# PASSIVE SOLAR ENERGY AS A FUEL
# 1990–2010

**A study of the current and future use of passive solar energy in buildings in the European Community.**

## REPORT ON BACKGROUND MATERIAL AND RESEARCH


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# 1 INTRODUCTION

## 1.1 Background

The Commission of the European Communities has supported the use of solar energy to provide heating and lighting to buildings since 1980. As a part of its support, this study was commissioned by the CEC in 1989 to assess the amount of passive solar energy which could be utilised in buildings over the 20 year period up to the year 2010, and to estimate the consequent reduction in the use of fossil fuels and in the resulting pollution.

## 1.2 Objectives

The sun directly provides heat and light to almost all buildings and the amount of this solar energy can be increased by specific design. It is therefore useful to quantify this solar contribution. The energy used by buildings is currently recorded in terms of their electricity, coal, oil and gas consumptions for the various functions - heating, lighting, cooling, hot water, process loads etc. The purpose of the study is to be able to add in the use (or consumption) of solar energy, so that due credit can be given to buildings with a high utilisation of solar energy and which therefore reduce the need for auxiliary energy use.

This concept is also applied to overheating and the consequent use of auxiliary energy for cooling. Buildings in all climates can be designed to reduce or eliminate overheating and just as the solar contribution to a heating demand can be quantified, so can this contribution of passive solar design to a cooling demand. This is discussed further in section 1.4 which deals with definitions.

Whilst the reduction in the use of "conventional" energy sources is desirable in the traditional terms of cost savings, conservation of dwindling fossil fuels etc, the growing awareness of the problems of global pollution have highlighted the importance of energy conservation and the use of renewable energy sources in averting global disaster. Thus a major objective of this study was to quantify the reduced pollution resulting from the substitution of auxiliary fuel use by passive solar energy.

## 1.3 Scope

This study covers energy use in both housing and non-domestic buildings in all 12 CEC countries. The use of passive solar energy for heating, lighting and cooling of all buildings is included where appropriate. The exact definitions of the "passive solar contribution" to each area are important and these are discussed in section 1.4.

The study is limited to general assessment and forecasting in several areas, with more detailed analysis in the area of heating in houses where research and information collection has been more common in recent years. As more data in individual countries becomes available, it will be possible to provide a more detailed estimate. Section 2 covers the scope of information sources used.

In terms of end results, the study assesses the amount of energy from "conventional" sources that is currently replaced by passive solar energy and how this could change over the next 20 years if passive solar design techniques were widely adopted both in new buildings and in refurbishment. The resulting savings in the whole range of pollutants produced by conventional fuels, including nuclear power, are analysed on a country by country basis.

The study does not include other uses of solar energy in buildings such as active solar heating, solar water heating, photovoltaics or solar heating for agriculture.

## 1.4 Definitions

It is not possible to measure the amount of solar energy used for a particular function in the same way as one can measure the amount of coal, oil, gas etc. As far as possible solar energy has been measured by its substitution of electricity or gas use, etc, factored back to primary energy units. There is still a need to clarify several aspects and define the boundaries.

**Passive solar heating.** Energy from the sun's rays entering the building envelope through a window or other transparent or translucent part of the envelope (Trombe wall, roof, sunspace etc.) which is useful in replacing auxiliary heating or improving comfort conditions within the building.

**Annual solar heating contribution.** The total passive solar energy which raises temperatures towards comfort levels throughout the year (not only during the "heating season").

The base line for measurement is taken as the internal temperature of the building resulting from the ambient (external) temperature plus internal gains from occupants, cooking, lights, equipment and hot water.

**Passive solar cooling.** Building design features which reduce the entry of sunlight into a building (overhangs, blinds, shutters, etc), promote passive ventilation (cross ventilation measures, stack ventilation etc) or reduce maximum temperatures (thermal mass, water cooling etc), to reduce auxiliary cooling loads or improve comfort levels.

**Passive solar cooling contribution.** The contribution of passive solar design to satisfying the "cooling demand", whether or not the remaining demand is satisfied by auxiliary cooling or acceptance of overheating.

The base line for measurement is taken as the temperature above which auxiliary cooling is commonly in use. (This varies between different building uses).

**Daylighting (as a passive solar measure).** Building design which maximises the entry of daylighting into a building (form, window size and location, skylighting, reflectors, etc) or reduces the unnecessary use of auxiliary lighting (responsive control systems), to provide acceptable levels of illumination.

**Non-domestic daylighting contribution.** The base line for measurement is taken as the current level of auxiliary lighting. The daylighting contribution is the reduction in auxiliary lighting use due to specific building design and incorporation of responsive control systems. The assumption is that the auxiliary lighting is normally in use during daytime hours irrespective of demand.

**Domestic daylighting contribution.** No contribution has been considered since auxiliary lighting is not normally used in houses during the hours of daylight, and design or control improvements would not normally reduce auxiliary lighting or improve comfort.

## 1.5 Technical potential solar contribution

The principle calculations within the study are aimed towards producing the "Technical Potential solar contribution" in the years 2000 and 2010. This is the technically possible target based on existing proven designs and technology and estimated building and refurbishment rates. It is based on all new and refurbished buildings incorporating appropriate passive solar measures but taking into account factors such as orientation and overshading. Thus the technical potential could never be achieved in practice, though various influencing factors could act towards reaching this target.

The following influencing factors have been identified and their effects examined:

- Fuel prices
- Legislation
- Public pressure/social change
- Global environmental concerns
- Climatic change
- Incentives
- Technical advances
- Technology transfer
- Competition with other energy saving measures

## 1.6 Passive Solar Technologies

The proven passive solar designs and technologies considered are as follows:

**Heating.**

Orientation and layouts (internal and external)
Direct gain through windows;
Sunspaces;
Thermal mass;
Convective loops for distribution of solar gains;
Indirect panels (Trombe walls).

**Cooling.**

Fixed overhangs;
External shading devices;
Blinds and shutters;
Thermal mass;
Natural ventilation, including stack ventilation;
Humidification.

**Lighting.** (Non-domestic only)

Special designs to allow entry of daylight;
Narrow plan designs;
Light wells, light reflectors;
Photo-electric controls.

There are other technologies, products and techniques that can be used to enhance solar performance and these will be applicable to various situations. The effect of these has been considered separately and this is discussed in section 3.1.

## 1.7 Passive solar design and the user

The main purpose of this study is to assess the contribution that passive solar design can make to reducing auxiliary fuel use in buildings and thus reducing environmental pollution. However, passive solar design has other benefits, particularly for the users or occupiers of the buildings, and these in turn will affect the success and growth of passive solar design.

In housing the contribution of passive solar design may not in practice reduce auxiliary fuel consumption but may be used to increase comfort. This is particularly true with cooling where passive cooling measures will reduce maximum temperatures, though auxiliary cooling would not be available or used. However, there is a trend towards the use of more auxiliary heating and cooling as standards of living rise, particularly in less developed countries such as Portugal and Greece. Thus the study recognises the value of solar gains both in raising standards of comfort and reducing auxiliary fuel use.

In the non-domestic sector the same trends are discernable though principally concerning cooling. The study anticipates a steady growth in the use of auxiliary cooling in non-domestic buildings.

The CEC Project Monitor series collected user response to passive solar buildings. In both houses and non-domestic buildings, users liked the buildings with few exceptions, though for different reasons. Occupiers of passive solar houses liked them for the light and airy feeling and generally for their appearance and comfort. Sunspaces were universally liked both as pleasant spaces and often for the "extra" space they provided. There was some evidence that the houses had greater market values and that occupiers wished to move to another solar house if they were to move.

The perceived benefits of non-domestic solar buildings in addition to being light and comfortable, were often related to the activity carried out in the building. Thus passive solar schools provided the right environment for learning about ecological issues, and a solar office/factory was used to demonstrate the use of the environmental control systems manufactured in the building.

Passive solar design in non-domestic buildings can also help to alleviate general building problems such as Sick Building Syndrome. A study by the Building Services Research and Information Association (BSRIA) the "Sick Building Syndrome", in the U.K. indicates that it is a complex "cocktail" of factors which cause the effect, which can be a serious problem leading to low user moral, absenteeism and loss of productivity. Several of the causal factors relate to building design and operation and these may be avoided or reduced by passive solar design, for example:-

- low fresh (outside) air ventilation rates;
- low air movements;
- some types of heating and ventilation systems;
- mechanical ventilation;
- poor control of building services;
- fluorescent lights (glare and flicker);
- proportion of daylight versus artificial lighting;
- non-openable windows;
- tinted or mirrored glass.

Passive design in non-domestic buildings uses more daylighting, elimination or reduction of air-conditioning, natural ventilation and greater use of passive solar heating and thus puts building users more closely in touch with the outside environment. Avoidance of any tendency towards "Sick Building Syndrome" is important in the design of non-domestic buildings and passive solar design can be an important part of the strategy.

## 2 INFORMATION SOURCES

### 2.1 General

The study methodology was to use published data, case study information and estimates of future trends where possible, supported by expert opinion and estimates where necessary. Information searches in the UK revealed that published data are not available in a large number of areas (see section 2.2). Subsequent approaches to experts in the other CEC countries confirmed that data and information are frequently simply not available.

In some cases, in some countries, the information required was thought to be available but the time and resources within the study were not sufficient to gather it together into a usable form.

The next approach was to use experts in various countries (see section 2.4) to make estimates for their countries where information was not published. In some cases experts were not able or prepared to make such estimates.

The last approach was for the study team in the UK to make estimates based on trends and comparison with other countries where information or estimates were available.

### 2.2 Published Material

The main sources of published information used in the calculations were as follows:

| | |
|---|---|
| CEC Eurostat Review | (Housing stock, population, non-domestic energy use, breakdown of energy by source) |
| Building Services Research and Information Association (BSRIA). Statistics Bulletins | (UK house building refurbishment and demolition rates, cooling information) |
| Building Research Establishment BRE Homes and BREDEM | (UK house energy use) |
| CEC Project Monitor Series | (Passive solar contribution throughout Europe, general energy consumption data) |

| | |
|---|---|
| Martin Centre "Passive Solar Heating in Existing Housing" | (UK housing heat losses) |
| Eurisol "Pollution Reduction Through Energy Conservation) | (Breakdown of house energy use by source) |
| Energy Technology Support Unit (ETSU) Harwell "Report 1142" (N. Baker) | (Sunspace performance) |
| Watt Committee on Energy. "Passive Solar Energy in Buildings" | (Non-domestic energy) |
| Building Research Establishment "Daylighting as a Passive Solar Option" | (Energy use in non-domestic buildings. Lighting estimates) |
| CEC Building 2000 Project | (Cooling in non-domestic buildings) |
| CEC/O. Hohmeyer "The Social Costs of Energy Consumption" | (Environmental costs of electricity production) |
| ETSU "Energy Use and Efficiency in UK Commercial and Public Buildings up to the year 2000" | |

## 2.3 European case studies

2.3.1 **Project monitor.** The 50 case studies of monitored passive solar buildings in Europe produced in the C.E.C Project Monitor series have been analysed to produce data useful to this study. The series contained 27 groups of "multiple" housing, 10 individual houses, 2 housing refurbishment projects, 1 sheltered housing scheme and 9 non-domestic schemes.

- Multiple Housing

In more than a third of the multiple housing schemes, passive solar gains contributed more than 30% to the space heating demand. Although the highest contributions, around 70%, were in southern half of Europe, Southern France, Spain and Italy, contributions of up to 40% were obtained in the north. Although many projects achieved less than 30% contribution, the analysis suggests that with good design and good operation 30% solar contribution is obtainable. The percentages of solar contribution are not directly related to latitude. The total amount of solar energy utilised per dwelling was above 3,300 kWh per year in a third of the projects and this applied to both large and small dwellings, in both northern and southern climates. Standardising for floor area between large and small houses shows that 30 kWh per square metre is achievable at all latitudes.

High solar percentages can only result from successful solar design and even where the heat load of a building has been reduced by careful use of insulation measures, high percentages were still achieved. However financial savings and environmental pollution reduction result from large absolute energy savings. Naturally there is a trend towards smaller savings resulting from solar gain as overall heat demand reduces. Nevertheless at all levels of heat demand (measured in $kWh/m^2$) there is a wide variation in useful solar gain, with a factor of 3 or more between worst and best (Diagram 4). The conclusion is that even with well insulated buildings, worthwhile passive solar contributions can be achieved.

All buildings benefit from solar gain to some extent even if not specifically designed to do so. On average the solar gain for the existing housing stock is estimated to vary from around 10% to 15.5%, for the northern climates. To take one example, the UK average solar energy utilised is 2500 kWh, a figure reflecting the low levels of insulation (and therefore high heating demand) of the existing housing. With better insulated new housing, and further insulation to existing housing, the amount of solar heating would decrease over time. However this can be changed if passive solar measures are incorporated. Thus the 'achievable' solar gain of 3300 kWh in a well insulated, passive solar house, represents an additional saving of around 1500 kWh, over that which would be achieved without any specific solar design.

- Individual Houses

The larger individual solar houses had solar contributions of 35% and above in 8 out of the 10 examples and large energy savings of above 8500 kWh were achieved in nearly half the projects. Even where the heating demand per unit area was small, high percentage and absolute solar contributions were achieved in the best examples. It is interesting that latitude has less influence on these figures than dwelling size and heat loss. The effect of the occupants in controlling their houses was frequently thought to have been one of the most important influences on the level of solar gains achieved.

- Housing Refurbishment

Adding passive solar features to an existing building or incorporating solar features during refurbishment, has great potential for the wider use of solar energy, due both to the large numbers of existing houses and the high heating demand of the older housing stock. The two examples included, Lievre d'Or in France and Baggesensgade in Denmark, use increased areas of south facing glazing, Trombe walls and sunspaces. Solar contributions of 20% and 27% were achieved and Baggesensgade recorded the highest overall solar contribution of all the projects, nearly 22,000 kWh per year per flat.

- Non-domestic Buildings

It is impossible to assign general figures to the solar energy usable in non-domestic buildings from those projects in Project Monitor, due to the wide variety of designs and uses. In Spain at Polysportive Esterri sports hall, passive solar energy supplied 94% of the heating load and at Los Molinos college, 80% (the remainder of the heating load being supplied by internal gains). In more northern latitudes, the JEL building in the UK achieved 29% solar contribution.

Large and valuable solar contributions are clearly possible. For example schools are well suited to passive solar design in at least two respects, they are occupied primarily in daytime when solar gains are available directly, and they are not occupied in the hottest summer months, so that overheating is less of a problem. However the passive solar design of non-domestic buildings is likely to be tailored more specifically to the building and its uses, compared to housing where similar solutions are satisfactory across the range of designs.

2.3.2 **Building 2000.** Draft brochures produced as part of the CEC "Building 2000" project were studied to investigate cooling loads and the contribution of passive solar design to reducing or eliminating auxiliary cooling demand. Building 2000 is a series of 36 design studies of non-domestic buildings carried out with the help of European experts, drawing on lessons learnt and techniques developed through the CEC's research and development programme on solar energy applications to buildings.

Nine projects referred to cooling loads and these are summarised below:-

| | | |
|---|---|---|
| 1. | Portugal (north) Business Innovation Centre | Central zone only cooled 15 kWh/$m^2$. Remainder naturally cooled. |
| 2. | Spain (Barcelona) Hotel/Restaurant | No auxiliary cooling needed. |
| 3. | France (mid north west) Business Development Area | Normal cooling load 60 kWh/$m^2$. As designed no auxiliary cooling needed. |
| 4. | Portugal Municipal Offices and Conference Centre | No auxiliary cooling needed. |
| 5. | Greece (north) School of Medicine | Normal cooling load 60 kWh/$m^2$. As designed no auxiliary cooling needed. |
| 6. | Greece (Crete) Hotel | Cooling load 3 kWh/$m^2$. |
| 7. | Greece (Crete) Holiday Complex | Normal cooling load 76 kWh/$m^2$. As designed (with shading 48 kWh/$m^2$. |
| 8. | Spain (Madrid) Educational Centre | Normal cooling load 60 kWh/$m^2$. As designed 0.5 kWh/$m^2$. |
| 9. | Greece (Paros) Holiday Complex | Normal cooling load 17 kWh/$m^2$. As designed no auxiliary cooling needed. |

It was concluded that these projects indicated that most buildings could be designed to avoid the need for auxiliary cooling.

In terms of typical annual cooling loads (per $m^2$) with traditional designs it is not possible to deduce an average value. The range quoted is between 76 kWh/m² and 17 kWh/m².

2.3.3 **Portuguese experience.** A consulting engineer in Portugal supplied some information for cooling in non-domestic buildings in a central Portuguese location (39° north). Total demand for cooling, including fan power, was estimated at 55 kWh/m². This could be reduced to 28 kWh/m² with the use of low emissivity double glazing and good thermal insulation in a newly designed building.

It was concluded that the cooling load alone (excluding fan power) would be approximately 45 kWh/m² and that a sophisticated passive solar design could reduce the cooling requirement to almost zero.

