

AIR

Swegon Air Academy

Part C

Energy
and

outdoor environment

DUNCAN:
THIS
CASTLE
HATH
A PLEASANT
SEAT;
THE
AIR
NIMBLY
AND
SWEETLY
RECOMMENDS
ITSELF
UNTO
OUR
GENTLE
SENSES

[William Shakespeare *Macbeth*]

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FOREWORD

Our need for fresh air, essential to our functioning as human beings, is not normally contested by anyone. This is because we have basic physiological needs - our brains and the cells in our bodies need oxygen so that they can develop and perform properly. However, the air we breathe contains more or less harmful substances and these cause more problems than most of us can probably imagine or understand. On their own, these substances might be troublesome - but collectively, they could be disastrous! Remember, that while we need about 0.75 kg of food and about 1.5 kg of liquid per day, we need at least 15 kg of air!

It is quite reasonable to compare an air handling system in a building to our own respiratory system with its airways and lungs, as both systems have enormous significance for our health and well-being. And, as the air is often used to supply or remove heat, this makes the importance of the air handling system even greater, as it significantly affects our comfort, well-being, productivity and efficiency. Buildings, too, need a continuous change of air to feel good.

LACK OF COMMON POINT OF VIEW

Bearing in mind all of the above, it is rather odd that those involved in planning a building rarely see things from the same point of view. Short-term economic interests are often allowed to determine the choice of technical solutions and, when costs are not critical, buildings are all too often designed in such a way that they are neither pleasant to occupy nor energy-efficient. And, up to now, it has been rather difficult to accept feedback and learn from expensive mistakes, and thereby avoid repeating them.

This book focuses on three main areas: Public health, energy and the environment. We are also convinced that economical aspects must be considered as well and this is a recurring topic throughout the book. No matter how efficient and health-promoting an investment might look, it would most probably never be carried out if it were not shown to be economically viable. Today, reliable research results show that there is a clear connection between poor indoor climate and ill-health. And ill-health costs a great deal of money. In other words, there is a real incentive for property owners to invest in good indoor climates now, as future tenants will almost certainly step up their demands.

In this electronic age, it is becoming increasingly obvious that control, regulation and monitoring will play a decisive role when it comes to maintaining good indoor climates and ensuring energy-efficient operation of buildings, with subsequent minimal impact on the outdoor environment. The importance of providing solutions that give the client maximum freedom of choice and flexibility is illustrated in Chapter 31/The intelligent building - a matter of choice, which discusses centralized building management systems, so-called BMS systems, for control, monitoring and management.

In this book, *Swegon Air Academy* has compiled ideas and points of view from a wide range of experts. The aim of the book is to put a spotlight on factors and circumstances that are important in the quest for pleasing indoor environments and comfortable indoor climates, with due regard to energy issues and the outdoor environment. Our ambition has been to explain complex relationships in an intelligible way. It is our profound belief that it is possible to radically improve poorly functioning systems - if we can explain the whys and wherefores.

The passage of air through an air handling system is described, from the outdoor air intake, via an air-conditioned room and into our lungs, with a full account of what happens on the way. The physiological aspects, as well as the comfort, energy and environmental aspects, are examined. How different building designs affect the opportunities for creating good indoor climates is also discussed. Here, the effects that different factors have on each other are not always self-evident or discernable, nor are their specific effects on the indoor climate and total costs. We have, therefore, chosen to illustrate a number of them in greater detail and hope that this will contribute to future developments, for the benefit of all concerned.

**PUBLIC HEALTH,
ENERGY AND
ENVIRONMENTAL
ISSUES - AND
ECONOMIC
REALITIES**

**CONTROL,
REGULATION AND
MONITORING - THE
DECIDING
FACTORS**

**COMPLEX
RELATIONSHIPS
- SIMPLE
EXPLANATIONS**

TARGET GROUPS This book is intended not only for clients, property owners and engineers, who can influence the design, layout and indoor climate of a building, but also for everyone who would like to learn more about the air we breathe and how it affects us.

Increased insight will make it possible to avoid unnecessary costs, both in the investment stage and in the operational stage of a building project. Attractive premises are a must for survival on a competitive property market.

THE AUTHORS This book blends theoretical knowledge from the academic world with practical market experience. Our ambition has been to portray the present-day situation and the opportunities in store in an objective and unprejudiced way, by engaging highly distinguished experts and writers from a representative cross-section of the industry.

Proceeds from the sales of this book will be reinvested in the activities run by *Swegon Air Academy*, i.e. in objective transfer of know-how and exchange of information via seminars, technical articles and publications. The contents of this book are available to schools and training programmes connected to the heating and ventilation industry at a subsidized rate.

Enjoy the book!

CONNY NILSSON

Director of the *Swegon Air Academy*

[*AIR Swegon Air Academy*]

PART A VENTILARE NECCESE EST...

PART B ECONOMIC AND SOCIAL RESPONSIBILITY

PART C THE ENERGY AND OUTDOOR ENVIRONMENT

PART D THE INDOOR ENVIRONMENT - IN A WIDER SENSE

PART E AIR TREATMENT AND INDOOR CLIMATE

AIR

Swegon Air Academy

Part C

Energy

and

outdoor environment

C. ENERGY AND THE OUTDOOR ENVIRONMENT

CONNY NILSSON *Swegon Air Academy*

Melting glaciers and spreading deserts. Trees starting to grow on mountainsides that have been bare from time immemorial. Sea levels rising so that coastal towns have to build protective dikes. People in large Asian towns buying a few lungfuls of oxygen to help them through the day, if they can afford to. Hurricanes and tornadoes, in increasing numbers, devastating whole communities in their paths. There is no limit to the phenomena that feel unnatural, strange - and frightening. It seems that a majority of researchers worldwide agree that the reasons behind them can be found in western lifestyles that we, today, look on as being quite natural. Of course, there are those who maintain that these phenomena are all results of natural climate variations and are, therefore, not worth worrying about. No matter what view you subscribe to, it ought to be in the interest of everyone to be cautious. If each and every one of us were to do what we could, to act as sensibly as possible and, thereby, contribute to averting a future catastrophe - wouldn't it be worth the trouble?

Greenhouse gases, i.e. gases that contribute to the so-called greenhouse effect, include carbon dioxide, which, to a great extent, comes from the combustion of fossil fuels for heating and from oil and coal fired power stations that are run to produce electricity.

CFCs, chlorofluorocarbons, also known as freons, have been used in air conditioning equipment for a great number of years and this use has, and still does, actively contribute to the greenhouse effect.

These are just a couple of examples from areas in which the building industry could play an active part towards more positive developments.

Time and again, we are reminded that supplies of oil, natural gas and

coal are not infinite and, even if supplies are not yet completely exhausted, it's high time we considered what we are going to do when they are. It is quite clear that the situation will entail great changes for everyone and the longer active and offensive investments are held back for shortterm economic gain, the harder it will be to achieve any real change.

Al Gore's film *An Inconvenient Truth* has placed worldwide public focus on environmental issues. Motivation, and the will to contribute towards something positive, has never been stronger.

The EU directive on the energy performance of buildings has also meant that energy and, consequently, environmental issues have been brought to the attention of property owners in an unprecedented way - possibly with the exception of the energy crisis in the 1970s. We are also very much aware of another aspect of the energy issue: A large proportion of the world's coal and oil reserves are found in countries that are not regarded as being sufficiently stable. There have also been a number of recent instances when oil has been used as an instrument of force for political purposes. Facts like these also tell us that we should do everything we can to reduce our dependency on fossil fuels.

The building and property industries are well equipped to contribute to a more sensible use of our limited energy resources. Know-how regarding energy-efficient installations is readily available. All that is needed now is a whole-hearted and concentrated effort to apply this knowledge and to find ways of establishing profitable and progressive cooperation, both between the different players on the market - and with researchers engaged in building and energy issues.

6. FOSSIL FUELS – A FINITE RESOURCE

Professor **KJELL ALEKLETT** Uppsala University, Sweden

In the twentieth century, we increased our standard of living through the use of coal, oil and natural gas; but now, in the 2000s, we must learn to use less fossil fuel. Carbon dioxide is released when we burn fossil fuels. Our climate will change if we continue to increase the concentration of carbon dioxide in the atmosphere; however, the real reason we must learn to live with lower fossil-fuel consumption is the fact that the supply of oil, coal and natural gas is finite. During the 2000s, production will also diminish.

Fossil fuels are stored solar energy. Millions of years ago, when plants and algae flourished in abundance, huge amounts of carbon dioxide were consumed and coal, oil and natural gas were formed. Now we are releasing this carbon dioxide. The carbon atom in coal, oil and natural gas reacts with oxygen in the air and carbon dioxide is formed when energy is liberated during combustion.

As a child, I lived on a small farm in Västergötland, Sweden. I remember that the coke bin was filled every autumn and how, each early morning in winter, my father had to shovel coke to heat our house. But during the 1950s, that fantastic day came when oil replaced coke. Two welders carried in enormous sheets of steel, which were to be the oil tank, and an oil burner was installed with the boiler. This was the age of oil heating, and during the 1960s and '70s, most newly built homes were equipped with oil-fired boilers.

In the 1970s, Sweden entered the nuclear era, and new single-family dwellings were most often heated electrically. As shown in Figure 1, our oil dependency began to sharply diminish. At the same time, we expanded our district heating. Oil, which had hitherto been the obvious choice

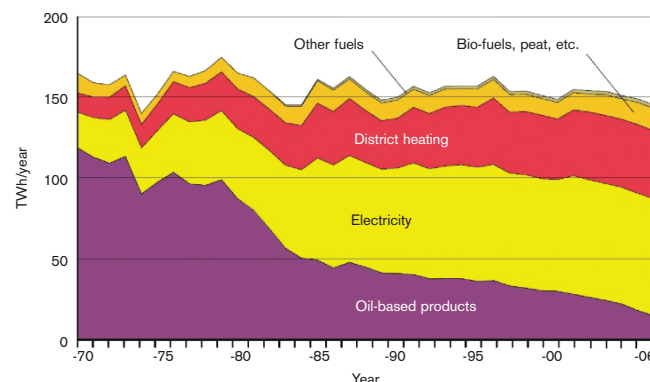


FIGURE 1. Energy end use in the residential and service sector, 1970–2006. Use of bio-fuel in district heating is indicated as district heating. [Energimyndigheten, Energiläget 2005]

for heating multi-family dwellings, was gradually replaced by district heating systems in which the use of bio-fuels has become all the more common.

In Sweden, there was a transformation during the twentieth century from chiefly bio-fuel to fossil-fuel-based heating. Now, we are shifting again to greater use of bio fuels, augmented by electricity. Direct electrical heating is still used, but it is above all the use of heat pumps that will make us dependent on electricity for a long time to come. A goal set by the Swedish Commission against Oil Dependency is that dependency on oil in the residential and service sector shall be broken by 2020. Sweden is well-placed to achieve that objective, though in that respect, internationally, we are an exception rather than a rule. While oil has become the energy source of principally the transport sector, the residential sector relies heavily on natural gas and coal for electrical power production. In a global perspective, bio-energy is still only marginally important.

