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.

EXECUTIVE SUMMARY

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PRINCIPAL CONCLUSIONS.

1. Solar energy is already a major fuel in the European Community, providing 13% of the primary energy used in houses and non-domestic buildings (excluding industrial process use).

2. Passive solar design reduces fossil and nuclear fuel consumption in five areas, heating and cooling in houses and non-domestic buildings and lighting in non-domestic buildings.

3. There are significant benefits in applying solar design in both the northern and southern latitudes in Europe.

4. Positive action could greatly increase the use of solar design and thus reduce the use of fossil fuels and consequent pollution in the future. By 2010 the amount of solar energy used in the European Community could be increased by 54% overall, and by up to 87% in individual countries.

5. If no positive action is taken, the use of passive solar energy may increase by only a small amount and may even decline (due to the reduced heating requirement due to higher insulation standards in buildings). Complementary passive solar design can supply an increased proportion of this reduced demand.

6. In modern houses, designed on passive solar principles, up to 33% of the heating demand can be supplied by solar energy; furthermore the cooling demand can generally be satisfied by passive solar design. In offices and factories, passive solar design can reduce heating demands by a similar amount and can frequently avoid the need for air-conditioning altogether. Passive solar design can generally improve living and working conditions.

7. Solar energy use could be dramatically increased if solar measures for retrofitting to existing buildings could be developed. Transparent insulation is an important development in this area.

8. Since solar energy is effectively pollution free, it presently saves 230 million tonnes of CO_2 per annum,equivalent to 17% of the CO_2 which would be produced in the European Community in the absence of solar gain. A further 103 million tonnes could be saved per annum by the year 2010. Based on the CO_2 emissions of an average UK fossil fuel power station, this further saving is equivalent to the pollution savings resulting from closure of 82 such power stations.

9. If these technically possible savings are to be realised, positive action is required on a number of fronts. All sectors, housing and non-domestic, heating, cooling and lighting, in all countries, must be addressed. Legislation and fuel price rises, combined with promotion and education in passive solar design, could work quickest and most effectively. Relying on incentives alone to encourage the voluntary adoption of passive solar design, will never achieve the full potential.

1. PURPOSE OF THE STUDY.

The study set out to answer three main questions:-

How much solar energy is currently used in buildings in the European Community?

How much solar energy could be used in the future, in the years 2000 and 2010?

What could be the consequent reduction in pollution, particularly the reduction in carbon dioxide (CO_2)?

Section 2 introduces passive solar design, section 3 describes the method of the study, section 4 discusses the results of the study in terms of solar energy use and pollution savings, section 5 gives a country by country assessment and section 6 looks at ways of increasing the use of solar energy. This summary report is based on the full background report prepared for the CEC.

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2. USING SOLAR DESIGN.

Making use of the sun's energy has always been an essential part of living. All buildings can be designed to make use of the sun for heating and to exclude the sun to stop overheating. The sun also provides natural daylighting inside buildings.

WHAT IS PASSIVE SOLAR DESIGN?

This study looks at the use of passive solar design in all buildings for heating, cooling and lighting. Heating by passive solar energy involves the sun entering a building directly through the windows or indirectly through sunspaces, wall panels etc, and being used or stored inside the building with little or no use of fans or pumps. (When fans or pumps are used this is "active solar" energy). Cooling by passive solar design involves shading, natural ventilation and the use of naturally cooled air (from the ground or evaporative cooling) to stop a building overheating. Daylighting by passive design means allowing natural light to enter deep into a building and ensuring that artificial lighting is only in use when natural lighting is insufficient.

THE ADVANTAGES OF PASSIVE DESIGN.

Good design optimises the utilisation of solar energy in all three areas and this can achieve large savings in the use of conventional fuels for heating, cooling and lighting. Reduction in the use of fossil fuels and nuclear power gives rise to two of the benefits of passive solar design:

- the preservation of finite fuel sources.
- the reduction in atmospheric pollution, particularly CO_2.
- the third benefit of solar design is the creation of pleasant, natural environments for living and working.

PASSIVE DESIGN IN NEW BUILDINGS, REFURBISHMENTS AND FOR RETROFITTING.

All buildings make use of some solar gain for heating and lighting and this use can be increased at any stage in the building's life. The simplest and most effective way is at the design stage, when solar heating, cooling and daylighting measures can be incorporated with minimal extra cost or inconvenience. During major refurbishment, some solar measures can be introduced with significant effects. Lastly, some solar measures can be added on to a building at any time, sunspaces, shading devices, transparent insulation cladding, etc.

PASSIVE DESIGN IN THE NORTH AND SOUTH.

The European Community includes a range of very different climates, from Scotland and Denmark to Greece and Spain. Passive solar design is applicable in all the climates, though naturally in different ways. In the northern latitudes winters are long and cold and most available solar gains are usable to reduce consumption of fossil (and nuclear) fuel for heating. In Mediterranean areas, passive design to reduce or prevent overheating and consequent use of air-conditioning, can give the largest returns, whilst even the small heating loads can be reduced by good solar design. Daylighting design is applicable in all climates.

The sun's energy is readily available to reduce Europe's consumption of fossil fuel and nuclear energy and to avoid investment in new power plants. Passive solar design in buildings can be used as part of a strategy to reduce global pollution.

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3. ESTIMATING SOLAR ENERGY USE.

THE "SPREADSHEET" AND INFORMATION SOURCES.

The method used was to build up the total solar usage for the European Community from all the constituent parts, in all the constituent countries. A computer "spreadsheet" was developed, one for each country, and available information, estimates and projections inserted. Information was collected from published sources such as the CEC Eurostats data, unpublished papers and documents and experts in each country. Much of the information required was simply not available, so estimates were made on the basis of what was available, comparison with other countries and expert opinion. The spreadsheet approach makes future updating, when new information becomes available, fairly straightforward.

BASE AND "TECHNICAL POTENTIAL" SOLAR CONTRIBUTIONS.

The "base case" solar usage was defined as the contribution of passive solar design to heating and cooling loads if no action is taken to increase the usage in the future. The base case does not include any solar contribution for daylighting in either houses or non-domestic buildings.

The "technical potential" solar contributions to heating, cooling and lighting were defined as the maximum achievable overall in the years 2000 and 2010, taking into account technical difficulties such as overshading but assuming that otherwise all houses would be built or refurbished according to solar principles. Clearly this potential will not be achieved without drastic measures. This is discussed later.

Solar heating in houses.

Using solar energy to heat houses is the best researched and documented area in the field of passive solar research. The current, or base, solar usage was built up for each country from the number of houses, their gross heating demand and the percentage solar contributions as determined from monitoring projects. New build, refurbishment and demolition rates were used together with solar contributions monitored in new and refurbished solar houses to estimate technical potential solar contributions for 2000 and 2010.

Natural cooling in houses.

The need for cooling in houses was only considered for countries in southern latitudes. Passive or natural cooling design is estimated in this study to currently provide half of the demand in houses where cooling is necessary but where air-conditioning is not used. In the small proportion of houses already using air-conditioning, no passive cooling contribution was considered. The possible contribution of passive design for the years 2000 and 2010 was built up from new build and refurbishment rates assuming increased natural design contribution rates to the cooling demand.

Daylighting in houses.

Daylighting in houses was not considered as an area of solar gain since auxiliary lighting is not normally required in houses in the daytime so no savings can be made by improved design.

Offices, factories, schools etc.

The non-domestic sector has far more diverse building types and less information is available. Broader estimates were made mainly on the basis of current energy usage and estimates of increases in energy consumption available from CEC research. New build and refurbishment rates were forecast and estimates made of possible solar contributions from case studies and other research. Solar design contributions to heating, cooling and lighting for year 2000 and 2010 were built up in this way.

POLLUTION SAVINGS FROM SOLAR DESIGN.

Pollution savings in terms of CO_2, SO_2, NO_x and nuclear waste for each country were calculated based on the fuel split within that country and the total equivalent savings resulting from the solar design.

DEVELOPMENT OF NEW TECHNOLOGIES.

The estimates are made on the basis of the use of tried and tested methods and components for optimising solar design. Whilst on the one hand it is unlikely that all these will be implemented, on the other hand it is possible that new technologies will be developed which could significantly increase solar usage. Over the next 20 years the development of transparent insulation seems likely to have the most significant effect.

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4. RESULTS - SOLAR ENERGY USE AND POLLUTION REDUCTION.

SOLAR ENERGY USE IN 1990 COMPARED WITH OTHER FUELS.

Passive solar design at present supplies the European Communities with the equivalent of 96 million tonnes of oil equivalent (mtoe) of primary energy per annum. This is 9% of the total fuel used in the European Community (figure 1), larger than the amount of coal directly burnt for heating (6%). In the building sector alone (ie excluding industrial process heat and transportation energy use) solar design supplies 13% of the total (figure 2). Thus it is clear that solar energy is already a very important fuel in Europe.

SOLAR ENERGY USE IN THE FUTURE.

Over the next 20 years, 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, falling back to 6% above 1990 use by the year 2010. The reduction is due to reduced heating demand resulting from higher insulation standards.

However if action is taken, the potential exists to greatly increase the use of solar energy. By the year 2000 the overall amount could be increased by 27% of the 1990 usage, an increase of 26 mtoe, and by 2010 the amount by 54%, or 52 mtoe per annum.

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 rates and poor design and operation.

WHERE MOST SOLAR ENERGY IS USED.

Figure 3 shows the increase in individual solar contribution in the 5 categories (domestic heating, non-domestic heating, domestic cooling, non-domestic cooling and non-domestic lighting) for the European Community.

Solar contributions to heating (nearly 76 mtoe per annum) are the largest, in absolute terms, but the largest increase is forecast in the use of daylighting in non-domestic buildings, an increase of nearly 18 mtoe per annum by 2010. The forecast increase in solar heating in non-domestic buildings is also large at over 17 mtoe per annum by 2010 and reflects the relatively high rates of new construction and refurbishment in this sector compared to housing.

The contribution of passive solar design to the reduction of cooling loads gives smaller total savings than that to the reduction of 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, for instance Denmark, Ireland and the Netherlands have negligible cooling demand while Greece, Spain, Italy and Portugal achieve 50% of their technical potential solar contribution through passive cooling design.

Overall a significant increase in the domestic natural cooling contribution of 9 mtoe is possible by 2010.

Whilst the largest absolute solar usage figures come from the countries with the largest populations, the greatest relative increases in solar design usage are likely to come from countries in southern latitudes, where solar design contributions to heating, lighting and cooling can be increased. (figures 4 and 5 and 8 to 19).

ATMOSPHERIC POLLUTION SAVINGS FROM THE USE OF SOLAR DESIGN.

At present passive solar design saves 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 the solar contribution. 1.3 million tonnes of SO_2 and 0.56 million tonnes of NO_x (Oxides of Nitrogen) are also saved by solar design.

Figure 6 shows the pollution savings arising from the use of passive solar design throughout Europe.

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 rise to 332 million tonnes, an increase of 45%. The annual saving 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.

Potential savings in SO_2 and NO_x are shown to reduce in the future due to implementation of legislation to reduce emissions of these gases from power stations. If targets for reduction in emissions are met, the problems associated with emissions of SO_2 and NO_x (principally "acid rain") will thus be greatly reduced.

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 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 generally showing the higher percentage savings.

NUCLEAR WASTE SAVINGS FROM THE USE OF SOLAR DESIGN.

At present solar design reduces nuclear waste by more than 18% from that which 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 of nuclear waste by around 70% by 2010. Figure 7 shows the potential savings in nuclear waste.

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5. COUNTRY BY COUNTRY ASSESSMENT

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 in solar usage is possible by 2010.

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 forecast for the use of solar heating in the non-domestic sector.

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.

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.

Greece. Population 5 million, with a solar contribution of less than 2.5% of the European total in 1990. Design for solar cooling 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.

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%.

Italy. With one of the highest populations in the European Community, 57 million, Italy's solar contribution is second highest at 18% of the European total. Cooling solar design 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.

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

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

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, providing 45% of the total saving, by 2010. Overall, solar usage could increase by 76% in 2010.

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

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%.

6. INCREASING THE USE OF SOLAR ENERGY.

PRODUCT AND SYSTEM DEVELOPMENT.

Passive solar heating in houses is a well researched and developed area and though some new systems and products are being developed and may become viable within the 20 year period, it is the application and refinement of existing products that will contribute most to overall solar gains. Transparent insulation systems do have the potential to make a major contribution, if applications can be developed successfully. Though much less research has been carried out on solar heating in non-domestic buildings, it is more the application of systems and products that is required than the developments themselves.

Cooling systems and products have been available for years though some adaptations may be necessary to incorporate modern building techniques, particularly in non-domestic buildings. Designers in northern climates can learn from those in southern climates where for obvious reasons passive cooling is better understood. Assessment methods for cooling loads and the contribution of passive design, need further development.

