examined here.

In terms of primary emissions (NOx, SO_2, N_20, CH_4, CO, VOC, PST), transport is by far and away the biggest source of these pollutants (88% of the total). It is followed by housing (7%) and tertiary activities (5%). Waste treatment currently provides the greatest potential for reducing greenhouse gases. Reduction of primary air emissions will have to focus on the transport sector.

Barcelona's satisfactory position in terms of CO_2 per capita means reduction of gas emissions will represent a greater effort that for other cities – see Table 5-9. However, it is also true that Barcelona needs to take decisive action if it is to retain its place in the ranking.

After analysing the current state of affairs, one should consider to what extent Barcelona needs to change its aims in the light of the Heidelberg and Klimabundnis accords, as described in Chapter 6.

Trends over the last five years indicate an increase in the greenhouse effect and rising use of fossil fuels as a result of the city's intensive development. Reversing this trend without endangering economic development means taking corrective measures. This is precisely the focus adopted in the projects of this Action Plan for energy saving and emissions reductions [APE], included in PEIB and a consequence of this.

[12] Data source: in brown (t CO_2/capita): "The Urban Audit Handbook", CE (only emissions from electricity and natural gas). Data source for cities marked in orange (t CO_2 equiv./capita): "Emission inventory for greenhouse gases in the City of Barcelona, 1987-1996" J.M. Baldasano et al. Atmospheric Environment, 33 1999. Data of Barcelona: 96 - Baldasano, idem, 97 – M. Pares et al. Barcelona, Ecologia d'una Ciutat. Data source 1999: Plan for Energy Improvement in Barcelona [PEIB]

3. Scenarios

Scenarios describe likely or desirable future situations. The Plan [PEIB] covers the period 2001 to 2010 while the scenario put forward here is for the year 2010.

3.1. Global demand

Forecast global energy demand is one of the main factors which need to be taken into consideration. This has been calculated by extrapolating present trends and taking into account macro-economic parameters such as GDP and their relationship with energy consumption (i.e. the intensity of energy use). This forecast needs to consider the impact of new technologies as a new differentiating factor (business as usual) in the growth of energy consumption as well as other factors such as greater demand for air conditioning for tertiary and residential uses. While demand in some sectors is highly elastic, others such as the transport, industrial and even the tertiary sector are much less sensitive to changes in energy prices. Energy prices have been taken as constant in forecasting future energy demand given that the City Council is powerless to influence them.

3.2. City population forecasts

Different population scenarios have been drawn up in order to arrive at a population figure for 2010. The results for the years 2005 and 2010 are shown in table 3-1.

Table 3-1 Population forecasts for Barcelona [p37]

Simulations and forecasts are based on the high scenario, although it should be noted that this does not differ greatly from either the trend-based or intermediate scenarios.

3.3. GDP Estimate

Scenarios for GDP growth consider various possibilities regarding economic development. The scenarios here are those contained in the study "European Union Energy Outlook to 2020". The publication contains four socio-political scenarios reflecting different social, economic and political trends:

- Conventional Wisdom – CW – The world will follow present trends.
- Battlefield – BF – The world will return to isolationism, political blocks and protectionism.
- Hypermarket – HM – The world will be dominated by free market forces and laissez-faire.
- Forum – FO – The world will increasingly be based on consensus and international co-operation.

These scenarios imply hypotheses concerning economic growth. In Spain's case, these are as shown in table 3-2.

Table 3-2 Type of growth according to EC scenario [p38]

It should be noted that the same figures were accepted for Catalonia in recent studies conducted by ICAEN [Catalan Energy Institute] for the Energy Plan for Catalonia 2001 – 2010. Forecasts by INE [Spanish Statistics Institute] and the Ministry for the Economy for 2001-2004 are all based on the high growth scenario.

3.4. Energy intensity

Energy intensity[13] is a macro indicator of energy efficiency. It expresses the relationship between energy consumption and GDP. Three scenarios have been considered with regard to energy intensity:

- Trend-based – energy intensity will average a 0.41% improvement per annum, totalling 4% for the period 2001-2010.
- Inefficient – energy intensity will worsen by 0.27% per annum, totalling 2% during the period 2001-2010.
- Efficient – energy intensity will improve by 1.46% per annum, totalling 15% over the whole period.

The relationship between changes in energy consumption with regard to changes in GDP is termed elasticity[14]. The elasticity of average total energy consumption in Spain between 1985 and 1998 was 1.21 whereas the figure for Barcelona between 1991 and 1999 was 0.78 and 0.98 for the period 1995-1999. The elasticity of electricity consumption between 1991 and 1999 was 0.89.

3.5. Scenarios for energy demand in Barcelona

The scenarios shown in table 3-3 for energy demand in the Barcelona municipality were obtained by combining scenarios for changes in energy intensity and in GDP:

Table 3-3 Forecast growth in energy consumption (with respect to base year 1999) under different scenarios. Energy-GDP [p39]

Fig 3-1 Demand scenarios [p39]

The trend/base scenario can be taken as a reference case. In this context, one should note that changes in the energy intensity trend plus base economic growth expresses energy trends in economic terms. Taking 1999 as our reference point, this hypothesis yields a 17% increase in energy demand for 2005 and a 30% increase for 2010.

At the time of writing this document, the economy is hovering on the brink of recession. However, one should nevertheless take the most ambitious growth scenario for the next ten years given that this imposes tougher conditions on the Plan.

[13] Energy intensity = Total energy consumption in the city/GDP in constant value Pesetas

[14] Elasticity = Δenergy consumption / ΔGDP

4. Projects and recommendations

This chapter sets out the objectives, strategies and projects proposed in the Plan. Related projects which have a big impact on energy consumption are included, as are recommendations to third parties.

4.1. Action Plan: Objectives and Strategies

The Action Plan for energy saving and emissions reductions [APE], within PEIB, covers Programmes and Projects, which define objectives, allocate resources, concern management, and monitor results. The projects considered here are those for which the Barcelona City Council has direct responsibility or has to approve. Recommendations regarding measures or requirements on third parties will be made in other cases.

