1 Climatic zones

The interaction of solar radiation with the atmosphere and the gravitational forces, together with the distribution of land and sea masses, produces an almost infinite variety of climates. However, certain zones and belts of approximately uniform climates can be distinguished.

The global classification of climatic zones is:

1. cool zones

2. temperate zones

3. arid / sub- tropical zones

4. tropical zones

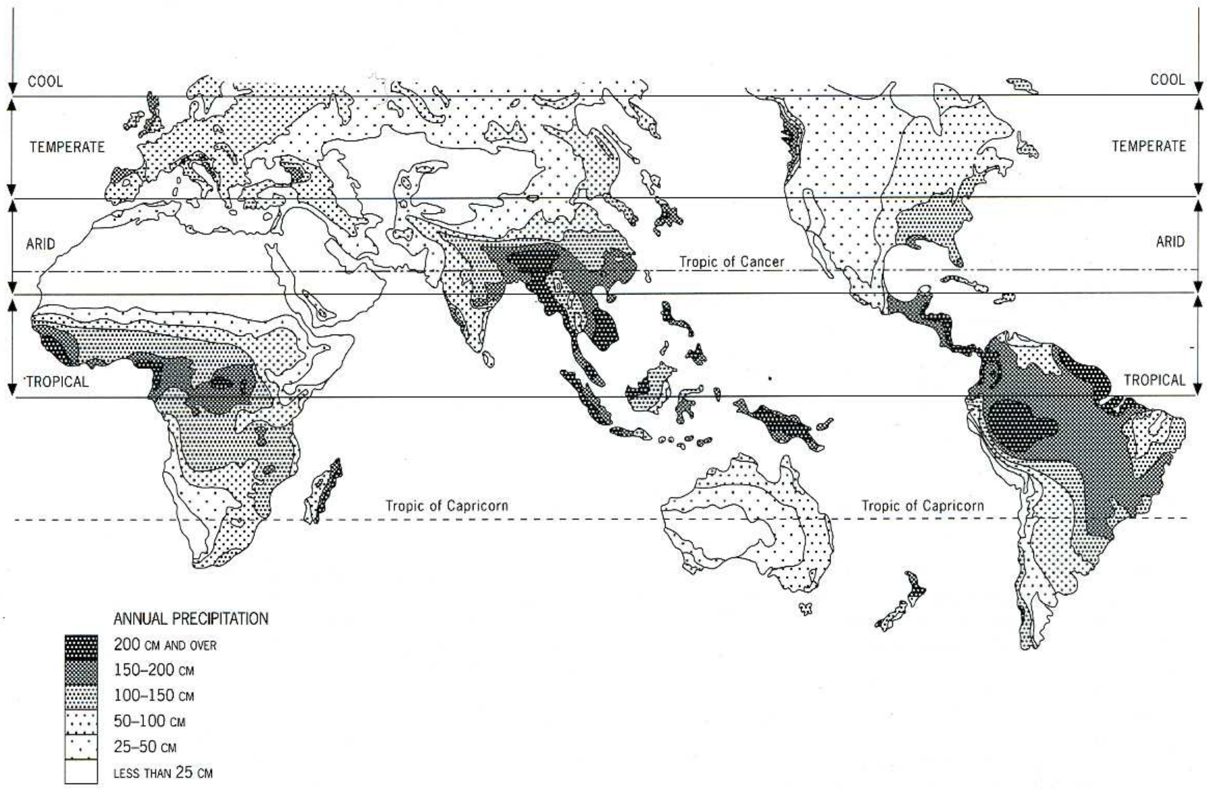


Figure 1.1 Global distribution of climatic zones [1]

2 Climatic factors

The climate of a given place / region / area is the total composition of many factors defining the state of the atmosphere at that place.

Such factors include temperature, humidity (wetness / dryness), wind (speed, direction), atmospheric clarity (or dustiness) etc. Some of the major factors influencing climate on a global scale will be further explained below.

2.1 Solar radiation

The sun is the major factor influencing climates. Almost all of the energy reaching the earth comes from the sun in the form of radiation.

2.1.1 Mode of action of

2.1.1.1 Solar power

The solar constant I_0 is defined as the intensity of radiation reaching the upper surface of the atmosphere. It varies slightly due to variations of the output of the sun itself and due to changes in the earth- sun distance.

Regardless of these effects the “standard” solar constant at the top of the atmosphere is defined as I_0 = 1395 W/m².

The amount of radiation reaching the earth´s surface depends (among other things) on the location and the time. For example in Germany the maximum is approximately 700 – 1000 W/m².

The resulting energy received per unit area is equally depending on location and time and averages for example in Dortmund, Germany, 1055 kWh/(m²a).

2.1.1.2 Position of the sun

The Earth´s Axis of rotation (the line between the North and South Poles) is tilted to the plane of the elliptical orbit and has a constant direction. The angle of tilt is a constant 23.5°.

If the axis of earth were perpendicular to the plane of the orbit, it would always be the equatorial regions which were normal to the direction of solar radiation and therefore receive the maximum intensity. There would be no summer / winter seasons.

Due to the tilted position, the area receiving the maximum intensity moves to the North and to the South, between the tropic of Cancer and the tropic of Capricorn, which is the main cause of seasonal changes.

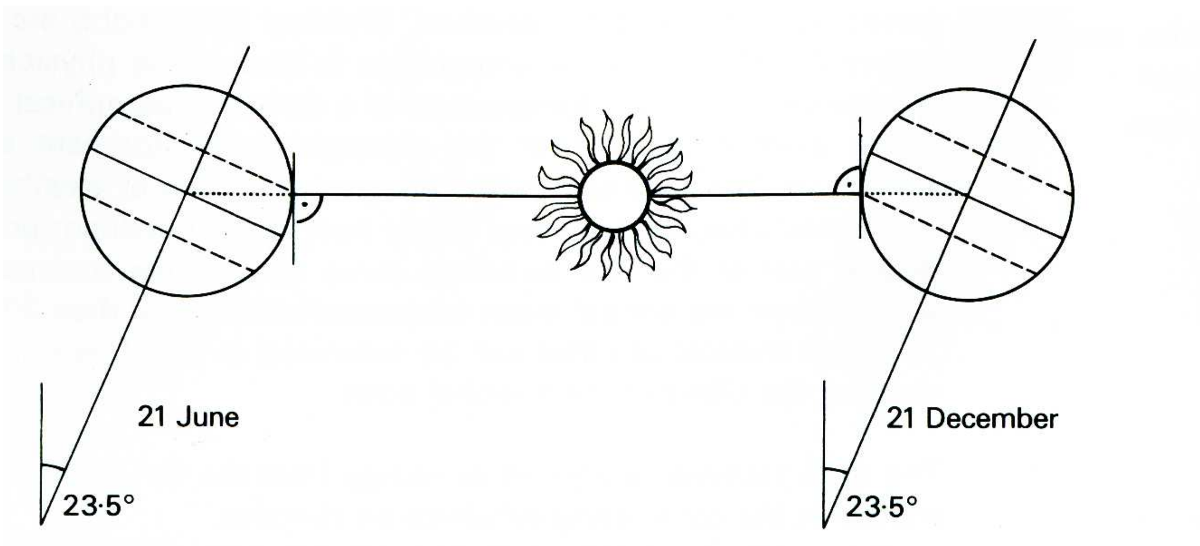


Figure 1.2 Earth- sun- relationship [2]

2.1.2 Influences of the sun´s position on the

2.1.2.1 Intensity of radiation

The earth- sun- relationship described before affects the amount of radiation received at a particular point on the earth´s surface three ways:

1) The angle of incidence effects that the intensity measured on normal surfaces is distributed on a larger surface that is tilted. This is described by the “cosine law”, as shown below.

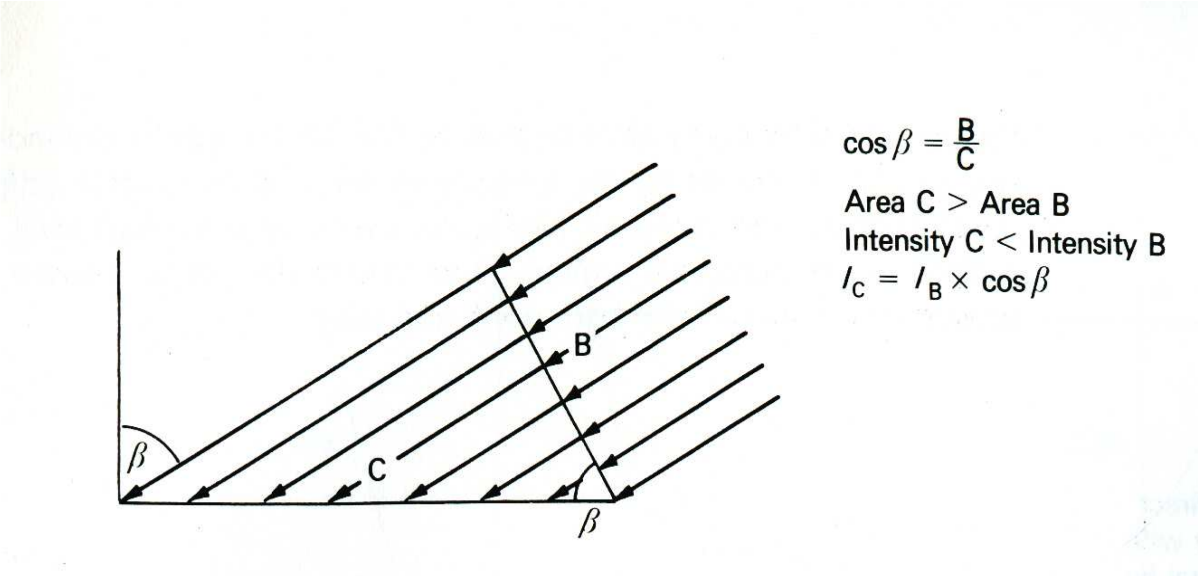


Figure 1.3 Angle of incidence of the sun [2]

2) The longer the path of radiation through the atmosphere (due to lower solar altitudes caused by the earth- sun- relationship), the higher is the atmospheric depletion. Atmospheric depletion (i.e. absorption, dispersion and reflection) creates a reduction factor of 0.2 to 0.7, generated by the the absorption of radiation by ozone, vapours, smoke and dust particles in the atmosphere.

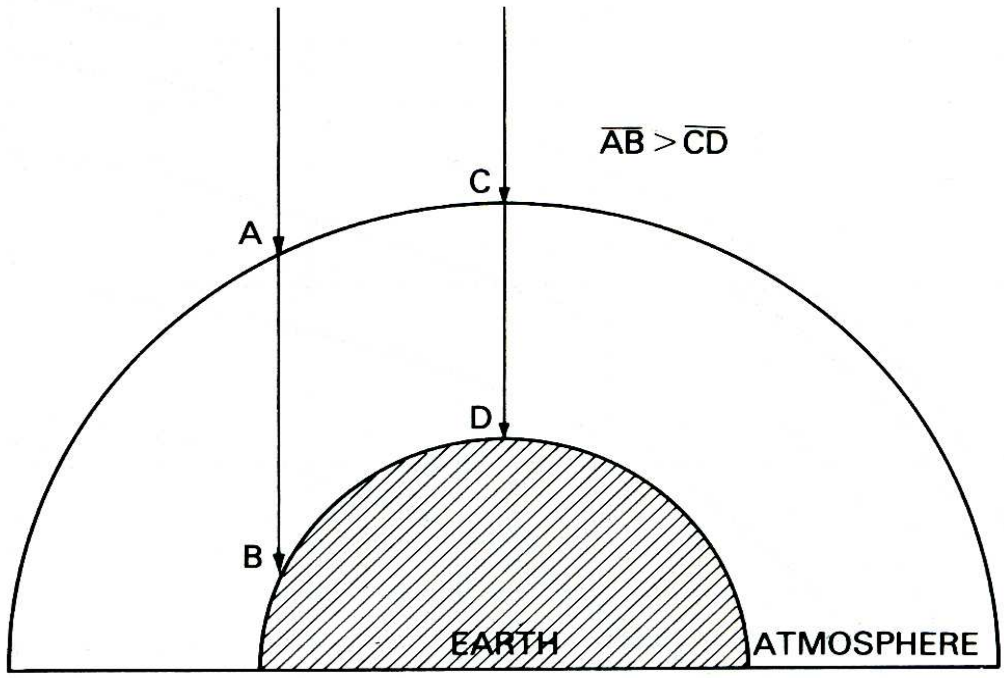


Figure 1.4 Length of path through the atmosphere [2]

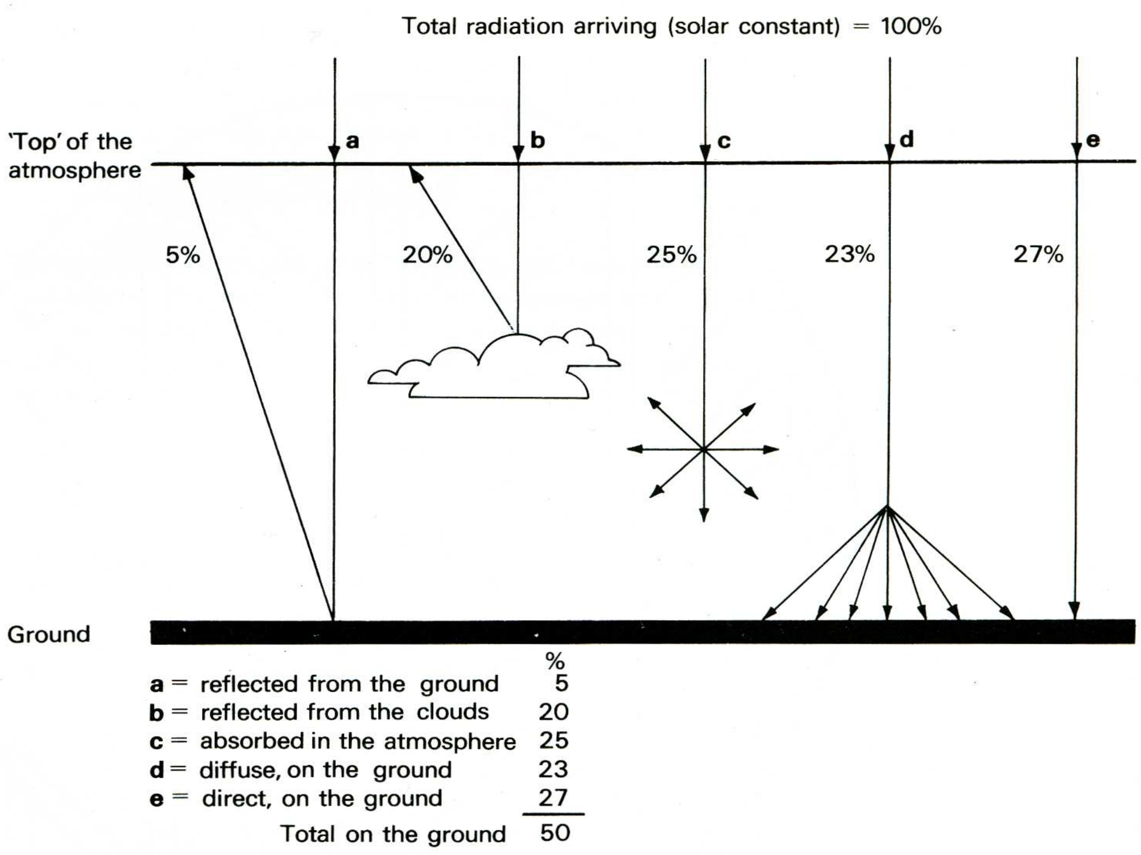


Figure 1.5 Passage of radiation through the atmosphere [2]

3) The duration of sunshine varies also due to the earth- sun- relationship and influences the radiation at the earth´s surface. The varying length of the daylight period between summer and winter in high latitudes is a well-known effect.

2.1.2.2 Thermal balance

The total amount of heat absorbed by the earth each year is balanced by a corresponding heat loss. Without this cooling the temperature of the earth and its atmosphere would increase day by day.