Daylighting in non-domestic buildings does require more understanding, and assessment methods require development and validation. Photoelectric controls are already widely available, but some other product development could be beneficial.

THE COSTS AND BENEFITS BALANCE.

Costs. Much passive solar design need cost no more than conventional design, though the design process may take longer initially, and possible associated problems such as overheating will need to be solved. Some solar features such as sunspaces, panels, shading devices and daylighting designs will always attract additional costs. Their adoption will thus depend on the benefits arising.

Benefits. Three main benefits may arise for solar designs: reduced running costs; improved comfort (higher or lower temperatures) and quality of living and working spaces; and reduced environmental effects (pollution, sick building syndrome, etc). The value of all these benefits is likely to increase in the future, fuel prices will rise, occupants will come to expect better standards of comfort and the costs of environmental pollution and building "problems", such as sick building syndrome, are likely to become fully recognised.

The conclusion is that passive solar design will perform well in cost-benefit analysis in the future if all benefits are taken into account.

OBSTACLES TO THE ADOPTION OF PASSIVE DESIGN.

There are several obstacles reducing the use of passive solar design in buildings at present.

- **Ignorance.** The benefits of passive design, and the design principles are often not known by architects, designers, builders and clients.

- **Lack of demand.** Building specifiers, purchasers and users do not generally ask for energy conscious buildings.
- **Fear of problems and failures.** The ideas and techniques of passive design, being not well known, can be thought to increase the risk of failure.
- **Non-availability of design tools.** The design tools to facilitate passive solar design and evaluation may not be widely available or understood.
- **Non-availability of materials and products.** Passive products may be more difficult to obtain than conventional products.

METHODS OF INCREASING THE USE OF PASSIVE SOLAR DESIGN.

Much can be done, and much should be done, to increase the solar content in the design of buildings.

- **Legislation.** Mandatory incorporation of passive design principles in new and existing buildings (via Building Regulations etc) would be most effective in achieving the potential solar gains identified in this study.
- **Fuel price increases, carbon tax.** All energy saving measures, including the use of solar design, would be stimulated by effective fuel price increases. Cost increases to reflect the social costs of energy consumption would benefit solar design solutions.
- **Grants and other incentives.** Financial incentives, at least in the beginning, are likely to increase solar designs.
- **Education.** Ensuring that passive design principles are taught to students of both architecture and engineering and are available to practising designers, is essential.
- **Publicity and promotion.** All participants in the construction industry need to be made aware of the benefits and principles of passive design.

WHERE EFFORTS SHOULD BE PLACED.

All countries within the European Community could take steps to optimise their use of solar energy and thus reduce their dependence on fossil and nuclear fuels. Passive design for cooling can contribute large savings in countries in southern latitudes, passive design for heating and non-domestic lighting contributes in all countries. Passive design is applicable to, and should be increased, in all 12 countries.

All five sectors identified - heating and cooling in houses and non-domestic buildings together with lighting in non-domestic buildings - should be targeted for increasing solar design. All can make significant contributions.

- **Domestic heating.** In individual buildings high solar energy usage is possible and this applies to all countries. The overall effects could be greatly increased if retrofitting of solar measures to existing buildings could be widespread.

- **Non-domestic heating.** Greater potential exists in this sector due to higher new build and refurbishment rates, but experience is less widespread. Education of designers and promotion should increase solar design.
- **Domestic cooling.** A large potential exists to increase passive design to reduce overheating and the use of air-conditioning in countries in southern latitudes. Integration of passive design for heating and cooling is important. Design tools need development.
- **Non-domestic cooling.** Avoidance of the use of air-conditioning (auxiliary cooling) or reducing cooling loads and usage, gives good energy savings in almost all countries. Promotion of the environmental benefits of the avoidance of cooling is important. Education of the industry is required.
- **Non-domestic lighting.** Design for daylighting, and the introduction of photocontrols give returns throughout the European Community. Daylighting design and assessment tools need developing.

FIGURE 1

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

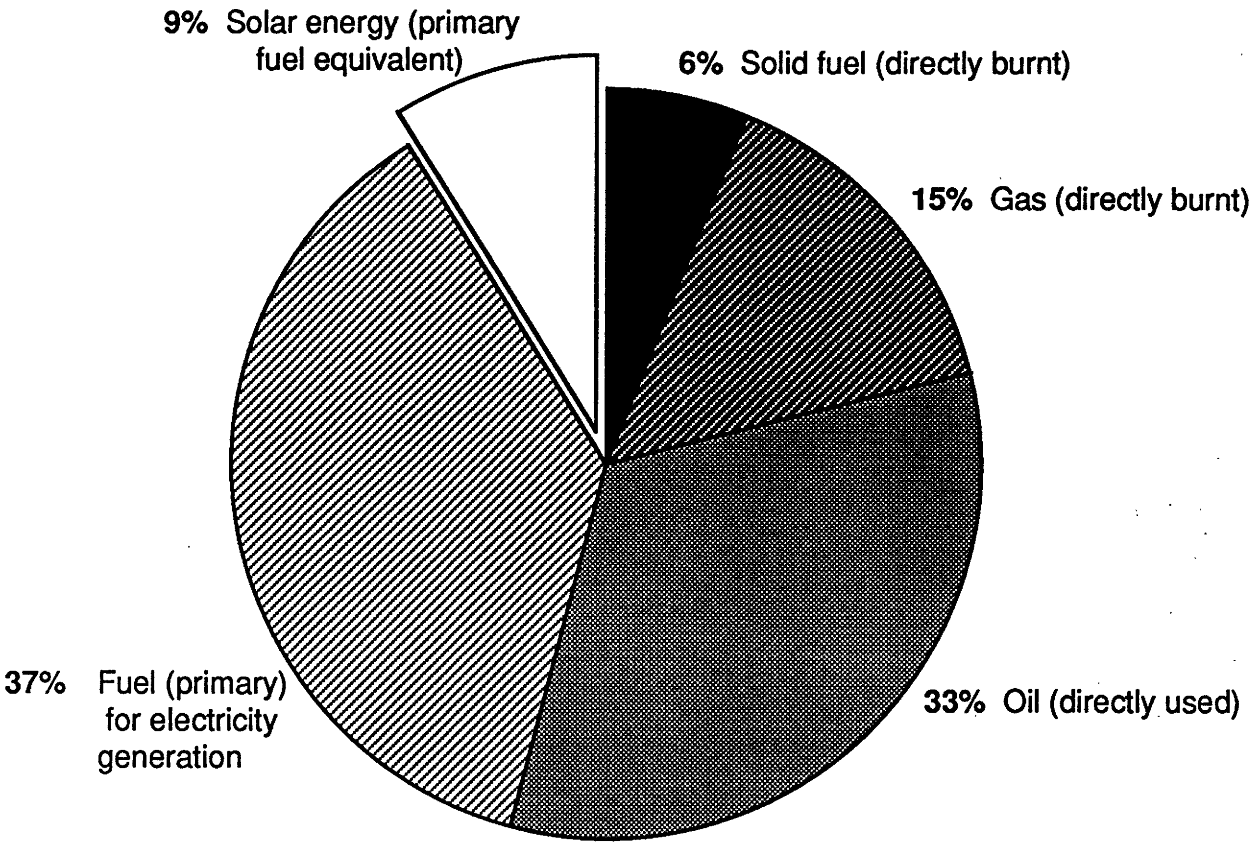


FIGURE 2

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

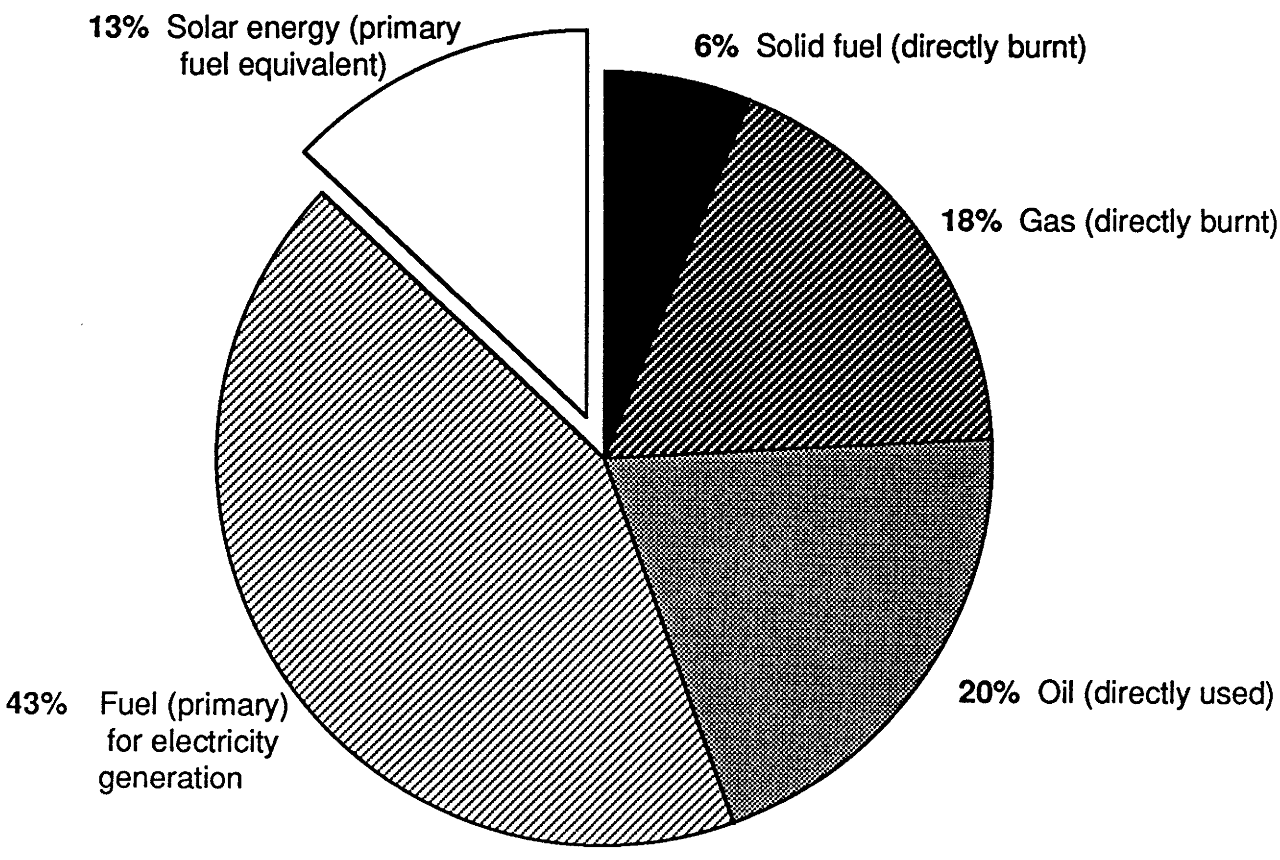
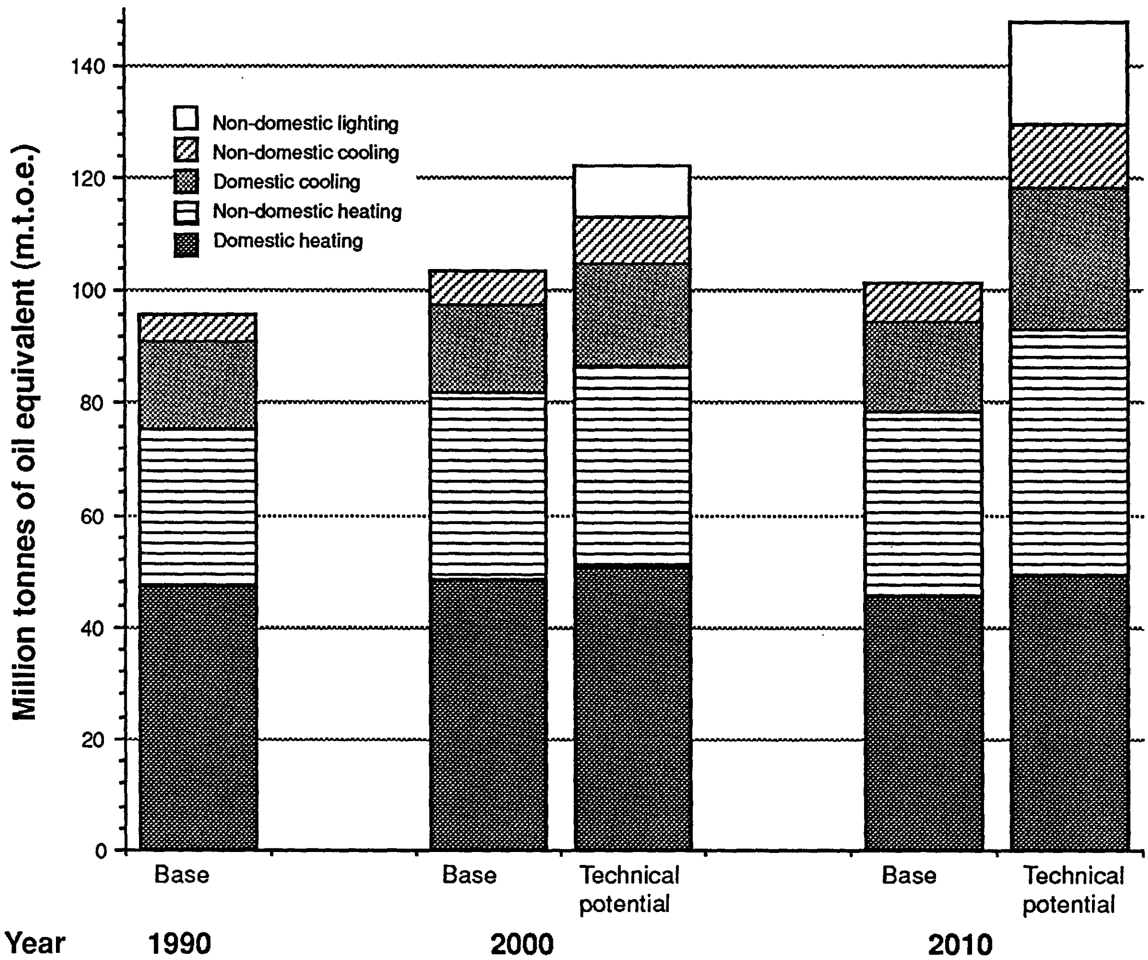