2.3.4 **U.K. Experience.** Research is in progress for ETSU in the UK in assessing the total energy use of a number of recent office blocks broken down into uses. Preliminary results indicate a maximum of 35 kWh/m² energy use for refrigeration in connection with air-conditioning (fan power is included as a separate item).

G. Kasabov in a publication for the RIBA in 1979 "Buildings The Key to Energy Conservation" gives cooling energy used in four low energy non-domestic buildings. These vary from 5 kWh/m² to 35 kWh/m².

The Building Services Research and Information Association (BSRIA) quotes (1989) a survey of office accommodation available in London, showing that 60% of the floor area had air-conditioning.

From this information the amount of energy used for auxiliary cooling in the U.K. has been estimated.

## 2.4 Expert assistance

The following experts provided information and assistance:-

**Overall**

| | |
|---|---|
| Rafael Serra | Universitat Politecnica de Catalunya. Spain. |
| Alex Lohr | Buro fur Energiegerechtes Bauen. W. Germany. |
| Owen Lewis | University College, Dublin (UCD). Ireland. |
| Nick Baker | The Martin Centre, Cambridge. UK. |

**Country specific**

| | |
|---|---|
| Belgium | André de Herde, Université Catholique de Louvain. |
| Denmark | Henrik Lewaetz, Danish Energy Agency. |
| France | Eric Durand, Agence Français pour la Maitrise de l'Energie. (AFME). |
| W. Germany | Dr. Kuebler, Bundesministerium fur Wirtschafte. |
| Greece | Mat Santamouris, Protechna Ltd. |
| Ireland | Owen Lewis, John Goulding, UCD. |
| Italy | Gianni de Giorgio. Progettazione & Ricerca. |
| Luxembourg | Romain Becker, Ministere de L'energie. |
| Netherlands | Woon Energy. |
| Portugal | Prof. Jose Abel Andrade, Universidade Do Porto. |
| Spain | Maria del Rosario Heras, CIEMAT. |
| UK | The ECD Partnership. |

Information was requested from the country experts by means of a questionnaire covering a whole range of matters. Respondents were requested to indicate the source of information where appropriate. Where information was not available, the experts were requested to make estimates since it was felt that their estimates were likely to be more accurate than those made by others.

## 2.5 Conclusions on information

Exhaustive library searches particularly at South Bank Polytechnic Information services and Queen Mary College Library (European Documentation Centre) demonstrated that while basic data for energy use in buildings are available across all CEC countries, other more detailed information for CEC countries is not available from central sources. Data and some future predictions for the UK were obtained from a wide range of published and unpublished sources and organisations such as the Building Research Establishment, so that a reasonable picture of energy use in buildings in the UK was constructed for the present and for the future.

In many other European countries it seems likely that similar information is not available, or that its collection would be outside the timescale of this study.

Clearly much more work has gone into the collection and publishing of data concerning the domestic sector compared to the non-domestic sector. Information about the non-domestic sector has proved much harder to find and fewer projections have been made for the future. Whilst research on energy use in some individual categories of buildings, such as schools, is available, the wide range of building types and uses makes generalisations of non-domestic energy use very difficult. Before this study very little effort seems to have been made and very little published, in this area.

## 3 FORECASTING THE FUTURE OF PASSIVE SOLAR ENERGY

### 3.1 Review of likely developments in systems, components and materials.

3.1.1 **Heating.** Considerable experience is available in passive solar heating in houses and much of the basic systems and components are well developed and reliable.

These include:
- direct gain
- use of thermal mass
- use of sunspaces
- thermal movements
- air heating panels and Trombe walls

Small performance improvements are possible in such areas as the transfer of warm air from sunspaces and in the use of air heating panels and Trombe walls. It is not felt that these improvements will significantly improve on the overall solar performance figures adopted in the study within a 20 year period.

One product is likely to make a significant effect on solar energy usage for heating - transparent insulation. There are several products and systems under development including honeycomb systems and "aero gels" and a whole range of applications can be foreseen. These include increased "glazed " areas where direct views are not required (or substitution of transparent insulation for normal glazing), use on air and water heating panels and cladding of walls of new and existing buildings. Take up of the theoretical potential will depend greatly on material and construction costs, dealing adequately with over heating and aesthetic considerations. A separate estimate has been made within the spreadsheet calculations of the technical potential resulting from the use of transparent insulation in housing.

Some passive solar heating systems or elements are currently not thought to be widely applicable nor cost effective enough to significantly improve overall solar performance figures. Roof space collection systems are usable and can contribute useful solar gains in both newbuild and refurbished housing but it is unlikely to become widespread due to high capital costs, the need to use fan power and potential problems with dust distribution. Thermal storage, using rock, brick or water stores have been used for diurnal storage of solar gains but performance is poor and it is unlikely that they will become cost effective within the next 20 years. Storage using phase change materials is still under development and similarly no significant contribution is expected over the period under consideration.

There are other passive solar systems or elements which have been developed and used successfully in particular instances, such as multi-layer windows, reflective panels and special air distribution systems, but their effect over the next 20 years on the total solar contribution is not likely to be significant.

There had been less development of systems and less recorded experience for space heating in non-domestic buildings. Figures adopted in this study for passive solar contributions to non-domestic heating are based on fewer examples and realisation of the potential solar contributions depend more on incorporation of systems and techniques than on development of new products etc.

Most of what has been said applies to both new buildings and refurbishment, except that once again there is much less experience available in refurbishment.

3.1.2 **Cooling.** Passive solar cooling techniques for housing are mostly applicable in southern latitudes, where they have been used for many years. Changing construction methods and the availability of auxiliary cooling have led away from passive cooling methods but the methods and components are well known and developed. No significant developments in systems, materials or components are envisaged within the next 20 years.

The picture is more complicated in the non-domestic sector. In southern latitudes passive techniques have always been in use but the effect of the availability of auxiliary cooling, new construction systems and new, intensive uses of buildings, has been very significant. Shading systems and the use of thermal mass to modify temperatures need no development but more complex ventilation and passive cooling methods, such as solar chimneys and use of cool air, while common in the past, need to be adapted and developed further in modern buildings. In this study it has been assumed that these developments will take place over the next 10 years and thus their use has been included. In non-domestic buildings in northern European latitudes there has been less need for cooling and less use in the past. However products and techniques are available and the experience of southern latitudes can be used. The more complicated ventilation techniques are not generally necessary for the smaller cooling loads and thus it has been assumed that adequate components and systems are currently available and that there will be little further development.

The main area where development is required is in developing assessment methods for annual cooling loads and the contribution of passive cooling techniques and components. It has been assumed that this will take place over the next 10 years.

3.1.3 **Lighting.** Passive contributions to reduce auxiliary lighting have only been considered for non-domestic buildings. There are two distinct areas of development, controls and increasing daylight penetration into buildings. Photo-electric controls that switch off unnecessary auxiliary lights when not required are well developed and experience is widely available. Increasing the penetration of daylight into buildings is a developing area and systems, products and materials are currently improving, including light shelves, reflectors and diffusors, narrow building widths, atria, and roof lights. The CEC competition "Working in the City" (1989) has developed assessment techniques and guidelines, stimulated interest and given experience on design for daylighting in non-domestic buildings throughout Europe. Considerable development is still required to establish daylighting widely in new building design and in refurbishment. The study has assumed that this development will take place over the next 20 years. Thus it has been assumed that lighting savings in this study come principally from photo-electric control systems with a smaller contribution from daylighting design.

3.2 Existing and projected costs and benefits

3.2.1 The extent to which passive design is adopted depends to a large extent on the costs and benefits attached. Much passive solar design need not have any additional costs attached (e.g. orientation, relocation of glazing, adequate ventilation, thermal mass and natural daylighting strategies), though more careful design may be required, at least at first, to optimise on new design principles. Other passive measures will always require additional funding, though if they become a regular feature, costs will be lower than at present (e.g sunspaces, indirect panels, shading devices, stack ventilation, humidification, some daylighting designs, light reflectors and photo electric controls). It should be remembered that some features have benefits other than in energy terms such as sunspaces, atria and fountains for humidification, so that the costs put towards energy use, should be offset for these other benefits.

The benefits resulting from passive solar design are threefold:-

- **financial**, in terms of reduced fuel consumption;
- **comfort**, in terms of higher temperatures in winter or lower in summer;
- **environmental**, in terms of pollution reduction, avoidance of "sick building syndrome", or improved "quality of life".

Traditionally cost and benefit analysis of passive solar design has been carried out using only the fuel savings and many of the basic passive measures have proved successful on this criterion alone. Clearly fuel price and future increase in fuel prices, have a major impact on this cost-effective balance, and though forecasting on fuel prices is impossible, it can be agreed that they will rise (in real terms) and thus passive measures will become more cost-effective in future. The economic balance will also be affected if environmental pollution costs are included, by a mechanism such as the "carbon tax". An attempt has been made by Hohmeyer in a study for the CEC, "The Social Costs of Energy Consumption", to start to quantify the costs of pollution in the production of electricity.

Improvements in comfort levels are mostly taken as benefits by householders where auxiliary heating or cooling are not available or felt to be too expensive to use. This is particularly common in the less developed countries and with the lower income groups. On the non-domestic side, improvements in comfort from a reduction in overheating are likely to be significant in southern latitudes, where auxiliary cooling is not common.

The contribution of passive solar design to environmental pollution reduction is clearly of great importance to the world as a whole. Traditionally this has only been recognised by some individuals and organisations but is likely to assume a greater importance in the future. As mentioned above environmental pollution is likely to be costed in the future and so enter the economic equation.

The non-energy benefits of passive design relate to the internal environment, and include an improved "quality of life" and may assist in the avoidance of "Sick Building Syndrome" (see section 1.7).

Building users, organisations and countries as a whole, will perceive the above benefits in different ways. In the home, fuel bill savings, increased comfort and quality of life will be appreciated, possibly together with helping to reduce atmospheric pollution. Organisations will appreciate fuel bill savings, improved comfort and quality of life, and avoidance of sick building syndrome in as much as they make employees happier and more productive. They may appreciate the reduction of environmental pollution though this may be from a marketing angle. At the national level, the benefits are in the reduced fuel imports bill, the reduction in environmental pollution and the improved efficiency of businesses through reduced fuel bills.

## 3.3 Non-technical obstacles to the adoption of passive solar design.

Five non-technical obstacles have been identified which are thought to be largely responsible for the low adoption of passive solar design at present.

Ignorance. There is certainly a lack of knowledge amongst designers of passive solar design and the benefits arising. Within the building industry the workforce lacks experience of passive buildings and traditional ways can be difficult to change. Clients, funding organisation and speculators, will generally have little knowledge of passive buildings.

Lack of demand. It is frequently claimed that there is a lack of demand for passive solar houses and other buildings i.e that users will not appreciate the design and will not be prepared to pay any additional capital costs nor operate the building to use the solar design to best advantage.

Traditionally house builders and non-domestic developers see their role as "satisfying the market"

Fear of problems or failures. Moving away from current practice and the use of new ideas techniques and products leads to fear that problems and possibly failures will occur. Few clients or designers will take these risks (as they see it) unless it can be demonstrated that adequate successful experience is available.

Non-availability of materials and products. Though materials and products to enhance passive solar performance may be developed, they may not be widely known to designers nor available to builders.

Non-availability of design and evaluation tools. To demonstrate the advantages of passive buildings, validated design tools are required. These need to be integrated into the design process and understood by designers. At present design tools are available in the area of heating and reasonable evaluations can be made. Fewer validated tools are available for lighting and cooling calculations and this is likely to be an obstacle to incorporating passive design in these areas.

## 3.4 Other factors affecting the adoption of passive design.

The future adoption of passive design in buildings is likely to be affected by several other factors which are under the control of governments.

Legislation. Introduction of passive solar design into building regulations as mandatory or optional for heating, lighting and cooling is possible, and has been used for example in France.

Grants or other incentives. Financial support for the use of passive designs could be given and justified on being in the national interest. Grants for other energy conserving measures are quite common.

Publicity and promotion. National publicity and information dissemination about the methods and benefits of passive solar design can be used with or without legislation or incentives. Numerous methods have been proposed and used.

Fuel pricing, carbon tax. Increasing fuel costs via taxation can be used as a mechanism to improve the financial payback of passive solar measures and thus stimulate interest in passive design.

Education. Ensuring that passive solar design principles are included in the education of architects and other designers, will in the longer term stimulate solar designs in practice. Post qualification, in-service training in solar design can also be used to stimulate interest.

## 4. METHODOLOGY

### 4.1 General

A computer spreadsheet calculation systems ("Framework") was used as the basis for the analysis and projections. The calculation sequence used is described in subsequent sections. For each of the twelve CEC countries it is broken down into three parts, domestic heating, domestic cooling, and all non-domestic energy use (heating, cooling and lighting).

The spread sheet system has several advantages mainly that it is "transparent" and thus can be examined by anyone, and that changes and revisions can be made at any stage and almost immediately incorporated into the final results.

### 4.2 Domestic heating

| ASPECT | CALCULATION | MAIN SOURCE |
|---|---|---|
| Year 1990 | | |
| 1 Present building stock | The total numbers of dwellings based on population and buildings stock per 1000. | Eurostat Review |
| 2 Typical dwelling energy analysis | Gross heating demand and how this is currently satisfied by internal gains, solar gains and auxiliary heating (taking efficiencies into account). Gives "unplanned solar-gain" and auxiliary heating load broken down by fuel type for whole dwelling stock. | Building Research Est. (UK)<br>Project Monitor |
| 3 Existing passive solar designed dwellings | Based on the number of new and refurbished "passive solar dwellings" known, average "planned solar contributions" and a factor to include all planned passive solar dwellings, gives total planned solar contribution. | Project Monitor |
| 4 Present summary of solar energy | Sums present solar gain (unplanned and planned). | |

Year 2000

| | | | |
|---|---|---|---|
| 5 | New dwellings - technical potential solar gain. | Based on estimated rate of new building, orientation, gross heat loss and estimated solar contributions (direct gain, indirect gain and sunspaces) gives total newbuild technical potential solar contribution. | BSRIA (UK) Project Monitor |
| 6 | Refurbishment | As above for refurbished dwellings | |
| 7 | Demolitions | Estimated rate of demolition of dwellings gives total number demolished. | BSRIA (UK) |
| 8 | 2000 summary of solar energy use. | Sums solar gain in year 2000. | |

Year 2010

| | | |
|---|---|---|
| 9 | | Calculated as year 2000. |

4.3 Domestic Cooling

Year 1990

| | | |
|---|---|---|
| 1 | Gross cooling demand | No cooling demand considered for countries in northern latitudes. For Portugal, Spain, Italy and Greece, 50% of dwellings stock was considered to have a cooling demand, and for France a 10% demand. Gross heating demand (per house) calculated for Greece (8000 kWh pa), other countries taken as 5000 kWh pa. |
| 2 | Dwellings using auxiliary cooling | Estimated percentages of dwelling stock that use auxiliary cooling, this is assumed to satisfy 100% cooling load. |
| 3 | Current contribution of passive solar cooling design | Assumed that in houses with a cooling load but without auxiliary cooling, passive design contributes 50% to the load (the remaining unsatisfied load results in overheating). |

Year 2000

| | | |
|---|---|---|
| 4 | Gross cooling demand | (Still no cooling in northern latitudes). Same proportion of new building and refurbishment will have a cooling demand as existing stock (i.e. 50% and 10% France). Cooling demand per dwelling kept constant. |
| 5 | Dwellings using auxiliary cooling | Assumed 20% of newbuild and 10% of refurbished dwellings (with a cooling demand) will use auxiliary cooling, but only 60% of this load will be supplied by the auxiliary cooling and 40% by passive solar design in newbuild (still 100% auxiliary cooling in refurbished dwellings). |
| 6 | Base case solar cooling contribution. | Sums 1990 non-auxiliary cooled dwelling contribution as above (3) with the 40% contribution as above (5). |
| 7 | Technical potential solar cooling contribution | In newbuild, taken as 85% of gross cooling demand and in refurbished dwellings, 70% (taken for all new and refurbished dwellings). |

Year 2010

| | | |
|---|---|---|
| 8 | Gross cooling demand | Calculated as year 2000. |
| 9 | Dwellings using auxiliary cooling | Assumed 30% of newbuild dwellings and 20% of refurbished dwellings (with a cooling demand) will use auxiliary cooling, with 60% supplied by the auxiliary cooling and 40% by passive solar design in newbuild (still 100% auxiliary cooling in refurbished dwellings). |
| 10 | Base case solar cooling contribution | Sums non-auxiliary cooled dwelling contribution above (6) with 40% contribution as above (9). |
| 11 | Technical potential solar cooling contribution | In newbuild taken as 95% gross cooling demand and in refurbishment 80% (taken for all new and refurbished dwellings between 2000 and 2010). |

## 4.4 Non-domestic Energy

Due to the availability of far less data than in the domestic sector in all countries, the calculation method was strongly influenced by available data (principally from Eurostats) and relied on interpretation of other information obtained in various countries but which could not be obtained on

a comprehensive basis. Basic data used for all countries were: total non-domestic energy used (1986); energy use growth forecasts and economic growth forecasts.
The approach is therefore very different from that used in the domestic sector.