The main purpose of the Action Plan [APE] is to allow an energy strategy to be drawn up for the City and to produce an Action Plan to put it into effect. The aim is to foster energy efficiency and the use of renewable energy sources in order to reduce emissions of greenhouse gases and health-threatening atmospheric pollutants.

Other important objectives are:

- Energy Planning
- Improving the quality of energy supply

Related objectives are:

- To determine and define energy efficiency measures
- To determine the kinds of energy and technology which should be promoted
- To take the steps required by the above objectives and commitments
- Foster energy saving
- Create the tools and obtain the data required to update an energy model for Barcelona and monitor energy flows

4.2. Action plan strategies

Next table briefly examine how the proposals for achieving the general objectives in this Plan are structured. The strategies are summarised in the list shown:

Management strategies
Barcelona Council's crucial leadership role
Structuring the Plan into manageable units
Promoting co-ordination and co-operation with other public bodies
Promoting partnership with business and professionals
Identifying the appropriate body for applying the Plan
Developing energy information systems
Supply and consumption strategies
Promoting a sustainable energy consumption model for Barcelona
Promoting the use of green and/or renewable energy
Improving the quality of energy products and services in Barcelona
Improving electricity generation and distribution
Fostering the production of renewable energy
Updating the Plan and creating measurement and control tools
Reducing Barcelona City Council's energy consumption
Commitment to the use of renewable energy sources
Social and communication strategies
Fostering a new pattern of energy consumption
Putting across the need to change energy use and the benefits of doing so
Create a high profile energy certification scheme
Foster the application of new technology
Stimulate measures in the educational field
Seize the opportunity presented by large projects underway in Barcelona
Economic and legal strategies
Maintain Barcelona's economic growth and development
Foster competitiveness and quality in energy supply
Help companies in the industry pursue their activities and set up at new sites in Barcelona
Seek co-operation with third parties by sponsoring suitable projects
Study the general economic impact of measures
Ensure measures reflect changes in the legal framework
Change municipal standards and bylaws to fit in with the Plan's proposals

4.3. Resume of Projects and Recommendations

Projects, related projects and recommendations are shown on table 4-2:

Table 4-2 Matrix of projects in the PEIB (also showing related projects and recommendations) [p50]

4.4. Projects and Recommendations

Sector: Housing

• Improvements of window frames and glazing
Replacement and repair of window frames and glazing in existing buildings. This will improve heat insulation and draft-proofing of buildings, making dwellings more comfortable and reducing noise indoors.

• Improvements in the insulation of existing dwellings
The project aims to improve the insulation of walls, ceilings and roofs in existing buildings. The purpose is to reduce the energy consumed by heating and air-conditioning in dwellings, offices and commercial premises.

• High performance boilers in dwellings
Promote the renewal of boilers in existing dwellings and improve boiler maintenance. Review the criteria adopted for installing high efficiency boilers in new dwellings (specifications to be set out in a special By-Law or through standards).

• Energy-saving lighting in dwellings and best practices
The citizens could save energy by adopting best practices and making small changes like replacing incandescent bulbs by compact fluorescent ones.
Promote rational energy use, make the general public aware of the benefits arising therefrom, and foster the adoption of energy-saving lighting in dwellings.
• Review energy standards in both new and refurbished dwellings
A study on the standards applicable to new buildings and refurbished ones, should be carried out with a view to improving energy savings. The proposals need to maintain existing comfort levels in dwellings. The initiatives could take the form of recommendations or be applied in a new By-law.
• Improving energy efficiency in blocks of flats**
Conduct a study for determining which measures/changes could improve the energy efficiency of existing blocks of flats. The conclusions drawn from the study could prove extremely useful in making recommendations and establishing standards for buildings in the future.
• Ensuring the right thermal mass characteristics in new dwellings
Carry out a study of the existing thermal mass behaviour of new dwellings, as well as construction trends in this respect. The aim is to assess the importance of thermal mass in reducing the energy used for heating and air-conditioning. Examine the possibility of exploiting outside temperature cycles to regulate building temperature and to reduce energy consumption during the Spring and Autumn months.

Sector: Public buildings & facilities

• Replacing existing street lighting
Reduce the electricity used by street lighting through replacement of mercury vapour lamps with high pressure sodium ones. The proposal is to replace certain types of street lamps with more energy-efficient ones. The aim is also to reduce light pollution and ensure lighting suits its purpose.
• LED traffic lights and improving energy efficiency
Reduce electricity consumption by replacing incandescent bulb traffic lights with LED ones.
• Improve and update energy management of lighting in public buildings
Set standards regarding the use of centralised lighting systems in buildings and streets to achieve better energy management and efficiency. Improve/update existing centralised management systems using new computerised monitoring and control techniques.
• Solar power in schools
The project has two purposes: (1) to educate schoolchildren in the technology used for producing and managing renewable energy sources, and (2) to yield worthwhile energy savings and thus foster greater public awareness of the whole issue.
• Public energy management programmes in schools and universities
Draw up energy management plans for schools and universities. The aims are to find out: (1) how energy use and consumption can be made most efficient, and (2) how worthwhile savings can be achieved through relatively small schemes.
• Performance Contracting and Energy Pools in public buildings
Application of energy performance-contracting to municipal buildings in Barcelona in order to save energy in the public sector, cut costs and reduce emissions.
Set an example for private companies to follow.
• Standards in municipal buildings and facilities
Study to define standards on energy use and comfort in municipal buildings.
• Decorative lighting
The aim of the study is to reduce the electricity consumed by decorative lighting. This includes street lighting, illuminations and floodlit fountains.