FIGURE 3

All European Member States

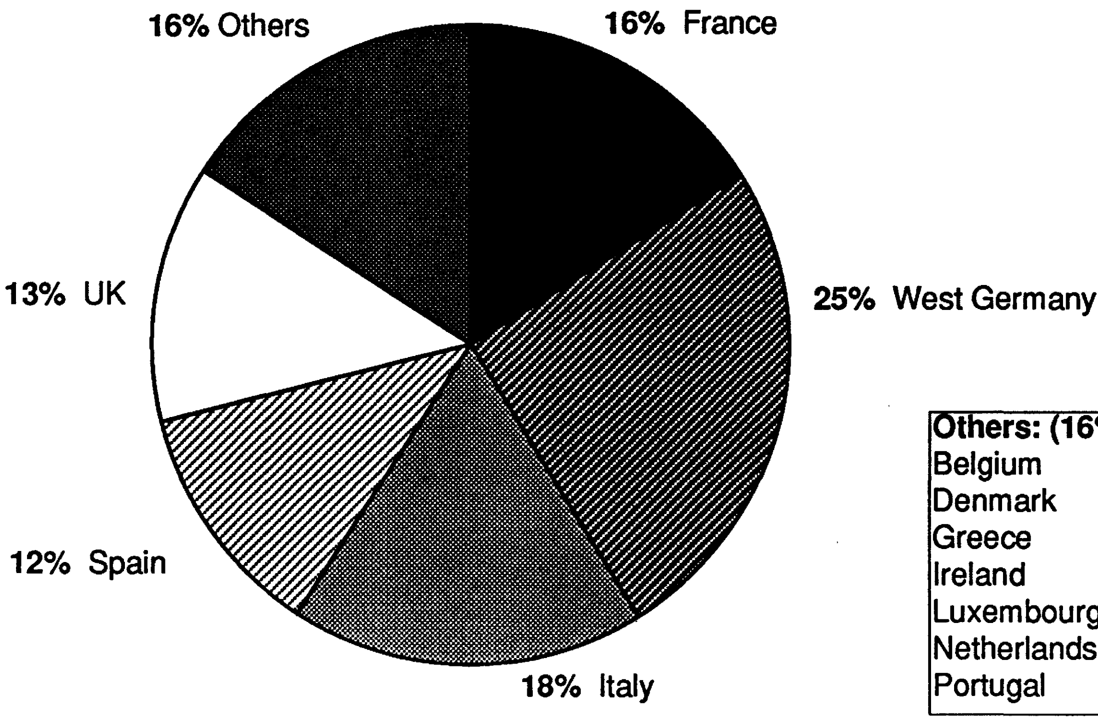
Solar energy contributions



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

Solar energy usage in the European Community 1990

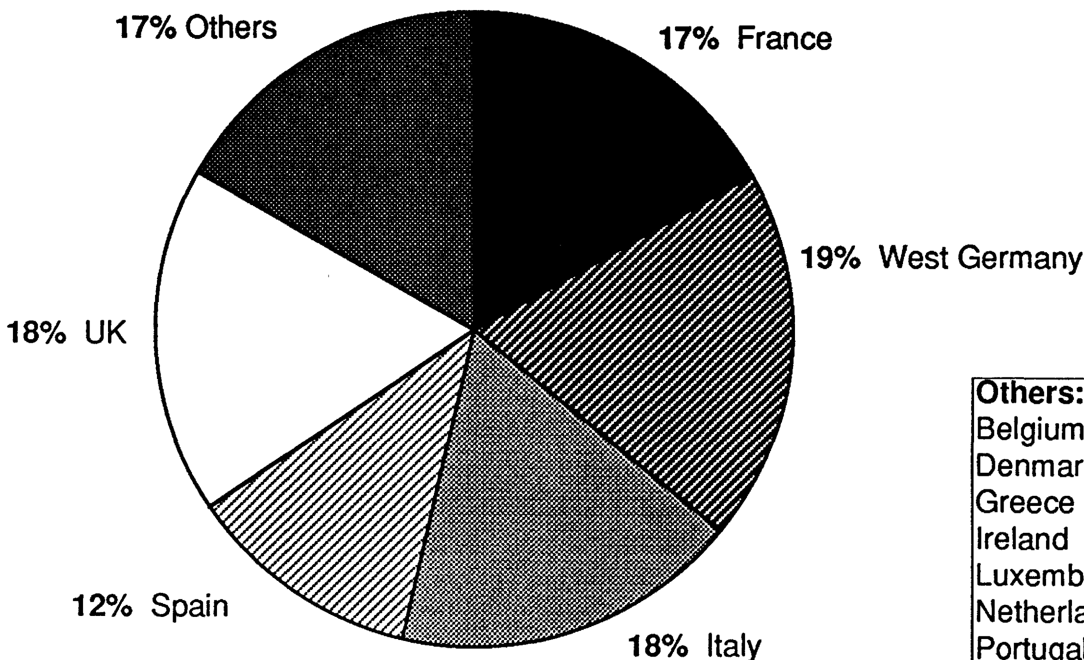
FIGURE 4



Others: (16%)	
Belgium	4
Denmark	1
Greece	2
Ireland	1
Luxembourg	0.3
Netherlands	3
Portugal	3

Population in the European Community 1990

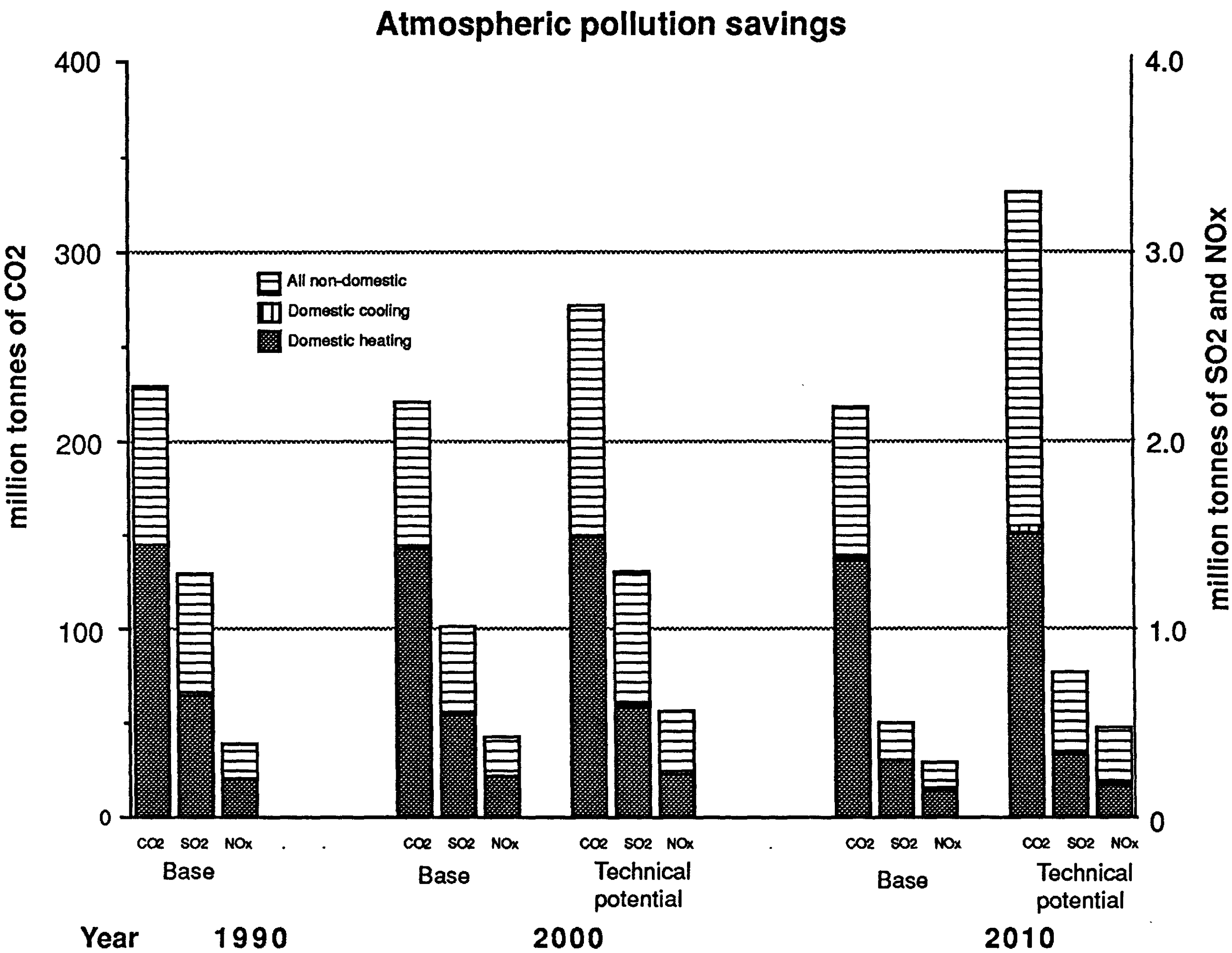
FIGURE 5



Others: (17%)	
Belgium	3
Denmark	2
Greece	3
Ireland	1
Luxembourg	0.1
Netherlands	5
Portugal	3

FIGURE 6

All European Member States



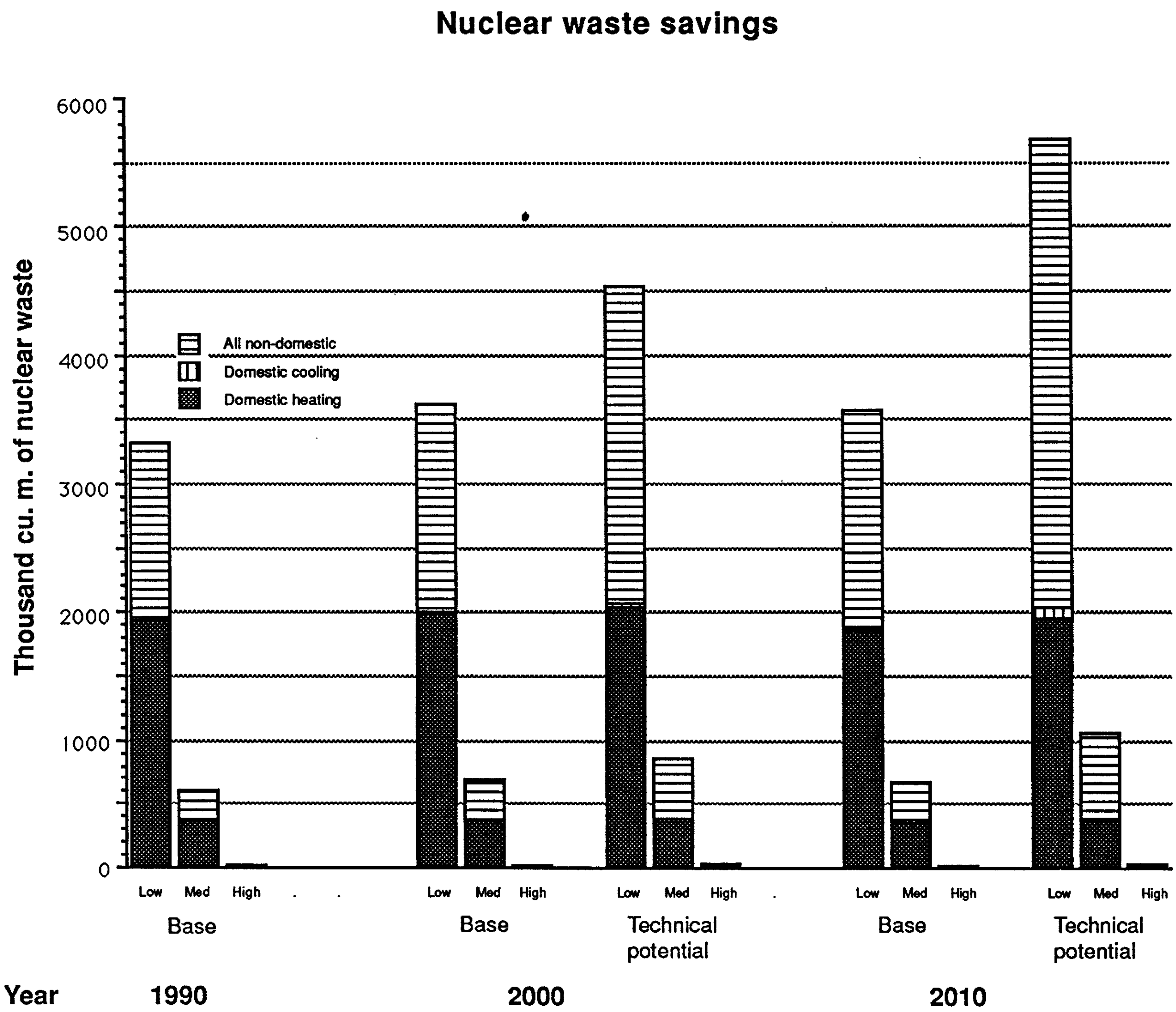
Notes

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.

