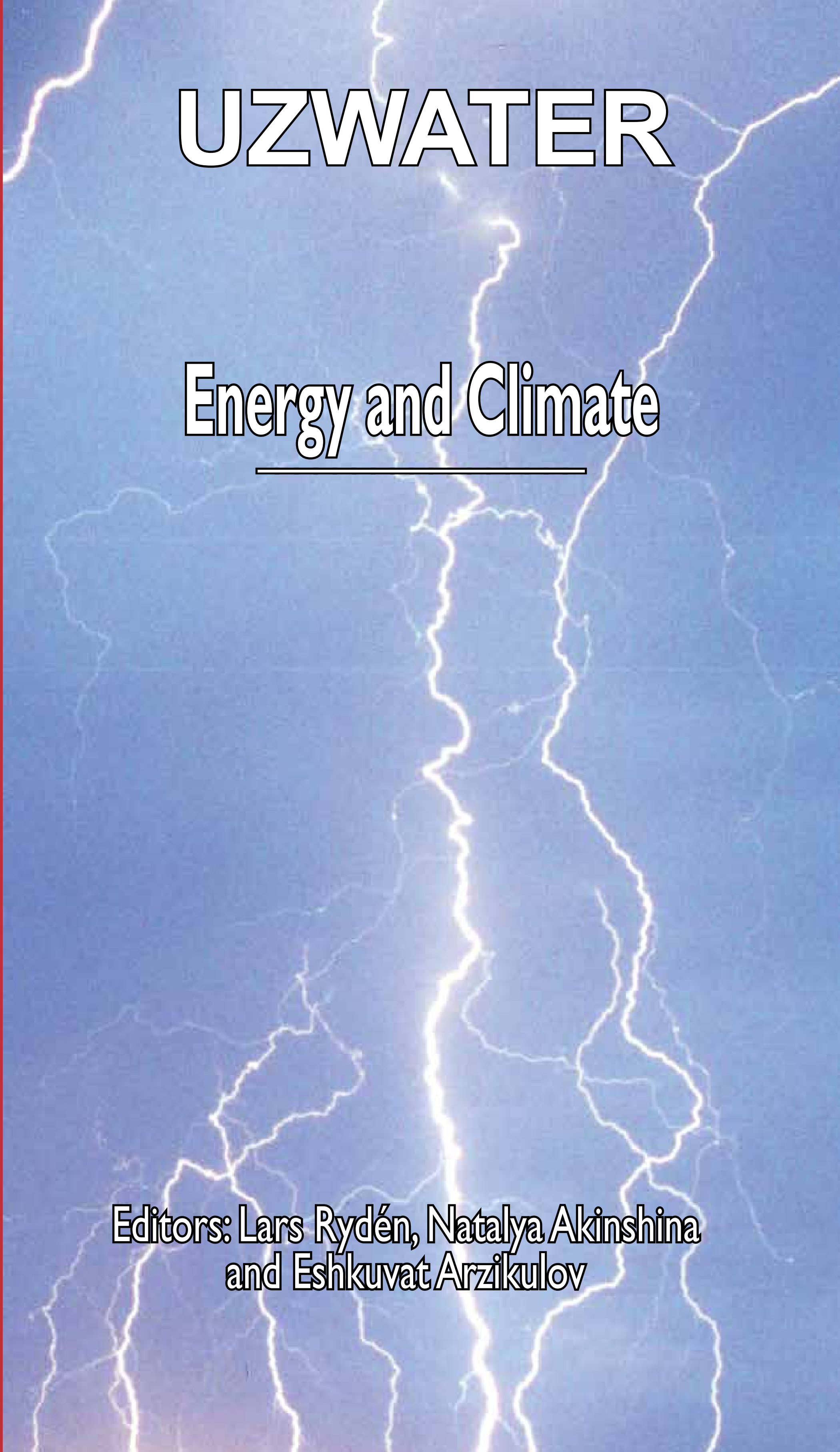

UZWATER

Energy and Climate

Editors: Lars Rydén, Natalya Akinshina and Eshkuvat Arzikulov

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1

Basics of Energy

Chapter 1
Energy and Sustainable Development

1.1 Energy is basic in our societies and our lives

Energy is fundamental in our lives. None of us can do anything without energy and in the way same society cannot do anything without energy. Development and energy consumption in a society is typically parallel up to a point. Then energy use is levelling off, even if economic turnover continues to grow. But then the *energy consumption* is already large.

An average person uses about 2.4 kWh per day as metabolic energy from the food we eat, that is, the base for keeping alive. This means that an average person has an effect of about 100 W (or perhaps a little less), like a traditional lamp. For a modern society, e.g. a West European country, the figure for energy use is typically 100 times larger counted per capita. Thus there are enormous amounts

Figure 1.1 Brown coal power plant near Otzenrath Nordrhein-Westfalen Germany, CC Photo: fxp

of energy used all the time for all kinds of purposes: keeping us warm (or cold in some countries), running our industries, for agriculture, for construction, for household purposes, for transport and so on. Still energy use differs much between countries and individuals, and also depends on methods for measuring it. Sweden, e.g. uses each year about 400 TWh for 10 million inhabitants, industries and all kinds of societal needs, so this is actually a little less than this average.

When discussing energy, it is useful to be acquainted with a few fundamentals. Energy is constant in the sense that it is not produced or consumed; it is only transformed from one kind to another, more or less useful for a purpose. Thus a power station transforms energy stored in e.g. fossil carbon, or biomass, or high-level water, into electricity in a generator run by a turbine. The energy produced during a set time period is the *effect* of the power station. The usefulness of the energy – its capacity to do work – is called *exergy*. Electricity has 100% exergy, while the exergy of hot water or gas depends on its temperature: higher temperature means higher exergy. We will come back to that below.

1.2 Kinds of energy

Energy exists in many different forms. *Energy can be stored* as in fossil carbon – coal, oil and gas – or biomass such as wood, biogas or vegetable oils. Stored energy functions as a fuel and can be used in many contexts.

Energy can also be in the form of *flowing energy*. This includes flowing water or wind (flowing air) or the sun (flowing light). Flowing energy on the other hand is intermittent, it needs to be used directly. The transformation of intermittent energy into stored energy is a key difficulty for energy management. Hydropower has a unique capacity here as it can be stored as water in a dam on higher level than the surrounding landscape.

We will discuss energy in three forms: *electricity* (the best) *heat* (mostly hot water) and stored fuel.

Energy is measured, quantified, using many different units. All of these can be converted into each other (See Box 1.1). By tradition *food energy* is measured in calories, *electric energy* is measured in Wh (Watt hours). In *thermodynamics* energy is mostly expressed in Joules (defined as Newton meter). In the world of *fossil fuels* (coal, oil and gas) energy is measured in *litres or barrels of oil* (one barrel = 159 litres) then referring to the amount of energy released when this volume of oil is burnt and heat released.

Since the amounts discussed vary enormously one uses prefixes for practical reasons. Prefixes are kilo (k), Mega (M), Giga (G) or Tera (T) for thousand, mil-

Box 1.1 Energy units and conversion of energy units

Energy is defined via work. *The SI unit for energy* is the same as the unit of work – the joule (J), named in honour of James Prescott Joule and his experiments on the mechanical equivalent of heat. In slightly more fundamental terms, 1 joule is equal to 1 newton-meter in terms of SI base units.

The *British thermal unit (BTU or Btu)* is a traditional unit of energy equal to about 1,055 joules. It is the amount of energy needed to cool or heat one pound of water by one degree Fahrenheit. The BTU is most often used as a measure of power (as BTU/h or BTUH) in the power, steam generation, heating, and air conditioning industries, and also as a measure of agricultural energy production (BTU/kg). In North America, the heat value (energy content) of fuels is expressed in BTUs.

In discussions of energy production and consumption, the unit *barrel of oil equivalen*t (BOE) and *ton of oil equivalent* (toe) are often used. The tonne of oil equivalent (toe) is the amount of energy released by burning one tonne of crude oil, approximately 42 GJ (as different crude oils have different calorific values, the exact value of the *toe* is defined by convention; unfortunately there are several slightly different definitions as discussed below). The *toe* is sometimes used for large amounts of energy, as it can be more intuitive to visualise, say, the energy released by burning 1,000 tonnes of oil than 42,000 billion joules.

The barrel of oil equivalent (BOE) is the approximate energy released by burning one barrel (42 U.S. gallons or 158.9873 litres) of crude oil. The U.S. Internal Revenue Service defines it as equal to 5.8×10^6 BTU. The value is necessarily approximate as various grades of oil have slightly different heating values. 5.8×10^6 BTU59 °F equals 6.1178632 × 109 J about 6.1 GJ (HHV, meaning higher heating value, then referring to an original temperature of 15 ^oC), or 1.7 MWh. If one considers the lower heating value instead of the higher heating value, the value for one BOE would be approximately 5.4 GJ. A commonly used multiple of the BOE is the kilo barrel of oil equivalent (kboe or kBOE), which is 1,000 times larger

Natural gas. One BOE is roughly equivalent to 5,800 cubic feet of natural gas or 58 CCF (volume of 100 cubic feet (cf) of natural gas). The USGS (U.S. Geological Survey) gives a figure of 6,000 cubic feet (170 cubic meters) of typical natural gas. Natural gas in the US is sold in Therms 100 cubic feet. One Therm is equal to about 105.5 mega joules. In the rest of the world, natural gas is sold in giga joules (GJ).

Electric energy. The energy unit used for everyday electricity particularly for utility bills, is the kilowatt-hour (kWh); one kWh is equivalent to 3.6×106 J (3,600 kJ or 3.6 MJ). Electricity usage is often given in units of kilowatt-hours per year (kWh/yr). This is actually a measurement of average power consumption, i.e., the average rate at which energy is transferred.

Thermal (heat) energy. The calorie equals the amount of thermal energy necessary to raise the temperature of one gram of water by 1 Celsius (centi) degree, at a pressure of 1 atm. For thermochemistry a calorie of 4.184 J is used, but other calories have also been defined, such as the International Steam Table calorie of 4.1868 J. Food energy is measured in "large" calories or kilocalories, often simply written capitalized as "Calories" (= 103 calories).

Measurement unit prefix and multiples. A metric prefix or SI prefix is a unit prefix that precedes a basic unit of measure to indicate a multiple or fraction of the unit. Each prefix has a unique symbol that is prepended to (written before) the unit symbol. The prefix *kilo-*, for example, may be added to *gram* to indicate *multiplication* by one thousand; one kilogram is equal to one thousand grams. The unit prefix *centi-*, likewise, may be added to *meter* to indicate *division* by one hundred; one centimetre is equal to one hundredth of a meter. The *unit prefix* mega, M, indicate multiplication by 1 million, giga, G, multiplication by 1 thousand millions and tera, T, by million millions, peta, P, by thousand million millions, exa, E, by million million millions. It may also be expressed in terms of 1000, 1000^2, 1000^3, 1000^4, 1000^5 and 1000^6.

lion, billion and trillions. Thus using the prefixes we may express amounts of energy as kWh, MWh, GWh or TWh. The same prefixes are used for the other kinds of energy measures. Thus we may talk about kilocalories, or mega barrels of oil.

It is important to know that energy sources are either renewable or non-renewable. Renewable energy can be renewed endlessly. This is the case with solar energy, or hydropower or wind energy. Non-renewable energy is available in a final amount and will at some point be emptied. This is the case with coal, oil and natural gas. They are called fossil energy sources, since they were formed many millions of years ago and are since then left in the ground and now recovered and used by us, mankind. Peat, recovered from wetlands, are sometimes counted as non-renewable and sometimes as renewable. The time required for peat to form is in the order of a few thousand years; thus depending on how mining of peat is conducted it may be counted as one or the other.

A society being dependent on fossil, non-renewable energy, is not sustainable. There are two reasons for this. First at some point the energy stores will be emptied and the society will stop working because of lack of energy. Secondly, to extract a natural resource from the ground (properly called the lithosphere) and releasing it into our living environment (the biosphere) will cause problems. These problems will grow as the amounts are building up. In the case of fossil energy resources, all consisting of carbon, it is caused by the carbon dioxide formed when the carbon is burnt. Carbon dioxide concentrations are increasing in the atmosphere and in the oceans and causing climate change, ocean acidification and other effects. We will come back to this later in the book.

Today some 83% of the global energy supply consists of fossil carbon: coal, oil and gas. This is not surprising considering that oil has a very high concentration of energy and is thus extremely valuable as an energy source. The access to large amounts of oil from the 1860s and on led to rapid industrialization, urbanisation and economic growth, proving its enormous value as energy. It should also be said that black coal has a very long tradition as energy source in many countries, and has been used even from medieval times. However, this is not sustainable.

1.3 Supply of energy

In many cases *stored fuels* are used in their original form. Thus coal, gas or wood are burnt to produce heat for cooking or heating in a household. Oil is most often processed in a refinery which delivers gasoline, heavy oil, and a number of other products based on oil. These are typically used for transport, for cars, trucks,

Figure 1.2 Hydropower. Akkats hydroelectric power plant in Swedish Lapland. Photo: Hans Blomberg

trains etc. They are of course also used as material in chemical industry which thus is also fossil energy dependent and in this sense unsustainable.

Electricity is the best form of energy for all kinds of mechanical movement such as in machinery, but in fact it can be used for anything. Electricity is also very practical for distribution of energy using grids. In most countries electricity are provided from *power plants*, which often use coal, lignite or natural gas as fuel. The fuel is incinerated to heat water, which is sent to a turbine, which runs a generator producing electricity. As mentioned this is not sustainable as it depends on fossil fuels.

Power plants may be improved in two ways. By using the hot water from the turbines for some purpose, typically district heating, the plant becomes a CHP, a Combined Heat and Power plant, and increases its efficiency from about 40% to about 90%. Secondly it may be improved by using a more sustainable fuel. Best is to use biomass such as wood from energy forests or wood waste (roots, branches etc). Then the power plant turns into a producer of renewable electricity. There are more options such as using household waste, which is an improvement,

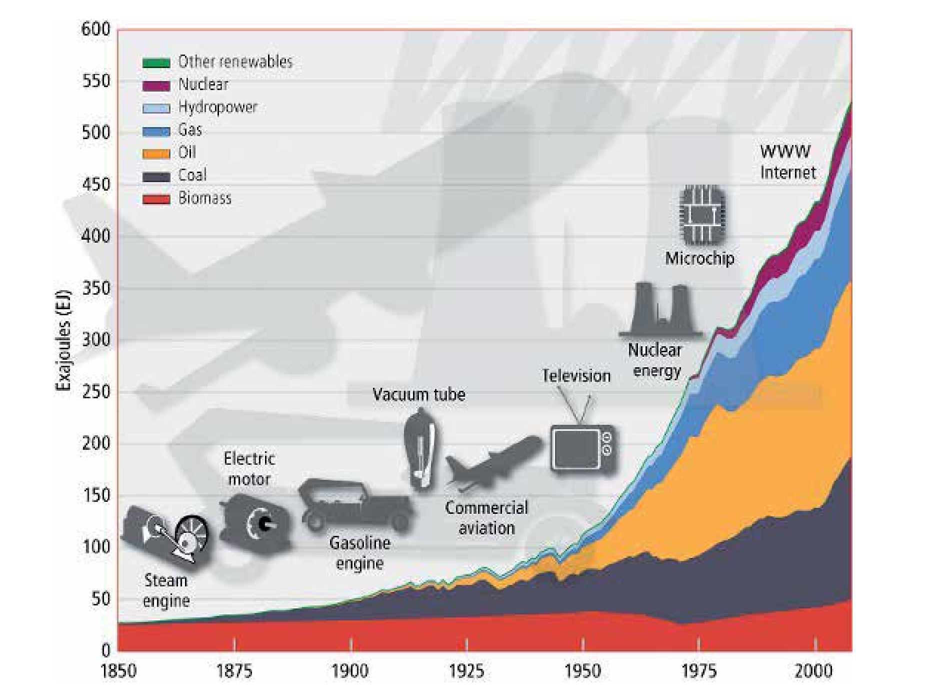


Figure 1.3 World Primary Energy Use: The figure shows the explosive growth of global primary energy with two clear development phases, the first characterized by a shift from reliance on traditional energy sources to coal and subsequently to oil and gas. Hydropower, biomass, and nuclear energy during the past decades have a combined share of almost 22%. New renewables such as solar and wind are hardly discernible in the figure. Biomass refers to traditional biomass until the most recent decades, when modern biomass became more prevalent and now accounts for one-quarter of biomass energy. Source: Grubler A et al. (2012). Chapter 1—Energy Primer. In: Global Energy Assessment—Toward a Sustainable Future, IIASA, Vienna, Austria and Cambridge University Press, Cambridge, UK and New York, NY, USA. (http://www.iiasa.ac.at/web/home/about/achievments/scientificachievementsandpolicyimpact/Sustainable.en.html)

but not completely sustainable since household waste normally has quite much plastics in it.

Nuclear power (NP) is not renewable for the simple reason that uranium is a fossil resource. Even if nuclear power plants can be safer and more efficient (3rd generation technology) than earlier, we are left with the problem of the nuclear waste, which remains toxic and radioactive for many thousands of years. It also appears that NP is too expensive for commercial investments and can only be built with governmental support. Very few NP plants are built today although many are being planned. However they do not emit carbon dioxide, which contributes to global warming, why many concerned scientists promote NP.

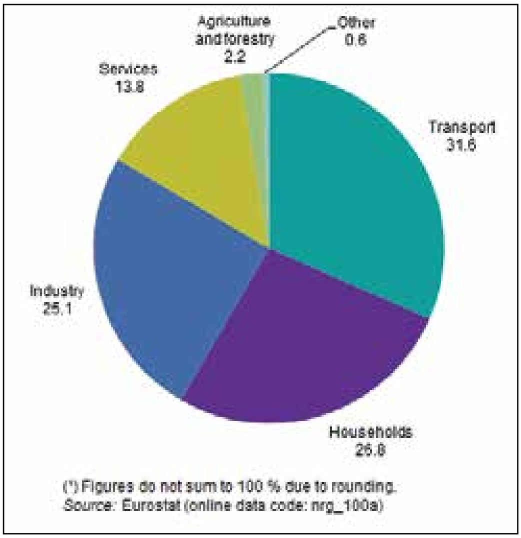


Figure 1.4. EU final energy consumption 2013. Source: http://ec.europa.eu/eurostat

To become a sustainable society we need to change our energy regime completely and rely on renewable resources. *Renewable energy resources* all ultimately come from the sun. The sun makes the water move, the wind blow and the trees and plants grow. In one-way or the other a sustainable society needs to find out how to use the sun well and cleverly. And there is enough for all of us. Humankind uses about 0.1 per mille of the energy content of the sun coming to us every day and minute. Just as the ecosystems found in Nature depend on the sun for its survival, human society needs to do the same thing. To replace the large scale dependency on fossil fuels to renewable energy schemes is perhaps the most difficult part of a transition to sustainable societies.

Renewable electricity is produced from hydropower plants, from wind power stations, and directly from solar cells, either photovoltaic, which directly transfers sun light into an electric current, or from CSP, Concentrated Solar Power, in which the heat of the sun is focused to produce hot liquid producing electricity in a turbine and generator. Hydropower is providing almost all of Norway's electricity and 50% of Sweden's electricity, and a fair share in some other countries. Wind power is very important in Denmark (about 40% of electricity) and Germany. Solar cells are not big anywhere but is increasing fast, by some 40% yearly. Other technologies include small hydropower plants, wave power at the coasts, electricity from running water, and electricity from power stations using renewable fuels such as biomass.

Renewable heat dependent on biomass is important to heat our houses. In the Nordic countries the earlier oil has been almost completely changed into biomass as wood chips, or wood pellets, all renewable biomass. In *district heating* the houses in urban areas are connected to one common power plant. This is much more efficient than a series of individual boilers, not the least because flue gases may be purified much more efficiently. Household waste incineration, the "waste to energy step" in waste management, takes care of waste and avoids landfill. This is seldom fossil fuel free as there is much plastic in household waste. It also requires good flue gas cleaning. Solar panels on the roof, or larger size on fields, may be used for solar heat. This is standard in Southern Europe. Heat pumps use electricity to extract heat from ground or outdoor air. This is up to 4 times more efficient than direct electric heating and is renewable if the electricity is. Heat pumps are important in Sweden.

Renewable fuel is mostly biomass either as solid (wood), liquid or gas. This is most critical for road traffic, which today is almost entirely oil dependent. Bio-ethanol from fermentation of sugar, e.g. sugar beet (1st generation bio-ethanol), or cellulose after hydrolysis (2nd generation bio-ethanol) is renewable if produced in such a way. Today all petrol in the European Union contains 5% ethanol; it may be increased to 10% without technical problems. Some cars and buses use E85 with 85% ethanol. Biodiesel is produced from oil crops, such as rapeseed, after extraction and methylation. It can easily replace standard diesel e.g. in buses and trucks. Production of biogas from anaerobic fermentation of organic waste (households, farms, wetlands etc) is increasing rapidly. In the Nordic countries it is mostly used for city buses. Biogas buses are more silent, less polluting and more sustainable. However transport is best done using an electric motor as it is about 4 times more efficient, less polluting, more silent and cheaper than a traditional combustion motor. The problem is the insufficient capacity of today's batteries.

1.4 Effect and electric power

Effect is the amount of energy transferred from a sending system to a receiving system during a specified unit of time. Effect is measured in Watt (W) defined as Joule per second (J/s) in the SI system. For mechanical energy also Newton meter per second (Nm/s) is used. Formerly horsepower (hp) was also used, for example for the power of car motors. 1 hp = 735.5 W.

Effect can be used for all kinds of energy per time unit. Thus the sun emits 3.92×10^{26} W of radiation energy. A strong car motor delivers some 100 kW of mechanical energy, a 60 W lamp delivers 60 W light and heat. An adult person delivers about 100 W (or a little less) as heat. The amount of energy transferred is received by multiplying the effect by the time.

Electric effect is often called *electric power*. It is the rate at which electric energy is transferred by an electric grid. Electric power is usually sold by the kilowatt hour (1 kWh = 3.6 MJ) which is the product of power in kilowatts multiplied by running time in hours.

1.5 Exergy is the ability to do work

Exergy is the ability to do work. The exergy quantity is defined as the ability to do work. It is present in a material system which can function as an energy supply. Exergy can also be described as composed of two measurable variables, one quality factor and its quantity, the latter being, like energy, measured in joules (J) or kilowatt hours (kWh). Whereas energy is omnipresent, exergy represents a contrast, or a 'tension', and it must be referred to for instance a system and its surrounding. This demonstrates that exergy is an ecological resource concept. Furthermore, since every contrast in natural systems has a tendency to weaken, and in the end to be eliminated, exergy can be consumed! This is in effect an expression for the second law of thermodynamics. It characterizes a relevant resource concept that it can be supplied, distributed, utilized and finally consumed. This is what holds for exergy, quite contrary to energy.

The definition of exergy. The Carnot principle (that can be studied in texts on Thermodynamics) demonstrates that the energy quality for quantities of heat can be calculated by means of a special temperature factor. If the temperature of the surrounding is T_o, a quantity of heat Q with temperature T (larger than T_o) can provide the work

$Q \times (T - T_o)/T$; (T must be expressed in kelvin).

The dimensionless factor $(T - T_o)/T$ measures the quality of the heat Q. This factor can be expressed as percentage or as a fraction, since it varies between zero and one. If $T = T_o$, that is if the two temperatures are equal, no work can be performed and the exergy is zero, all energy is background energy. Only if the surrounding temperature is close to absolute zero, does the factor become one in the limit.

Exergy can do work and is the 'driving agent' of all material processes and all changes of structure in matter. Exergy is a creative force in the small and the large scale. It provides the capability to develop new atomic architecture as well as architecture for humans. The solar flux to the surface of the earth contributes large amounts of exergy. It is exergy, not energy, which in essence sustains life and all evolutionary processes, also in the long and in the short time-scale.

Natural systems are exergy efficient. The exergy theory forms a framework for thinking about resource supply in a way that is relevant to an ecological perspective. It can clearly demonstrate that all physiological systems function with a practically perfect exergy efficiency. But the exergy concept can also be utilized to study very practical matters of housekeeping and energy conservation in a society with high technology. Needless to say, most human constructions operate at a much lower exergy efficiency than natural systems do. Those who want to study the potential of energy conservation measures ought to work within the framework of the exergy theory.

1.6 Energy efficiency – better exergy efficiency

An important starting-point for the discussion of energy efficiency (as it is called by most people today) is that one must consider effective utilization of both the quantity and the quality of energy. The traditional energy conservation measure is to use less energy, to tighten the leaks and to be careful with all kinds of spending.

Exergy efficiency also depends on clever handling of energy quality. High energy quality has in practice some clear demonstrations: mechanical energy, electrical energy and high temperature heat. The quality factor of electric energy is perfect. Electricity can be used for almost any purpose in technological systems, including production of heat. It has a very high 'temperature capacity'. The frequently applied technique of producing low-temperature heat (less than 100 degrees centigrade) by means of electricity is in principle extremely wasteful. Its exergy efficiency is in most cases less than 10 per cent. Therefore one now often defines special applications for electricity, namely, those that concern motion and high temperatures: transportation, mechanical machinery, lighting and hot-steam devices. For heating different sources than electricity should be considered.

Exergy, is the most important natural resource to humans and the society. When reading and using the conventional word energy it should be kept in mind that exergy is the essential part of the energy. In the perspective of human ecology the first and most important energy source is food. It is surprising that most scientists today still do not observe that the food supply to humans is a part of the energy supply to the society. Energy is required also for collecting all other resources, water, minerals etc and for maintaining the whole collective machinery. A modern society develops mechanical structures for housing and performance of various activities such as communications and transportation, farming and industry etc.

1.7 Emergy – an ecological concept for "embodied energy"

To measure the energy content of materials and products, based on an ecological view, for comparison and to make choices, researchers use the special concept of emergy. Different energies and materials can be measured on the same scale using emergy calculations. The following is a basic explanation of emergy principles.

This human energy food chain shows the joules in the units as they are processed from sun to electricity to human work. At each process some energy is used up, lost from the chain. The emergy of each unit is the amount of energy it took to make it: all of them used the whole 20 million joules of sunlight.

For example, think of you, a human. If I put you in an oven, how much heat would I get out of you? That's your energy. But to evaluate the emergy of a human you count all the different kinds of energy taken to make him, from genetics, to tender loving care, to school, trips, everything that has gone in to make him. Your emergy is a much bigger quantity than your energy. UEV (energy unit value) is a related special concept. UEV is the amount of solar emergy joules it takes to make 1 joule of a material or service. The abbreviation for solar emergy joules is sej. Table 1.1 compares energy and emergy for quantities in the diagram in Figure 1.5.

This is a hierarchical concept of value. Power and quality are different from physical quantity. This is a way to quantify the idea everyone has that the value of something is more than just the energy and materials in it. This does not represent the monetary value. Price is not its emergy value; price is just what someone would pay for it. Using emergy as the way of comparing different things on the same scale, its emergy value, we can calculate different choices.

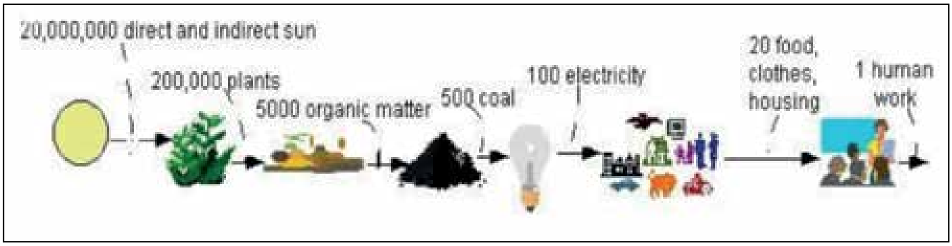


Figure 1.5. Emergy. 20 million joules of direct and indirect sunlight are used to produce each part of this energy chain. 20 million joules is the solar emergy of each component

Table 1.1.**Comparison of energy, emergy and transformity** for quantities in Figure 6.

	Sun	Electricity	Food, housing
Energy	20 E^6 joules	100 joules	20 joules
Emergy	20 E^6 sej	20 E^6 sej	20 E^6 sej

Between 1986 and today, the emergy methodology has continued to develop as the community of scientists has expanded and as new applied research into combined systems of humans and nature has presented new conceptual and theoretical questions. The maturing of the emergy methodology has resulted in more rigorous definitions of terms and nomenclature and refinement of the methods of calculating transformities. There is now an International Society for the Advancement of Emergy Research and a biennial International Conference held on the campus of the University of Florida.

Chapter 1 sources:

Main text Lars Rydén The Sustainable development course of the Baltic University Programme http://www.balticuniv.uu.se/index.php/introduction

Box 1.1 Wikipedia material

On Exergy: Tage Sundström in the Environmental Science book by Baltic University Programme http://www.balticuniv.uu.se/index.php/boll-online-library#environmental-science

On Emergy: A Prosperous Way Down, by Howard T. Odum and Elisabeth C. Odum, 2001 University Press of Colorado, Boulder, see http://emergysociety.org/

Chapter 2
How much energy do we use? – Energy statistics

2.1 The history of energy use

The energy use in the world has been increasing over the whole history of mankind. In table 2.1 you see an estimation of the energy use per capita on different stages of the development of human society. The big leap is with industrial society when fossil energies started to be used on a larger scale. This also changed the society to a more advanced level as economy increased. The societies which entered the industrial civilisation left behind most of extreme poverty, starvation, bad housing and so on.

The increase in energy use per capita needs to be multiplied with population increase to get a total energy use. The period from about 1900 when use of fossil fuels started on a larger scale to year 2000 the global population increased from 1.5 billion to 6 billion, that is a factor of 4. During the same period the increase in energy use is about 16 times, that is the energy use per capita increased 4 times (J. McNeil, 2000).

During the same period the kinds of energy used and as well the purposes of energy use changed. In the earlier stages biomass, wood in particular but also everything else which was grown, was important. It is well illustrated by the changes in transportation. 100 years ago horses and other animals were providing transportation on land and sailing ships did the same on sea. Sources of energy were biomass for the horses and wind for the ships. These were replaced by cars and steamships, using either oil or coal as a source of energy.

Table 2.1 Estimated energy use per capita in different societies (Source: A Sustainable Baltic Region Book 5. Energy, Baltic University Programme, 1997).

Stage of development	Energy use/capita (kWh/day)
Biological	2.4
Gatherers, hunters	10
Agriculture	25-50
Industrial society	50-100
Contemporary	250

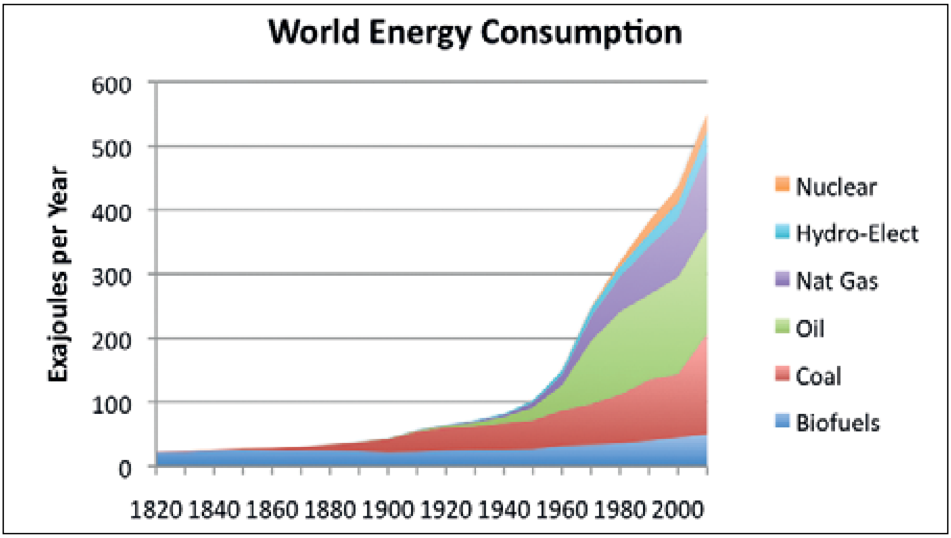


Figure 2.1 World Energy Consumption by Source. Based on Vaclav Smil estimates from Energy Transitions: History, Requirements and Prospects together with BP Statistical Data for 1965 and subsequent http://gailtheactuary.files.wordpress.com/2012/03/world-energy-consumption-by-source.png.

An estimation of the increase in global energy production and use and different kinds of energy is shown in Fig. 2.1. It is clear that biofuels is the original form of energy, followed by coal. Oil and natural gas became large parts of the energy budget from the 1920s. Hydro power as the first form of renewable energy after biomass is entering on a larger scale in the 1960s. Nuclear power is expending from the 1980s.

Energy utilisation in the welfare states towards the end of the twentieth century is at a level that has been reached rather recently. A study of energy growth in Scandinavia shows that commercial energy has grown by about 5% a year over a period of nearly 200 years. This corresponds, if the growth is exponential, to a doubling time of about 15 years. Indeed there are fluctuations – such as minor decreases during the world wars – but growth patterns have been remarkably constant over a long period. In the history to be written on human ecology this will be regarded as an important cause for the ensuing problems. Sustainability cannot be consistent with such a dramatic growth and not even with such a high level of energy use.