Sector: Networks

• District heating & cooling network for the 2004 Forum site
Introduce a DHC system for the 2004 Forum area to cover local needs while reducing environmental impact and electricity consumption. The scheme will provide new energy services and improve the quality of life and work in the new district.
• PV power central for the 2004 Forum
Installation of an electricity grid connected solar PV power plant on the 2004 Forum site.
• District heating & cooling network for District 22@
Install a DHC system for District 22@ to cover local needs while reducing environmental impact and electricity consumption. The scheme will provide new energy services and improve the quality of life and work in the new district.
• Use cold produced by the LPG re-gassing plant in the Port of Barcelona for air conditioning purposes
Study the feasibility of building a network for distributing cold water from the Port of Barcelona re-gassing plant.

sector: Services and Commercial Premises

• Combined heat power (CHP) generation for sports centres
The overall aim is to achieve an improvement in the ratio of primary to final energy employed in sports centres and to install co-generation equipment for generating electricity and providing heating.
• Combined heat power (CHP) generation in commercial buildings of over 3,500 m²
The overall aim is to achieve an improvement in the ratio of primary to final energy employed in shopping centres and to introduce tri-generation equipment for producing electricity and providing heating/air-conditioning. The resultant primary energy saving in fossil fuels may be as high as 24%.
• Combined heat power (CHP) generation in large hotels and clinics
The overall aim is to achieve an improvement in the ratio of primary to final energy employed in hotels and clinics and to introduce tri-generation equipment for producing electricity and providing heating/air-conditioning. The resulting reduction in the use of primary fossil fuels may be as high as 24%.
• Solar power generation systems for commercial and service premises over 3,500 m²
To ensure that 10% of the electricity consumed by large new commercial and service premises in Barcelona is supplied by solar power stations. Large commercial and service premises are defined as those over 3,500 m².
• Solar thermal panels for providing hot water in sports centres
Promote the use of solar thermal panels to meet the annual demand for tap hot water, architectural considerations permitting.
• Medium temperature solar systems for heating and air-conditioning in commercial premises
The short-term objectives are to: to demonstrate the viability of such systems; acquire the experience needed to install and operate them; and to assess their performance and costs. In the long-term: assess whether solar energy is a viable option for providing 20% of the cityís hot water and air-conditioning needs in commercial premises ranging between 500 and 3,500 m².
• Review energy standards in new buildings and in the envelope refurbishment of old ones
Carry out a study for reviewing building, lighting and ventilation standards in new commercial premises, based on the present situation. The purpose of the study will be to improve energy savings in both new buildings and ones subject to envelope rehabilitation schemes whilst maintaining or improving the level of user comfort. The results of the study could lead to recommendations or a By-Law covering new standards.

Sector: Offices

• CHP in office blocks of over 4,000 m²
The overall aim is to achieve an improvement in the ratio of primary to final energy employed in offices and to introduce systems for producing electricity and providing heating/air-conditioning in those which consume significant amounts of energy (e.g. those over 4,000 m²).
• Solar PV power generation systems for offices over 1,500 m² in Barcelona
To ensure that 12% of the electricity consumed by both new and rehabilitated offices over 1,500 m² is met by solar PV power.
• Medium temperature solar systems for heating and air-conditioning in offices
The short-term objective is to: demonstrate the viability of such systems; acquire the experience needed to install and operate them; and to evaluate their performance and costs.
In the long-term: assess whether solar energy is a viable option for providing 20% of the tap hot water and air-conditioning needs in offices of between 500 and 4,000 m².
Ensuring the right thermal mass characteristics in new offices
Carry out a study of the existing thermal mass behaviour of new offices, as well as construction trends in this respect. The aim is to assess the importance of thermal mass in reducing the energy used for heating and air-conditioning. Examine the possibility of exploiting outside temperature cycles to regulate office temperature and thus cut the energy needed for heating/air-conditioning, especially during the Spring and Autumn months.
• Review energy standards in new offices and in the rehabilitation of old ones
Carry out a study for reviewing building, lighting and ventilation standards in new offices and ones subject to envelope rehabilitation schemes. The aim is to improve energy saving whilst maintaining or improving the level of staff comfort. The results of the study could lead to recommendations or a By-Law covering new standards.

Sector: Transport

• Environmental management of traffic and development of a traffic simulator
Manage traffic in the city in a way which takes into account environmental efficiency; define the criteria to be adopted and implement the tools required. These tools would include simulation systems for estimating and assessing vehicle emissions. Consider traffic co-ordination measures to minimise emissions.
• Introduce more energy-efficient vehicles
Promote the purchase of electrical and hybrid vehicles, etc. and those which generally use less polluting fuels as part of a strategy to reduce the use of petrol and diesel vehicles. The project places particular importance on public awareness campaigns, technology demonstrations and pilot studies on the viability and effectiveness of such vehicles. The project also covers the efficiency of the underground railway infrastructure.
• Promote walking and cycling as mobility mode
Promote walking and cycling as environmentally friendly ways of getting around the city. Such measures, together with public transport initiatives, are vital for achieving an environmentally sustainable city.
• Standards for municipal vehicle fleets
Study defining standards on vehicle energy consumption and emissions in the municipal fleet.
• To promote the Car Sharing in Barcelona
To promote the Car Sharing in Barcelona. The vehicles linked to this program must be these that use less contaminant fuels or these with low consumption (in case of petrol vehicles). This project has a finalist character of implantation and also promote communication, and demonstration of feasibility and the efficiency of this way of transportation.