There are three processes of earth´s heat loss, as shown in the picture below:

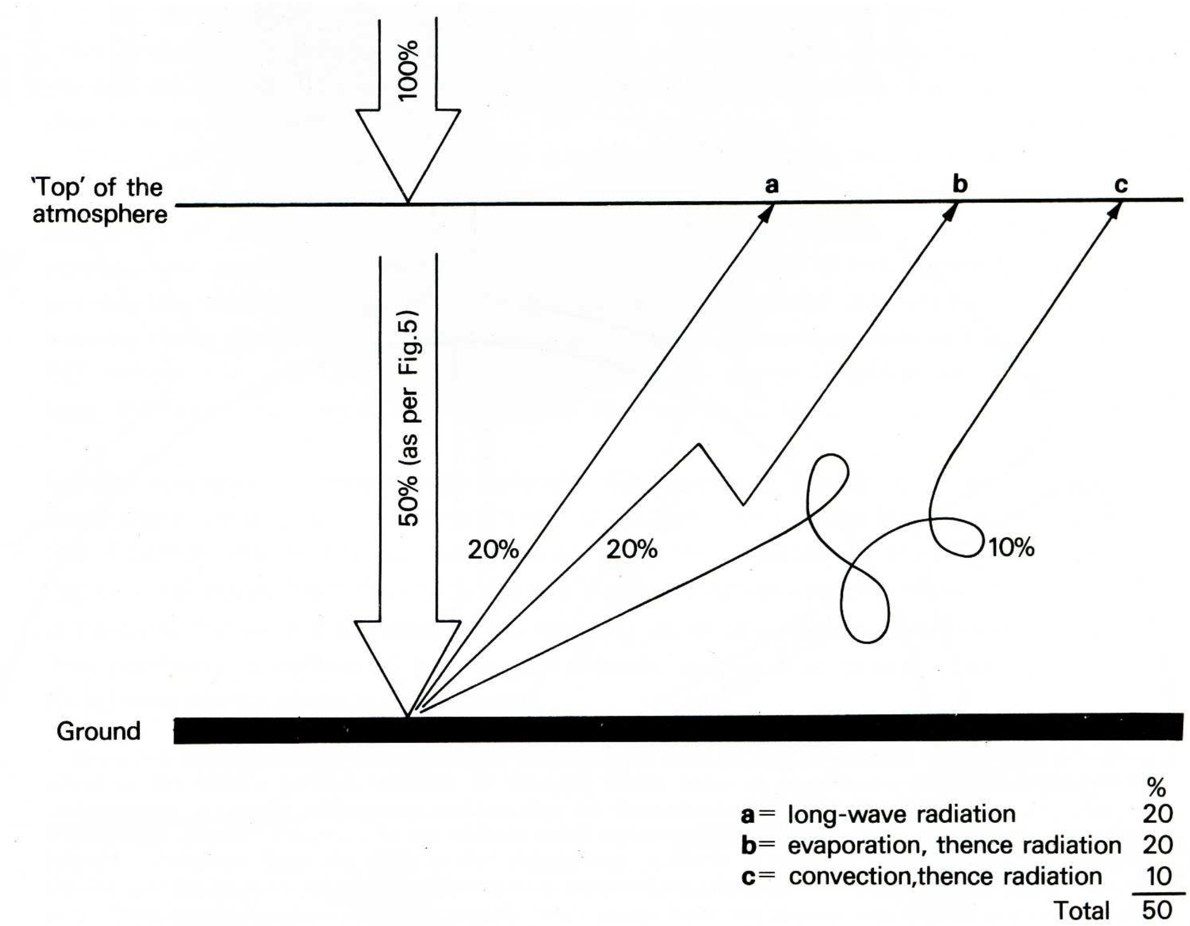


Figure 1.6 Heat release from the ground and the atmosphere [2]

1. Long- wave- radiation to cold outer space (only 16% of this reradiation escapes to space, the rest is absorbed again in the atmosphere)
2. Evaporation: As liquid water changes into vapour and mixes with air, the earth´s surface is cooled.
3. Convection: Air heated by contact with the warm earth surface becomes lighter and rises to the upper atmosphere, where it dissipates its heat to space.

2.1.2.3 Sky condition

As described before, the amount of solar radiation passing through the atmosphere depends significantly on the amount of water vapour it contains. The presence or absence of clouds in the atmosphere relative to the total size of visible atmospheric hemisphere is usually expressed as a percentage.

For example a cloudiness of 50% would indicate that half of the sky hemisphere is covered by clouds.

The following picture shows different sky conditions. With special cameras you can take such hemispherical pictures (imagine you lying on the ground, looking to the sky).

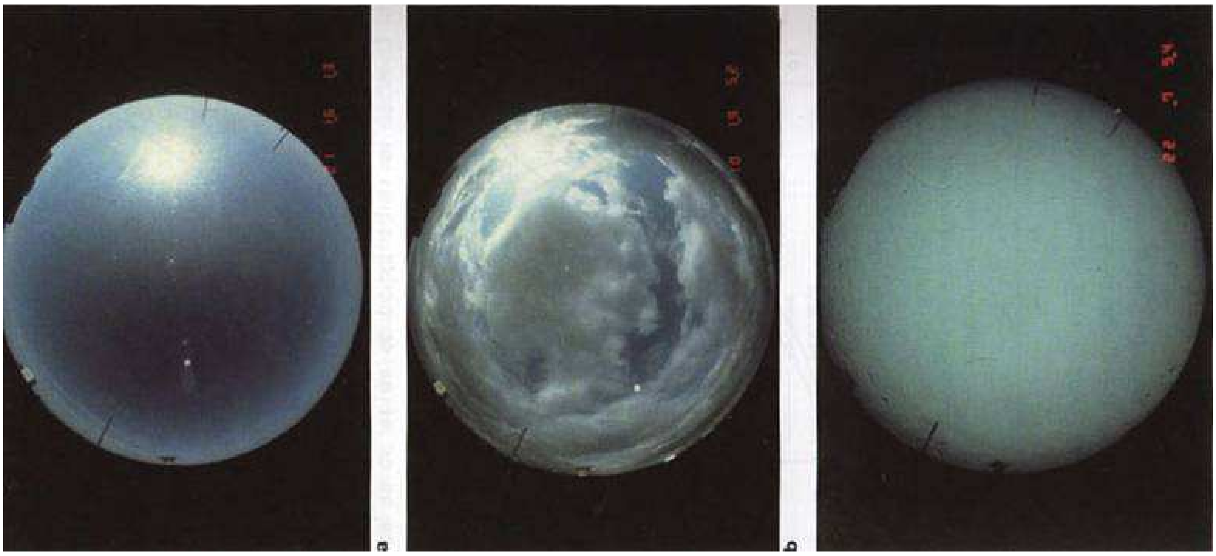


Figure 1.7 Sky conditions (0%, ~80%, 100% cloudiness)

On the left picture, the hemisphere contains no clouds (0% cloudiness), on the right picture the cloudiness is 100 %. From the picture in the middle you can measure the sky´s and the clouds´ surfaces and thereby calculate the actual cloudiness factor.

2.2 Air temperature

Temperature is usually expressed in degrees Celsius (°C), but absolute temperature is usually expressed in Kelvin (K), which is a SI-Unit (SI: International System of Units). The Kelvin scale starts at - 273.15 °C and goes by the same steps as °C.

Therefore the freezing point of water (0 °C) is already 273.15 K.

This leads to the relation

°C = K - 273,15 and K = °C + 273,15.

The differences between two temperatures is expressed in absolute values, i.e. Kelvin. For example: The difference between 10°C and 15 °C is 5 K, or the temperature is rising by 3 K from 15°C to 18 °C.

In some English-speaking countries usually temperature is measured on the Fahrenheit scale (°F) where the freezing point of water is 32 °F (0 °C).

The relation of the Fahrenheit scale to the SI-Unit Kelvin is described by

K = (°F + 459,67) / 1,8 and °F = K x 1,8 – 459,67.

This shows, that the difference between for example 20 °F and 21 °F equals only 0,56 K.

Herewith you can make a conversion between the °C and the °F scale using the formula

°C = (°F - 32) / 1,8 and °F = °C × 1.8 + 32.

2.2.1 Measured quantities

The most interesting measured quantities are

- air temperatures and
- surface temperatures.

In the appraisal of climates the differences between minimum and maximum temperature in any day can also be helpful.

2.2.2 Essential quantities in solar influence

The air and surface temperatures of climates are particularly influenced by

- solar radiation (Intensity [W/m²] and Duration [h])
- winds (velocity [m/s], duration [h] and direction) caused by global weather conditions
- local influences, especially at ground level.

2.2.3 Mechanisms of heating and cooling

In detail temperatures are influenced by the following mechanisms:

- Solar radiation heats the atmosphere (through absorption by water vapour, dust, CO_2, etc) and the ground
- The energy absorbed by the ground and other surfaces is transformed into infra-red (IR) radiation
- The IR radiation emitted by the ground cools the ground. This effect diminishes with growing cloudiness.
- The IR radiation emitted can be absorbed by the atmosphere again. This heats the atmosphere and the ground.

- With increasing levels of CO_2 and other absorbing “greenhouse” gases the heat becomes trapped in the atmosphere and causes the “greenhouse effect” (see section 3.2.1 below).
- The warm air above warm grounds rises. This effect leads to an air movement at ground level which is called thermal lift. This thermal lift dissipates energy and cools the ground.
- Evaporation of water cools the atmosphere immediately above the area where it evaporates. Winds may modify this situation by transporting the moist air somewhere else. At ground level humid surfaces (water bodies, fountains, plants etc.) pass vapour to the air.

The impact of cloud conditions on temperatures is shown in the following diagram.

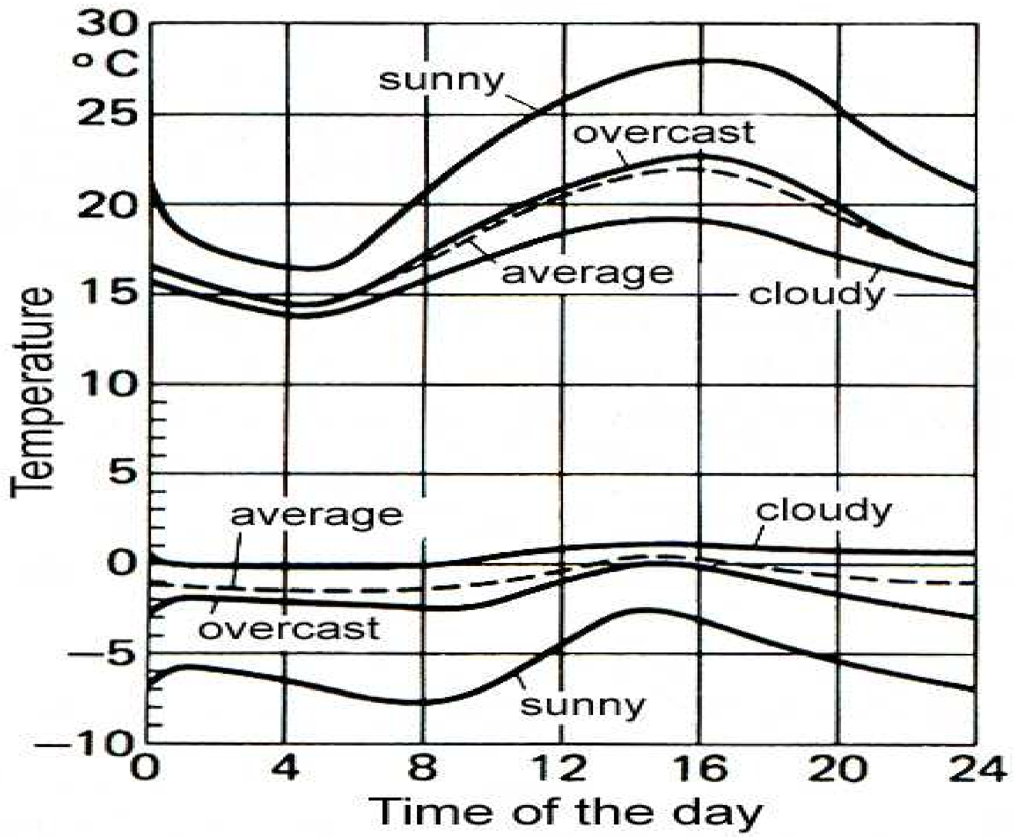


Figure 1.8 Impacts of cloudiness on temperatures [3]

2.2.4 Other influencing parameters

Climate is also influenced by other parameters, such as

- Topography / Slope towards the sun:
  Plains, inclinations, valleys and mountain peaks have different absorptions, wind situations etc.

- Vegetation:

Trees act against prevailing temperature layering by mixing the air. Furthermore shading and evaporation by trees as well as from vegetation and crops have a cooling effect.

- Dry pavements:
  The warming effect of different surfaces depends on their colour (reflection / absorption / emittance) and thermal storage capacity.

- Water surfaces:
  Water surfaces reflect some radiation and water is evapourated at the surface, cooling the body of the water. At the same time water tores a lot of thermal energy due to its good thermal capacity. As a result, water bodies have a balancing influence on the climate of a locality and even larger areas when they act in conjunction with other factors (esp. wind).

Figure 1.9 Different urban surfaces (dry pavements, water surfaces) influencing the climate

- The Heat island effect:
  Due to different wind situations, surfaces, thermal storage of buildings, industrial and transport activities and other anthropogenic factors there is a significant difference between city- and rural temperatures.

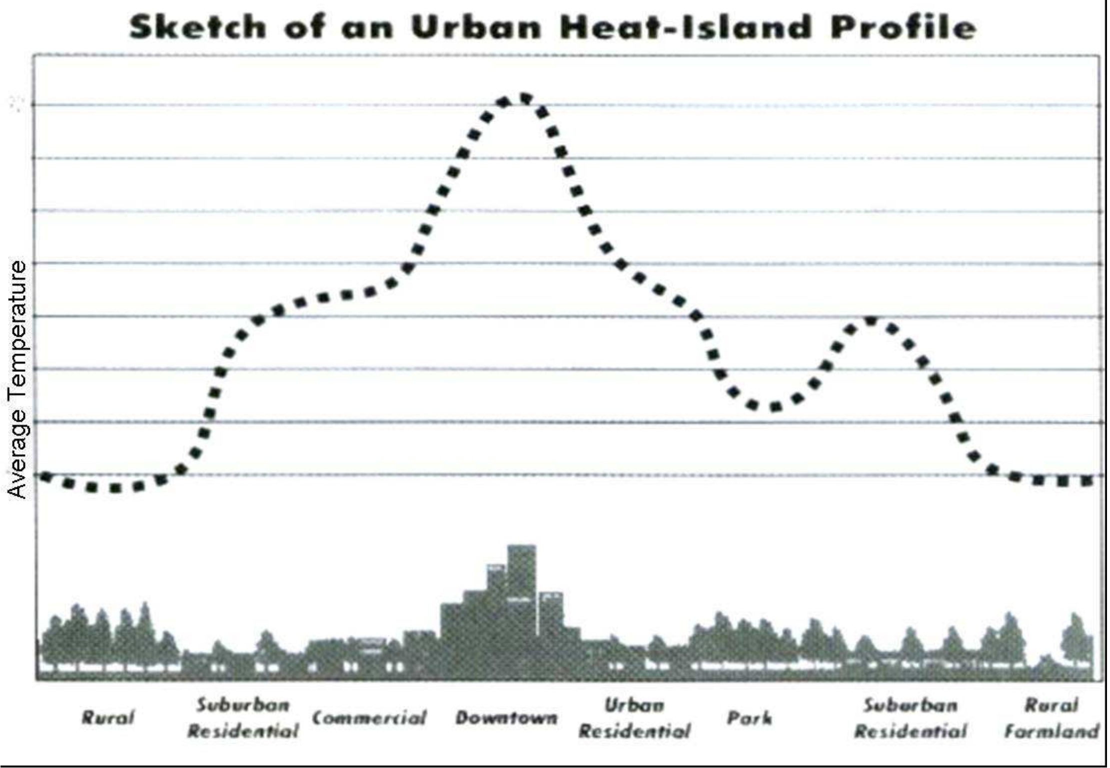


Figure 1.10 Urban Heat- Island Profile

2.3 Winds

Air movement is another important part of climate, in local as well as in global dimensions. Through the action of winds the different climatic zones interact with each other..

2.3.1 Quantities of measurement

The first important vaeiable is the windspeed, usually measured in m/s. Free wind velocities are normally recorded in open flat country at a height of 10 m. Measurements in urban areas are often taken at a height between 10 and 20 m to avoid obstructions. Velocities near the ground are lower than the free wind speed.

The other important consideration is the wind direction. This is usually grouped into eight: the four cardinal (N., E., S. and W.) and four semi- cardinal compass points (NE., SE., SW. and NW.). Occassionally these 8 are further subdivided into 16 (e.g. NNW, WNW, NNE etc)

The exact direction can be described in a degree- scale, where North usually is 0 ° growing clockwise. This degree scale is called the bearing or azimuth.

2.3.2 Data sources

Wind data can be received from special literature such as standards, Test Reference Years (TRY) and other weather data files.

From for example hourly data statistics on wind direction a picture of the prevailing (i.e. Most likely) wind direction can be deduced and a "wind rose" showing the likelihood of winds from different directions can be compiled. Average windspeeds and their distribution can be computed as well as predictable daily or seasonal shifts.

2.3.3 Global differences in air pressure

Winds are basically convection currents in the atmosphere, tending to even out the differential heating of various zones. The pattern of movements is modified by the earth´s rotation.