No nations exhibit today the extreme growth that characterised the first few decades after the World War. An estimate based on reasonable human ecological values is that whatever growth there will be in the global per capita use of energy

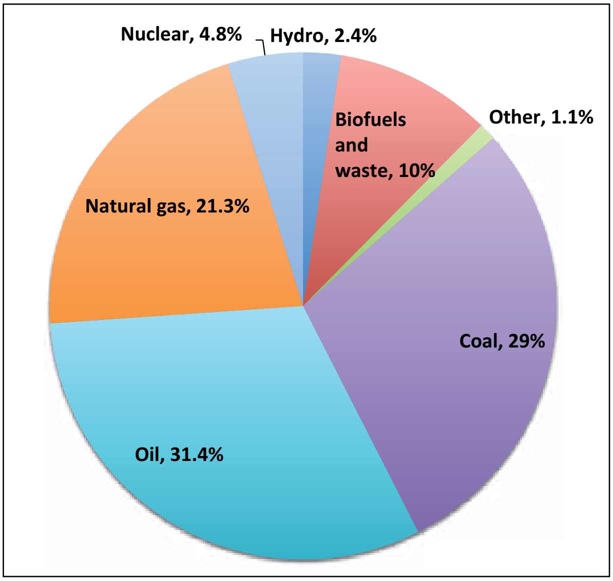


Figure 2.2 World Energy Production 2012 in Mega tonne of oil equivalents. Source: IEA.

in the future, it ought to be devoted to the poorer countries. Renewable resources will in the longer term have to replace the non-renewable ones. The replacement of fossil fuels and present nuclear technology are all-embracing projects for the near future in many modern societies. There are several alternatives. Biomass has great potential as an energy source, even for replacement of the petrol and diesel oil in cars with alcohol and biodiesel. Biogas is one further possibility. Solar technologies are developing. Most countries in Europe have a resource consumption, which is so high that it is technically no difficulties to save energy.

The question to be asked with this background is: how much energy consumption is possible in the world? How much energy do we need in the world? A simple answer is that the sun, which is our ultimate energy source, is still far from maximally exploited. An estimation is that human energy consumption is about 0.01% of the total energy coming from the sun. The problem from this point of view is not the total amount. It is the kind of energy used. Below we will look into prospects for much more efficient energy (exergy) management.

2.2 Oil production and consumption

Today some 85% of the global energy supply consists of coal, oil and gas. Studying the production and consumption of fossils fuels is thus very important when dealing with energy questions. Oil was extracted on a larger scale from about

1865. Then the first American Oil well was discovered in Pennsylvania. Almost at the same time the oil resources at Baku on the shore of the Caspian Sea were extracted. The amounts of oil produced worldwide have increased ever since, especially with the discoveries of large oil fields in the Middle East. The global production of fossil fuels is shown in figure 2.3

Oil turns out to be extremely practical for many reasons. It has a very high energy content. It is easy to transport. It can be used in all kinds of chemical productions, in particular plastics of all kinds. Oil is so good that the world has turned into oil addicts. It is thus a shock for countries that have relied on these sources of energy since even hundreds of years to learn that they cannot continue burning fossil carbon as it leads to emissions of carbon dioxide, which cause climate change.

The development of production/consumption of oil from 1965 is shown on a more detailed level in Fig. 2.4. It is an ongoing increase. The increase was linear in the 1960s. In 1973 was the first so-called oil crisis when when the members of the Organization of Arab Petroleum Exporting Countries proclaimed an oil embargo. By the end of the embargo in March 1974 the price of oil had risen from

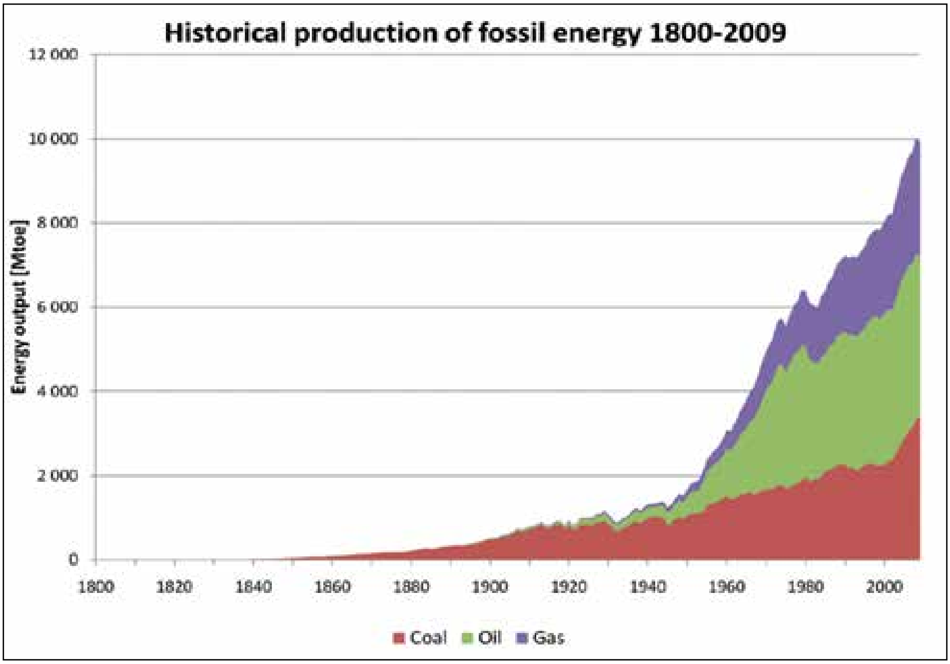


Figure 2.3 Global production of fossil energy from 1800 to 2010. Sources: adapted from M. Höök et al 2012.

Figure 2.4 Global oil production 1965-2010. Source: Kumhof & Muir (2012) Oil and the World Economy: Some Possible Futures. IMF Working Paper WP/12/256.

$3 per barrel to nearly $12, a 4-fold increase. From 1974 a new period of linear increase followed up to the next crisis period in 1979 when another quick change occurred raising this price once more, this time by a factor of three. Since then many countries have achieved a drastically reduced oil consumption as the higher price spurred technical innovations. From here followed a new period of slower but linear increase. This has in our time come to a standstill, a plateau, at a level of 85 million barrels of oil per day. A short dip occurred in 2008 because of the economic crisis but then it is back to the plateau level.

This needs to be understood in terms of production conditions. Up to the 2000s oil has been almost entirely so called *conventional oil*. This is oil pumped from oil wells without much difficulties. As these sources have been slowly emptied oil is produced from *non-conventional sources*. These includes oil pumped from *deep water*, e.g. from the Gulf of Mexico on a depth of 2,000-3,000 meters. It also includes oil produced from *tar sand* mostly in Canada. More recently *fracking of shale gas* has been used to produce oil. All these non-conventional production of oil is more expensive both in term of economic investments and energy needed to produce it. It is often expressed in terms of EROI, meaning Energy Return Of Energy Invested. EROI is very high for conventional oil, up to 100, but much lower for the non-conventional sources, perhaps 10 or 15. Obviously when a company invests more than what is earned by selling the oil they cannot continue, nor is it possible to do so if more energy is needed to produce the oil than what the oil itself contains.

This means that at some point in time the production will peak and then decline. The time of maximum production and consumption is called *peak oil.*

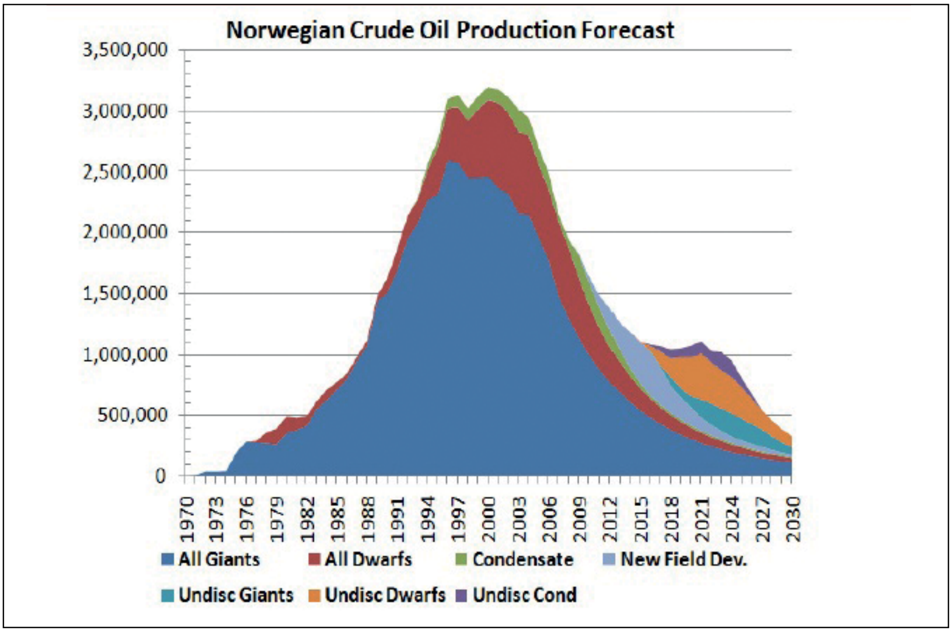


Figure 2.5 Norwegian oil. The production of oil and predicted future production. The Norwegian peak oil occurred in about 1999. A field by field analysis with maximum discovery potential. As Norway uses 0.2 Mbpd the export in 2030 will be around 0.2 Mbpd. (Source Kjell Aleklett et al, Uppsala University)

It is much studied but difficult to predict as much data are hidden. For specific countries and fields it is, however, well known. Thus US peak oil occurred in 1970 and the Norwegian peak oil was 1996-1999 (Fig.2.5). Global peak oil occurs right now as a plateau, not really as a peak. Conventional oil peaked at about 2005. The decline in the production of conventional oil has thus been replaced by unconventional oil since then. At some time this will not suffice and we will see a decline in production.

Box 2.1 Energy statistics

World energy statistics as well as statistics for individual countries is collected by several institutions. The International Energy Agency (IEA) is perhaps the best source for detailed statistics. It is available at http://www.iea.org/statistics/statisticssearch/

Another source is World Energy Council (WEC)
http://www.worldenergy.org/data/resources/

BP Statistical Review of World Energy is another standard publication used widely for energy statistics. http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy-2013.html

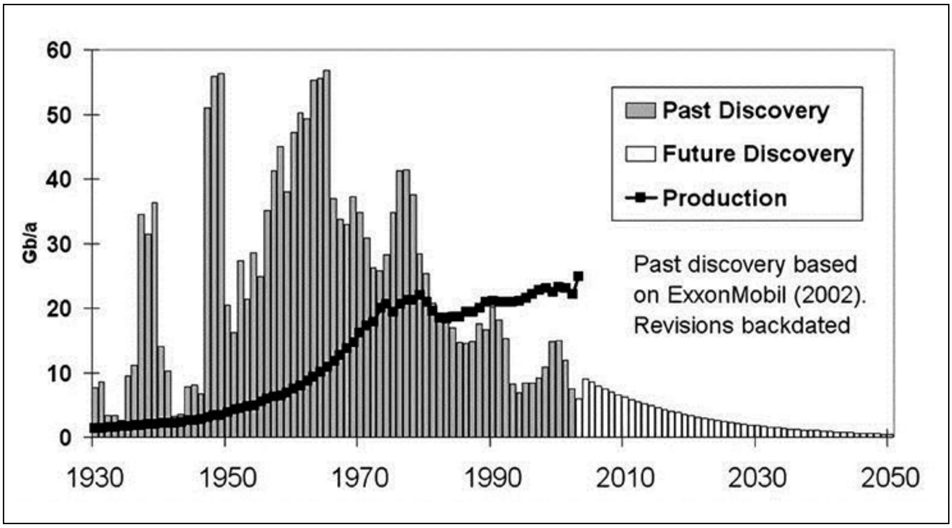


Figure 2.6 Oil discoveries. The growing gap between discoveries of oil fields and the production of oil, the global situation. (Source: ASPO; Association for the Study of Peak Oil, http://www.hydrex.be/case-story/81).

It is not realistic to believe that this situation will change because of discovery of new oil fields. The discovery of oil fields have been declining since the 1960s (Fig. 2.6). The typical time from discovery to maximum production is about 30 years. Now globally we are 50 years after the peak of discoveries and it is expected that we have a peak of oil production.

Of course the price of coal, oil and gas will increase when less is produced after the peak, if demand continues. Today we see a declining price because oil has been replaced by other means of energy. We will come back to that.

It is important here to ask what kind of energy supply we find in Uzbekistan. The data provided by the International Energy Agency (IEA) (Fig 2.7) tells that the total amount is around 50,000 ktoe per year, that is about 580 TWh. This is completely dominated by gas. Oil and coal has the second and third place. It seems that the energy budget of Uzbekistan is close to 100% fossil fuel.

The more detailed figures for recent years can be found at International Energy Agency on http://www.iea.org/statistics/statisticssearch/ or at World Energy Council (WEC) http://www.worldenergy.org/data/resources/. The data for gas in Uzbekistan from IEA was extracted from IEA and is shown in Table 2.2. Here we can see that conventional Power plants and CHP each provide 50% of electricity production in the country. Households use almost 50% of the final consumption, while industry uses about 24%. Agriculture is minimal probably because they are

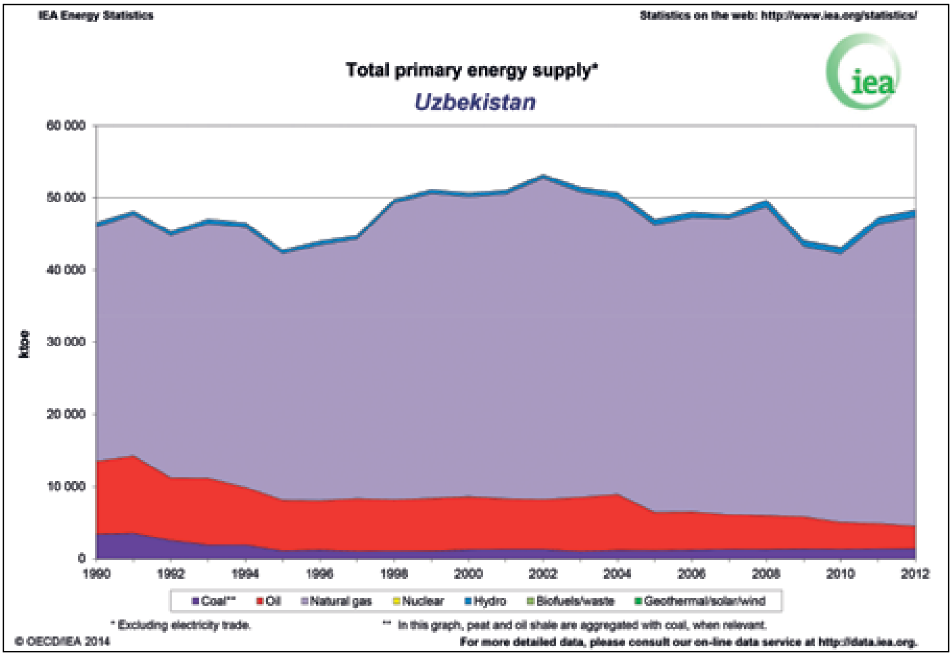


Figure 2.7 Energy in Uzbekistan. Total primary energy supply. (Source: http://www.iea.org/stats/WebGraphs/UZBEKISTAN5.pdf)

completely dependent on electricity. There are no data on biomass in the statistics of Uzbekistan, although one would expect at least on the country side some biomass would be used.

2.3 Use of energy

Main users of energy in our societies are

Residential/households. The largest energy consumption in households is due to heating/cooling. It may be either fuels incinerated in local boilers in the homes or from district heating when fuels is burnt in heat plants or CHPs. Other means of heating is using electricity or heat pumps. Cooling is using electricity for air conditioning and is in some countries a very large user of electricity. Electricity is used for all kinds of purposes in households. Lighting is typically using about 25-30% of electricity. Commercial and public services have very similar uses of energy.

Industry. The industry sector is a large consumer of energy, mostly in the form of electricity. This depends entirely on the kind of industries in the country.

Table 2.2 Natural gas data for Uzbekistan for 2012 (Source: International Energy Agency, http://www.iea.org/statistics/statisticssearch/report/?country=UZBEKISTAN&product=natural-gas&year=2012)

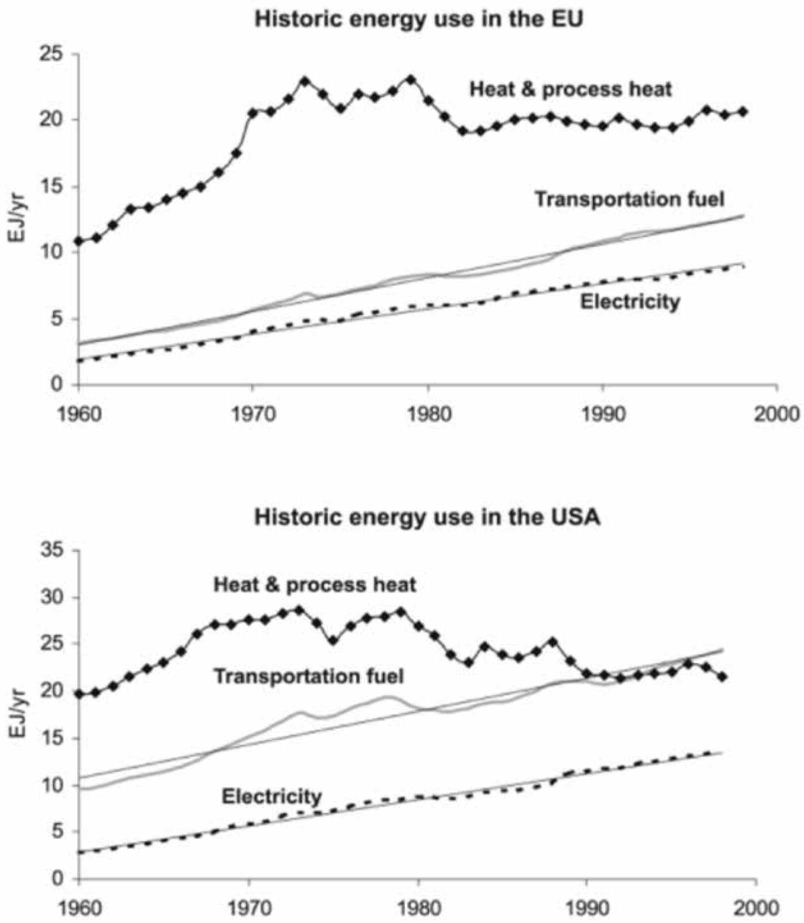
Category	Amount (TJ)
Production	
Total production	2,377,306
Domestic supply	1,991,858
Export	-385,448
Energy industry own use	77,443
Consumption	
Electricity plants	272,050
CHP plants	278,132
Heat plants	81,383
Industry	288,528
Transport	63,407
Residential	653,089
Commercial/ public services	130,626
Agriculture/Forestry	6,981
Non-energy use	67,569
Final consumption	1,210,200
Transformation	631,565

In Sweden big users of electricity includes the pulp and paper industry, the steel mills and the forestry industry such as saw mills. The building and construction industry, included here, is as well as large consumer of electricity.

Transport. The transport sector is a large consumer of fossil fuels, mostly as oil based products, such as diesel and petrol. This sector is for that reason one of the most difficult to work with for increasing sustainability.

Agriculture/forestry. This sector is very dependent on transport and machinery. In a situation when fuels are getting scarce this sector will be the first to be seriously affected, which of course will be a difficulty for the entire society.

Looking at the development in the EU and the USA (Fig. 2.8) it is clear that energy use for heat and process heat has been more or less constant since the 1970s, while electricity and transport fuel has been increasing in a linear way almost the whole period studied. This is still the case both in EU and the USA. The source of energy is changing much more than the use of energy.



Note: For the EU, the future electricity and transportation fuel demand is assumed to follow the linear historic extrapolation (the correlation coefficient r^2 is 0.99 for both electricity and transport fuel) while the heat demand is assumed to be constant, 18.5 EJ yr^{-1}, in the reference demand scenario. For the USA, the future electricity and transportation fuel demand is assumed to follow the linear historic extrapolation (the correlation coefficient r^2 is 0.99 for electricity and 0.93 for transport fuel) while the heat demand is assumed to be constant, 20.5 EJ yr^{-1}, in the reference demand scenario

Figure 2.8 Historic energy use in the EU and the USA. Source: ?????????????

2.4 Energy sufficiency and efficiency

When discussing energy management it is crucial to ask if there are possibilities to reduce the energy intensity of the sectors mentioned. This is the question of *energy sufficiency*. Even if energy is necessary it may be used more efficiently. *Energy efficiency* is as well a key task in energy management.

The residential sector has been very successful in reducing energy needs. Insulation of buildings, better construction of windows and doors, as well as more effective heat exchangers are part of the technical solutions. Today *low energy house* become more common in northern Europe. These use much less energy (15-25%) for heating and sometimes even have their own supplies of electricity and hot water. *Passive houses* have efficient insulation, heat exchanger for ventilation, and use heat from persons and machinery. Even if passive houses are not common low energy houses start to be so. These are slightly more expensive to build but much less expensive to use. Also retrofitting of present buildings is possible and profitable. As an example energy use in the building sector in Sweden could, according to the sector, be reduced by 20% with profitable investments. This figure is probably large also in other countries in the region.

The agriculture sector has several shortcomings which lead to energy wasting.

Food waste is large (some 20-30% of edible food) in many places. This can be reduced by simple means, such as better planned shopping, proper storage and taking care of leftovers. This refers both to producers, retailers and households/restaurants. Different food has very different carbon footprints. Meat production is by far most energy consuming while vegetables are much less so. But the trend in our societies is that meat consumption is increasing; 80% of the crops on farmland in the EU are used for animal feed. Denmark has five times more pigs than people. Less meat consumption is an important step to reduce energy needs.

Figure 2.9 A German ICE high-speed trains leaves the Schellenberg-tunnel at the Nuremberg-Munich high-speed track

The *transport sector* is by far the most difficult to improve. It is also the only sector where energy consumption is increasing and fossil fuels dominate. The first concern is to reduce travelling. For example many meetings may be replaced by video conferencing. Secondly improving public transport is a main concern especially in cities, to reduce the role of the private car. Here we also see an important technical development. New bio fuels, such as biogas, biodiesel and bio ethanol are introduced. But in the longer term electricity should be introduced since the electric motor is at least 4 times better than the combustion engine for mechanical work; train and tram is even better since rail requires less energy than tyres. Finally air traffic increases much; at present the environmental impacts of air traffic, including emissions, are not paid by the sector and there is a need for economic reforms. In the end lifestyle changes are needed. We simply have to travel differently and less.

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Chapter 3
Energy efficiency strategies

3.1 Principles of good energy management

There are many ways to deal with energy management in order to become more sustainable.

A general rule is that demand management is better than supply management. Thus much work is done today to reduce energy use in the consumption phase. Reducing energy use in households may illustrate this. Energy for lighting provides a dramatic example: Low energy light bulbs, especially LED lamps, is 5 to 10 times more efficient than conventional bulbs. As lighting uses about 28% of electricity in an average household (in the EU), a fivefold reduction is important. It is also important that machinery such as freezers, washing machines etc. is energy efficient. Standby should be avoided, and simple rules, like not lighting garages and toilets when nobody is there, contribute much. In the EU new directives supporting these changes are introduced.

On the *supply side* the main task is to move from fossil energy sources to renewable energy sources. As already has been described this is ongoing in all countries in the EU. At present Sweden has the highest share of renewable energy in the EU, about 50%, followed by Finland and Latvia. The main reasons are good supply of hydropower and much increased use of biomass.

In the industry sector there are many good examples on energy efficiency programs although much is left to be done. The pulp and paper industry, which is a high energy user, use the cellulosic fibres for producing paper while the lignin in the wood is turned into black liquor, a highly alkaline dark "soup" with a very high energy content. It is used for energy purposes in some factories, e.g. turned into biodiesel, but this could be much improved. The cement industry is using much energy and also emits carbon dioxide from the process itself (heating calcium carbonate). Building in wood, including multi-store houses and some other constructions, is now improving very much and some traditional uses of concrete should be possible to replace. Such a change includes several energy efficiency steps from transport to the building site, the construction itself, and maintenance of the building.

Proper waste management saves much energy. Thus it costs about 6 times less energy to produce steel from scrap iron compared to virgin ore, a figure that is 30 times for copper and 50 times for aluminium. Recycling paper saves energy as cutting trees is reduced and the production itself saves energy. Household waste incineration (waste to energy step) may provide about 5-10% of energy in a country.

In general both industries and households are reluctant to invest in energy improvements, even if the investments are profitable and money is coming back in only few years. Policies for supporting such investments are thus important. These include taxation on energy as well as subsidies for investments, or loans on good conditions.

Several management systems are available for energy improvements. These include Environmental Management Systems, EMS, such as ISO 14001; since December 2011 a certifiable international standard for energy management has been released, the ISO 50001.

3.2 Energy Supply Systems

There will always be a demand for primary energy. To meet the need for primary energy there are basically three classes of energy sources: Fossil fuels – coal, oil, and natural gas - nuclear power and renewable energy sources, i.e. energy from the sun. These are hydropower, biomass, wind, solar energy, wave and tidal energy, and geothermal energy. (Table 3.1)

It is useful to distinguish between *dispatchable* and *intermittent* sources of energy. Dispatchable sources can be stored – to be used later – and to some

Table 3.1 different kinds of energy sources.

Energy source	Dispatchable stored	Intermittent
Coal	as fuel	
Oil	as fuel	
Gas	as fuel	
Nuclear power	as fuel	
Solar photovoltaic	In a battery	used on line
Concentrated Solar Power, CSP	As hot water	
Solar heat panels	as hot water	
Hydropower	in reservoir	
Biomass	as fuel	
Wind energy	in a battery	used on line
Wave & tidal energy	in a battery	used on line
Geothermal	in ground	

extent transported to the place where the energy is converted to heat or electricity. Dispatchable generation refers to sources of electricity that can be dispatched at the request of power grid operators; that is, power plants that can be turned on or off, or can adjust their power output on demand Power plants that convert solar radiation, wind or wave power directly into electricity cannot be dispatched since the flowing energy will be lost unless it is utilised when it is available. Solar radiation, wind, wave and tidal power sources are therefore considered as intermittent sources. To some extent the energy generated by an intermittent source can be stored however. Thus hot water can be stored as such, and electricity can be stored in a battery or used e.g. to pump water to a high level reservoir.

Fossil- and biomass-fuelled power plants – as well as other energy converters such as vehicle engines – are dispatchable since the energy is stored in the fuel. The use of biomass, especially in the form of wood chips and bio pellets, has increased much recently. Biomass is produced in forestry, where the residual is taken care of, from energy forests but also from e.g. rape seed and other vegetable oil plants and grain, especially oat.

Hydropower stations are mostly dispatchable since they often have dam-capacity to allow storage of water so that the production of electricity can be regulated according to the demand. It is not likely that there will be any additional large hydropower plants in the European Union. The capacity was taken into use in the 20th century. Proposals for new large hydropower plants have been developed, but protests against these plans have been voiced, as they would destroy much of the natural beauties of the rivers to be used. In northern Norway, Sweden and Finland expansion of hydropower also meets protests. The technology of small scale hydropower, to provide e.g. a neighbourhood with electricity, has developed in an interesting way, and there are many thousands of small hydro power plants in several countries in the EU.

Wind power stations and wind farms are increasing since the 1990s. Wind power will provide some 10-40% of electricity in many parts in the region, e.g. Denmark and north Germany. Wind energy is more efficient on a water surface and many wind farms are located outside the coasts. Wind power electricity is fed into the general electricity net of the country and in this way can be stored, as hydropower is resting. As with hydropower, wind farms disturb the landscape.

Wave power technology is now developing in an interesting way and may have the capacity to be just as important as wind power in the future. A large wave power field was in 2014 installed on the west coast of Sweden. Wave power is also developed on the coasts of England and Ireland. Tidal power is of very limited significance generally. In regions with high tidal differences it is however a feasible technology. The Rance Valley Tidal Power Station close to St Malo in Normandy, France, has an installed capacity of 240 MW, distributed on 24 turbines. The amplitude of the tide here is in the order of 13,5 m.

Solar panels producing hot water from the heating sun have been mostly known as solutions for individual buildings, but solar panel fields also exist and is a growing energy sector. The largest today seem to be the one at Aeroe in southern Denmark and Kungsbacka in mid Sweden. It provides all district heating needed for the towns from March to November. In southern Europe household size solar panels are common on many houses. The technology for solar panels develops. Today they are quite efficient also in winter as long as the sun is shining. Community size solar energy may be stored as warm water in large spaces in the rock. In this sense they are semi-dispatchable. It provides much more heat per surface area, up to 50 times, than growing of biomass which then is incinerated. Geothermal energy, where it is available, is similar. Large geothermal power plants are found on Iceland, in Poland and in Denmark.

Photovoltaic cells convert sunlight to electricity. Research on photovoltaic cells has advanced and the efficiency of PV cells is increasing. Also the production costs are cut dramatically. Over the period 2010 to 2014 the costs were reduced by a factor of four, much due to large scale production in China. The cost of the electricity, measured as Euro per kWh, is now competitive to many other sources of energy. PV cells both for household use and in larger scale mounted on fields for an area or a town is developing rapidly. In Concentrated Solar Power plants (CSP) the heat of the sun is used to produce very hot water (or rather liquid) which is running a turbine and then a generator to produce electricity. CSP is common in e.g. Spain. It has generally a higher efficiency than PV cells but requires more maintenance.

3.3 Power Plants

Power plants are mostly based on burning of fuels. These are fossils, biomass (wood or peat), or waste. In general fossil fuels totally dominate the picture in most countries in the world. When burning a fuel, the remains are various gases and a solid waste. Which gases are produced and the amount of each depends on the fuel used, as well as the conditions during the combustion. The emissions from a combustion plant can to an extent be controlled by the choice of fuel and conditions under which the combustion takes place, i.e. process integrated measures. Another possibility is, of course, to use external cleaning technology

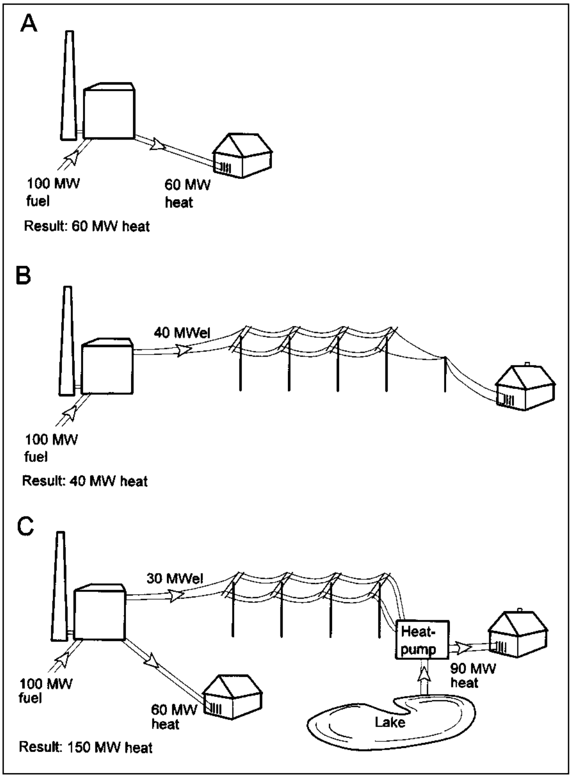

Figure 3.1 Energy plants. Comparison between three different alternatives for production of heating energy for households. A "bad" energy plant (A). An energy plant where all produced electricity is used for heating purposes (B), and an energy plant where the produced electricity is used to run a heat pump (C). (Illustration: Gunnar Svedberg, Royal Institute of Technology.

to avoid pollution. The proper cleaning of the flue gases is important in all kinds of power plants using fuels.

The aim of a power plant is to supply us with energy in the form of heat and electricity. We can also use some other source of energy instead of the fossil fuel, for instance nuclear power. We must then realise that we have other environmental problems to consider. Figure 3.1 shows some alternatives which gives very different results regarding the consumption of raw materials and, consequently, emissions of pollutants. From an environmental point of view the above mentioned outlook on the problem of supplying us with energy is considerably more important, compared to the discussion of how to increase the efficiency in an exhaust cleaning process by some percent.

Cogeneration, also known as combined heat and power (generation) or CHP, is an efficient, clean, and reliable approach to generating (electric) power and thermal energy from a single fuel source. Cogeneration uses heat that is otherwise discarded from conventional power generation to produce thermal energy.