Only the energy use within the non-domestic sector that can be influenced by passive solar design was considered. This is heating, lighting and auxiliary cooling. Within cooling only the refrigeration part has been considered despite the considerable energy used by fans for air movement in air-conditioned buildings and for mechanical ventilation. The reason for this stance is that whilst frequently both refrigeration and mechanical ventilation can be avoided by passive solar design, there are many situations where mechanical ventilation will be necessary (or anyway used) to avoid refrigeration, and thus the fan energy element of an air-conditioning system may not be eliminated and may in practice be increased.

## 4.5 Non-domestic existing forecast, base case, no increased use of passive solar design.

| SECTION | DATA/CALCULATION | SOURCE |
|---|---|---|
| 1 Total energy used in the non-domestic sector | The 1990 and 2000 figures are calculated from the 1986 data and the predicted growth in energy consumption. Total energy consumption in 2010 was kept at the 2000 level to reflect both energy efficiency measures plus growth in usage. | Eurostat Review |
| 2 Energy used for heating | Breakdowns of non-domestic energy by use were used to calculate heating energy for 1990, with figures for 2000 and 2010 calculated as above. Where no breakdown was available, estimates were made on the basis of similar countries. | BRE (UK) |
| 3 Energy used for lighting | As above to give (delivered) lighting energy consumption. No allowance was made here for photo-electric control usage as this was considered as use of passive solar daylighting (see definitions section 1.4). | BRE (UK) |

| | | | |
|---|---|---|---|
| 4 | Energy used for cooling | 1990 UK estimates made on the basis of a survey of the proportion of office space with auxiliary cooling, the area of office space, typical annual cooling energy used (from survey data) and an estimate of the other uses of auxiliary cooling (in stores, banks, restaurants, hotels, conference centres, etc). Estimates for 2000 and 2010 made on the basis of newbuild and major refurbishment rates (both 2% of 1990 floor areas) and proportions with auxiliary cooling. Cooling estimates were provided for two other countries, Italy and Portugal, and these three countries, together with typical cooling energy consumption were used to interpolate estimates for other countries taking into account latitude, level of development, economic growth rates, etc. | BSRIA (UK)<br>BRE (UK)<br>RIBA<br>Kasabov<br>CEC Buildings 2000 |
| 5 | Unplanned solar contributions to heating | Based on estimates of solar contributions as a percentage of gross heating loads (varying from 10-15%) derived factors were applied to the auxiliary heating loads to give unplanned solar contributions. | Project Monitor |
| 6 | Unplanned solar contributions to daylighting | No unplanned daylighting contributions were included (see definitions section 1.4). | |

| | | | |
|---|---|---|---|
| 7 | Unplanned solar contributions to cooling | No contributions were assumed for the countries in northern latitudes as there is thought to be little or no design in buildings to reduce cooling loads. In the southern latitude countries (Portugal, Spain, Italy and Greece) assumed that 50% of buildings without auxiliary cooling have a cooling load, of which 50% is satisfied by passive solar design (remainder results in overheating). In France 10% of buildings have a cooling load. It is accepted that these figures are crude estimates only. They are made to give a reasonable base for measuring change. | |

4.6 Non-domestic passive solar forecast - technical potential

| | | | |
|---|---|---|---|
| 8 | Technical potential solar contribution to heating | Made up of three parts:<br><br>- the unplanned contribution from the existing stock, which reduces over time due to demolitions and refurbishment (3% pa stock reduction);<br><br>- the technical potential from newbuild (2% pa of 1990 stock) average 30% solar contribution to gross heating load (but this is a reduced load compared with 1990 load), estimated equivalent to 20% of 1990 heating load. Ireland and Denmark assumed lower values (18% and 15% respectively), Greece and Portugal assumed higher values (30%);<br><br>- the technical potential from refurbishment (2% pa of 1990 stock), assumed at 17% of 1990 heating load (i.e. between existing and newbuild). Ireland and Denmark assumed lower rates (15%), Greece and Portugal assumed higher (20%). | Project Monitor |

| | | | |
|---|---|---|---|
| 9 | Technical potential solar contribution to lighting | No contributions to the (unchanged) existing stock was taken. 50% contribution to both newbuild and refurbishment assumed from design (to increase daylighting) and controls (to reduce unnecessary auxiliary lighting). | BRE |
| 10 | Technical potential solar contribution to cooling | Made up of two parts:<br>- the unplanned solar contribution as in 7 above;<br>- for newbuild, assumed technical potential is to eliminate all cooling load and for refurbishment to reduce the cooling load by 50%. | Building 2000 |
| 11 | Total technical potential solar contribution | Broken down into delivered electric energy only (lighting and cooling) and heating energy saved. Also total primary energy equivalent saved due to technical potential solar contributions. | |

4.7 Pollution

| | | | |
|---|---|---|---|
| 1 | Pollution 1990 | Based on fuel split, including fuel used to generate electricity, and pollutants arising from each fuel, gives total weights of pollutants produced in 1990. Includes the effect of forthcoming legislation on powerstation emissions. | Eurisol (UK)<br><br>UK Energy Statistics<br>SKEA - Electricity for Life |
| 2 | Pollution savings 2000 | Gives savings in pollutants resulting from reduced fossil (and nuclear) fuel consumption resulting from use of technical potential solar contributions. Pollution reduction for cooling contribution taken only as substitution of auxiliary cooling by passive solar design (not total passive solar design contribution). | |
| 3 | Pollution savings 2010 | Calculated as year 2000. | |

## 5. RESULTS

### 5.1 Energy - Europe wide

Passive solar design at present (1990) supplies the European Community with the equivalent of 96 mtoe (million tonnes of oil equivalent) (1150 TWh) of primary energy per annum. This is 9% of the total fuel used in the European Community (figure 1), larger that the amount of coal directly burnt for heating (6%). Compared with the use of fuels in the housing and non-domestic building sectors (i.e. excluding industrial process heat and transportation energy use) solar energy supplies 13% of the total (figure 2). The majority of the solar energy (78%) is used directly to heat buildings with the remaining 22% arising from passive cooling design in countries in southern latitudes. Thus it is clear that solar energy is already a very important fuel in Europe.

Over the next 20 years, the amount of solar energy used will change depending on a number of factors. If no specific action is taken to promote the use of passive solar design, a small rise of 8% above the 1990 levels is predicted by the year 2000 and a rise of 6% by the year 2010. These changes result mostly from an increase in the number of buildings, but this is modified by increased levels of fabric insulation. This effectively reduces the solar utilisation, as the heating season and therefore the period when solar gain is useful is shortened when higher levels of insulation are used.

However if action is taken to increase solar measures, the potential exists to greatly increase the use of solar energy in buildings in the future. By the year 2000 the overall amount could be increased by 27%, an increase of 26 mtoe (313 TWh), and by 2010 the amount could increase by 54% of the current level of utilisation, or 52 mtoe (620 TWh) per annum. Figure 3 shows the increase in solar contribution in the 5 categories, domestic heating, non-domestic heating, domestic cooling, non-domestic cooling and non-domestic lighting, for the whole of the European Community.

These potentials are the maximum technically possible and include allowances for buildings which cannot be oriented optimally etc. In practice the potential will be reduced by such factors as low take-up and poor design and operation.

Whilst the solar contributions to heating are the largest, in absolute terms, the largest <u>increase</u> is forecast in the use of daylighting in non-domestic buildings, an increase of nearly 18 mtoe(220 TWh). The forecast increase in solar heating in non-domestic buildings is also large at over 16 mtoe (190 TWh) per annum and reflects the relatively high rates of new construction and refurbishment in this sector compared to housing.

The use of passive solar design to reduce cooling loads gives smaller total savings than that resulting from solar design to reduced heating loads, but this is due to the small need for cooling within Europe as a whole. Within individual countries the picture is very different, (section 5.2). For example while Denmark, Ireland and the Netherlands have negligible cooling demand and therefore negligible passive solar contribution to cooling, Greece, Spain, Italy and Portugal achieve 50% of their technical potential solar contribution through passive cooling design.

Overall an increase in domestic cooling solar contribution of 9 mtoe (110 TWh) is possible by 2010. The lower contribution for the non-domestic sector compared to the domestic sector, is due to the larger amount of housing in southern latitudes compared to the amount of non-domestic buildings.

The small potential increase in the use of solar energy for heating houses, 2 mtoe (25 TWh) or a 4% increase over 1990 usage, is a result of assumed increased levels of fabric insulation (resulting in reduced absolute utilisation of solar gains), combined with the very small newbuild and refurbishment rates for housing. Whilst greatly increased solar contributions are possible in new houses and during refurbishment, it is the unchanged existing stock which forms by far the largest part of the housing stock (for instance 80% by the year 2010 for the UK). The low newbuild and refurbishment rate means that the large increase in solar contribution from individual houses takes a very long time to affect the energy consumption of the section as a whole. This situation is exacerbated by the assumption that insulation of the <u>existing</u> housing stock will take place over the next 20 years reducing the utilisation of solar heating by 10%.

One possible solution which could lead to a significant increase in solar utilisation in this section is the development of new technologies which could be retrofitted to the existing housing stock on a large scale. Section 6.2 discusses one idea currently under development - transparent insulation.

It is important to note that increased solar contributions from individual uses, when added together produce the significant overall increase of 54%.

## 5.2 Energy - Individual Countries

Figure 4 shows the solar-energy usage in the various countries, and figure 5 the country populations for comparison. Figures 8-19 show the solar-energy usage in each country together with the pollution savings.

5.2.1 **Belgium.** With a population of 10 million, Belgium's solar usage is currently around 4% of the European total solar usage. In the year 2010 solar heating accounts for 85% of the technical potential solar, with non-domestic cooling and lighting making up the rest. A 32% overall increase is solar usage is possible by 2010.

5.2.2 **Denmark.** With 5 million population, Denmark contributes 1% to the total European solar usage. The requirement for cooling in Denmark is negligible but a doubling in the use of solar heating in the non-domestic sector is thought (by Danish sources) to be possible by the year 2010, contributing to an overall increase in solar usage of 79%. This high figure is due to the above average projection for solar heating in the non-domestic sector.

5.2.3 **France.** With a population of 55 million, France contributes nearly 16% to the total solar usage. Solar heating makes by far the largest contribution to the technical potential solar contribution, 72%, cooling supplies 16% and lighting 12%. An overall increase in solar usage of 42% is possible by 2010.

5.2.4 **West Germany.** With the largest population, 61 million, and the largest energy usage, Germany's solar usage is by far the highest in Europe, above 25% of the total. Again solar heating dominates the technical potential solar contribution in 2010, 85%, with non-domestic cooling contributing only 2.5% (due to the lack of cooling demand). Nevertheless, due to the large size of the German energy use, this cooling contributing is nearly 8% of the total non-domestic cooling. An overall increase in solar contribution of 38% is possible in Germany by 2010.

5.2.5 **Greece.** Population 5 million, with a solar contribution of less than 2.5% of the European total in 1990. Solar design <u>cooling</u> contributions dominate here, 55% at present. Overall, an increase in solar usage of 87% is thought possible by the year 2010. The large increase is due to the potential for passive design to reduce cooling loads.

5.2.6 **Ireland.** With the second smallest population in Europe, 3.5 million, Ireland has a solar contribution of less than 1% of the total. No cooling loads have been included and the non-domestic sector provides the majority of the potential increase in solar usage, nearly 70% according to local experts. By 2010, overall solar usage could be increased by nearly 70%.

5.2.7 **Italy.** With one of the highest populations in the EC, 57 million, Italy's solar contribution is second highest at 18% of the European total. Solar design cooling contributions could provide more than 53% of the total by 2010, an increase in usage of 64% over the 1990 figure. An overall increase in solar contribution of 71% is possible by 2010.

5.2.8 **Luxembourg.** The smallest country with a population of 370,000, naturally only contributes a small part 0.3% of the total solar usage. Non-domestic heating provides by far the largest solar contribution, 58% by 2010. A 74% overall increase in solar contribution is possible by 2010 due to the large size of the non-domestic sector compared to the housing sector.

5.2.9 **Netherlands.** With a population of 14.5 million, the Netherlands contribute 3.5% to solar usage. Cooling energy use is very small, non-domestic heating contributes nearly half the solar energy use by 2010. An overall increase in solar usage by 2010 of 65% is possible.

5.2.10 **Portugal.**With a population of 10 million, Portugal currently contributes under 3% to the total solar usage. Domestic cooling is potentially the largest single usage of solar design, 45% of the total by 2010 is possible. Overall, solar usage could increase by 76% in 2010.

5.2.11 **Spain.** Population 38.5 million, Spain contributes 12.5% of the total solar usage in 1990. Cooling contributes nearly 50% of the energy savings by 2010 with non-domestic lighting contributing 11.5%. A 73% increase in solar usage from 1990 to 2010 is possible.

5.2.12 **United Kingdom.** 56.5 million population contributes 13% of total solar usage in 1990. Cooling energy is small relative to heating and this contributes to the low possible increase in overall solar usage by 2010 of 45%.

5.2.13 Whilst the largest absolute solar usage figures come from the countries with the largest populations, the greatest relative increases in solar usage are likely to come from countries in southern latitudes, where solar contributions to heating, lighting and cooling can be increased. This demonstrates that a policy to increase usage of solar design, to reduce consumption of fossil fuel, should not concentrate on any one sector, nor countries in northern or southern latitudes only, but should spread across all sectors, throughout Europe.

5.3 Pollution reduction

5.3.1 **Europe.** Figures 6 and 7 show the pollution savings arising from the use of passive solar design throughout Europe. At present passive solar design is saving 229 million tonnes of $CO_2$ per annum a reduction of nearly 17% in the $CO_2$ which would be produced in the absence of solar contribution. 1.3 million tonnes of $SO_2$ and 0.56 million tonnes of $NO_x$ (Oxides of Nitrogen) are also being saved by solar gain.

If the technical potential solar contributions determined in this study were achieved, the amount of $CO_2$ saved per annum by the year 2010 would increase to 332 million tonnes, an increase of 45%. The annual reduction in $CO_2$ production below 1990 levels due to solar design could be 43 million tonnes by the year 2000 and 103 million tonnes by the year 2010.

The potential savings in $SO_2$ and $NO_x$ decrease in the future due to implementation of legislation to reduce emissions of these gases from power stations. These will not be discussed further in this report since the effect of the legislation greatly outweighs the solar effect. If targets for reduction in emissions are met, the problems associated with emissions of $SO_2$ and NOx (principally "acid rain") will be thus greatly reduced.

The possible reduction in nuclear waste obviously reflects the use of nuclear power within a country, together with overall fuel use reduction. At present (1990), solar energy reduces nuclear waste by more than 18% from what would be produced without the solar contribution. Seven countries use nuclear power but France dominates and contributes around 70% of the 1990 savings and 57% of the 2010 potential savings. Overall, solar design could increase savings in nuclear waste by around 70% by 2101.

5.3.2 **Country analysis.** Figures 8-19 show the pollution savings for each country. Three countries, Germany Italy and the UK, currently contribute two thirds of the savings in $CO_2$ due to solar design. France contributes only 9% to the savings due to its large nuclear energy sector. The picture is broadly unchanged by 2010, if the technical potential is achieved.

The increase in savings in $CO_2$ pollution possible by 2010, varies greatly between countries, from 19% in Belgium to 104% in Greece. The variations roughly reflect the changes in solar contributions, with the countries in southern latitudes thus showing the higher percentage savings. The use of non-fossil fuels (mostly nuclear generated electricity) also affect the possible $CO_2$ reduction.

# 6 CONCLUSIONS

## 6.1 Achievement of the "technical potential"

The energy and pollution savings discussed in the previous section for 2010 are derived from the technical potential solar contributions as described in section 1.5. Sections 3.3 and 3.4 discuss the factors which will affect the achievement of this technical potential.

Assessment of the level of achievement that are likely or possible is virtually impossible. Many of the factors are under the control (at least partially) of governments and thus a high level of achievement is theoretically possible if the political will exists. If for example the reduction of the "greenhouse effect" became a policy priority within the EEC, legislation by itself could be used to achieve virtually all the technical potential solar contribution and consequent reduction of $CO_2$ production. On the other hand without any legislation or incentives to increase solar energy usage, even assuming the promotion of passive solar design within education and generally outside, achievement of more than 25% of the technical potential seems most unlikely.

If fuel prices rise dramatically as has happened in the past and as is possible within the next 10 years, uptake of passive solar design, together with other energy saving techniques, could be high without legislation or other incentives. Unfortunately since large individual solar contributions can only be achieved in new or converted buildings using solar design principles, the low newbuild and refurbishment rates generally, mean that the overall savings are only built up over a number of years. If solar design is not widely adopted before the year 2000, only a small part of the technical potential will be achieved by 2010.

## 6.2 New Technology

Development of new technologies which are applicable to existing buildings are a means of further increasing solar usage. The work on transparent insulation is a step in the right direction. One calculation carried out as part of this study indicates that replacement of half of all glazing in all housing by transparent insulation could alone save 28 mtoe (342 TWh) of heating energy per year. This is equivalent to increasing by 50% the total solar energy used for heating houses in the 2010 technical potential scenario. Clearly this is not an achievable target but indicates the potential of applying passive solar measures to the existing housing stock.