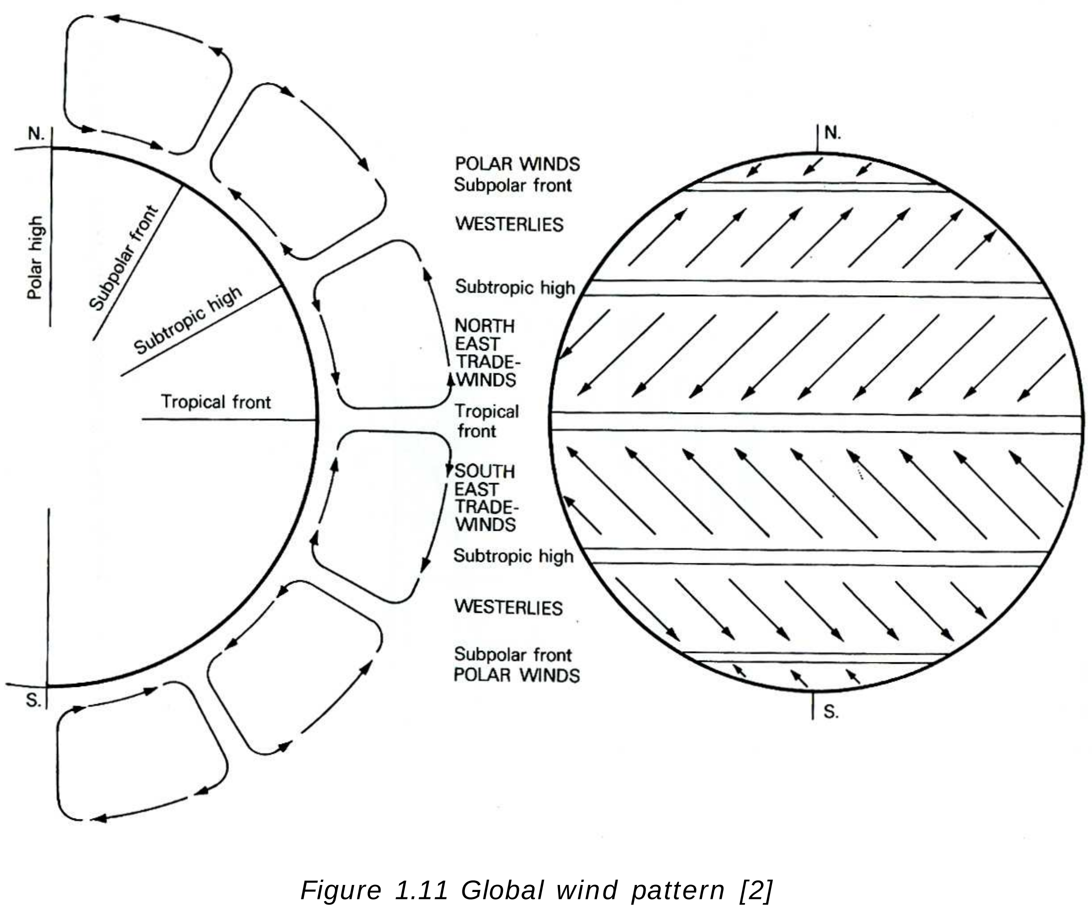


Figure 1.11 Global wind pattern [2]

2.3.4 Resulting weather systems

The global wind patterns described before, result in four different zones:

- Tropical or equatorial zones between the tropics of Cancer and Capricorn with strong thermal air movements, NE-winds north of the Equator and SE-winds south of the Equator. There is little seasonal and diurnal (daily) of temperatures in these areas, and humidities are often high.
- The Inter- tropical convergence zone, with calms and unsteady wind directions. Within this zone the wind patterns shift seasonally from north to south and back again. Most arid (dry) areas are found in these latitudes and there tends to be a relatively large seasonal and diurnal temperature swing.
- Mid- latitude westerlies between 30 ° and 60 ° N and S, where SW-winds (northern hemisphere) and NW-winds (southern hemisphere) dominate as a physical reaction ("Coriolis force") to the tropic air movements.
- Polar winds, thermally induced, from colder to warmer zones (NE- or SE-winds).

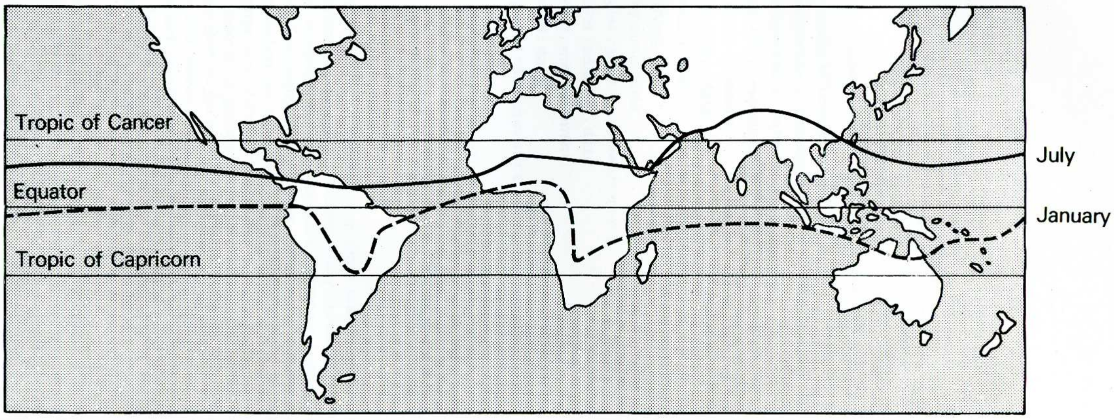


Figure 1.12 Seasonal shift of the inter- tropical convergence zone [2]

2.3.5 Local situations close to the ground

The topography and type of ground cover affects the wind speed gradient.

Near to the ground the wind speed is always less than higher up, but with an uneven ground cover the rate of increase in speed with height is much more than with an unbroken smooth surface, such as water.

Wind speed can be reduced after a long horizontal barrier for example by 50% at a distance of ten times the height and by 25 %at a distance of twenty times the height.

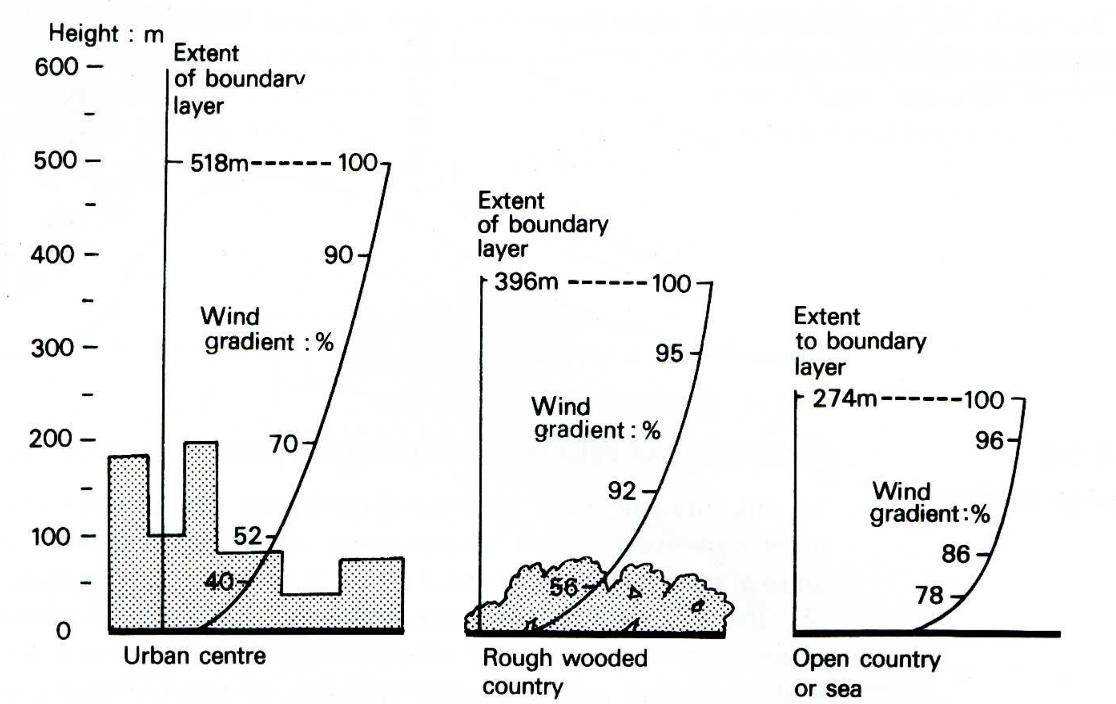


Figure 1.13 Wind velocity gradients for different topographies [2]

2.4 Humidity

In addition to temperatures and winds, humidity is the third important parameter in climate. It appears as vapour and rainfall. Rainfall is measured in mm/a

2.4.1 Rainfall quantities

Depending on the climatic zone and regional influences the periodical rainfall quantities vary a lot.

- The mean global rainfall is about 860 mm/a.
- The minima in warm- dry zones are < 250 mm/a.
- The maxima appear in warm- humid zones. They may reach or exceed 2000 mm/a .

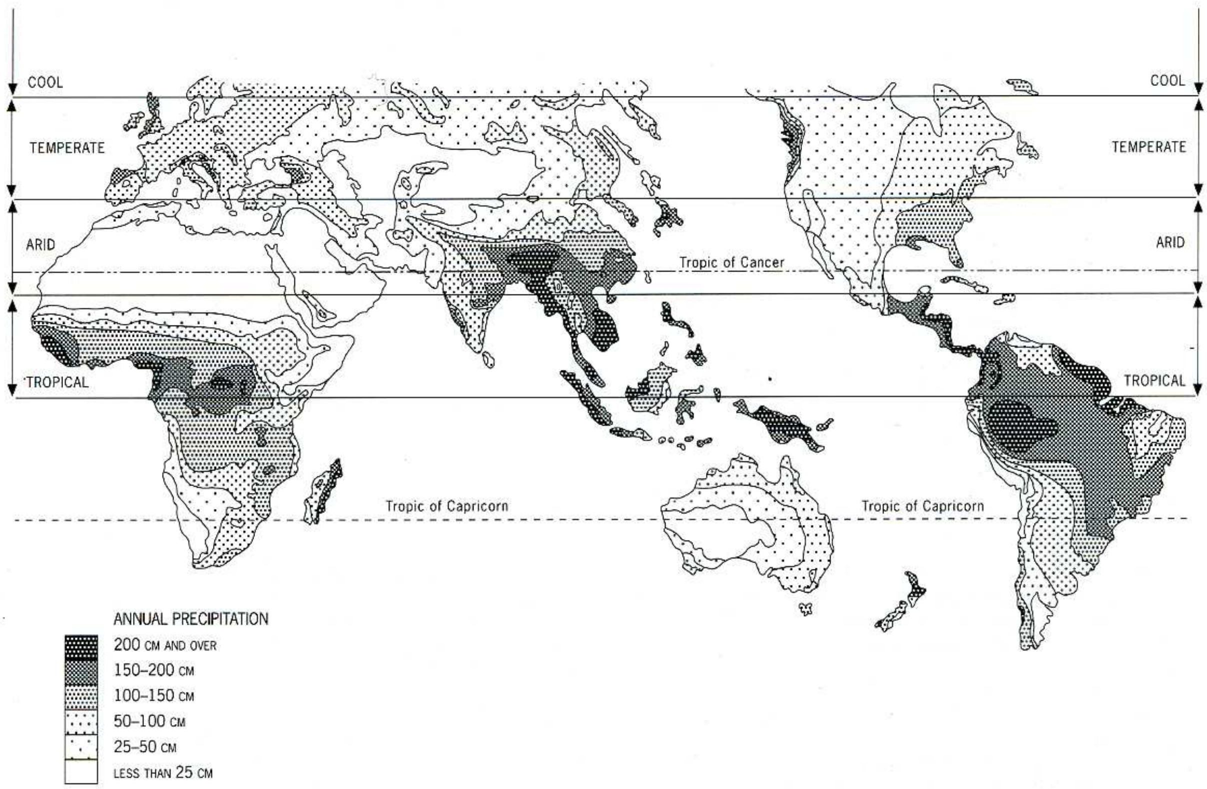


Figure 1.14 Global rainfall quantities [1]

2.4.2 Magnitudes of influence

As described before, evaporation is powered by insolation. This means that high temperatures cause intense evaporation which leads to intense rainfalls. This can cause high humidity in warm zones near the equator. However many hot dry areas also have high levels of solar radiation, this can dry the soil and the air giving low humidities and big temperature ranges where little vegetation is present.

2.4.3 How relative humidity works.

The humidity of the air is often expressed as the “relative humidity”. This can be a difficult concept because relative humidity depends as much on the air temperature as on the actual amount of water vapour present in the air. At higher temperatures, air can contain more water vapour, than at cold temperature.

For example:

- Imagine 1 m^3 of air at a temperature of 20 °C. Let this air contain 7.36 g of water vapour per kg of dry air. This means, the absolute humidity (AH) is 7.36 g/kg.

- The relative humidity (RH) is only 50%, because the saturation (100 % relative humidity, RH) of 20 °C-warm air is at 14,9 g/kg.

- If the air (20 °C, 50 %RH) is heated to 30 °C, the AH stays the same (7.36 g/kg), but the RH reduces to approx. 28 %, because saturation of 30 °C-warm air is at 27.5 g/kg. These correlations are non- linear!

Humidity can be absorbed until the saturation for the actual air temperature is reached.

During the day (especially in the morning), as the lowest layer of air is being heated by the ground surface, evaporation increases, the vapour can be assimilated by the warm air. Winds even out the differences in air temperature and humidity between lower and higher air layers.

As long as temperature is rising and the absolute humidity keeps its level, the relative humidity decreases.

In the evening and during the night, the situation is reversed. Especially on a clear night with still air, as the lowest layer cools, its relative humidity increases, the point of saturation is soon reached and with further cooling the excess moisture condenses out in the form of dew.

When the air reaches the dewpoint temperature fog will start to form, and if there is no further rapid cooling and no air movement, a thick layer of fog can develop near to the ground.

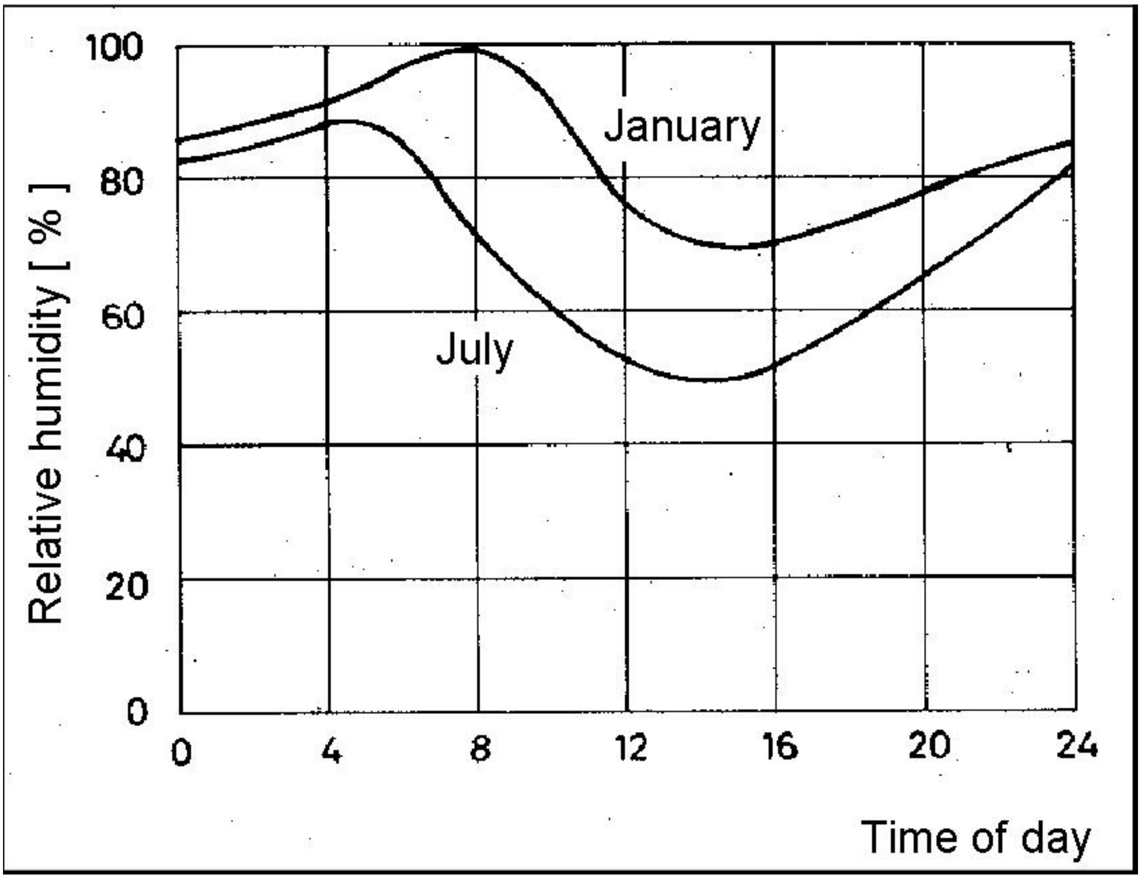


Figure 1.15 Example of daily course of relative humidity in January and July [3]

3 CONTEXT

3.1 ENVIRONNENTAL CONSCIOUS DESIGN

An awakening to environmental problems began at the end of the twentieth century, both on the part of the public and private decision makers, and from the general public. In particular concerns arose about:

- the destruction of the ozone layer,
- climate change caused by greenhouse gas emissions,
- management of waste,
- pollution of water resources,
- storage of the radioactive products,
- decrease in natural resources,
- attacks against bio- diversity,
- etc...

Militancy of some ecological organizations led to decisions at the international level:

- 1972 Stockholm : first international conference on the environment,
- 1987 protocol of Montreal : protection of ozone layer by the prohibition of some refrigerants,
- 1992 Rio : introduction of the concept of sustainable development,
- 1997 protocol of Kyoto : the fight against climate change.

and to the introdution of environmental legislation and changes in industrial practice.

However, much remains to be done:

- in information and education,
- in the training of professionals,
- in the development of technologies which respect the environment,
- in the creation of, and the respect for, a legal framework,
- in the research and the development of new technologies.

3.2 GREENHOUSE EFFECT

Among the environmental impacts of human activities, the emmission of greenhouse gases is a significant threat in the medium term. The construction sector is strongly involved there (Fig 1.16) because of its energy consumption (responsible for about 20% of the emissions):

- when manufacturing constitutive materials (extraction, transformation, transport...),
- when the construction is built (building worksite),
- during use (heating, air- conditioning, lighting...).