This energy is used to provide heating (or cooling) for industrial facilities, district heating systems, and commercial buildings. By utilising this waste heat, cogeneration systems achieve typical effective energy efficiencies of 50% to 70%, a dramatic improvement over the average 33% efficiency of conventional fossil-fuelled power plants. Cogeneration's higher efficiencies reduce air emissions of nitrous oxides, sulphur dioxide, mercury, particulate matter, and carbon dioxide, the leading greenhouse gas associated with climate change.

Another example of a cogeneration process would be the automobile in which the primary fuel (gasoline) is burned in an internal combustion engine. This produces both mechanical and electrical energy (cogeneration). These combined energies, derived from the combustion process of the car's engine, operate the various systems of the automobile, including the drive-train or transmission (mechanical power), lights (electrical power), air conditioning (mechanical and electrical power), and heating of the car's interior when heat is required to keep the car's occupants warm. This heat, which is manufactured by the engine during the combustion process, was "captured" from the engine and then re-directed to the passenger compartment.

Trigeneration is the simultaneous production of cooling, heating and power, in one process. Trigeneration, when compared to (combined-cycle) cogeneration, may be up to 50% more efficient than cogeneration. When found in a hospital, university, office-campus, military base, downtown or group of office buildings, a trigeneration plant has also been referred to as a district energy system or integrated energy system and, as previously mentioned, can be dramatically more efficient and environmentally friendly than cogeneration.

Case Study 3.1 Co- and Trigeneration

A factory requires 1 MW of electricity and 500 refrigeration tons* (RT) of heat/cooling. The gas turbine generates electricity required for the on-site energy processes as well as the conventional vapour compression chiller.

Assuming an electricity demand of 0.65 kW/RT, the compression chiller needs 325 kW of electricity to obtain 500 RT of cooling. Therefore, a total of 1,325 kW of electricity must be provided to this factory. If the gas turbine has an efficiency of 30%, primary energy consumption would be 4,417 kW.

A cogeneration system with an absorption chiller (thereby making this a "trigeneration" plant) can provide the same energy service (power and cooling) by consuming only 3,333 kW of primary energy, thereby saving nearly 25% in primary energy usage.

** Note: A refrigeration ton (RT) is defined as the transfer of heat at the rate of 3.52 kW, which is roughly the rate of cooling obtained by melting ice at the rate of one ton per day.*

The trigeneration energy process produces four different forms of energy from the primary energy source, namely, hot water, steam, cooling (chilled water) and power generation (electrical energy). Trigeneration allows greater operational flexibility at sites with demand for energy in the form of heating as well as cooling. This is particularly relevant in tropical countries where buildings need to be air-conditioned and many industries require process cooling. When a trigeneration energy and power system is installed on-site, that is, where the electrical and thermal energy is needed by the customer, so that the electrical energy does not have to be transported over long distances, and the thermal energy is utilised on-site, system efficiencies can reach and surpass 90%.

3.4 Energy for transport

Transport is today using about 40% of the energy budget of industrial societies, a share that is increasing. In a combustion car engine the heat released when combusting the fuel (gasoline or diesel) is used to generate the mechanical work needed to drive the car forward. This is a quite inefficient process. Up to 18% of the energy content in the fuel becomes kinetic energy. The yield is slightly higher in a Diesel motor in which the combustion temperature is higher.

Efforts to reduce energy use in transport have priority, but are the least successful today. A few measures are the following: Car motors can be made much more efficient and the mileage of a car can be improved by up to 50%. Thus diesel engines today have almost doubled the mileage of the cars.

Alternative renewable fuels include ethanol and biogas. Today petrol in the European Union has 5% ethanol content. This may increase.

Cars which can take either ethanol or petrol (flexi fuel cars) are used and a conventional motor may easily be converted into one that runs on ethanol. However the use of ethanol as a biofuel is decreasing worldwide, although in some countries it is still important, such as Brazil (produced from sugarcane) and USA (produced from corn). Biogas is increasingly used as a fuel for cars and buses.

So-called environmentally friendly ("green") cars have in many countries been promoted by policy tools. These include no tax on ethanol or biogas, no parking fees in some cities etc. which will make them less expensive to drive. Electric cars, and hybrid vehicles (with both an electric and a combustion motor), are increasingly used. Electric energy can be transformed to movement (and vice versa when braking) with high efficiency. Drawbacks include the lack of efficient batteries, and high cost.

Transport on rail is at least one order of magnitude more energy efficient than road transport in traditional cars. More efficient use of cars should be mentioned as a separate measure. This includes car-pooling, but also that transport in industry is not dependent on owned cars, but rather that the service is bought from the car provider.

A complete reorganization of transport in society is the most far-reaching measure. A society in which the need for transport is decreasing, and the remaining transport is using mainly rail, would decrease energy use in this sector dramatically.

3.5 Electric Energy – More Efficient Lighting, Motors and Processes

Electricity accounts for close to 50% of national energy budgets. Electric energy is used for lighting, movements in electrical motors and a number of industrial processes such as electrolysis in which the final energy form is electricity.

Industry spends more money on electric energy than on any other energy source. Big total savings can be realised through small savings in electricity consumption practices, thus increasing the ratio between production volumes to energy costs.

In a house, electricity is used to heat the kitchen stove as well as in many cases for direct or indirect heating of the house. In industry many energy intensive processes rely on heat from direct firing of fossil fuels, but electricity is used in induction ovens where it is converted to heat. But electricity is a higher form of energy. This becomes clear with the concept of exergy. Exergy expresses the capacity of energy to do work. Electricity has 100% capacity to do work and thus its exergy is 1. For heat the capacity to do work is dependent on temperature. Low temperature heat, which may be excellent to heat a building, has very little capacity to do work and has little exergy. It is clear that electric energy has to be carefully used and only exceptionally used for heating.

The equipment using electricity in industry as well as in households has developed to become more efficient. This is a considerable source of energy saving. In cities the local electricity companies may inform and encourage the inhabitants to buy and use more energy-saving products in order to lower the consumption of electricity. The use of low energy lamps may reduce energy costs considerably. It is also important to turn off lamps when they are not needed.

Electric motors – that is, movement – are often used less carefully in that they are either on or off. If the work output from the engine is regulated by rotation speed control, considerable savings are possible. Electricity using processes are more difficult to change. This applies to all kinds of motors but is dramatically

Figure 3.2 Wind power is now rapidly expanding in the in Denmark, northern Germany, and southern Sweden, where this wind power park is found. The environmental costs of wind power are mainly related to landscape intrusion. If fully ex-ploited, wind power could not, it is projected, provide more than up to 7% of Sweden's electricity

illustrated by fans, in which rpm may be controlled by the need to ventilate, e.g. the temperature.

3.6 Heating Energy – Saving, Upscaling and Downscaling

In many cases the final use of energy is in the form of heat. It is thus crucial that the use of heating in society is optimally organised. The largest share is the heating of housing, about 30% of total energy use in the EU. Traditionally heating was done independently for each house or even household, by an individual boiler using wood, coal, coke, etc. These burners were seldom efficient (too low temperature) and often gave rise to considerable pollutants in the flue gases, especially particles.

One measure which has proven to give large environmental gains in urban areas is *district heating*. This involves replacing all small household heating systems with a large power plant, a form of *upscaling*. By building a central power plant with improved process control, as well as cleaning equipment, and with an energy distribution net instead of a number of small household heaters, the amount of air pollutants is drastically decreased. Central power plants may also use a fuel, which is difficult to use for a household, such as household waste or peat.

There are also a number of other ways to save energy and economise with the produced energy, as for instance controlling the temperature in our flats and houses. These measures are dependent on incentives, for example increased cost of heating. With proper insulation it is today possible to build houses which use very little or even no heating at all, so called passive energy houses (< 15 kWh/m^2/year) or low energy houses (< 40 kWh/m^2/year). Energy use in residential areas in the EU has been decreasing for several years.

It is also possible to save energy by finding proper local solutions, used for individual buildings, that is, *downscaling*. These include *solar panels* and *heat pumps*. Solar panels, producing hot water, in many cases are enough to provide a household with warm water for long periods of the year. Solar panels are usually added to roofs and then do not require extra space. Of course these measures also apply to the heating of industrial buildings. Heat pumps use electricity to extract heat from the surrounding. The possible savings, compared to electric heating, are up to 2.5 times or a reduction of 60%. Here it is important that the electricity does not come from combustion. Then there is no systems gain. Alternatives include e.g. hydropower. Heat pumps may be very profitable if the heat is extracted from e.g. wastewater or surface water. Alternatives are so-called rock heat (from great depths) or even from the air.

3.7 Integrated solutions

Energy together with materials, waste, and water make up the physical flows of a society, its metabolism. Considerable gains can be made by coordinating these flows. E.g. wastewater always carries some heat, which may be extracted by a heat pump. The sludge from a wastewater treatment plant may be fermented to produce biogas, which is an excellent source of energy, for example for buses or cars. Solid waste may be incinerated to produce district heating and cogenerated electricity.

Integrated solutions include the coordination of several facilities, sometimes referred to as *industrial symbiosis*. The steam produced in one factory may be sold to another factory, instead of just emitted. Several factories may produce their extra heat for the district heating system in the city where they are located. Many times the waste in one production can be used in the next production. Slaughter house organic waste may be fermented to produce biogas.

Special solutions are also possible. In cities in the north of Sweden snow, collected when cleaning the streets in wintertime, is deposited in one place to be used for local cooling in a hospital during the rest of the year. In another city the not fully cleaned wastewater from the treatment plant is used for growing energy forests, which is used as fuel in the local power plant. Good thinking, a developed systems approach and creativity allows the possibility to improve energy management by integrated solutions.

Chapter 3 sources:

Main text Lennart Nilsson, from Chapter 6 in Cleaner Production – Technologies and Tools for Resource Efficient Production of the Baltic University Programme http://www.balticuniv.uu.se/index.php/boll-on-line-library/827-em-2-cleaner-production-technologies-and-tools-for-resource-efficient-production

Introduction and editing by Lars Rydén. See The Sustainable development course of the Baltic University Programme http://www.balticuniv.uu.se/index.php/introduction

Chapter 4
Energy sources and energy use in Uzbekistan

4.1 The energy sector in Uzbekistan

The total annual energy budget in Uzbekistan is about 580 TWh or 50,000 ktoe (2012 data) (chapter 2). About 47 TWh of this is electric energy (2010 statistics). About half of the electricity is produced in conventional power plants and the other half in CHP (combined heat and power) plants. The energy sources are dominated by natural gas and has a very small content of renewable energy sources (RES) (see further in chapter 2).

Since 2001 Uzbekistan's energy sector has been run by the state company Uzbekenergo, an open joint-stock company (JSC), which also includes coal sector companies. Uzbekenergo is the primary electricity producer in Uzbekistan. It supplies centralized electricity to the national economy and the public, as well as heat to industrial companies and domestic households in a number of cities in Uzbekistan. The share of power plants that are not part of Uzbekenergo is less than 3% (320 MW).

The energy sector in Uzbekistan is in need of modernisation. A modernisation of its industrial capacities and technologies should include improved energy efficiency based on new, preferably environmentally friendly, technologies. A technological development will contribute to the national economic development of the country and mitigate climate change. The development needs to meet the environmental standards and priorities.

In selecting the technologies for mitigation and adaptation of climate change the following criteria have been applied:

- Importance of economic sectors for purposes of GHG emission reduction;
- Assessment of existing technologies;
- Interaction and compatibility with other technologies;
- Stability in emission reduction and project implementation periods;
- Amounts of GHG emission reduction to be achieved by the application of technologies;
- Environmental, economic and social importance of technologies;
- Possibility of further improvement and replication.

Low energy efficiency and a slow renewal of production assets remain the main problems in the power engineering, and oil and gas sectors. The present lack of required accounting and control over the use of energy carriers have a negative impact on the efforts to raise energy efficiency. To this is added a shortage of funds and difficulties in obtaining credits at favourable terms for the required investments.

The current growth of total production output as well as increasing consumption of electric and thermal energy and fuel by internal combustion engines asks for energy efficiency and use of energy-saving technologies. It requires the development of alternative energy sources, primarily renewable energy sources (RES) such as hydropower, wind, solar and geothermal energy, bio mass, biogas and wastes. All these sources and technologies are already used, or are close to application, on an industrial scale. The gross reserves of studied RES sources in Uzbekistan constitute almost 51 billion toe. The technical reserve of the RES has been assessed at 179.3 million toe, of which only 0.6 million tons or 3% are used. The complete technical reserves of renewable energy corresponds to a reduction of 448 million tons of CO_2.

4.2 Oil and Gas Sector – GHG emissions

The oil and gas sector of Uzbekistan is developing dynamically. In 2000 approximately 7.7 million tons of oil and gas condensate and about 56 billion m^3 of natural gas were extracted, which is 2.7 and 1.4 times respectively higher than the 1991 level. This figure had increased to 74 billion m^3 by 2012 (IEA statistics), an increase of 32% compared to year 2000. The share of the oil and gas industry in the country's GDP is 3.3%.

The oil and gas industry of Uzbekistan falls under the jurisdiction of Uzbekneftegaz National Holding Company (NHC) – a major production and economic complex securing a wide range of activities starting with the exploration of oil and gas deposits and ending with the sale of end products for which oil and gas are used as raw materials.

Uzbekneftegaz is comprised of 17 subdivisions, the largest of them are *Uzbekneftegazdobycha* Joint-Stock Company (JSC) (43.5% of the NHC total output) extracting oil and natural gas and refining natural gas with the production of gas sulphur, liquid gas and stable condensate; Uzgaztrans JSC (27.8% of the NHC total output) securing transportation of natural gas and its underground storage for covering seasonal consumption irregularities; and *Uzneftepererabotka* JSC (28.7% of the NHC total output) refining crude oil and stable condensate into oil products. As regards the oil, condensate and gas output (96-97%) and gas refining (100%), the largest subdivisions of Uzbekneftegazdobycha are enterprises situated in Kashkadarya Province.

The total emissions of GHG in Uzbekistan in 2012 was 160 million tons of CO_2. An analysis of the existing technologies of natural gas and oil extraction as well as the production of gas condensate and oil refining has shown that the following processes account for the largest emission of greenhouse gases:

- the burning of emergency and technologically required natural gas disposal in flare systems;
- the burning of natural gas in technological and domestic boiler houses as fuel;
- the burning of tail gases from Klaus sulphur production facilities (Mubarek gas refining plant) and direct oxidation sulphur production facilities (Mubarek plant and Shurtanneftegaz oil and gas refining facility) in after-burning furnaces;
- the burning of gas in heating furnaces at condensate stabilisation facilities (Mubarek plant and Shurtanneftegaz oil and gas refining facility);
- the burning of gas at absorption and adsorption sulphur-cleaning facilities, and natural gas drying facilities (fire regenerators, heating furnaces);
- leaks through fixture connections in oil and gas collection systems, during preliminary and integrated gas preparation for remote transportation, and during pre-treatment and storage of oil and gas condensate.

Therefore, a major reserve of cutting GHG emission lies in the introduction of modern flare facilities, maximum utilisation of valuable flare gases components, application of modern thermal energy generation plants, modernisation of the existing heat supply lines, maximum extraction of sulphur from tail gases in Klaus facilities, modernisation of condensate stabilisation plants, replacement of the physically and morally outdated equipment in oil and gas extraction, and refining as well as introduction of fuel gas and thermal energy meters, use of energy efficient lamps, etc.

However, financial constraints in the oil and gas sector, lack of domestic production of the required equipment, high taxes and lack of internal currency exchange put up barriers to the implementation of the above interventions.

As regards the emission of gases with a direct greenhouse effect (such as CO_2, CH_4) the share of oil refining in the power-engineering sector is insignificant. However, the entire range of oil products (gasoline, aviation kerosene, diesel fuel, furnace fuel, fuel oil and others) produce GHG emission when fuel is burnt in various economic sectors. Crude oil is mostly refined at Bukhara, Ferghana and Altynaryk oil refineries (OR), where equipment, with the exception of the Bukhara OR, is outdated. The largest GHG discharge is observed both in emergency and technological disposal similar to operations involved in oil and gas extraction and refining, and in some specific processes such as leaks and discharge during storage of oil products in tank pools; and evaporation from purification facilities in various systems. Thus, GHG emission may be reduced by:

- technological modernisation of tank pools and railway flyovers;
- maximum coverage of purification facilities evaporation surface;
- utilisation of valuable components of flare gases;
- application of modern facilities in thermal energy generation;
- replacement of physically and morally outdated equipment;
- improvement of energy efficiency.

Since technological requirements of oil refineries vary, individual approaches to their modernisation should be taken.

The system of main *gas transportation* in Uzbekistan is represented by Uztransgaz. A lot of equipment, mostly large-diameter pipelines, is involved in this process, and most of it has been in operation for a considerably long time and therefore has a considerable depreciation, which defines the gas industry as rather funds-intensive. Natural gas transportation consists of *reception* of gas from suppliers (gas fields, gas refineries and other systems); long-distance gas *transportation*; the *pumping* of gas into underground *storage* reservoirs and its withdrawal as required; and gas *distribution* among wholesale and direct consumers.

Practically the entire methane emission during gas transportation along mains is determined by the amount of natural gas discharged during operations intended for technological requirements of enterprises as well as technological losses due to lack of leak-proof-ness of equipment and breakdowns. All this is combined in the notion of ‘own requirements and losses’.

4.3 Leaks of natural gas from the gas sector

In 2000 the total amount of gas lost and used by Uztransgaz for its own requirements was equal to 3.6 billion m^3. Losses constituted 365 million m^3 or 0.8% of the amount of the sold gas. Of this amount: leaks in gas pipelines – 360 million m^3; leaks in gas distribution networks – 2 million m^3; losses at compressor stations – 3 million m^3. Uztransgas uses 2.7 billion m^3 or approximately 6% of the amount of the gas sold for its own needs. This consisted of:

- fuel for gas pumping units – 870 million m^3;
- gas for heating purposes – 22 million m^3;
- technological requirements of compressor stations & gas mains – 14 million m^3;
- blow-down of purification facilities – 1,394 million m^3;
- cleaning of gas pipelines – 225 million m^3;
- liquidation of breakdowns & hydrates – 152 million m^3;
- technological requirements of transit gas storage – 18 million m^3.

Most *leaks* occur in gas pipelines and gas processing units using fuel gas, and during blow-down of purification facilities. Gas losses in supply lines of gas mains occur in case of pipe rupture, therefore a reduction in the accident rate on pipelines will decrease methane emission. The introduction of telemetry and teleautomatics will reduce losses due to pipe rupture 2 to 3 times over. Gas losses in the supply lines of the gas mains at gas distribution and compressor stations will be reduced by the application of a better valve lubricant, which will fill loose spaces and thus prevent gas leaks. Unfortunately, in the past few years the issue of delivery of the valve lubricant has become increasingly pressing due to lack of its manufacturers in Uzbekistan.

The application of such lubricant will cut gas losses by approximately 200 million m^3. Besides that, it is possible to reduce gas emission due to technological causes during planned repair of pipelines by using compressor of ejector units pumping out gas from those parts of the pipelines that are under repair.

The technological needs of compressor and gas distribution stations as well as underground gas storage stations are caused by the use of equipment, which requires gas discharge into the atmosphere as a part of the technological process. Therefore, there can be no question of cutting the emission due to this cause.

Most considerable are emissions due to the blow-down of purification facilities, the cleaning of pipelines, and liquidation of breakdowns and hydrate formations. All these activities are not caused by the specific operation of gas pipelines and their systems, and are induced. Even considering the shortcomings of the regulatory framework, gas losses due to these requirements amounted in 1995 to 711 million m^3 or 1.17 of the normal amount. In 2000 such losses reached 1,771 billion m^3, which is twice as high as the norm. The increase in gas losses is related to the low quality of gas supplied to the main pipelines by Uzgeoneftegazdobycha and lack of tertiary treatment equipment in the main pipelines.

It should be noted that losses of natural gas, methane, is more serious than emission of CO_2 since the GHG potential of methane is about 21 times higher than that for carbon dioxide.

4.4 Electric Power Engineering

The main producers of electric power in Uzbekistan are thermoelectric power plants (TEPP) generating about 86% of electricity, hydroelectric power plants (HEPP) generating about 13% and other renewable energy sources about 1%.

TEPPs use solid, liquid and gas fuel. Coal accounts for 4-5%, oil for 10-11% and gas for 84-85% of power generation in Uzbekistan, respectively. The aggregate installed capacity of the power system in Uzbekistan is 11,264 MW.

Electricity is generated in condensation steam-turbine power pants (CPP) generating only electric power, or combined heating and power plants (CHP) generating both electric and thermal power. The efficiency of CPP in Uzbekistan does not exceed 33%. (The best power plants in the west achieves about 43%.) The CO_2 emission is currently 640 g/kWh. Specific fuel consumption by CPPs for generating electricity is approximately 380 g/kWh.

The capacity of HPs is approximately 650 MW or 6% of the aggregate power system capacity, while electricity generation constitutes 4.4%. Thanks to utilisation of the used heat the HPs save fuel for power generation. Specific consumption of fuel for power generation at HPs does not exceed 210 g/kWh. Construction of additional HPs in Uzbekistan is rather limited due to lack of major demand for steam and heat.

One of the most important ways of raising the efficiency of power generation in the country is modernisation of the existing capacities and replacement of outdated equipment with more efficient one. Table 4.1 shows key technologies used in the power-engineering sector of Uzbekistan. All power plants in the country originally used former Soviet technologies with little efficiency. After independence the energy sector, as all other economic sectors, was modernized and outdated equipment were replaced to increase capacity and efficiency. Thus since 2010 Sirdarya, Navoi and Tallimarjan power plants have received highly efficient Japanese turbines, and other power plants are step by step also modernized.

Table 4.1 Key technologies used in the power-engineering sector of Uzbekistan.

Sector	Technology
Electric power engineering	Introduction of new technologies for power generation with steam- and gas turbines at TEPPs. Large-scale introduction of small hydroelectric power plants and renewable energy sources. Introduction of water-accumulating power plants. Introcuction of gas-expansion equipment for utilising pressure in gas pipelines.

Introduction of energy-saving equipment (gas-expansion machines – GEM) and the use of steam-and-gas units (SGU) as well as gas-turbine units (GTU) are the most effective ways of raising the energy efficiency of electric power plants.

A considerable reduction of CO_2 emission (one million tons a year) can be achieved by introducing combined generation of thermal and electric power at half of the existing boiler houses as regards hot water supply alone (Table 4.2).

4.5 Energy efficiency improvements – the grid

Energy efficiency improvements is one of the most profitable ways to modernise the energy system of a country, or for that matter region, city or local consumer. Recently the republic Ministry of Economics informs that Energy consumption in Uzbekistan can fall to 25% by 2030. Reaching the share of renewable energy sources in the energy budget of the country to 20% by 2030 will reduced the energy budget by 3,28 million toe.

The conditions and structure of the networks – the grids – for energy transportation and distribution are highly important. Electricity to consumers in Uzbekistan is mostly supplied through cable networks put into operation in 1966 through 1972. These are in need of modernisation. The construction of new facilities and development of the infrastructure also require modernisation of the elec-

Table 4.2 Characteristics of steam-and-gas (SGU) and gas-turbine units (GTU)

Indicator		**Unit of measure**	**Station**				
			TashGRES (SGU)	**NavGRES (SGU)**	**TashTEC (GTUHP)**	**MubTEC (GTUHP)**	**Bukh EM (GTU HP)**
Capacity	Electric Thermal	Mw Gcal/h	370 78	350 150	64 71	106 260	62 72
Annual output	Electric Thermal energy	Million kWh 000 Gcal	2,800 267	2,650 821	486 552	850 2,000	463 330
Specific fuel consumption for	Electric Thermal energy	G/kWh Kg/Gcal	225 170	232 170	152 170	158 155	172 155
Fuel saved		000 tons conv. fuel/year	434	458	106	220	96
CO_2 emission rate		G/kWh	370	380	250	260	280
Reduction of CO_2 emission		000 tons conv. fuel/year	710	750	175	362	165
Year of commisioning			2005	2008	2010	2008	2007

tricity supply lines. Implementation of projects aiming to rehabilitate electricity supply lines will reduce the CO_2 emissions by 85,000 tons annually.

Of great practical importance is saving electricity in the electric power engineering sector itself. This consumes 5.6% of all electric energy generated by TEPPs for its own purposes and 7.5% of energy for its transportation. Phase 1 of the energy saving programme stipulates the introduction of tested energy-saving engineering and logistical interventions. This does not require any considerable expenses and they will produce a maximum effect within the shortest possible time. Their introduction into electric power engineering may reduce the annual CO_2 emission by approximately one million tons. The total possible reduction of GHG emission in electric power engineering is 7 to 8 million tons annually. Small-scale power engineering may contribute with an additional possible reduction of 12 to 13 million tons. The total GHG emission in the electric power-engineering sector is at present approximately 32 million tons, or 20% of the total GHG emission in the country. It is predicted that the GHG emission in the country will increase. This is due to the increased use of coal and reduced gas consumption.

4.6 Hydroelectric power plants (HEPPs)

Hydroelectric power plants (HEPPs) utilising the energy of falling water presently generate up to 15% of the electric power in Uzbekistan. The hydroelectric power contributes to renewable electricity but also to the peak capacity of the country's power system and to the regulation of its frequency.

31 hydroelectric power plants with an installed capacity of 1.7 GW and the annual electricity generation of 5 to 7 TWh have been built on rivers and water reservoirs. Major HEPPs are the Charvak (installed capacity 620 MW), Hojikent (165 MW), Tuyamuyun (150 MW), Andijan (140 MW), Farhad (126 MW) and Gazalkent (120 MW). However these and other plants needs to be taken care of. 90% of the existing hydropower plants have already exceeded their service life time.

There is a considerable capacity to increase hydropower in the country. The gross hydroelectric reserve of the main rivers of Uzbekistan is mostly concentrated in four regions in the northern parts of the country: the Chirchik-Angren basin (33.4% of the gross reserve), the Ferghana Valley (24%), the Southwest of Uzbekistan (34.8%) and the lower reaches of the Amudarya River (7.8%). This corresponds to more than 100 TWh, of which the technical reserve is over 21 TWh. The building of a large power plant in the To'polong River in Qashqadaryo region has almost been finished.

The potential capacity of s*mall-scale hydropower* with a capacity of less than 10 MW (30 MW) constitutes up to 8 TWh (10 MW), which corresponds to a 5.2 million ton reduction of carbon dioxide emission. The Ministry of Water Resources and Agriculture of Uzbekistan has designed a scheme of development of small HEPPs until 2010 with the technical possibility of construction of 43 small HEPPs near water reservoirs and 98 small HEPPs on irrigation canals with an aggregate capacity of approximately 400 MW. The technical capacity corresponds to building 250 hydroelectric power plants (HEPPs) with an aggregate capacity of 5.8 GW on rivers, water reservoirs and canals. By now only one third of this reserve has been utilised.

In other regions only small hydropower plants are built. The most promising are the following: Pskem (installed capacity of 400 MW). The possible annual power generation at Pskem is in the order of 900 GWh. The Pskem water reservoir with a capacity of 520.8 million m^3 is intended for seasonal regulation of the Pskem River water run-off to create additional irrigated lands. Tupolang has the capacity of 175 MW, Ahangaran 20 MW, and Sokh 14 MW, and a number of others with an aggregate annual generation of 5.5 TWh have been included into the development programmes of the relevant sectors. Implementation of these projects would permit to replace fossil fuels corresponding to the emission of 1.1 million tons of CO_2.

The construction of *water-accumulating electric power plants* (WAEPPs) has good prospects in Uzbekistan. They consume electricity in periods of small load (at night) for pumping water into the upper reservoir and generate it in the period of peak load thus relieving electric power plants operating on fossil fuel from participation in regulating the frequency and capacity in the power system. Thereby it reduces the use of organic fuel and greenhouse gas emission. At present the Hydro project Institute in Uzbekistan is designing options of WAEPPs construction in various parts of the country.

4.7 Solar Energy

The geographical position of Uzbekistan has predetermined the availability of a considerable *solar energy reserve*. According to observations duration of sunshine in various parts of the country varies between 2,413 and 3,095 hours annually, with a radiation balance of 1,718 to 2,722 Mj/m^2. The gross reserve of the solar energy is assessed at 50,973 million tons oil equivalent. This constitutes 99.97% of the gross reserve of all studied renewable energy sources in the country. This reserve is distributed unevenly throughout Uzbekistan. The largest solar energy reserve is in the Republic of Karakalpakstan (19,548 billion toe), and the smallest is in Andijan Province (129 million toe).

The main methods of possible utilisation of the solar energy for electricity generation are direct conversion of solar radiation into electricity with the help of photoelectric converters, and conversion of the solar energy into low-reserve (for heating, hot water supply, air conditioning and drying) and high-reserve (for technological processes and electricity generation) heat.

The available solar energy reserve is not well utilised in Uzbekistan at present. It is mostly used for generating thermal energy for hot water supply and for smelting super-pure metals. But the sector is rapidly expanding. Within the framework of realization of the Decree of the President of the Republic Uzbekistan № DP-4512 dated March 03, 2013 «About Measures on the Further Development of Alternative Energy Sources» the works on construction of photo-voltaic plant with 100 MW and 50 MW capacity in Samarkand and Tashkent regions respectively has started.

The technical reserve of the solar energy is assessed at 176.8 million toe or 98% of the total technical reserve of renewable energy sources in Uzbekistan.

4.8 Wind power

In Uzbekistan air currents have a seasonal nature due to the peculiarities of their origin and the country's geographical position on the Asian continent. In the plains the average annual wind velocity varies between 2 and 5 m/sec. The gross wind energy reserve in Uzbekistan is assessed at 2,223,200 toe, and is distributed throughout its territory extremely unevenly, from 4,300 toe in Ferghana Province to 924,700 tons in the Republic of Karakalpakstan. The average specific capacity of the wind current in Uzbekistanis 85 W/m^2 and varies from 20 w/m^2 in Andijan Province to 1,043 W/m^2 in Navoi Province. The technical reserve of the wind energy is assessed at 426,900 toe.

A team of Uzbek and German scientists produced an interactive digital and analytical map of wind energy potential (WEP) of Uzbekistan, called WIND ATLAS, using modelling software. Preliminary conservative analysis shows that wind energy potential makes more than 520,000 MW of installed capacity and more than a 1 TWh electric energy a year. This agrees with the estimation by the International engineering and consulting company INTEC for development of wind parks. The distribution of the regions are:

- the Navoi area is region with the best and greatest wind zones for working out of wind parks;
- Karakalpakstan, Bukhara and Samarkand areas have the big zones for working out of wind parks;
- Small zones have been defined in Tashkent and Namangan areas.

Attempts at using wind-driven power plants (WDPP) of different capacity in various parts of Uzbekistan (such as remote areas of Navoi and Bukhara provinces and in the vicinity of the Farhad HEPP in Syrdarya Province) have not yielded the expected results. Feasibility studies of the possible use of the wind energy in specific locations have not been done and therefore unsubstantiated selection of WDPP parameters and characteristics have been used.

Lately Uzbek scientists have revealed promising areas for wind energy in several regions of the country dominated by winds with a velocity of over 6 m/sec and an annual repeatability of 42%. In these 400 wind-driven power plants with a total capacity of 240,000 kW and an annual electricity generation of over 800 million kW/h can be built. One area is between the towns of Bekabad and Kokand in Tashkent Province.

4.9 Geothermal energy and biomass

Geothermal waters are available in practically all parts of Uzbekistan. Their average temperature across the country is 45.5 ^oC, with the hottest water in Bukhara (56 ^oC) and Syrdarya (50 ^oC) Provinces. The gross reserve of the geothermal waters in Uzbekistan is assessed at 170,800 toe. The largest reserve is in Bukhara (56,800 toe.) and Namangan (29,800 toe.) provinces. The technical reserve has not been assessed.

Biomass. Forests cover an insignificant part of the territory of Uzbekistan (3.2% of the total land area). The largest forests are covered by haloxylon, juniper and saltwort. All forests of Uzbekistan refer to Group 1, and commercial cutting there is forbidden. Only reforestation, sanitary and other non-commercial cutting is permitted. Most of the country's agriculture is based on irrigated farming, and most lands are under cotton, cereals, rice and potatoes, and the crops are used as fodder for domestic animals or local fuel. Studies have revealed that 2 to 4 tons of cotton stalks can be obtained from one hectare of land under cotton. The gross energy reserve of this biomass is assessed at 1.1 to 2.2 million tons of o.e., while the technical reserve (in case of the thermo-chemical conversion of the biomass) ranges from 0.13 to 0.26 million tons.

4.10 Heat Supply

Over 7.0 million tons of conventional fuel, or 12% of total fuel consumption in Uzbekistan, are spent on heat generation annually. Technological processes involved in the production of thermal energy are major sources of greenhouse gas-

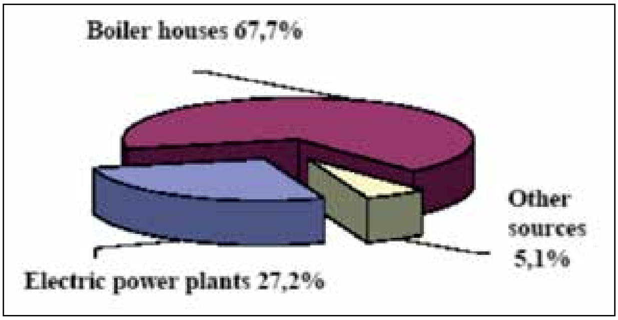

Figure 4.2 Structure of thermal energy supply in Uzbekistan in 2000

es. Electric power stations and boiler houses with a capacity of 3 Gcal/hour and more supplying thermal energy in the form of steam and hot water are responsible for almost 10% of total GHG emission in the country.