## 6.3 Where effort should be put

6.3.1 The total technical potential solar energy capable of being utilised in 2010 is made up of the five sectors. Taken individually these contributions are not all large, but together the potential savings are significant. Effort should therefore be put into each sector to maximise achievement of this potential.

6.3.2 **Domestic heating.** The potential increase in use of solar energy is limited by the unchanged housing stock, which under normal conditions receives no major attention for periods of up to 50 years. Thus, whilst stimulation of passive solar design for new and refurbished houses is necessary, development of new technologies such as transparent insulation, and methods of implementation to apply to the existing housing stock is required if a major increase in solar contribution is to be achieved in this sector.

6.3.3 **Non-domestic heating.** Greater potential for increasing solar utilisation is available here due to higher newbuild and refurbishment rates. Education of architects and other designers in solar design should be effective as should the demonstration of cost effective solar measures. Development and use for transparent insulation could have an even greater effect in this sector than in the housing sector.

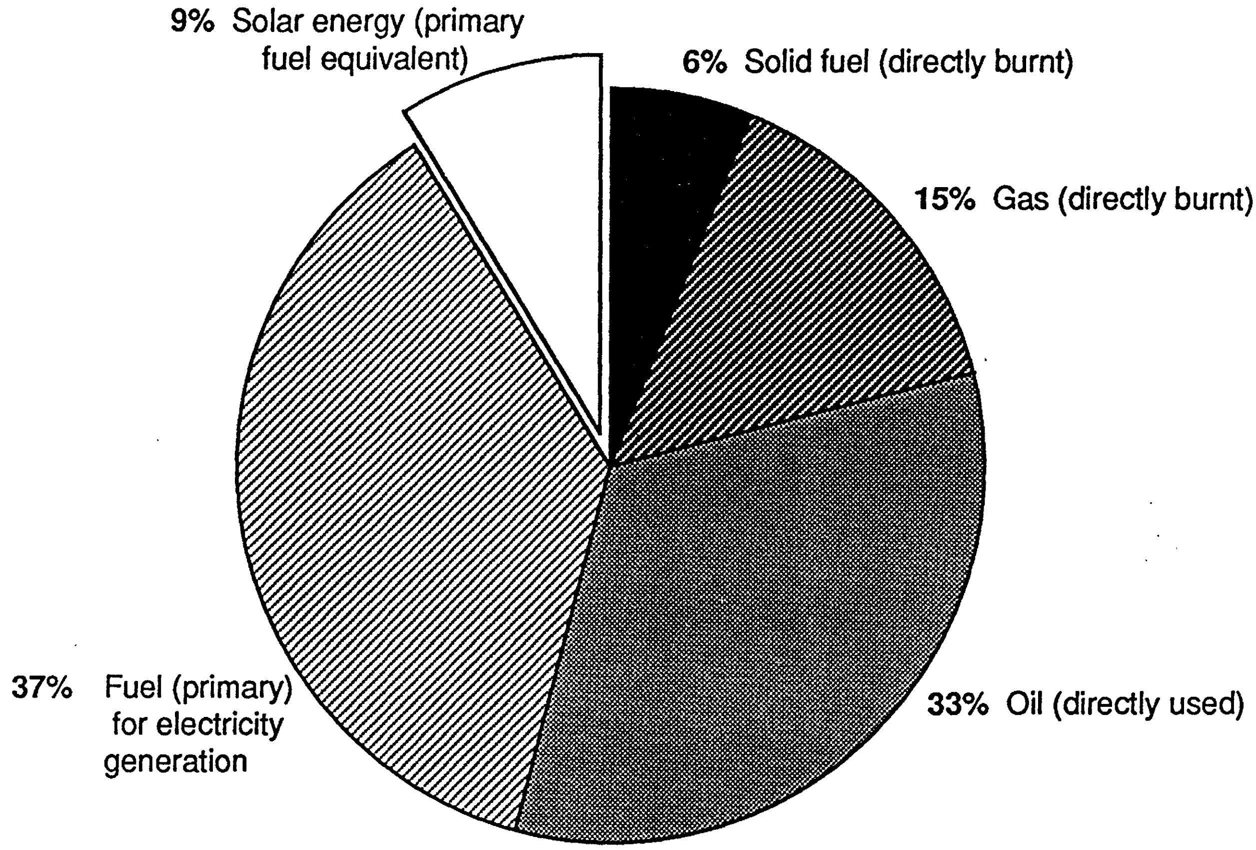
6.3.4 **Domestic Cooling.** Promotion and education for solar design to avoid overheating and the consequent demand for auxiliary cooling is very important. The techniques and products are readily available in countries which have a domestic cooling load but validated and user friendly design tools are needed to design and to demonstrate the effectiveness of solar design. There is a need to integrate solar design for heating and cooling in southern latitudes so that neither is compromised by the other.

6.3.5 **Non-domestic cooling.** Large benefits are available in this sector since there is a general move towards an increase in the use of air conditioning in many non-domestic buildings. Since naturally ventilated and cooled buildings have many advantages over air conditioned buildings other than reduced energy consumption (see section 1.7), promotion of these concepts is important. Solar design principles and tools are available though these are not generally applied. Legislation is used in Denmark to avoid air conditioning in new offices.

6.3.6 **Non-domestic lighting.** Large savings are possible in this sector in all countries from both lighting controls and daylighting design. Education and promotion of both the principles and design tools is needed. A large part of the technical potential should be achievable in this sector.

**Total fuel use in the European Community 1990**
**(includes transport and industrial process use)**

FIGURE 1




**Fuel use in housing and non-domestic buildings in the European Community 1990**
**(excludes transport and industrial process use)**

FIGURE 2

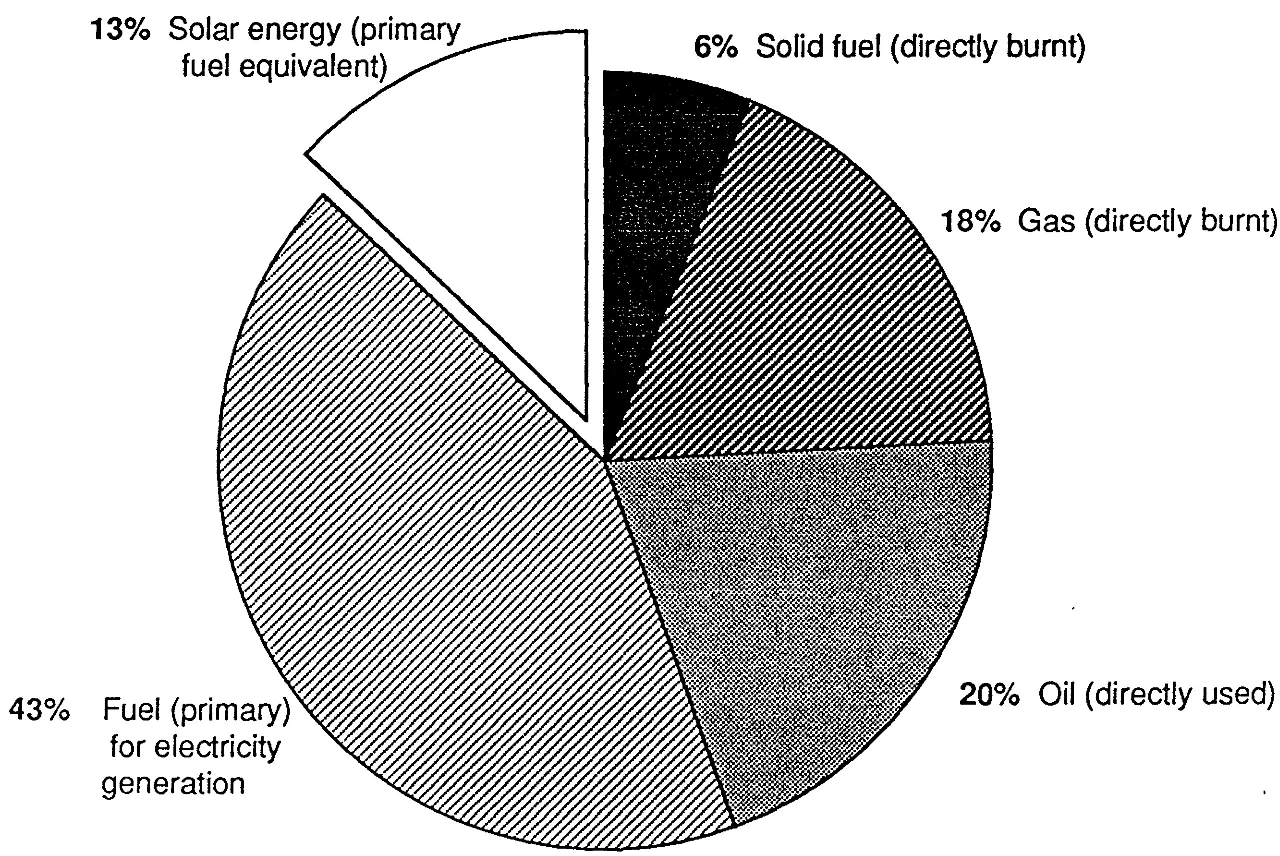
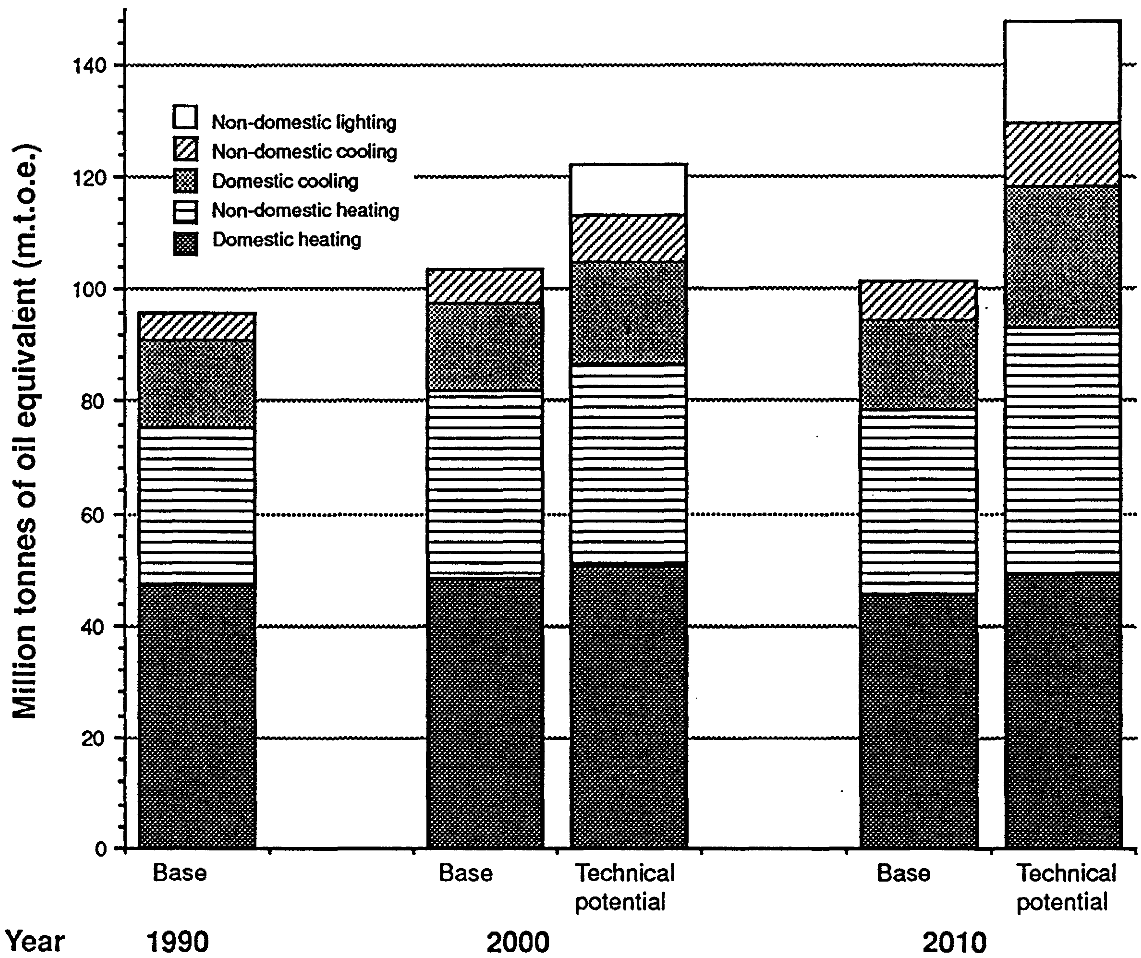


FIGURE 3

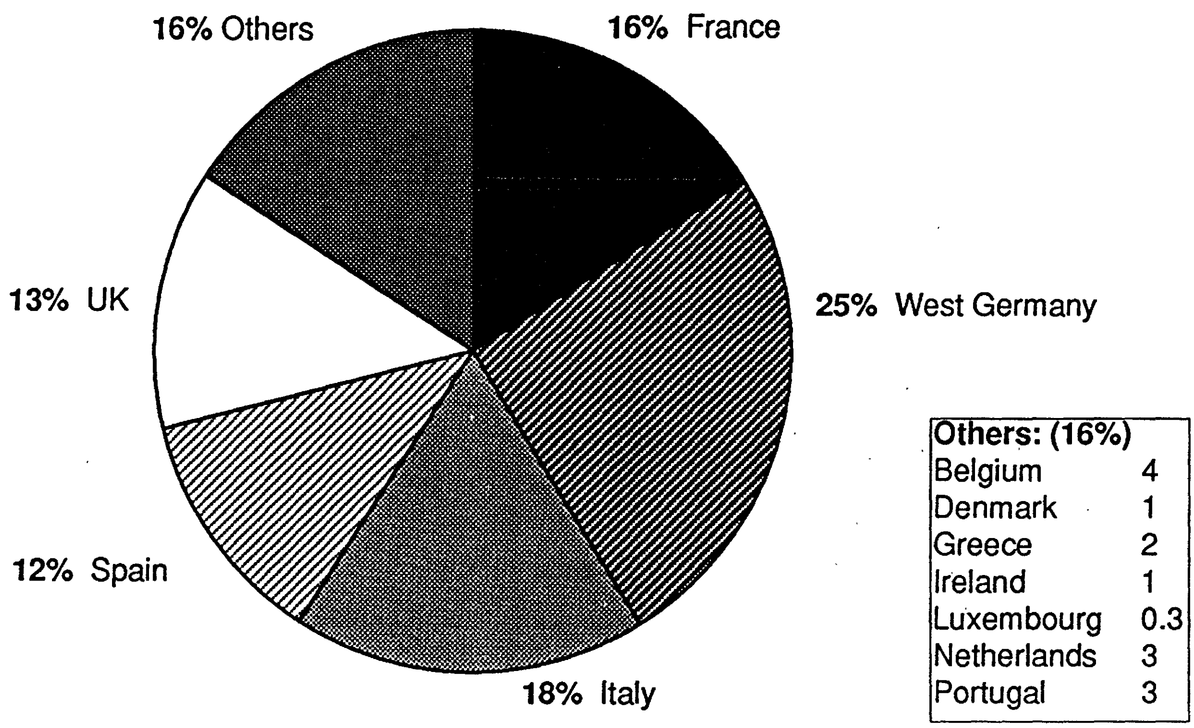
# All European Member States

## Solar energy contributions




Base case – no action to increase passive solar usage.
Technical potential – maximum achievable passive solar usage.