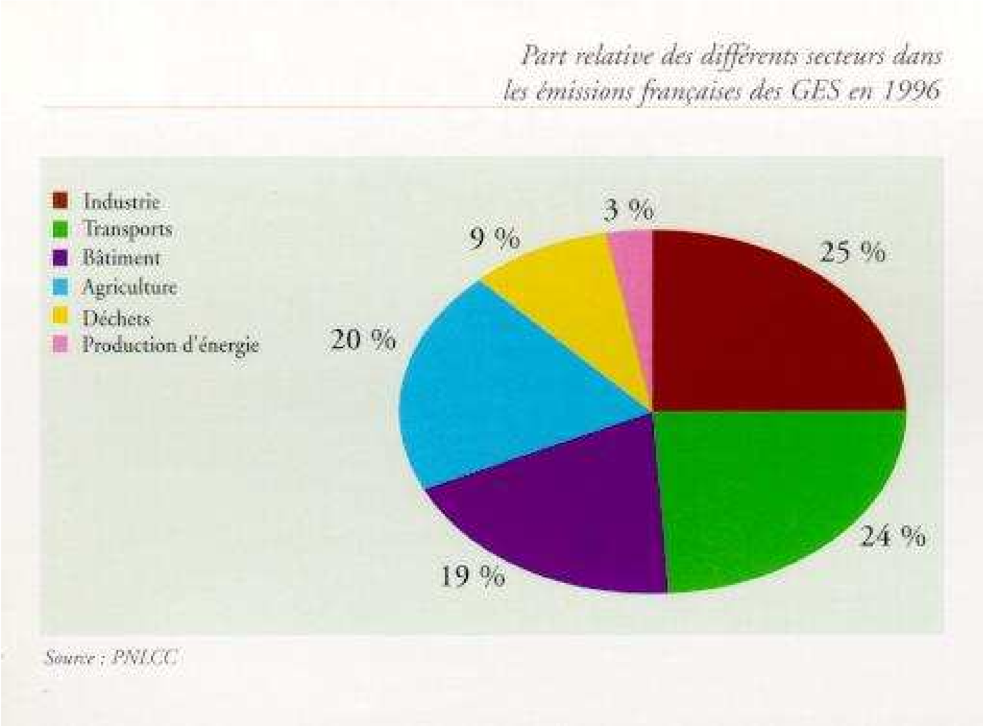


Figure 1.16 greenouse gas emissions by sector (Ademe / PNICC)

Though the greenhouse effect is one aspect of the environmental impact of human activities. It is not obviously the only one to be considered within the field of "sustainable development".

3.2.1 mechanism

The greenhouse effect is a natural mechanism caused by the presence of various gaseous compounds in the Earth's atmosphere.

A large part of solar energy, mainly short wave infra- red and visible radiation, arrives on the ground through the atmosphere (weak reflexion and weak absorption). A fraction of this radiation is reflected by the ground and goes back in space, the remaining part is absorbed by the ground, which leads to its heating and that of the very low layers of the atmosphere (Fig. 1.17).

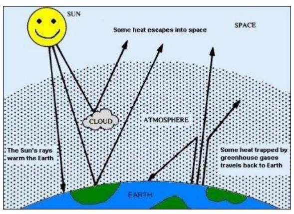


Figure 1.17 Radiation exchanges in the atmosphere (Manchester university)

Then, the heated ground emits long wave energy by radiation. This radiation passes through the atmosphere, where some gases are not very transparent to long infra- red radiation. Thus a part of the radiation from the ground is absorbed or returned towards the ground instead of disappearing in space.

This phenomenon is similar to that of a greenhouse, the glazed cover acting in the same way: letting though the visible radiation from the sun and absorbing the infra- red radiation from the ground.

There is a lot of greenhouse effect gases, but in the Earth's atmosphere, the more important are the water vapor (content 3 to 4%) and carbon dioxide (content 0.03- 0.04%).

Gas	Greenhouse contribution
H_2O water vapor	55%
CO_2 carbon dioxide	39%
CH_4 methane	2%
N_2O nitrous oxide	2%
O_3 ozone	2%

Table 1.1 Greenhouse contributions

The contribution of water vapor is considered separately, because human activity does not have a quantifiable influence on it. However carbon dioxide plays an essential role in causing the greenhouse effect (Fig 1.18).

Figure 1.18 contributions to different greenhousse gases by source (Ademe / CITEPA)

3.2.2 Temperature on the ground

The average temperature of the Earth on the ground level is directly related to the energy balance between the absorbed solar radiation and the infra- red radiation emited by the ground (Fig 1.19).

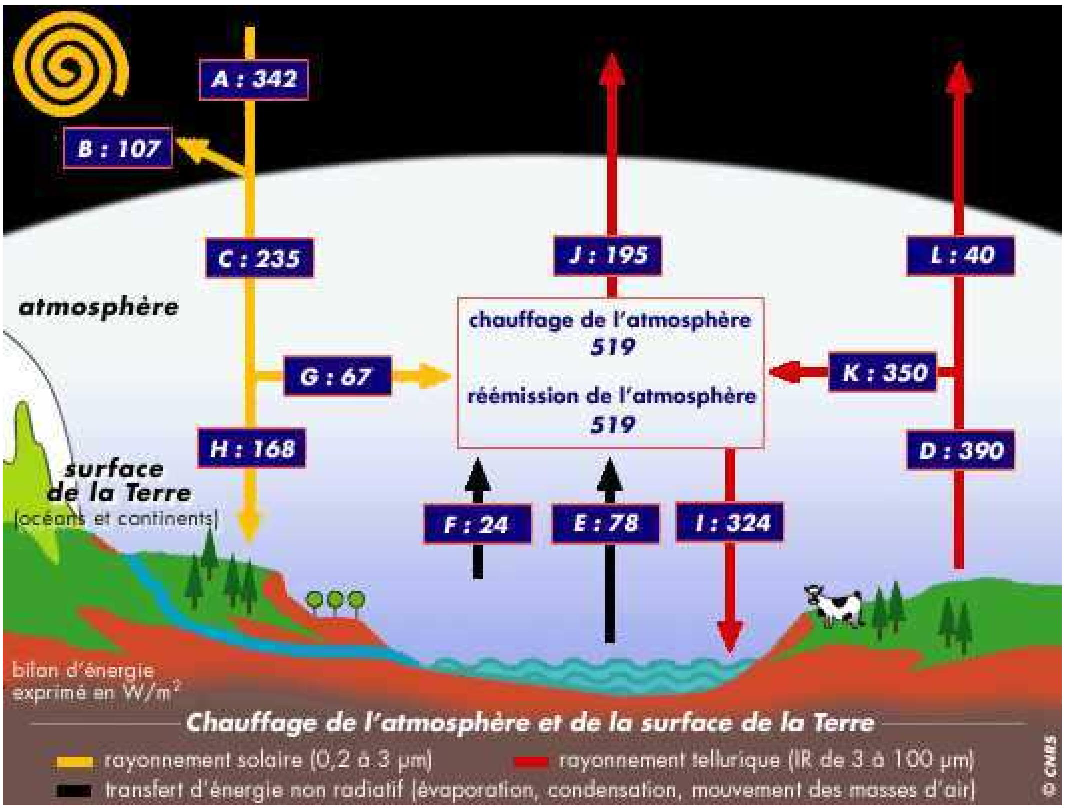


Figure 1.19, heat balance of the atmosphere and the ground (C.N.R.S)

Overall we should be thankful for the greenhouse effect. Without it, the balence temperature of the ground would be minus18 [°C]. With the current composition of the atmosphere, it is about 15 [°C] (NOTE this is an average throughout the year and over the whole surface of the Earth. The temperature is obviously variable around this value according to the place and time).

3.2.3 Greenhouse effect gas content

The carbon dioxide content of the atmosphere results from a balance between (Fig 1.20):

- CO_2 emissions : natural chemical conversions of vegetation and earth, salting out of the oceans, volcanic activity, forest fires and so on. The CO_2 created by human activity is added to these natural releases, primarily through the combustion of fossile fuels (gas, coal, oil),
- CO_2 absorptions : storage by photosynthesis in vegetation, dissolving in the oceans. These are called the "carbon sinks".

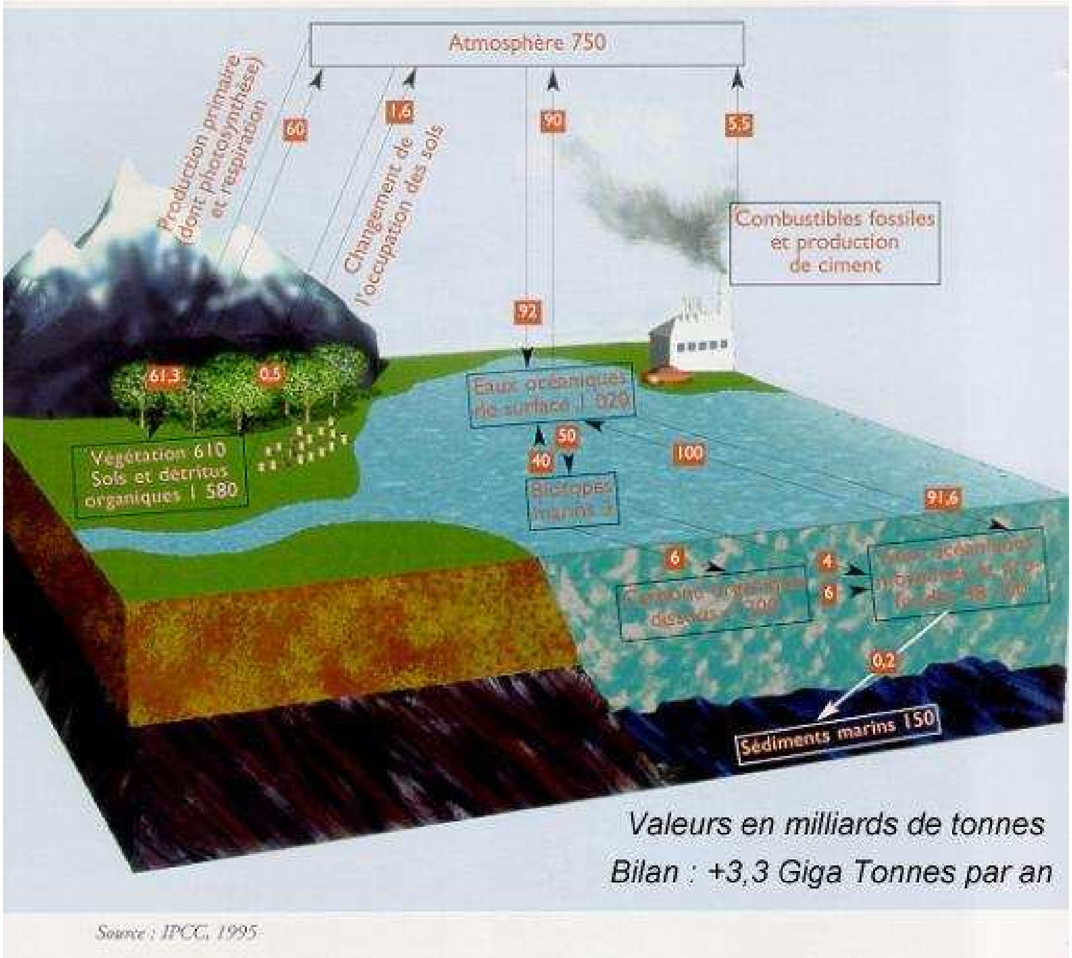
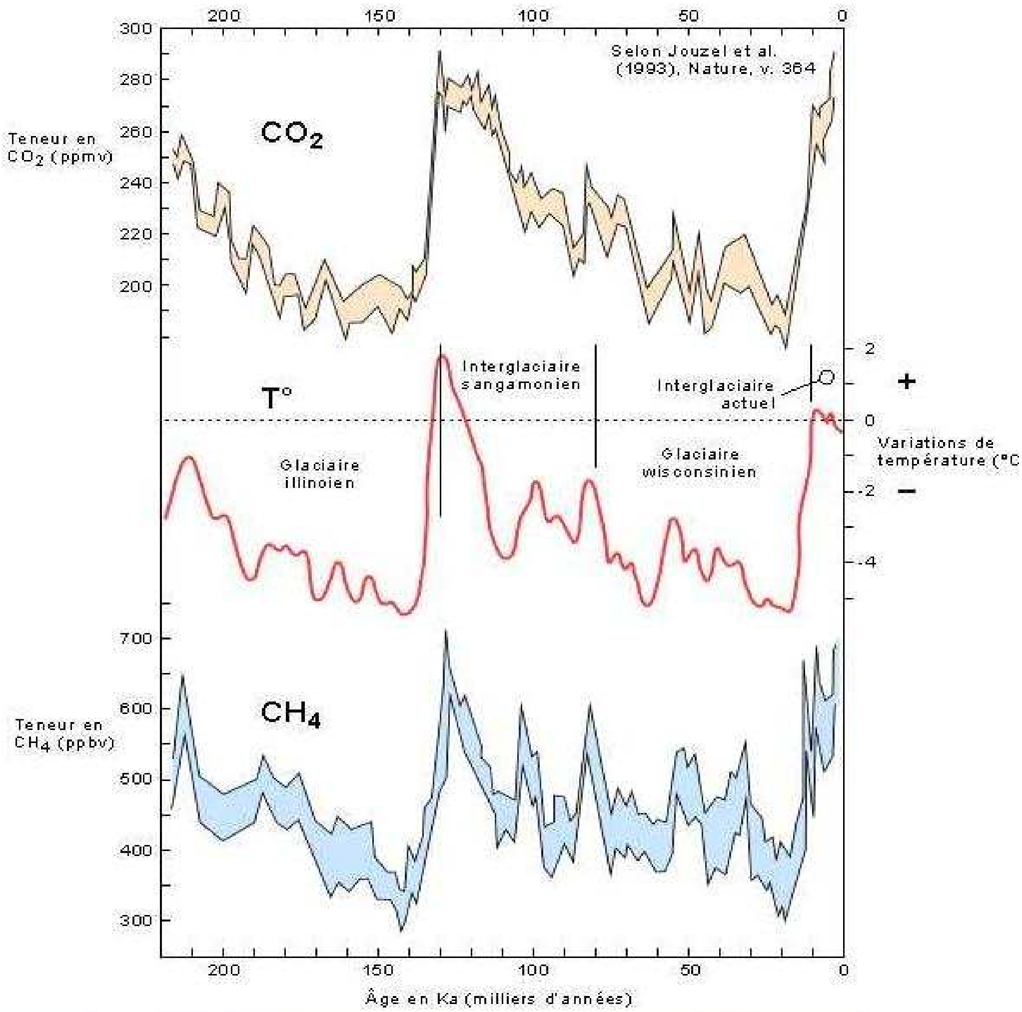


Figure 1.20, the carbon cycle (Ademe / I.P.C.C)

3.2.4 Evolutions

The carbon dioxide content of the atmosphere has not always been rthe same. Samples from the deep ices of the poles (Fig 1.23) makes it possible to go back up to more than 500 000 years and to highlight the correlation between:

- CO_2 content, measured in the microbubbles of air included in the ice,
- the temperature, determined by the nature of crystallization during the formation of the ice, the isotopic composition of water and the oxygen content (fig 1.21)



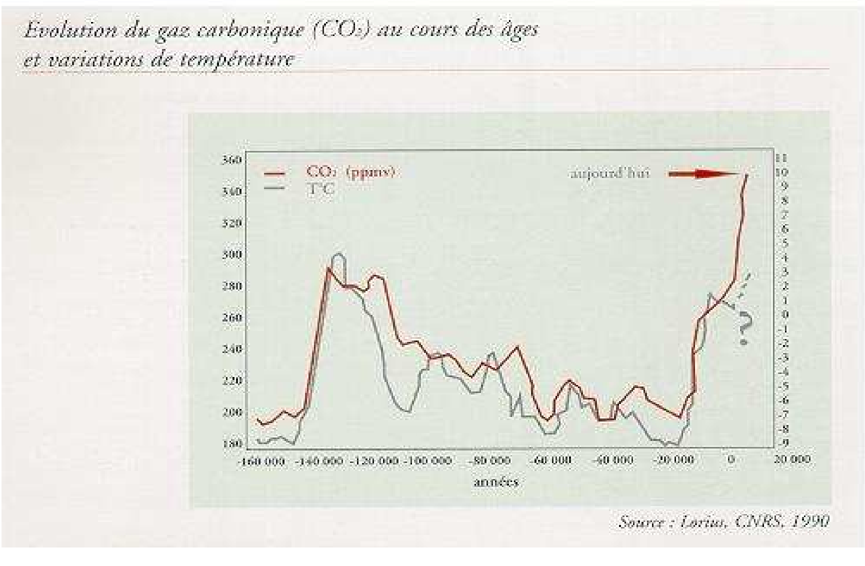


Figure 1.21 1.22. Changes in the composition of the atmosphere over time (Université Laval / I.P.C.C / Ademe)

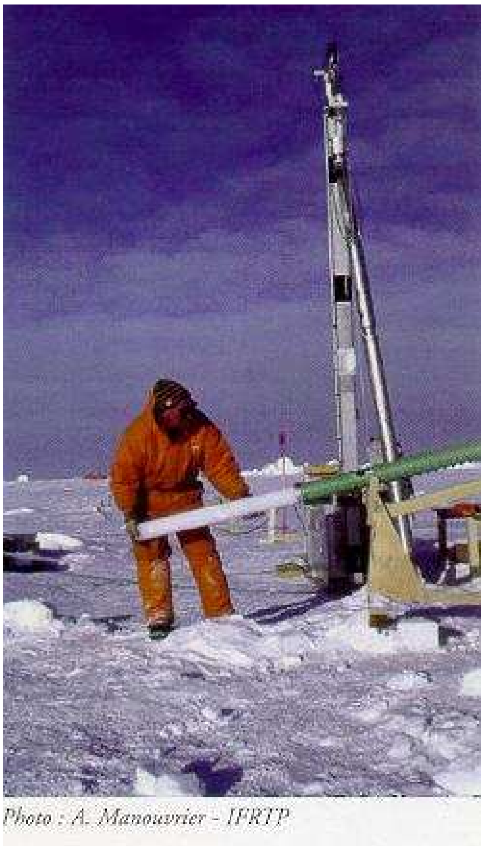


Figure 1.23, taking an ice core (Ademe / IFRTP)

This correlation is well found by the coupled modeling of the heat balance and carbon dioxide balance of the Earth (Figs 1.21 and 1.22).