In Uzbekistan heat is supplied to production consumers, the social sector and the population both from centralised (electric power plants in general use, district and neighbourhood boiler houses) and isolated sources (heating plants of industrial enterprises, local boiler houses and individual heat sources). Some requirements in thermal energy of industrial consumers and the social sector are met by non-heating sources such as utilisation units and electric boilers.

More than one third of the thermal energy supplied are spent on heating and hot water supply to the population. The share of the social sector is significant and constitutes almost 17%. Consumers are provided with heat both from centralised and isolated sources, especially in towns, settlements and rural areas.

District heat supply to consumers is well developed in all major cities of Uzbekistan. In all of them the heat supply system does not include any meters installed at consumers' places. Such a system is inefficient and unreliable since considerable amounts of heat (4.5% of the total supply) are lost during transportation along main heat supply lines from the source to the consumer.

In industry a considerable amount of thermal energy is spent on oil and natural gas refining (approximately 15%), production of chemical goods (approximately 3%), mechanical engineering, manufacture of cotton and silk fabrics, food products and canned foods, construction materials and reinforced concrete structures. Most industrial enterprises meet their requirements in thermal energy from their own sources such as heating plants and boiler houses, and only partially from centralised ones.

The structure of heat supply by sources is presented in Fig. 4.2.

The main suppliers of thermal energy are boiler houses, which account for over two thirds of total supply. There are over 7,500 boiler houses of various capacities in Uzbekistan where almost 25,000 boilers of various types and designs are installed. At the end of 2000 the number of boiler houses with a capacity of 3 to 1,000 Gcal/h alone reached 1,186.

The technological base of municipal thermal power engineering was mostly formed some 25 to 35 years ago in conditions of complete technological and energy sufficiency, when the issues of accelerated and large-scale provision of the population in cities and towns with district heating were addressed. Boiler houses belong to various departments. Prior to this year the most powerful of them (with a capacity of over 100 Gcal/hour) were mostly operated by Uzbekenergo State Join-Stock Company. In 2001 the Government of the Republic of Uzbekistan, with the aim of furthering the process of de-monopolisation, privatisation and corporatisation of power-engineering enterprises, decided to turn over all district boiler houses to local authorities. The share of Uzbekenergo, which constituted almost half of total heat supply in the country, will now be considerably decreased.

The design efficiency of the largest and most advanced boilers is 90 to 92%, while their actual efficiency is only 50 to 75%. The output of thermal energy from boiler houses is not controlled due to the absence of meters. The metering of heat consumption by end consumers is also practically absent. The output of heat is computed by boiler houses staff indirectly, based on the indications of two water consumption meters, with a measurement error of over 5%. Only 0.4% of the 70,000 industrial, agricultural and domestic consumers have meters. Despite the high technical parameters of the existing equipment in medium and large boiler houses, the actual energy efficiency does not meet the required standards because this equipment is outdated.

Due to absence of production of effective small boiler units, a considerable number of boilers with a low efficiency of 60 to 75% were installed in small boiler houses. Such boilers produce over 40% of thermal energy in municipal power engineering. Lack of production of modern small boilers as well as automation and control equipment and boiler pipes in Uzbekistan is a considerable barrier to maintaining an efficient operation of boiler houses.

Operation of boiler equipment in medium and small boiler houses under an incomplete technological cycle due to lack of required water treatment, smoke exhausters and ventilators leads to accelerated external and internal corrosion of heat supply lines and blockage of distribution networks. The period of operation of boiler pipes is thereby reduced to half of the design one. Operation of small boiler houses with ineffective equipment under a curtailed technological scheme results in over-consumption of fuel and energy resources and, therefore, in a higher cost of the heat produced. No modernisation of boiler house is undertaken because of lack of funds in the sector.

Heat supply lines in which heat is delivered to consumers and distributed among them, are the most vulnerable spot in the heat supply system. The total length of municipal heat supply lines in Uzbekistan is 3,945 km in two-pipe calculus. Accelerated corrosion of heat supply lines, especially those laid under the ground, is explained by a rising groundwater table and submersion of heat supply routes by drainage and irrigation water and causes their rapid wear and tear. The cause of a considerable heat loss during transportation is the considerable length of heat supply lines, especially in the event of centralised heat supply. Outdated technologies of pipe insulation with mineral wool covers are used in Uzbekistan, leading to considerable losses of heat during transportation. Lack of manufacture of pipes with medium and large diameters, locks and modern pipe insulation materials such as ceramic and polymeric covers makes the repair and maintenance of heat supply lines more difficult and lowers the efficiency of heat supply. Possible energy saving in heat supply lines in case of application of effective modern insulation materials may amount to 5-7%, which will permit to save up to 250,000-300,000 Gcal annually.

4.11 Transport

Uzbekistan has a well-developed transportation sector including automobile, railway, air and river transport and pipelines. The share of transport in the total carbon dioxide emission exceeds 9%. The automobile transport takes the lead both in development rates and carbon dioxide emission growth. Its share in the transportation sector accounts for more than 60%. The establishment of domestic production of cars and mini-buses has considerably alleviated the problem of replacing outdated and energy-inefficient cars. However, the problem of renewing the existing transport pool, mostly trucks, with energy-efficient vehicles remains sufficiently acute.

The main areas for reformation of the transport sector include:

- introduction of diesel engines, which is key to providing transport with quality fuel;
- availability of required resources of diesel fuels in the oil refining sector;
- use of condensed natural gas as local fuel in automobile transport, especially town buses;
- construction of gas compression filling stations;
- diversification of transport as regards load-carrying capacity and services;

- improvement of the vehicles pool structure;
- use of electric traction in railways;
- development of town electric traction transport;
- optimisation of freight and passenger transportation schemes.

A programme of reducing gas emission by automobile transport is being designed in Uzbekistan. It includes the development of an engineering strategy and interventions aiming to reduce gas emission in the automobile sector and proposals on improving the legal and regulatory framework on air protection in the Republic of Uzbekistan.

Chapter 4 sources:

1. United Nations Framework Convention on Climate Change. UNFCC Secretariat, Bonn, 1998.
2. Kyoto Protocol to United Nations Framework Convention on Climate Change. UNFCC Secretariat, Bonn, 1998.
3. First National Communication of the Republic of Uzbekistan on Climate Change. Tashkent, 1999.
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II

Climate Science

Chapter 5
The Climate system

5.1 Factors of Earth's climate

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The atmospheric component of the climate system most obviously characterises climate; climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years). The climate system evolves in time under the influence of its own internal dynamics and due to changes in external factors that affect climate (called 'forcings'). External forcings include natural phenomena such as volcanic eruptions and solar variations, as well as human-induced changes in atmospheric composition. Solar radiation powers the climate system.

There are three fundamental ways to change the radiation balance of the Earth:

1) by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself);
2) by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and
3) by altering the long wave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

The amount of energy reaching the top of Earth's atmosphere each second on a surface area of one square metre facing the Sun during daytime is about 1,370 Watts, and the amount of energy per square metre per second averaged over the entire planet is one-quarter of this (Fig. 5.1). About 30% of the sunlight that reaches the top of the atmosphere is reflected back to space. Roughly two-thirds of this reflectivity is due to clouds and small particles in the atmosphere known as 'aerosols'. Light-coloured areas of Earth's surface – mainly snow, ice and deserts – reflect the remaining one-third of the sunlight.

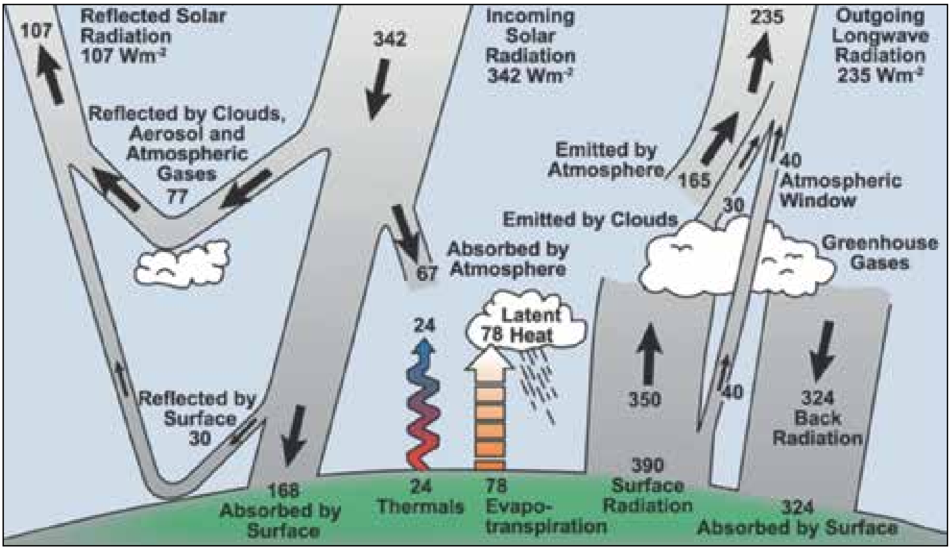

Figure 5.1. Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing long wave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by long wave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates long wave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).

The most dramatic change in aerosol-produced reflectivity comes when major volcanic eruptions eject material very high into the atmosphere. Rain typically clears aerosols out of the atmosphere in a week or two, but when material from a violent volcanic eruption is projected far above the highest clouds, these aerosols typically influence the climate for about a year or two before falling into the troposphere and being carried to the surface by precipitation. Major volcanic eruptions can thus cause a drop in mean global surface temperature of about half a degree Celsius that can last for months or even years. Some man-made aerosols also significantly reflect sunlight. The energy that is not reflected back to space is absorbed by the Earth's surface and atmosphere. This amount is approximately 240 Watts per square metre (W/m^2). To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing long wave radiation. Everything on Earth emits long wave radiation continuously. That is the heat energy one feels radiating out from a fire; the warmer an object, the more heat energy it radiates.

To emit 240 W/m^2, a surface would have to have a temperature of around -19 °C. This is much colder than the conditions that actually exist at the Earth's surface (the global mean surface temperature is about 14°C). Instead, the necessary -19 °C is found at an altitude about 5 km above the surface. The reason the Earth's surface is this warm is the presence of greenhouse gases, which act as a partial blanket for the long wave radiation coming from the surface. This blanketing is known as the natural greenhouse effect. The most important greenhouse gases are water vapour and carbon dioxide. The two most abundant constituents of the atmosphere – nitrogen and oxygen – have no such effect. Clouds, on the other hand, do exert a blanketing effect similar to that of the greenhouse gases; however, this effect is offset by their reflectivity, such that on average, clouds tend to have a cooling effect on climate (although locally one can feel the warming effect: cloudy nights tend to remain warmer than clear nights because the clouds radiate long wave energy back down to the surface). Human activities intensify the blanketing effect through the release of greenhouse gases.

For instance, the amount of carbon dioxide in the atmosphere has increased by about 45% in the industrial era, and this increase is known to be due to human activities, primarily the combustion of fossil fuels and removal of forests. Thus, humankind has dramatically altered the chemical composition of the global atmosphere with substantial implications for climate. Because the Earth is a sphere, more solar energy arrives for a given surface area in the tropics than at higher latitudes, where sunlight strikes the atmosphere at a lower angle. Energy is transported from the equatorial areas to higher latitudes via atmospheric and oceanic circulations, including storm systems. Energy is also required to evaporate water from the sea or land surface, and this energy, called latent heat, is released when water vapour condenses in clouds (Fig. 5.1). Atmospheric circulation is primarily driven by the release of this latent heat. Atmospheric circulation in turn drives much of the ocean circulation through the action of winds on the surface waters of the ocean, and through changes in the ocean's surface temperature and salinity through precipitation and evaporation.

Due to the rotation of the Earth, the atmospheric circulation patterns tend to be more east-west than north-south. Embedded in the mid-latitude westerly winds are large-scale weather systems that act to transport heat toward the poles. These weather systems are the familiar migrating low- and high-pressure systems and their associated cold and warm fronts. Because of land-ocean temperature contrasts and obstacles such as mountain ranges and ice sheets, the circulation system's planetary-scale atmospheric waves tend to be geographically anchored by continents and mountains although their amplitude can change with time. Because of the wave patterns, a particularly cold winter over North America may be associated with a particularly warm winter elsewhere in the hemisphere.

5.2 Changes in the climate system

Changes in various aspects of the climate system, such as the size of ice sheets, the type and distribution of vegetation or the temperature of the atmosphere or ocean will influence the large-scale circulation features of the atmosphere and oceans. There are many feedback mechanisms in the climate system that can either amplify ('positive feedback') or diminish ('negative feedback') the effects of a change in climate forcing. For example, as rising concentrations of greenhouse gases warm Earth's climate, snow and ice begin to melt. This melting reveals darker land and water surfaces that were beneath the snow and ice, and these darker surfaces absorb more of the Sun's heat, causing more warming, which causes more melting, and so on, in a self-reinforcing cycle. This feedback loop, known as the 'ice-albedo feedback', amplifies the initial warming caused

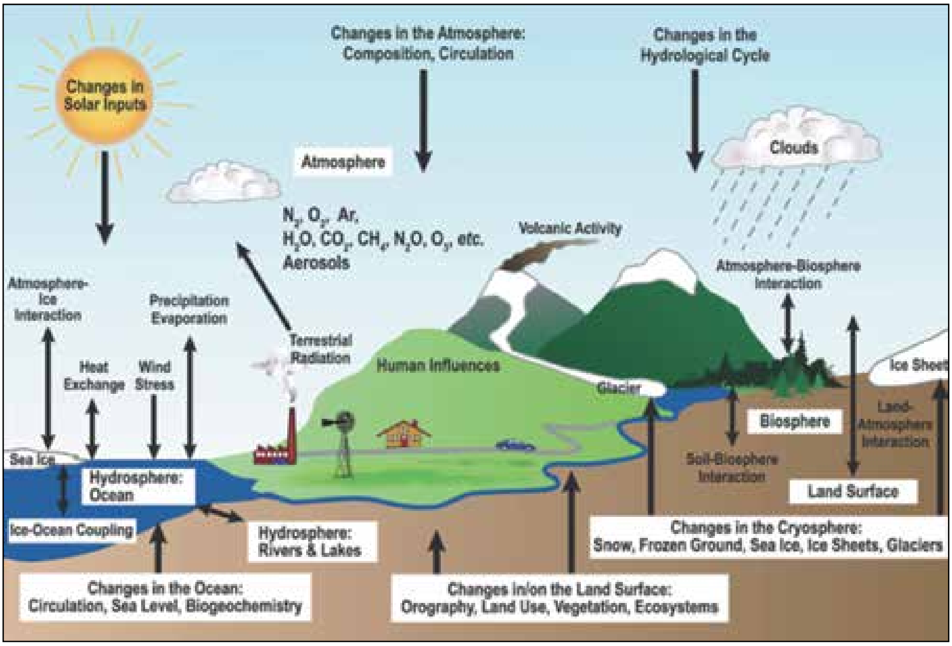

Figure 5.2. Schematic view of the components of the climate system, their processes and interactions (source: ???)

by rising levels of greenhouse gases. Detecting, understanding and accurately quantifying climate feedbacks have been the focus of a great deal of research by scientists unravelling the complexities of Earth's climate.

Climate can be viewed as concerning the status of the entire Earth system, including the atmosphere, land, oceans, snow, ice and living things (Fig. 5.2) that serve as the global background conditions that determine weather patterns. An example of this would be an El Nino affecting the weather in coastal Peru (See Section 5.6 below on the large ocean currents). The El Nino sets limits on the probable evolution of weather patterns that random effects can produce. A La Nina would set different limits.

Another example is found in the familiar contrast between summer and winter. The march of the seasons is due to changes in the geographical patterns of energy absorbed and radiated away by the Earth system. Likewise, projections of future climate are shaped by fundamental changes in heat energy in the Earth system, in particular the increasing intensity of the greenhouse effect that traps heat near Earth's surface, determined by the amount of carbon dioxide and other greenhouse gases in the atmosphere. Projecting changes in climate due to changes in greenhouse gases 50 years from now is a very different and much more easily solved problem than forecasting weather patterns just weeks from now. To put it another way, long-term variations brought about by changes in the composition of the atmosphere are much more predictable than individual weather events. As an example, while we cannot predict the outcome of a single coin toss or roll of the dice, we can predict the statistical behaviour of a large number of such trials.

While many factors continue to influence climate, scientists have determined that human activities have become a dominant force, and are responsible for most of the warming observed over the past 50 years. Human-caused climate change has resulted primarily from changes in the amounts of greenhouse gases in the atmosphere, but also from changes in small particles (aerosols), as well as from changes in land use, for example. As climate changes, the probabilities of certain types of weather events are affected. For example, as Earth's average temperature has increased, some weather phenomena have become more frequent and intense (e.g., heat waves and heavy downpours), while others have become less frequent and intense (e.g., extreme cold events).

5.3 Solar radiation and the global heat balance

The sun shines on the planet with an intensity of about 1,330 Watts per square metre at the outer reaches of the atmosphere, and varies according to location and time of year. How much of this reaches the surface of the planet? Reflectivity, or the so called *albedo*, is an important phenomenon. About 25% of incoming solar radiation is reflected by the clouds and the atmosphere and does not contribute to the heat balance of the planet. The atmosphere and clouds absorb another 25%. Only half of the solar radiation thus reaches the surface of the Earth, some being again reflected, or backscattered. If the surface is covered by clean snow the albedo is very high, about 90%, while black soil, which hardly reflects light at all, has an albedo close to 0%. The Earth on average has a 5% albedo – mostly since the oceans, which cover large areas, absorb much of the sunlight. The 25% reflected by clouds in the atmosphere should be added, to make up a total albedo of 30% for Earth as a whole. About 45% of incoming radiation is finally absorbed by the surface of the planet. This energy is used for e.g. evaporation of water. All of it is, however, in the end radiated back to maintain heat balance. However, since the outgoing radiation comes from the colder Earth it is very different from the incoming radiation. It is mostly low energy, longer infrared wavelength radiation (heat radiation).

The atmosphere is much less transparent to outgoing heat radiation than it is to the incoming solar light. Thus, much of the energy is used to heat up the lower atmosphere and indirectly the surface of the Earth. This effect contributes to the heat balance of the planet with about 35 ^{o}C. Without this effect, the Earth would not harbour life as we know it. The heating through absorption of infrared back radiation is called the "greenhouse effect," comparing the atmosphere to the glass

Table 5.1 Solar radiation

Incoming solar radiation	**%**
Reflected by clouds and the atmosphere	25
Absorbed by the atmosphere and clouds	25
Reflected by the surface	5
Absorbed by the surface	45
Use of solar input	**%**
Heating the surface	50
Evaporation of water from the surface running the hydrological cycle	23
Convection in the oceans, currents	20
Winds	7
Photosynthesis	0.1
Human energy turnover	0.01

in a greenhouse that makes the inside warmer by absorbing outgoing radiation. The most important component in the Earth's atmosphere that absorbs the infrared light from the Earth is water vapour. However, any gas that absorbs infrared light contributes. Most important are carbon dioxide and methane. The concentrations of each of these gases are decisive for the heat balance of the planet.

The present dramatic increase of carbon dioxide and other greenhouse gases is obviously influencing this balance and causes a shift towards a warmer climate. The energy available for processes on the surface of the Earth, such as the hydrologic cycle, photosynthesis and heating of soil layers and vegetation, is called the net radiation. This is the net income of energy to the Earth's systems. Net radiation consists of the nets of long-wave and short-wave radiation. In the energy balance of the Earth's surface the net radiation is distributed between sensible heat flux (heating air and vegetation), latent heat (evapotranspiration) and ground heat flux (heating the ground).

5.4 The water cycle

The third crucial component, after the soil and the atmosphere, of the planet is water, or the *hydrosphere*. Water is a very special substance. Water constitutes a liquid in a temperature range that is perfect for life, and in fact is the only substance with such properties. When it solidifies to ice it becomes slightly lighter and thus floats on liquid water, a behaviour which is also quite unique. It takes a considerable amount of energy to vaporise water, and thus it stays liquid over an unusually wide temperature range.

There is about 1,403 million km^3 of water on the Earth. If this was evenly spread out over the planet, and if the surface was smooth, it would cover the whole Earth in a layer about 3 km deep. The surface is of course not smooth and about 70% of the surface of the planet is covered by water. Most water on Earth is not immediately useful to us. Ocean and saline water accounts for about 97.6% of all water on Earth. The rest, 33,400 km^3, is fresh water. Most of this is bound in ice and glaciers. Liquid fresh water makes up 4,400 km^3. It is distributed between about 4,000 km^3 of ground water and smaller amounts of surface water. Lakes, rivers and brooks, wetlands, etc., contain about 130 km^3 on the Earth as a whole, and the atmosphere holds about 13 km^3. Considerable amounts are contained in biota (65 km^3) and soil moisture (65 km^3).

Surface water is constantly re-circulated in what is called a natural *hydrological cycle*. Water evaporates from land, surface water and organisms. It enters the atmosphere and forms clouds as it condenses. It is transported by the winds and

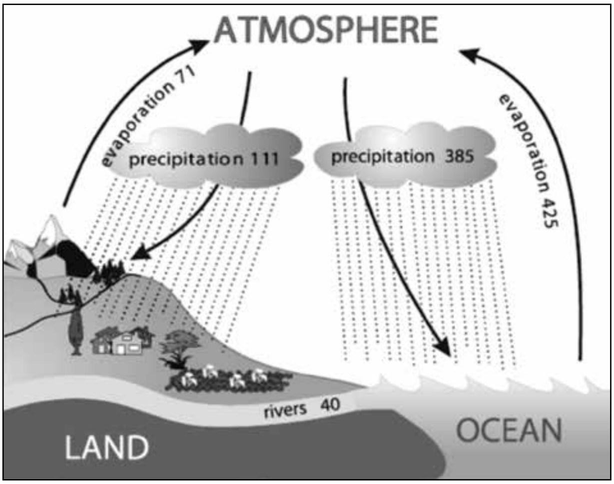

Figure 5.3. The hydrological cycle. Water evaporates from the oceans and land, is transported in the atmosphere, condenses as clouds and finally precipitates and runs through rivers back to the oceans. The numbers in the Figure are millions of Mtonnes of water per year globally.

as it cools, especially at higher altitudes over mountains, it precipitates as rain and snow. Back on the ground it flows by gravity, coming back to the sea.

The water flow described involves a considerable amount of energy. Mass (here water) present at higher altitudes contains potential energy, i.e., the flow down to lower levels represents an enormous amount of energy, which is used in e.g. hydropower plants. *Evaporation* of water from land surfaces and transpiration from plants, called evapotranspiration, constitutes a considerable flow of water. Sublimation should also be included here. Sublimation is evaporation directly from the solid form of the substance without becoming a liquid first, e.g. snow, can sublimate on sunny winter days. Water as vapour, in a gaseous form in air, constitutes the humidity of the air. In the reverse process, condensation, water vapour forms droplets of liquid water. Most often, condensation leads to cloud formation. When it occurs on ground or plant surfaces the water that appears is called dew. Some plants get all their water from dew.

Precipitation is the general term for rainfall, snowfall and other forms of frozen or liquid water falling from clouds. Precipitation is intermittent, and the character of the precipitation when it occurs depends greatly on temperature and the weather situation. The latter determines the supply of moisture through winds and surface evaporation, and how it is gathered together in storms as clouds. Precipitation forms as water vapour condenses, usually in rising air that expands and hence cools. The upward motion comes from air rising over mountains, warm air riding over cooler air (warm front), colder air pushing under warmer air (cold front), convection from local heating of the surface, and other

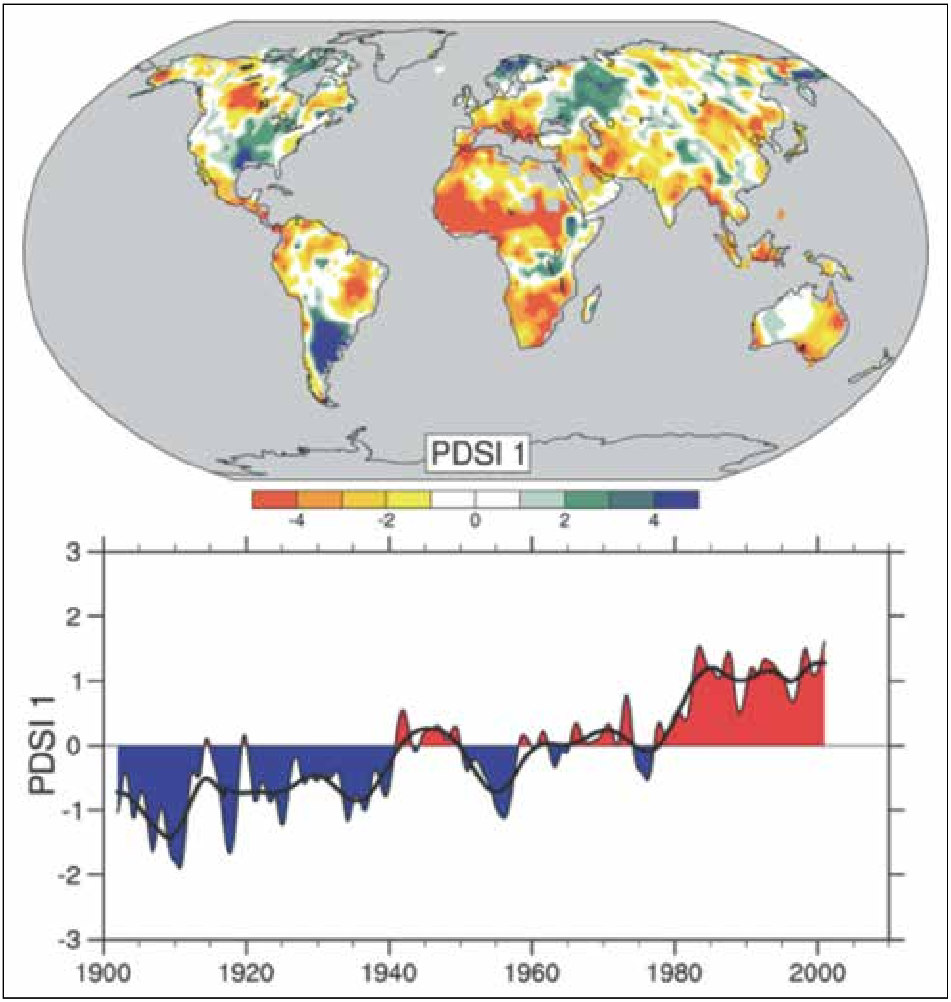

Figure 5.4. Palmer Drought Severity Index (PDSI) The most important spatial pattern (top) of the monthly index (PDSI) for 1900 to 2002. The PDSI is a prominent index of drought and measures the cumulative deficit (relative to local mean conditions) in surface land moisture by incorporating previous precipitation and estimates of moisture drawn into the atmosphere (based on atmospheric temperatures) into a hydrological accounting system. The lower panel shows how the sign and strength of this pattern has changed since 1900. Red and orange areas are drier (wetter) than average and blue and green areas are wetter (drier) than average when the values shown in the lower plot are positive (negative). The smooth black curve shows decadal variations. The time series approximately corresponds to a trend, and this pattern and its variations account for 67% of the linear trend of PDSI from 1900 to 2002 over the global land area. It therefore features widespread increasing African drought, especially in the Sahel, for instance. Note also the wetter areas, especially in eastern North and South America and northern Eurasia. Adapted from Dai et al. (2004b).

weather and cloud systems. Hence, changes in any of these aspects alter precipitation. As precipitation maps tend to be spotty, overall trends in precipitation are indicated by the Palmer Drought Severity Index (Fig. 5.4), which is a measure of soil moisture using precipitation and crude estimates of changes in evaporation.

Observations show that *changes are occurring in the amount, intensity, frequency and type of precipitation*. These aspects of precipitation generally exhibit large natural variability, and El Nino and changes in atmospheric circulation patterns such as the North Atlantic Oscillation have a substantial influence. Pronounced long-term trends from 1900 to 2005 have been observed in precipitation amount in some places: significantly wetter in eastern North and South America, northern Europe and northern and central Asia, but drier in the Sahel, southern Africa, the Mediterranean and southern Asia. More precipitation now falls as rain rather than snow in northern regions. Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, especially at lower latitudes. There are also increases in some regions in the occurrences of both droughts and floods.

Fig. 5.4, adapted from Dai et al. (2004b), shows the most important spatial pattern (top) of the monthly Palmer Drought Severity Index (PDSI) for 1900 to 2002. The PDSI is a prominent index of drought and measures the cumulative deficit (relative to local mean conditions) in surface land moisture by incorporating previous precipitation and estimates of moisture drawn into the atmosphere (based on atmospheric temperatures) into a hydrological accounting system. The lower panel shows how the sign and strength of this pattern has changed since 1900. Red and orange areas are drier (wetter) than average and blue and green areas are wetter (drier) than average when the values shown in the lower plot are positive (negative). The smooth black curve shows decadal variations. The time series approximately corresponds to a trend, and this pattern and its variations account for 67% of the linear trend of PDSI from 1900 to 2002 over the global land area. It therefore features widespread increasing African drought, especially in the Sahel, for instance. Note also the wetter areas, especially in eastern North and South America and northern Eurasia.

Precipitation occurs when water condensed in clouds forms large enough water droplets. Precipitation varies over the globe from several thousand millimetres per year down to almost zero. The main Uzbek River Armu Darya, which flows into the Aral Sea, receives most of its water, about 78 km^3, from the glacier and snow melt in the Pamir Mountains. The steppes in the drainage basin have an annual precipitation of about 300 mm per year. Much of this evaporates. The runoff equals precipitation minus evapotranspiration.

The hydrologic cycle includes the slow movement of ground and soil water. Here, movement is typically in the order of metres per year, as compared to metres per second for streams and metres per days for lakes. The storage of water in the ground and soil functions to even out water supply in nature. Even after prolonged draughts, some water is left in the soil and as ground water.

There are two implications of these aspects of water storage. First, seasonal water balances must include changes in the amount of water stored in the ground and soil. Second, polluted ground water moves slowly and may remain a problem even for future generations.

The water balance is connected to the heat balance by evapotranspiration. Net radiation is the driving force and sets the limit for evapotranspiration. In this way, the hydrological cycle is powered by precipitation which is the mass income, and net radiation is the power source.

The hydrological cycle thus constitutes a large solar powered pump that moves water and substances carried by water. Water evaporates in warmer areas, is transported by weather systems and precipitates in other colder areas.

5.5 The global carbon cycle

The carbon of the planet is found in the atmosphere as carbon dioxide, dissolved in ocean water, bound in biomass, and stored in the lithosphere as carbonate minerals. Although the atmosphere holds only 0.036% of CO_2 this substance is a key component in the physics of the planet since it interacts, as explained above, with the heat balance. It is also essential to all living cells as it is used when new biomass is built up in carbon dioxide fixation.

The carbon cycle starts when carbon dioxide in the atmosphere is formed from carbonates in the lithosphere. Carbon has been added to the atmosphere, through volcanic activities, throughout the history of the planet. An important part of the carbon flow is the formation of calcium carbonate in the seas especially as shells in marine organisms. As these die and their shells sink to the bottom, carbonate is transferred from the atmosphere to the sediments which finally become limestone rock, and thus return to the lithosphere. This slow, but in the history of the planet, major part of the carbon cycle, is estimated to have taken care of some 60 entire atmospheres of carbon dioxide, and that each carbon atom has made about 30 such round trips.

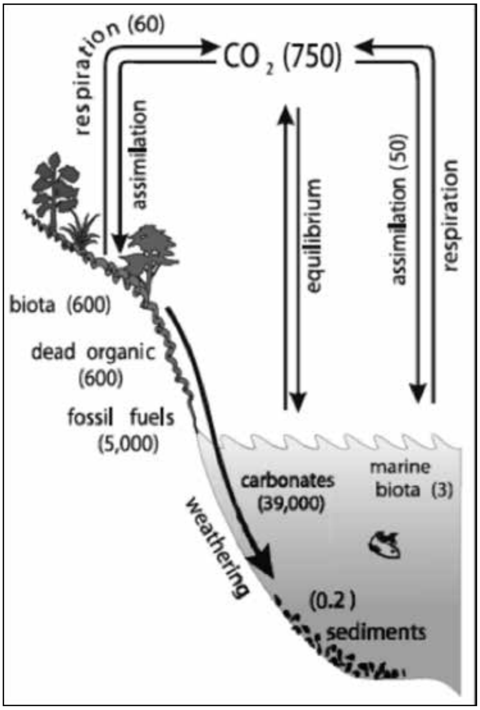

Figure 5.5. The natural carbon cycle. Carbon is available in the ecosphere as carbon dioxide in the atmosphere or dissolved in sea water as carbonates. A large amount is also present in organic form in living organisms or in dead organic matter in the soil and the sea. A rapid turnover between these two pools occurs through photosynthesis and respiration. The inorganic and organic pools correspond to around 400 and 20 years of photosynthesis, respectively. The carbon in fossil fuels, if used, is enough to significantly change the carbon concentrations in the atmosphere. The numbers denote for flows gigatonnes per year globally and for storages gigatonnes.