Sector: General

• BARCELONA ENERGY AGENCY
Set up a Barcelona Energy Agency to: manage the Action Plan for Saving Energy; reduce air emissions; and manage projects arising from the Plan (e.g. monitoring of measures affecting energy use and the city environment).
• Energy Observatory
Set up an energy observatory for monitoring the energy sector, its local impact, quality, prices, measures taken in the city, and to make recommendations for improvements. This task could form part of those performed by the Barcelona Energy Agency.
• Barcelona Energy Partnership
The co-operation of the various parties involved in the energy industry needs to be sought: professionals, companies, trade unions, guilds, consumers, universities, etc. An Energy Accord for Barcelona would provide the framework for such co-operation, facilitating the measures contained in the Energy Plan.
• Information and Public Awareness Campaigns
Disseminate information on project-related measures in order to make the general public aware of the need for energy-saving, best available technology, and energy management. The environmental impact of the Energy Plan would also be pressed home. Communicate to the citizens the information sources, public subsides, etc.
• Energy Eco-Label
Create a quality mark for energy management in Barcelona. This mark would identify buildings, companies, institutions or groups which apply best energy practices in conducting their activities.
• Barcelona energy web site
Creation of a web site, "Energy in Barcelona" with information, educational content, advice, news, details of subsidies, computing tools, showcasing of city projects using renewable energy sources, real-time updates on projects with an impact on energy consumption, etc.
• Energy Management Information Systems (GIS-E)
Promote the application of energy management computing tools in various sectors and among companies, professionals and members of the public in Barcelona.
• Energy audits in companies and the application of energy-saving measures
Promote voluntary energy audits to detect improvements in energy savings in companies.
• Disseminate educational content to schools
Ensure that future generations pick up energy-saving habits, know about renewable energies and the measures needed to protect the environment.
• Promotion of energy-saving, environmentally-friendly products in co-operation with manufacturers
Promote the use of energy-saving household appliances, etc. in co-operation with manufacturers and suppliers. The aim is to reduce energy use in dwellings, offices and commercial premises. Encourage the purchase of systems/items which are most energy-efficient and have least impact on the environment.
• Draw up an Action Plan for saving energy and reducing GHG emissions in industrial areas
Draw up an Energy and Environmental Action Plan for industrial areas and factories in Barcelona in order to improve energy efficiency.
• Energy certification of buildings
Dispose of the tools and bodies needed to certify that new and refurbished buildings: (1) meet the energy standards stipulated for granting the Eco-label; (2) comply with standards regarding control and verification procedures. New buildings will need to be inspected to ensure that they meet the objectives set out in the project. Improvements in existing buildings will need to be verified before granting an Eco-label to applicants.
• Foster training of professionals in energy efficiency and energy management
Develop programmes, tools, etc. to familiarise professionals in the field with new energy design concepts, tools, technology, use and management.
• The environment and health
Carry out studies covering primary (local) emissions and their consequences for public health.
Study the heat sink effect in the city and increase the number of air pollution sensors.
• Energy standards for large consumers
The purpose of this project is to require large energy users to submit energy-saving plans.
• Reduction of night sky light pollution
This study aims to determine the situation regarding light pollution of night sky in Barcelona and propose measures to mitigate the problem in both private and public spheres.
• Pilot studies using the latest environmental and energy technology
Carry out pilot projects covering the latest energy and environmental technology (microgeneration, fuel cell, thin film PV, urban wind turbines, microturbines, etc.). Introduce new energy information and management systems to make Barcelona a pioneer in the development of such systems.
• Annual Energy Awards
Establish prizes for the Annual Energy Awards. This social event would make the public more aware of research into and development of energy-saving measures and renewable energy sources. The awards would help publicise the efforts of public and private parties involved in the production, management and control of energy.
• Monitoring of the Solar Energy By-Law
The aim is to: reveal how far the Solar By-Law has met with acceptance and been implemented; draw up an inventory of installations (including the area of panels installed); monitor the state of existing installations and their operation performances.

Other related projects: Waste treatment

• Use of bio-gas from the Garraf municipal USW disposal
Use methane gas (produced by natural decomposition of organic waste) from the Garraf municipal USW disposal to produce energy and acheive a considerable reduction in emissions of this greenhouse gas.

5. Project evaluation and their impact

• ECOPARKS

This project (already underway) comprises the building of 4 Ecoparks to ensure proper environmental treatment of the Metropolitan Regionís urban waste. Measures will include composting, re-cycling, and methane processing to produce fuel.

Other related projects: transport

• IPT: Infrastructure Master Plan for Transport; Improvements to and Promotion of Public Transport

The Infrastructure Master Plan for Transport is based on a 10 year time scale. It aims to meet the growing infrastructure needs of public transport. The energy and environmental impact of the existing programme is evaluated within the PEIB.

Recommendations evaluated within the plan

• Extended IPT: Extended Infrastructure Master Plan for Transport

Push the Infrastructure Master Plan towards a ìmaximum scenarioî to ensure that public transport absorbs all the growth in transport needs over the next 10 years whilst maintaining private vehicle use at present levels.

• Project for the future installation of a plant for treating the USW

Proposal for an environment-friendly plant for treating all of Barcelonaís urban waste. This would operate in conjunction with the Ecoparks mentioned earlier.

Recommendations by APE: General recommendations

• Review of energy standards for new dwellings and building refubishment

Carry out a joint study with the Catalan government for reviewing existing energy standards. Review Spanish building standards for new dwellings, offices, commercial premises and building refubishment with a view to improving energy-saving.

• Electricity billing according to the primary energy employed, and progressive pricing.

Ensure that consumers receive electricity bills detailing the origin of the energy used (fossil fuels, nuclear power, wind power, hydro-power, etc.) and make it possible to directly purchase kWh generated from a range of renewable energy sources. The billing should be easy to understand and detail prices.

Apply progressive energy pricing (over and above a certain threshold) in some sectors. This measure would encourage energy-saving.

• Forum for fostering co-operation with the power industry

Carry out a joint study (involving power companies and the City Council) to establish the measures required to provide Barcelona with a reliable, high quality electricity supply.

Create a working party to: study this issue, carry out monitoring, and update information where necessary.

The summary tables in this chapter give an overall view of the energy and environmental impact of the proposed measures. Among other methods, the impact evaluations were based on simulations run on a programme which was expressly developed for this Plan. The results are shown in summarised form or in the tables 5-1 and 5-2.

5.1. Number of projects

Fifty four projects are proposed in the Plan. The following table shows the sectors and kinds of the projects involved and whether the City Council has begun the execution.

Table 5-1 Summary of projects by sector and type [p53]

Final Projects: Those whose results can be directly quantified in terms of a reduction in energy consumption or gas emissions.

Instrumental Projects: Those which are difficult to quantify directly in terms of a reduction in energy consumption or GHG emissions but which are nonetheless vital to the success of a project.

Table 5-2 groups the projects by the programme and the type of measures involved:

Table 5-2 Programmes and related projects [p53]

5.2. Summary of energy savings, emission reductions and the impact of projects

The following table group all of the projects forming part of the Action Plan [APE]. The data covers: savings in energy consumption; reductions in emissions and investment. Transport and waste treatment projects which bear on the Action Plan are also shown, even though they do not strictly form part of it.