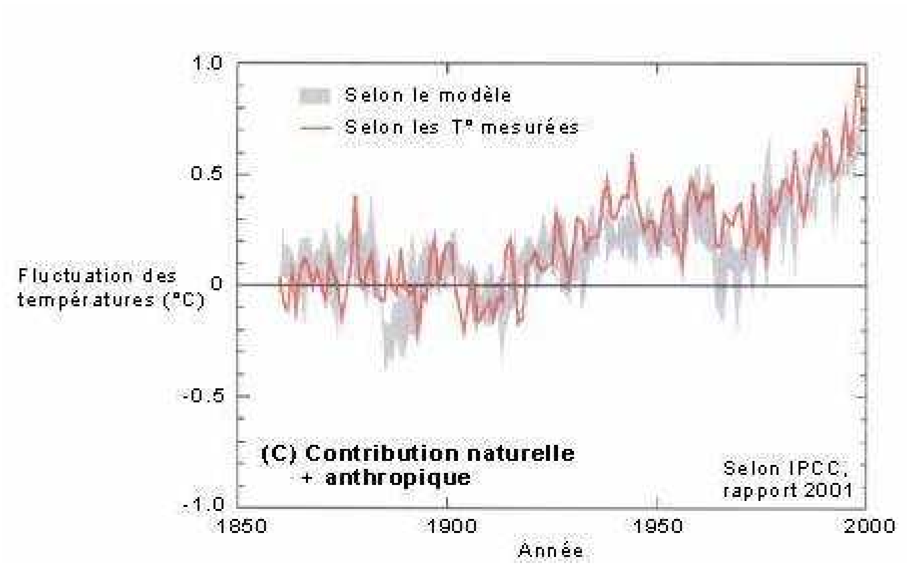


Figure 1.24 Recent changes in CO_2 content of the atmosphere (Université Laval / I.P.C.C)

However, the human activity seems responsible for a fast rise in CO_2 concentration ("anthropic" production). Thus, in one and half centuries, the greenhouse gas content has increased approximately of 30% from 280 ppm to 360 ppm, (a "ppm" being a part per million, or one millionth volume). This has led to a rise of 0,6 [°K] in the average temperature and an increase of the sea level of from 10 to 25 [cm] (e.g. A 1 [°K] increase of the average temperature at La Rochelle since 1946).

This variation is very new in its speed and its scale, because the temperature of the Earth did not change more than 4 [°K] between glacial and hot periods, over the last 400 000 years.

The 1990s were the hottest decade of 20th century (Fig 1.25). Models predict an incease in the average temperature of from 1,5 to 5,8 [°K] during the 21st century, concurrent with a CO_2 concentration ranging between 500 and 1000 ppm. Strong uncertainty still results from an incomplete account of the oceans and from uncertaintities about the future emissions scenario (Fig 1.26).

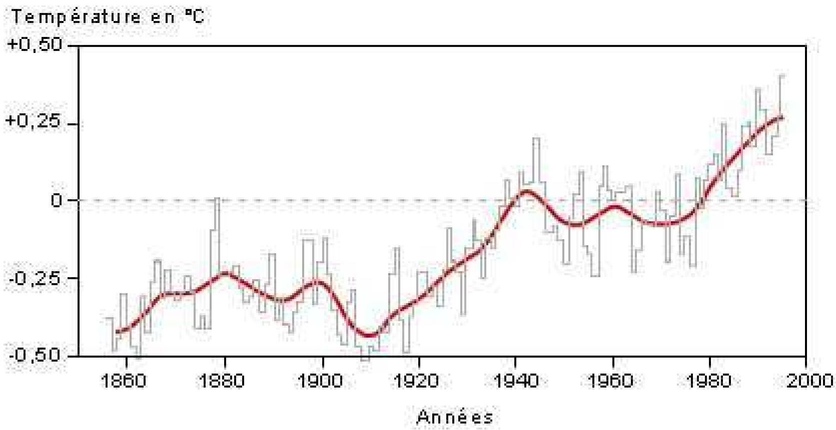


Figure 1.25 changes in the global mean temperature over the last 150 years (Université Laval / I.P.C.C)

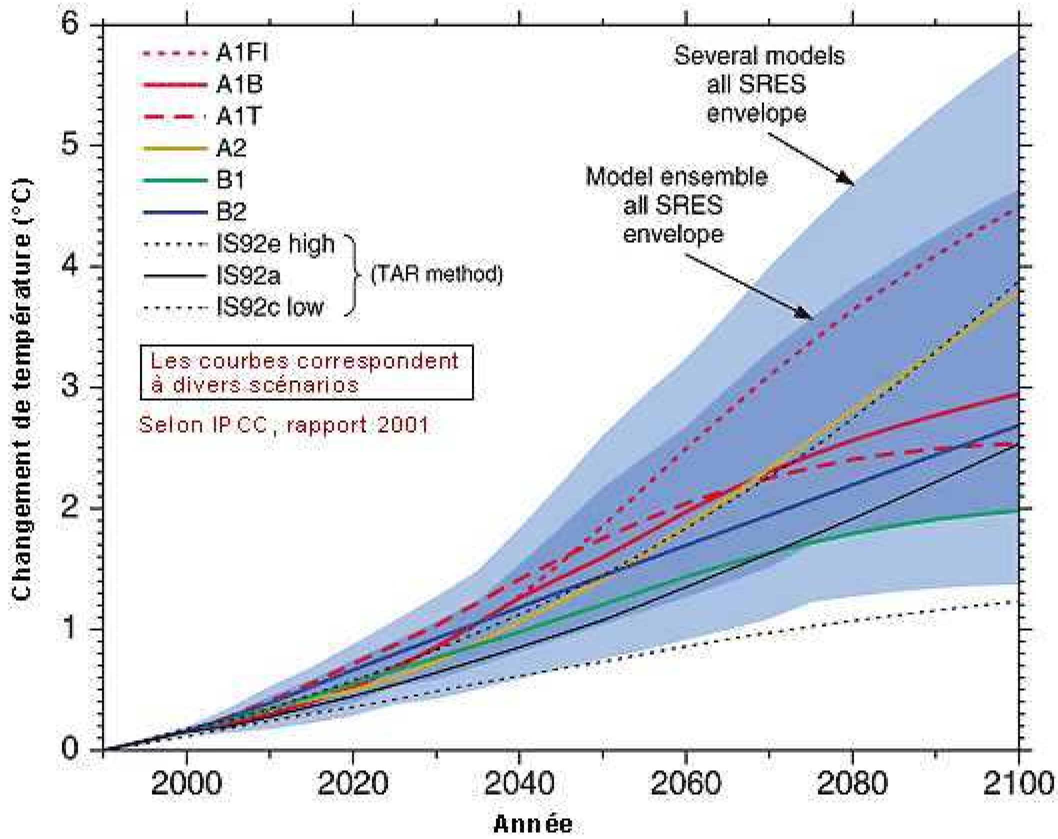


Figure 1.26 Predicted increases in global temperatures according to various scenarios (Université Laval / I.P.C.C)

According to the Intergovernmental Group on Climate Evolution (G.I.E.C, 2002 report), the foreseeable consequences are:

- a rise of the ocean levels of from 0,1 to 1 [m] (thermal dilatation, continental ice melting),
- an important change in the climate,
- an impact on fauna and flora : displacement of populations or disappearance, no species being able to accept without damage so fast environmental evolutions.

For France, the average variation in temperature is estimated around +2 [°K], but it could strongly fall (-4 [°K]) on the Atlantic coast because of the weakening of the Gulf Stream. Strong marine erosion is expected and submerging of the land. More rain is expected in winter (but no snow under 1500 [m]) and more drought in summer. Globally, rainfall will increase in the northern part and decrease in the south. Marshy land could become widespread.

On the whole Earth, climate change could generate 150 million "climatic refugees".

3.3 REDUCTION OF THE EMISSIONS

3.3.1 Balance of the emissions

All the greenhouse effect gases do not have the same influence on global warming. Carbon dioxide is taken as reference to establish the capacity for global heating (Global Warming Potential G.W.P). By considering the effects over the same time (generally of a century), one can establish the following equivalences:

GAS	$G.W.P_{100}$
Carbon Dioxide CO_2	1
méthane CH_4	21
Nitrogen Oxide N_2O	310
H.F.C	140 to 11700
P.F.C	6500 to 9200
SF_6	23900

P.F.C : Perfluorocarbonates

Table 1.3. Global Warming Potential of different greenhouse gases

From this equivalence coefficient, we can enter an emission in "equivalent CO_2".

However this methodology of "relative" G.W.P is often discussed because it takes little account of the lifetime of the gas in the atmosphere. Thus, the action of methane is it significant, but only over a short time scale because methane disappears in 12 years approximately (rain, dissociation, recombination, absorption) whereas the action of CO_2 can last up to 200 years. Thus over one century, the total effect of CO_2 is not taken into account, whereas the total effect of the CH_4 is considered. It is the same for certain refrigerants (R13A : 14 years) whereas the very prolonged action of certain halocarbons (up to 50 000 years) is also not correctly reflected.

That gives place to discepances on the value of the G.W.P (Picture 1.3.a), it would be thus better to introduce an "absolute" G.W.P bearing on the radiative effect cumulated during all the lifetime of gases. Such values (in [W/m^2.year.ppm]) are sometimes used.

GAZ	$P.R.G_{20}$	$P.R.G_{100}$	$P.R.G_{500}$
CH_4	35	11	4
N_2O	260	270	170

GWP direct

Table 1.4 PRG over different time periods (I.P.C.C)

Carbon combination:

$C + O2 \rightarrow CO_2$

gives 44 [g] of carbon dioxide (12+2x16) for 12 [g] of carbon. The ratio:

$$\frac{12}{44}=0.2727$$

is used as a basis for the definition of "the carbon equivalent":

1 Ton CO2 $\Leftrightarrow$ 0,2727 Ton Carbon

The evaluation of the emissions in "carbon equivalent" could be used as a basis for a future environmental tax.

3.3.2 Inequalities in emissions

It has been computed that an emission of 500 [kg] of carbon equivalent per capita and per year (1,8 ton of equivalent CO2) can enter the carbon cycle without causing a continuous increase in the greenhouse effect.

All the developed countries are over this limit (Table 1.5).

Country	***Annual emmissions in CO2 equivalent (CO2, CH4, N2O) (millions of Tonnes)***	
	1990	1998
Germany	1201	1012
Italy	515	541
Spain	301	325
UK	759	684
Sweden	69.5	63.3
France	632	641
EU	4159	4015
USA	5903	6514 (1997)
Canada	591	675 (1996)
Japan	1175	1280 (1997)
Russia	2999	2111 (1994)

Table 1.5 annual carbon emmissions by country (CITEPA 2003)

The average emission of the industrialized countries is around 5 tons of equivalent CO2 per year and per capita, it is only 0,4 ton in third countries (Table 1.6 and Figure 1.27).

PAYS (1998)	Emissions annuelles d'équivalent CO2 (CO_2+CH_4+N_2O) en millions de tonnes par habitant
Irlande	17,22
Luxembourg	14,75
Finlande	14,62
Pays Bas	14,30
Danemark	14,26
Belgique	14,18
Allemagne	12,34
Royaume Uni	11,52
France	10,49
Autriche	9,69
Italie	9,15
Espagne	8,24
Suède	7,79
Portugal	7,49
Union Européenne	10,74
Etats Unis (1997)	23,90
Canada (1996)	22,05
Japon (1997)	10,11
Russie (1994)	14,36

Table 1.6 Carbon emmisions per head by country (CITEPA 2003)

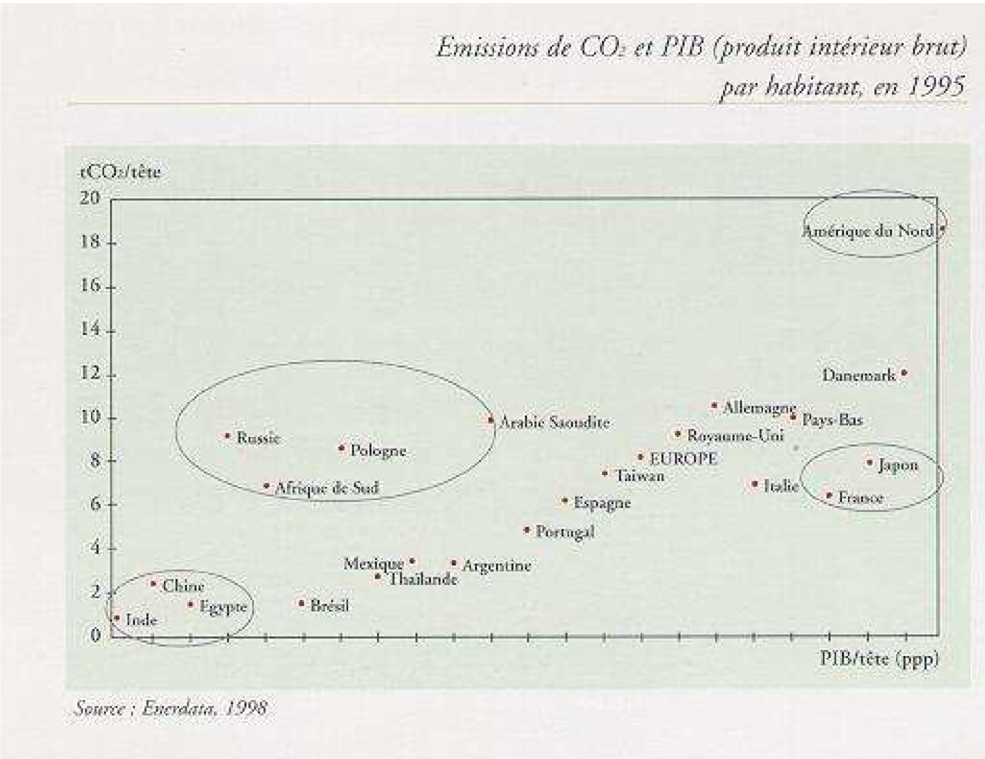


Figure 1.27 Carbon emmissions per head and gross national product (units?) (Ademe / EnerData)

15% of the Earth's population emit 50% of greenhouse gases (World Bank), or 25% of the population emit 75% of greenhouse effect gases (CITEPA).

France is in a median situation with its partners, with an average emission of 2000 [kg] of carbon equivalent per capita and per year.

3.3.3 Engagements

The "Earth Conferences", firstly it in Rio in 1992, concretised the international awakening with respect to climatic change.

The aim of the Kyoto protocol (1997) is to decrease greenhouse gas emissions for 38 industrialized countries (Table 1.7). For 2010, the European Union (15 countries) will have to decrease its emissions by 8% compared to 1990 (objective to be reached between 2008 and 2012). India and China, large potential emitters, do not have obligations until 2012.

Pays	Objectif (Ref 1990)
Luxembourg	-27%
Allemagne	-21%
Autriche	-13%
Royaume Uni	-12,5%
Belgique	-7,5%
Italie	-6,5%
Pays Bas	-6%
Finlande	0
France	0
Suède	+4%
Irlande	+13%
Espagne	+15%
Grèce	+25%
Portugal	+27%
Moyenne U.E	-8%

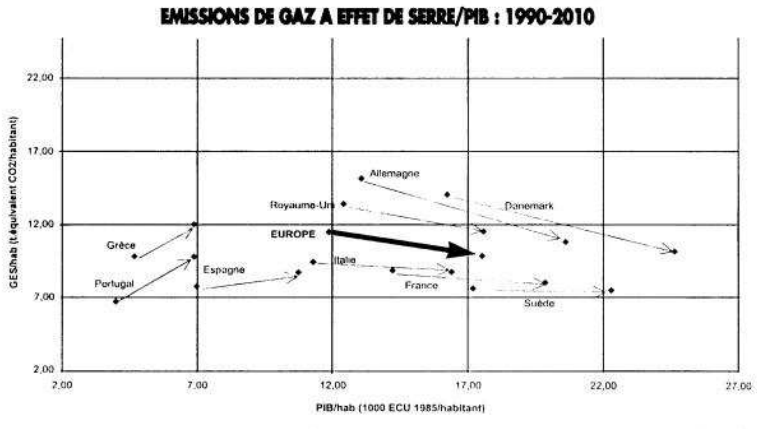


Table 1.7 changes in Carbon emmissions for European countries suggested by the Kyoto agreement (Ademe)

Figure 1.28, Graphical represetation of Kyoto changes

France "supported" by its hydroelectric and nuclear electricity generation will have to stabilize its emissions at the level of those of 1990. Taking into account the growth envisaged for this period, an improvement of the total energy efficiency of fossile fuels of about 20% that will be necessary to obtain this result (Figure 1.29).

Evolutions pour la France Métropolitaine en millions de tonnes de CO_2

90	91	92	93	94	95	96	97	98	99	00	01
504	530	514	486	478	490	503	490	504	484	484	477

Gaz	CO_2	CH_4	N_2O	HFC	PFC	SF_6
Emissions françaises en 1999	336 Mt	2.84 Mt	0,25 Mt	2739 t	268 t	101 t
Emissions françaises en équivalent CO_2	336 Mt	60 Mt	79 Mt	4,8 Mt	1,9 Mt	2,4 Mt

Source : CITEPA

Figure 1.29 changes in French CO_2 production in the years 1990- 2001 (Ademe / CITEPA)

Den Hagen Conference (2000) did not completely succeed in defining methods of setting Kyoto protocol. In Bonn (2001), the international community laid down these methods, in spite of the withdrawal of the United States of America.