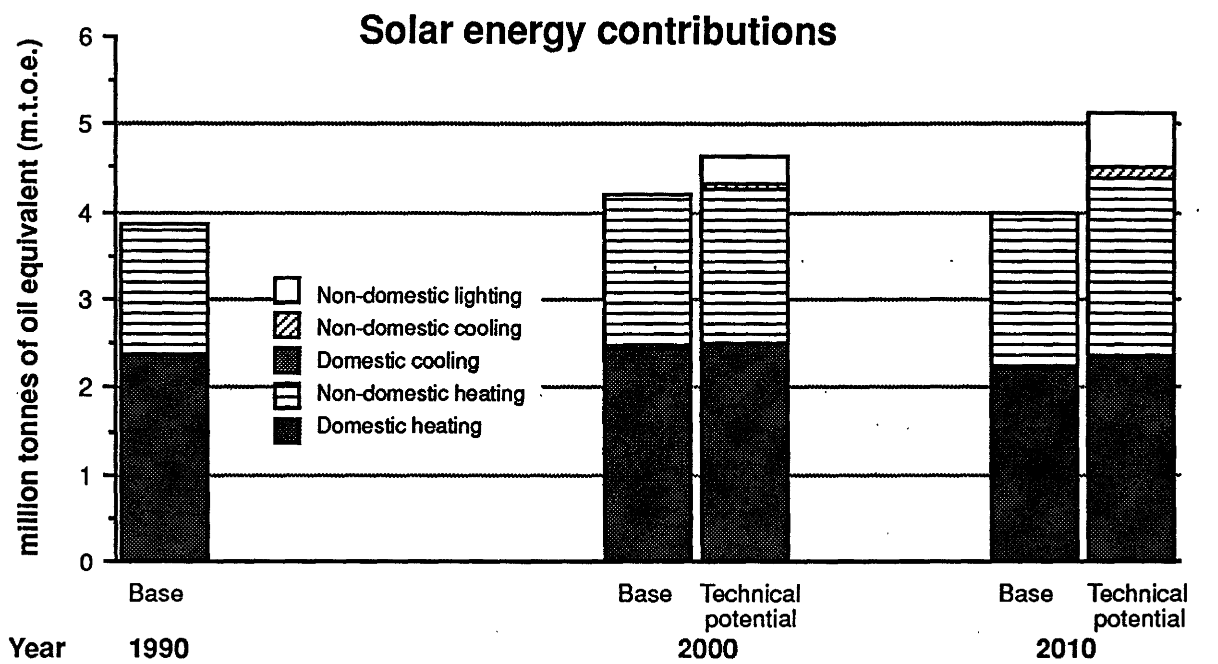
FIGURE 7

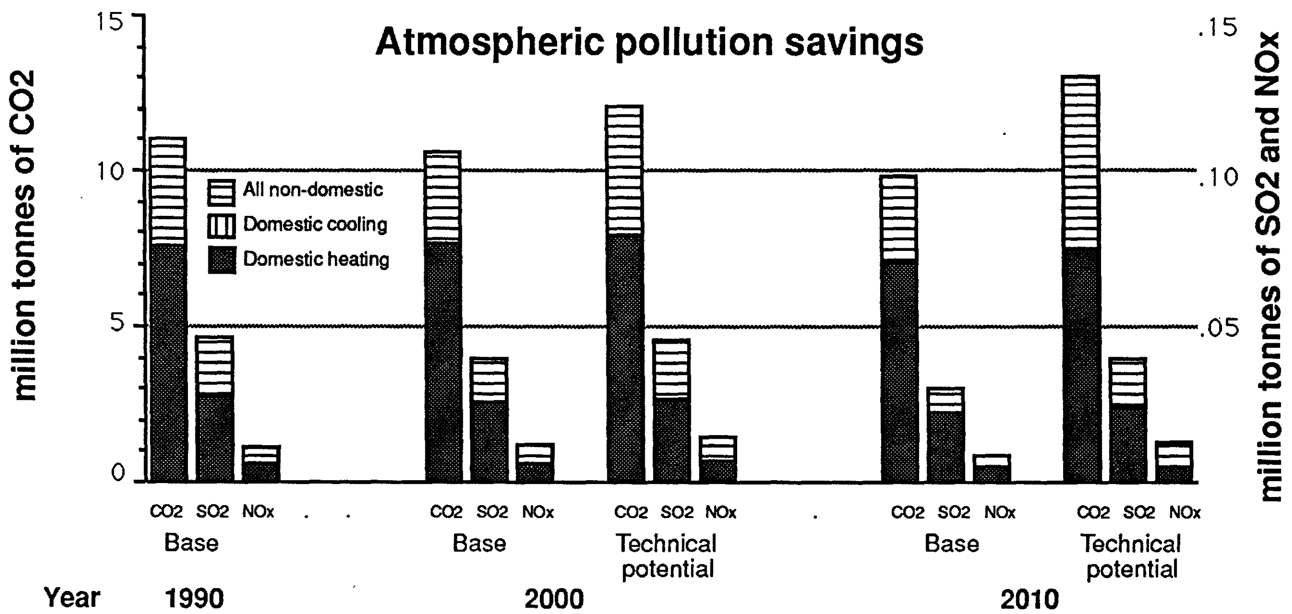
All European Member States



Belgium

FIGURE 8





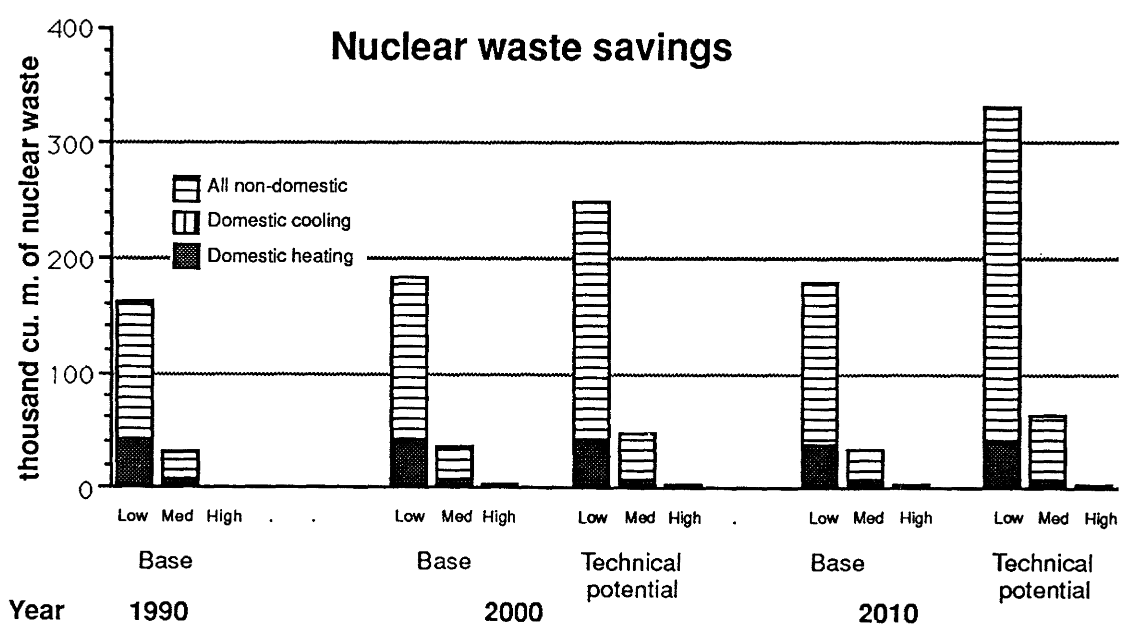
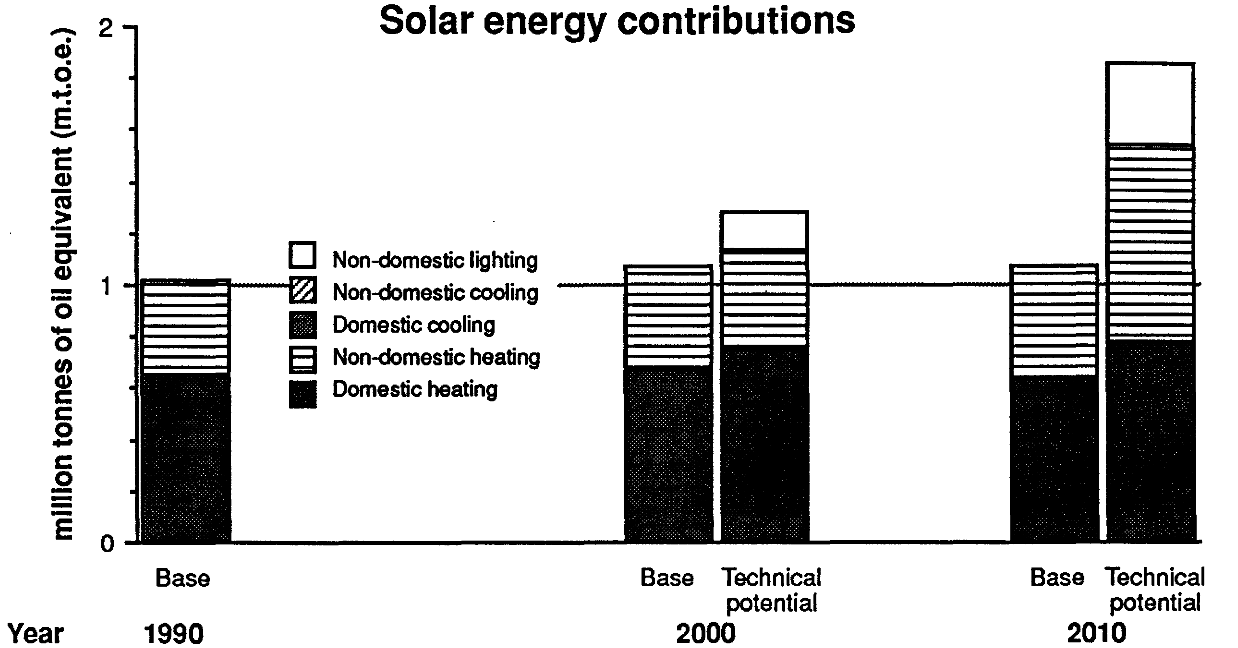