The likely impact of recommendations is also shown, and this, together with the APE projects form the Global Action scenario.

In general, the estimates have erred on the cautious side, particularly with regard to instrumental projects.

Table 5-3 Outstanding results of some scenarios [p54]

5.3. Evaluation of the proposed measures impact

One should look at the impact of various projects by putting forward a set of scenarios (all of are variations on the trend-based scenario defined earlier). Later it will be presented energetic and environmental results respect de trend-base scenario.

• SCENARIO A: The current situation. 1999 is the base year on which all calculations of future growth are made. This scenario has been calibrated with the real measured data.

• SCENARIO B: Trend-based. This is the trend-based scenario up to 2010, based on the hypotheses stated in this Plan [PEIB].

• SCENARIO C: Barcelona Action Plan Projects [APE] This scenario takes into account the impact of energy-saving and emission reduction measures forming part of the Action Plan for energy saving and emissions reductions [APE][15], this projects are described in Chapter 4.4.

• SCENARIO D: Garraf + ECOPARKS. This scenario only takes into account the impact of closing the Garraf SUW disposal (with consequent reduction of GHG emissions) and the building of 4 Ecoparks recyclable materials recovering on destination and digestion of organic waste producing biogas.

• SCENARIO E: D + Future Urban Solid Waste treatment plant. This is the same as scenario D above, except for the addition of one more plant for treating solid urban wastes. The plant would deal with the excess waste not processed by the four Ecoparks. The Plan recommends building of the plant given the projected growth in urban waste up to 2010. In this context, one should bear in mind the current Metropolitan SUW Treatment plan deals with the period until 2006. The waste processing plant will generate electricity from biogas.

• SCENARIO F: Infrastructure Plan for Transport. This scenario simulates the impact of the approved Infrastructure Plan [IPT] itself.

• SCENARIO G: IPT + Extended infrastructure Plan for Transport. Given the forecast growth in journeys in 2010, this Plan recommends measures be taken to complement the IPT. Even though it will be difficult for public transport to absorb 100% of the future growth in journey needs, it has been adopted as a working hypothesis. These hypothesis have been termed the "Maximum-based Transport Scenario".

• GLOBAL ACTION SCENARIO – SCENARIO H: C + D + F. This composite scenario comprises scenario C (APE projects), D (Garraf+Ecoparks) and F (IPT). This scenario is the most likely if all the Action Plan [APE] measures are carried out, given that the plans contained in scenarios D and F are already underway.

• SCENARIO I: C + D + F. This takes in the following scenarios: C (APE projects), E (Garraf+Ecoparks + the urban solid waste treatment plant) and F (IPT). The adoption of this scenario is highly recommended given that it would ensure proper environmental treatment of 100% of Barcelona's solid urban waste.

[15] Included in PEIB and a consequence of this

• TARGET SCENARIO – SCENARIO J: C + E + G. This is based on maximum goals and takes in the following scenarios: C (APE projects), E (Garraf+Ecoparks + the urban solid waste treatment plant) and G (IPT + extended IPT). The adoption of this scenario is also highly recommended in this Plan given that it would not only ensure proper environmental treatment of 100% of Barcelona's solid urban waste but also make an all-out commitment to public transport in meeting the growth in the city's mobility needs. However, one should note that it would be extremely difficult to meet these objectives in practice.

The figures 5-1, 5-2, 5-3 and 5-4, and the tables 5-4, 5-5, 5-6, 5-7, show the impact of the aforementioned scenarios and implementation of the projects contained in the Plan. The data were produced by the Plan simulation tool and are based on (1) the Catalan electricity generation mix and (2) the specific hypotheses applicable to each project and scenario. [p56-59]

5.4. Results analysis

Energy evaluation

After running various simulations and analysing different scenarios, the working hypothesis have been based on average economic growth of 2.8% per annum or 35.5% cumulative growth in the period 1999-2010 (i.e. no recession). The projection for energy consumption is based on present trends and incorporating technological changes. This yields a 31.3% increase in energy consumption over the same period. Per capita energy consumption would thus rise from 33.65 GJ/year to 43.67 GJ/year. This scenario would produce an elasticity of 0.87, higher than the figure for the last decade (0.78). It will be recalled from previous comments that the lower the elasticity figure, the better. In this scenario, economic growth, rising energy consumption and emissions are all strongly linked.

The Global Action Scenario (on which the Action Plan [APE] measures are based) is considered a feasible one. If the Metropolitan Waste Management Programme and the Infrastructure Plan are included, the forecast growth in energy consumption would be 25.9% for 1999-2010 (i.e. 41.87 GJ per capita). This scenario would yield 4.14% or 2.75 PJ less energy consumed with respect to the trend-based scenario for 2010 [this energy reduction is equivalent to, approximately the energy consumption of a municipality of 80,000 inhabitants]. The Global Action scenario generate 148.7 GWh per year by small scale installations (employing CHP and renewable sources) distributed throughout Barcelona.

This scenario would yield to an elasticity of 0.72, appreciably lower than the figure for the last decade and even lower still than the one arising from the trend-based scenario. This kind of elasticity behaviour is highly desirable given that it would gradually weaken the link between economic growth and increased energy consumption. In this scenario, the final energy intensity in 2010 would be 1184.6 kJ/€ of GDP (at 1999 values) representing a reduction of 8.2% compared with the previous decade. In annual terms, energy intensity would fall by 0.85%. The resulting reduction is close to the EU target of improving energy intensity by 1% per annum during the period 1998-2010 (COM[1998] 246 final).

Table 5-8: Global Action Scenario: Action Plan [APE] +Infrastructure Plan Transport [IPT] + Metropolitan Waste Management Programme: energy saving by sectors compared with sectoral energy consumption forecast for 2010 [p60]

The Action Plan [APE] represents a serious attempt to exploit the city's renewable energy sources to the maximum. The two kinds of renewable energy sources available are organic wastes (the raw material for producing biogas) and solar energy. The City Council has taken a bold step in exploiting thermal solar energy. The Plan will reinforce this initiative by making a strong commitment to installing solar panels.