**Solar energy usage in the European Community 1990** FIGURE 4




**Population in the European Community 1990** FIGURE 5

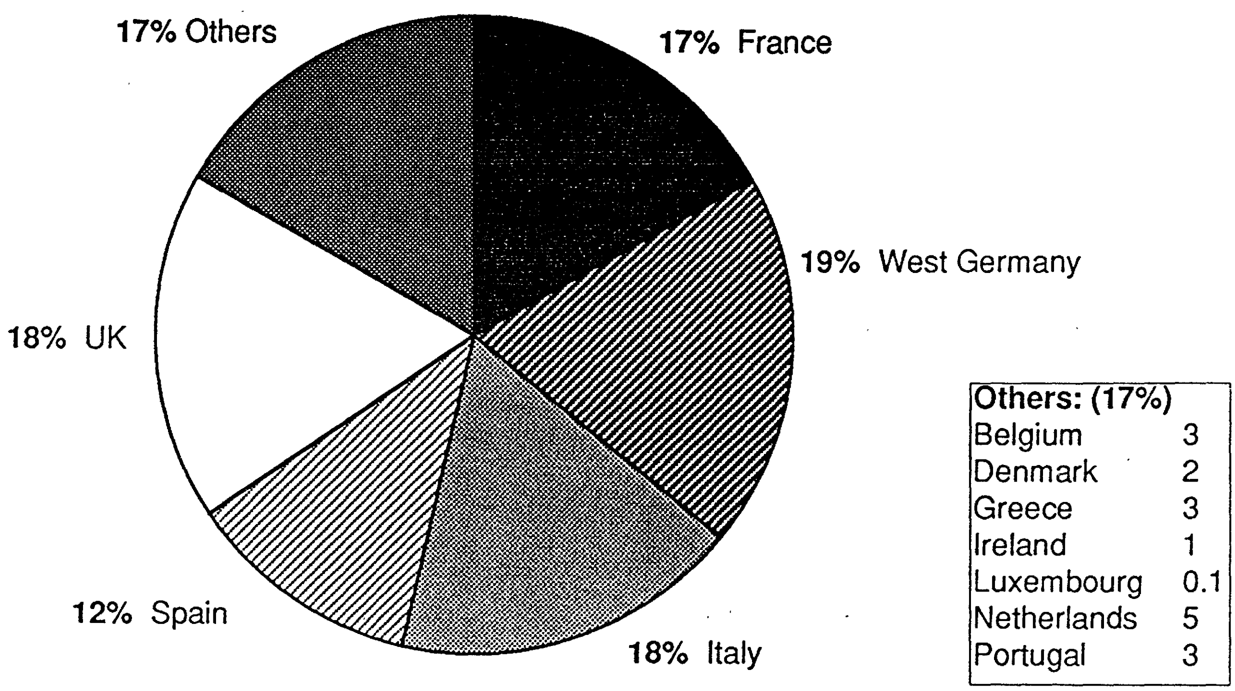
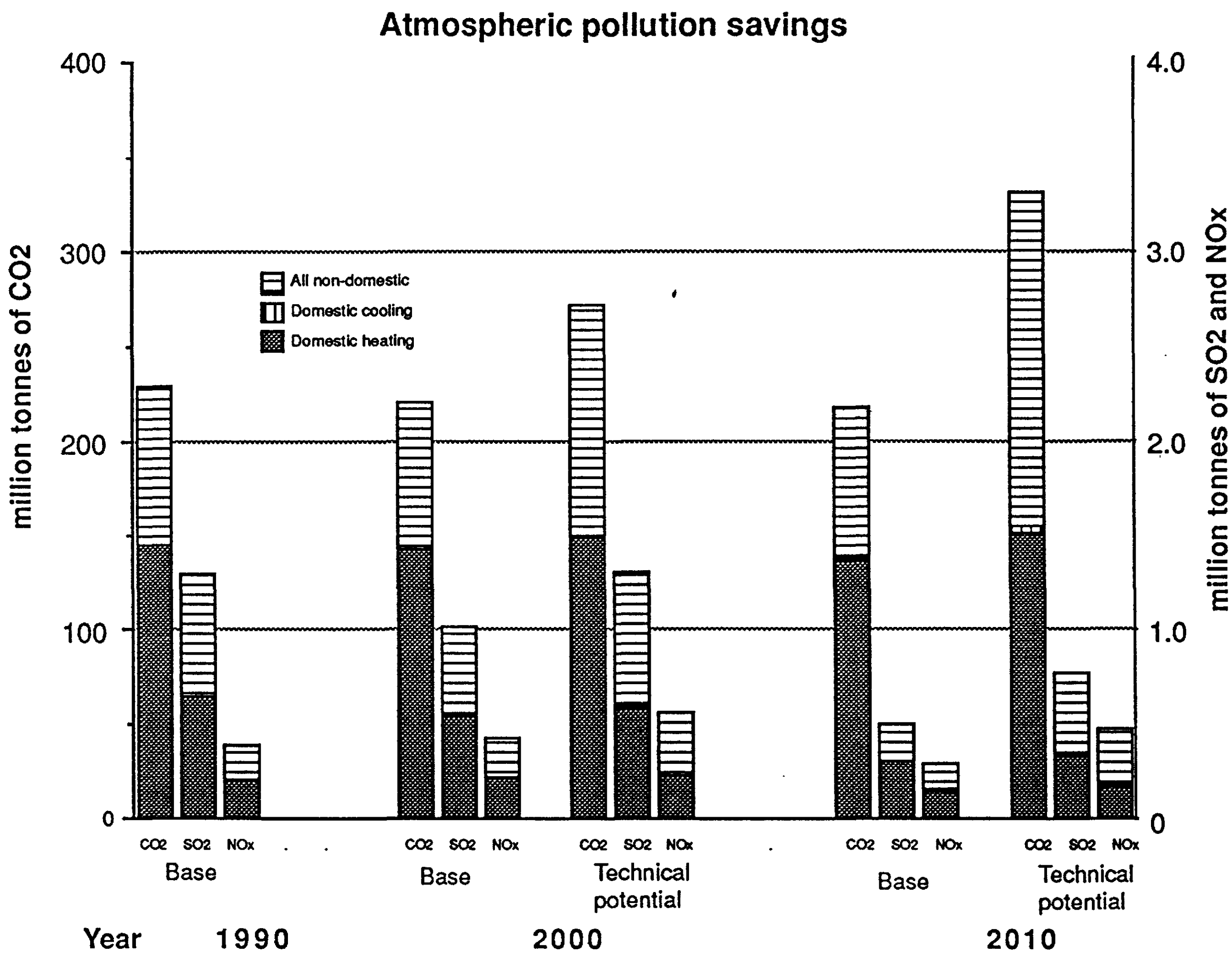


FIGURE 6

# All European Member States




Notes

1. Base case = no action taken to increase solar usage.
   Technical potential = all potential solar usage exploited.

2. $SO_2$ and $NO_X$ reductions are largely due to implementation of legislation to reduce power station emissions of these gases.