Globally, oil remains the most important source of energy. Research at Uppsala University shows that we are nearing peak production. The Uppsala Hydrocarbon Depletion Study Group (www.tsl.uu.se/uhdsg) has done a thorough study of the global production of oil and oil reserves, a study that has resulted in the scenarios presented in Figure 2.

“Worst Case” is a scenario in which we have already reached a peak

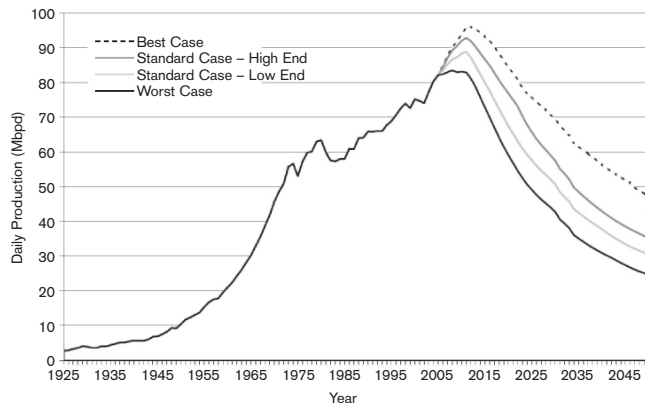


FIGURE 2. Future oil production (millions of barrels/day). Source: Uppsala Hydrocarbon Depletion Study Group. “Best Case” applies if we use the largest estimates of indicated reserves for the world’s giant oilfields. If, instead, we use the most conservative figures for indicated reserves, the outcome is a worst-case scenario.

production of about 85 million barrels a day, a peak that will be sustained for about 7 years before production begins to diminish. The best-case scenario is based on optimistic estimates of the world’s oil reserves. Statistics for the past two years point to Worst Case as the most likely outcome, but this cannot yet be verified. When the oil begins to run out, bio-fuels and electricity will also become important for transportation; subsequently, the sector which includes dwellings and other buildings will face competition for the supply of energy.

**THE GLOBAL BUILDING
SECTOR'S FUTURE
PRIMARY ENERGY
SOURCE**

Once reliant on oil, the residential sector is on its way to becoming dependent on electricity and natural gas. Electricity is also being used to an increasing extent for cooling offices and other premises – even dwellings.

Dubai, in the United Arab Emirates, is among the world’s most extreme cities when it comes to air conditioning. A colleague who lives in Dubai tells of how the city was without power one evening, about a year ago. It started to get insufferably hot in his apartment and he came upon the brilliant idea that he could cool down by driving around in his car with the air conditioning switched on. It became apparent that he was not the only one with this idea, and the streets were soon overflowing with cars. In the middle of the night, Dubai experienced its greatest-ever

traffic jam. Soon, the traffic came to a standstill, and to avoid overheating their engines, motorists were forced to turn off the air conditioning. Perhaps the most extreme example is the indoor ski slope that was built in the desert; without electricity, snow soon turns to water.

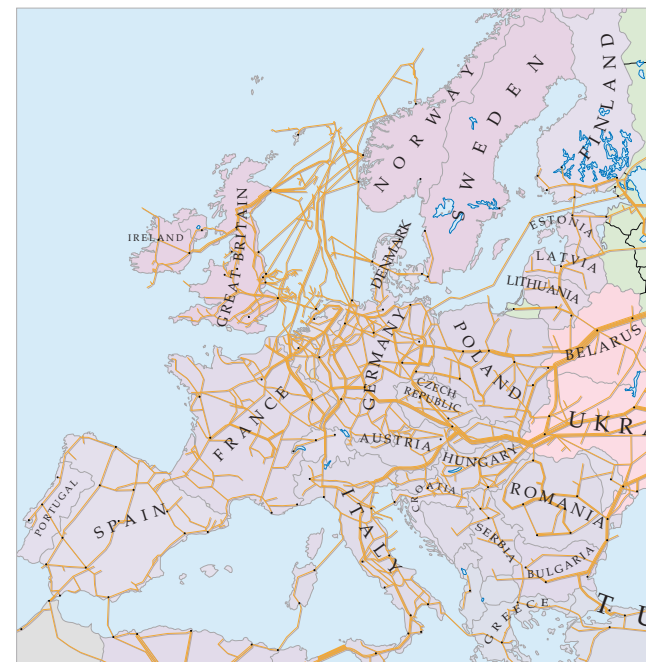


FIGURE 3. Europe’s existing and planned gas transmission networks. Illustration: GAZPROM in questions and answers (<http://eng.gazpromquestions.ru/>), GAZPROM.

If we look to our neighbour, Denmark, we see that the use of fossil fuel in the residential and service sector is much greater than in Sweden. The same applies to Europe and many other countries throughout the world. Natural gas was long considered a problem in conjunction with oil extraction, and the most common solution was simply to burn it off. This is still done in many places. Eventually, its value was recognized and pipeline systems were built, first in the USA and later in Russia and

Europe, see Figure 3. The west coast of Sweden receives natural gas via Denmark, but the rest of the country remains a blank on the natural-gas map. There are many who are in favour of purchasing natural gas from Russia via the pipeline now being planned in the Baltic, but that would make us dependent on a single supplier. The studies we are now conducting indicate that Russia will soon reach peak production, after which buyers will compete for natural gas. Personally, I hope that Sweden will remain a blank spot on the map.

More than 40 percent of the natural gas consumed in the European housing sector is used for heating and cooking. For the consumer, natural gas is convenient, almost as convenient as electricity, but in terms of energy efficiency, natural gas is preferable to electricity. If natural gas is used to generate electrical power, 60% of its energy content is lost; unless, as in cities like Gothenburg, the residual heat is utilized in district heating. Compared to direct use in e.g., heating or cooking, much of the heat simply goes up the chimney.

According to EU estimates, in Europe, the share of natural gas used by industry will remain relatively constant up until 2030, while use of natural gas for electrical power generation is expected to increase considerably. It is estimated that European consumption of natural gas will rise by 60% by 2030. The question is: who will supply Europe with gas?

Currently, slightly more than 50% of the natural gas consumed in Europe is produced domestically, but the future will bring greater dependency on imported gas. The planned pipeline in the Baltic Sea indicates that imports from Russia will increase, but perhaps the real reason for its construction is that Russia wishes to remain independent of Belarus and Ukraine as transit countries for delivery of natural gas to Europe, see Figure 3. Europe's dependency on imports from Russia effectively places Europe's future, in this respect, in Russia's hands.

NATURAL GAS IN THE USA AND RUSSIA

Natural gas is widely used in the USA. Throughout the 1900s, the US was completely self sufficient, but this is no longer the case. Imports are increasing, above all from Canada. The next problem is that Canada will eventually no longer be able to meet US demands for natural gas. When natural gas is cooled and condensed into its liquid phase it can be shipped using tanker vessels. The USA is on its way to becoming totally dependent on sea-borne imports of natural gas. Most new buildings constructed in the USA over the past 30 years rely on natural gas as their primary energy source. Without natural gas, Americans would face enor-

mous problems, a scenario that has been confirmed by studies conducted at Uppsala University. The US has quite literally built itself into a system that cannot easily be replaced.

As for Russia, the housing sector is also entirely dependent on natural gas; but unlike the Americans, the Russian's will be the last to have to abandon it as a primary source of energy. The problem is that, for so many years, people have had access to a seemingly inexhaustible supply of energy, which is why conservation is an unfamiliar notion. If it gets too hot, one simply opens a window rather than lowering the temperature on the heating system. Now, however, it is probably time for the Russian people to rethink their situation. The major gas fields are showing signs of depletion, and successively smaller fields account for an ever-greater share of production. To be able meet the export commitments, prices must increase and the Russian people will be compelled to curb their consumption.

Natural gas has the same origin as oil, though the original layer of sediment from which it formed was exposed to a higher temperature. Discoveries of oil reserves reached a maximum during the 1960s. For natural gas, the peak came 10 years later. In Figure 4, we clearly see a distinct downward trend. Much of the natural gas discovered during the 1900s has yet to be exploited, but it will become increasingly difficult to find

THE FUTURE OF NATURAL GAS

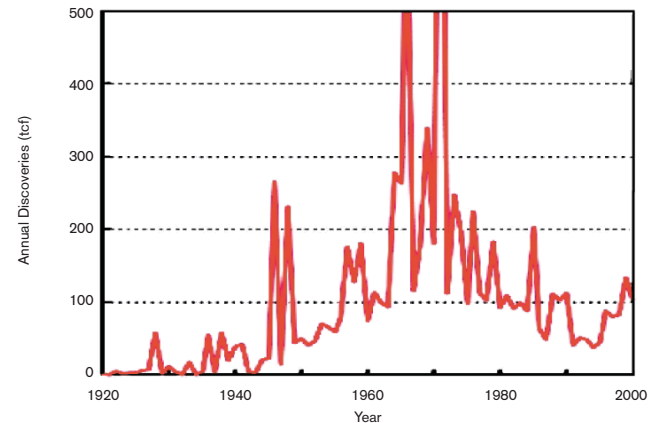


FIGURE 4. Annual new discoveries of natural gas.

new reserves. Preliminary studies indicate that global consumption will peak within 20 years, and the housing sector, like other sectors in which natural gas is used, will have to find other sources of energy.

**FUTURE ENERGY
SYSTEMS FOR
DWELLINGS**

Building a house is really about building for the future. The house my family built in 2000 in Uppsala will probably be gone in 100 years. We wonder if we have chosen the right energy supply system for the house. We probably should have placed considerably higher demands on the builder, but such considerations were overshadowed by our joy at finding a building lot. Even so, the result is quite satisfactory. An extract-air heat pump is a good means of providing indoor heat; the heat is recovered from the air that is evacuated from the building. The laws of physics also help us, since a higher extract-air temperature increases the efficiency of the heat pump (Carnot's Law). The waterborne system also invites the possibility of installing a solar hot water system. A tiled wood-burning stove helps to reduce electricity use when the extract air heat pump cannot deliver sufficient heat. Another positive feature is that the bio-energy in the wood is recycled via the heat pump.

We are approaching a time when houses of the future must be zero-energy homes. The use of energy for heating and cooling must be minimized. If we start by making radical changes now, we will reap the benefits tomorrow.

7. THE EUROPEAN UNION – ENERGY DIRECTIVES

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The European Union (EU) has a common energy policy, of which there are several objectives. The overall objectives are to secure energy supply, promote international co-operation and sustainable development, integrate the European energy market and promote research and technical development. An energy policy has existed in the EU since the birth of the union. European co-operation had its starting point as early as 1952, with the regulation of the coal sector under the terms of the European Coal and Steel Community Treaty. However, it was not until the oil crisis of 1973 that more extensive legislation in the energy area began to be introduced.

In this section, energy efficiency improvement, with a particular focus on efficient use of energy in buildings, will be presented. In the EU, buildings account for about 40 % of energy end use, which is par with the situation in Sweden.

In the area of energy efficiency improvement, several directives have been issued:

- Energy Performance of Buildings Directive (2002/91/EC).
- Directive on marking to indicate energy consumption of electric refrigerators and freezers (even in combination) for household use (2003/66/EC).
- Directive on promotion of combined heat and power generation (2004/8/EC).
- European Framework Directive on Ecodesign of Energy-using Products (2005/32/EC).