The Plan envisages the following energy contribution from renewable sources:

- 341,800 GJ/year of electricity generated from biogas
- 58,000 GJ/year of electricity using solar PV technology, with a generating capacity of 14.14 MWp. The breakdown of this capacity would be as follows: 11.44 MWp in offices, 1.1 MWp in commercial, 0.25 MWp in schools and 1.35 MWp in a centralised plant on the 2004 Forum site.
- Installation of 96,300 m^2 of thermal solar panels with a heat generation capacity of 280,000 GJ/year.

These installations would turn Barcelona into one of the cities making most use of solar energy and provide 679,800 GJ/year from renewable sources or 1.1% of the city's total energy consumption in 2010. This is consistent with the target set by the Spanish government's plan for fostering use of renewable energy sources for Catalonia autonomy. The Central Government Plan envisages for Catalonia 539,000 m^2 of thermal panels and 16.5 MW of generating capacity for solar power panels. Achieving 100% of the Action Plan [APE] in this field would represent attaining 18% of the Spanish target for solar thermal panels and 95% of the target for solar PV technology.

The Plan does not consider bio-fuels production given that they fall outside its geographic scope (i.e. Barcelona Municipality), but of course it is open to support this kind of application.

Table 5-9 Comparison of the results obtained under different scenarios [p61]

It should be noted that there is no significant difference in the mix of final energy consumed between the "Trend-based" and "Global Action Plan" scenarios. The most-used final energy continues to be electricity (42% compared with 41% at present); followed by natural gas (28% compared with 25% at present); oil (28%-29%, compared with 31% at present); and lastly LPG (1.6%, compared with 3% at present).

The "Target" scenario should be to achieve the measures contained in (1) the Energy Plan (2) the Metropolitan Waste Management Programme (with an additional facility to deal with waste once the existing plan comes to an end); and (3) the extended Infrastructure Plan of Transport. These combined measures would yield a 21.58% increase in energy consumption to 2010 (or 40.43 GJ/year per capita). This represents an energy saving compared with the trend-based scenario of 4.94 PJ. This is a maximalist but realistic scenario which would nevertheless prove difficult to achieve in its entirety.

This scenario would produce a relatively insignificant change in the mix of final energy consumed. In this case, electricity would rise to 44% of the total, natural gas to 29%, while LPG would remain virtually unchanged at 1.7% and oil would fall to 25%.

A scenario covering the technical potential of projects called "APE ideal" scenario, was created in order to place the Plan in technological context. The scenario considered ideal implementation of the projects proposed in the Action Plan. It should be said that this "APE ideal" scenario is based on consistent hypotheses and logical restrictions. In other words, it is not simply the result of applying all the projects in their entirety (100% of applicability) and ignoring incompatibilities and resource constraints. Rather, the "APE ideal" scenario is one which is feasible from a physical point of view but which would nevertheless prove technically difficult and require considerable investment to bring it to fruition.

Fig 5-5 Changes in final energy consumption share, by energy sources for different scenarios [p62]

The "APE ideal" scenario, together with the transport hypotheses (Infrastructure Plan of Transport plus extended Infrastructure Plan of Transport), the Waste Plan (closure of the Garraf disposal + opening of the Ecoparks + future waste treatment plant) constitute the "BARCELONA CEILING SCENARIO". This "ceiling" scenario projects an energy saving of 11.94 PJ, placing per capita consumption at 35.84 GJ in 2010, a figure only slightly higher than the present one.

Table 5-10 Comparison between the results of the Ceiling Scenario, the Target Scenario and APE [p62]

Comparison of the APE with the "APE ideal scenario" reveals that the Action Plan saves 22.7% of the energy which could be spared using today's best available technology.

An analysis of the impact of planned measures on the kinds of energy used compared with the trend-based scenario is shown in Fig 5-2 It should be noted that the trend-based scenario for 2010 would result in greater use of electricity and natural gas to the detriment of petrol, LPG and thermal solar energy.

One should note there exists the difference of percentages between figures Fig 5-1 and Fig 5-2 is due to the fact that the first set takes into account all energy consumption in the city while the second only consider the energy types studied in the Plan (i.e. without the "Others" category), thus increasing the relative weight of electricity consumption.

The Global Action Plan scenario directly affects changes in the relative weight of energy sources, reducing the importance of petrol and boosting thermal solar power and air conditioning (the last one through co-generation (CHP) and tri-generation systems).This is also reflected in the electricity generation mix for Barcelona alone[16], in which a much more significant part comes from renewable energy sources (solar PV and electricity generated from biogas recovered in the waste treatment plant), rising from 0.01 per 1000 to 2% of electricity generated[16]. This represents a strong commitment to efficient energy and the use of renewable sources.

Lastly, the Target scenario involves making big changes in the transport sector (with the extended Infrastructure Project) and a strong commitment to treating 100% of the city's waste (with the help of the future urban waste processing plant). These initiatives will reduce the proportion accounted for by diesel oil in total energy use and boost the relative importance of electricity and natural gas (both cleaner energy sources than diesel oil with regard to pollutant and greenhouse gas emissions). At the same time, the proportion of total consumption made up by renewable energy sources will increase appreciably (from 2% to 2.5%[17]).

Fig 5-6 Pie charts showing the breakdown of energy sources included in the Plan under different scenarios[17] [p63]

Environmental impact

This global study of energy flows and emissions reveals that Barcelona has a lower index of energy consumption and emissions than other European cities of a similar size. In this respect, one can say that Barcelona is a relatively clean, efficient city. However, this will make it harder for Barcelona to reduce gas emissions by a given amount than for other cities. Various cities, particularly in Germany, have made considerable efforts over the last decade to reduce greenhouse gas emissions, but their emissions are high with regard to the emissions of Barcelona.

The table 5-11 shows some of the reductions achieved.

Table 5-11: Reduction in greenhouse gas emissions other cities [p64]

It will be seen that Table 5-7 cities in the former German Democratic Republic are those which had the easiest job of reducing air pollution. The replacement of outdated technology by new has led to a significant improvement in air quality and emission control. In the most technologically developed cities, environmental improvement implies carrying out measures which are unlikely to achieve the same savings as cities with old technologies.