In Marrakech (2001), the legal rules necessary to the ratification and the effective setting of the Protocol were adopted.

With the obligations of reduction of emissions, a "market of emission licence" between industrialized countries and developing countries was authorized. In the same way, excessive emissions could be compensated by non- polluting industrial investments (except nuclear power) in a developing country.

The current evolution of the global CO_2 emissions remains very unfavourable. The International Energy Agency records that from 1990 to 2000, the increase was +13%, and that, on this rate, it will reach +29% instead of the desired reduction of 5,2% for all industrialized countries.

3.3.4 Actions

There are many actions which can be put in place, for example:

- to increase the proportion of renewable energies (low or zero emissions) in the production of electricity and heating,
- to improve the energy efficiency for industrial processes and energy

production,

- better control of industrial processes,
- to promote energy saving, which is the main to reduce greenhouse gas emissions.

That needs at least:

- more constraining regulations, on the European and National level,
- an new research and development policy,
- tax incentives or targeted financial assistances, or taxes on the emissions,
- information and education of the populations.

Today, the achievement of French comitments seems difficult to reach without an intensification of existing efforts.

3.3.5 Polemic

The climatic change is always the subject of a polemic between scientists on the one hand, and politicians on the other hand.

From a scientific point of view, the report of global warming is currently recognised by almost the whole research community. But differences appear on the influence of the CO_2 human emissions over and above the natural variation of the climate. The warming effect on climate are also the object of different hypotheses, from the worst catastrophia to an unconditional confidence in the adaptive capacity of nature (and humans).

From a political point of view, one cannot neglect the influence of industrial lobbies (oil and mining companies, nuclear industry). In addition, the fulfillment of the Kyoto protocol will have a social and financial cost (of as much as 1000 billion dollars), and a questioning of the consumerist way of life, which will be accepted with difficulty by the inhabitants of industrialized countries.

Finally, beyond uncertainties, the environmental benefit of Kyoto protocol remains weak, since the estimated influence on the average temperature in 2100 would be only 0,15 [°K], which would only delay the warming effect by 4 or 5 years. The United States of America for example, consider the effort disproportionate compared to the anticipated result.

Even if the alarmist vision of warming consequences would be contradicted by reality, it is necessary in any case:

- to reduce cost of heating by energy saving

- to preserve limited fossil fuel resources,
- to avoid air pollution,
- to develop alternative technologies.

The more so if we hope that humanity will exceed 2100...

4 BUILDINGS AND ENVIRONMENT

4.1 TIME SCALE

In most of cases, a building will have a lifetime of 50 to 100 years. To be complete, environmental impacts analysis must consider the whole "life cycle" of the building. Three periods have to be differentiated:

4.1.1 period of construction work

It is a quite short period (one to two years), but it can have important environmental consequences. There are all the nuisances of the building site (noise, dust, disturbance of urban traffic), and the impact of manufacturing and transporting materials to the building site (materials working out, water consumption, pollution and wastes of building site),

4.1.2 period of use

This is the longest period, in which the Interaction with the environment happen principally through the technical facilities (space heating, air–conditioning, sanitary installations) and the managment of domestic waste. Remember also that during this period there will be retrofitting to replace worn out items and upgrade the building.

The environmental aspect of retrofitting should be considered in the same way as during the construction period, taking into account that they often include a phase of demolition and that they provide the opportunity to modify some initial choices (improvement of the insulation, change of heating system, and so on).

4.1.3 period of demolition

This is a very short period, that may develop some important environmental polution. These can be reduced by any choices made at the conception (recycling or biodegradable materials, possibility of an organized "deconstruction").

However, the long lfe of buildings means that the techniques which will be available at the time of the demolition are not fully understood at the design stage (or of the new appeared constraints, as for example the use of abestos).

4.2 SPACE SCALE

A building presents three distinct spaces, for which the environmental parameters are different:

4.2.1 Indoor space

This is in this space that we will create a controlled climate which has to correspond to many and interdependant criteria of comfort (thermal, acoustical, light) and health. This aspect is very important as human beings spend the major part of their life in these artificial spaces.

4.2.2 Urban space

This is the immediate surroundings of the building. At this scale, there are many environmental aspects to be considered (local atmospheric pollution, noise, management of wastes, water resources, and so on). The relations with the city will also appear at this scale too (urban micro- climate for example).

4.2.3 Earth space

The global effects are located on this scale. It includes the use of raw materials for the manufacture of products for construction and the use of fossil energy stocks. It includes the impact on the climate of greenhouse gas emissions, or of halogenous gases destroying the ozone layer.

4.2.4 Conclusion

The analysis of environmental impacts have therefore to consider these three spaces, otherwise there is a risk of some transfers of pollution between them. That is the case for example of the use of electricity for space heating, which considerably improves the indoor environment, but results in a planetary environmental impact (weak final output power plant, management of nuclear wastes).

For more detail on environmental impacts of buildings see chapter 5 of the notes to Core Module 2 Low Energy Architecture.

5 ENERGY IN BUILDINGS

5.1 ENERGY TARGETS

Consideration of the complete set of environmental parameters on the whole life- cycle and within all the space scales, still remains very difficult. Some evaluation tools are being developed, but a lot of information is not always available.

For example, it is the case for embodied energy in construction products (Figure 1.30):

- extraction of raw materials,
- working out of the construction products,
- using of it.

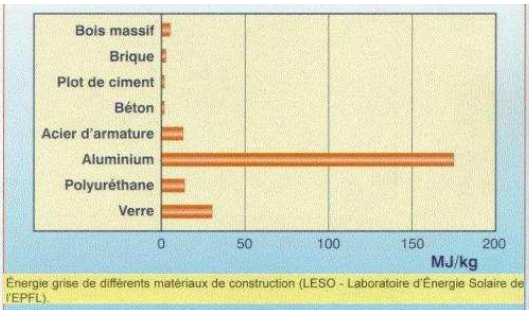


Figure 1.30 relative embodied energy of different building materials (Liebard et De Herdre / L.E.S.O)

This energy has a direct influence on the building CO_2 emissions, even before use (Table 1.8).

Maison traditionnelle					Maison privilégiant les matériaux d'origine végétale				
Matériaux	Kg CO_2/Kg ou m² *	Densité*	Volume ou surface	CO_2 éq	Matériaux	Kg CO_2/Kg ou m² *	Densité*	Volume ou surface	CO_2 éq
Bois	-3,49	680	10	-23 732	Bois	-3,49	680	120	-284 784
Béton	0,13	2 355	150	45 923	Béton	0,13	2 355	40	12 246
Tuiles fibrociment	0,88	1 600	4	5 632	Tuiles	0,35	1 900	4	2 660
Laine minérale	0,98	25	60	1 470	Ouate de lin	0	125	60	0
Carrelage	0,0038	1 980	150	1 083	Revêtement collé (m²)	0,26	-	150	39
Fenêtres ouvrants aluminium (m²)	29,1	-	25	728	Fenêtres ouvrants bois (m²)	-15,57	-	25	-389
Total				31 104 Kg	Total				-270 228 Kg
Soit une *émission* de 207 KgCO_2/m² habitable					Soit un *stockage* de 1 802 KgCO_2/m² habitable				

* Source : ETH de Zurich et Ecole des Mines de Paris

Comparaison des bilans carbone entre une maison traditionnelle et une maison privilégiant les matériaux d'origine végétale pour une surface habitable de 150 m² et un volume de 375 m³.

Table 1.8 comparison of a traditional building and one with materials having low embodied energy (Liebard et De Herdre / E.H.T / Mines de Paris)

The energy necessary for construction and for the destruction of the building and the embodied energy in materials, is imperfectly quantified, but it remains small in comparaison with the amount of the energy consumed during the period of use. For example, the embodied energy of mineral wool used for the insulation is equivalent to the energy saved by insulation during just one winter month.

Among the identified targets of a building environmental quality, we can define three important related targets (Table 1.9 and Fig 1.31):

- management of energy,
- hygrothermal comfort,
- good indoor air quality.

MAÎTRISE DES IMPACTS SUR L'ENVIRONNEMENT EXTÉRIEUR.

Les cibles d'écoconstruction :

• Cible n°01 "Relation harmonieuse des bâtiments avec leur environnement immédiat" :
- Utilisation des opportunités offertes par le voisinage et le site
- Gestion des avantages et désavantages de la parcelle
- Organisation de la parcelle pour créer un cadre de vie agréable
- Réduction des risques de nuisances entre le bâtiment, son voisinage et son site

• Cible n°02 "Choix intégré des procédés et produits de construction" :
- Adaptabilité et durabilité des bâtiments
- Choix des procédés de construction
- Choix des produits de construction

• Cible n°03 "Chantier à faibles nuisances" :
- Gestion différenciée des déchets de chantier
- Réduction du bruit de chantier
- Réduction des pollutions de la parcelle et du voisinage
- Maîtrise des autres nuisances de chantier

Les cibles d'écogestion :

• Cible n°04 "Gestion de l'énergie" :
- Renforcement de la réduction de la demande et des besoins énergétiques
- Renforcement du recours aux énergies environnementalement satisfaisantes
- Renforcement de l'efficacité des équipements énergétiques
- Utilisation de générateurs propres lorsqu'on à recours à des générateurs à combustion

• Cible n°05 "Gestion de l'eau" :
- Gestion de l'eau potable
- Recours à des eaux non potables
- Assurance de l'assainissement des eaux usées
- Aide à la gestion des eaux pluviales

• Cible n°06 "Gestion des déchets d'activités" :
- Conception des dépôts de déchets d'activités adaptée aux modes de collecte actuel et futur probable
- Gestion différenciée des déchets d'activités, adaptée au mode de collecte actuel

• Cible n°07 "Entretien et maintenance" :
- Optimisation des besoins de maintenance
- Mise en place de procédés efficaces de gestion technique et de maintenance
- Maîtrise des effets environnementaux des procédés de maintenance

CRÉATION D'UN ENVIRONNEMENT INTÉRIEUR SATISFAISANT.

Les cibles de confort :

• Cible n°08 "Confort hygrothermique" :
- Permanence des conditions de confort hygrothermique
- Homogénéité des ambiances hygrothermiques
- Zonage hygrothermique

• Cible n°09 "Confort acoustique" :
- Correction acoustique
- Isolation acoustique
- Affaiblissement des bruits d' impact et d'équipements
- Zonage acoustique

• Cible n°10 "Confort visuel" :
- Relation visuelle satisfaisante avec l'extérieur
- Eclairage naturel optimal en termes de confort et de dépenses énergétiques
- Eclairage artificiel satisfaisant et en appoint de l'éclairage naturel

• Cible n°11 "Confort olfactif" :
- Réduction des sources d'odeurs désagréables
- Ventilation permettant l'évacuation des odeurs désagréables

Les cibles de santé :

• Cible n°12 "Conditions sanitaires" :
- Création de caractéristiques non aériennes des ambiances intérieures satisfaisantes
- Création des conditions d'hygiène
- Facilitation du nettoyage et de l'évacuation des déchets d'activités
- Facilitation des soins de santé
- Création de commodités pour les personnes à capacités réduites

• Cible n°13 "Qualité de l'air" :
- Gestion des risques de pollution par les produits de construction
- Gestion des risques de pollution par les équipements
- Gestion des risques de pollution par l'entretien ou l'amélioration
- Gestion des risques de pollution par le radon
- Gestion des risques d'air neuf pollué
- Ventilation pour la qualité de l'air

• Cible n°14 "Qualité de l'eau" :
- Protection du réseau de distribution collective d'eau potable
- Maintien de la qualité de l'eau potable dans les bâtiments
- Amélioration éventuelle de la qualité de l'eau potable
- Traitement éventuel des eaux non potables utilisées
- Gestion des risques liés aux réseaux d'eaux non potables

Table 1.9 considerations for the external and internal environment of buildings (Association "H.Q.E")

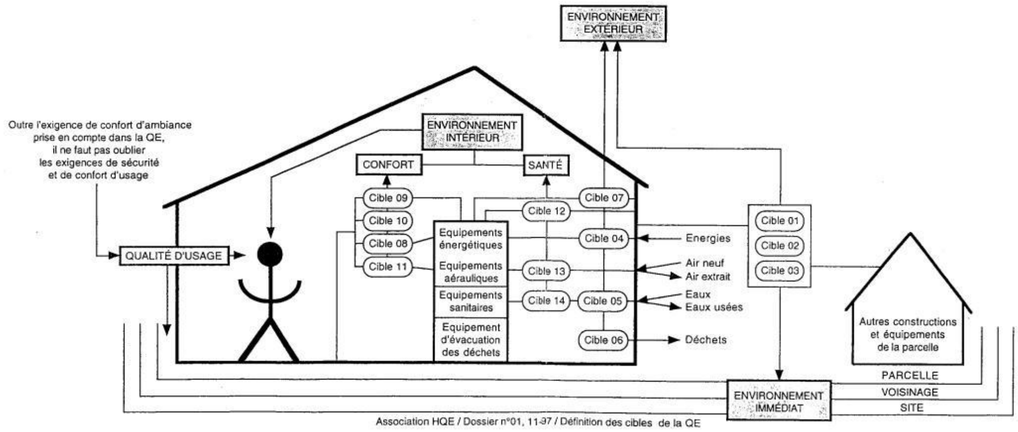


Figure 1.31 Targets for a good building (Association "H.Q.E")

5.2 ENERGY MANAGEMENT

In France (but in the European Union too), the energy consumption of the building sector represents more than 40% of the final energy (Picture 3.2.a et Picture 3.2.b), of which 2/3d for the space heating, the air- conditioning and domestic hot water, and 1/3d for the lighting and domestic appliances (Picture 3.2.c).

Consommation d'énergie finale par secteur (corrigée du climat)

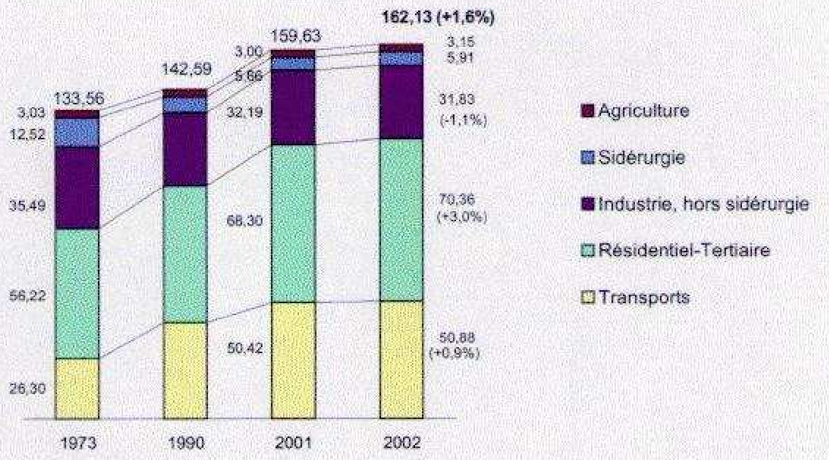
en Mtep	1973	1980	1990	1999	2000	2001	2002	TCAM 01-02	TCAM 73-02
Industrie	48,0	44,8	38,5	38,3	38,8	37,9	37,7	-0,3	-0,8
dont sidérurgie	12,5	10,7	7,0	6,2	6,2	5,7	5,9	+4,4	-2,6
Résidentiel-tertiaire	56,2	54,0	59,3	65,9	66,7	68,3	70,4	+3,0	+0,8
Agriculture	3,0	3,2	3,1	3,1	3,0	3,1	3,2	+2,9	+0,1
Transports	26,3	32,1	41,7	49,4	49,4	50,4	50,9	+0,9	+2,3
Total énergétique	**133,6**	**134,1**	**142,6**	**156,7**	**157,9**	**159,6**	**162,1**	**+1,6**	**+0,7**
Non énergétique	10,9	11,8	12,4	17,2	17,4	16,4	16,1	-2,0	+1,3
Total	**144,5**	**145,8**	**155,0**	**173,9**	**175,2**	**176,0**	**178,2**	**+1,2**	**+0,7**

TCAM (taux de croissance annuel moyen) en %

Structure sectorielle de la consommation énergétique finale (corrigée du climat)

en %	1973	1980	1990	1999	2000	2001	2002	VAM 01-02	VAM 73-02
Industrie	35,9	33,4	27,0	24,4	24,6	23,7	23,3	-0,4 pt	-0,4 pt
dont sidérurgie	9,4	8,0	4,9	3,9	3,9	3,5	3,6	+0,1 pt	-0,2 pt
Résidentiel-tertiaire	42,1	40,2	41,6	42,0	42,2	42,8	43,4	+0,6 pt	-
Agriculture	2,3	2,4	2,2	2,0	1,9	1,9	1,9	-	-
Transports	19,7	24,0	29,3	31,5	31,3	31,6	31,4	-0,2 pt	+0,4 pt
Total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**		

VAM (variation annuelle moyenne) en points



Consommation énergétique finale corrigée du climat en 1973, 1990, 2001 et 2002 (en Mtep)

Consommation énergétique finale par énergie (corrigée du climat)