- Directive on energy end-use efficiency and energy services (2006/32/EC).
- Council decision concerning conclusion of the Agreement between the Government of the United States of America and the European Community on the coordination of energy-efficiency labelling programmes for office equipment (2006/1005/EC).

Of these directives, three are outlined in detail below:

1. The Energy Performance of Buildings Directive.
2. Framework Directive on Ecodesign of Energy-using Products.
3. Directive on energy end-use efficiency and energy services.

The Energy Performance of Buildings Directive appears to be the one that will have the greatest impact on energy end use in buildings, which is why it is discussed here at greater length.

The directive concerning marking to indicate energy consumption of household refrigerators and freezers has already had an impact on energy consumption in households. The directive also gives manufacturers of these products an incentive to continually strive to improve their energy performance. The directive on promotion of combined heat and power generation is aimed primarily at creating possibilities for reducing primary energy use in conjunction with the production of heat and electricity rather than improving energy end-use efficiency. The new, five-year agreement between the EU and the USA on energy-efficiency marking of office equipment is an extension of an earlier, similar agreement. Marking covers power consumption of office equipment in both stand-by mode and during operation. Marking will be further developed and adapted in line with future technologies and market trends.

This is a so-called framework directive, meaning that each individual member state has considerable scope to choose its own means and methods within the framework of guidelines set out in the directive. The directive came into force on 16 December 2002. The directive states that member states shall bring into force the laws, regulations and administrative provisions necessary to comply with the directive at the latest on 4 January 2006. There is one exception: if there is a lack of qualified and/or accredited experts, member states have an additional period of three years to apply the relevant provisions fully, i.e. until 4 January

**THE ENERGY
PERFORMANCE OF
BUILDINGS DIRECTIVE**

2009. Most member states have elected to use all possible means to postpone full implementation of the directive until after 2006.

The directive lays down requirements as regards five different areas. The five areas are:

- a) The general framework for a methodology of calculation of the integrated energy performance of buildings.
- b) The application of minimum requirements on the energy performance of new buildings.
- c) The application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation.
- d) Energy certification of buildings¹.
- e) Regular inspection of boilers and of air-conditioning systems in buildings and, in addition, an assessment of the heating installation in which the boilers are more than 15 years old.

In the directive, a number of terms are used, the meanings of which are important for understanding the content of the directive. Two of these are outlined below. These terms do not necessarily have the same meanings throughout this book, but are used in this chapter according to the following definitions:

energy performance of a building: the amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building, which may include, inter alia, heating, hot water heating, cooling, ventilation and lighting. This amount shall be reflected in one or more numeric indicators which have been calculated, taking into account insulation, technical and installation characteristics, design and positioning in relation to climatic aspects, solar exposure and influence of neighbouring structures, own-energy generation and other factors, including indoor climate, that influence the energy demand.

air-conditioning system: a combination of all components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity and air cleanliness.

¹ In Sweden, it has been decided that the terms 'energy certification' and 'energy performance certificate' will not be used, since these may be confused with the term *elcertifikat* (electricity certificate), which is already in use. Instead, the term 'energy declaration' is used. This term will be applied in the following text.

The definition of the energy performance of a building can be somewhat difficult to interpret.

Guidelines for this may be found in the new EN standards.

The new EN standards suggest alternatives for indicating energy performance. These consist of the so-called operational rating, i.e., measured energy consumption, and of the so-called asset rating, which is a variant of calculated rating.

Operational rating: Total measured annual supply of energy to the building.

Asset rating: Calculated rating of energy use of a building (heating, cooling, ventilation, hot water and lighting) based on standard outdoor climate/weather and standard building use. Energy performance calculated according to asset rating does not include office equipment, kitchen appliances, industrial processes, etc.

In Sweden, variants of operational rating and asset rating will be used, as compared with the definitions given above. The common indicator of the energy performance of a building will be operational rating, though reduced to household electricity and electricity used for other purposes within the building, respectively. In cases where measurable values are unattainable, asset rating will be applied. In Sweden, for example, no performance indicators will include electricity for lighting. In both cases, energy is divided by the so-called temperature-controlled area; energy performance is thus expressed as kWh/m². The temperature-controlled area corresponds to the entire heated area (>10°C) within the outer walls of the building.

Application of minimum requirements is regulated in most cases by national building codes or standards. Such is the case in Sweden, with the new building regulations, *Boverkets regelsamling för byggande*, BBR, (National Board of Housing, Building and Planning) published in June 2006.

Undoubtedly, the two most extensive parts of the directive will concern energy declaration and regular inspection of boilers and air-conditioning systems. Both entail the involvement of independent experts and both constitute sections of the directive that could lead to postponement

of its introduction. Further consideration of both is warranted, particularly with respect to the content of energy declaration of buildings.

Energy declaration

In principle, all buildings in the EU will be subject to energy declaration. According to the directive, only a few exceptions can be made.

Among these are:

- Buildings of particular architectural or historical significance.
- Buildings used for devotional or religious purposes.
- Buildings which are intended to be used for a period of two years or less, and industrial premises.
- Dwellings which are intended for use during at most four months of the year.
- Freestanding buildings with a usable floor area of less than 50 m².

An energy declaration (energy performance certificate) is to be made available to the owner or to any prospective buyers or tenants when a building is built, sold or rented. The validity period of an energy declaration may not exceed 10 years. The declaration must contain reference values of at least an extent and type that allow consumers to compare and assess the building's energy performance. It must also contain proposals for cost-effective measures for improving the building's energy performance. However, the directive does not specify any requirements for implementing the proposed measures. In buildings with a total useful floor area over 1000 m² occupied by public authorities and by institutions providing public services, a valid energy performance certificate must be displayed in a prominent place clearly visible to the public.

The directive addresses indoor climate issues only very briefly, stating that values for ranges in current and recommended indoor temperatures may be displayed. The same applies, in some cases, to other relevant climate factors. In Sweden, an indication is given as to whether radon measurement has been carried out in the building, for example, and if the mandatory performance inspection of the building's ventilation system has been carried out.

Inspection of boilers and air-conditioning systems

Boilers and air-conditioning systems must be inspected. For boilers, two alternative options are specified in the directive. The first option (inspection of boilers) requires regular inspection of boilers fired with non-re-

newable liquid or solid fuel of an effective rated output of 20 to 100 kW. Boilers of an effective rated output of more than 100 kW are to be inspected at least every other year. One-off inspection of entire heating systems of more than 20 kW rated output which are older than 15 years is required. As a result of the inspections, the independent experts/inspectors will advise on measures to improve energy efficiency.

The other option concerns advice to the users of heat pumps. Advice to the users shall include information that will help to achieve an overall equivalent impact to that of inspection. Member states that choose this option shall submit a report on the equivalence of their approach to the Commission every two years. The onus is therefore on the building owner to demonstrate that advice has led to a result equivalent to that of inspection. Sweden has opted for the advice alternative.

For air-conditioning systems, there is no corresponding advice alternative. Here, the directive states that air-conditioning systems of an effective rated output of more than 12 kW must be inspected regularly. The inspections must be conducted by independent energy experts. This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. The expert shall provide advice on possible improvement or replacement of the air-conditioning system and on alternative solutions.

Independent experts

Member states shall ensure that the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts. As mentioned earlier, only a lack of independent experts can delay implementation of the directive.

The approaches used by the individual member states differ with respect to, among other things, the requirements for technical expertise and how the independence of experts is to be determined. In Sweden, for example, the independence of energy experts is guaranteed on the basis of accreditation. To be accredited, the expert must meet formal requirements with respect to education and practical experience and must pass an accreditation examination. Only accredited experts may carry out energy declarations. The accredited expert must be employed by an accredited inspection body. In Sweden, an energy expert can be accredited for three different levels of qualification: normal, qualified and air conditioning. The designation 'normal' corresponds to authorisation to issue

	energy declarations for simple buildings; ‘qualified’, for complex buildings, and ‘air conditioning’ for air-conditioning systems. The designation ‘qualified’ also includes authorisation for normal and air conditioning.
DIRECTIVE ESTABLISHING A FRAMEWORK FOR THE SETTING OF ECODESIGN REQUIREMENTS FOR ENERGY-USING PRODUCTS	The directive refers to energy-using products (EuPs), but does not apply to means of transport for persons or goods. This is a so-called framework directive for setting the ecodesign requirements for energy-using products with the aim of ensuring the free movement of those products within the internal market. The directive came into force on 26 July 2005. Member states were to have implemented, no later than 11 August 2007, regulations and laws pursuant to compliance with the directive. Member states will also designate public authorities with responsibility for surveillance of the market and will ensure that these authorities have, and exercise, the necessary authorisation to take appropriate measures in accordance with their obligations under the terms of the directive. Ecodesign refers to the integration of environmental aspects in product design with the aim of improving the energy-using product’s environmental performance throughout its entire life cycle while preserving the quality of product performance. As early as possible in the product design phase, it is desirable to take measures to ensure energy efficiency, since it is during this phase that the subsequent environmental impact of the product is determined and that the opportunities for influencing product design with respect to energy use are greatest. The directive states that energy-using products complying with the ecodesign requirements should bear the ‘CE’ marking and associated information, in order to enable them to be placed on the internal market and move freely. At the same time, the directive emphasises that self-regulatory initiatives by industry should be prioritised if it is likely that such initiatives will deliver the policy objectives faster or in a less costly manner than mandatory requirements. An energy-using product (EuP) that meets the criteria below will be covered by an implementing measure¹ or by a self-regulation measure (via, e.g., voluntary agreements).

Criteria:

- The EuP shall represent a significant volume of sales and trade, indicatively more than 200 000 units a year within the Community according to most recently available figures.

¹ Measures adopted in accordance with the directive and which establish ecodesign requirements for specified energy-using products or for environmental aspects of these.

- The EuP shall, considering the quantities placed on the market and/or put into service, have a significant environmental impact within the Community, as specified in Community (according to strategic priorities as set out in Decision No. 1600/2002/EC).
- The EuP shall present significant potential for improvement in terms of its environmental impact without entailing excessive costs.

Particular attention should be given to the following conditions:

- The absence of other relevant Community legislation or failure of market forces to address the issue properly.
- A wide disparity in the environmental performance of EuPs available on the market with equivalent functionality.

The aim of this directive is to reduce energy consumption in the Community, partly by promoting energy services offerings and partly by stimulating demand for energy services. It is emphasised that public sector entities should set an example with respect to investments, maintenance costs and other expenditures for energy-using equipment, energy services and measures to improve energy efficiency. Therefore, the public sector should be encouraged to integrate energy efficiency improvement considerations into its investments, depreciation allowances and operating budgets. Furthermore, the public sector should endeavour to use energy efficiency criteria in tendering procedures for public procurement.

The directive came into force on 25 April 2006. Member states are expected to Member bring into force the laws, regulations and administrative provisions necessary to comply with this directive not later than 17 May 2008.

Article 1 clearly states the objective of the directive.

“Member States shall adopt and aim to achieve an overall national indicative energy savings target of 9 % for the ninth year of application of this Directive, to be reached by way of energy services and other energy efficiency improvement measures. Member States shall take cost-effective, practicable and reasonable measures designed to contribute towards achieving this target.”