FIGURE 7

# All European Member States

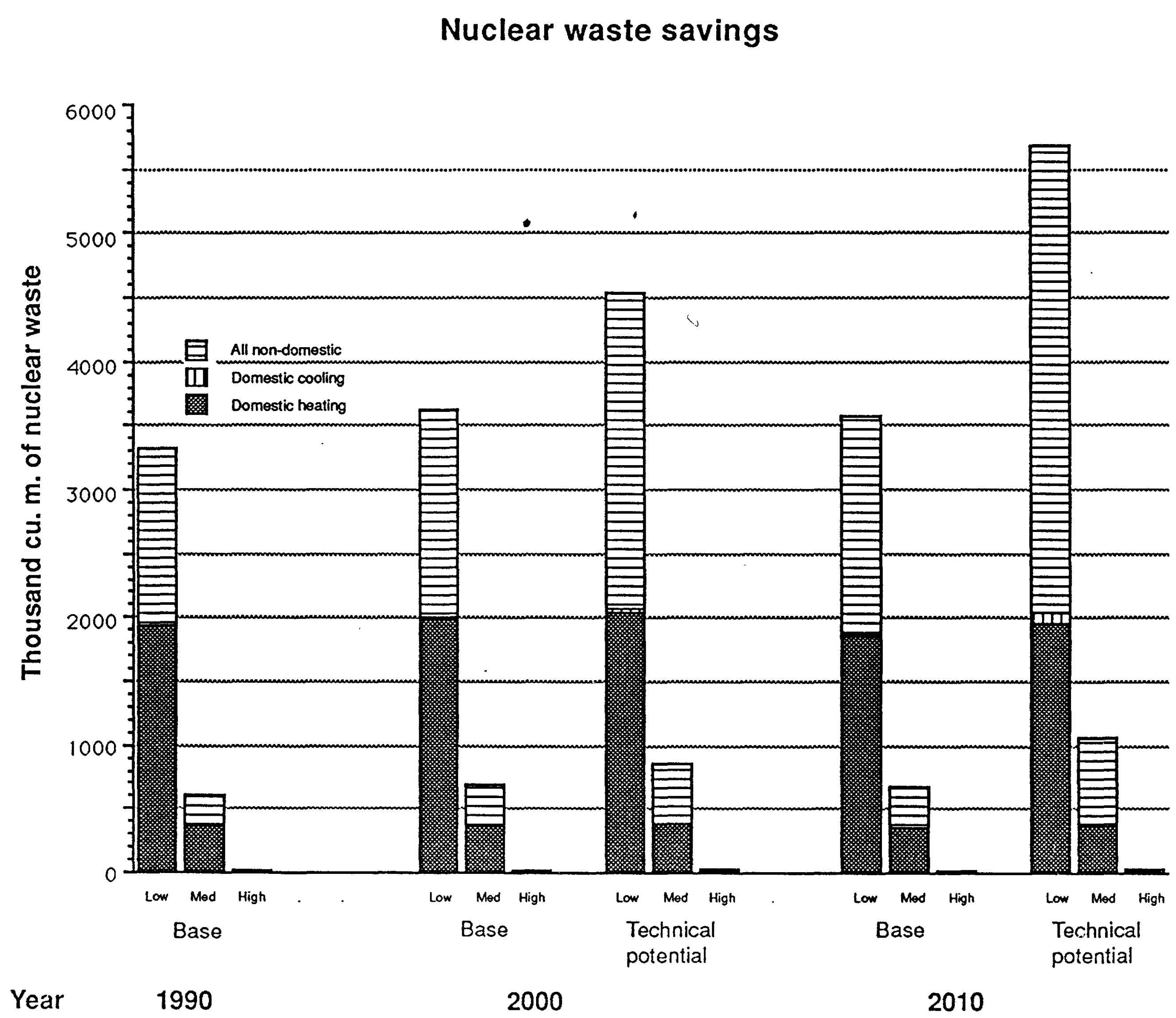


FIGURE 8

# Belgium

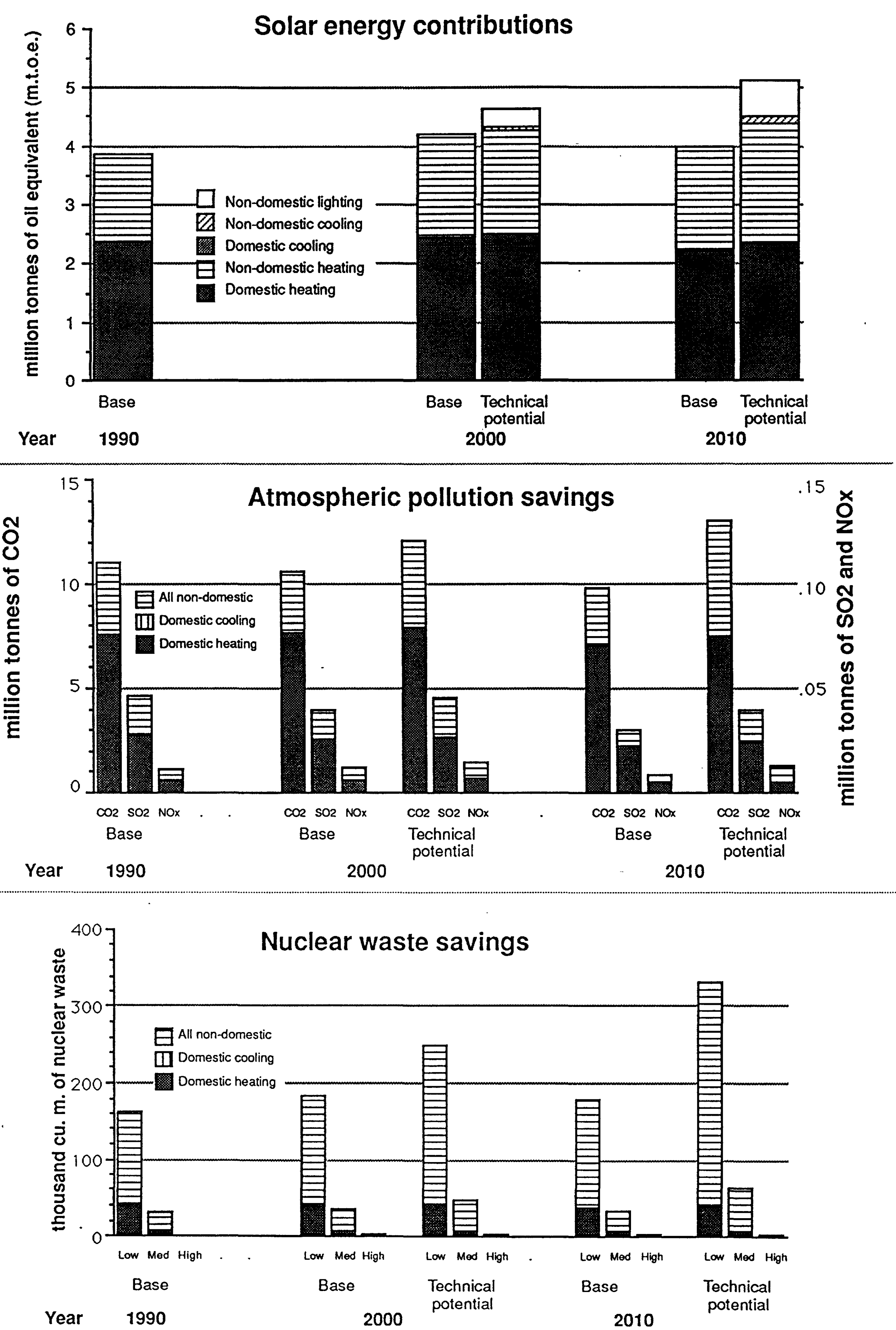


FIGURE 9

# Denmark

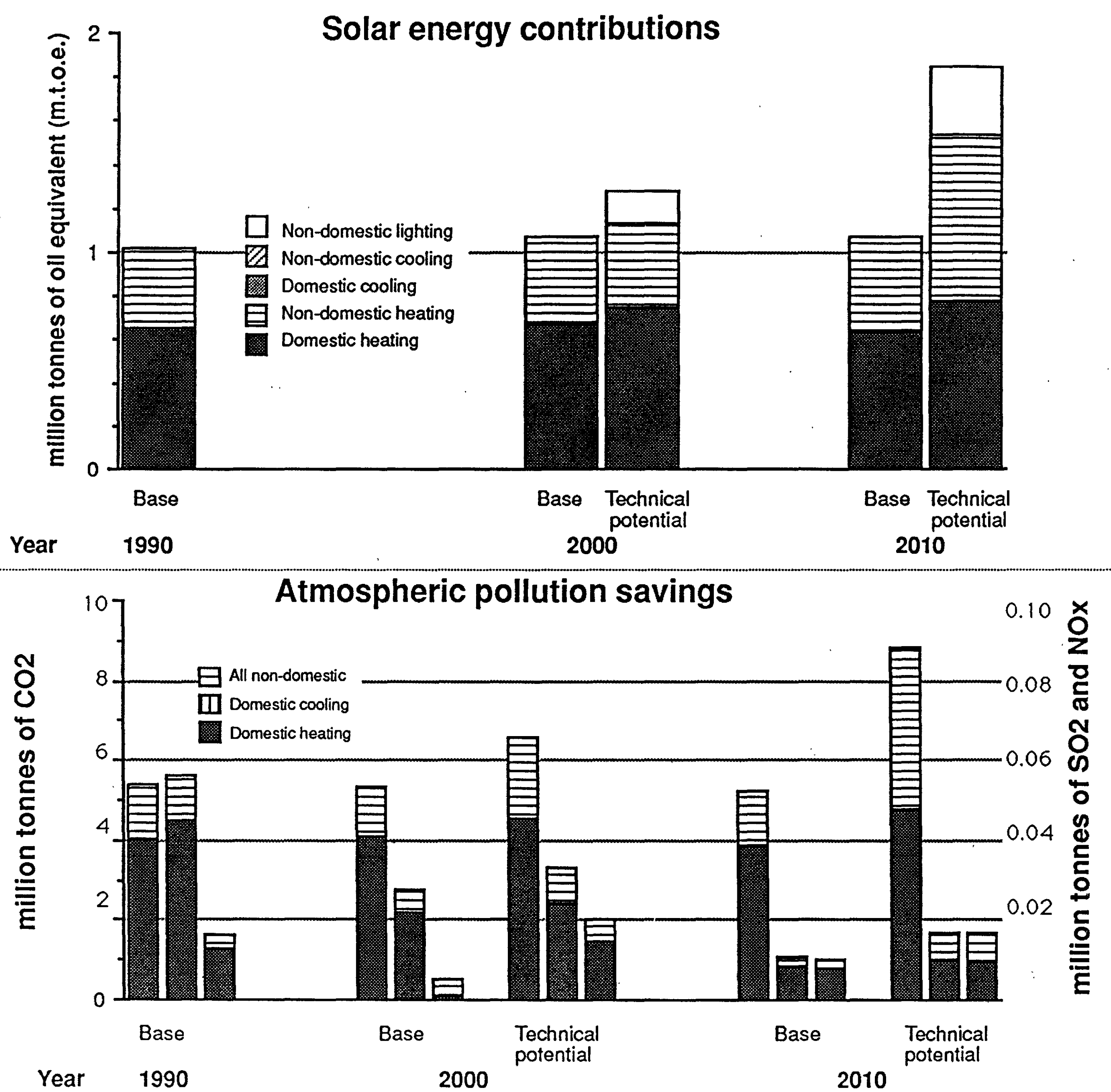
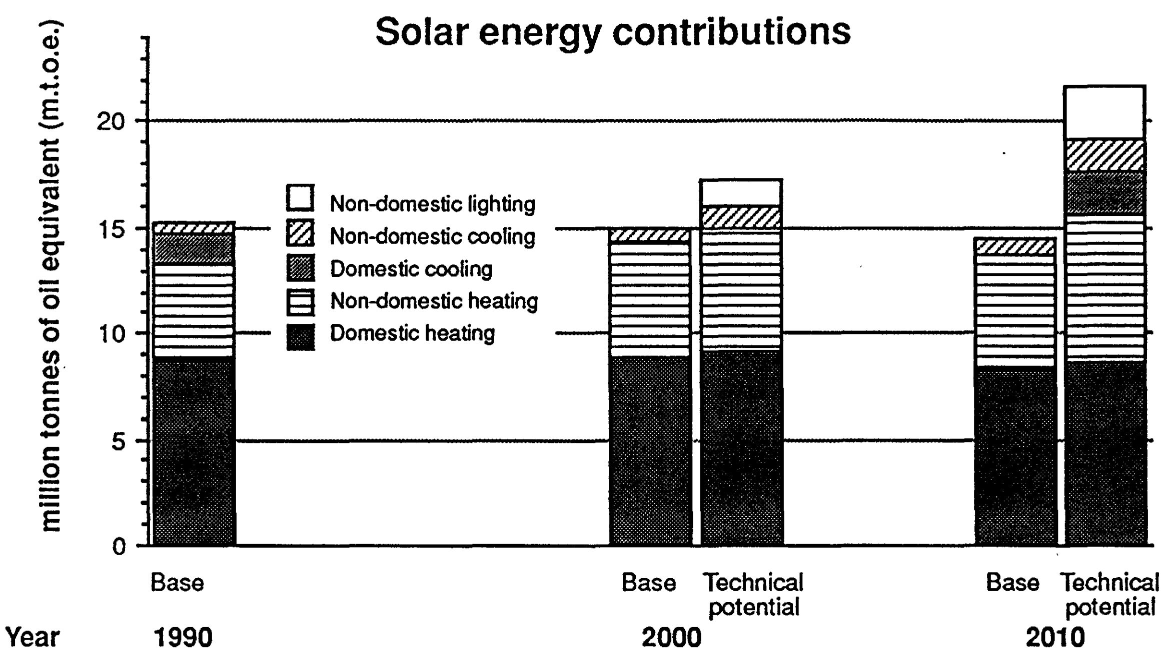
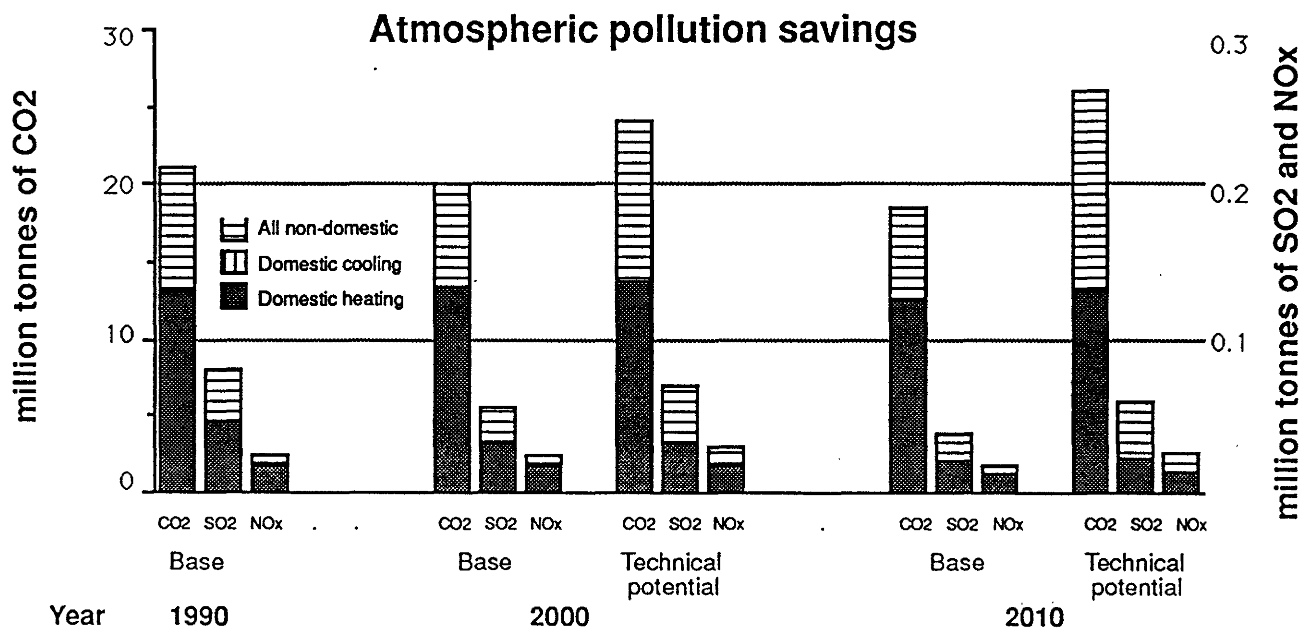


FIGURE 10

# France



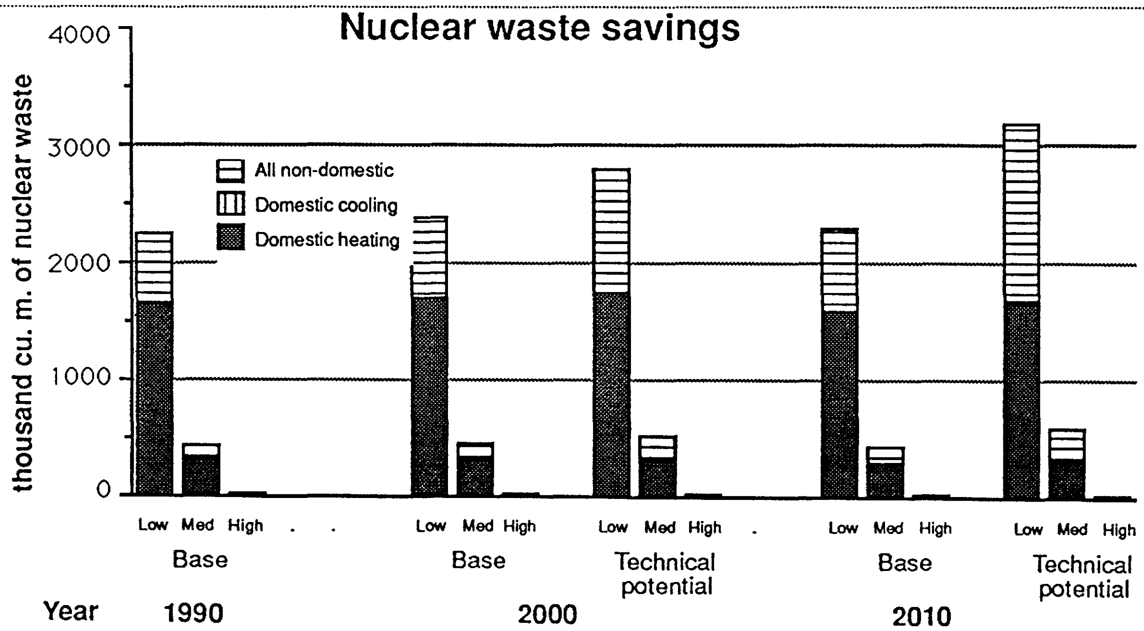
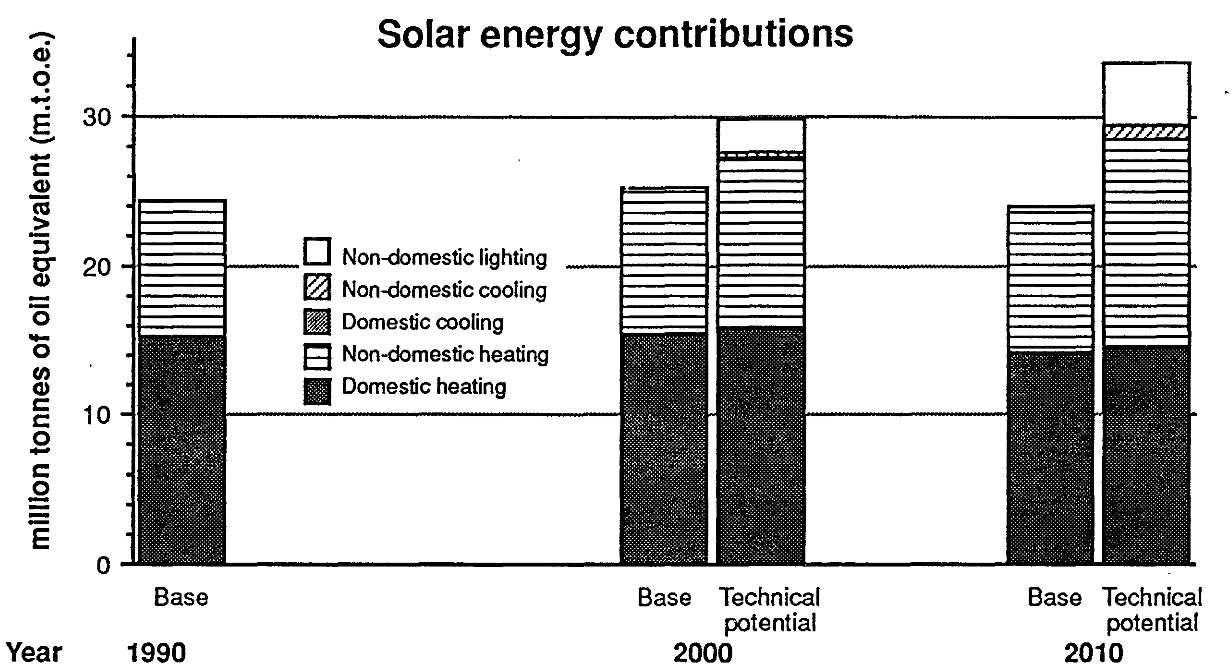
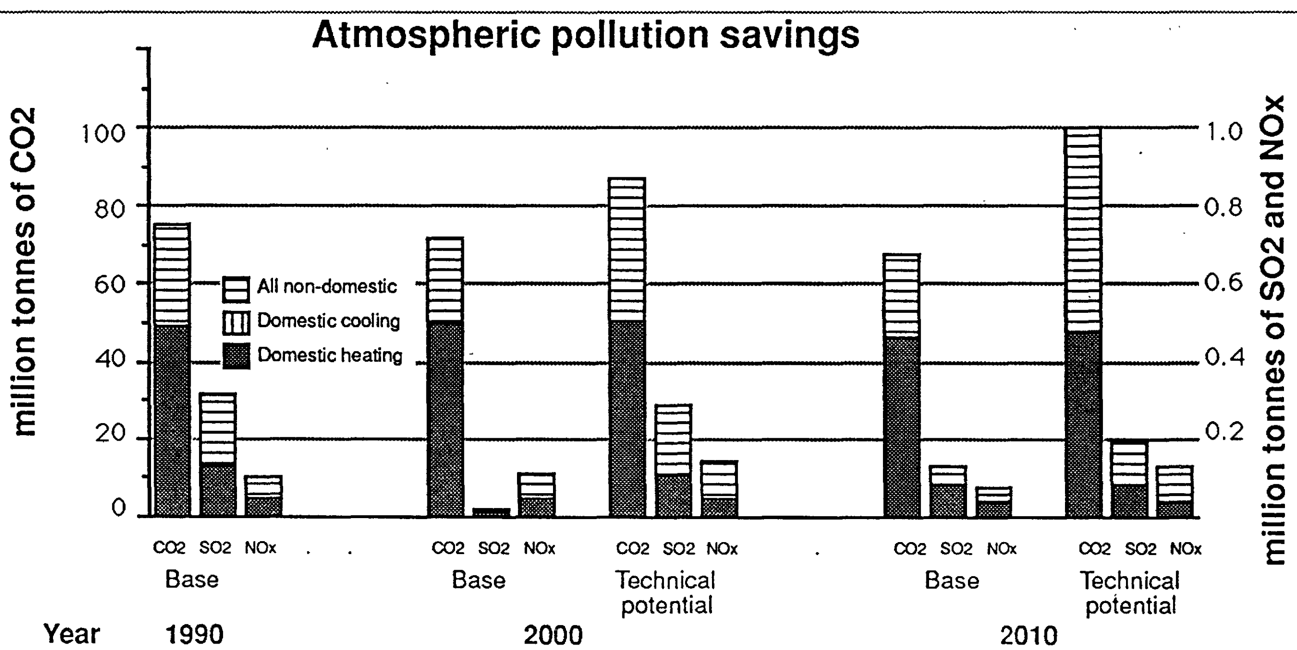
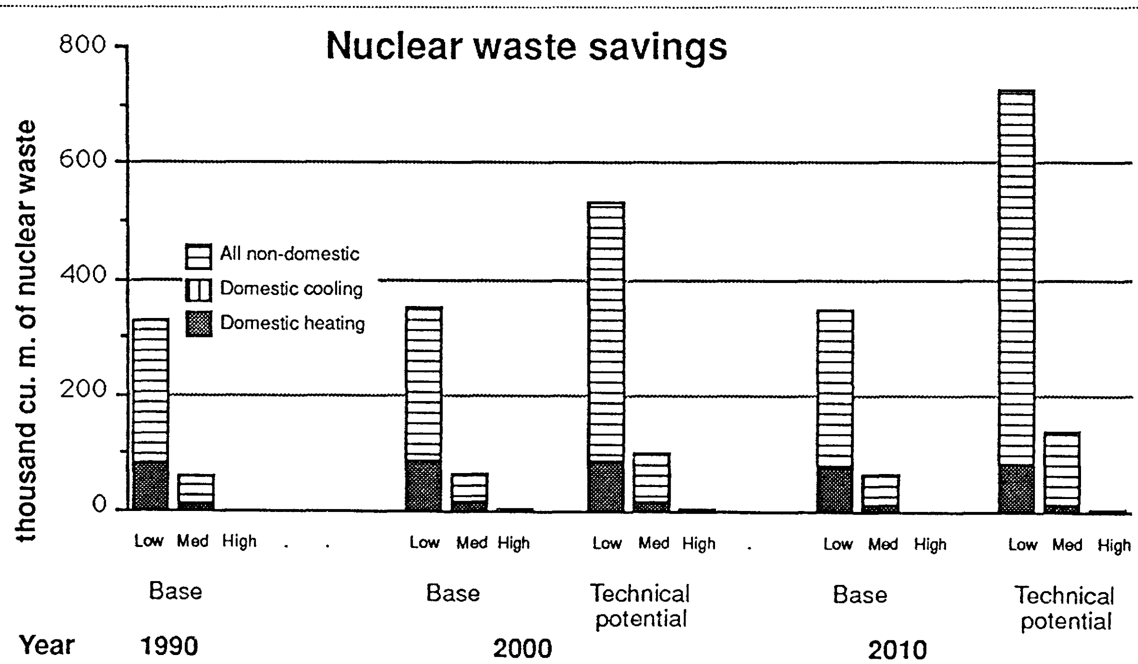