The absorption of carbon dioxide in ocean water is slow however, and in addition, limited by the slow mixing of the upper layer with the rest of the water in the oceans. An immediate component is the fixation of carbon dioxide to organic substances by living organisms during photosynthesis. As the biosphere builds up to considerable amounts of biomass, this constitutes a major carbon sink, not the least in the forests of the planet, but also organic material in soil.

Carbon dioxide fixation removes carbon from the atmosphere and respiration returns it back. In respiration organic molecules are oxidised with oxygen to provide energy to living cells. The by-products are water and carbon dioxide. All kinds of combustion and decay processes add to this flow.

Today, the comparatively immense utilisation of fossil fuels seriously disturbs the balance between natural processes. Modern combustion practices cause the concentration of carbon dioxide to increase. This increase is the key factor behind the enhanced greenhouse effect. The people of the Earth now consume 6 gigatonnes carbon/year, a mass that exceeds the mass of all the metals used by mankind during the period of time by a factor of ten! In addition, the handling of many fossil fuels involves flows of other matter than pure carbon, particularly

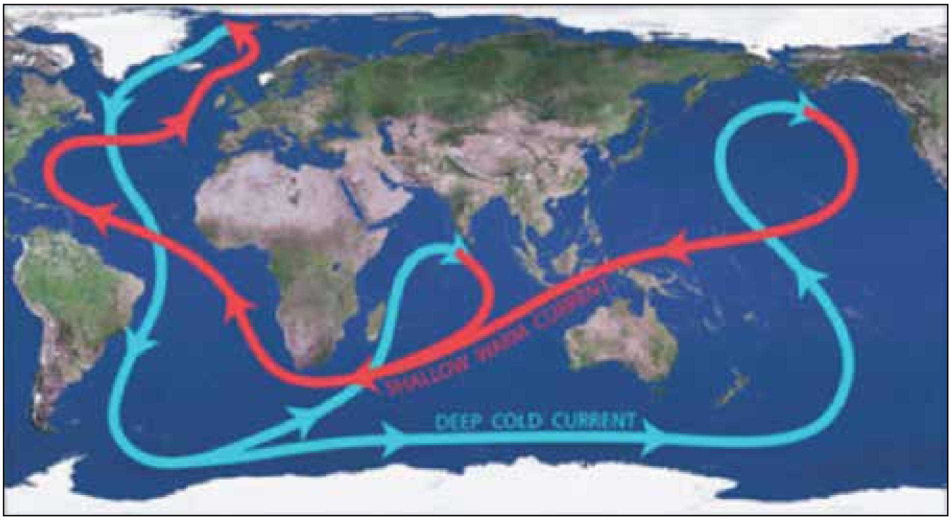

Figure 5.6 Ocean Conveyor Belt. Source: http://cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_conveyor_kit.htm

sulphur (see below), which adds to the turnover of matter and many profound environmental stresses.

5.6 The large global ocean and atmospheric currents

In many parts of Earth the climate is strongly dependent on the large ocean or atmospheric currents. An ocean current is a continuous, directed movement of seawater. It is influenced by forces such as waves, wind, the Coriolis effect, temperature and salinity differences. Ocean currents flow for great distances, and together, create *the global conveyor belt*. As ocean currents influence travel through a region warm currents increase the temperature of the coasts along which they move. The most striking example is the *Gulf Stream*, which makes northwest Europe much more temperate than any other region at the same latitude. A second important ocean current is the Humboldt Current which cools the western coast of South America along Peru.

The predominant driving force of the ocean currents is differences in density, caused by salinity and temperature variations. The density of ocean water is not globally homogeneous, but varies significantly and discretely. Sharply defined boundaries exist between water masses which form at the surface, and subsequently maintain their own identity within the ocean. Warm seawater expands and is thus less dense than cooler seawater. Lighter water masses float over denser ones, a phenomenon known as “stable stratification”. This thermohaline circulation is mainly triggered by the formation of deep water masses in the North Atlantic and the Southern Ocean caused by differences in temperature and salinity of the water.

The great quantities of dense water sinking at polar ocean basin edges must be offset by equal quantities of water rising elsewhere. The cold water in polar zones sink relatively rapidly over a small area, while warm water in temperate and tropical zones rise more gradually across a much larger area. It then slowly returns pole-ward near the surface to repeat the cycle. In this way the ocean currents contribute to the distributions of heat over the planet. A threat against the Gulf Stream would be large scale melting of the Greenland ice cap which would reduce the salinity of sea water and thus inhibit the sinking of the water and thus arrest the stream.

El Niño is the warm phase of an ocean current called *El Niño Southern Oscillation* (commonly called ENSO) and is associated with a band of warm ocean water that develops in the central and east-central equatorial Pacific, including off the Pacific coast of South America. El Niño Southern Oscillation refers to the cycle of warm and cold temperatures of the tropical central and eastern Pacific Ocean. El Niño is accompanied by high air pressure in the western Pacific and low air pressure in the eastern Pacific. The cool phase of ENSO is called “La Niña” with surface temperatures in the eastern Pacific below average and air pressures high in the eastern and low in western Pacific. The ENSO cycle, both El Niño and La Niña, causes global changes of both temperatures and rainfall. Developing countries dependent upon agriculture and fishing, particularly those bordering the Pacific Ocean, are the most affected.

The name La Niña originates from Spanish, meaning “the girl”, analogous to El Niño meaning “the boy” (referring to the newborn Jesus, Christ Child, as it often begins in December). During a period of La Niña, the sea surface temperature across the equatorial Eastern Central Pacific Ocean will be lower than normal by 3-5 °C. It has extensive effects on the weather in North America, even affecting the Atlantic Hurricane Season. La Niña often, though not always, follows an El Niño.

An important atmospheric air current is originating over the Amazonas. This very unique part of our planet holds nearly 25% of all fresh water in the world. Part of this is transported to other regions of the world and thus contribute to their possibility for agriculture. A large scale deforestation of the Amazonas may have global consequences for the climate.

5.7 Regional climate

Climate varies from region to region. This variation is driven by the uneven distribution of solar heating, the individual responses of the atmosphere, oceans and land surface, the interactions between these, and the physical characteristics of the regions. The perturbations of the atmospheric constituents that lead to global changes affect certain aspects of these complex interactions.

Some human-induced factors that affect climate ('forcings') are global in nature, while others differ from one region to another. For example, carbon dioxide, which causes warming, is distributed evenly around the globe, regardless of where the emissions originate, whereas sulphate aerosols (small particles) that offset some of the warming tend to be regional in their distribution. Furthermore, the response to forcings is partly governed by feedback processes that may operate in different regions from those in which the forcing is greatest. Thus, the projected changes in climate will also vary from region to region.

5.8 Climate science

Research to understand climate in all its variability has a very long history. In recent years this research has increased dramatically as a consequence of the climate change and a wish to understand and predict future climate changes. The development of computer tools and modeling have been important in this development.

The Intergovernmental Panel on Climate Change (IPCC), initiated by the World Meteorological Association in 1988, is a global cooperation between climate scientist with the intention to define, for political purposes, the best understanding of present changes in climate. It recruits several thousand researchers all over the world.

Climate science is an atmospheric science and belongs to physical geography and thus the Earth sciences. It most often also cooperate with oceanography and the study of the large biogeochemical flows, that is, biogeochemistry. The study of contemporary climates incorporates meteorological data accumulated over many years: this includes records of precipitation, temperature and atmospheric pressure and composition. Basic knowledge of climate can be used for weather forecasting, which covers days or weeks.

A region's climate is generated by the *climate system*. The basic components of the climate system are the atmosphere, the hydrosphere, the cryosphere (snow and ice), the lithosphere, and the biosphere. Climatologists thus study the atmospheric and ocean circulation patterns and boundary layers, heat transfer (radiative, convective and latent), the interactions between the atmosphere and the

Box 5.1 The Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC.

The IPCC is a scientific body under the auspices of the United Nations (UN). It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters.

Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. IPCC aims to reflect a range of views and expertise. The Secretariat coordinates all the IPCC work and liaises with Governments. It is supported by WMO and UNEP and hosted at WMO headquarters in Geneva.

Source: http://www.ipcc.ch/organization/organization.shtml

oceans and land surface (particularly vegetation, land use and topography). The chemical and physical composition of the atmosphere are important parts of climate science. It is a difficult and complex because of the large scale, the long time periods, and the complex processes which govern climate.

Climate is governed by physical laws which can be expressed as differential equations in mathematical climate models. The equations are coupled and non-linear, so that approximate solutions are obtained by using numerical methods to create global climate models. Statistical climate models integrate different observations and test how they fit together.

Modeling is used for understanding past, present and potential future climates. In the models the atmosphere and the earth are divided into small interacting elements (pixels), and the development of a number of parameters (such as temperature) in these are studied over a time period which in turn is divided into parts. Running climate models require supercomputers. A more detailed study requires smaller elements and then becomes more complex and requires longer computational time. In this way regional and global climate change have been studied.

All climate models balance, or very nearly balance, incoming energy as short wave (including visible) electromagnetic radiation to the earth with outgoing energy as long wave (infrared) electromagnetic radiation from the earth. Any unbalance results in a change in the average temperature of the earth. The most talkedabout models of recent years have been those relating temperature to emissions of carbon dioxide and other greenhouse gases. These models predict an upward trend in the surface temperature record, as well as a more rapid increase in temperature at higher latitudes.

Chapter 5 sources:

Sections 5.1 Factors of Earth's climate and 5.2 Changes in the climate system:

IPCC Fourth Assessment Report: Climate Change 2007 (AR4) http://ipcc.ch/report/ar4/

IPCC Fifth Assessment Report: Climate Change 2013 (AR5) http://ipcc.ch/report/ar5/

Contribution of Working Groups I, II and III to AR4 of the IPCC http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

Contribution of Working Group I to the AR4 of IPCC. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.) Cambridge University Press. 996 pp. http://ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Sections 5.3 Solar radiation and the global heat balance, 5.4 The water cycle and 5.5 The global carbon cycle: BUP Environmental Science, Lars-Christer Lundin and Lars Rydén Chapter 2 How the Environment Works - Turnover of Matter and Energy,

http://www.balticuniv.uu.se/index.php/boll-online-library/834-es-environmental-science

Section 5.6 The large global ocean and atmospheric currents and Section 5.7 Climate science

Basic information from Wikipedia and other Internet resources.

Chapter 6
Climate Change – causes and consequences

6.1 Observed Changes in the Climate System – Global warming

Observations of the climate system are based on direct measurements and remote sensing from satellites and other platforms. Global-scale observations from the instrumental era began in the mid-19th century for temperature and other variables, with more comprehensive and diverse sets of observations available for the period 1950 onwards. Paleoclimate reconstructions extend some records back hundreds to millions of years. Together, they provide a comprehensive view of the variability and long-term changes in the atmosphere, the ocean, the cryosphere, and the land surface.

The data in this chapter is mainly based on the 5th assessment report (AR5) from the Intergovernmental Panel on Climate Change, IPCC (See Box 6.1).

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983-2012 was likely the warmest 30-year period of the last 1400 years. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 °C, over the period 1880 to 2012, when multiple independently produced datasets exist. The total increase between the average of the 1850-1900 period and the 2003-2012 period is 0.78 °C, based on the single longest dataset available..

The degree of certainty in key findings in this assessment is based on the author teams' evaluations of underlying scientific understanding and is expressed as a qualitative level of confidence (from very low to very high) and, when possible, probabilistically with a quantified likelihood (from exceptionally unlikely to virtually certain). Confidence in the validity of a finding is based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, and expert judgment) and the degree of agreement. Probabilistic estimates of quantified measures of uncertainty in a finding are based on

Box 6.1 Intergovernmental Panel on Climate Change, IPCC, 5th report, AR5

The Intergovernmental Panel on Climate Change, IPCC releases its assessment reports (AR) each 5 years. The reports are consensus documents meaning that everyone in the network have accepted the statements. Thus the reported conclusions tend to be conservative. They are also several years old since research results take much time to be reviewed by the panel and incorporated in the common conclusions. The most recent reports, No 5, was released in 2013 and 2014 by the three working groups of IPCC. More recent data have been taken from several of the large institutions working with climate science in the world. Important institutions include the NASA Goddard Institution (USA) the Potsdam Institute for Climate Impact Research (Germany) and the The Grantham Research Institute on Climate Change (UK).

The IPCC Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) considers new evidence of climate change based on many independent scientific analyses from observations of the climate system, paleo-climate archives, theoretical studies of climate processes and simulations using climate models. It builds upon the Working Group I contribution to the IPCC's Fourth Assessment Report (AR4), and incorporates subsequent new findings of research. As a component of the fifth assessment cycle, the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) is an important basis for information on changing weather and climate extremes.

The degree of certainty in key findings in this assessment is based on the author teams' evaluations of underlying scientific understanding and is expressed as a qualitative level of confidence (from very low to very high) and, when possible, probabilistically with a quantified likelihood (from exceptionally unlikely to virtually certain). Confidence in the validity of a finding is based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, and expert judgment) and the degree of agreement. Probabilistic estimates of quantified measures of uncertainty in a finding are based on statistical analysis of observations or model results, or both, and expert judgment. Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers. The data on uncertainty and variation have not been included in these chapters but can be found in the original reports, here as summaries for policy makers

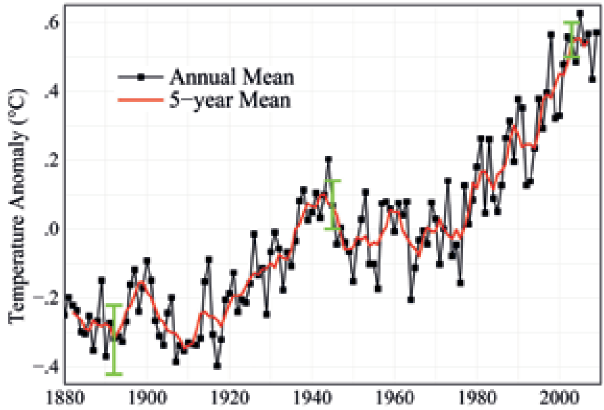

Figure 6.1 Global Land Ocean Temperature index. Data source: NASA Goddard Institute for Space Studies http://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A2.gif

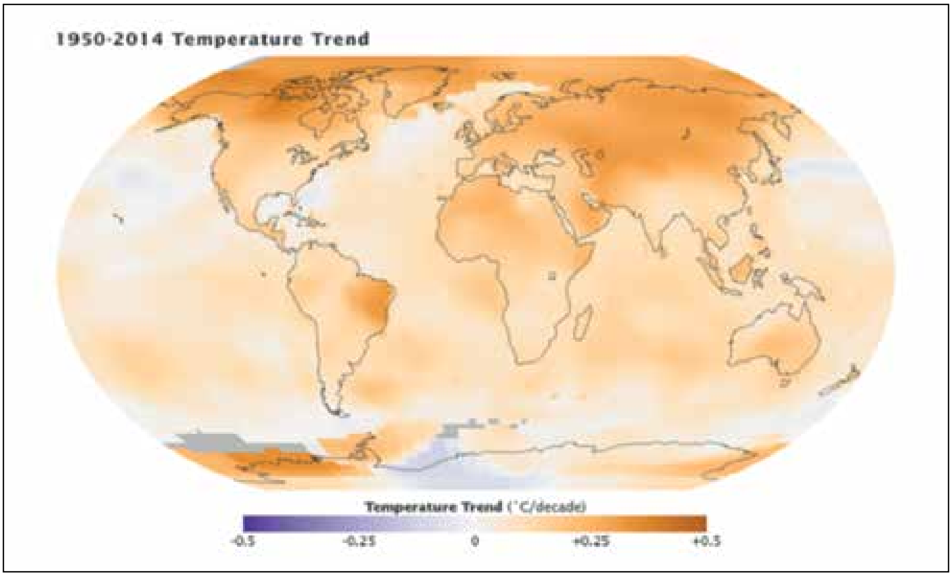

Figure 6.2 Regional temperature trends. This color-coded map in Robinson projection displays a progression of changing global surface temperature anomalies from 1880 through 2014. Higher than normal temperatures are shown in red and lower than normal temperatures are shown in blue. The final frame represents the global temperatures 5-year averaged from 2010 through 2014. Source: NASA Goddard Institute http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4252&button=recent.

statistical analysis of observations or model results, or both, and expert judgment. Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers. The data on uncertainty and variation have not been included in these chapters but can be found in the original reports, here as summaries for policy makers.

A long term temperature curve is shown in Fig. 6.1. The data are from NASA Goddard Institute. In a recent report Goddard Institute says that the year 2014 ranks as Earth's warmest since 1880, according to two separate analyses by NASA and National Oceanic and Atmospheric Administration (NOAA) scientists. The 10 warmest years in the instrumental record, with the exception of 1998, have now occurred since 2000. This trend continues as a long-term warming of the planet, according to an analysis of surface temperature measurements by scientists at NASA's Goddard Institute of Space Studies (GISS). Since 1880, Earth's average surface temperature has warmed by about 0.8 degrees Celsius, a trend that is largely driven by the increase in carbon dioxide and other human emissions into the planet's atmosphere. The majority of that warming has occurred in the past three decades. A short film showing the temperature increase as distributed of the planet is available as seen in Fig. 6.2.

In summary the climate change looks like this: 2014 were the warmest years since measurements began; 2007 second warmest; 2011 the warmest for a La Nina year. Climate variability is increasing. 2010 was warm in Russia, 2012 in North America, while winter was strong in Europe. Present warming is very fast: 0.16 ^{o}C per decade. Compare to the warming after the last ice age, which was 0.1 ^{o}C per century. Climate sensitivity according to IPCC is around 3.7 watts per m^2. This means that there is a 3 ^{o}C increase for a doubling of CO_2 levels. Studying the long term changes in atmospheric carbon dioxide concentrations we notice that during previous warming events CO_2 levels started to increase after an increase in temperature. Now it is the opposite. We do not know what it will lead to.

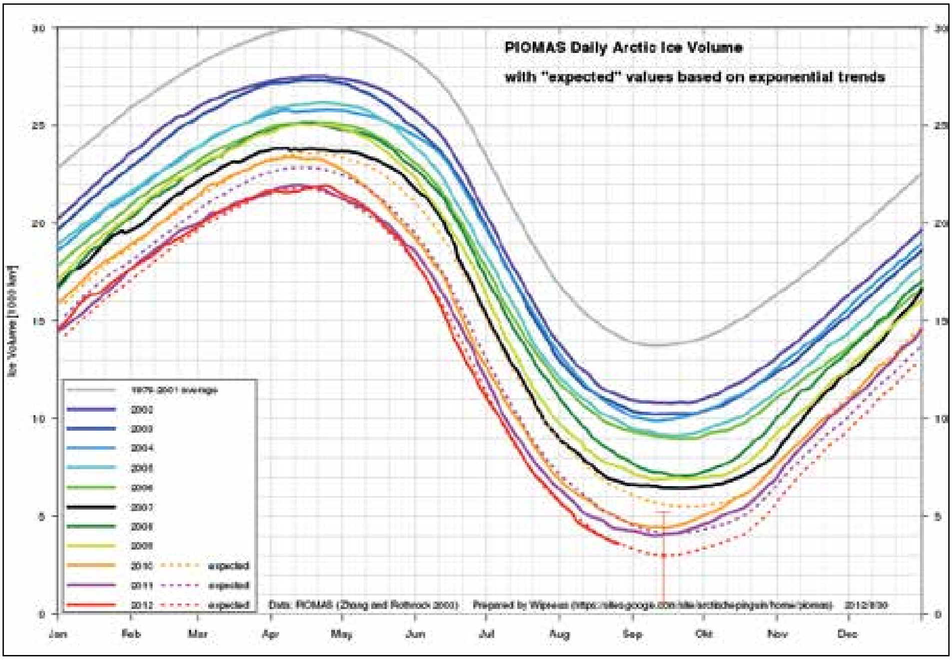

Figure 6.3 The trend line on the PIOMAS sea ice volume anomaly graph has gone up another notch into the positive two standard deviation zone, as compared to the linear trend. Source Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS).http://neven1.typepad.com/blog/piomas/

6.2 Declining ice and glaciers – the Arctic

The most rapid warming has occurred in the Arctic. The most visible change in the Arctic region in recent years has been the rapid decline of the perennial ice cover, the arctic summer ice. The perennial ice is the portion of the sea ice floating on the surface of the ocean that survives the summer. This ice that spans multiple years represents the thickest component of the sea ice cover. It is illustrated in Fig. 6.3 showing the 2012 minimum. It was 760,000 square kilometers below the previous record minimum extent in the satellite record, which occurred on September, 2007. This is an area about the size of Germany and Poland together (or one and a half Uzbekistan). The September 2012 minimum was in turn 3.29 million square kilometers below the 1979 to 2000 average minimum, representing an area nearly twice the size of the state of Alaska. A short film showing the declining ice is available (Fig. 6.3). The Arctic summer ice may be gone by 2035, and the Canadian Arctic Ocean coast, the Northwest Passage, start to be used for ship transport. This is in fact already the case.

The rapid melting of the Arctic ice has so far not been predicted by global climate models. There may be at least two factors which have been difficult to include in the models, both contributing to making the temperature increase rapid. One is that the exposure of sea surface as the ice melts changes the albedo drastically. Thus the black water surface absorbs sunlight much more efficient than the white ice. Secondly the permafrost in the Arctic area is melting and thereby releasing enormous amounts of methane which so far has remained frozen in the tundra. Methane is a very strong greenhouse gas. As it tends to remain in the atmosphere above the Arctic the concentration of methane is large and it contributes to a strong greenhouse effect. This is thus a strong self-reinforcing mechanism.

Another effect of global warming is the melting of glaciers (ice on a land surface) all over the world. An illustration is provided by the Upsala glacier in South America shown in 1928 and 2004 illustrating how the glacier has turned into a lake.

Most far reaching has the consequences been for the Greenland ice sheet. Over the last two decades, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink almost worldwide, and Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent. Greenland's 2012 melt season started early, surpassing the 30-year average for melt-covered area in mid-May, and remaining far in excess of typical conditions for June, July, and through mid-August (Fig. 6.6).

On 6 August, 2012 updated compilation of NASA MODIS observations of Greenland ice sheet reflectivity (albedo) indicate that through the 2012 melt sea-

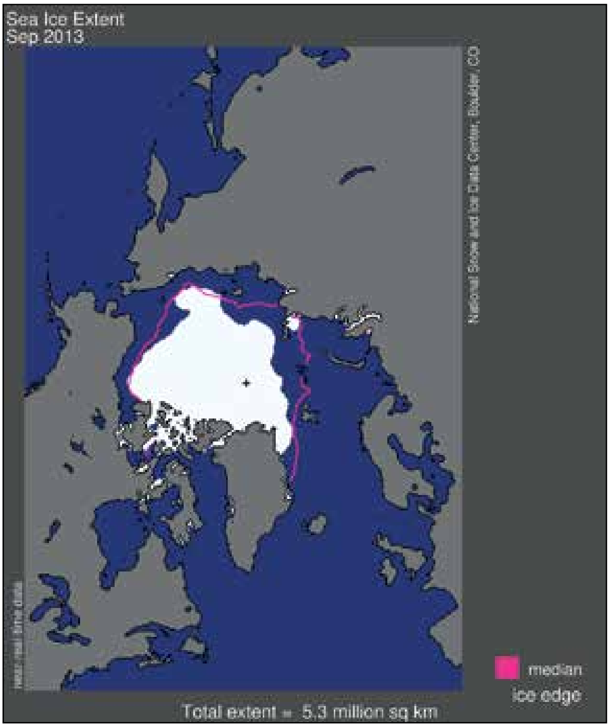

Figure 6.4 The Arctic sea ice cover at its minimum measured on September 6, 2013. A film showing the perennial Arctic sea ice from 1979 to 2014 is available at http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4251&button=recent. It has a graph overlay which shows the area's size measured in million square kilometres for each year. Credit: National Snow and Ice Data Center

Figure 6.5 The Upsala Glacier, Patagonia, Argentina. Original photograph taken in 1928, ©Archivo Museo Salesiano / De Agostini. Comparison image taken in 2004, © Greenpeace/Daniel Beltrá 02/06/2004. Courtesy Greenpeace Argentina.

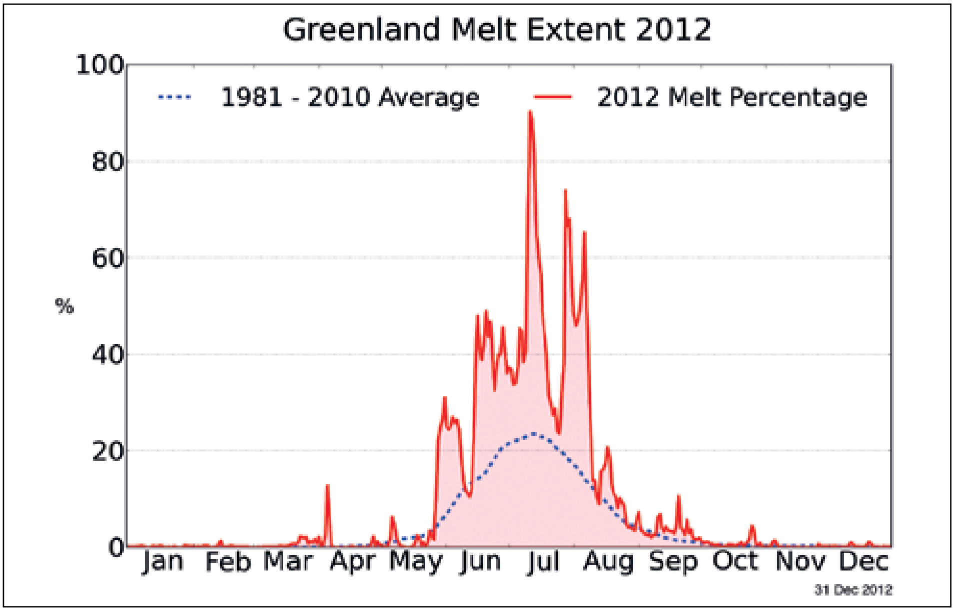

Figure 6.6 Melting of Greenland ice. For the peak melt days in early July and again in early August, more than 70% of the surface of the ice sheet experienced some melt, and the peak melt event on July 10 to 11 occurred over 97% of the ice sheet. Source: National Snow and Ice Data Center http://nsidc.org/)

son, beginning ~28 May, the ice sheet has remained in a darkened state as in 2011 and 2010. Remaining in this condition, the ice sheet has absorbed ~200 Exajoules more solar energy for June-July, more than twice the US annual energy consumption, in a self-reinforcing feedback loop. For July, the 100 Exajoules more energy absorption is sufficient, for example to melt 136 Gt of ice at a temperature of 0 ^{o}C. (http://bprc.osu.edu/wiki/Greenland_Ice_Albedo_Monitoring).

6.3 Rising sea levels

Another effect of global warming is the increased level of the surface of the oceans, sea level rise. It should be noted that the melting of the Arctic Sea ice does not contribute to sea level rise since it is a sea ice, while the melting of the Greenland and Antarctic ice does contribute since they are on land. Another factor is the increased temperature of the ocean water, since it leads to volume increase of the water. Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010. The upper ocean (0-700 m) warmed from 1971 to 2010 and

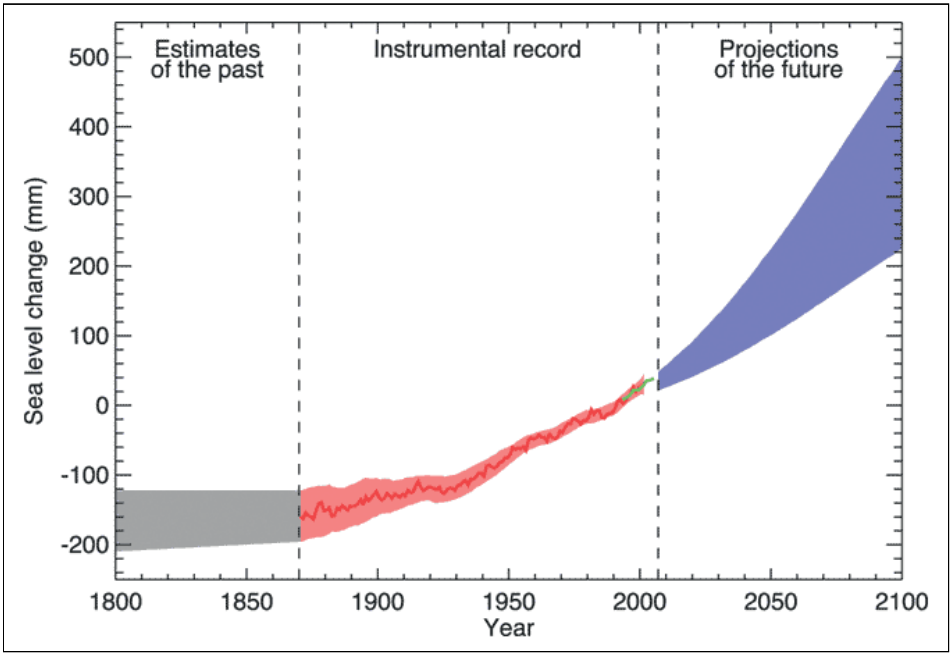

Figure 6.7 Time series of global mean sea level (deviation from the 1980-1999 mean) in the past and as projected for the future. For the period before 1870, global measurements of sea level are not available. The grey shading shows the uncertainty in the estimated long-term rate of sea level change (Section 6.4.3). The red line is a reconstruction of global mean sea level from tide gauges (Section 5.5.2.1), and the red shading denotes the range of variations from a smooth curve. The green line shows global mean sea level observed from satellite altimetry. The blue shading represents the range of model projections for the SRES A1B scenario for the 21st century, relative to the 1980 to 1999 mean, and has been calculated independently from the observations. Beyond 2100, the projections are increasingly dependent on the emissions scenario (see Chapter 10 for a discussion of sea level rise projections for other scenarios considered in this report). Over many centuries or millennia, sea level could rise by several metres.

it likely warmed between the 1870s and 1971. On a global scale, ocean warming is largest near the surface, and the upper 75 m warmed by 0.11 °C per decade over the period 1971 to 2010.

Global sea level gradually rose in the 20th century and is currently rising at an increased rate, after a period of little change between the years AD 0 and AD 1900. Sea level is projected to rise at an even greater rate in this century (see Figure 6.7). The two major causes of global sea level rise are thermal expansion of the oceans (water expands as it warms) and the loss of land-based ice due to increased melting. Global sea level rose by about 120 m during the several millennia that followed the end of the last ice age (approximately 21,000 years ago), and stabilised between 3,000 and 2,000 years ago. Sea level indicators suggest that global sea level did not change significantly from then until the late 19th century. The instrumental record of modern sea level change shows evidence for onset of sea level rise during the 19th century. Estimates for the 20th century show that global average sea level rose at a rate of about 1.7 mm/year.

The global sea level is projected to rise during the 21st century at a greater rate than during 1961 to 2003. Under the IPCC Special Report on Emission Scenarios (SRES) A1B scenario by the mid-2090s, for instance, global sea level reaches 0.22 to 0.44 m above 1990 levels, and is rising at about 4 mm/year. As in the past, sea level change in the future will not be geographically uniform, with regional sea level change varying within about ±0.15 m of the mean in a typical model projection. Thermal expansion is projected to contribute more than half of the average rise, but land ice will lose mass increasingly rapidly as the century progresses. An important uncertainty relates to whether discharge of ice from the ice sheets will continue to increase as a consequence of accelerated ice flow, as has been observed in recent years. This would add to the amount of sea level rise, but quantitative projections of how much it would add cannot be made with confidence, owing to limited understanding of the relevant processes.

6.4 Extreme weather events

A most serious effect of global warming are the extreme weather events. These are predicted to be stronger and come more often. This includes heat waves, tornados, hurricanes, storm, floods and draughts. A study of extreme temperatures show that these occur more often (Fig. 6.8).