The Commission requires member states to submit national plans of action describing how the objectives are to be achieved. The first plan is to be submitted no later than 30 June 2007, the second by 30 June 2011 and the third no later than 30 June 2014.

As mentioned, the public sector is expected to set an example (take

**DIRECTIVE ON ENERGY
END-USE EFFICIENCY
AND ENERGY
SERVICES**

the lead) in implementing measures to improve energy efficiency. Here, there are opportunities for achieving this by setting demands via legislation and/or voluntary agreements. The directive explicitly states that the public sector shall apply at least two requirements from the following list:

- a) Requirements concerning the use of financial instruments for energy savings, including energy performance contracting, that stipulate the delivery of measurable and pre-determined energy savings.
- b) Requirements to purchase equipment and vehicles based on lists of energy-efficient product specifications of different categories of equipment and vehicles to be drawn up by authorities or agencies, using, where applicable, minimised life-cycle cost analysis or comparable methods to ensure cost-effectiveness.
- c) Requirements to purchase equipment that has efficient energy consumption in all modes, including in standby mode, using, where applicable, minimised life-cycle cost analysis or comparable methods to ensure cost-effectiveness.
- d) Requirements to replace or retrofit existing equipment and vehicles with the equipment listed in points (b) and (c).
- e) Requirements to use energy audits and implement the resulting cost-effective recommendations.
- f) Requirements to purchase or rent energy-efficient buildings or parts thereof, or requirements to replace or retrofit purchased or rented buildings or parts thereof in order to render them more energy-efficient.

With respect to public buildings, the directive also states that member states must publish guidelines for energy efficiency and energy savings as possible criteria for assessment in tendering procedures for public procurement.

Another important target group comprises energy distributors, distribution system operators and retail energy sales companies.

These may be required to provide on request, but not more than once a year, aggregated statistical information on their final customers to the authorities or agencies. This information must be sufficient to 1) properly design and implement energy efficiency improvement programmes, and 2) to promote and monitor energy services and other energy efficiency improvement measures. In addition, they must refrain from any activities that might impede the demand for and delivery of energy services and other energy efficiency improvement measures. Nor are they al-

lowed to hinder the development of markets for energy services and other energy efficiency improvement measures.

Member states must choose one or more of the following requirements to be complied with by energy distributors, distribution system operators and/or retail energy sales companies:

- Ensure the offer to their final customers, and the promotion, of competitively priced energy services.
- Ensure the availability to their final customers, and the promotion, of competitively-priced energy audits conducted in an independent manner and/or energy efficiency improvement measures.
- Contribute to the funds and funding mechanisms.

As an alternative to the above, voluntary agreements and/or other market-oriented schemes, such as white certificates¹, can be set up if their effect is equivalent to one or more of the requirements referred to above. If voluntary agreements are used they must be assessed, supervised and followed up by the member state in order to ensure that a satisfactory effect is achieved.

For other players, such as energy services companies, installers, energy advisors and energy consultants, member states shall ensure that there are sufficient incentives, equal competition and level playing fields to dependently offer and implement the energy services, energy audits and energy efficiency improvement measures.

With regard to end users of electricity, natural gas, district heating and/or cooling and domestic hot water, member states shall ensure that, in so far as it is technically possible and financially reasonable in relation to the potential energy savings. Invoicing is to be presented in clear and understandable terms.

Among the reasons cited for adopting the directive, it is acknowledged that the motor fuels and transport sectors have an important role to play regarding energy efficiency and energy savings.

In this chapter, EU directives concerning energy use, with a particular emphasis on the use of energy in buildings, have been presented. On the following page, examples of other documents that may serve to provide a more complete overview of the Commission's stance on energy matters are given. All are available for downloading via the Internet.

**OTHER IMPORTANT
ENERGY-RELATED
DOCUMENTS FROM
THE EU**

¹ Companies that implement energy efficiency improvement measures should be issued so-called white certificates, valued in proportion to the improvement achieved, which may subsequently be traded on a common energy exchange.

Suitable starting points include:

<http://europa.eu.int>

http://ec.europa.eu/energy/demand/index_en.htm.

- Action Plan For Energy Efficiency: Realising the Potential, Saving 20% by 2020, October 2006.
- Green paper on Energy Efficiency or Doing More with Less, Luxembourg: Office for Official Publications of the European Communities, 2005 ISBN 92-894-9819-6.
- Communication From the Commission to the European Council and the European Parliament: An Energy Policy for Europe, Brussels, 10.1.2007, COM(2007) 1 final.
- Communication from the Commission: Energy for the future: Renewable sources of energy. White Paper for a Community Strategy and Action Plan.

REFERENCES Energy Performance Buildings Directive (2002/91/EC).

Directive on marking to indicate energy consumption of electric refrigerators and freezers (even in combination) for household use (2003/66/EC).

Directive on promotion of combined heat and power generation (2004/8/EC).

European Framework Directive on Ecodesign of Energy-using Products (2005/32/EC).

Directive on energy end-use efficiency and energy services (2006/32/EC).

Council decision concerning conclusion of the Agreement between the Government of the United States of America and the European Community on the coordination of energy-efficiency labelling programmes for office equipment (2006/1005/EC).

8. THE CHANGING CLIMATE

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When an ice age occurs, large parts of Europe, Asia and North America become covered with hundreds of metres of ice. At the same time, the sea levels in the Atlantic, the Pacific and elsewhere are up to one hundred metres lower than today. These are not unusual climate conditions and nature, without the help of mankind, has been behind variations like these numerous times.



FIGURE 1. Glaciers in Greenland. Photo: Torkel Idestrom.

There are many ways in which different climate situations can be described and one of the more common is to compare mean air temperatures. Over the last hundred years, we have measured temperatures using instruments and prehistoric temperatures have been calculated indirectly

by studying chemical and biological traces in nature, for example, pollen that has been stored in peat bogs and sediment under the oceans, and chemical traces in glaciers or deposits in rocks. These traces provide us with a picture of how the climate has changed over hundreds of thousands of years, in some cases millions of years, until today. These traces are important if we are to understand the factors that have affected the climate and what the consequences have been. Observations of factors affecting our present climate show that over the next hundred years we will be confronted by a climate change of a magnitude equivalent to a half or a whole ice age – but in the other direction. By now, everyone has heard that it will become warmer but just as important, or even more important, are the other consequences this will have on the climate system. Among other things, we will see smaller glaciers, higher sea levels, changed vegetation and forest fires as well as enormous effects on the ecosystems on land, in lakes and at sea. In the following, the reader will be orientated about the factors that influence the climate on Earth and that cause changes in its heat balance. Furthermore, the changes in nature, societies and economies that climate change can lead to will be put into perspective. These climate changes will not pass by unnoticed.

By studying glacial ice, it is possible to recreate a picture of how the climate has changed over hundreds of thousands of years. Snow is deposited layer by layer, year after year. Over thousands of years, snow is pressed into ice, eventually creating large glaciers. Traces of volcanic eruptions, for example, can be seen in the form of ash that has settled and been stored in the snow. Also frozen into the snow are small bubbles of air containing traces of the atmosphere that prevailed when the snow fell. From these sources it is also possible to describe the chemical composition of the air hundreds of thousands of years ago. And by comparing the proportions of different isotopes of oxygen, it is possible to describe how temperatures have varied.

Ice ages come and go. Samples from glaciers, ocean sediments, etc show that nature itself can change, depending on climatic extremes. Estimations of the temperature variations in Vostok, Antarctica, show that the climate over the last 10 000 years or so has been relatively stable whereas the preceding period was one of significantly lower temperatures, i.e. an ice age with extreme variations in climate. These changes had nothing to do with man other than that he had to adapt himself to them. (Our ability to communicate by speech was developed about

**GLACIERS PROVIDE
ANSWERS TO SOME
QUESTIONS**

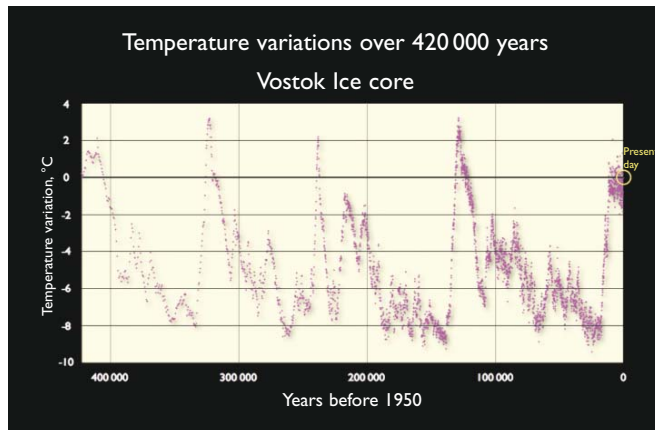


FIGURE 2. The graph shows temperatures reconstructed from core samples of glacial ice from Vostok, Antarctica. The scale shows the temperature relative to 1950, which is used as a reference year. The core samples show regional temperature changes and can provide a qualitative picture of the variations in global temperature. Global temperature variations are roughly half those seen in Antarctica.

100 000 years ago and we changed from being nomadic to more settled, farming and living in small communities, about 10 000 years ago.)

The Earth's climate system is a complicated phenomenon. It comprises the atmosphere (air), the hydrosphere (water), the cryosphere (frozen water), the geosphere (mountains and land surfaces), the biosphere (plants and animals) and the anthroposphere (mankind), and how they all interact with each other.

It is sometimes heavily criticized that far too large conclusions have been drawn about how the climate has varied, as results have only been based on studies of conditions in individual places. The research community is very much aware of the uncertainties in measuring data and results based on computerized models and that there is a great deal of information that can never be verified. Some have maintained that the climate variations in the 1900s have been caused by sunspots, others that human emissions of greenhouse gases are too small to be able to influence the climate system. If it had been a question of sunspots, then the temperature should have fallen over the last ten years instead of risen. On a yearly basis, human emissions are admittedly less than natural flows of, for example, carbon dioxide, but over time they have meant that the con-

centration of carbon dioxide has increased by about 35%, which is not a negligible amount. An important difference between nature and mankind is that nature both releases and absorbs carbon dioxide whereas mankind only releases it.

Some people maintain that the climate has always varied and that this is nothing new. The observation is correct and this, in fact, is an extremely important reason why it should be taken very seriously: Nature has been subject to climate changes before and they are not just fantasies only found in computerized models! And we must not forget the implications of the enormous changes caused by climate variations and the fact that our towns were never built to withstand the accompanying stresses. Prudence is obviously called for but, instead, mankind has spent years denying or belittling information that could turn out to be of decisive importance with regard to our ability to reduce our impact on the climate to a sustainable level.

The flow of energy from the sun to the Earth is the origin of practically all energy flows above the crust of the earth. Variations in solar radiation initiated early climate changes that we today can observe by studying traces in nature, for example, in ice core samples, ocean sediments etc.