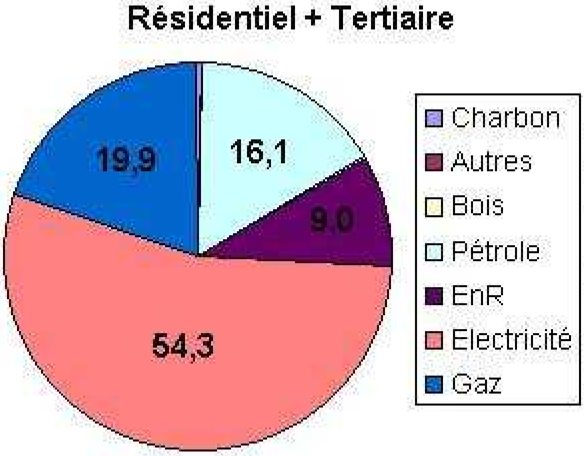
en Mtep	1973	1980	1990	1999	2000	2001	2002	TCAM 01-02	TCAM 73-02
Charbon	17,7	13,2	10,3	7,4	7,4	6,6	7,0	+5,0	-3,2
Pétrole	85,2	78,4	71,3	75,3	74,2	75,6	75,7	+0,1	-0,4
Gaz	8,8	16,5	23,3	30,0	31,4	32,5	33,4	+3,1	+4,7
Électricité	13,0	18,1	26,5	32,9	34,0	34,4	35,1	+2,1	+3,5
Énergies renouvelables thermiques (*)	9,0	7,9	11,2	11,1	10,8	10,5	10,9	+3,8	+0,7
Total énergétique	**133,6**	**134,1**	**142,6**	**156,7**	**157,9**	**159,6**	**162,1**	**+1,6**	**+0,7**

(*) Hors hydraulique, éolien et photovoltaïque *TCAM (taux de croissance annuel moyen) en %*

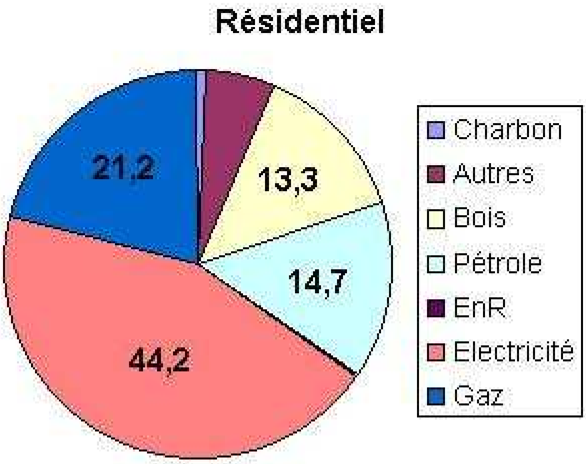
Structure par énergie de la consommation énergétique finale (corrigée du climat)

en %	1973	1980	1990	1999	2000	2001	2002	VAM 01-02	VAM 73-02
Charbon	13,2	9,9	7,2	4,7	4,7	4,2	4,3	+0,1 pt	-0,3 pt
Pétrole	63,8	58,5	50,0	48,0	47,0	47,4	46,7	-0,7 pt	-0,6 pt
Gaz	6,6	12,3	16,4	19,1	19,9	20,3	20,6	+0,3 pt	+0,5 pt

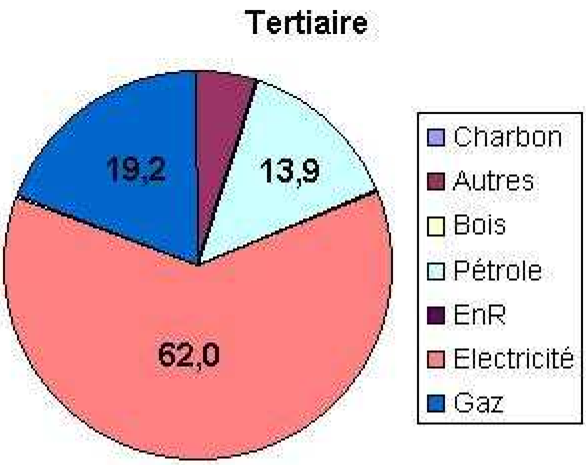
Table 1.10 , table 1.11, figure 1.32 (Ministère de l'économie, des finances et de l'industrie)



	[M T.E.P]	%
Charbon	0,66	0,7
Pétrole	16,16	16,1
EnR	9,11	9,0
Electricité	54,71	54,3
Gaz	20,03	19,9



	[M T.E.P]	%
Charbon	0,52	0,8
Autres	3,8	5,9
Bois	8,56	13,3
Pétrole	9,47	14,7
Electricité	28,52	44,2
Gaz	13,69	21,2



	[M T.E.P]	%
Autres	1,4	4,9
Pétrole	4	13,9
Electricité	17,8	62,0
Gaz	5,5	19,2

Figure 1.33 Energy use by building type and source (Ademe)

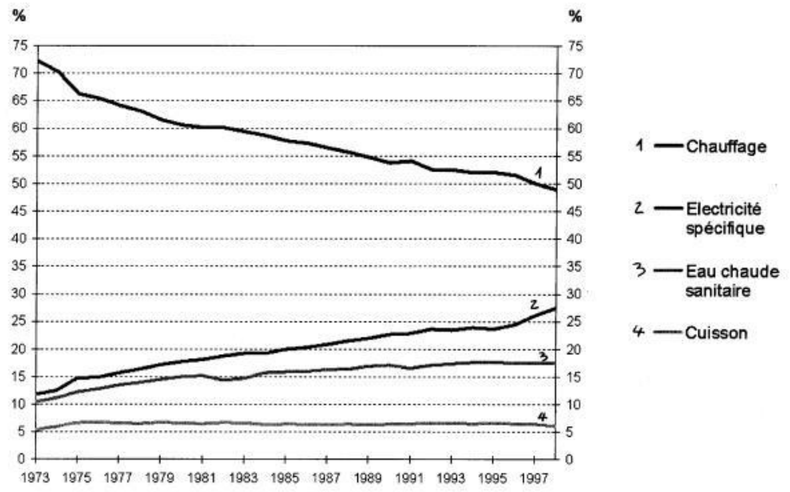


Figure 1.34 Changes in energy use (France) (Ministère de l'économie, des finances et de l'industrie)

Note the important part played by electricity in energy production, fuel and gas being strongly in competition (Fig 1.35).

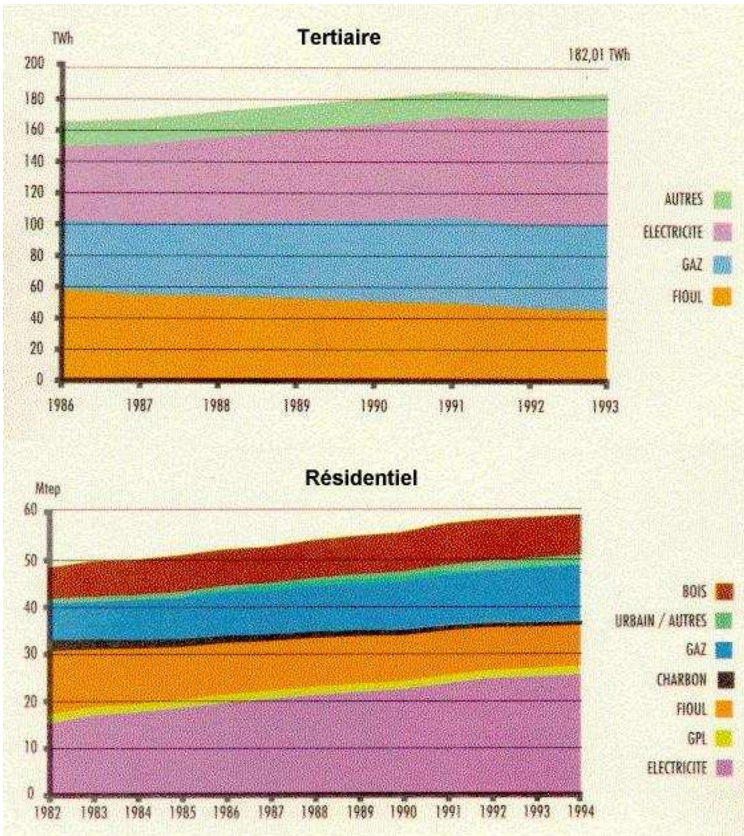


Figure 1.35 changes in energy source (France) (Ademe)

If we consider the impact at the local or worldwide scale of this energy consumption, around 20% of the greenhouse emissions (Fig 1.36), we can see the importance of its management to getting a decrease (stabilization) in its environmental consequences (pollution, depletion of resources).

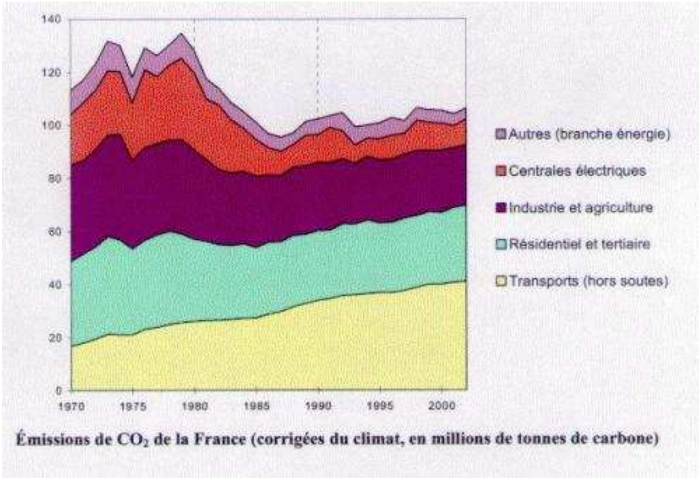


Figure 1.36 energy source and associated CO_2 in different building types (Ministère de l'économie, des finances et de l'industrie)

Note : using "Tons of Oil Equivalent" (T.O.E) makes it possible to add and compare energies from different origins (Table 1.12).

Les coefficients d'équivalence énergétique utilisés en France jusqu'en 2001 étaient ceux adoptés en 1983 par l'Observatoire de l'Énergie. En session du 14 février 2002, le Conseil d'Orientation de l'Observatoire de l'Énergie a résolu d'adopter, dès la publication du bilan énergétique portant sur 2001, la méthode commune aux organisations internationales concernées (Agence Internationale de l'Énergie, Eurostat, ...). Cela concerne :

- le coefficient de conversion de l'électricité, de kWh en tonne d'équivalent pétrole (tep)
- les soutes maritimes internationales.

• Les nouveaux coefficients d'équivalence entre unité propre et tep sont précisées ci-après. Seuls les coefficients relatifs à l'électricité ont été modifiés.

Énergie	Unité physique	Gigajoules (GJ) (PCI)	tep (PCI)
Charbon			
Houille	1 t	26	26/42 = 0,619
Coke de houille	1 t	28	28/42 = 0,667
Agglomérés et briquettes de lignite	1 t	32	32/42 = 0,762
Lignite et produits de récupération	1 t	17	17/42 = 0,405
Produits pétroliers			
Pétrole brut, gazole/fioul domestique, produits à usages non énergétiques	1 t	42	1
GPL	1 t	46	46/42 = 1,095
Essence moteur et carburéacteur	1 t	44	44/42 = 1,048
Fioul lourd	1 t	40	40/42 = 0,952
Coke de pétrole	1 t	32	32/42 = 0,762
Électricité			
Production d'origine nucléaire	1 MWh	3,6	0,086/0,33 = 0,2606
Production d'origine géothermique	1 MWh	3,6	0,086/0,10 = 0,86
Autre type de production, échanges avec l'étranger, consommation	1 MWh	3,6	3,6/42 = 0,086
Bois	**1 stère**	**6,17**	**6,17/42 = 0,147**
Gaz naturel et industriel	**1 MWh PCS**	**3,24**	**3,24/42 = 0,077**

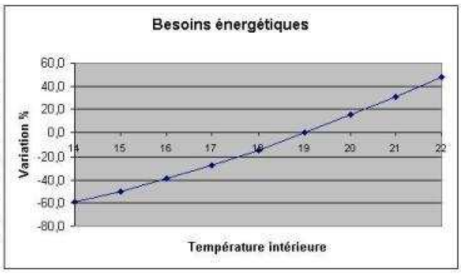
L'ancienne méthode utilisait strictement " l'équivalent primaire à la production " : c'est-à-dire que quel que soit l'emploi ou l'origine de l'énergie électrique, un coefficient unique était utilisé, égal à 0,222 tep/MWh depuis 1972 (auparavant, il était de 0,4 tec/MWh, soit 0,27 tep/MWh). Autrement dit, l'électricité était comptabilisée dans les bilans de l'Observatoire de l'Énergie, à tous les niveaux (production, échanges avec l'étranger, consommation), avec l'équivalence 0,222 tep/MWh, c'est-à-dire comme la quantité de pétrole qui serait nécessaire pour produire cette énergie électrique dans une centrale thermique classique théorique de rendement égal à 0,086/0,222 = 38,7% (contre 31,9% avant 1972).

Table 1.12 (Ministère de l'économie, des finances et de l'industrie)

5.3 HYGROTHERMAL COMFORT

The energy consumption for space heating and air-conditioning is directly dependent of the indoor conditions set in the building (Picture 3.3.a).

Température intérieure [°C]	Besoins énergétiques [kW.h]	Ecart %
14	523	-59,2
15	644	-49,7
16	780	-39,1
17	934	-27,1
18	1101	-14,1
19	1281	0,0
20	1475	15,1
21	1680	31,1
22	1898	48,2



Chambre universitaire 12 [m²]

Simulation sur Codyba

Température intérieure [°C]	Besoins énergétiques (kW.h]	Ecart %
19 permanent	1281	0,0
19/15	1065	-16,9
20 permanent	1475	0
20/15	1218	-17,4

Figure 1.37 dependenc of energy use on indoor temperature (Simulation sur Codyba)

For example, in permanent heating, reducing by 1 [°C] the indoor temperature (from 20 [°C] to 19 [°C] for example) generates an energy saving generally higher than 10%.

In the same way, programming a reduced temperature at night, or during unoccupied periods, constitutes an effective means to save energy without harming the users comfort.

An accurate estimate of the indoor conditions is one part of consumption management. Various tools, such as standard EN-ISO 7730 make possible to choose set point values according to clothing level of the occupants (Fig 1.38). Section 2 of these notes discusses ideas aboiut provision of comfort and indoor air quality.

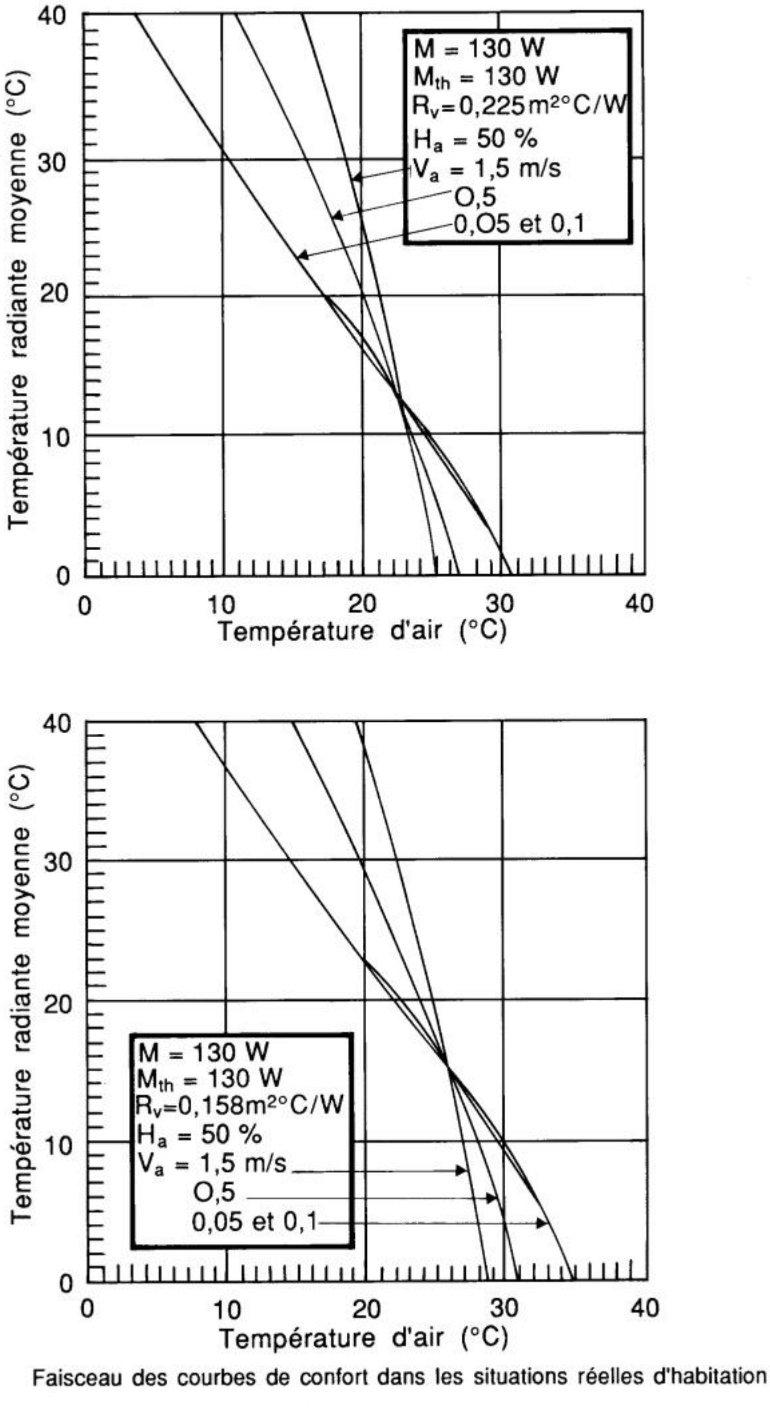


Figure 1.38 combinations of conditions for comfort according to ISO 7730 (OSI/ISO Geneva)

5.4 INDOOR AIR QUALITY

Preserving an acceptable indoor air quality requires the knowledge of:

- the nature and the action of the contaminants found in the buildings,

- the allowable thresholds, taking into consideration the combined action of contaminants and the duration of the exposure,
- the methods available to maintain the indoor conditions within acceptable limits.