The table 5-12 shows forecast greenhouse gas emissions under different scenarios.

Table 5-12: Comparison of greenhouse gas emissions under different scenarios [p64]

Greenhouse gases would increase by 27% in the period up to 2010 under the trend-based scenario with regard to 1999, giving emissions of 3.96 t CO_2 per year per capita. In absolute terms, this represents 6.03 million tons of CO_2 per year.

Under the Global Action Scenario (which includes the measures contained in the Plan, plus those in the Metropolitan Waste Management Programme, and the Infrastructure Plan for Transport), the emission of greenhouse gases would remain at present levels (4.8 million tons of CO_2 equivalent or 3.15 t CO_2 equiv. a year per capita. Under the Trend-based Scenario, emissions would be reduced 20.3% in 2010.

In the Target Scenario, CHG emissions would be reduced by 30.3% (including reduction of gas emissions from the Garraf Disposal) compared with the Trend-based Scenario for 2010, resulting in emission cuts till 2.76 t CO_2 equiv. per capita.

Under the "Ceiling Scenario" (which assumes technical potential), emissions would be reduced by 37% compared with the Trend-based Scenario for 2010. This would yield per capita emissions of 2.49 t CO_2 equiv. a year per capita.

With regard to the international commitments made by Barcelona (Heidelberg, Klimabündnis) a more realistic objective might be to maintain low emissions levels per capita or to try to reduce the emission of greenhouse gases below 3 t CO_2 equiv/ per year per capita. If these objectives are to be attained, it is essential to continue building treatment plants beyond 2006 (which is when the current metropolitan Waste Management Plan ends).

A target of 3 t CO_2 equiv. a year per capita is extremely ambitious, bearing in mind unfavourable trends in the electricity generating mix and a significant increase in the demand for transport. However, reaching this figure would make Barcelona a leader in terms of reducing greenhouse gas emissions.

If action is not taken, Barcelona could fall in the international rankings – a good reason for taking steps to maintain the present moderate emission levels and to improve them where possible.

Economic assessment

The total cost of the Action Plan is estimated at 667.88 M€. It has been assumed that 5.8% of this amount could comprise grants and subsidies from third parties.

If only related projects are considered (i.e. those whose main purpose is transport and waste treatment but which will make a fundamental impact on the environment and energy consumption), the investment involved is 3,383.12 M€.

Total investment for the Global Action Scenario: H (Plan projects, closure of the Garraf Disposal, waste treatment in Ecoparks and implementation of the Infrastructure Plan of Transport) amounts to 4,050.99 M€.

The global payback of the Action Plan [APE] projects in terms of the internal rate of return (IRR) in 1999 Euros solely in terms of energy savings and energy generation is 4.44%.

In order to calculate the marginal cost and benefit associated with increasing investment, we have studied the APE ideal Scenario which states maximum objectives. As mentioned earlier, this scenario is based on consistent hypotheses and logical restrictions. The APE ideal is one which is feasible from a physical point of view but which would nevertheless prove technically difficult and require considerable investment to bring it to fruition. The likelihood of achieving its objectives is therefore a remote one. One should note that the investment required in this case would be 13,443.55 M€. Under such circumstances, the IRR would be negative (-4.23%).

With reference to the chosen Global Action Scenario and comparing it with the Ceiling Scenario, one should note that carrying out just 5% of the investments required by the latter would yield an energy saving of 22.7% and a reduction in emissions of practically 34%.

As investments rise towards the ceiling figure, the marginal environmental and energy returns decrease, making it progressively harder to achieve acceptable results for the investment made. Accordingly, it seems reasonable to confine investment in projects to the levels established by the Action Plan [APE].

The cost of saving a tonne of CO_2 equivalent has been calculated, the totals and results by sectors being shown in table 5-13.

Table 5-13 Cost in Euros and Pesetas to save a tonne of CO_2 equivalent [p66]

It should be noted that the cost of saving a tonne of CO_2 equivalent CHG emission is relatively small in the waste treatment sector compared with alternative, less direct measures (e.g. energy saving).

The stated costs are considerably higher than those stated in rough estimations[18] done by CE: less than 20€/tonne reduced of CO_2eq (12,01€ for every tonne of CO_2 reduced to the atmosphere for Spain)

[16]Only in Barcelona's power generation (to highlight changes produced by external measures)

[17]Percentages of electricity generation in Barcelona (to highlight changes produced by external measures)

[18]Results from the press conference by Commissioner Margot WALLSTRÖM on the new report from the European Climate change Programme on 11/06/2001 [reference 20269]

6. Summary and Conclusions

The Plan set out in this document covers the Barcelona municipality and a ten year time span. It aims to address the concerns in the Green Book for a European Energy Strategy [COM(2000) 769] and is consistent with the EU's objective of obtaining 12% of its energy needs from renewable energy sources by 2010.

Energy consumption and its environmental impact is one of the most pressing problems facing our society. That is why a great deal of international effort is being put into developing new technologies and sources of energy. One of the aims of this Plan is to prepare Barcelona both technically and culturally for these technological changes and to foster technology changes in all spheres of economic activity.

Local councils' scope for taking action with regard to energy is determined by the range, type and size of activities which take place within their municipal boundaries. External factors include: technological developments; the availability and cost of local and international energy sources; and -in particular- the action taken by regulatory bodies. In Barcelona's case, the scope for generation using local energy sources is extremely limited given that distribution and sale of energy is controlled by companies while regulation of the industry is basically in the hands of other public bodies and tiers of government.

Barcelona City Council has elaborated this Plan for energy improvement in Barcelona [PEIB], that includes an Action Plan for energy saving and emissions reduction [APE] containing projects and recommendations. The projects represent municipal commitments. Recommendations are made to third parties where the proposed measures fall outside the Council's jurisdiction. The Plan gives wide scope for municipal action in promoting an environmentally sustainable city, reducing air pollution and the consumption of fossil fuels in the process. Achieving these aims requires:

- Knowledge of the measures required and the alternatives available
- The Council's commitment to action (given that it is a large consumer of energy).
- Use of the Council's powers to regulate new installations requiring less energy.
- Promotion of public transport
- Promotion of energy-saving and giving a major impetus to the use and generation of renewable energy.
- A policy of fostering the availability and use of more efficient, high quality technology, equipment, systems and services in Barcelona.
- A policy of encouraging a change in attitudes regarding the use of energy.