**A FEEDBACK DRIVEN
SYSTEM**

FACTS AND FIGURES:

Variations in solar radiation, so-called Milankovitch cycles, mean that different amounts of energy reach the Earth and that their distribution over its surface changes, for example, due to the angle of the planet's axis. The cycles vary, with periods lasting about 20 000, 40 000 and 110 000 years. Changes in the Earth's albedo (Latin for whiteness) determine the proportion of incident sunlight that is reflected. A lighter planet becomes colder and a darker one hotter. Cloud, snow, vegetation, land changes, volcanic eruptions and air pollution all change the Earth's albedo.

Greenhouse gases absorb and reradiate heat radiation. Water vapour, carbon dioxide, methane, nitrous oxide, freons etc cause the average temperature of the atmosphere to be +15 °C instead of -18 °C, its temperature if the greenhouse effect had not existed. It would have been -18 °C, if there had been no greenhouse gases and the earth had had the same albedo as today. As the absence of greenhouse gases would make the Earth colder it would also mean that a larger proportion of the water would be frozen. This, in turn, would create a higher albedo or lighter planet and lead to further reductions in temperature. The compositions and concentrations of greenhouse gases have always varied due to natural emissions and absorptions from and to, for example, the sea and the biosphere. At present, forests and seas absorb about half of all human emissions but, depending on how the climate changes, the biosphere and seas could, instead, become a net source of greenhouse gases.

But solar variations cannot, on their own, explain the extensive variations in, for example, temperatures, precipitation or ocean currents. However, it looks as though the majority of the prehistoric climate changes were initiated by changes in solar radiation, how much of it reached Earth and how the energy was distributed over the planet. These variations were then propagated into the Earth's climate system via feedback, domino effects and threshold effects. This meant, and still means, that climate changes could take place rapidly when critical threshold values are reached. Melting glaciers and sea ice accelerated climate changes by changing the Earth's albedo, its ability to reflect radiation. Increasingly warmer oceans started to release more carbon dioxide than they absorbed. Changes in weather patterns drove the changes in vegetation. Some feedback mechanisms brake and others speed up climate change. The climate is a continuous dynamic process.

There are three basic ways in which the climate of a planet can be changed:

1. By altering the degree of solar radiation.
2. By changing the planet's albedo, i.e. its ability to reflect incoming energy (water, snow, forests and clouds all have different colours or reflectivities).
3. By changing the amounts of greenhouse gases.

Historical climate changes, such as ice ages that have come and gone, were caused by variations in solar radiation being propagated into the climate system and, among other things, causing changes in albedo and the amount of greenhouse gases. What we have done over the past hundred years is to change the Earth's albedo and presence of greenhouse gases. These changes have been so large that there has been a shift in the climate balance and climate change will now take place until a new equilibrium has been reached. This new level will mean that it will be one – or up to six – degrees Celsius warmer than today. This change in balance will continue as long as the climate system is imbalanced, at best for another 50 to 100 years, at worst for hundreds or thousands of years.

GREENHOUSE EFFECT

Everyone has heard about it but how does it actually work? The expression itself is a bit misleading, as the earth's atmosphere does not work in the same way as a greenhouse. In a greenhouse, large amounts of solar energy are transmitted through the panes of glass and heat up the sur-



FIGURE 3. A greenhouse. Without the greenhouse effect, the Earth would, to a great extent, be frozen and covered by glaciers. The greenhouse effect is essential for life on Earth, although it is only partly similar to that in a real greenhouse.

faces inside the greenhouse. So far the analogy is correct. But the reason why it is hotter in the greenhouse than outside (where the ground and air are also heated by the sun) is that the glass prevents the heated air from flowing anywhere else. The atmosphere and the glass in the greenhouse, however, have the same function, as both admit a large proportion of the incident short wave solar radiation but prevent the long wave heat radiation from escaping.

The atmosphere is permeable to most of the incident solar energy. The sunlight heats the ground, which, in turn, heats the air closest to the ground by convection. This creates vertical winds caused by the differences in density of the air. The heated ground can also radiate energy out into space. This radiation has different wavelengths to when it arrived. The sun has a temperature of about 6000°C and emits light in the 0.3 to 1µm wavebands, i.e. visible light. Within this range, the atmosphere offers a window, i.e. it is permeable to radiation, see Figure 4. Short wavelength light, UV radiation, is absorbed to a certain degree in the ozone layer and some of the longer wavelengths are absorbed by water vapour, but most of them reach the Earth's surface.

The same amount of energy that reaches the Earth must also, in some way, leave the planet. As a vacuum exists in space, radiation is the only way in which energy can leave or reach the planet. As the surface of the

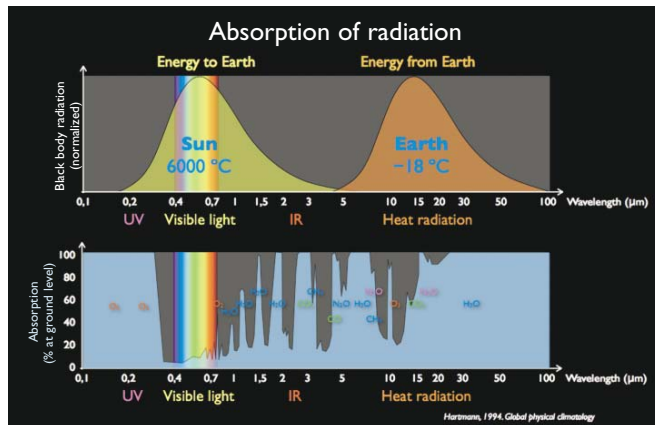


FIGURE 4. The high temperature of the sun allows it to radiate its energy at other wavelengths than the Earth. Greenhouse gases are gases that can absorb and emit radiation. Different gases are affected by different wavelengths of radiation. The Earth's atmosphere has a window through which the majority of the sun's radiation is transmitted. On the other hand, radiation from the Earth is, to a great extent, absorbed by the greenhouse gases in the air.

Earth and its atmosphere maintain considerably lower temperatures than the sun, they will radiate energy at longer wavelengths than the sun, see Figure 4. The earth radiates energy in the infrared spectrum at wavelengths from 8 to 30 μm .

It is possible to calculate the temperature that the Earth should have based on the amount of energy that reaches us from the sun. That fact that about 30 % of the energy is reflected and the effect of the Earth's albedo must also be taken into account. The result is that we only receive enough energy to sustain a temperature of about -18°C ! This coincides well with the temperature that the Earth seems to have if it is observed using an infrared camera from space. That the Earth appears to be at a temperature of -18°C , or about 255 Kelvin, is explained by the fact that the visible part of the Earth is the atmosphere a couple of kilometres above its surface. Infrared cameras only provide rather hazy pictures, as only certain wavelengths manage to reach the camera from the surface. Most of the radiation registered by infrared cameras comes from the greenhouse gases in the atmosphere. The concentration of water vapour, also a greenhouse gas, in the atmosphere varies considerably due to the

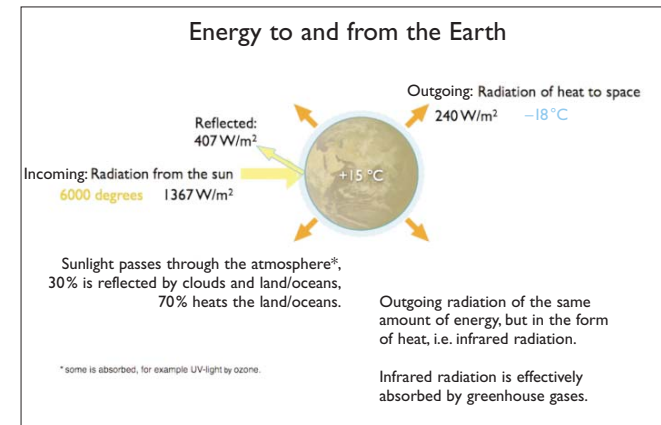


FIGURE 5. Radiation is the only way in which energy can reach or leave the Earth. The same amount of energy reaching the Earth also leaves it. Energy radiates into space from an area that is four times greater than that which receives energy from the sun. The average amount of radiated energy corresponds to a temperature of -18°C or 255 Kelvin. The radiation comes from greenhouse gases about 5 km up in the atmosphere; on the ground it is just over thirty degrees warmer.

weather and the dryer it is the deeper into the atmosphere you can see. The other greenhouse gases are relatively well mixed and haze the view to about the same degree over the whole of the world. Note that this haziness cannot be observed in the visible spectrum – this is where the atmosphere has a window – but it is clearly visible in the infrared spectrum.

But isn't it, on average, hotter than -18°C ? The difference is caused by the greenhouse gases that absorb and reradiate energy, and the fact that temperature falls the higher up in the atmosphere it is measured. It is not the ground itself that radiates energy out into space. Most of the heat energy that is radiated by the ground is absorbed by the greenhouse gases in the atmosphere, which leads to the atmosphere having a temperature that is not solely dependent on its direct contact with the ground. Most of the radiation that leaves the Earth derives from the atmosphere at an altitude of a couple of kilometres.

The temperature of the atmosphere decreases with altitude above sea level; it is colder on the top of a mountain than at its foot. The reduction in temperature is between 6 and 10 degrees per kilometre up to an

altitude of between 10 and 15 kilometres. It is here, in the troposphere, that the tropopause occurs, an area of constant temperature that blocks a large proportion of the transportation of water vapour and particles etc up into the stratosphere.

The effects that greenhouse gases in the air have on the air itself would be experienced as haze – if our eyes were sensitive to heat radiation instead of visible light. The more greenhouse gases, the hazier it would be. The effect on the Earth's radiation balance is that the temperature at which the Earth appears to radiate its energy into space comes from a level in the atmosphere that corresponds to a temperature of -18°C . This level is about 5 km above sea level.

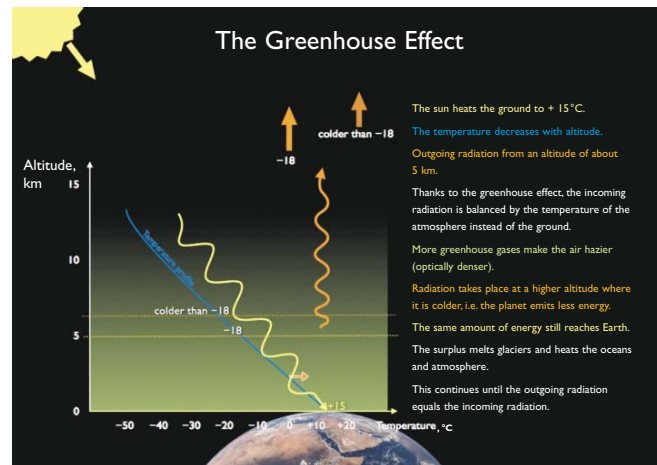


FIGURE 6. Most of the incoming solar energy passes through the atmosphere and heats the surface of the Earth. However, the greenhouse gases make the atmosphere hazy, when seen as heat radiation leaving the planet. The energy that leaves the planet does not radiate from the ground surface directly but from the atmosphere about 5 km up, where it is about -18°C . More greenhouse gases will haze the atmosphere even more and radiation will take place from an even higher level where it is colder, i.e. less energy will leave the earth. This surplus energy can be observed in the form of melting glaciers and rising sea and air temperatures.