FIGURE 9

Denmark

Solar energy contributions



Atmospheric pollution savings

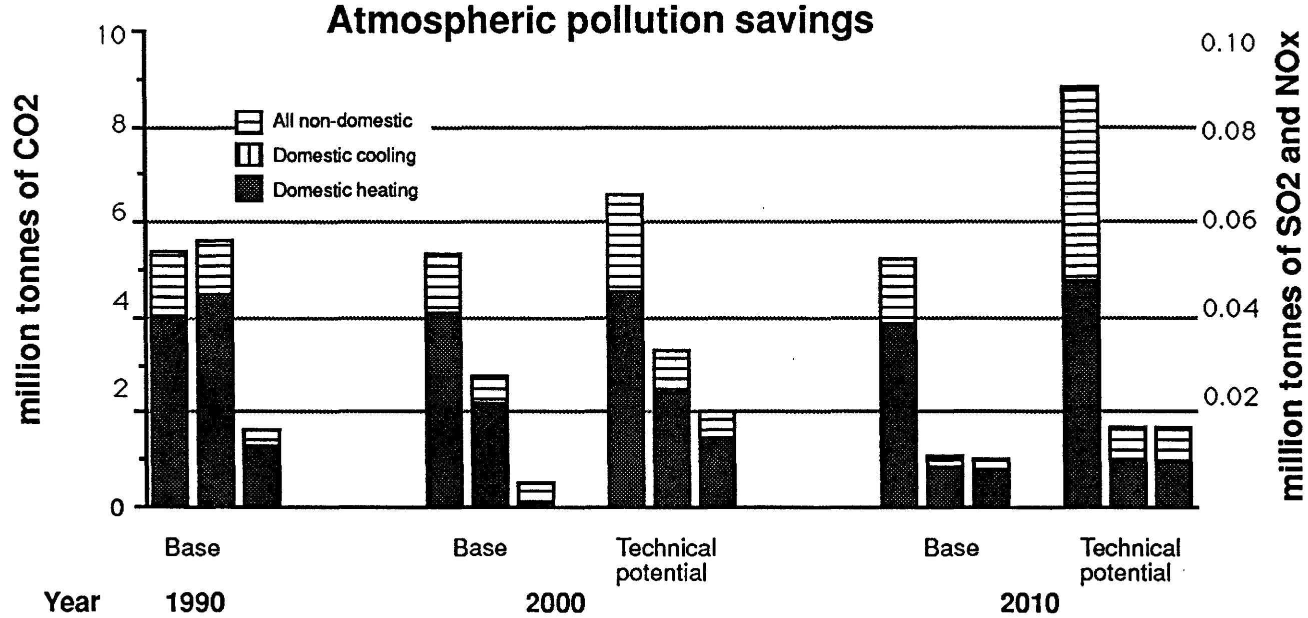


FIGURE 10

France

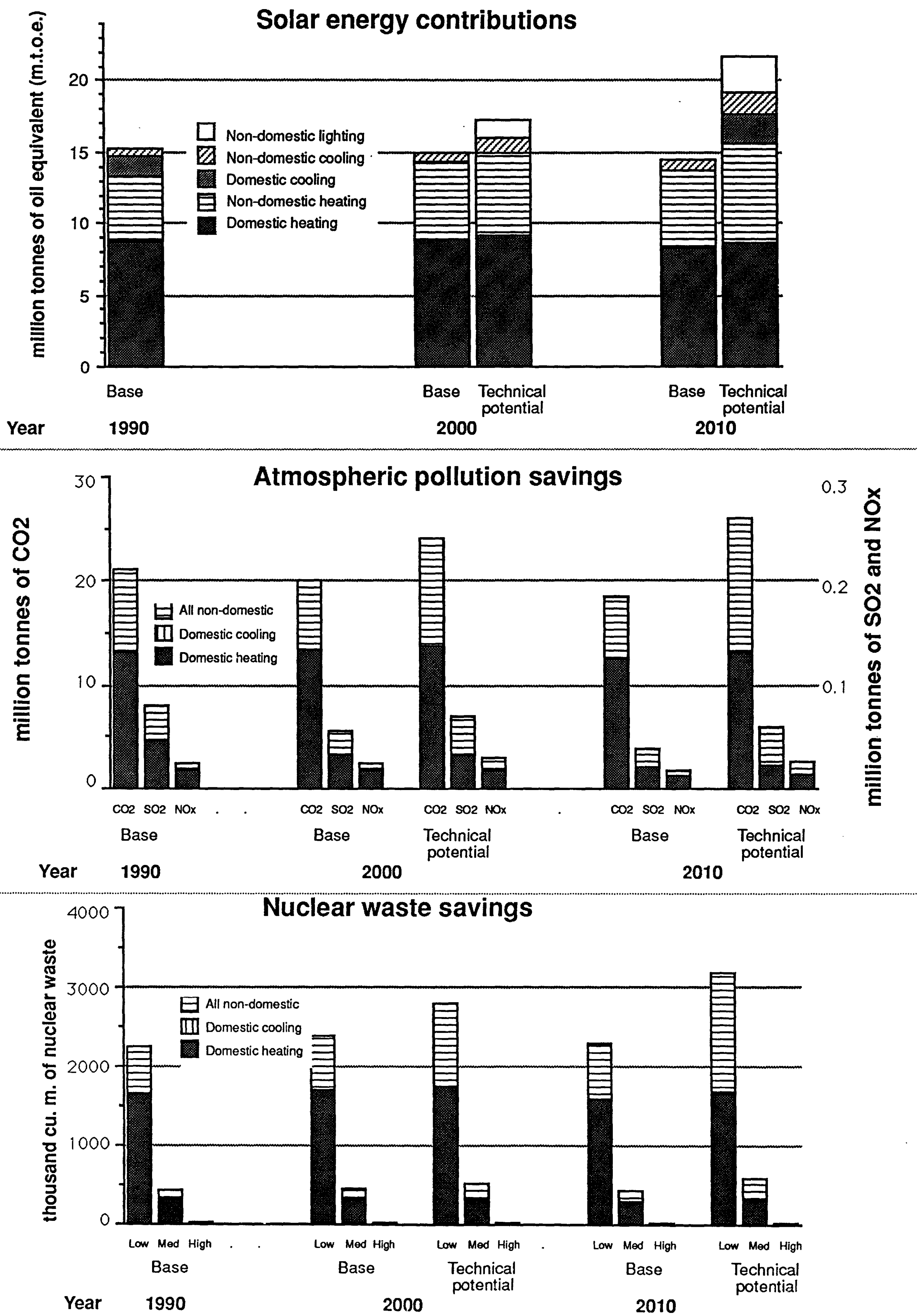


FIGURE 11

Germany

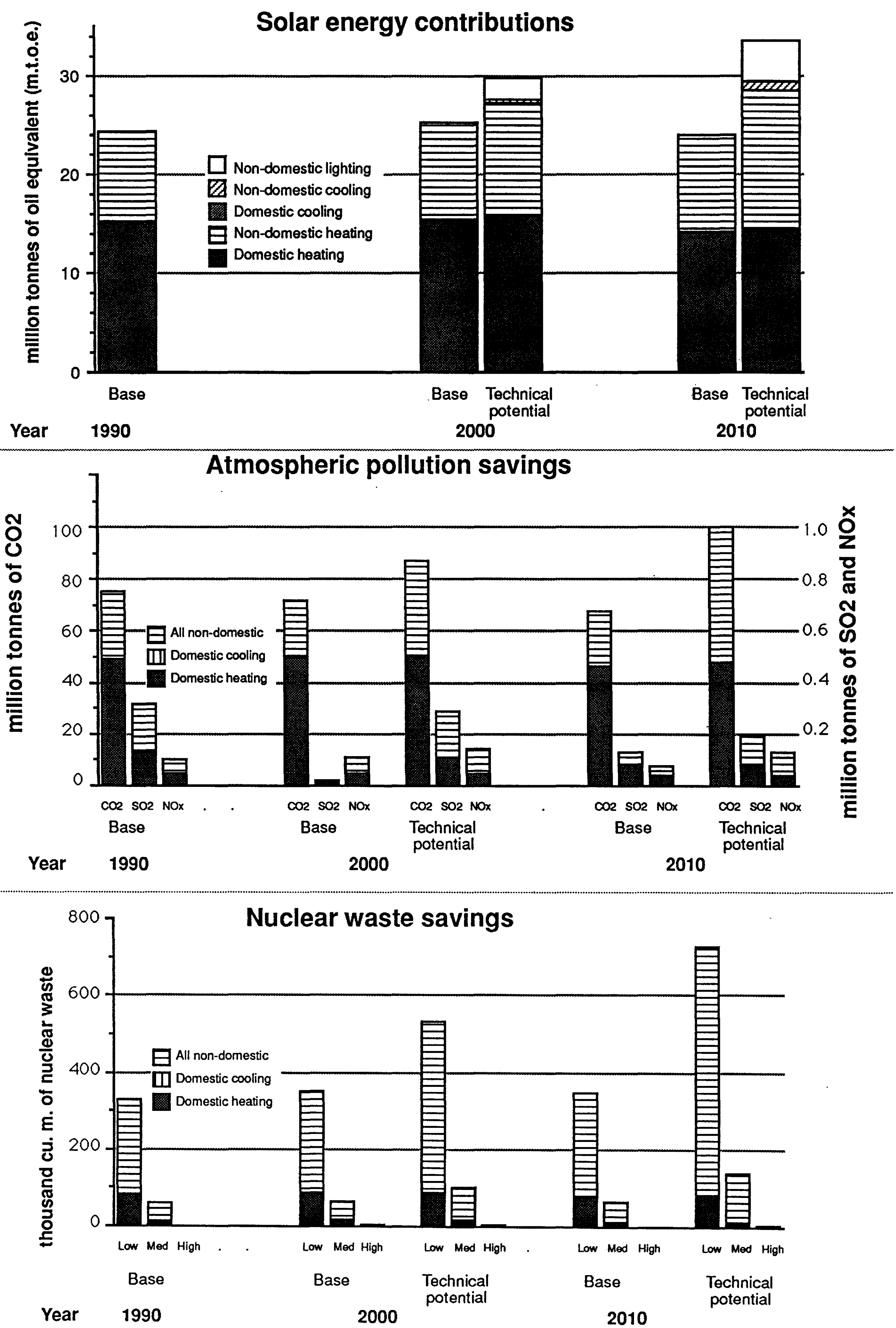
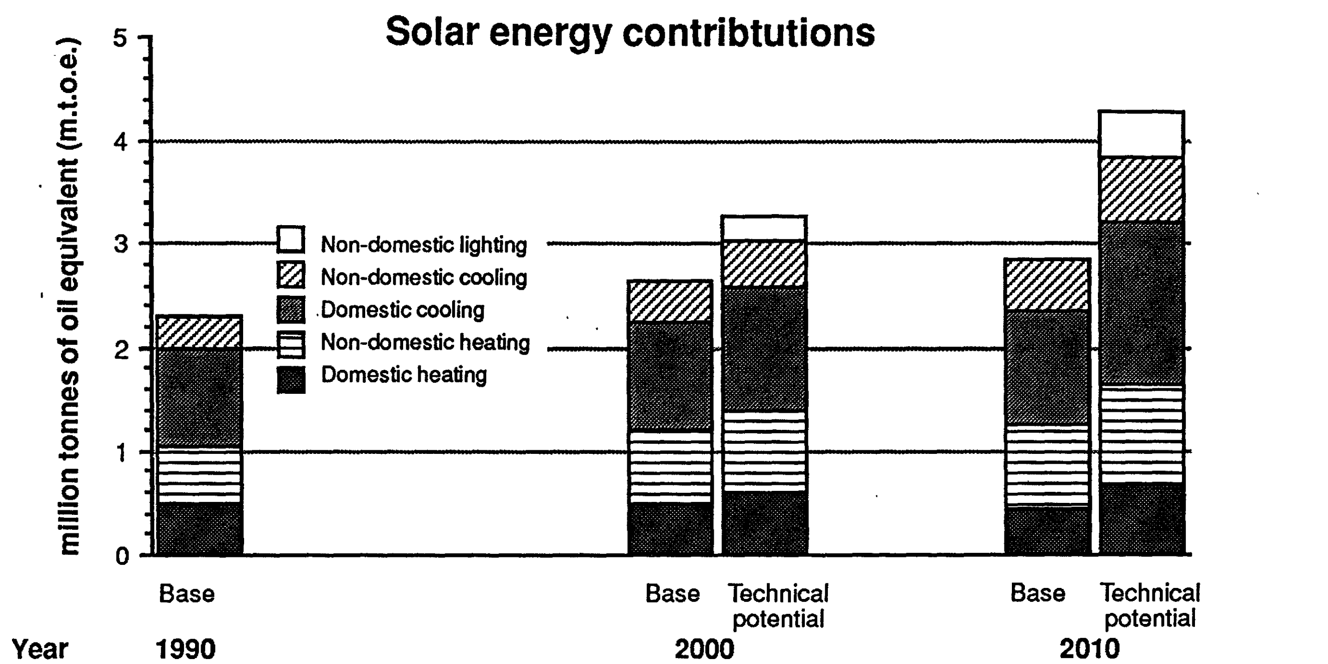