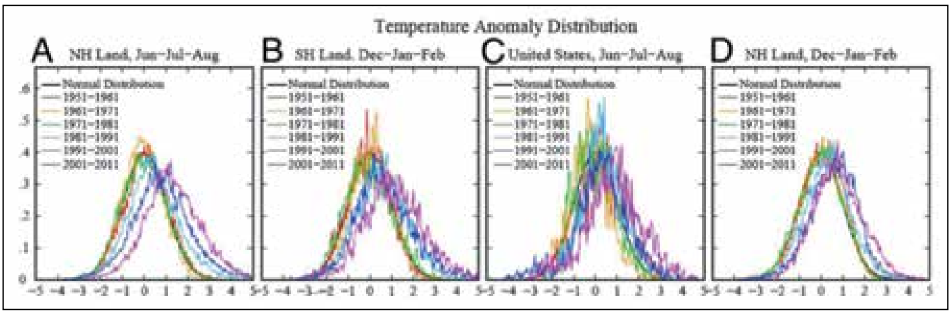

Figure 6.8 Frequency of occurrence of local temperature anomalies (relative to 1951–1980 mean) divided by local standard deviation obtained by counting gridboxes with anomalies in each 0.05 interval of the standard deviation (x axis). (Source: Hansen J et al. PNAS 2012;109:14726-14727)

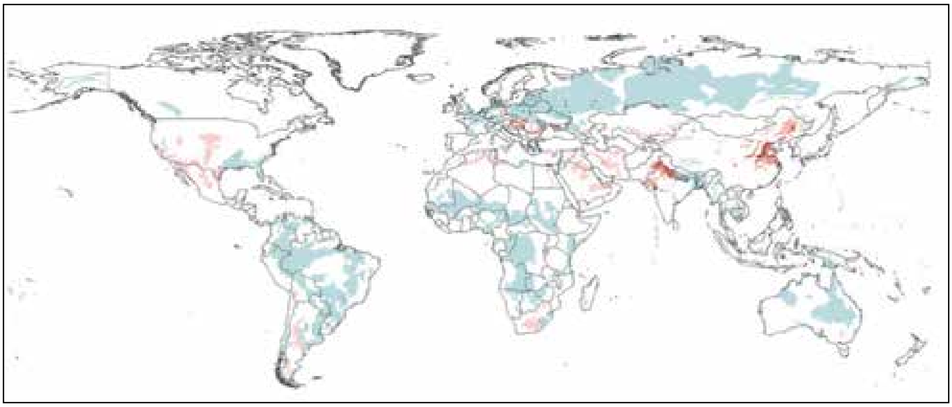

Figure 6.9 Groundwater stress may be affecting 1.7 billion people and could limit the potential to increase agricultural production in the world. Blue: Population density in areas with less stressed regional aquifers (km^2). Red: Population density in areas with more stressed regional aquifers (km^2). Source: Tom Gleeson, Yoshihide Wada, Marc F. P. Bierkens & Ludovicus P. H. van Beek, Nature Vol 488, August 9, 2012.

The higher temperature of ocean surfaces will lead to stronger storms and tornadoes. This has occurred already many times by increased incidence on the USA east coast, and in south-east Asia. The number of serious floods are also increasing, especially in areas which already previously had regular flooding. There are also increased droughts. For example in 2012 the USA had a very serious drought which destroyed some 30% of food production. The general patter is that wet areas will be wetter and dry areas drier.

The social, economic and environmental consequences of these extreme weather events are serious (Fig. 6.9). Thus the particularly hot year of 2003 in Europe had an additional 30,000 casualties due to heat. Agriculture will change and harvests decrease in some areas (and increase in others). Hurricanes, storm, and floods in densely inhabited areas destroy infrastructure and property for immense values.

A general trend is that ground water levels are decreasing all over the world. In some areas it is more serious (Fig. 6.9). This may lead to a water crisis in the near future.

There will also be large consequences for ecosystems which all are very climate dependent. Thus warmth-craving southern species (including insects being vectors for diseases) will move north while northern species (e.g. polar bears) become marginalised or disappear. Some of these effects are already painful. Crops have to be adapted to a different climate and in some areas irrigation will be problematic.

Figure 6.10. The effects of climate change are already serious for the civil society in many parts of the world, especially in the poorer countries. (courtesy of picture World Bank)

6.5 Increased greenhouse gases concentrations

The large scale combustion of fossil fuels, which have been going on since the beginning of industrialisation around 1750, has led to massive emissions of carbon dioxide into the atmosphere. In addition changes in land use, especially deforestation, have also contributed to large emissions of carbon dioxide. Estimations are that 1,200 Gigatonnes of CO_2 have entered the atmosphere in this way, almost all of it since 1900, and at a rate which is still increasing (about 32 Gt was emitted in 2008). Emitted carbon dioxide is partly dissolved in the world's oceans. This reduces the content in atmosphere but also makes the ocean water more acidic. This is a threat to the world's coral reefs and much marine biodiversity.

Atmospheric carbon dioxide concentration has been carefully monitored since 1958 at a research station in Hawaii (Fig. 6.11). It was 392 ppm (parts per million) in 2011. The first values of 400 ppm was measure during 2014. The concentration has increased from pre-industrial levels of about 280 ppm. The contribution from fossil fuel combustion can be estimated from the ^{14}C content of atmospheric CO_2, since there is no ^{14}C in the fossil carbon. Through measurements of ice cores from the Antarctica and other data, we have estimations of

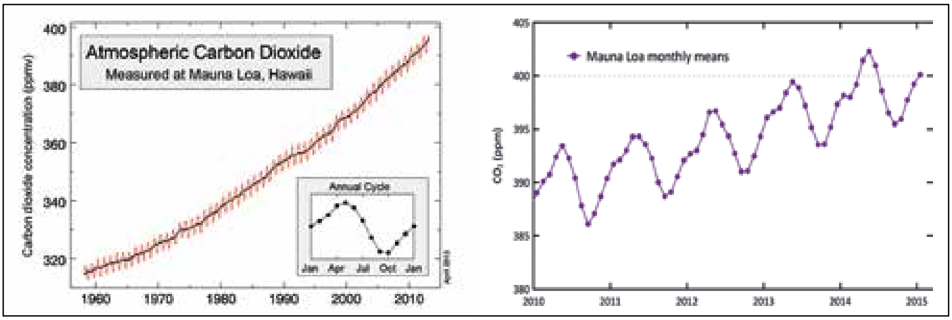

Figure 6.11. Monitoring of the atmospheric CO_2 at the Mauna Loa Observatory on Hawaii. The variation over the year is due to the large land mass on the northern hemisphere gives a lower atmospheric CO_2 level during the northern summer as more photosynthesis is then occurring.

carbon dioxide concentrations in the atmosphere since about 800,000 years. At no time during this period it was as high as it is today (Fig.6.11). There a steady increase is seen, still going on.

The atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have all increased since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases were 391 ppm, 1,803 ppb, and 324 ppb, and exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. Concentrations of CO_2, CH_4, and N_2O now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years (Fig. 6.12). The mean rates of increase in atmospheric concentrations over the past century are, with very high confidence, unprecedented in the last 22,000 years.

Carbon dioxide is a greenhouse gas (GHG) and contributes to the so-called *enhanced greenhouse effect* of the atmosphere. Carbon dioxide absorbs heat and radiates it back, and thus increases the temperature of the planet. A greenhouse effect has already increased the planet temperature some 35 degrees due to already present GHGs (mostly water) that is why the effect caused by CO_2 is called “enhanced”.

Table 6.1 Greenhouse gases in the atmosphere; preindustrial levels and today.
ppm = parts per million, ppb = parts per billion

Gas	Conc in 1750	Conc in 2011	Increase (%)
CO_2	279 ppm	391 ppm	40
CH_4	721 ppb	1,803 ppb	150
N_2O	270 ppb	324 ppb	20

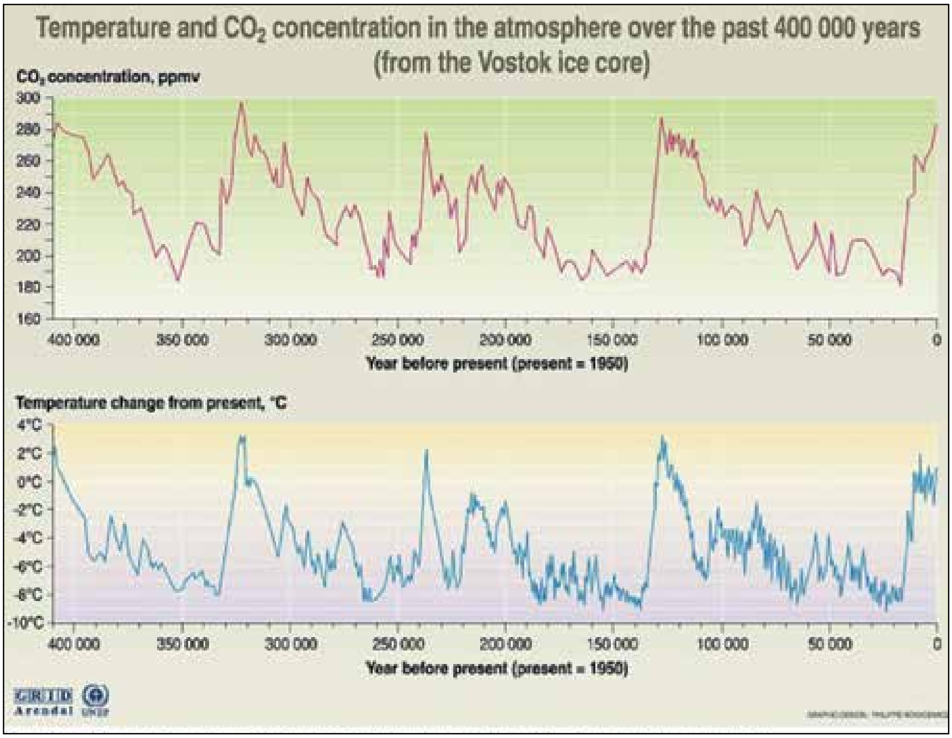

Figure 6.12 Variations in concentration of carbon dioxide (CO_2) and temperature in the atmosphere during the last 400 thousand years. Data from the Vostok ice core. www.grida.no/climate/vital/02.htm

Other greenhouse gases which contribute to the enhanced greenhouse effect, include methane with 21 times higher radiative forcing than CO_2, nitrous oxide N_2O, and CFCs also called freons. Even if these three GHGs, also emitted from society, have a much larger effect, they are emitted in smaller volumes and have a shorter half-life in the atmosphere (they are broken down to CO_2 and other components). Thus CO_2 with a very long half-life is the most serious one. If all GHGs are included according to their contributions recalculated as CO_2 equivalents, we have today about 420 ppm CO_2e (e stands for equivalent).

The effect of the greenhouses gases on the climate is quantified in terms as radiative forcing. Natural and anthropogenic substances and processes that alter the Earth's energy budget are drivers of climate change. Radiative forcing (RF) quantifies the change in energy fluxes caused by changes in these drivers for 2011 relative to 1750, unless otherwise indicated. Positive RF leads to surface warming, negative RF leads to surface cooling. RF is estimated based on in-situ and remote observations, properties of greenhouse gases and aerosols, and calculations using numerical models representing observed processes. Some emitted compounds affect the atmospheric concentration of other substances. The RF can be reported based on the concentration changes of each substance. Alternatively, the emission-based RF of a compound can be reported, which provides a more direct link to human activities. It includes contributions from all substances affected by that emission. The total anthropogenic RF of the two approaches are identical when considering all drivers.

Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.

The total anthropogenic RF for 2011 relative to 1750 is 2.29 W/m^2, and it has increased more rapidly since 1970 than during prior decades. The total anthropogenic RF best estimate for 2011 is 43% higher than that for the year 2005. This is caused by a combination of continued growth in most greenhouse gas concentrations and improved estimates of RF by aerosols indicating a weaker net cooling effect (negative RF). The RF from emissions of well-mixed greenhouse gases (CO_2, CH_4, N_2O, and Halocarbons) for 2011 relative to 1750 is 3.00 W/m^2. The RF from changes in concentrations in these gases is 2.83 W/m^2. Emissions of CO_2 alone have caused an RF of 1.68 W/m^2. Including emissions of other carbon-containing gases, which also contributed to the increase in CO_2 concentrations, the RF of CO_2 is 1.82 W/m^2.

Globally, economic and population growth continue to be the most important drivers of increases in CO_2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has risen sharply. Between 2000 and 2010, both drivers outpaced emission reductions from improvements in energy intensity (Fig. 8.3). Increased use of coal relative to other energy sources has reversed the long-standing trend of gradual decarbonisation of the world's energy supply.

Without additional efforts to reduce GHG emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 to 4.8 °C compared to pre-industrial levels. Baseline scenarios (scenarios without additional efforts to constrain emissions) exceed 450 parts per million (ppm) CO_2eq by 2030 and reach CO_2eq concentration levels between 750 and more than 1,300 ppm CO_2eq by 2100.

Box 6.2 Trends in stocks and flows of greenhouse gases

Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period. Despite a growing number of climate change mitigation policies, annual GHG emissions grew on average by 1.0 gigatonne carbon dioxide equivalent (Gt CO_2eq), that is 2.2% per year from 2000 to 2010 compared to 0.4 Gt CO_2eq (1.3%) per year from 1970 to 2000.

Total anthropogenic GHG emissions were the highest in human history from 2000 to 2010 and reached 49 Gt CO_2eq/yr in 2010. The global economic crisis 2007/2008 only temporarily reduced emissions. CO_2 emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emission increase from 1970 to 2010, with a similar percentage contribution for the period 2000-2010. Fossil fuel-related CO_2emissions reached 32 Gt CO_2/yr, in 2010, and grew further by about 3% between 2010 and 2011 and by about 1% between 2011 and 2012. Of the 49 Gt CO_2eq/yr in total anthropogenic GHG emissions in 2010, CO_2 remains the major anthropogenic GHG accounting for 76% (38 Gt CO_2eq/yr) of total anthropogenic GHG emissions in 2010. 16% (7.8 Gt CO_2eq/yr) come from methane (CH_4), 6.2% (3.1 Gt CO_2eq/yr) from nitrous oxide (N_2O), and 2.0% (1.0 Gt CO_2eq/yr) from fluorinated gases. Annually, since 1970, about 25% of anthropogenic GHG emissions have been in the form of non-CO_2 gases.

Table 6.2 Emissions of Greenhouse gases in 2010 (CO_2-eq)

Source	Emissions (Gt)	Emissions (%)
CO_2	38.0	76
CH_4	7.8	16
N_2O	3.1	6.2
fluorinated gases	1.0	2.0

About half of cumulative anthropogenic CO_2 emissions between 1750 and 2010 have occurred in the last 40 years. In 1970, cumulative CO_2 emissions from fossil fuel combustion, cement production and flaring since 1750 were 420 Gt CO_2; in 2010, that cumulative total had tripled to 1300 Gt CO_2. Annual anthropogenic GHG emissions have increased by 10 Gt CO_2eq between 2000 and 2010, with this increase directly coming from energy supply (47%), industry (30%), transport (11%) and buildings (3%) sectors. Accounting for indirect emissions raises the contributions of the buildings and industry sectors. Since 2000, GHG emissions have been growing in all sectors, except AFOLU (Agriculture, Forestry and Other Land Use).

6.6 Understanding the Climate System and its recent changes

Understanding recent changes in the climate system results from combining observations, studies of feedback processes, and model simulations. Evaluation of the ability of climate models to simulate recent changes requires consideration of the state of all modelled climate system components at the start of the simulation and the natural and anthropogenic forcing used to drive the models.

Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

The today improved climate models reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid-20th century and the cooling immediately following large volcanic eruptions. The long-term climate model simulations show a trend in global mean surface temperature from 1951 to 2012 that agrees with the observed trend. There are, however, differences between simulated and observed trends over periods as short as 10 to 15 years (e.g., 1998 to 2012).

The observed reduction in surface warming trend over the period 1998 to 2012 as compared to the period 1951 to 2012, is due in roughly equal measure to a reduced trend in radiative forcing and a cooling contribution from natural inter-

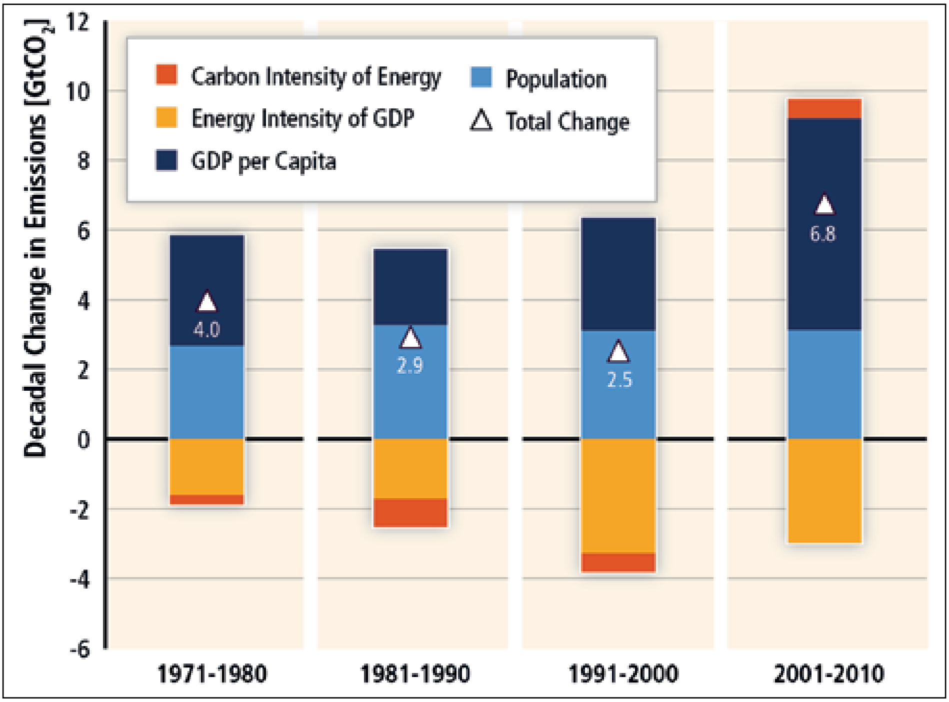

Figure 6.13 Decomposition of the decadal change in total global CO_2 emissions from fossil fuel combustion by four driving factors; population, income (GDP) per capita, energy intensity of GDP and carbon intensity of energy. The bar segments show the changes associated with each factor alone, holding the respective other factors constant. Total decadal changes are indicated by a triangle. Changes are measured in giga tonnes (Gt) of CO_2 emissions per decade; income is converted into common units using purchasing power parities.

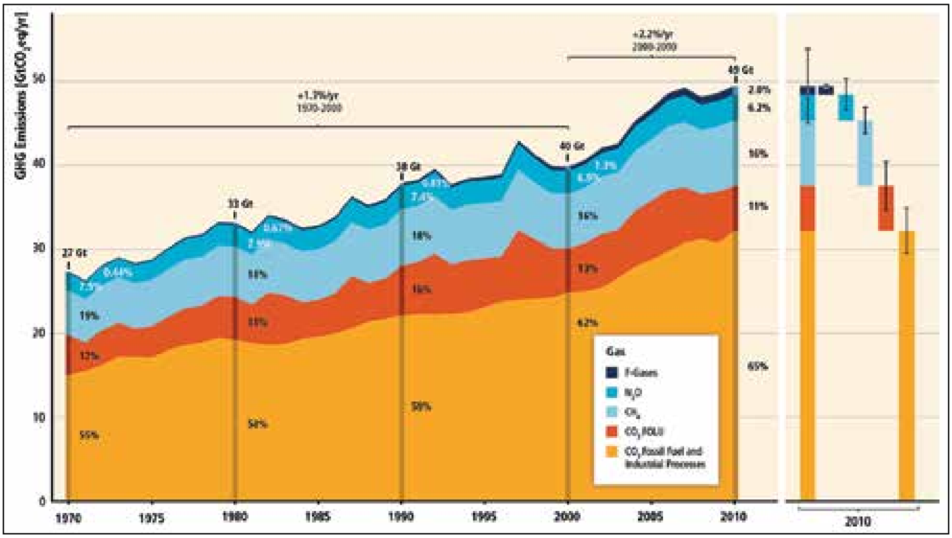

Figure 6.14 Total annual anthropogenic GHG emissions (Gt CO_2eq/yr) by groups of gases 1970-2010: CO_2 from fossil fuel combustion and industrial processes; CO_2 from Forestry and Other Land Use (FOLU); methane (CH_4); nitrous oxide (N_2O); fluorinated gases covered under the Kyoto Protocol (F-gases). At the right side of the figure GHG emissions in 2010 are shown again broken down into these components with the associated uncertainties (90% confidence interval) indicated by the error bars

nal variability, which includes a possible redistribution of heat within the ocean. The reduced trend in radiative forcing is pri-marily due to volcanic eruptions and the timing of the downward phase of the 11-year solar cycle. The net feedback from the combined effect of changes in water vapour, and differences between atmospheric and surface warming amplifies changes in climate. Uncertainty in the sign and magnitude of the cloud feedback is due primarily to continuing uncertainty in the impact of warming on low clouds.

The equilibrium climate sensitivity quantifies the response of the climate system to constant radiative forcing on multi-century time scales. It is defined as the change in global mean surface temperature at equilibrium that is caused by a doubling of the atmospheric CO_2 concentration. Equilibrium climate sensitivity is in the range 1.5°C to 4.5°C. Estimates of these quantities for recent decades are consistent with the assessed range of the equilibrium climate sensitivity providing strong evidence for our understanding of anthropogenic climate change.

Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. Human influence has been the dominant cause of the observed warming since the mid-

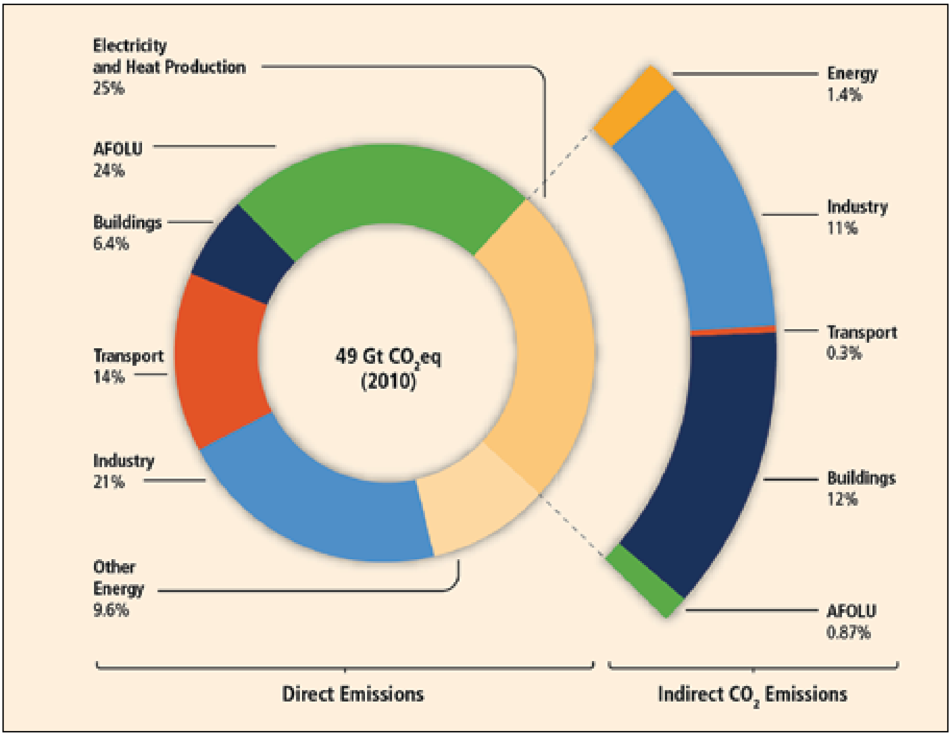

Figure 6.15 Total anthropogenic GHG emissions (Gt CO_2eq/yr) by economic sectors. Inner circle shows direct GHG emission shares (in% of total anthropogenic GHG emissions) of five economic sectors in 2010. Pull-out shows how indirect CO_2 emission shares (in% of total anthropogenic GHG emissions) from electricity and heat production are attributed to sectors of final energy use.

20th century. The best estimate of the human-induced contribution to warming is similar to the observed warming over this period.

Greenhouse gases contributed a global mean surface warming is 0.5°C to 1.3°C over the period 1951 to 2010, with the contributions from other anthropogenic forcings, including the cooling effect of aerosols, -0.6°C to 0.1°C. The contribution from natural forcings is small. Together these assessed contributions are consistent with the observed warming of approximately 0.6°C to 0.7°C over this period.

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2.

6.7 The Climate sceptics – climate deniers

There is a considerable number of individuals – among the general public, politicians and even some researchers – who does not at all agree with the picture of climate change and the reasons for climate change which have been delineated in this chapter. These are commonly called climate sceptics or even climate deniers. Some of them disagree that we have climate change at all, for example by referring to the flattening of the temperature curve the first years of this century. Some also maintain that we are not measuring the temperature changes in a correct way, e.g. by not taking into account that measuring stations are located close to cities.

However it is more common to accept that there is a climate change but argue that this is perfectly normal and has happened many times before both in the recent history, for example by referring to the so-called small ice age (the 17th century) or earlier, for example during the much warmer conditions in the Palaeolithic period. It is of course true that there has been quite many periods of climate change in our more recent as well as older history.

This group is also arguing that the warming we see today is not due to human intervention but has natural causes, just as during previous events.

The deniers have very many arguments. The most common seems to be "it is the sun, idiot!". Now, this statement is very easy to check since the sun irradiance can be measured very precisely and it is certainly not increase of sun which is behind the present climate change. (Change in sun irradiance has been causing several of the earlier climate change events, as it does vary but has a very long periodicity.)

It is also possible to point to quite many differences between the present climate change and the changes in the previous periods. A most striking difference is that the warming now is much faster. It is about 16 times faster than the warming following the last glaciation. Carbon dioxide concentration in the atmosphere has also changed in connection with earlier climate change, but as far as it is possible to see it has happened as a consequence of increased temperature rather than causing warming.

The number of arguments from the climate deniers are, as mentioned, very many. Several are discussed in detail on the website called *Skeptical Science*. The link is https://www.skepticalscience.com/argument.php. In May 2015 there were 150 arguments discussed on both simple and more scientific level. Another site is http://grist.org/series/skeptics/.

Reasons for climate denial seem to be more on the personal than on the scientific level. Climate deniers are more common in the countries which are very dependent on fossil fuels, such as USA and Russia. Of course these countries have much to lose if we have to stop using fossil fuels. In addition many in the US have a tradition of forming their own opinion regardless of science. In Central and Eastern Europe there is on the other hand a tradition of always accepting what the political authorities say. Both these attitudes strengthen climate denial.

The two circumstances to remember is that precisely because of the nature of the issue the Intergovernmental Panel of Climate Change was formed to provide the very best summary of our present knowledge and understanding of climate change. Why deny that? Secondly it is true that in natural science we can never have certainty in the mathematical sense. In fact we seldom have for anything in real life. But we should be wise enough to act on the best knowledge available. For ourselves, our future fellow human beings and our world.

Chapter 6 sources:

This chapter includes excerpts from the Summary for Policy-makers from the IPCC's Fifth Assessment Report (AR5) Working Group I published in September 2013 (http://www.climat-echange2013.org/images/report/WG1AR5_SPM_FINAL.pdf).

WG I is reporting on the scientific background of the study of Climate Change.

The section on climate deniers was written by Lars Rydén

Chapter 7
A future of climate change – assessing the risks

7.1 Observed Impacts, Vulnerability, and Exposure

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Evidence of climate-change impacts is strongest and most comprehensive for natural systems. Some impacts on human systems have also been attributed to climate change.

In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Glaciers continue to shrink almost worldwide due to climate change, affecting runoff and water resources downstream. Climate change is causing permafrost warming and thawing in high-latitude regions and in high-elevation regions.

Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change. Only a few recent species extinctions have been attributed as yet to climate change. Natural climate change at rates slower than current anthropogenic climate change caused significant ecosystem shifts and species extinctions during the past millions of years.

Many studies on a wide range of regions and crops have recorded negative impacts of climate change on crop yields. A small number of studies have shown positive impacts on crop yields mainly at high latitudes, although it is not so clear if the balance of impacts has been negative or positive. Climate change has negatively affected wheat and maize yields for many regions and in the global aggregate. Effects on rice and soybean yield have been smaller.

At present the world-wide burden of human ill-health from climate change is relatively small compared to other causes. However, there has been increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming. People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change and also to some adaptation and mitigation responses.

Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires have proved that both ecosystems and many hu-

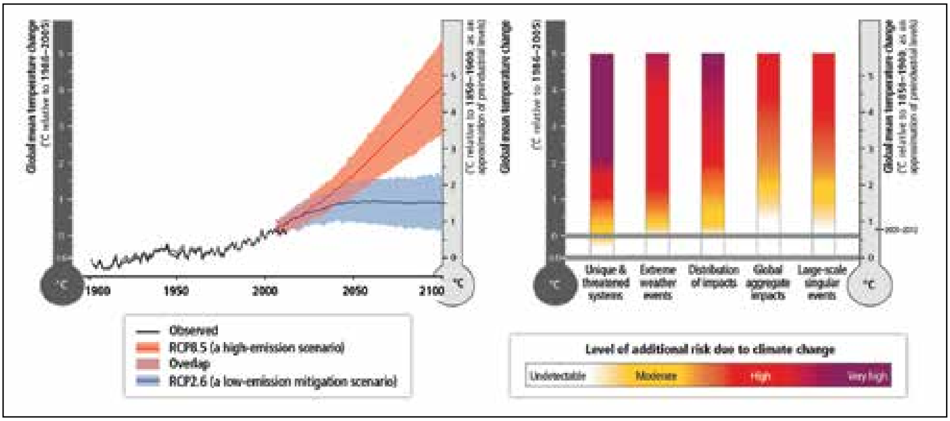

Figure 7.1 Illustration of the core concepts of climate related risks. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. The scenarios shown are the RCPs (Representative Concentration Pathways) of the IPCC. The numbers of RCP refers to the radiative forcing values in the year 2100 relative to pre-industrial values for the respective scenario. RCP 8.5 has +8.5 W/m^2 forcing in 2100, the so-called baseline or "business-as-usual" scenario, while RCP 2.6 has +2.6, W/m^2 forcing in 2100 which is a high mitigation scenario.

man systems are very vulnerable to current climate variability. Impacts of such climate-related extremes are many. They include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, bad health and death of humans, and consequences for mental health and human well-being. Climate-related hazards affect poor people's lives directly through impacts on livelihoods, reductions in crop yields, or destruction of homes. Indirect effects include for example, increased food prices and food insecurity. In addition violent conflict increases vulnerability to climate change.

The risk associated with different future climates are shown as scenarios in the IPCC reports (Fig. 7.1). These go from the business-as-usual, meaning no efforts are done to reduce emissions, to a low emission scenario assuming very large reductions of emissions.

7.2 Climate-related risks

Below follow a list of key risks. All of these have been identified with high confidence, and they span sectors and regions. Many key risks constitute particular challenges for the least developed countries and vulnerable communities, given their limited ability to cope.

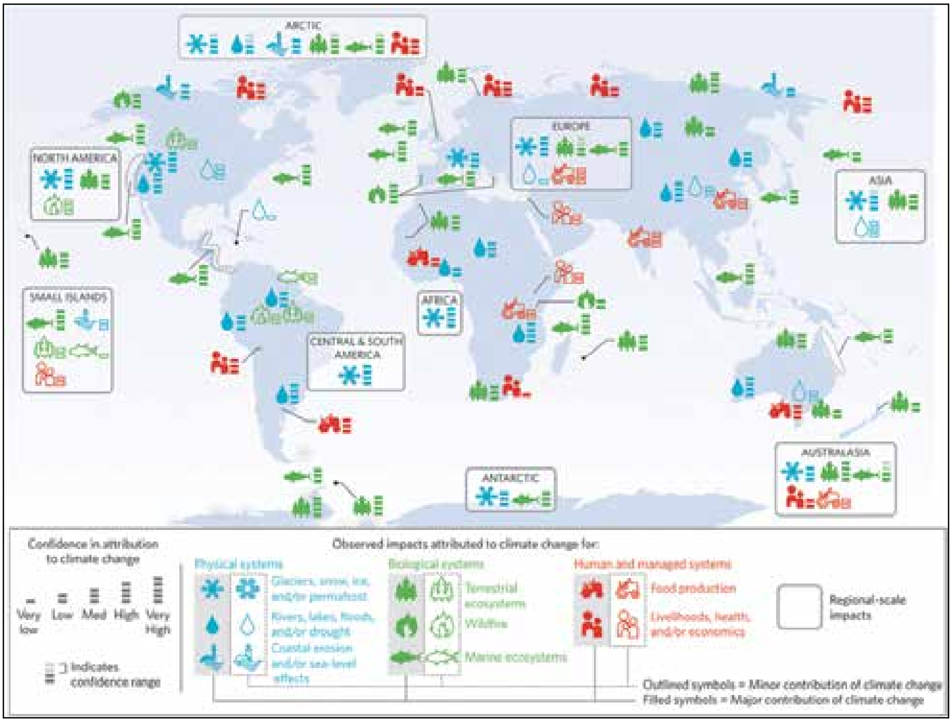

Figure 7.2 Regional distribution of risks with widespread impacts in a changing world. (A) Global patterns of impacts in recent decades attributed to climate change. Impacts are shown at a range of geographic scales. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution.

1. Risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, *coastal flooding*, and *sea-level rise*.
2. Risk of severe ill-health and disrupted livelihoods for large urban populations due to *inland flooding* in some regions.
3. Systemic risks due to extreme weather events, such as *storms and tornadoes*, leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services.
4. Risk of mortality and morbidity during periods of *extreme heat*, particularly for vulnerable urban populations and those working outdoors in urban or rural areas.
5. Risk of *food insecurity* and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.

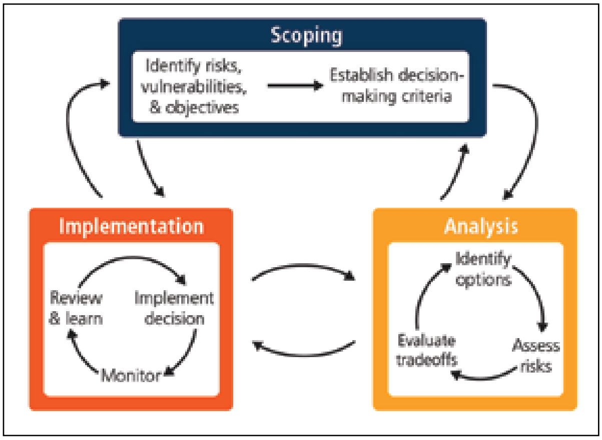

Figure 7.3 Climate-change adaptation as an iterative risk management process with multiple feedbacks. People and knowledge shape the process and its outcomes.

6. Risk of loss of rural livelihoods and income due to *insufficient access to water* for drinking and irrigation and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions.
7. Risk of *loss of marine and coastal ecosystems,* biodiversity, and the ecosystem goods, functions, and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic.
8. Risk of loss of terrestrial and *inland water ecosystems*, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods.

Below follows an estimation of the vulnerability of the different systems given as temperature increase which will cause significant harm. Five integrative reasons for concern provide a framework for summarizing key risks across sectors and regions. They provide one starting point for evaluating dangerous anthropogenic interference with the climate system. All temperatures below are given as global average temperature change relative to 1986-2005 ("recent").

1. *Unique and threatened systems*: Some unique and threatened systems, including ecosystems and cultures, are already at risk from climate change. The number of such systems at risk of severe consequences is higher with additional warming of around 1 °C. Many species and systems with limited adaptive capacity are subject to very high risks with additional warming of 2 °C, particularly Arctic-sea-ice and coral-reef systems.
2. *Extreme weather events*: Climate-change-related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are already moderate and high with 1 °C additional warming. Risks associated with some types of extreme events (e.g., extreme heat) increase further at higher temperatures.

3. *Distribution of impacts*: Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development. Risks are already moderate because of regionally differentiated climate-change impacts on crop production in particular. Based on projected decreases in regional crop yields and water availability, risks of unevenly distributed impacts are high for additional warming above 2 °C.
4. *Global aggregate impacts*: Risks of global aggregate impacts are moderate for additional warming between 1-2 °C, reflecting impacts to both Earth's biodiversity and the overall global economy. Extensive biodiversity loss with associated loss of ecosystem goods and services results in high risks around 3 °C additional warming. Aggregate economic damages accelerate with increasing temperature but few quantitative estimates have been completed for additional warming around 3 °C or above.
5. *Large-scale singular events*: With increasing warming, some physical systems or ecosystems may be at risk of abrupt and irreversible changes. Risks associated with such tipping points become moderate between 0-1 °C additional warming, due to early warning signs that both warm-water coral reef and Arctic ecosystems are already experiencing irreversible regime shifts. Risks increase disproportionately as temperature increases between 1-2 °C additional warming and become high above 3 °C, due to the potential for a large and irreversible sea-level rise from ice sheet loss. For sustained warming greater than some threshold, near-complete loss of the Greenland ice sheet would occur over a millennium or more, contributing up to 7m of global mean sea-level rise.

7.3 Impacts in individual sectors

Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts. Some risks of climate change are considerable at 1 or 2 °C above preindustrial levels. Global climate change risks are high to very high with global mean temperature increase of 4 °C or more above preindustrial levels in all reasons for concern, and include severe and widespread impacts on unique and threatened systems, substantial species extinction, large risks to global and regional food security, and the combination of high temperature and humidity compromising normal human activities, including growing food or working outdoors in some areas for parts of the year. The precise levels of climate change sufficient to trigger tipping points (thresholds for abrupt and irreversible change) remain uncertain, but the risk associated with crossing multiple tipping points in the earth system or in interlinked human and natural systems increases with rising temperature.

Freshwater resources. Freshwater-related risks of climate change increase significantly with increasing greenhouse gas concentrations. The fraction of global population experiencing water scarcity and the fraction affected by major river floods increase with the level of warming in the 21st century.

Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions, intensifying competition for water among sectors. In presently dry regions, drought frequency will likely increase by the end of the 21st century. In contrast, water resources are projected to increase at high latitudes. Climate change is projected to reduce raw water quality and pose risks to drinking water quality even with conventional treatment, due to interacting factors: increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods. Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can help create resilience to uncertain hydrological changes and impacts due to climate change.

Ecosystems and biodiversity. A large fraction of both terrestrial and freshwater species faces increased extinction risk under projected climate change during and beyond the 21st century, especially as climate change interacts with other stressors, such as habitat modification, over-exploitation, pollution, and invasive species.

Within this century, magnitudes and rates of climate change associated with medium- to high-emission scenarios pose high risk of abrupt and irreversible regional-scale change in the composition, structure, and function of terrestrial and freshwater ecosystems, including wetlands.

Examples that could lead to substantial impact on climate are the boreal-tundra Arctic system and the Amazon forest. Carbon stored in the terrestrial biosphere (e.g., in peatlands, permafrost, and forests) is susceptible to loss to the atmosphere as a result of climate change, deforestation, and ecosystem degradation. Increased tree mortality and associated forest dieback is projected to occur in many regions over the 21st century, due to increased temperatures and drought. Forest dieback poses risks for carbon storage, biodiversity, wood production, water quality, amenity, and economic activity.

Due to sea-level rise projected throughout the 21st century and beyond, coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion.

Due to projected climate change by the mid-21st century and beyond, global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services.

For medium- to high-emission scenarios, ocean acidification poses substantial risks to marine ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population dynamics of individual species from phytoplankton to animals

Food, economy and development. All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability. For the major crops (wheat, rice, and maize) in tropical and temperate regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2 °C or more above late-20th-century levels, although individual locations may benefit.

Many global risks of climate change are concentrated in urban areas. Steps that build resilience and enable sustainable development can accelerate successful climate-change adaptation globally. Heat stress, extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, and water scarcity pose risks in urban areas for people, assets, economies, and ecosystems. Risks are amplified for those lacking essential infrastructure and services or living in poor-quality housing and exposed areas.

Major future rural impacts are expected in the near-term and beyond through impacts on water availability and supply, food security, and agricultural incomes, including shifts in production areas of food and non-food crops across the world.

For most economic sectors, the impacts of drivers such as changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance are projected to be large relative to the impacts of climate change. Climate change is projected to reduce energy demand for heating and increase energy demand for cooling in the residential and commercial sectors.

Global economic impacts from climate change are difficult to estimate. Economic impact estimates completed over the past 20 years vary in their coverage of subsets of economic sectors and depend on a large number of assumptions, many of which are disputable, and many estimates do not account for catastrophic changes, tipping points, and many other factors. With these recognized limitations, the incomplete estimates of global annual economic losses for additional temperature increases of ~2 °C are between 0.2 and 2.0% of income (±1 standard deviation around the mean).

Human health, security and livelihood. Until mid-century, projected climate change will impact human health mainly by exacerbating health problems that already exist. Throughout the 21st century, climate change is expected to lead

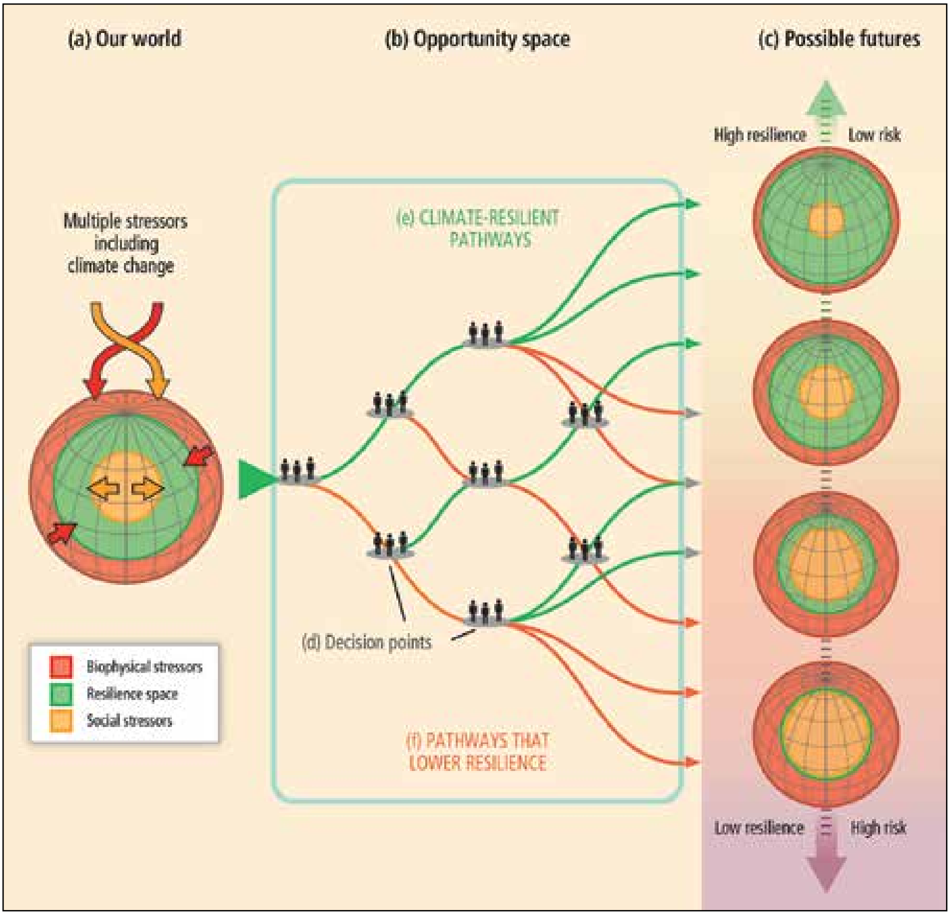

Figure 7.4 The solution space. The picture illustrate overlapping entry points and approaches, as well as key considerations, in managing risks related to climate change.

to increases in ill-health in many regions and especially in developing countries with low income, as compared to a baseline without climate change. Examples include greater likelihood of injury, disease, and death due to more intense heat waves and fires; increased likelihood of under-nutrition resulting from diminished food production in poor regions; risks from lost work capacity and reduced labor productivity in vulnerable populations; and increased risks from food- and water-borne diseases and vector-borne diseases.

Climate change over the 21st century is projected to increase displacement of people. Displacement risk increases when populations that lack the resources for planned migration experience higher exposure to extreme weather events, in both rural and urban areas, particularly in developing countries with low income. Climate change can indirectly increase risks of violent conflicts in the form of civil war and inter-group violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks.

Throughout the 21st century, climate-change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger.

Chapter 7 sources:

This chapter is based in and consists mostly of edited excerpts from the Summary for Policy-makers from the IPCC's Fifth Assessment Report (AR5) Working Group II (WGII) published in December 2013.
(https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf).
WG II is reporting on the consequences of climate change. There is also some material from the Summary for Policy-makers from IPCC AR5 WG III.

Chapter 8
Mitigating and adaptation of climate change

8.1 Managing future risks and building resilience – mitigation and adaptation

Throughout history, people and societies have adjusted to and coped with climate, climate variability, and extremes, with varying degrees of success. In this chapter we will see how impacts and risks related to climate change can be reduced and managed through adaptation and mitigation. The report assesses needs, options, opportunities, constraints, resilience, limits, and other aspects associated with adaptation.

Responding to climate-related risks involves decision-making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation. Adaptation and mitigation choices in the near-term will affect the risks of climate change throughout the 21st century. Uncertainties about future vulnerability, exposure, and responses of interlinked human and natural systems are large.

Mitigation refers to actions which reduces the rate as well as the magnitude of warming, Mitigation also increases the time available for adaptation to a particular level of climate change, potentially by several decades. Delaying mitigation actions may reduce options for climate-resilient pathways in the future.

Adaptation refers to the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Resilience refers to the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Managing the risks of climate change involves adaptation and mitigation decisions with implications for future generations, economies, and environments. National governments can coordinate adaptation efforts of local and subnational governments, for example by protecting vulnerable groups, by supporting economic diversification, and by providing information, policy and legal frameworks, and financial support. Local government and the private sector are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households, and civil society and in managing risk information and financing.

A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability. Strategies may include actions with co-benefits for other objectives.

Existing and emerging economic instruments can foster adaptation by providing incentives for anticipating and reducing impacts. Instruments include public-private finance partnerships, loans, payments for environmental services, improved resource pricing, charges and subsidies, norms and regulations, and risk sharing and transfer mechanisms.

Significant co-benefits, synergies, and tradeoffs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions. Examples of actions with co-benefits include

1) improved energy efficiency and cleaner energy sources, leading to reduced emissions of health-damaging climate-altering air pollutants;
2) reduced energy and water consumption in urban areas through greening cities and recycling water;
3) sustainable agriculture and forestry; and
4) protection of ecosystems for carbon storage and other ecosystem services.

Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. At the same time, some mitigation efforts could undermine action on the right to promote sustainable development, and on the achievement of poverty eradication and equity. Effective mitigation will not be achieved if individual agents advance their own interests independently.

Climate change has the characteristics of a collective action problem at the global scale, because most greenhouse gases (GHGs) accumulate over time and mix globally, and emissions by any agent (e.g., individual, community, company or country) affect other agents. International cooperation is therefore required to effectively mitigate GHG emissions and address other climate change issues. Issues of equity, justice, and fairness arise with respect to mitigation and adaptation.

Countries' past and future contributions to the accumulation of GHGs in the atmosphere are different, and countries also face varying challenges and circumstances, and have different capacities to address mitigation and adaptation. Many areas of climate policy-making involve value judgements and ethical considerations. These areas range from the question of how much mitigation is needed to prevent dangerous interference with the climate system to choices among specific policies for mitigation or adaptation. Among other methods, economic evaluation is commonly used to inform climate policy design. Practical tools for economic assessment include cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and expected utility theory.

8.2 Emission and Mitigation scenarios and measures in the context of sustainable development

A number of mitigation scenarios or pathways under different assumptions of GHGs emission reductions have been examined (see Fig. 8.1). These are seen in the light of the global agreement (the Copenhagen accord) that countries will work to keep global warming within or below 2 °C, a level that is perceived as not too dangerous to human society. The scenarios where it is likely that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2 °C relative to pre-industrial levels are characterized by atmospheric concentrations in 2100 of about 450 ppm CO_2eq. Scenarios reaching concentration levels of about 500 ppm CO_2eq by 2100 are more likely than not to limit temperature change to less than 2 °C relative to pre-industrial levels.

The baseline scenario is the “business as usual” development, that is, a future where no particular mitigation activities are made and emissions are continuing to rise in the fashion we see today. All other scenarios assumes different mitigation options to reduce emissions. In the IPCC reports the scenarios, called *Representative Concentration Pathways* (RCPs), are named RCP 8.5, RCP 6.0, RCP 4.5 and RCP 2.6. The numbers refers to the radiative forcing values in the year 2100 relative to pre-industrial values, +2.6, +4.5, +6.0, and +8.5 W/m^2, respectively.

Scenarios reaching atmospheric concentration levels of about 450 ppm CO_2eq by 2100 include substantial cuts in anthropogenic GHG emissions by mid-century through large-scale changes in energy systems and potentially land use. Scenarios reaching these concentrations by 2100 are characterized by lower global GHG emissions in 2050 than in 2010, 40-70% lower globally, and emissions levels near zero Gt CO_2eq or below in 2100. In scenarios reaching 500 ppm CO_2eq by 2100, 2050 emissions levels are 25-55% lower than in 2010 globally. In scenarios reaching 550 ppm CO_2eq, emissions in 2050 are from 5% above 2010 levels to 45% below 2010 levels globally. At the global level, scenarios reaching 450 ppm CO_2eq are also characterized by more rapid improvements of energy efficiency, a tripling to nearly a quadrupling of the share of zero- and low-carbon energy

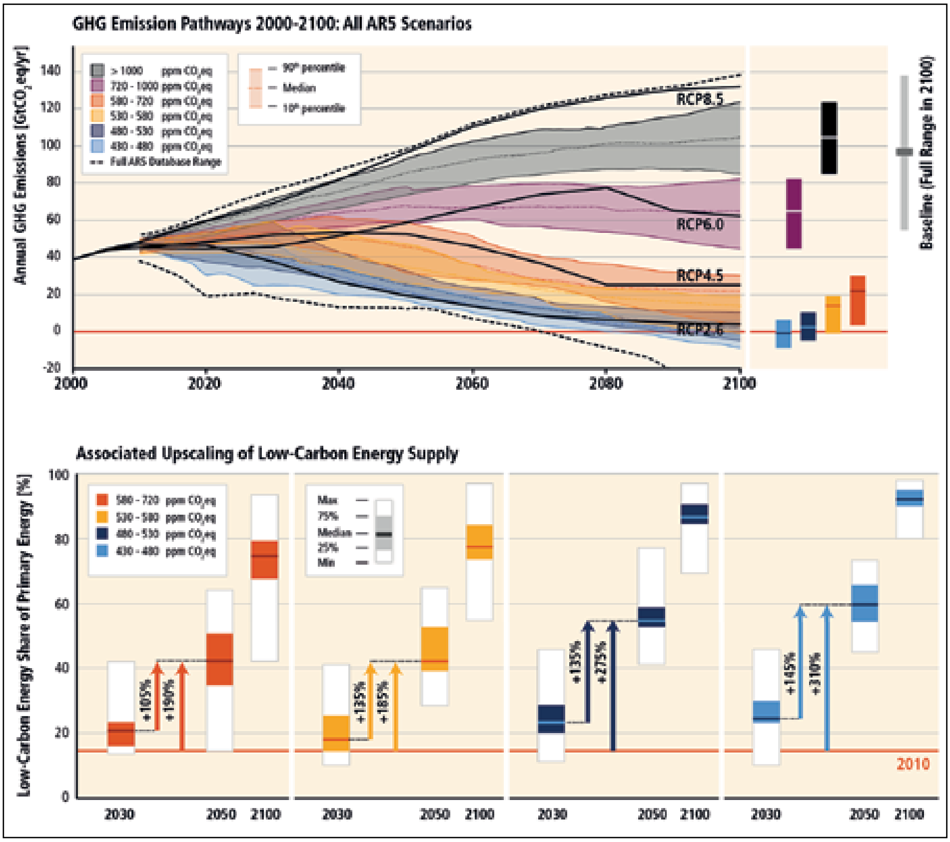

Figure 8.1. Pathways of global GHG emissions (Gt CO_2eq/year) in baseline and mitigation scenarios for different long-term concentration levels (upper panel) and associated up-scaling requirements of low-carbon energy (% of primary energy) for 2030, 2050 and 2100 compared to 2010 levels in mitigation scenarios (lower panel). The upper and lower panels exclude scenarios with limited technology availability and the lower panel in addition excludes scenarios that assume exogenous carbon price trajectories.

supply from renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by the year 2050.

Mitigation scenarios reaching about 450 ppm CO_2eq in 2100 typically involve temporary overshoot of atmospheric concentrations, as do many scenarios reaching about 500 ppm to 550 ppm CO_2eq in 2100. Depending on the level of the overshoot, overshoot scenarios typically rely on the availability and widespread deployment of BECCS and afforestation in the second half of the century. The availability and scale of these and other Carbon Dioxide Removal (CDR) technologies and methods are uncertain and CDR technologies and methods are, to varying degrees, associated with challenges and risks.

Meeting the 2 °C goal would require further substantial reductions beyond 2020. Delaying mitigation efforts beyond those in place today through 2030 is estimated to substantially increase the difficulty of the transition to low longer-term emissions levels and narrow the range of options consistent with maintaining temperature change below 2 °C relative to pre-industrial levels. Cost-effective mitigation scenarios that make it at least as likely as not that temperature change will remain below 2°C relative to pre-industrial levels are typically characterized by annual GHG emissions in 2030 of roughly between 30 and 50 $GtCO_2eq$.

8.3 Mitigation pathways and measures

In baseline scenarios, GHG emissions are projected to grow in all sectors, except for net CO_2 emissions in the AFOLU sector. Energy supply sector emissions are expected to continue to be the major source of GHG emissions, ultimately accounting for the significant increases in indirect emissions from electricity use in the buildings and industry sectors. In baseline scenarios, while non-CO_2 GHG agricultural emissions are projected to increase, net CO_2 emissions from the AFOLU sector decline over time, with some models projecting a net sink towards the end of the century. Infrastructure developments and long-lived products that lock societies into GHG-intensive emissions pathways may be difficult or very costly to change, reinforcing the importance of early action for ambitious mitigation. This lock-in risk is compounded by the lifetime of the infrastructure, by the difference in emissions associated with alternatives, and the magnitude of the investment cost. As a result, lock-in related to infrastructure and spatial planning is the most difficult to reduce.

There are strong interdependencies in mitigation scenarios between the pace of introducing mitigation measures in energy supply and energy end-use and developments in the AFOLU sector.The distribution of the mitigation effort across sectors is strongly influenced by the availability and performance of BECCS and large scale afforestation. Well-designed systemic and cross-sectorial mitigation strategies are more cost-effective in cutting emissions than a focus on individual technologies and sectors. At the energy system level these include reductions in the GHG emission intensity of the energy supply sector, a switch to low carbon energy carriers (including low-carbon electricity) and reductions in energy demand in the end-use sectors without compromising development. Mitigation scenarios reaching around 450 ppm CO_2eq concentrations by 2100 show large-scale global changes in the energy supply sector. In these selected scenarios, global CO_2 emissions from the energy supply sector are projected to decline over the next decades and are characterized by reductions of 90% or more below 2010 levels between 2040 and 2070.

Efficiency enhancements and behavioural changes, in order to reduce energy demand com-pared to baseline scenarios without compromising development, are a key mitigation strategy in scenarios reaching atmospheric CO_2eq concentrations of about 450 or 500 ppm by 2100. Near-term reductions in energy demand are an important element of cost-effective mitigation strategies. Behaviour, lifestyle and culture have a considerable influence on energy use and associated emissions, with high mitigation potential in some sectors, in particular when complementing technological and structural change. Emissions can be substantially lowered through changes in consumption patterns (e.g., mobility demand and mode, energy use in households, choice of longer-lasting products) and dietary change and reduction in food wastes. A number of options including monetary and non-monetary incentives as well as information measures may facilitate behavioural changes.

8.4 Energy supply

In the baseline scenarios direct CO_2 emissions from the energy supply sector are projected to almost double or even triple by 2050 compared to the level of 14.4 Gt CO_2eq/year in 2010, unless energy intensity improvements can be significantly accelerated beyond the historical development. In the last decade, the main contributors to emission growth were a growing energy demand and an increase of the share of coal in the global fuel mix. The decreased availability of fossil fuels alone (past peak oil, gas and coal) will not be sufficient to limit CO_2eq concentration to levels such as 450 ppm, 550 ppm, or 650 ppm.

Therefore reducing the carbon intensity of electricity generation is a key component of cost-effective mitigation strategies. Thus fossil fuel based electricity generation must be exchanged for *renewable (RE) technologies*, such as biomass based generation, hydropower, wind and wave power, and solar electricity. Nuclear power is also included; even if it is not counted as renewable, it is not fossil fuel based.

Since 2007, many RE technologies have demonstrated substantial performance improvements and cost reductions, and a growing number of RE technologies have achieved a level of maturity to enable deployment at significant scale. Regarding electricity generation alone, RE accounted for just over half of the new electricity-generating capacity added globally in 2012, led by growth in wind, hydro and solar power. However, many RE technologies still need direct and/or indirect support, if their market shares are to be significantly increased; RE technology policies have been successful in driving recent growth of RE. Challenges for integrating RE into energy systems and the associated costs vary by RE technology, regional circumstances, and the characteristics of the existing background energy system.

Nuclear energy is a mature low-GHG emission source of base load power, but its share of global electricity generation has been declining since 1993. Nuclear energy could make an increasing contribution to low-carbon energy supply, but a variety of barriers and risks exist. Those include: operational risks, and the associated concerns, uranium mining risks, financial and regulatory risks, unresolved waste management issues, nuclear weapon proliferation concerns, and adverse public opinion. New fuel cycles and reactor technologies addressing some of these issues are being investigated and progress in research and development has been made concerning safety and waste disposal.

Carbon Capture and Storage (CCS) refers to a technology where the carbon dioxide generated from fossil fuel incineration is collected and transferred to underground storage place, often a chalk mine. A major drawback with this technology is that the incineration has to be done in almost 100% clean oxygen prepared from air, at a considerable energy cost. If air is used to burn the gas to be stored would consist of 80% nitrogen and be five times as large as otherwise. CCS technology has been used for ex by Norway to store carbon dioxide extracted together with natural gas from the North Sea fields. The storage has then been under the sea bottom. For CCS plants in Germany public protests have been considerable; people are afraid of gas leaking from the storage. Thus CCS plants are at present not allowed in the country. Still experts believes that CCS constitutes an essential technology for mitigating climate change in the future.

Bioenergy with CCS (BECCS) refers to a power plan using biomass and CCS. This means that effectively carbon dioxide will be removed from the atmosphere as the carbon in the biomass is not fossil. It is the most important out of several technologies on the drawing board for removing CO_2 from the atmosphere.

GHG emissions from energy supply can be reduced significantly by replacing current world average coal-fired power plants with modern, highly efficient natural gas combined-cycle power plants or combined heat and power plants (CHP), provided that natural gas is available and the fugitive emissions associated with extraction and supply are low or mitigated. In mitigation scenarios reaching about 450 ppm CO_2eq concentrations by 2100, natural gas power generation without

CCS acts as a bridge technology, with deployment increasing before peaking and falling to below current levels by 2050 and declining further in the second half of the century.

Carbon dioxide capture and storage (CCS) technologies could reduce the lifecycle GHG emissions of fossil fuel power plants. While all components of integrated CCS systems exist and are in use today by the fossil fuel extraction and refining industry, CCS has not yet been applied at scale to a large, operational commercial fossil fuel power plant. For the large-scale future deployment of CCS, well-defined regulations concerning short- and long-term responsibilities for storage are needed as well as economic incentives. Barriers to large-scale deployment of CCS technologies include concerns about the operational safety and long-term integrity of CO_2 storage as well as transport risks. There is, however, a growing body of literature on how to ensure the integrity of CO_2 wells, on the potential consequences of a pressure build-up within a geologic formation caused by CO_2 storage (such as induced seismicity), and on the potential human health and environmental impacts from CO_2 that migrates out of the primary injection zone

Combining bioenergy with CCS (BECCS) offers the prospect of energy supply with large-scale net negative emissions which plays an important role in many low-stabilization scenarios, while it entails challenges and risks. These challenges and risks include those associated with the upstream large-scale provision of the biomass that is used in the CCS facility as well as those associated with the CCS technology itself.

8.5 Transport

The transport sector accounted for 27% of final energy use and 6.7 Gt CO_2 direct emissions in 2010, with baseline CO_2 emissions projected to approximately double by 2050. This growth in CO_2 emissions from increasing global passenger and freight activity could partly offset future mitigation measures that include fuel carbon and energy intensity improvements, infrastructure development, behavioural change and comprehensive policy implementation. Overall, reductions in total transport CO_2 emissions of 15-40% compared to baseline growth could be achieved in 2050. Technical and behavioural mitigation measures for all transport modes, plus new infrastructure and urban redevelopment investments, could reduce final energy demand in 2050 by around 40% below the baseline, with the mitigation potential assessed to be higher than reported in the 2007.

Projected *energy efficiency and vehicle performance improvements* range from 30-50% in 2030 relative to 2010 depending on transport mode and vehicle type. Integrated urban planning, transit-oriented development, more compact urban form that supports cycling and walking, can all lead to modal shifts as can, in the longer term, urban redevelopment and investments in new infrastructure such as high-speed rail systems that reduce short-haul air travel demand. Such mitigation measures are challenging, have uncertain outcomes, and could reduce transport GHG emissions by 20-50% in 2050 compared to baseline.

Exchange of fossil fuels for bio based fuels is a main technology here. Strategies to reduce the carbon intensities of fuel and the rate of reducing carbon intensity are constrained by challenges associated with energy storage and the relatively low energy density of low-carbon transport fuels. Integrated and sectorial studies broadly agree that opportunities for switching to low-carbon fuels exist in the near term and will grow over time.

Methane-based fuels (biogas) are already increasing their share for road vehicles and waterborne craft. Electricity produced from low-carbon sources has near-term potential for electric rail and short- to medium-term potential as electric buses, light duty and 2-wheel road vehicles are deployed. Hydrogen fuels from low-carbon sources constitute longer term options. Commercially available liquid and gaseous biofuels already provide co-benefits together with mitigation options that can be increased by technology advances. Reducing transport emissions of particulate matter (including black carbon), tropospheric ozone and aerosol precursors (including NO_x) can have human health and mitigation co-benefits in the short term.

The cost-effectiveness of different carbon reduction measures in the transport sector varies significantly with vehicle type and transport mode. The levelized costs of conserved carbon can be very low or negative for many short-term behavioural measures and efficiency improvements for light- and heavy-duty road vehicles and waterborne craft.

Increased use of *electric cars and vehicles* constitute a main option. Electric motors are much more energy efficient than combustion motors. The main difficulty lies in the limited performance of batteries. Until battery technology has improved the use of electric vehicles will probably be limited to shorter travels e.g. in cities. Still about 80% of car travels presently are shorter than 5 km.

Change in *mobility behaviour* is an important development. Thus the use of ICT for meetings, and distance work has increased tremendously with the increased use of computer networks and Internet, which reduced travelling. In the same vein we should point to the increased use of *public transport* in large cities. This also contributes to reduced use of the private car, which is the most difficult to replace when discussing low carbon travelling options.

Regional differences influence the choice of transport mitigation options. Institutional, legal, financial and cultural barriers constrain low-carbon technology uptake and behavioural change. Established infrastructure may limit the options for modal shift and lead to a greater reliance on advanced vehicle technologies; a slowing of growth in light duty vehicle demand is already evident in some OECD countries. For all economies, especially those with high rates of urban growth, investment in public transport systems and low-carbon infrastructure can avoid lock in to carbon-intensive modes. Prioritizing infrastructure for pedestrians and integrating non-motorized and transit services can create economic and social co-benefits in all regions.

Mitigation strategies, when associated with non-climate policies at all government levels, can help decouple transport GHG emissions from economic growth in all regions. These strategies can help reduce travel demand, incentivise freight businesses to reduce the carbon intensity of their logistical systems and induce modal shifts, as well as provide co-benefits including improved access and mobility, better health and safety, greater energy security, and cost and time savings.

8.6 Buildings

In 2010, the building sector accounted for around 32% final energy use and 8.8 Gt CO_2 emissions, including direct and indirect emissions, with energy demand projected to approximately double and CO_2 emissions to increase by 50-150% by mid-century in baseline scenarios. This energy demand growth results from improvements in wealth, lifestyle change, access to modern energy services and adequate housing, and urbanisation. There are significant lock-in risks associated with the long lifespans of buildings and related infrastructure, and these are especially important in regions with high construction rates.

A main concern in this sector is the *heating of buildings* at least in cold climates. Presently most buildings use fossil fuel for heating, either coal, oil or gas. One option is to exchange the fuel used to biofuel. Well established is wood pellet, small balls of wood such as sawdust, which are easy to handle and can be treated almost as a liquid. Less comfortable but also in wide use is wood chips, especially for larger buildings. To go from heating individual buildings to district heating use to contribute with a considerable lower use of energy as efficiency is increasing. It is also connected to a considerable improvement in cleaning of flue gases. Heating power plants may use either forest wood waste (roots and branches) or wood chips. Other options are peat and household waste. Waste incineration may contribute some 5% of the energy budget of a country. District heating and waste incineration are recognised as the most efficient options for reducing energy in the building sector within the EU.

Other heating technologies which are increasing include *heat pumps*. These work as “reversed refrigerators” extracting heat from the outside air or ground or even water such as rivers and lakes. They are using electricity but close to 3-4 times more efficiently that direct heating with electricity. Solar heating by *solar panels* mounted on roofs of buildings may provide all hot water during a large part of the year. Solar panels are very common in southern Europe.

Improved insulation of buildings is just as important. For new buildings, the adoption of very low energy building codes is important and has progressed substantially since 2007. New buildings are improved by careful design, in *low energy buildings*. The cost is slightly higher but this investment is quickly coming back as the energy costs are much lower. *Passive houses* are buildings in which practically all heating needs are covered by internal sources, such as people and machinery. Passive houses are becoming more common in northern Europe, especially Germany, Denmark and Sweden. *Retrofits* form a key part of the mitigation strategy in countries with established building stocks, and reductions of heating/cooling energy use by 50-90% in individual buildings have been achieved. More typically retrofitting of older buildings to become more energy efficient most often reduce energy needs by 20-40%. Investments required are paid back typically after 7-9 years.