What happens when more greenhouse gases are emitted into the atmosphere is that it becomes hazier in the infrared spectrum via which the planet radiates energy. The radiated energy will then be emitted from a higher level in the atmosphere than previously. It's rather like not being

able to see deep into a lake with muddy water. At this altitude the atmosphere is colder, which means that the Earth radiates less energy than before. An imbalance occurs between the incoming amount of radiation from the sun and the outgoing heat radiation from the Earth, i.e. not as much energy is radiated from the planet as reaches it. This difference in energy causes glaciers to melt, seas to become warmer and the temperature of the air to rise. This process will continue until the temperature in the atmosphere has risen to such an extent that the amount of emitted energy equals the incoming amount or until the Earth's albedo is raised so much that a larger proportion of the sunlight is reflected. (Melting glaciers reduce the albedo in a similar way to the expansion of forests in the most northerly latitudes. The expansion of deserts also raises the albedo but this is hardly desirable.)

This leads to – or might lead to – consequences that affect the weather systems, glaciers, sea levels, ocean currents, ecosystems and many other factors that make up the climate system. “Won’t the atmosphere heat up quite quickly and a new equilibrium be reached?” The answer is both yes and no. It has been seen that a significant proportion of the surplus energy is used to melt glaciers and raise ocean temperatures. These are slow processes, from a human point of view, but they do form the basis for permanent changes. Some of the changes feed back into the cli-

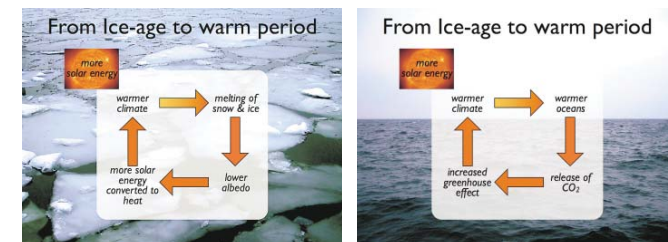


FIGURE 7. Feedback created earlier climate changes. An initial change in the incoming amount of solar energy allowed the Earth to emerge from its last ice age about 10 000 to 12 000 years ago. This change in amount of solar energy melted glaciers, making more of the land and water surfaces visible and more solar energy was absorbed, making it warmer, which led to... Similar processes occurred in the oceans and when they became warmer there was a net emission of carbon dioxide, which reinforced the greenhouse effect, which made it warmer... These processes are still occurring today but the changes now have not been caused by changes in solar energy but by the greenhouse effect, now enhanced as a result of human activities.

mate system inasmuch as they create further climate changes. Similar processes have occurred before, for example, when the planet emerged from its last ice age.

Then, about 10 000 to 12 000 years ago, the Earth began to warm up, due to changes in incoming solar energy and the angle of the Earth's axis etc. This resulted in a certain amount of snow, ice and glaciers melting. In turn, this led to the planet becoming a little darker, as the surfaces under glaciers and oceans are darker than snow and ice. The darker surfaces absorbed more of the solar energy and the climate became warmer. And the system was reversed: the warmer climate caused more snow and ice to melt and similar processes occurred in the oceans. They also became warmer but at a slower rate than the temperature rise in the air. As the oceans became warmer they began to emit carbon dioxide. More carbon dioxide in the air increased the intensity of the greenhouse effect (still 10 000 to 12 000 years ago). The enhanced greenhouse effect made the climate warmer and the oceans became even warmer. Precisely the same effects are taking place today. The difference is that the changes in incoming solar radiation are small compared to the human effects on the climate. We have started climate changes that could become self-perpetuating. For further explanations, see Basic Radiation Calculations at Discovery of Global Warming by Spencer Weart [www.aip.org/history/climate/radmath.htm].

NOT ONLY CARBON DIOXIDE

Judging by the debate in the media it is easy to get the impression that carbon dioxide emissions from oil, coal and gas are the main culprits and that, for example, carbon dioxide from bio fuels (methanol, ethanol, etc) is neutral or even beneficial to the climate, i.e. environmentally friendly. Carbon dioxide is carbon dioxide; nature does not care where it comes from. It is the sum of all emissions of carbon dioxide that causes changes in the greenhouse effect. As long as there is a surplus of greenhouse gases in the atmosphere it is in the interests of humanity to reduce all emissions, even natural ones from decay or combustion of biomass. This is why manufacturers of bio-fuels should take on greater responsibility and permanently store the carbon dioxide that is created as a bi-product of ethanol and other bio-fuel manufacturing processes. Today, the carbon dioxide created in these processes is released, the argument being that it is natural. It would, however, be quite easy to compress and permanently store it while it is still in a concentrated form. However, not only human emissions affect the climate; there are other greenhouse gases.

The concentrations of methane and nitrous oxide have increased over the last two hundred years. And we have also added new artificial substances that are also greenhouse gases, for example, freon and perfluoromethane. We must also remember that greenhouse gases are not the only factors that affect the climate, we also affect it in other ways, for example, by turning forest into open fields or generating pollutants such as soot, sulphur compounds and other particles.

People contribute in many ways to all aspects of climate change. Extra greenhouse gases heat up the atmosphere while emissions of particles of soot, sulphur compounds etc, generally speaking, have a cooling effect. To a certain extent, these can compensate for each other where the mean temperature is concerned but they have other effects on the climate system that cannot be compensated for. For example, particles are nothing but pollutants and higher concentrations of air pollutants can hardly be regarded as a justifiable means of compensating for a rise in the mean temperature.

**WE HEAT AND WE
COOL**

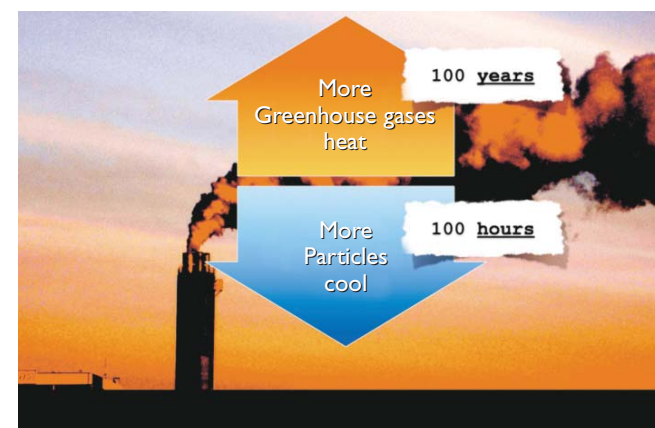


FIGURE 8. Man both heats and cools the climate. The heating effect, however, lasts far longer than the cooling effect.

When we study the causes of climate change over the past 200 years it can be seen that:

- Human effects are greater than natural causes, such as variations in solar radiation.

- The climate is being heated as a result of the increased presence of greenhouse gases. Changes in carbon dioxide concentrations are mostly responsible.
- Part of the heating effect is, however, hidden, as we also emit other pollutants than greenhouse gases, in the form of airborne particles, into the atmosphere. More air pollution means a greater proportion of the solar radiation is reflected away from the planet.
- Deforestation affects ecosystems, local weather conditions and global climate as the ground surface becomes lighter (changed albedo).
- The air pollutants that have a cooling effect can remain in the atmosphere for days whereas greenhouse gases remain for hundreds and, in some cases, thousands of years.

Man thus affects the Earth's radiation balance and, thereby, its climate in a number of ways. The change in carbon dioxide concentrations is the

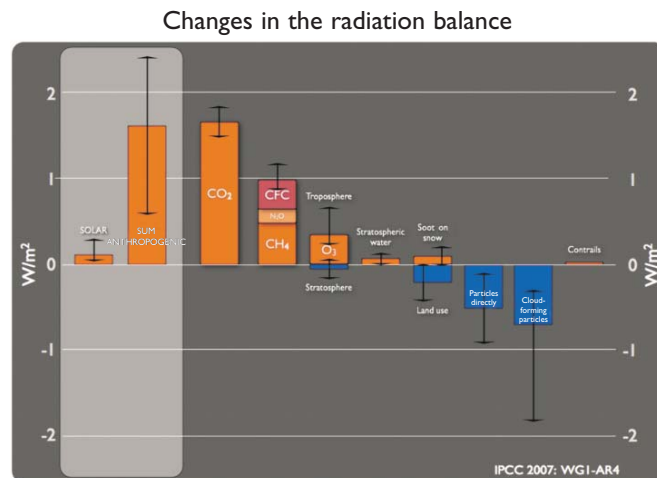


FIGURE 9. The change in radiation balance over the past 200 years. Human effects on the climate have been greater than the natural effects (solar variations). The black lines denote the margins of uncertainty. Note that the climate effects are not only due to carbon dioxide, not even only to greenhouse gases. Man is also responsible for processes that cool the climate system, for example, deforestation (changing the ground surface conditions) and air pollution (the bar 'Cloud-forming particles' represents the effects of particles that act as condensation nuclei for forming clouds).

largest single factor. This, in combination with the fact that a great deal of the emissions are derived from energy production, transportation, etc., makes it the most important problematic area. Climate changes caused by man are larger than those caused by nature, for example, those caused by variations in solar radiation (the variations in solar radiation effects on the climate have in no way been forgotten). Man also contributes further via processes that both heat and cool. The margins of uncertainty are large, especially with regard to the effects of particles. The net change is in the magnitude of 2.5 W/m^2 . If we can clean the air (primarily over parts of Asia) we will win on the health account but cause a greater heating effect, as part of the cooling effect will disappear as the particles disappear. The change in the radiation balance of about 2.5 W/m^2 is to be compared to the energy that is radiated from the Earth, which is about 240 W/m^2 . The radiation balance contributes towards heating the oceans, melting glaciers and raising the temperature of the air.

During periods with small climate changes, the flows of carbon to and from the atmosphere are approximately the same. Today, human activi-

THE CARBON CYCLE

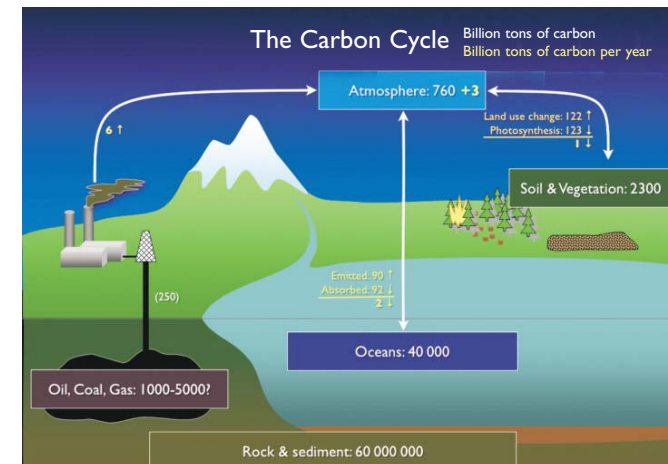


FIGURE 10. The carbon cycle. Despite man's emissions being relatively small compared to those in nature, they still affect the climate system. Nature releases and absorbs carbon dioxide, man only releases it. And, slowly but surely, we have changed the greenhouse effect and the climate system.

ties, such as the burning coal, oil and natural gas, provide a net surplus of carbon in the atmosphere. Before the industrial revolution, the atmosphere contained about 600 billion tons of carbon and now there are about 760 billion tons and this is noticeable, among other things, as a reinforced greenhouse effect. There are, however, other larger reservoirs of carbon on the planet: biomass and soils contain just over 2000 billion tons and in the bedrock there are a further 60 000 000 billion tons of carbon. By extracting and combusting oil, coal and natural gas, mankind has contributed to increased concentrations of carbon in the atmosphere. And this is despite the fact that nature absorbs about half of the carbon dioxide annually released by man into the air.