FIGURE 12

Greece



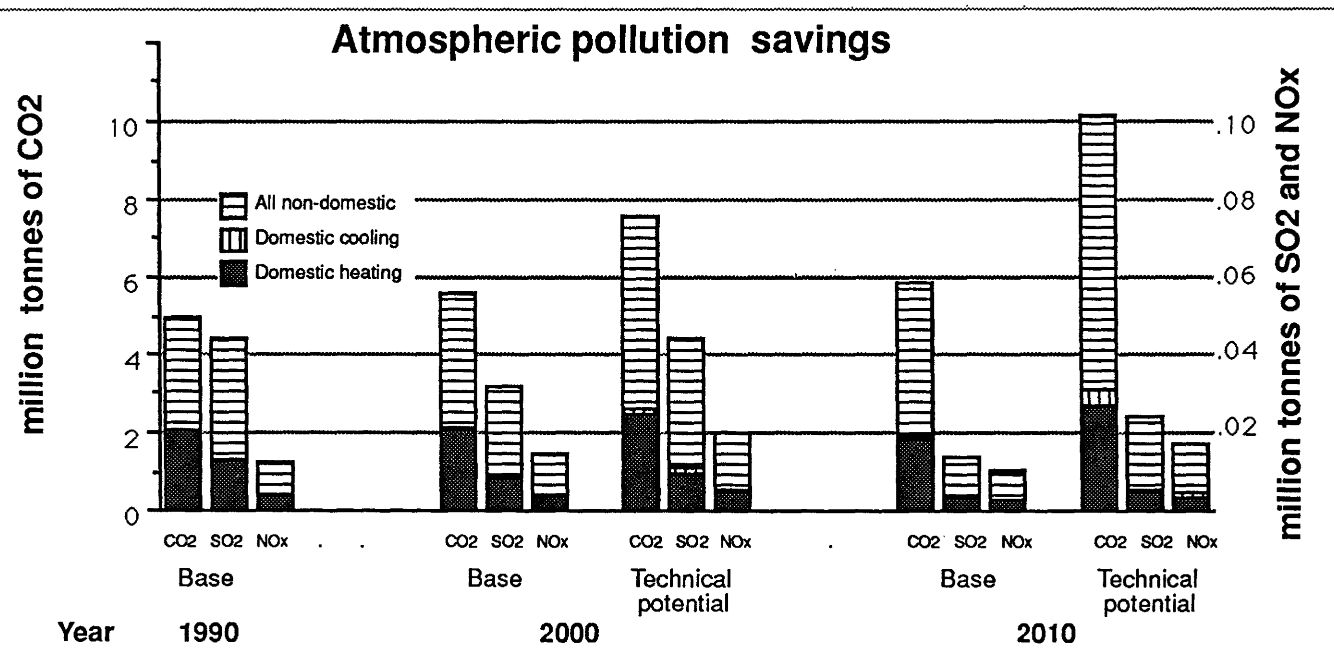
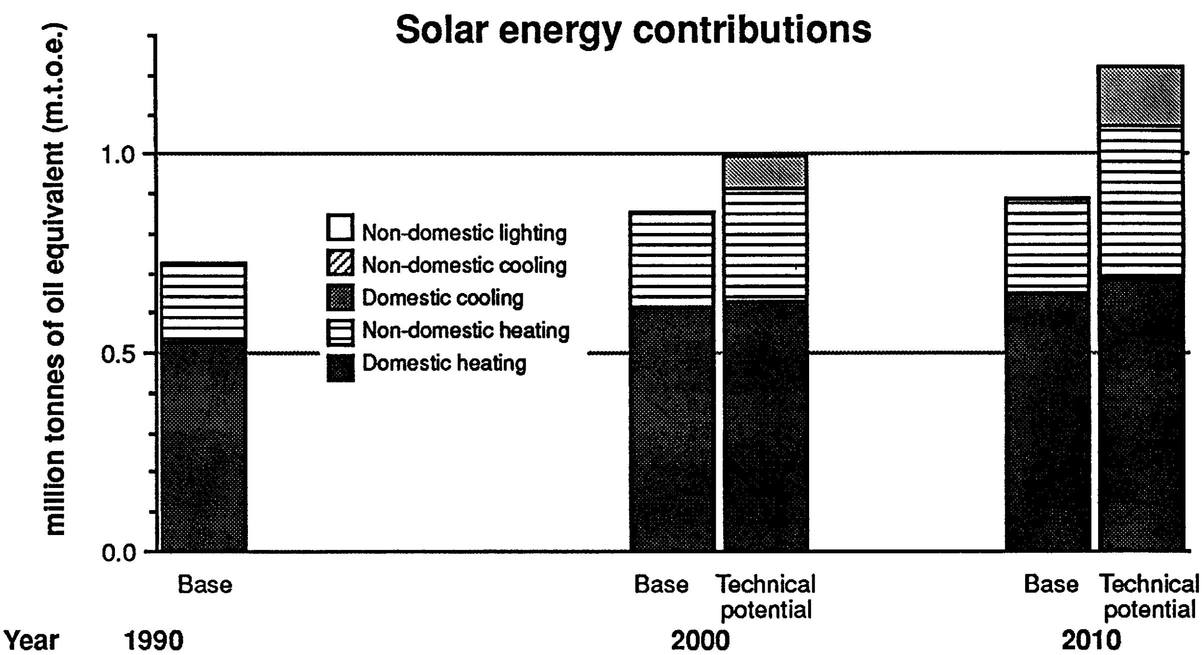


FIGURE 13

Ireland



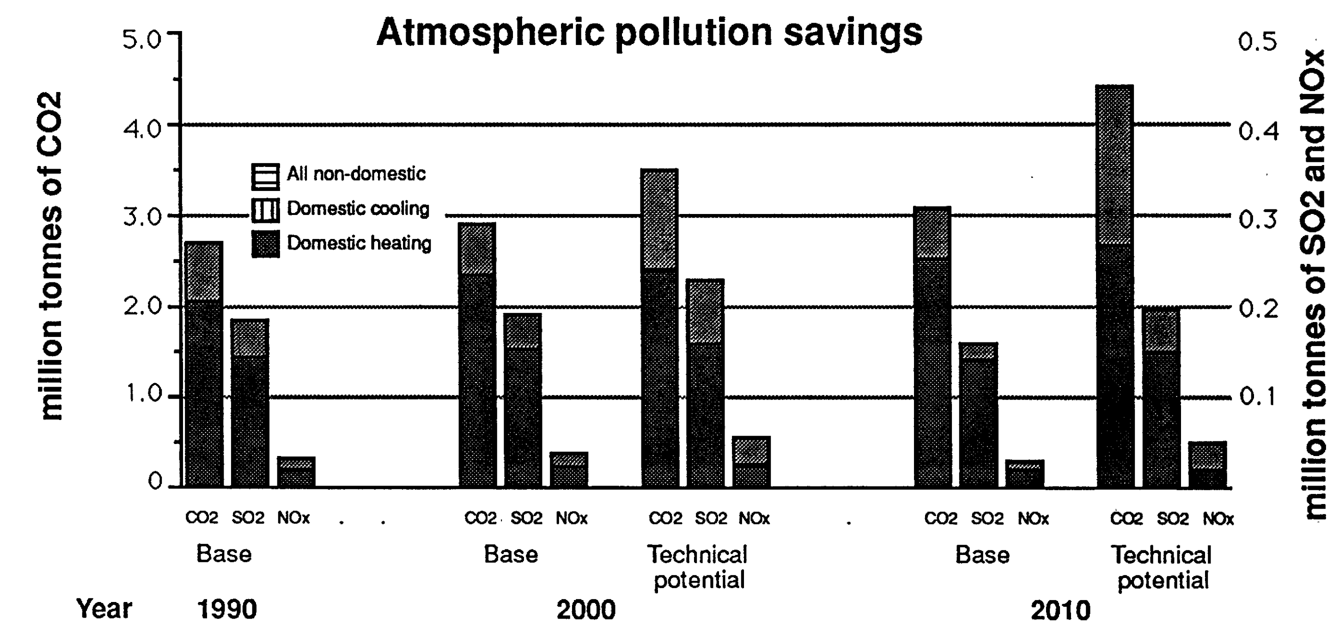


FIGURE 14

Italy

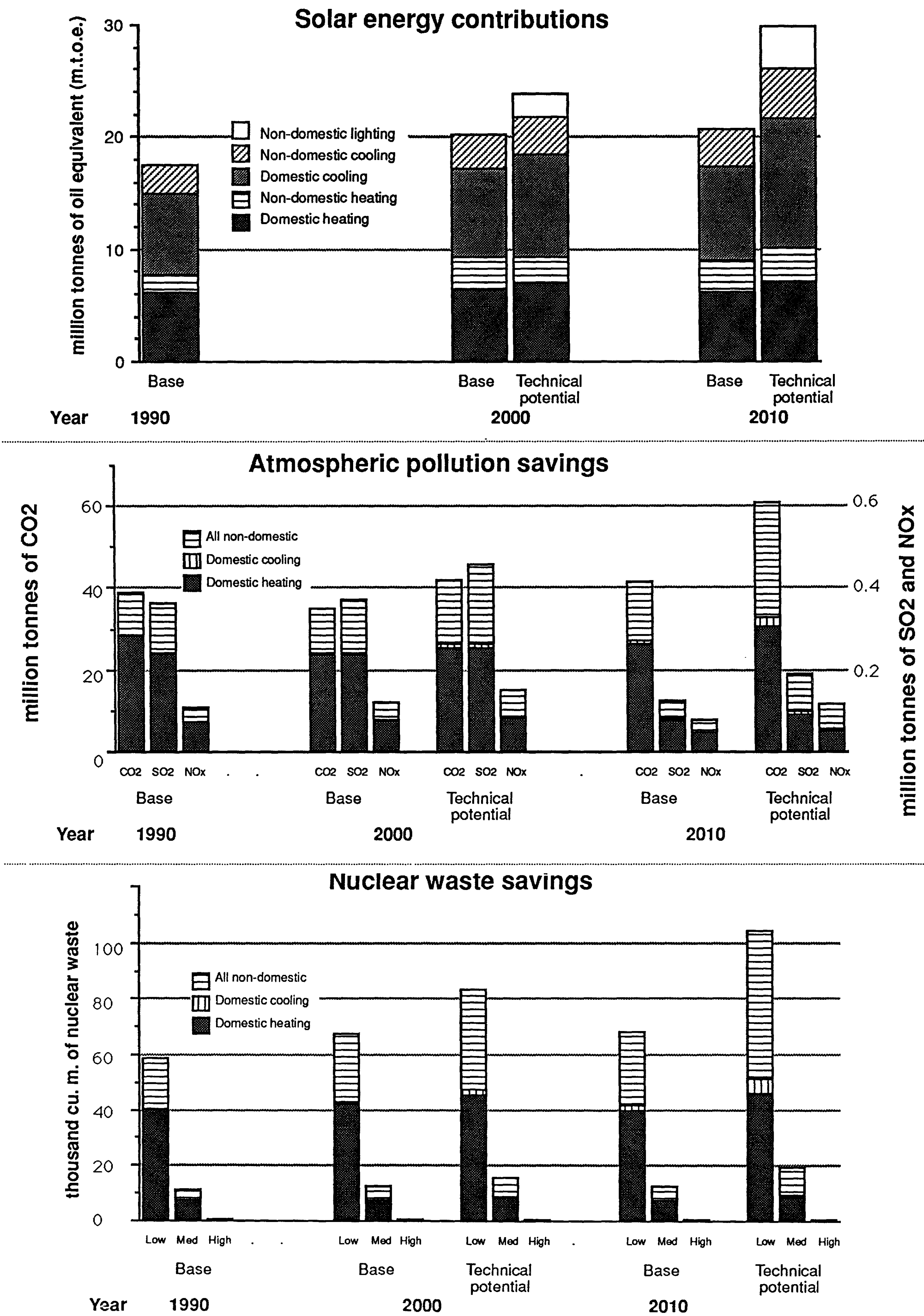
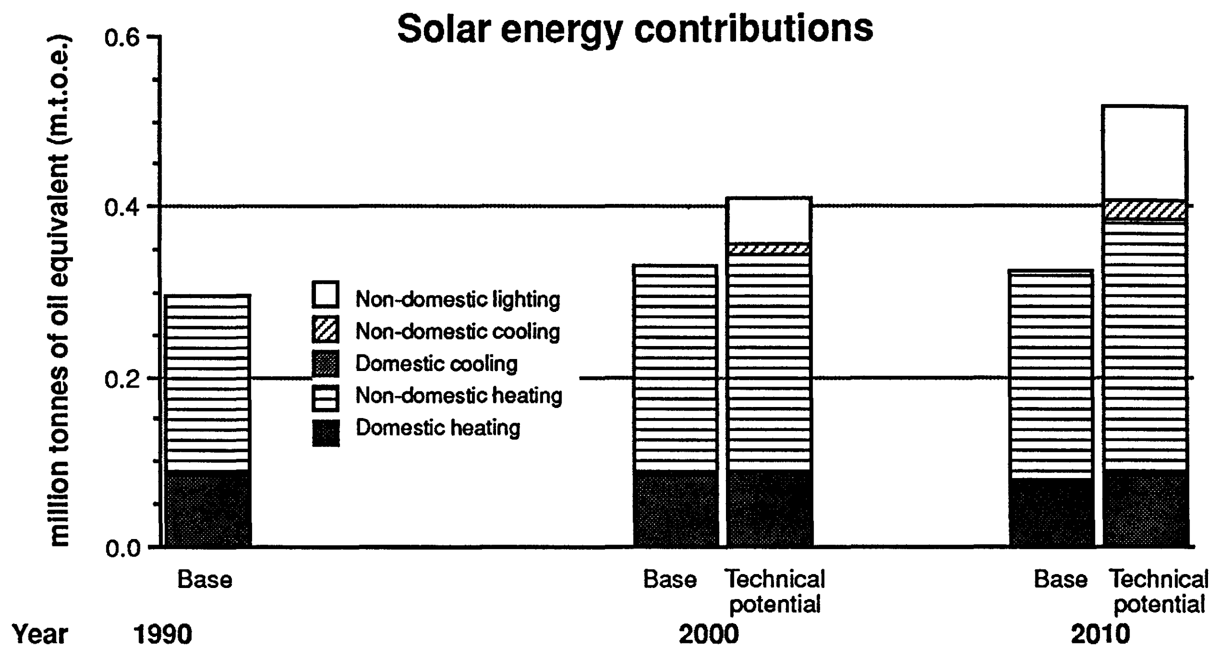