This last aspect generally requires the use of natural or mechanical ventilation. An efficient understanding of these mechnanisms allows the occupant:

- to minimize the energy consumption of the ventilation,
- to optimize the outdoor air flow rate, which has among other things, the consequence of reducing energy consumption for space heating or air- conditioning.

Many installations use an air flow, which varies according to the production of polluting emissions (Picture 3.4.a).

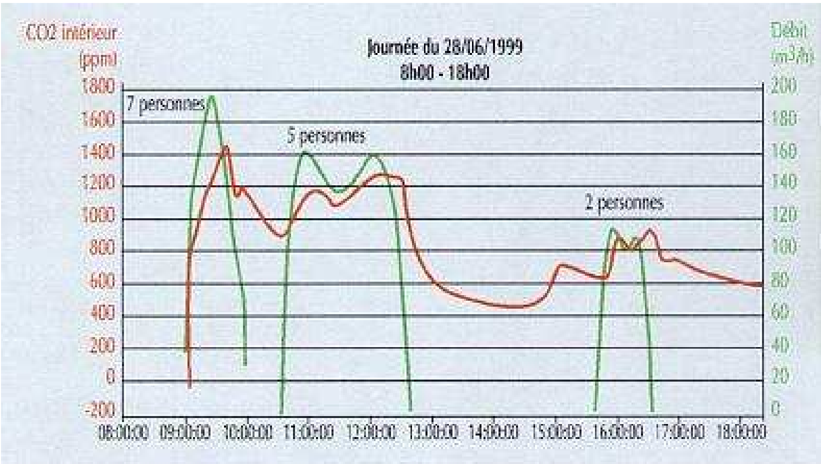


Figure 1.39 changes in ventilation rate to suit occupancy (Cetiat)

We indeed notice that in a building, the occupancy schedule can strongly vary during a day, making it unecessary to maintain the maximum ventilation air flow rate (Fig 1.40).

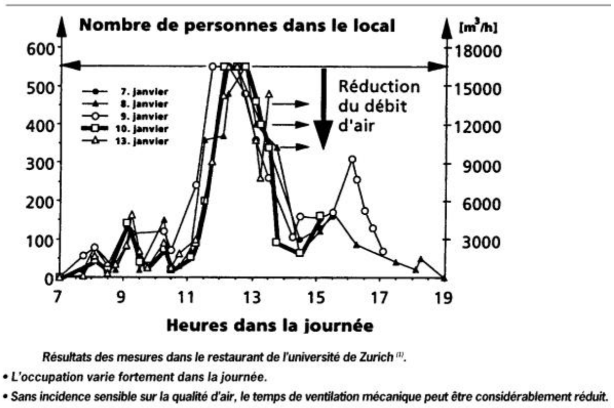


Figure 1.40 daily changes in occupancy (Revue Clim Pratique)

Control can be based on (Table 1.12):

- a flow program related to the occupation schedule of the building (clock with possible override),
- counting the number of occupants (swivel input/output),
- a presence- detector in the building (detector on the type used for security control),
- an indicator of the pollution level in of the building, like humidity (hygroadjustable ventilation) or of the air content of carbon dioxide (probe of air quality).

	Tout ou rien	Asservissement					
Application	Détection de présence	Optique	CO_2	Humidité	Température	CO	Autres
Bureaux							
Individuels	Particulièrement recommandé	Satisfaisant	Satisfaisant	NA	NA	NA	
Paysagés	Satisfaisant	Particulièrement recommandé	Particulièrement recommandé	NA	NA	NA	
Salles de réunions							
Petites	Satisfaisant	Particulièrement recommandé	Satisfaisant	NA	NA	NA	
Grandes, amphis...	NA	Satisfaisant	Particulièrement recommandé	NA	NA	NA	*comptage*
Restaurants							
Salle (grande)	NA	Satisfaisant	Particulièrement recommandé	NA	NA	NA	
Cuisine	Satisfaisant	NA	NA	Particulièrement recommandé	Particulièrement recommandé	NA	*opacité*
Lieux publics							
Zone Fumeurs	NA	*Selon application (voir ci-dessus)*					*multigaz**
Hôtel / Habitat							
Sanitaires	Satisfaisant	NA	NA	Particulièrement recommandé		NA	
Chambres	Particulièrement recommandé	Satisfaisant	Satisfaisant	Satisfaisant	NA	NA	
Parkings, garages	NA	NA	NA	NA	NA	Particulièrement recommandé	*multigaz*

(*) : différenciation du débit fumeur / non fumeur : un capteur multigaz peut être employé en addition des autres systèmes afin de bien rendre compte de l'occupation réelle.

Particulièrement recommandé *Satisfaisant* NA *Non Adapté*

Table 1.12 a matrix of requirements for good IAQ in different types of building (Cetiat)

Fans using a variable speed motor make it possible to make important savings in electrical energy. The power consumption for a fan is roughly proportional to the cube of the airflow. Thus dividing the flow by 2 divides electricity consumption by 8.

6 ENERGY RESOURCES

6.1 FOSSIL ENERGIES

To satisfy the energy needs of buildings, we can use many types of energy.

Fossil fuels are those which are created through a long term process (millions of years) by the storage of combustible material underground. For instance:

- vegetation is transformed into coal varying from the lignite (the less elaborated) to the anthracite (the most pure),
- planktons: this transformation has given either oil or natural gas.

From an environmental point of view, the use of fossil fuels presents two main problems:

- depletion of limited reserves (Table 1.13), and the local impact of mining,
- greenhouse gas (CO_2) emissions into the atmosphere (Table 1.14).

Combustible	Durée restante d'exploitation des réserves*	
	estimation 1978	estimation 2000
Charbon		230 ans
Pétrole	28 ans	42 ans
Gaz naturel	47 ans	60 ans
Uranium		50 ans

* au même rythme de consommation et au même coût d'extraction

Table 1.13 reserves of fossil fuels and their duration (U.F.I.P / C.E.A)

	Emission CO_2 [kg/kWh]
Electricité marginale hiver	0,383
Electricité moyenne annuelle	0,066
Gaz naturel	0,200
Fioul	0,270
Charbon	0,360
bois (dans le cycle court du carbone)	0,360

Table 1.14 emmissions by fuel type (Ademe)

However the environmental impact of fossil fuels can be reduced by:

- an improvement in fuel quality (e.g. reducing the sulphur content of oil),
- an increase in the energy efficiency of equipment (Table 1.15). For medium size boilers, a regulation sets a minimal output efficiency (Table 1.16),
- optimising control of equioment for instance by a centralized Building Management System.

Evolution du rendement des chaudières fioul (chauffage individuel)			
	1965	1975	2000
Rendement moyen annuel	54%	70%	92%
CO2 [g_{CO2}/kW.h_{UTILE}]	493	380	289
SO2 [g_{SO2}/kW.h_{UTILE}]	2,415	1,28	0,354

Table 1.15 fuel efficiency of defferent equipment (U.F.I.P)

Chaudière	Rendement à puissance nominale P_N		Rendement à charge partielle 0,3 P_N	
$P_N \le 400[kW]$	Température moyenne de l'eau [°C]	Exigence de rendement %	Température moyenne de l'eau [°C]	Exigence de rendement %
Standard	70	$\ge 84 + 2 Log P_N$	≥ 50	$\ge 80 + 3 Log P_N$
Basse température	70	$\ge 87{,}5 + 1{,}5 Log P_N$	40	$\ge 87{,}5 + 1{,}5 Log P_N$
Condensation	70	$\ge 91 + Log P_N$	30 (alimentation)	$\ge 97 + Log P_N$

Table 1.16 Output efficiency of heating appliances (Directive européenne 92/42, arrêté du 9/5/94)

6.2 RENEWABLE ENERGIES

6.2.1 Définition

Any energy source which is naturally available in unlimited quantities with a permanent source of replacement is called a “renewable energy” source. Examples are:

- solar energy,
- wind energy ,
- biomass (which is renewed by rgrowing the vegetation),
- hydraulic energy,
- geothermal energy.

The replacement is not necessarily immediate (e.g. 1 year for straw, 20 to 50 years for wood, several centuries for the geothermics) but it will appear in time.

By contrast coal, gas and petroleum are not renewable, because the conditions of their creation do not any longer exist.

6.2.2 Interest

The interest in the use of renewable energies lies in:

- the non- use of limited reserves (sustainable development),
- in an almost nil contribution to the atmospheric pollution, at the local and the planetary scales.

This last point is debatable: the collection of solar, hydraulic and wind energy requires collection devices whose complete life- cycle needs consideration(e.g. fabrication, possible requuirement for electric batteries, demolition of installation, use of heavy embodied energy materials as aluminium and so on).

In the case of the biomass, either by wood combustion or methane biogas created by the transformation of waste materials, there is an emission of contaminants in the atmosphere, therefore an impact at the local scale. However, the impact at the earth scale remains quite small, because the released CO_2 will have been taken from the atmosphere by the photosynthesis. Therefore we are in this case of a carbon cycle on a various decade scale.(Fig 1.41).

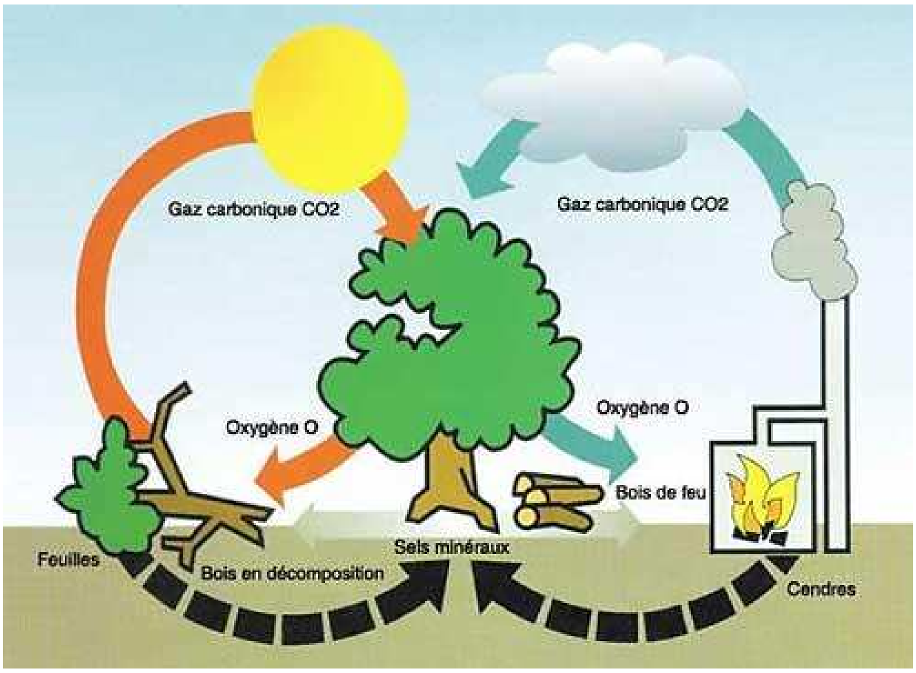


Figure 1.41 the carbon cycle (Comback)

The problem is more complex in the case of geothermal energy, which is a strong consumer of electricity, especially for the deep reinjection of used geothermal water. This reinjection is necessary to avoid pollution of the ground and of the surface water (the geothermal water is sulphurous and heavily charged with mineral salts), but also to maintain the conditions of exploitation (pressure of aquifer). This electrical consumption important in the environmental balance of the geothermal energy, but the production of electricity by co- generation brings an overall decrease in the planetary impact, even if it increases the impact at the local scale.

6.3 PLACE OF RENEWABLE ENERGIES

The place of the renewable energies in the global energy consumption is very different according to the countries (Table 1.17).

PAYS	Part des EnR dans la consommation	Remarque
U.E en moyenne	6%	dont production électrique
France	6%	grâce à l'hydraulique
Suède	28%	valeur maxi
Grande Bretagne	2%	valeur mini

Table 1.17 proportion of generation by renewables by country (Direction Générale de l'Energie)

However, the European Union level, a trend to develop renewable energies has been affirmed by the last international meetings. The ambition is to reach 12 % of the total energies consuption by around 2010 (Table 1.18).

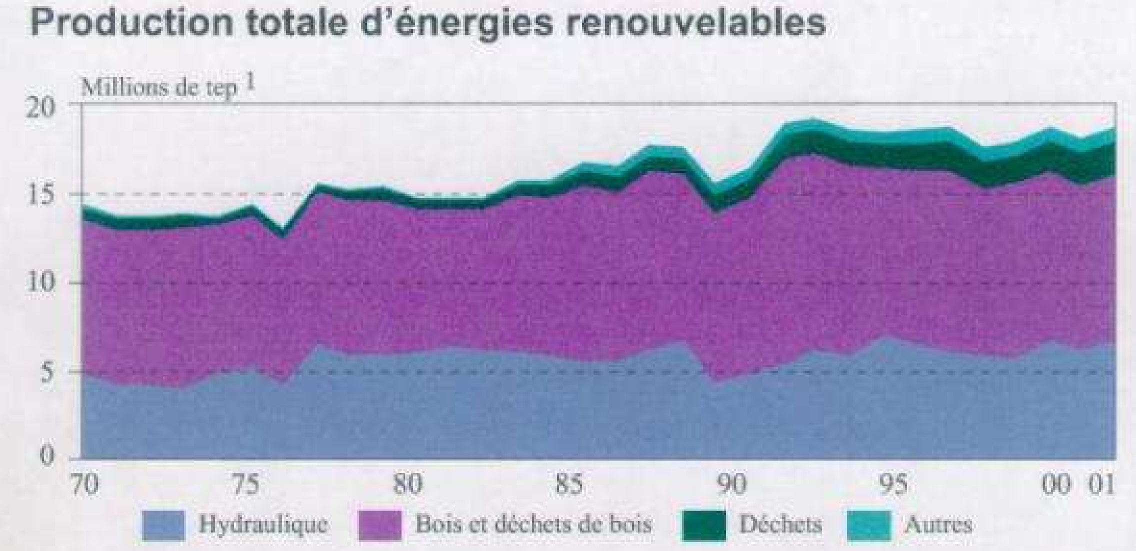
UNION EUROPEENNE : Energies renouvelables (millions de T.E.P)			
Type	**1995**	**2000**	**2010 ?**
Eolien	0,35	1,83	6,89
Hydraulique	24,8	27	28,8
Photo-voltaïque	0,002	0,011	0,26
Biomasse	44,8	48,65	135
Géothermie	2,5	3,42	5,2
Solaire	0,26	0,38	4
Total EnR	72,7	81,3	180,16
Total énergies primaire	1366	1460	1581
% EnR	5,3%	5,6%	11,4%

Table 1.18 Europeaan take- up of renewable energies (Eurobserv'ER)

In France (Table 1.19), renewable energy production (with the exception of hydro- electricity) is still small (4.1 millions of T.O.E., that is to say it is roughly 2 %of the final energy), and has stagnated for about ten years (Fig 1.42).

Production 2000 (1999) FRANCE (dont D.O.M)	Electricité [GW.h]	Thermique [kT.E.P]
Hydraulique	73 432 (78 543)	
Eolien	92 (49)	
Solaire	11 (9)	33 (33)
Géothermie	1700 (1449)	628 (629)
Bois	1510 (1466)	8949 (9298)
Résidus agricoles	370 (378)	192 (201)
Bio-gaz	346 (213)	63 (62)
Bio-carburants		335 (278)
TOTAL	**77 782 [GW.h] (82 127) 16 987 [kT.E.P] (17 681)**	**10 323 [kT.E.P] (10 618)**

Table 1.19 French use of renewable energies (Ministère de l'Industrie)



La France est riche en ressources énergétiques renouvelables ; avec la première forêt d'Europe occidentale, le deuxième "gisement" éolien et un fort potentiel hydraulique et géothermique, elle est le premier producteur et le premier consommateur d'énergies renouvelables d'Europe. En 2001, avec 19 Mtep comptabilisés en production primaire (soit 14 % de la production nationale énergétique) pour l'ensemble des énergies de sources renouvelables (y compris la production d'électricité), l'hydraulique en représente 36 %, le bois et les déchets de bois 49 %, les déchets urbains solides 10 % et les biocarburants 2 %.

1 : Équivalence pour l'électricité : 0,86 tep/MWh pour la géothermie et 0,086 tep/MWh pour les autres origines.

Figure 1.42 contributions of renewable energies (France) (Observatoire de l'énergie / CEREN)

To reach this objective, the European states (and the European Union) have some developed means of encouragement and promotion, for example in France:

- biomass: «wood-energy» program with aid for the construction of 200 wood central heating plants,
- solar: Helios 2006 program with aid for the installation of 15000 solar water-heaters per year,
- wind energy: installation of 500 MW for 2005.

6.4 INTEGRATION OF RENEWABLE ENERGIES

The use of the renewable energies in buildings is not simply a substitution of a fossil energy.

In fact, the use of renewable energies requires the designer to be aware of their specific at requirements the beginning of the project , for example:

- solar: integration of the collectors in the architecture of the building, integration of active or passive heat storage,

Figure 1.43 Photovoltaic array (Joannes)

Figure 1.44 Solar thermal (International Energy Agency)

- geothermy: providing a distribution network of heating generally at city scale and integration of the project inside this structure,

Figure 1.45 Geothermal heating network (S.M.T / épocal)

Figure 1.46 (O.P.H.L.M de l'Oise)

- biomass: requires a local network for the supply and the integration of storage facilities and feed in the architectural or urban project.

Figure 1.47 (O.Sebart / A.F.M.E)

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