The annual flows of carbon to and from biomass sources and the oceans is about 30 times greater than human emissions – just over 200 billion tons to man's 6 billion tons. But, as man only adds but never removes carbon dioxide, these emissions have caused the concentrations of carbon dioxide to change. The capacity of the oceans and the biosphere to absorb carbon is also dependent on temperature, weather, ocean currents etc. Increasingly warmer oceans will release carbon while the cold ocean surfaces that absorb carbon are diminishing in size. Expected results of climate change include forest fires that will release carbon into the atmosphere and further reinforce the greenhouse effect. The system could find itself in a situation where there is a net release of carbon dioxide to the atmosphere from the sea and biosphere instead of the situation today, in which they absorb more than they release.

It is uncertain how large the reserves of carbon, in the form of oil, coal and gas actually are. Probably there is not enough carbon to achieve the worst case scenarios depicted by the IPCC (UN's climate panel, the Intergovernmental Panel on Climate Change). However, there is more than enough to shift the climate system far from acceptable levels. Shortages of oil, coal and gas are not large enough to prevent us from creating enormous climate changes. Oil and gas are the resources estimated to run dry first (which in itself will create enormous problems in western economies and societies). This will happen long before carbon reserves begin to give out, as most of the fossil resources are in the form of coal. From a climate perspective, the greatest problem connected with fossil energy is the risk that we will continue to use coal as an energy source for a long time (more than another ten years), without separating and permanently storing the carbon dioxide. Coal is not estimated to be in short supply this century.

Nature has experienced numerous climate changes. Our modern societies have never been close to even the most modest climate changes that we now fear. We assume that ecosystems (for example, vegetation), basic ecosystem processes (for example, filtration processes that create drinking water) and weather patterns (such as storms and sea levels) will not change to a greater degree than we, and nature, can adapt to. Risks of conflicts between people increase when basic ecosystem processes change. They change our infrastructures, economic systems, security policies, food supplies, etc, and put stress on and undermine society values. Sluggishness in the system means that it will take hundreds, maybe thousands, of years before a new climate stabilizes, as seen in sea levels, vegetation zones etc. The climate is never stationary but can be relatively stable over shorter or longer periods of time.

A significant proportion of the climate changes can be attributed to human emissions of greenhouse gases and air pollutants, and to deforestation. To avoid catastrophic climate situations we must reduce our emissions by 50 to 85 % within the next few decades, according to estimates made by the IPCC. The climate system will not become stable as long as there are sub-systems, for example, mankind, that add more greenhouse gases than they remove. As long as we keep on adding more than nature or we can absorb, it will shift the climate and ecosystem, for example, via changed pH values in the sea, away from earlier positions of equilibrium. If we want to avoid this, net human emissions will have to decrease by at least 100 % and finally reach a level at which there is a net absorption of greenhouse gases instead of persistent generation, experienced up to now. The research community has not reached consensus about the time limits within which we will have to reduce our net emissions to zero. Depending on what climate consequences are acceptable and how quickly the reduction can take place, the conclusions drawn vary, from having already passed the point in time when our emissions should have been zero to having 10, 20, 50 or even 80 years to go. There is a risk that seas, land areas and the biosphere will start to release more greenhouse gases into the atmosphere than they absorb. If and when this happens, man will have completely lost the initiative for opportunities to limit climate change. Nature itself will then drive the changes instead of, as today, slowing them down by storing about half of the human emissions.

Stopping the use of fossil resources is easier said than done. An essential part of our welfare has been created and is maintained by energy that

**HOW LARGE A
CLIMATE CHANGE CAN
SOCIETY COPE WITH?**

comes from fossil resources. Nonetheless, it is important to avoid continued effects on the climate. Continued use of fossil resources is motivated by the argument that they are needed to keep the wheels turning, that our social structures require them. The question, however, has not been completely answered because, at the same time, we choose not to see the enormous consequences that follow in its wake, partly due to the physical shortage of oil that will occur as a result of supplies drying up and partly due to the enormous strains on our societies that will arise as a consequence of climate change. And these changes will not stop until long after we have stopped affecting the climate.

Completely new market forces and incentives arise as knowledge about our vulnerability due to climate change is spread among the general public, politicians, markets and investors. “Peak Oil” and “Peak Coal” are two other large problems that emphasize the necessity for making processes energy-efficient and reducing our dependency on fossil energy. Peak Oil and Peak Coal mean that the production/extraction of these resources has reached their maximum rates. Supplies will then decrease despite rising demand. The shortages of oil, coal and gas will not solve the climate problem; on the contrary, they will increase instability in society. We have had plenty of time to make ourselves less dependent on fossil resources. To a certain extent we have been successful, but to a certain extent we also continue to use and even create new infrastructures that assume the availability of fossil resources. The argument is often that we must have access to cheap energy or that alternatives are too expensive. What will happen then when the Peak Oil rate is reached? Will the arguments for cheap energy still be valid? Will the alternatives then be cheap? The Peak Oil situation will occur; the question is when. ASPO, the Association for the Study of Peak Oil and Gas, is looking into these questions and at the time of writing, January 2008, their scenarios suggest that the peak will be reached around 2010, see www.peakoil.net.

However, there is no shortage of energy on Earth. There is 10 000 times as much renewable energy (instantaneous power) available than we currently use. The fuel is free in the form of solar, wind and wave energy and will never cease to be available. Hydropower is also renewable but affects watercourses and ecosystems in an irreversible way, i.e. the change can never be restored. Even bio-fuels are renewable but must be used very carefully as supplies are limited and production processes affect ecosystems and the climate. The production of bio-fuels is also carried

out in competition with the production of foodstuffs. Ethical questions arise around the morals of producing fuels rather than food.

In order to describe what can happen to the climate, computer models of climate systems are created. These are complex, non-linear systems with feedback loops that try to answer questions about how climate systems – the atmosphere, hydrosphere, cryosphere, geosphere and biosphere – will change over the coming years, based on different scenarios about our behaviour and how sensitive the climate system is to changes, feedback, etc.

All scenarios show that the climate will change more, the more greenhouse gases and particles we release into the atmosphere and the more forest we chop down. Airborne particles, for example, those created by combustion, can have a temperature damping effect. The net effect of the particles, air pollutants, is that they damage health, affect farming production negatively and hide a significant part of the heating effect that the surplus of greenhouse gases entails. Particles can remain in the air for a few days compared to greenhouse gases that can remain for hundreds or thousands of years. This means that to retain the cooling effect we would have to continue to pollute the air, which, of course, is not acceptable. In addition, the particles cannot compensate for all the effects of the extra greenhouse gases – they can only affect the mean temperature. This illustrates yet another dimension of the problem of global warming, as different human effects on the climate, under certain conditions, cancel each other out but can still not provide complete compensation. This is worth bearing in mind when we, in the future, will most probably discuss the possibilities of compensating for human climate effects via other human effects, so-called geo-engineering.

So far, we have mostly talked about change of temperature as a climate parameter and, in particular, the mean temperature. There are, of course, other climate parameters that are undergoing change, as well as secondary effects such as changes in the biosphere, i.e. in abilities of plants and animals to adapt, or changes in the hydrosphere and cryosphere, i.e. in water in both liquid and solid states.

An important consequence of temperature changes can be seen in adaptations in the cryosphere, i.e. in the amounts of snow and ice. Measurements verify the assumption that temperature rises, to a great extent, cause land and sea glaciers to melt. At present, rises in sea levels are in the order of 3 mm per year, of which 1 to 2 mm are a result of the

SCENARIOS FOR THE FUTURE

increasingly warmer water expanding and 0.5 to 1 mm as a result of land based glaciers melting. The IPCC, the UN climate panel, estimates that the sea level in the next hundred years will rise by at least 0.2 to 0.6 m above today's level. The stabilization level, i.e. the level reached before the sea level ceases to rise is estimated to be 0.4 to 3.7 m above today's level. This could take hundreds or thousands of years. But this is only the rise in sea level due to the expansion of water due to increased temperature and the melting of glaciers from the Alps. The melting away of other land based glaciers, especially in Antarctica, will contribute significantly to the rise in sea level but is so difficult to quantify that discussions have been in qualitative rather than quantitative terms – the IPCC in their 2007 report could not agree on any actual figures.

Even half-metre-higher sea levels will affect many of the planet's large coastal cities. And even if these cities will not be completely flooded, there will be severe consequences with regard to the quality of drinking water and risks of flooding in sewage systems, communication systems (such as underground railways) and power distribution systems. The costs of adapting to or fending off the consequences are difficult to assess.

There are some researchers, however, who maintain that the IPCC estimates are far too low with regard to the rise in sea level. Prehistoric climate changes show examples of very large rises in sea levels over very short spaces of time and they question why such rises should be excluded in the near future. 14 000 years ago the sea level rose by 20 m within the space of 400 years, i.e. at an average rate of 1 m every 20 years. The creation of glaciers, and corresponding lowering of the sea level, is a dry and slow process. Their melting away and the subsequent rise in sea level is a wet and quick process. James E. Hansen, adjunct professor at Columbia University and head of research at NASA, wrote about "multi-metre sea level rise on the century time scale" in the "Business as usual" scenarios. He also says that a 5 m higher sea level is most probably a better estimate than the IPCC's 0.2 to 0.6 m for 2100 [Hansen, 2007].

The IPCC's compilations and quantifications should be regarded as the *smallest imaginable* changes, not necessarily the most probable ones. Above all, these are not the greatest changes that can occur. The IPCC does not rule out that changes could be quicker or larger. This is precisely what happened in the late summer and early autumn in 2007 when an unexpectedly large area of the Arctic ice cap melted. Seasonal variations mean that the ice cap normally has its smallest spread in the middle of

September every year. It was known that the ice cap was gradually diminishing and it was estimated that the North Pole would be ice-free by the summer of 2100. Satellite surveys, however, showed a situation in 2007 that had not been anticipated until 2040 [Carbon Equity: The Big Melt].

Glaciers are melting. This means that water flows in rivers are increasing, which initially will affect farming in a positive way. On the other hand, as glaciers melt, the risk of landslides increases, both close to the glaciers and along the river courses. Within a few decades, smaller volumes of water will be seen in rivers, as the water reservoirs in the form of glaciers quite simply will have melted away and run out to sea.

Forest fires are occurring more often. As the climate changes, the conditions under which plants can survive, after having adapted themselves for thousands of years to comparatively stable climates, also change. It is not unusual for forest fires to start because of human actions, for example, due to sparks from a train or people setting them alight on purpose, or for natural reasons, such as being struck by lightning. As the climate changes quicker than most plants, and especially trees, can adapt, this will most probably mean that the amount of dry biomass will increase in the future. Climate models also show that certain areas, for example southern Europe, will experience more hot and dry summers in the future. The number of forest fires will most probably rise and they will most probably be more difficult to put out. In the summer of 2003 there was an incredibly intense heat wave in southern Europe. Climate models show that summers like these will probably be the norm within 10 years or so from now. Many places will experience changes in weather patterns, primarily with regard to the probability of experiencing, for example, unprecedented precipitation and temperatures. Note that this does not necessarily mean higher temperatures; changes could be in the form of sustained hot periods. Many climate models show that the probability of heat waves will increase at the same time as extreme cold periods decrease. Furthermore, the paths of low pressure will be displaced while the probability of heavier precipitation will increase.