FIGURE 15

Luxembourg



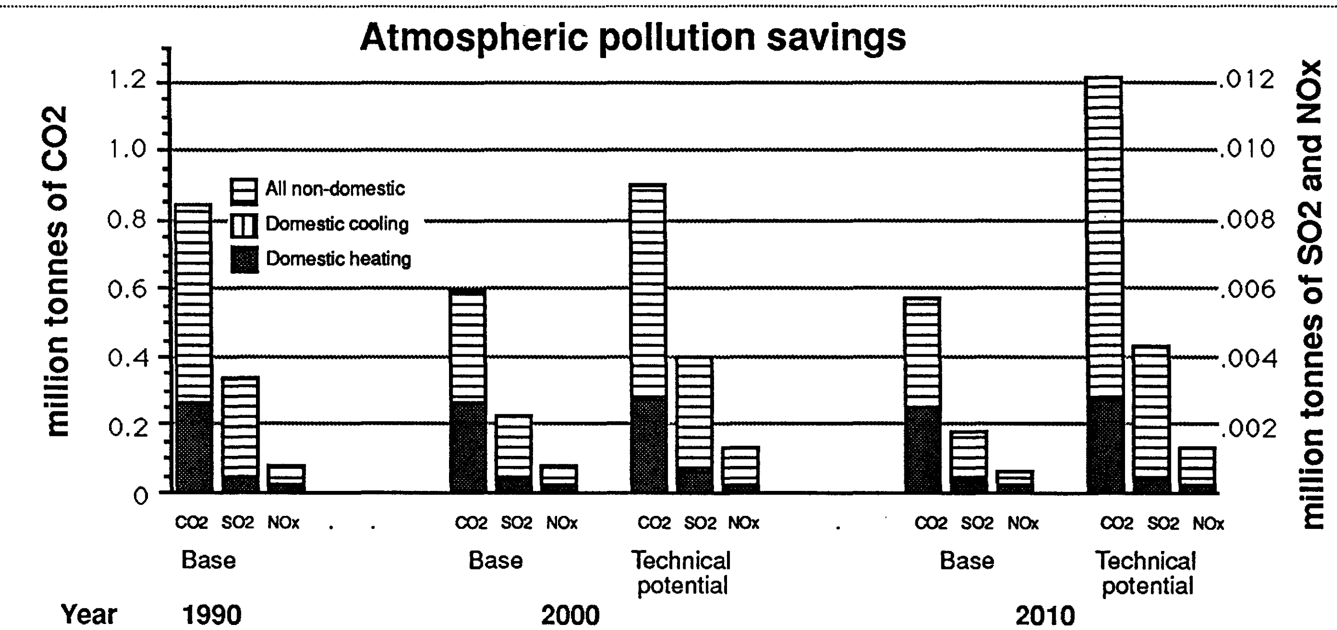
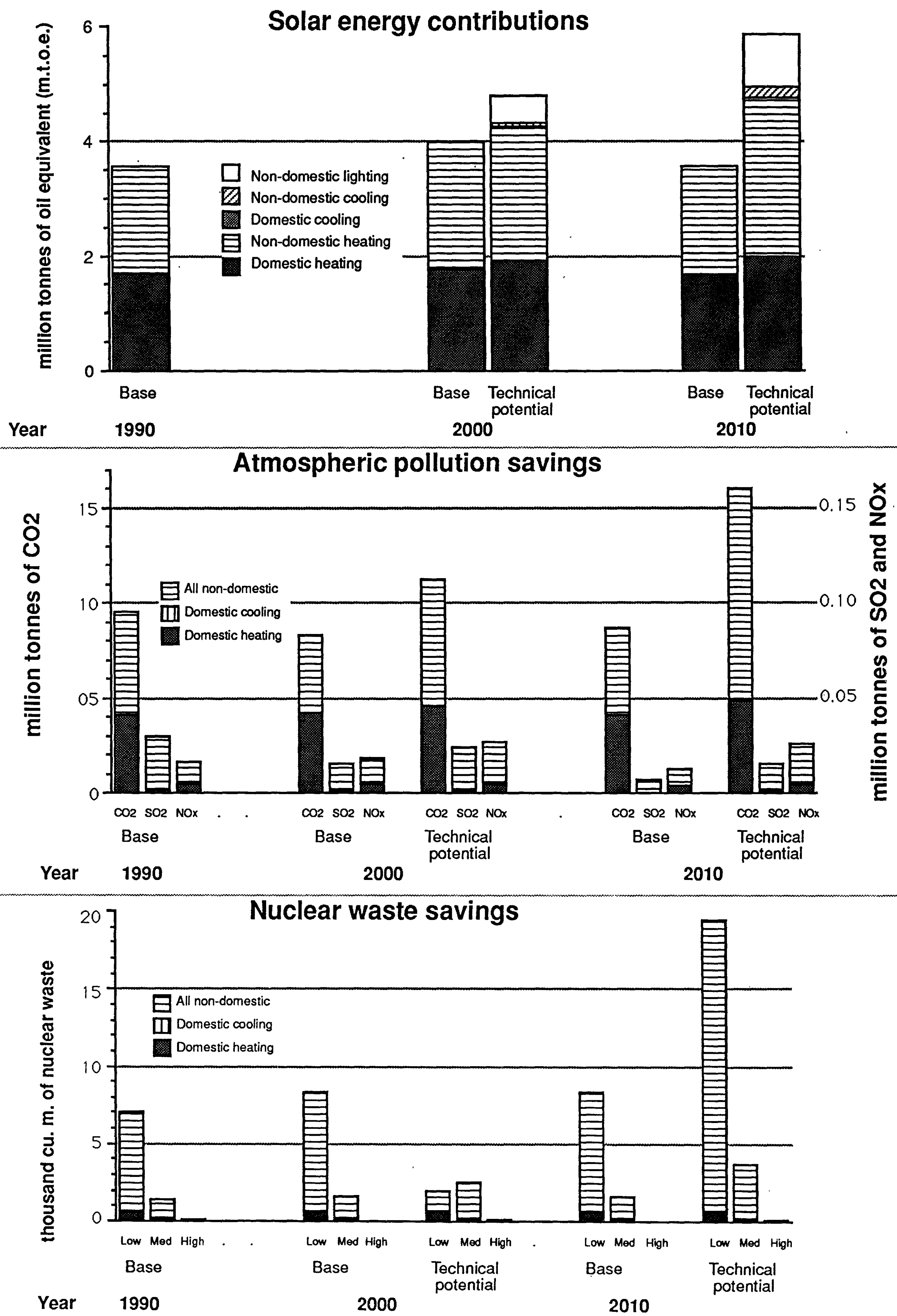


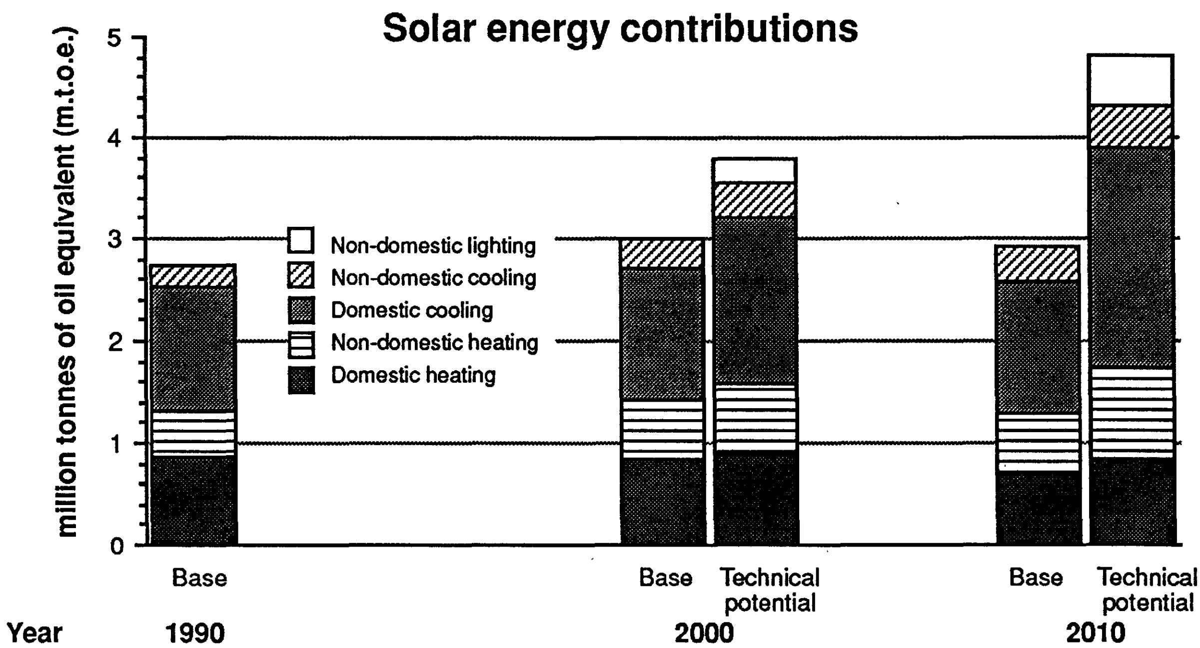
FIGURE 16

Netherlands



Portugal

FIGURE 17



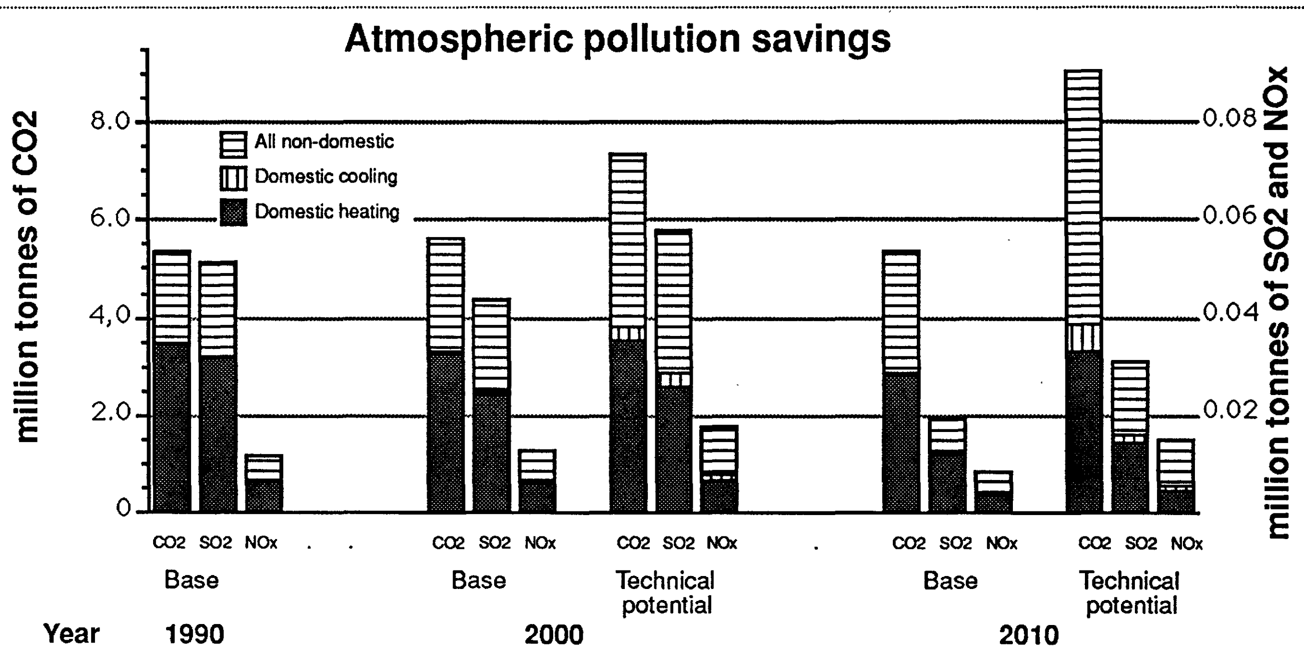
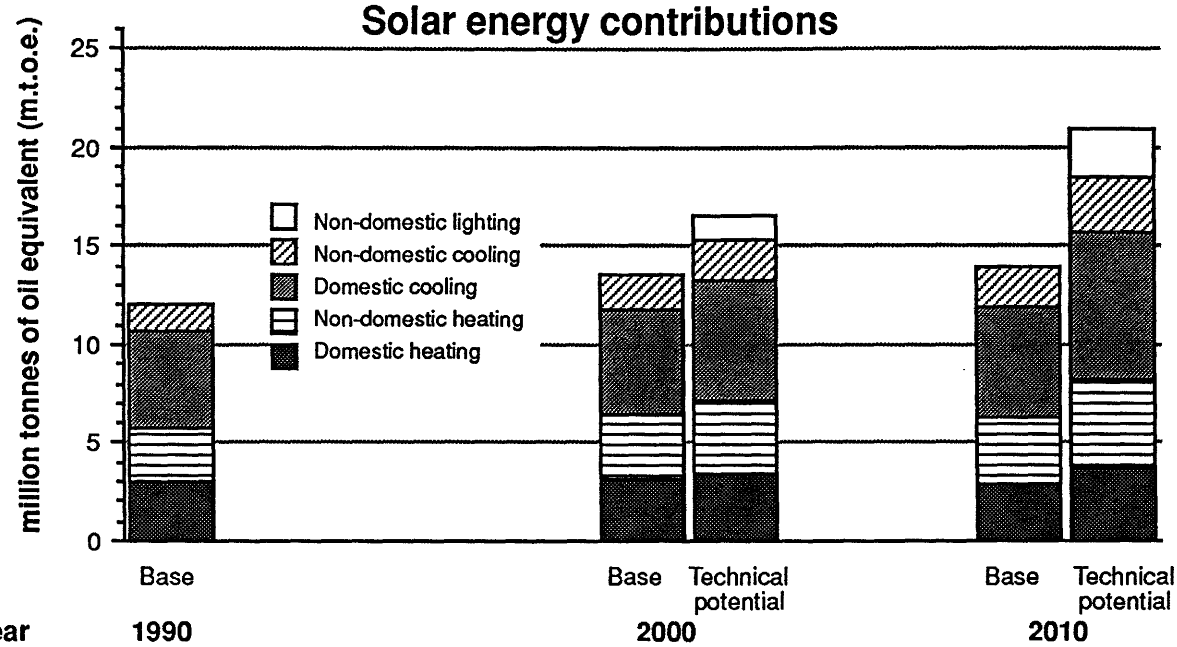