FIGURE 11

# Germany

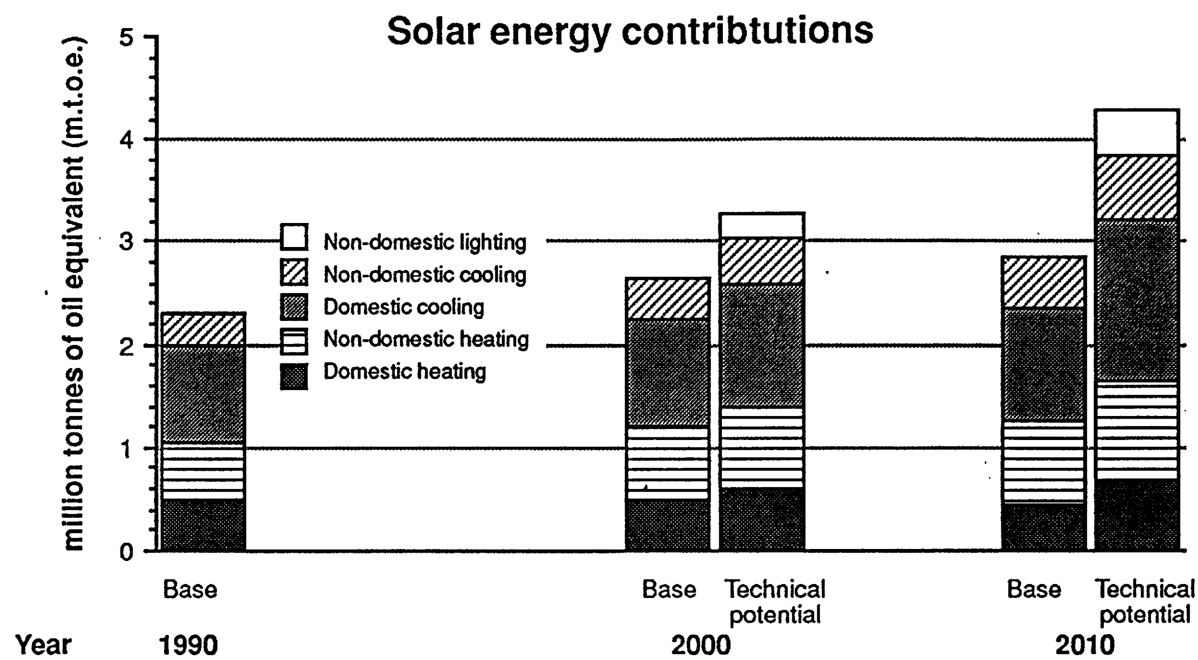


# FIGURE 12

# Greece



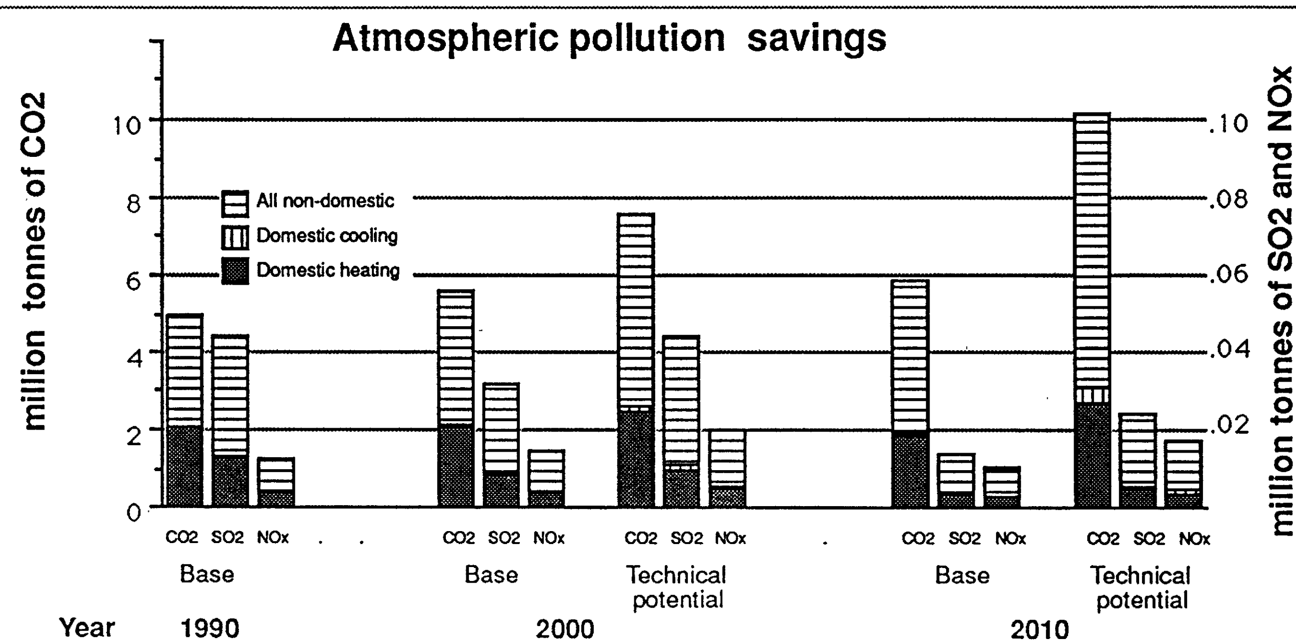
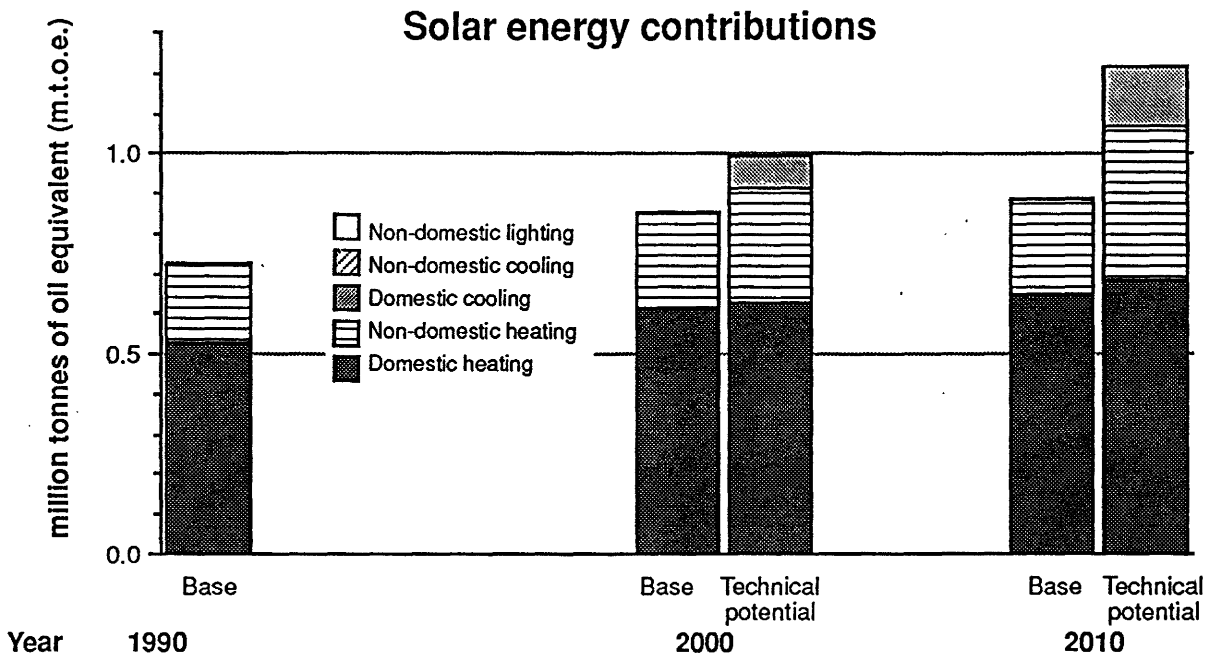



FIGURE 13

# Ireland



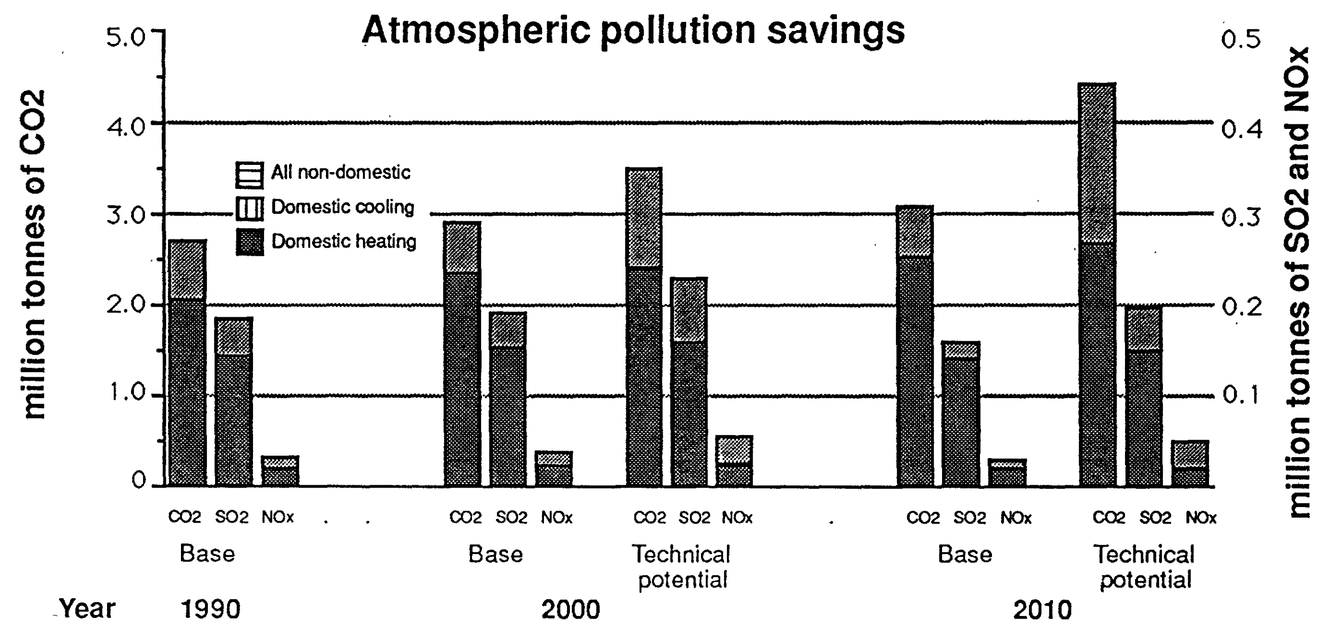



FIGURE 14

# Italy

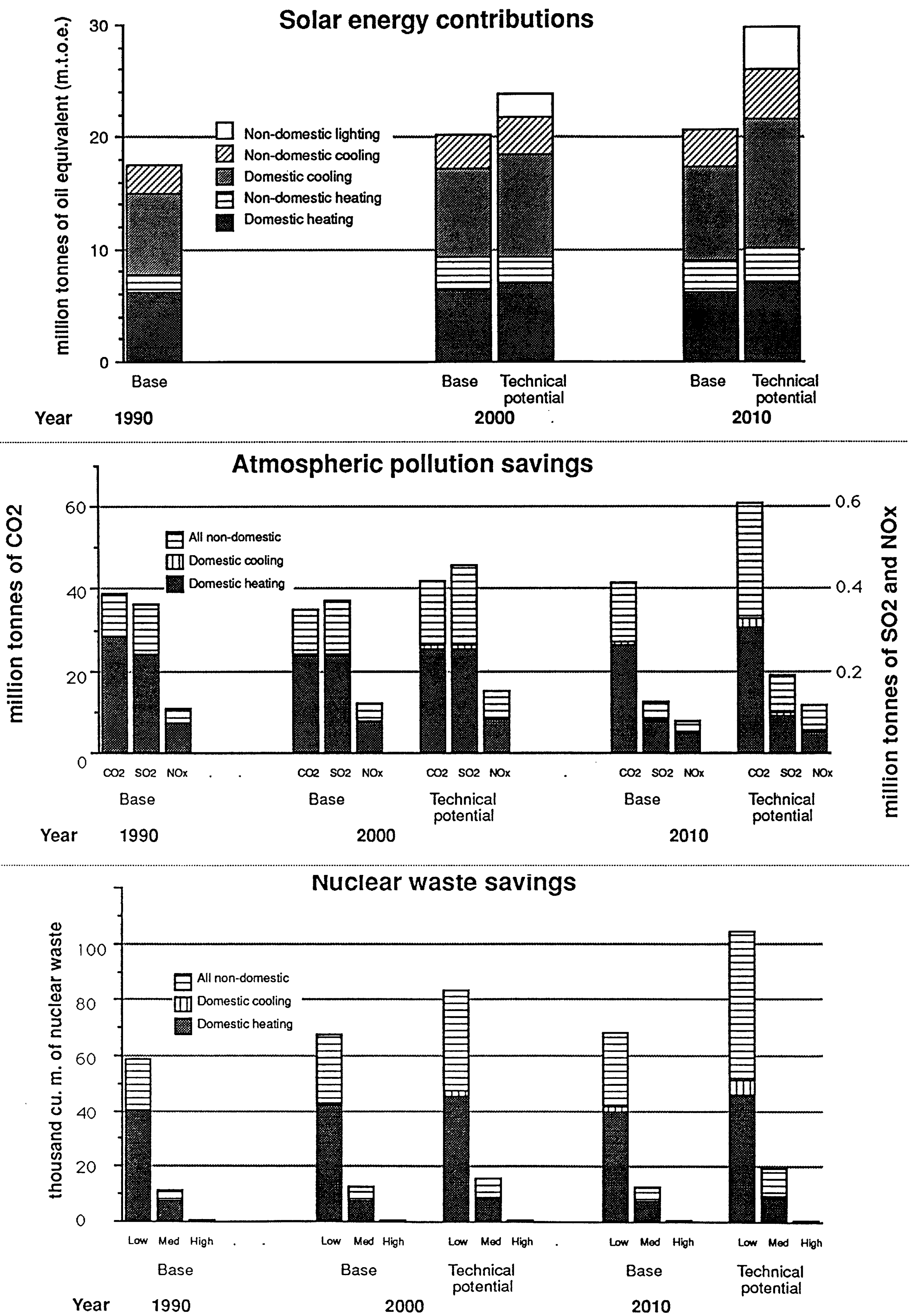
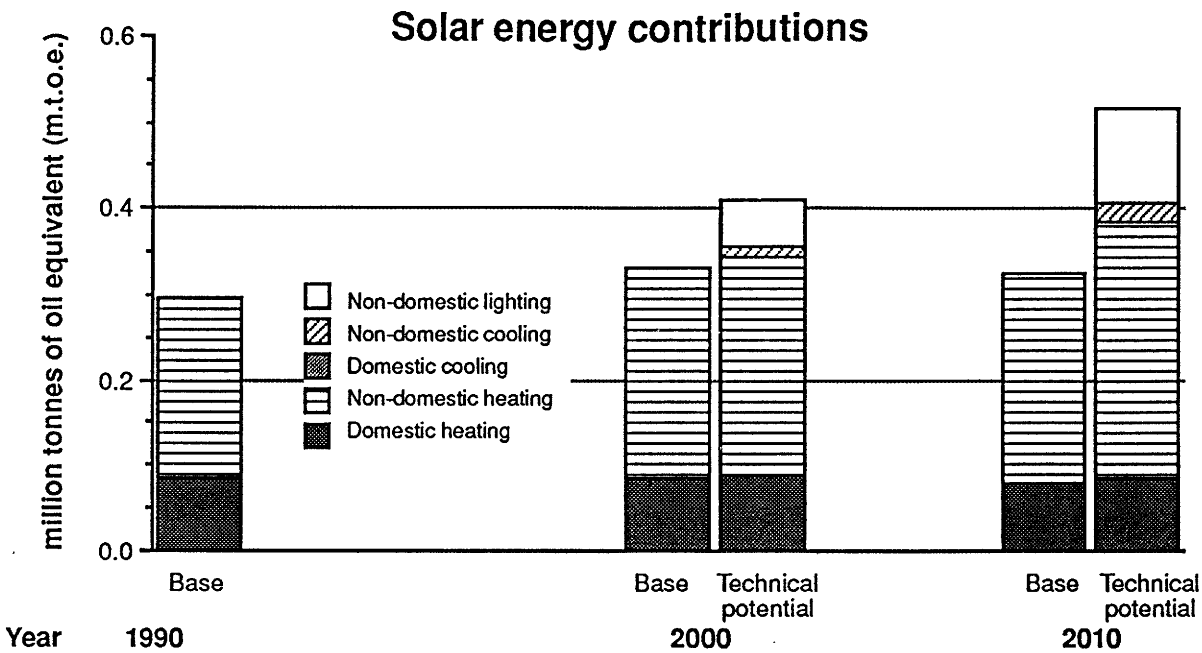