The greenhouse effect was described by the French mathematician Joseph Fourier [Fourier, 1824]. He also suggested that the temperature of a planet depended on the relationship between the incoming and outgoing radiation, that the Earth received short-wave radiation from the sun and re-emitted long-wave radiation. The Swedish chemist Svante Arrhenius described in 1896 how a halving of the concentration of car-

**WE HAVE KNOWN
FOR SOME TIME**

bon dioxide in the air could explain the colder climate that prevails during an ice age. His colleague Arvid Högbom carried out calculations on the natural flow of carbon dioxide and together they realized that human combustion of coal could change the climate. All that was required was to burn enough coal for a sufficiently long period of time. Two American oceanographers, Revelle and Suess, described in 1957 how “Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future, due to the combustion of a significant amount of fossil carbon and are, thereby, changing the chemical compositions of the atmosphere and seas” [Revelle och Suess, 1957]. Over the past two hundred years, many other researchers have contributed to the increase in knowledge about our effects on our environment. For a long time, we have known that the lives we are leading are neither sustainable nor responsible. However, researchers have not been very good at communicating this knowledge to the general public, trade and industry and politicians. Nor has society been interested in listening to and understanding the extent of this knowledge. A great change has taken place in recent years with respect to the attitudes to this knowledge and our ability and willingness to be informed.

IT IS NOT THE ELEVENTH HOUR

There are many who would like to use the symbolic expression of “eleventh hour” and say that we must now act forcefully to avoid climate change. Unfortunately, it’s already past twelve o’clock – climate change can no longer be avoided. On the other hand, as the climate is an on-going dynamic process, we can influence the degree and speed of change but only within certain limits.

Unfortunately, we might find ourselves in a situation in which nature itself is the driving force behind climate change and we will be powerless to stop it. Many researchers maintain that this limit will occur around a temperature rise of three degrees. When we have reached this point the oceans and biosphere will turn into sources of carbon dioxide instead of being the carbon dioxide sinks they are today. In that case, a temperature rise of more than four degrees Celsius will be inevitable. These are pure speculations and are actually unnecessary, as all our efforts must be directed towards avoiding climate changes of 1 to 2 degrees. Even at this level we will find ourselves at the limits of what we can expect our social structures to be able to manage. The impact on basic functions such as food production, clean water, existing infrastructure etc will be enor-



FIGURE 11. For ten thousand years our climate system has been relatively stable, with only a few minor variations. It has now left its historical state and departed on a journey into the unknown; the Earth’s climate systems are now undergoing real changes. Hopefully, we can stop climate change relatively soon. We will, however, never be able to return to those of the 1900s.

mous. Conflicts and even wars due to lack of basic human needs cannot be ruled out. Besides the underlying social, ethnic and political reasons, it has been pointed out by the UNDP (United Nations Environment Programme) that the conflict in Darfur was partly caused by environmental changes due to erosion and partly caused by climate changes. The desert has spread more than 100 kilometres in 40 years, 12 % of the forest in Sudan has disappeared in the last 15 years and precipitation has been reduced by a third over the last 80 years in northern Darfur [UNDP, www.unep.org]. These climate changes are estimated to reduce farming productivity by a further 70 %. An important issue for the peace-keeping activities in Sudan is the extent to which a sustainable environment can be attained, primarily by limiting erosion of forest and farming land. The tragedy in Sudan is an example of how man’s use of natural resources, such as fertile land and forests, in combination with climate change can destabilize communities and even whole nations. The slow processes innate in climate systems and societies mean that climate changes must be reduced long before critical limits are reached. The consequences will otherwise escalate and become self-perpetuating.

CONSEQUENCES

If we do not act forcefully to reduce climate change, the consequences will be disastrous. An increase of only two degrees will mean that millions of people will risk being without fresh water, 20 to 30% of our ecosystems will die out etc. Nobody knows how this will affect our social structures and the changes will not be easy to handle. Nicholas Stern, former head of the World Bank wrote in his report *The Economics of Climate Change: The Stern Review* [www.hm-treasury.gov.uk/] that the consequences can be compared to the depression in the 1930s or to the World Wars and that it could be very difficult to find a way out of the crisis. "In order to stabilize the amount of greenhouse gases in the atmosphere, emissions must first peak and thereafter decline", wrote the IPCC in one of its reports in 2007 [IPCC Summary for Policymakers, 2007]. "The sooner the peak occurs and the greater the decline becomes, the smaller the climate changes will be." It is of extreme importance that man's effects on the climate are rapidly reduced. And when we have reached this goal, when net emissions of greenhouse gases into the

Stabilization

In order to stabilize the amount of greenhouse gases, GHGs, in the atmosphere, the emissions must first peak and thereafter decrease.

IPCC Fourth Assessment Report, Working group III

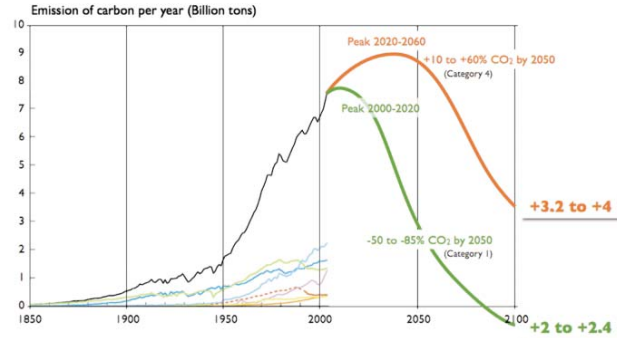


FIGURE 12. The amount of carbon in the carbon dioxide emitted from human sources per year. The black line shows the total emissions, the coloured lines to the left in the diagram show the proportions for the respective regions: Green for Europe, blue for USA. Emissions exploded after the 1950s. Two scenarios for reduced emissions and the consequences in the form of changed mean temperature are shown. Note that the curve representing the greatest reduction falls below zero before the year 2100.

atmosphere are no longer created, the climate will continue to change because of all the sluggishness in the system. But, the sooner we act, the smaller the problems will be.

As significant proportions of the emissions are connected to our fundamental ways of creating welfare, these innately slow processes will have to be taken into consideration: For example, it will take time to change our transportation systems, now mainly driven by fossil fuels. The same applies to the generation of electricity. We must, however, remember that there is no lack of energy on the planet: our momentary power output is 13 TW (13 000 000 000 000 Watts). This is the power that we, 6.5 billion people, use to generate our welfare. At the same time, nature can offer 120 000 TW in the form of solar energy, wind, wave energy, biomass etc. This is the amount of energy that originates from the sun and that is converted into different forms. Consequently, there is no shortage of energy sources on the planet, but there is a shortage of methods that we can use to harness them.

The first lesson we will have to learn is how to increase energy efficiency, from changing light bulbs to using waste energy from industrial processes for heating homes. At the same time we must question our own ways of living. This becomes very obvious when we see how the western world questions the ambitions of developing countries to create their own welfare in similar ways to how we created ours.

We must, of course, increase the proportion of renewable energy sources, for example, by harnessing wind and solar energy, and via a sustainable use of forest and farm produce. However, it is not enough only to do what is right; we must also greatly reduce doing what is wrong. Seen from a supply perspective, it might be more important to increase our ability to use renewable energy but, from a climate perspective, it might be more important to reduce fossil combustion and deforestation. Naturally, these two processes must take place simultaneously: we must reduce energy use, increase the proportion of renewable energy sources and reduce the use of fossil energy sources. We should strive to carry this out both in our own and other countries. We must adapt ourselves and help others to adapt themselves to new climate situations.

We must also understand that it is not only a question of climate change and energy. We have created a number of processes that change ecosystems, the ability of plants and animals to reproduce (among other things, we have created environmental toxins that can even be found in

ENERGY

our own bloodstreams). However, the most clearly noticeable fact is, perhaps, that man has not just been an observer: he has actually been a player in the evolution of this planet by causing climate change. Unfortunately, the learning curve about the climate has been unnecessarily long. Many wise scientists raised the question and threw light onto it half a century ago. Ironically enough, man has, via his capacity for reasoning, his sense of competition, curiosity, egoism etc, first created welfare (and jealousy) but lacked the ability to realize in time the real threats to this welfare. And we have now really fallen behind. Henceforth, it will be a question of reducing climate effects, as well as fending off/adapting to climate change. If we had started earlier, it would, to a great extent, have sufficed to reduce effects on the climate. And, strange as it may seem, the solution in itself is neither threatening nor unwelcome. The solution lies in the use of renewable energy sources and refraining from using the limited, non-renewable sources. There is no shortage of energy, ideas or willingness to do the right things. Most important of all, however, is not to do the wrong things.

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COMMENT

Never before has so much justifiable attention been paid to the outdoor environment. No matter whether the issues have concerned diminishing fossil fuel resources or the effects of man on the outdoor environment and climate, there is every reason why we should exert ourselves to the limit to reduce the effects of these actions. This is probably the most profitable investment we can make – not only for ourselves but also, and above all, for future generations.

EPILOGUE

The *Swegon Air Academy* hopes that this book will, to some extent, contribute towards an increased understanding of how a good indoor climate can help to make a building comfortable, efficient and profitable. We also hope that this book will increase understanding between the different players in the building industry and pave the way for an even better dialogue between property owners, architects, builders, consultants and installation contractors.

The chapters that discuss the present energy situation and how we ourselves affect the outdoor climate will, hopefully, cause us to reflect on these issues and stimulate active engagement. We can hardly prevent climate changes but we can join together to try and reduce them.

We would like to take this opportunity to thank all those who have made this book possible. In addition to all the contributing authors, we would like to thank Dr. Per-Erik Nilsson and his colleagues at CIT Energy Management for their valuable advice and especially Dr. Lars E. Ekberg, both for contributing three chapters and for his careful scrutiny of the other author's contributions.

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numerous ideas and suggestions, as well as a good dose of encouragement when I was almost ready to give up.

With your help and that of the authors, the result has not been a dry textbook but a timeless publication with a soul of its own. You don't have to read it from cover to cover in one go: read it as you please - just pick out a suitable chapter and satisfy your curiosity!

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Director of the *Swegon Air Academy*

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The *Swegon Air Academy* is a forum for objective and company-neutral sharing of knowledge and experiences related to air handling and indoor climate issues.

One of our primary goals is to explain complex relationships in an intelligible way, so that those who are interested in a subject can understand it at a deeper level.

Via seminars, newspaper articles and literature, the *Swegon Air Academy* contributes to a greater awareness of the importance of indoor air quality for health and well-being, to an increased understanding of the energy issue and to a higher level of involvement in matters concerning the outdoor environment.

The *Swegon Air Academy* provides information and educational activities all over Europe and co-operates with well-known experts in relevant fields.

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