The Energy Plan [PEIB] is a planning and monitoring tool and will therefore need to incorporate changes in the light of changes in the energy industry and the City's development. As an example, one should note one of the most important external factors is the share of the power generating mix. If we consider variations in the Catalan generating mix, the substitution of part of nuclear energy's contribution by fossil fuels rather than by renewable energy sources will tend to worsen Barcelona's emission figures. The adverse trend in emissions arising from electricity use will be less pronounced if the Spanish generation mix is used (given that nuclear power plays a smaller role in total Spanish power generation). However, Barcelona cannot influence either the Catalan or Spanish generation mixes.

As mentioned in the diagnosis section, Barcelona's emission and energy consumption figures are among the best for cities of comparable size. By the same token, the cost of the technology, services and other facilities needed to reduce emissions will be higher than for more polluted cities. Implementation of the projects planned over the 10 year period will be affected by these costs, the energy savings available, and market profit perspectives (which are linked to economic and environmental payback as well as to energy savings). In this respect, energy cost trends and the ability of citizens to choose between energy sources will prove important.

After running various simulations and analysing different scenarios, the figures indicate that the economy is likely to grow by 2.8% per annum and that this will push up energy consumption by 31.3% between 1999 and 2010. The latter figure is based on present trends but also takes technological changes into account. Per capita energy consumption would rise from 33.65 GJ/year to 43.67 GJ/year over the same period. In terms of greenhouse gas emissions, this represents a 27% increase to 2010 or 3.96 tonnes of CO_2 equivalent per year per capita.

The most feasible starting point is considered to be the Global Action Scenario (which takes on board the Action Plan measures) plus the Metropolitan Waste Management Programme and the Infrastructure Plan for Transport. These combined measures would yield a 25.9% increase in energy consumption to 2010 (or 41.87 GJ/year per capita). Greenhouse gas emissions would remain at a level of 3.15 tonnes of CO_2 equivalent a year per capita. This scenario gives a 4.14% reduction in energy consumption compared with the 2010 trend-based scenario - 148.7 GWh/year of electricity would be generated by small-scale installations scattered throughout Barcelona (employing CHP and renewable sources). This would also reduce emissions by 20.3% in 2010 compared with the trend-based scenario. The scenario yields an elasticity of 0.72. This is much lower than the elasticity figure for the past decade and ever more so in comparison with the trend-based scenario.

The "Target Scenario" should be to achieve the measures contained in (1) the Action Plan (2) the Metropolitan Waste Management Programme (with an additional Ecopark to deal with waste once the existing plan comes to an end in 2006); and (3) the extended Infrastructure Plan for Transport. These combined measures would yield a 21.58% increase in energy consumption to 2010 (or 40.43 GJ/year per capita). In the Target Scenario, greenhouse gas emission would be reduced by 30.3% in comparison with the Trend-based Scenario for 2010, resulting in emission cuts till 2.76 t CO_2 equivalent per capita. This scenario represents a ceiling with regard to transport and would be difficult to achieve in its entirety. Nevertheless, it should serve as a guideline for taking action. The Plan emphasises the environmental importance of both kinds of measures.

The Action Plan represents a serious attempt to exploit the city's renewable energy sources to the maximum. The two kinds of renewable energy sources available are organic wastes (the raw material for producing biogas) and solar energy. The City Council has taken a bold step in exploiting thermal solar energy. The Plan will reinforce this initiative by making a strong commitment to installing solar panels.

The Plan envisages the following energy contribution from renewable sources:

- power generation of 341,800 GJ/year using biogas
- power generation of 58,000 GJ/year using solar PV, with a maximum installed capacity of 14.14 MWp
- Installation of 96,300 m^2 of thermal solar panels with a heat generation capacity of 280,000 GJ/year

These installations would turn Barcelona into one of the cities making most use of solar energy.

This is consistent with the target set by the Spanish government's plan for fostering use of renewable energy sources for Catalonia autonomy. The Central Government Plan envisages for Catalonia 539,500 m^2 of thermal panels and 16.5 MWp of PV technology. Achieving 100% of the Barcelona Energy Plan in this field would represent attaining 18% of the target for Catalonia for thermal panels and 95% of the target for solar PV.

With regard to the international commitments, a realistic objective is to maintain the current low emission levels per capita or to try to reduce the emission of greenhouse gases below 3 tonnes CO_2 equivalent/a year per capita. However, this target is extremely ambitious, bearing in mind unfavourable trends in the electricity generating mix and a significant increase in the demand for transport. If these objectives are to be attained, it is essential to continue building USW treatment plants beyond 2006, which is when the current Metropolitan Waste Management Plan comes to an end. It should be noted that reaching a figure of 3 tonnes CO_2 equiv./a year per capita would make Barcelona a leader in terms of reducing greenhouse gas emissions.

If action is not taken, Barcelona's place in the rankings could be adversely affected – a good reason for taking steps to maintain the present moderate emission levels and to improve them where possible.

Fig 6-1 Emissions of CO_2 equivalent per capita[19], including the results from the Action Scenario (dark brown) and the Trend-based Scenario (soft brown); the figures for 1997 are from different sources [p71]

[19] "Data source: in brown (t CO_2/capita): "The Urban Audit Handbook", CE (only emissions from electricity and natural gas). Data source for cities marked in orange (t CO_2 eq/capita): "Emission Inventory for Greenhouse Gases in the City of Barcelona, 1987-1996" J.M. Baldasano et al. Atmospheric Environment, 33 1999. Data for Barcelona: 96 - Baldasano,idem, 97 – M. Pares et al. Barcelona, Ecologia d'una Ciutat. Data source 1999: Plan for Energy Improvement in Barcelona. [PEIB]
Data Spain COM (2000) 749 final. Data for other countries: John Byrne, personal communication.