FIGURE 15

# Luxembourg



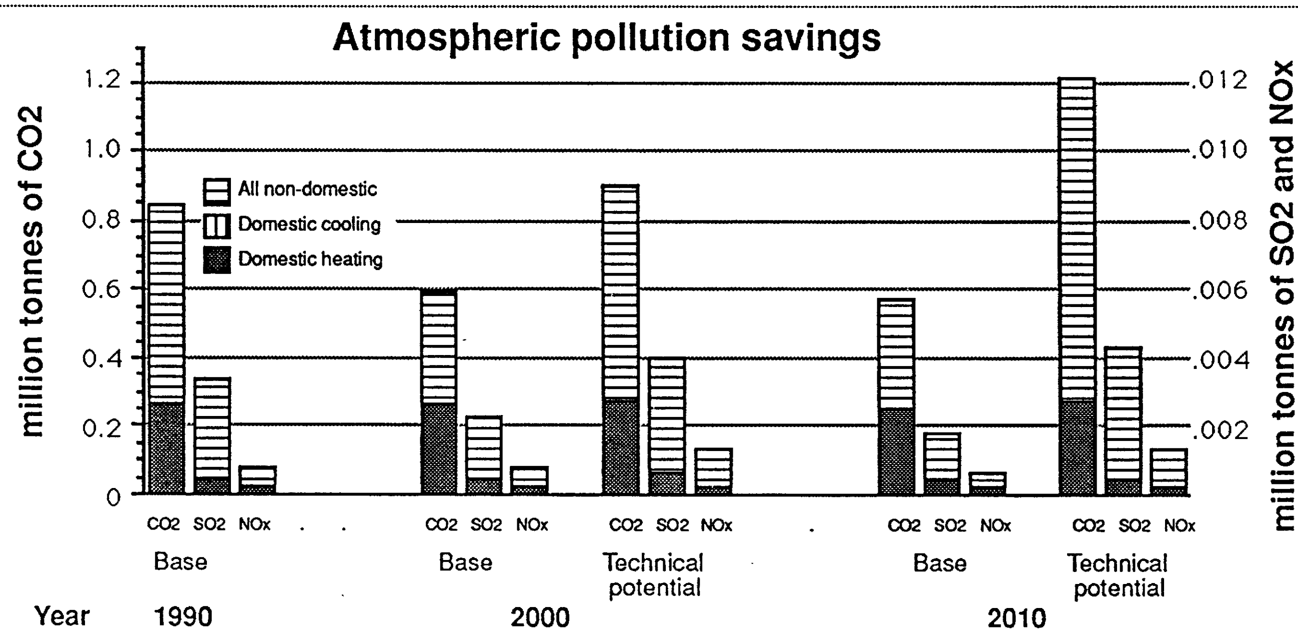
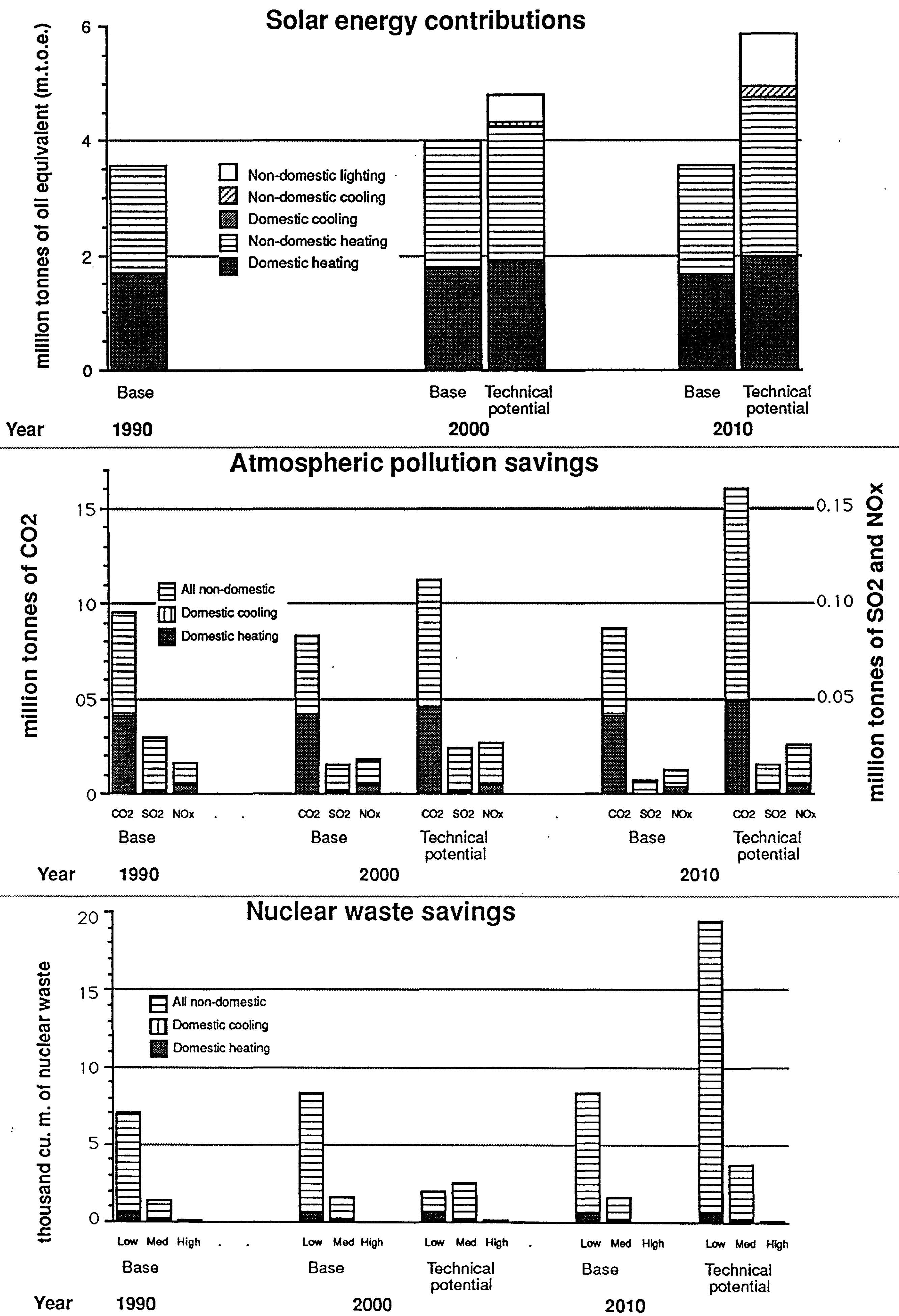



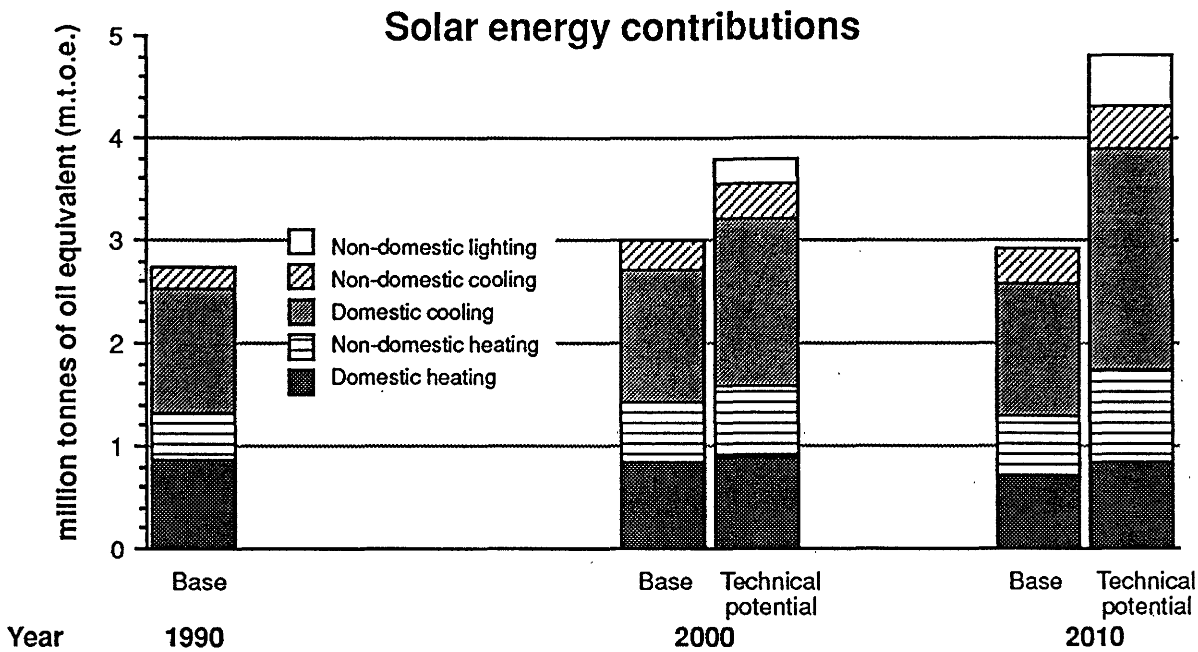
FIGURE 16

# Netherlands



# Portugal

FIGURE 17



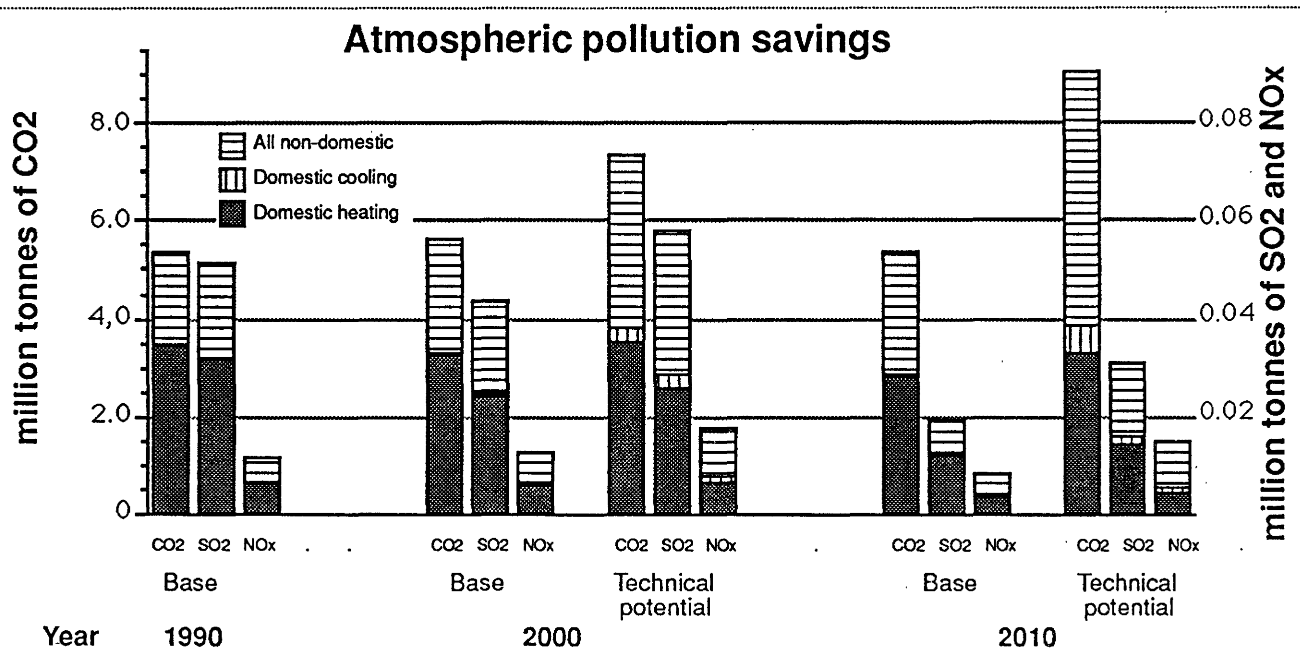
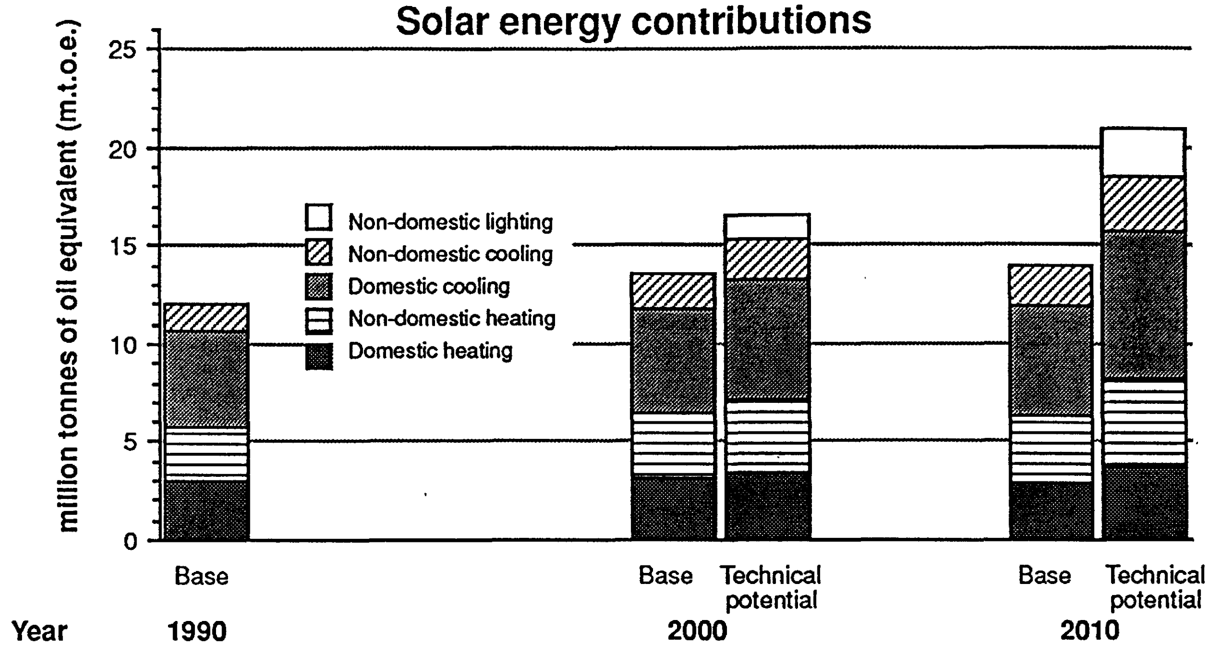
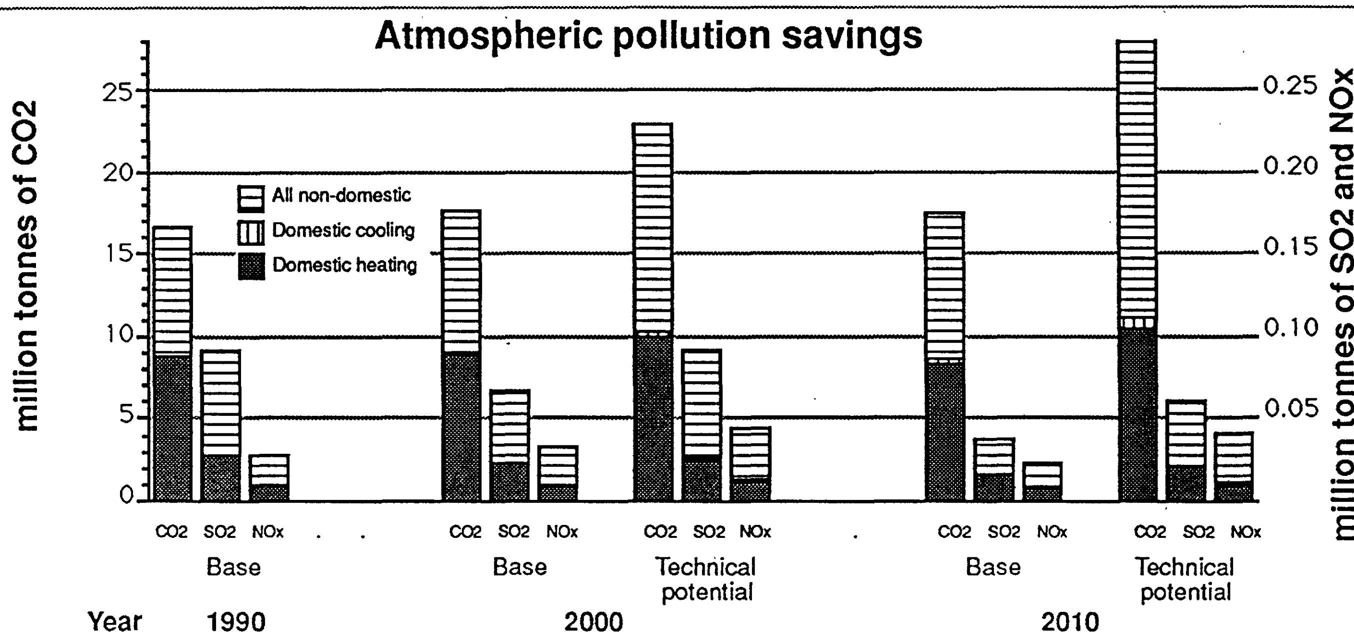



FIGURE 18

# Spain



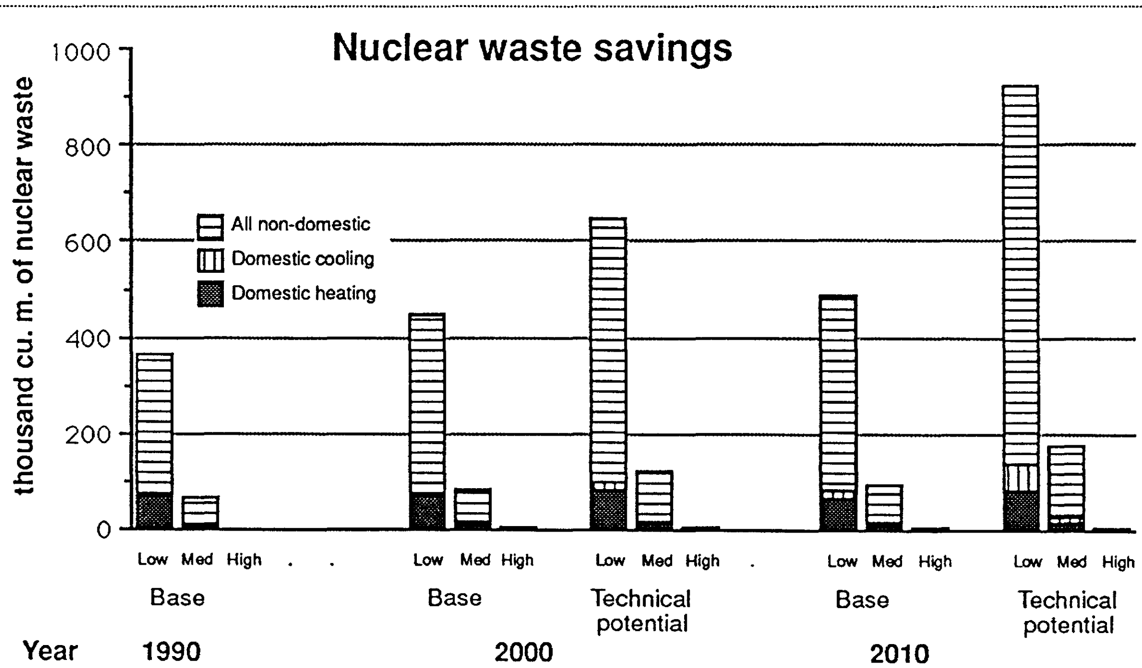



FIGURE 19

# United Kingdom