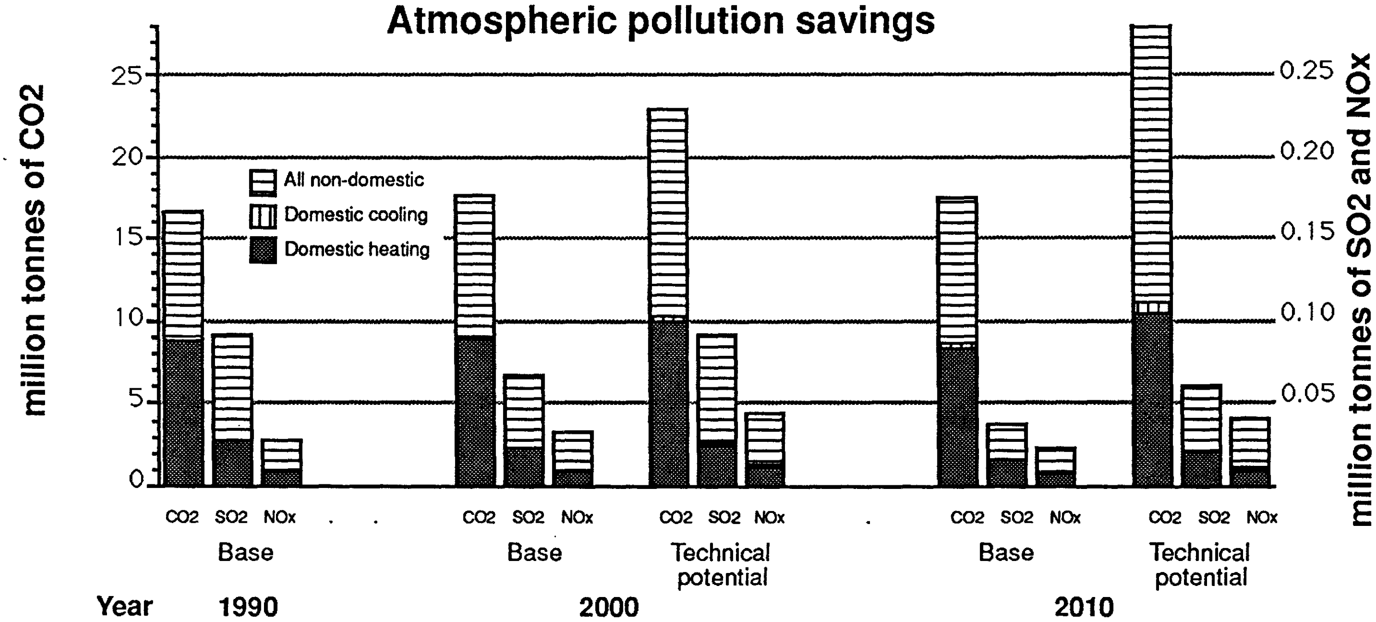
FIGURE 18

Spain

Solar energy contributions



Atmospheric pollution savings



Nuclear waste savings

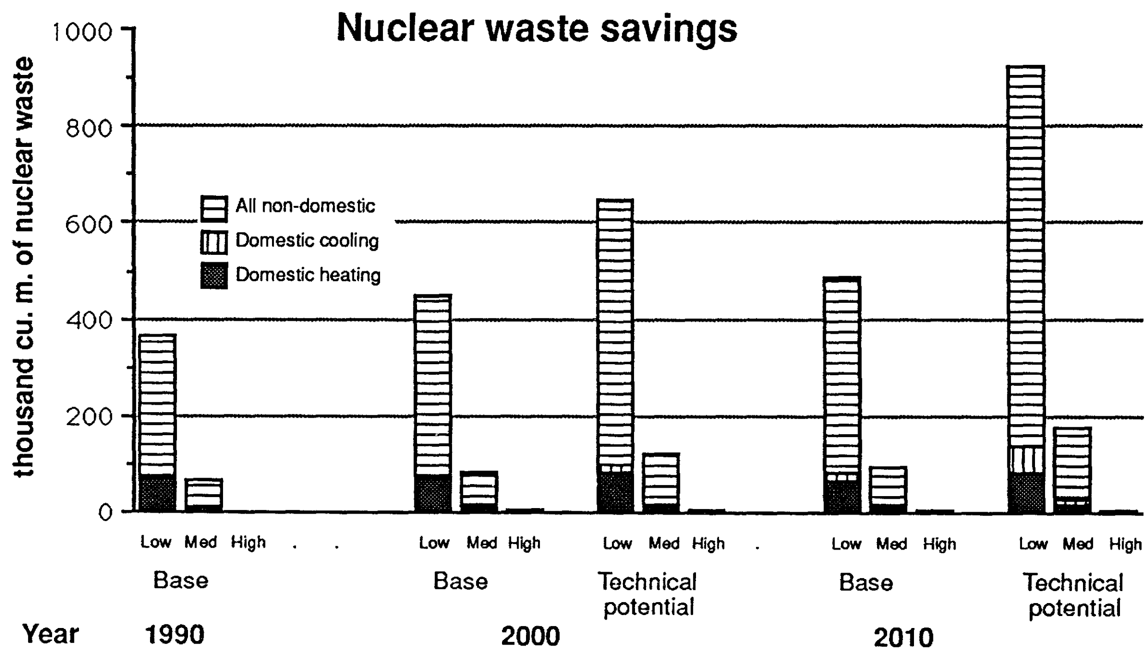
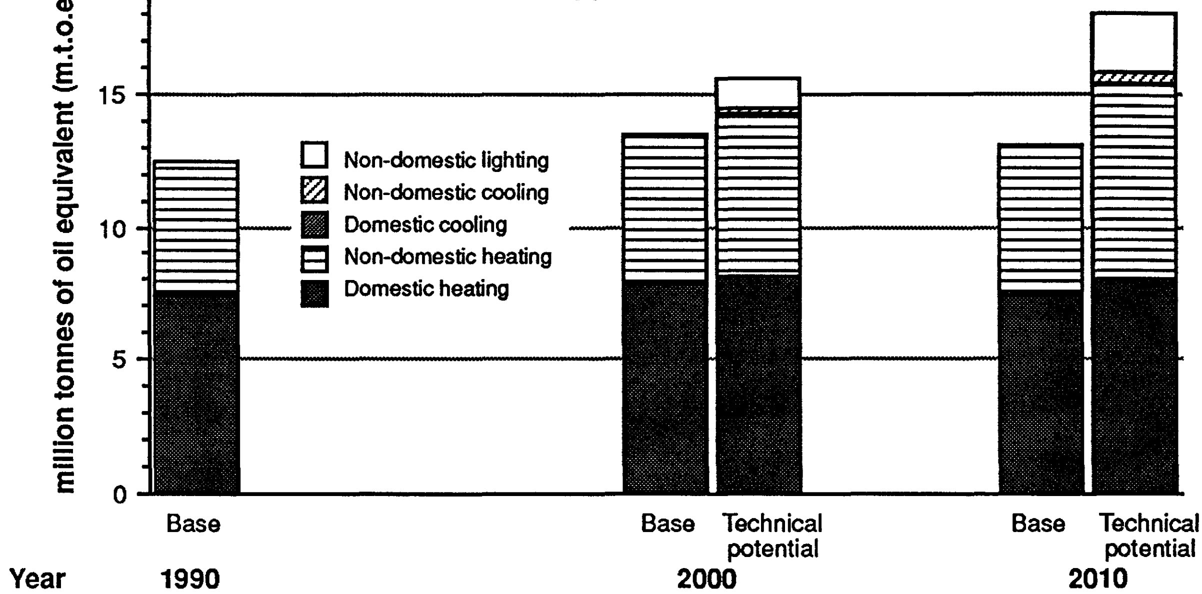


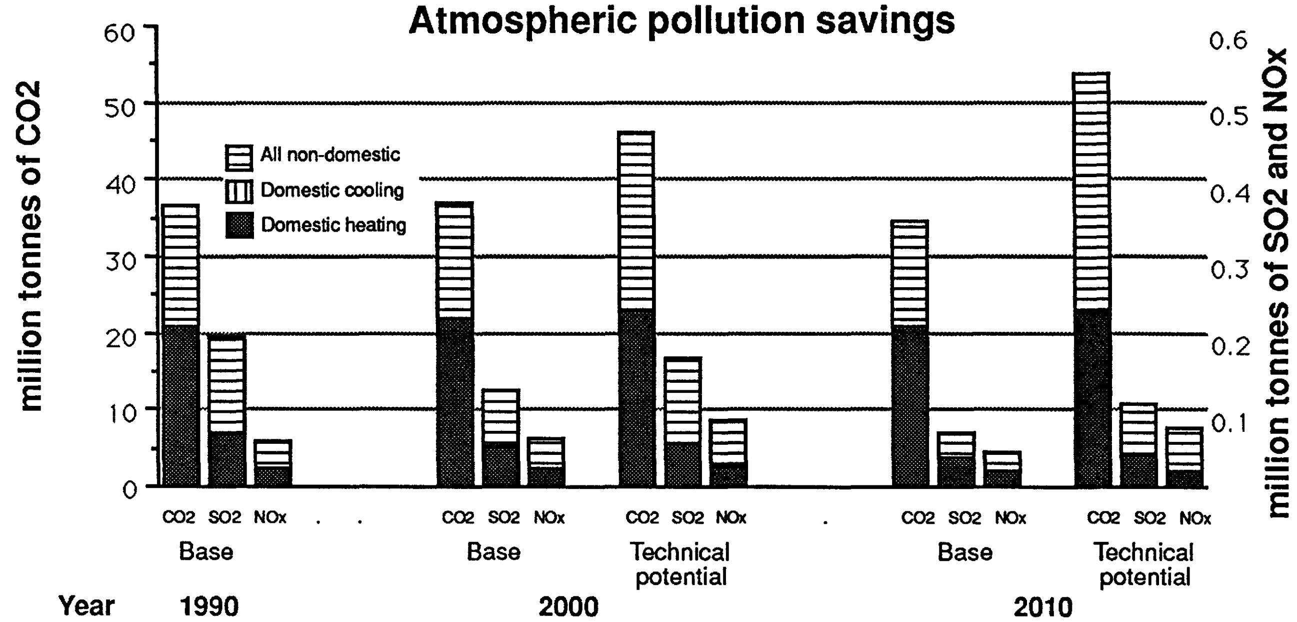
FIGURE 19

United Kingdom

Solar energy contributions



Atmospheric pollution savings



Nuclear waste savings