Lifestyle, culture and behaviour significantly influence energy consumption in buildings. A three- to five-fold difference in energy use has been shown for provision of similar building-related energy service levels in buildings. For developed countries, scenarios indicate that lifestyle and behavioural changes could reduce energy demand by up to 20% in the short term and by up to 50% of present levels by mid-century. In developing countries, integrating elements of traditional lifestyles into building practices and architecture could facilitate the provision of high levels of energy services with much lower energy inputs than baseline.

Most mitigation options for buildings have considerable and diverse co-benefits in addition to energy cost savings. These include improvements in energy security, health (such as from cleaner wood-burning cook stoves), environmental outcomes, workplace productivity, fuel poverty reductions and net employment gains.

Studies which have monetized co-benefits often find that these exceed energy cost savings and possibly climate benefits. Strong barriers, such as split incentives (e.g., tenants and builders), fragmented markets and inadequate access to information and financing, hinder the market-based uptake of cost-effective opportunities. Barriers can be overcome by policy interventions addressing all stages of the building and appliance lifecycles.

Adaption measures in this sector most importantly is not to allow buildings near water ways or on coasts. Flooding of rivers and water ways are becoming more common and buildings may then be flooded or in the extreme removed by the water masses. Buildings close to coasts may be flooded as sea level rise increases towards the end of the 21st century. Regulations on building sites have to include these concerns.

8.7 Industry

Emissions from industry accounted for just over 30% of global GHG emissions in 2010 and are currently greater than emissions from either the buildings or transport end-use sectors.

There are big potentials to reduce the energy use in the industry sector. The energy intensity of the industry sector could be directly reduced by about 25% compared to the current level through the wide-scale upgrading, replacement and deployment of best available technologies, particularly in countries where these are not in use and in non-energy intensive industries. Additional energy intensity reductions of about 20% may potentially be realized through innovation. Barriers to implementing energy efficiency relate largely to initial investment costs and lack of information. Information programmes are a prevalent approach for promoting energy efficiency, followed by economic instruments, regulatory approaches and voluntary actions. Improvements in GHG emission efficiency and in the efficiency of material use, recycling and reuse of materials and products, and overall reductions in product demand (e.g., through a more intensive use of products) and service demand could, in addition to energy efficiency, help reduce GHG emissions below the baseline level in the industry sector.

Together these measures are part of the *Cleaner Production* (CP) approach. This is well established in the industrialised countries since the 1990s. Parts of CP are very simple to introduce, the so-called low-hanging-fruits. These include insulation of tubes and containers, covering of containers, simple adjustments of temperatures. The more advanced include recycling of process water or solvents, more efficient use of the raw materials in the process. Even more advanced are the development of the technologies used themselves and so-called green engineering.

Many emission-reducing options are cost-effective, profitable and associated with multiple co-benefits (better environmental compliance, health benefits etc.). In the long-term, a shift to low carbon electricity, new industrial processes, radical product innovations (e.g., alternatives to cement), or CCS (e.g., to mitigate process emissions) could contribute to significant GHG emission reductions. Lack of policy and experiences in material and product service efficiency are the major barriers.

CO_2 emissions dominate GHG emissions from industry, but there are also substantial mitigation opportunities for non-CO_2 gases. CH_4, N_2O and fluorinated gases from industry accounted for emissions of 0.9 Gt CO_2eq in 2010. Key mitigation opportunities include, e.g., the reduction of hydrofluorocarbon emissions by process optimization and refrigerant recovery, recycling and substitution, although there are barriers.

Systemic approaches and collaborative activities across companies and sectors can reduce energy and material consumption and thus GHG emissions. The application of cross-cutting technologies (e.g., efficient motors) and measures (e.g., reducing air or steam leaks) in both large energy intensive industries and small and medium enterprises can improve process performance and plant efficiency cost-effectively. Cooperation across companies (e.g., in industrial parks or in *industrial symbioses*) and sectors could include the sharing of infrastructure, information, and waste heat utilization.

Important options for mitigation in waste management are waste reduction, followed by re-use, recycling and energy recovery. Waste and wastewater accounted for 1.5 Gt CO_2eq in 2010. As the share of recycled or reused material is still low (e.g., globally, around 20% of municipal solid waste is recycled), waste treatment technologies and recovering energy to reduce demand for fossil fuels can result in significant direct emission reductions from waste disposal. Compostable waste may be used for bio gas production while solid organic waste can be used for incineration, in both cases the management option is waste to energy. Landfilling of organic waste is since some years not allowed according to the EU waste directives.

8.8 Agriculture, Forestry and Other Land Use (AFOLU)

The AFOLU sector accounts for about a quarter (~10-12 Gt CO_2eq/year) of net anthropogenic GHG emissions mainly from deforestation, agricultural emissions from soil and nutrient management and livestock. Most recent estimates indicate a decline in AFOLU CO_2 fluxes, largely due to decreasing deforestation rates and increased afforestation. However, the uncertainty in historical net AFOLU emissions is larger than for other sectors, and additional uncertainties in projected baseline net AFOLU emissions exist. Nonetheless, in the future, net annual baseline CO_2 emissions from AFOLU are projected to decline, with net emissions potentially less than half the 2010 level by 2050 and the possibility of the AFOLU sectors becoming a net CO_2 sink before the end of century.

AFOLU plays a central role for food security and sustainable development. The most cost-effective mitigation options in forestry are afforestation, sustainable forest management and reducing deforestation, with large differences in their relative importance across regions. In agriculture, the most cost-effective mitigation options are cropland management, grazing land management, and restoration of organic soils. The economic mitigation potential of supply-side measures is estimated to be 7.2 to 11 Gt CO_2eq/year in 2030 for mitigation efforts consistent with carbon prices up to 100 USD/t CO_2eq, about a third of which can be achieved at a <20 USD/t CO_2eq. There are potential barriers to implementation of available mitigation options. Demand-side measures, such as changes in diet and reductions of losses in the food supply chain, have a significant, but uncertain, potential to reduce GHG emissions from food production. Estimates vary from roughly 0.76-8.6 Gt CO_2eq/year by 2050.

Bioenergy can play a critical role for mitigation, but there are issues to consider, such as the sustainability of practices and the efficiency of bioenergy systems. Barriers to large-scale deployment of bioenergy include concerns about GHG emissions from land, food security, water resources, biodiversity conservation and livelihoods. The scientific debate about the overall climate impact related to land use competition effects of specific bioenergy pathways remains unresolved. Bioenergy technologies are diverse and span a wide range of options and technology pathways. Evidence suggests that options with low lifecycle emissions (e.g., sugar cane, *Miscanthus*, fast growing tree species, and sustainable use of biomass residues), some already available, can reduce GHG emissions; outcomes are site-specific and rely on efficient integrated ‘biomass-to-bioenergy systems’, and sustainable land-use management and governance. In some regions, specific bioenergy options, such as improved cook stoves, and small-scale biogas and bio-power production, could reduce GHG emissions and improve livelihoods and health in the context of sustainable development.

Adaptation measures are important and prevalent in this sector. Crops have to be adapted to higher temperatures, and perhaps also less water requiring species and varieties to maintain food production. More efficient irrigation techniques may be needed in many regions, such as drip irrigation, as water scarcity starts to be felt. Land, which is close to water, risks being flooded and measures to increase the capacity of land surrounding the large rivers to store water are needed and already implemented in many countries. In other areas dams are built to protect land from being flooded. Measures may also be needed to reduce the dependency of this sector of fossil fuels, by turning to bio fuels, or electricity which may be locally produced e.g. by solar electricity to wind energy fields.

8.9 Human Settlements, Infrastructure and Spatial Planning

Urbanization is a global trend and is associated with increases in income, and higher urban incomes are correlated with higher consumption of energy and GHG emissions. As of 2011, more than 52% of the global population lives in urban areas. In 2006, urban areas accounted for 67-76% of energy use and 71-6% of energy-related CO_2 emissions. By 2050, the urban population is expected to increase to 5.6-7.1 billion, or 64-69% of world population. Cities in developing countries generally have higher levels of energy use compared to the national average, whereas cities in industrialised countries generally have lower energy use per capita than national averages.

The next two decades present a window of opportunity for mitigation in urban areas, as a large portion of the world's urban areas will be developed during this period. Accounting for trends in declining population densities, and continued economic and population growth, urban land cover is projected to expand by 56-310% between 2000 and 2030. Mitigation options in urban areas vary by urbanization trajectories and are expected to be most effective when policy instruments are bundled. Infrastructure and urban form are strongly interlinked, and lock-in patterns of land use, transport choice, housing, and behaviour. Effective mitigation strategies involve packages of mutually reinforcing policies, including co-locating high residential with high employment densities, achieving high diversity and integration of land uses, increasing accessibility and investing in public transport and other demand management measures.

The largest mitigation opportunities with respect to human settlements are in rapidly urbanizing areas where urban form and infrastructure are not locked in, but where there are often limited governance, technical, financial, and institutional capacities. The bulk of urban growth is expected in small- to medium-size cities in developing countries. The feasibility of spatial planning instruments for climate change mitigation is highly dependent on a city's financial and governance capability.

Thousands of cities are undertaking climate action plans, but their aggregate impact on urban emissions is uncertain. There has been little systematic assessment on their implementation, the extent to which emission reduction targets are

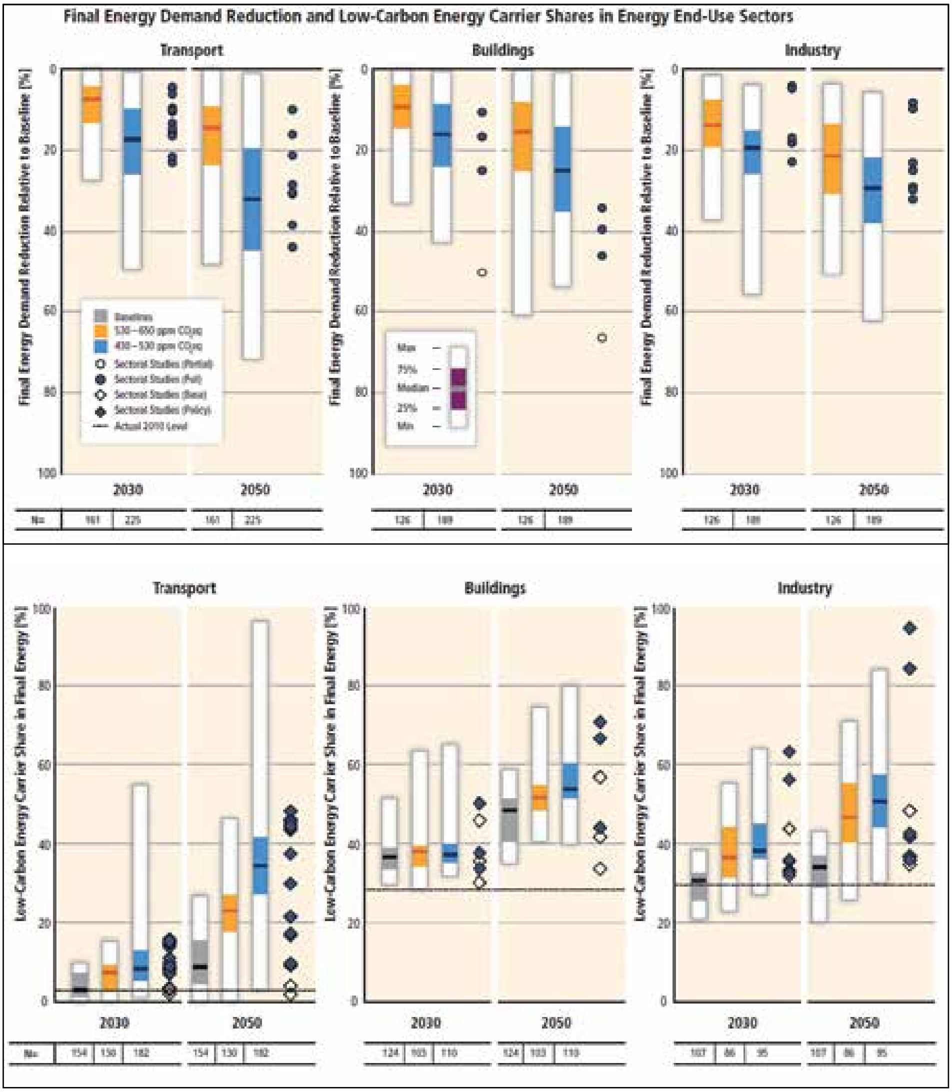

Figure 8.2. Final energy demand reduction relative to baseline (upper row) and low-carbon energy carrier shares in final energy (lower row) in the transport,(upper row) and low-carbon energy carrier shares in final energy (lower row) in the transport, buildings, and industry sectors by 2030 and 2050 in scenarios from two different CO_2eq concentration categories compared to sectorial studies. Low-carbon energy carriers include electricity, hydrogen and liquid biofuels in transport, electricity in buildings and electricity, heat, hydrogen and bioenergy in industry. The numbers at the bottom of the graphs refer to the number of scenarios included in the ranges which differ across sectors and time due to different sectorial resolution and time horizon of models.

being achieved, or emissions reduced. Current climate action plans focus largely on energy efficiency. Fewer climate action plans consider land-use planning strategies and cross-sectorial measures to reduce sprawl and promote transit-oriented development.

Successful implementation of urban-scale climate change mitigation strategies can provide co-benefits. Urban areas throughout the world continue to struggle with challenges, including ensuring access to energy, limiting air and water pollution, and maintaining employment opportunities and competitiveness. Action on urban-scale mitigation often depends on the ability to relate climate change mitigation efforts to local co-benefits.

Adaptation measure in this sector is dominated by actions to reduce the risk for flooding, by building the proper infrastructure and protecting existing one. Man cities are close to coasts and this constitute a special challenge as sea water level is rising. Building of dams and other protection measures have started or is planned in many large and old, even ancient, cities.

Chapter 8 sources:

This chapter builds on and includes edited and shortened excerpts from the Summary for Policy-makers from the IPCC's Fifth Assessment Report (AR5) Working Group III published in April 2014.
http://mitigation2014.org/.

Chapter 9
Adaptation to climate change impacts in Uzbekistan

9.1 Predicting climate change in Uzbekistan

An analysis of the trends of standard climate parameters proves that they change as a consequence of global warming.

For assessment of Climate Change impact on economic sectors that considers regional Climate Scenarios based on GHG emission scenarios A2 and B2 (see chapter 8), the standard climate parameters were calculated for 2030 and 2080 and evaluated as compared with the period 1971-2000.

Average duration of the heating (cold) season in Uzbekistan will be 8-9% shorter 2030 as compared with the reference period, and 2080 this period will be 25% shorter.

Figure 9.1 show the decrease in power consumption for heating in conditions of warming for different mean temperatures and heating season duration. According to the estimate, in 2030 energy saved on heating as compared with the baseline period for scenario A2 amounts to 12%, and for scenario B2 16%. The savings in 2080 will reach 35% for scenario B2 and 41% for scenario A2.

The estimates show that the mean temperature of the coldest days for the two scenarios will be 3 °C higher by 2030 and 6.6 °C higher by 2080.

Consequently, warming up for winter season in Uzbekistan will lead to a reduction of energy consumption for heating as well as to a decrease of building materials inputs in some types of construction works.

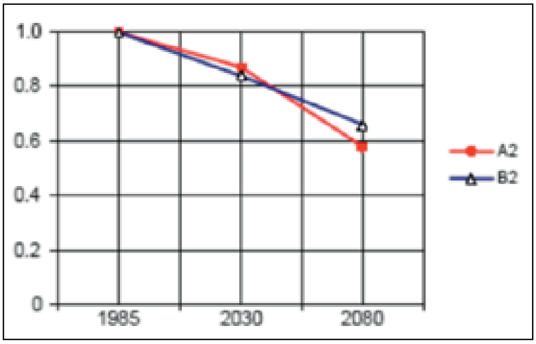

Figure 9.1 Trends of energy resource consumption for heating

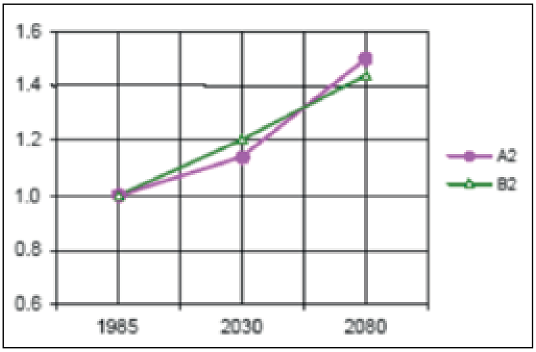

Figure 9.2 Trends in energy consumption for air conditioning

According to the estimate, the duration of the hot period will increase comparative to the reference period by 16% for scenario A2 and 20% for scenario B2 in 2030 and by 43% for scenario B2 and 49% for scenario A2 in 2080, which will significantly impact energy consumption for air conditioning (Figure 9.2).

The temperature for the hottest days in the south of Uzbekistan will exceed 40 °C in 2080 for scenario A2. According to the data for the centre of Uzbekistan, the mean temperature of the hottest days for two scenarios will increase by 1.3 °C in 2030 and 3.7 °C in 2080.

9.2 Climate Change consequences or different economic sectors

Increased summer temperatures may cause:

- increase of energy consumption for ventilation and air conditioning;
- increase in material costs for new residential, agricultural and industrial projects designed for extremely hot and arid conditions, as well as for manufacturing of new building materials;
- intake of additional resources for cooling of equipment to maintain it in operational condition;
- growth of energy and other material costs to maintain optimal pressure in cold water supply system.

Moreover, climate warming will require a re-planning of light and food industry as well as retail trade commodity circulation as it relates to the allocation of goods in the country which will lead to additional material costs.

According to the estimates (Figure 9.3), by 2080 sustainable periods with the mean daily temperature below 0 °C will occur on 18-20% in the Northern part

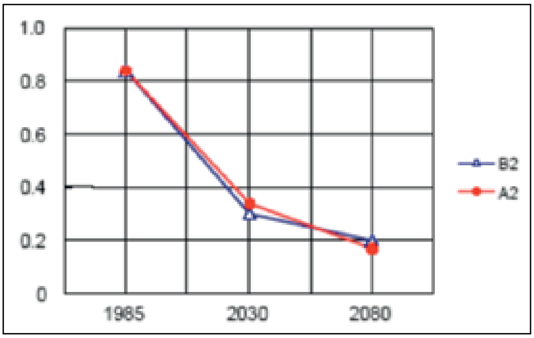

Figure 9.3 Tendency of diminishing of the territory with a stable mean temperature below 0 °C in Uzbekistan.

and in the highlands of Uzbekistan, which will lead to a reduction of fuel and lubrication materials consumption in the winter season for the motor transport sector. Intensification of extreme summer season will increase the areas where fuel consumption becomes larger.

An upsurge of the mean monthly air temperature peaks, and an increased length of the hot period will lead to an increase in natural loss of mineral oil. Improper use of climate zoning, and outdated climate information may lead to notable errors (up to 8%) when considering natural loss of mineral oil.

The key adaptation measures to provide for a rational use of energy and material resources, ensure reliability and the sustainability of economic sectors in climate change condition, as well as for development of certain projects, include:

- Update normative documents comprising climatic data for design and construction every 10 years.
- Develop differentiated climate based zoning according to the economic sectors specificity.
- Develop new approaches to consideration of climate factors in oil and gas industry, transportation sector and the other industries.
- Consider Climate Change when revising the energy consumption rates.
- Manufacture and import machinery, equipment, and materials appropriate for hot climate conditions in Uzbekistan.
- Consider scenario assessments of climate parameters for long-term planning in various economic sectors.

9.3 An assessment of adaptation requirements

The assessment of the vulnerability of different sectors and consequences of Climate Change for the environment, resources and socio-economic living conditions has shown that it is necessary to take adequate action to reduce the negative consequences and adapt to new conditions. Uzbekistan is implementing a number of national and sectorial programs, measures and actions, which directly and indirectly contribute to adaptation.

The primary negative consequences of Climate Change in Uzbekistan are linked to the increase in water resources deficiency. Water deficiency has become a factor that limits the opportunities of the country's economic development, particularly agriculture, which plays a pivotal role in the economy and employment of the country. The extensive use of water and land resources has led to large-scale salinization of irrigated lands, degradation of natural pastures, drying up of the Aral Sea, and a large ecological crisis.

The problem of water resources deficiency is directly linked to increased desertification in the region, loss of biodiversity and increasing risks for food supplies. The measures to deal with existing urgent problems are thus overlapping with the adaptation needs brought about by Climate Change.

An assessment of Uzbekistan's existing practice for adaptation to Climate Change was thus conducted using available information to study vulnerability and adaptation needs.

Parts 5.2-5.8 of the study provide a description of vulnerability to Climate Change by sectors: agriculture, water resources, population health, hazardous weather phenomena, water ecosystems and fish resources, forests and forestry, communal household and particular sectors of agriculture (oil, gas, transport, construction, planning, energy, etc.). The vulnerability of the above-mentioned sectors is determined by the current and expected climatic changes:

- increase in the duration of the dry and hot season;
- reduction of water resources and deterioration of water;
- increase in the use of water within all sectors and increase in water deficiency;
- increase in the recurrence of hazardous and extreme weather phenomena such as high temperatures, heavy precipitation, drought, growth of water deficiency, etc.;
- worsening of all types of land degradation, such as salinization, erosion, movement of salt and dust from dry parts of the Aral Sea, etc.;
- decline in yields of modern crop cultures, pasture productivity and animal husbandry;
- growth of risks for food supplies and population health.

Experts from diverse sectors analysed the factual and potential unfavourable consequences of Climate Change and determined possible options for adaptation-related action, including increase of scientific, institutional and legal potential.

The analysis conducted has been used in the preparation of sectorial questionnaires (list of measures classified by sectors). After consultations with interested organizations, five criteria for the assessment of adaptation measures, on a 5 point scale, were used:

- need for international aid,
- the effectiveness of measures,
- the cost of measures,
- achievability of goals, and
- usefulness at the present time.

The adaptation strategies and measures outlined in the questionnaires were analysed within the interested organizations according to the adopted criteria and points given. The completed questionnaires were then used to extract average points and particular adaptation strategies and measures were prioritized by sectors. Then, based on the rating and average points, the measures most appropriate to each sub-sector, strategy or actions were considered.

The drawback to such assessment was the absence of weight quotients for each criterion which were hard to determine numerically. Therefore, the final decision to prioritize particular adaptation measures was made based on expert judgment. Thus the opinions of the experts became, thus, an additional sixth criterion. In this way, as a result of the multi-criterion analysis which involved respective ministries, departments, and scientific organizations, the most significant adaptation measures were identified.

9.4 Agriculture and water resources

The agriculture and water resources sectors underwent broad-based consideration as they are closely interlinked. The vital adaptation needs are reflected by the strategy "Water saving and rational use of irrigated lands". The measures it includes, especially those dealing with the improvement of irrigation infrastructure and drainage, and the introduction of such irrigation technologies as drop, impulse, and intra-soil, are very costly.

The resolution of issues related to the rational management of water and land resources does not require much investment, but it calls for coordination and adoption of international agreements dealing with the management of trans-border water resources.

Regional interaction and international support are necessary for the development and improvement of meteorological and hydrological monitoring and the creation of monitoring posts for the observation of snow and ice resources in the mountainous areas where rivers flowing into the Aral Sea start. Without regional interaction it will not be possible to implement adaptation measures revealed in “water ecosystems and fish resources” sector because the implementation of these measures requires, first of all, setting the quota for water resources.

“Water saving in industrial and communal household water use” also requires sizeable investments, but compared with water saving in irrigation, it saves much less water. However, measures for water saving in the household sector have priority as it is necessary to provide the population with clean drinking water and raising their awareness of the problem.

Table 9.1 below provides prioritized strategies and measures of adaptation to Climate Change in water resources and agriculture sectors which are frequently undertaken in Uzbekistan with the active support of the government and the international community.

9.5 Public health

The strategies are deemed as the most promising adaptation measures for the public health sector include: organization of prophylaxis; increasing public awareness; conservation of the environment and providing safe drinking water for the population; introduction of new and improved water treatment technologies; maintenance of heating facilities in rooms and reduction of heat islands in towns. The most prioritized measures for the public health sector are shown in Table 9.2.

9.6 Hazardous weather phenomena

For adapting to hazardous weather phenomena, measures aimed at the improvement of the insurance system and raising public awareness have been found to be the least expensive. Measures to improve the regional monitoring of lakes prone to bursting, including those outside Uzbekistan, have the largest adaptation potential. Just as important are measures dealing with the improvement of weather monitoring and forecasts as well as measures to protect crucial objects from hazardous weather phenomena. The most prioritized measures are illustrated in Table 9.3.

9.7 Water ecosystems and fish resources

For the water ecosystems and fish resources sector, the following strategies have been found to have the largest adaptation potential: conservation and increase

Table 9.1 Prioritized strategies and measures of adaptation to Climate Change in water resources and agriculture sectors.

Sector	Action/ consequences	Adaption strategies and measures				Obstacles to implementation
Water resources	Reduction in snow and ice resources in mountains and river flow Disturbance in annual river flow distribution Deterioration of water quality Increase in water consumption in all sectors Increase in loss during irrigation Increase in recurrence and depth of hazardous phenomena (extreme floods and drought)	Improvement of land and water resources management at national and transboundary level Improvement of legal mechanisms Introduction of IWRM Increase of the role of land users and water consumers Development of programmes and action plans for melioration of irrigated land Complex assessment of changes in land use, salinization and other types of land degradation Optimization of crop zone selection with an account of climatic change Correction of water consumption schemes and norms Development of long-term programme plans for agriculture and water management-development Improvement of the monitoring of seed beds and pasture conditions Improvement of agrometeorological services (information and forecasts) Increasing awareness of land and water use at all levels (from local communities to decision-making officials)	Water saving and rational water use in irrigated land Introduction of economical irrigation methods (short furrows, through furrows, night-time irrigation, field leveling and others). Reconstruction and mainenance of channels and drainage system Restoration of field-shelter belts Broader introduction of irrigation technologies Reutilization of water with low mineral concentration Improvement of methods for return water treatment Pilor projects on water saving and land degradation Artificial selection of high-yield heat- and salinity-resistant crops Teaching farmers modern skills in land use and water consumption, including new crop cultivation technologies	Improving water resources monitoring system Development of hydro meteorological networks in the region, tool (device) supply Improvement of harvesting, processing and exchange of information among countries in the region Improvement of transboundary monitoring of water resources Organization of the tabbing of water cosumption in households	Water saving in industrial and household water consumption Introduction of advanced water-saving technologies in industry and households Use of equipment reducing water consumption Record of water consumption and tariff policy	Insufficient regional coordination Insufficient financial resources Poor technical opportunities within Uzbekistan Insufficient investment Insufficient applied research and developments
Agriculture	Increase in deficiency of water for irrigation Increase in land salinization Increase in recurrence of extreme weather conditions Decrease in crop yields and pastures Increase in fodder deficiency, increase in heat stress for animals Decrease in animal husbandry productivity			Increase for plant growing productivity Introduction of high-yield and salinity- and drought-resistant crops Introduction of cotton and lucerne crop rotation Programmes to support farmers working on low-yield land Support of fruit and grapes producers Support of businesses involved in fruit and vegetable product recycling Study of profitability of agricultural crops in households	Increase of animal husbandry productivity Setting load norms for pastures Rehabilitation of degraded pastures (plant melioration, creation of sown pastures, improvement of water supply) Creation of fodder base for animal husbandry (increase of the share of fodder crops) Stabilizing sands, forest plantation of dried part of the Aral Sea Measures to cut heat and water stress in free-range animal husbandry	Lack of coordination of land use and water consumption Insufficient financial resources Poor technical opportunities within Uzbekistan Insufficient investment Insufficient applied research and developments

Table 9.2. The strategies for adaptation measures in the public health sector.

Sector	Action/ consequences	Adaption strategies and measures				Obstacles to implementation
Population health	Increase in duration of heat wave and heat load on humans Increase in heat-related and cardiovascular disease Increase in acute intestinal infections Increase in risk of parasitic disease and malaria	Conservation of environment Improvement of legislative and normative framework to reduce environment-related risks for health Improvement of material and technical base of sanitary and epidemological services Increase responsibility of economic entities Improvement of drinking water resources monitoring and protection	Provision of sufficient drinking water Construction of new and repair of existing water pipes and drainage Improvement and introduction of water treatment technologies Introduction of polymer and fibre-glass Creation of local sources of water supply for rural population	Organization of prevention and profylaxis Determination of cardiovascular risk groups Improvement of the system for the prevention of acute intestinal infections and transmissible diseasees: introduction of electronic monitoring Development of action plan against heat wave, including instructions for medical personnel Control of disease carrying breeds and spots with high concentration of infections Maintenance of heating facilities in rooms and reduction of heat islands in towns (landscaping, shading of buildings)	Research and raising public awareness Raising population awareness of increase in disease risk Complementing research and educational programmes with sections on climate and health Development of a system warning of a beginning heat wave including regional criteria Improvement of forms of medical accountability and provision of access to data	Shortage of financial resources Weak technical opportunities within Uzbekistan Insufficient applied research and developments Insufficient dat for assessment of climate impact on health

Table 9.3 Measures adapting to hazardous weather phenomena

Sector	Action/ consequences	Adaption strategies and measures				Obstacles to implementation
Hazardous phenomena **Heavy precipitation, hail** **Avalanche** **Drought**	Increase in mudflow risk period and mudflow recurrence Growth of risk of mountain lake overflow Persistence of high risk of avalanche Increase in recurrence and depth of drought, recurrence of high temperatures, heavy precipitation, hail	Insurance system development Expansion of the spectrum and improvement of the insurance service quality Improvement of the legal framework, increase of transparency Increase of population's financial insurance-related knowledge	Boosting the potential of quick response and protection Improvement of notification systems Protection of housing and objects from mudflow and avalanches in high-risk areas Introduction of drought early warning system Active impact on hydrometeorological processes	Research and developments Discovery and mapping of maximum risk zones Improvement of methods for hazardous hydrometeorological phenomena forecasts Development of drought early warning system Development of criteria of hazardous phenomena for different economic branches with an account of geographical area peculiarities	Improvement of hydrometeorological monitoring Expansion of terrestrial network of hydrometeorological observations, including foreign mountainous territory Development and application of methods of distance mmonitoring Restoration of top atmospheric layer observations	Insufficient financial resources Insufficient applied research and developments Insufficient regional coordination Weak technical opportunities within Uzbekistan Shortage of specialsts

of fish resources; second, development of political dialog in the management of trans-boundary water resources; third, development and improvement of the system of complex ecological monitoring of water and respective ecosystems. Priority measures are provided in Table 9.4.

9.8 Forests and forestry

For forests and forestry sector, the following strategies have been determined: the improvement of the forestry management system, including legislative initiatives and institutional changes, increase of the effectiveness of forestry activity, growth of the scientific and personnel potential of the field. Priority measures are illustrated in Table 9.5.

9.9 Gas, oil, transport and construction, planning and household

For gas, oil, transport and construction, planning and the household sectors, measures related to applied research for each sector directed at the development of new approaches to the assessment of the impact of climatic factors and renewal of respective normative documents have the most adaptation potential. Priority measures for the above-mentioned economic sectors are shown in Table 9.6.

9.10 priority strategies for adaptation

The multi-criterion and inter-sector analysis has made it possible to map out priority strategies of adaptation to Climate Change. Presently, the implementation of these strategies is vital for Uzbekistan:

1. Water saving and rational water use.
2. Combating land degradation (melioration of irrigated lands and rational use of pastures).
3. Increase of plant growing and cattle breeding productivity.
4. Taking preventive measures in healthcare sector.
5. Reduction or prevention of damage from drought and other hazardous hydro meteorological phenomena.
6. Creation of conditions for the conservation and maintenance of lake and river ecosystems.

Table 9.4 Adaptation measures in the water ecosystems and fish resources sector

Sector	Action/ consequences	Adaptation strategies and measures				Obstacles to implementation
Biodiversity	Shifting of ranges northwards, threat of alien species Disappearance of endangered species Reduction in ranges and degradation of wild ecosystem outside protected territories	Development of environmental protection legislation Setting ecological limits in water legislation Improvement of norms and rules for the use of significant water ecosystems Development of legislative framework for setting rights and obligations of users and fish product manufacturers and protection of their interests	Enhancement of the current measures' effectiveness Implementation of the National Strategy for Biodiversity Conservation Introduction of economic mechanisms for the use of nature and environmental protection Development of a strategy for fish industry development with an account of international experience and FAO recommendations Creation of conditions enabling natural reproduction of fish resources in the most vulnerable areas	Development of ecological monitoring Organization of Climate Change indicators Restoration of baseline monitoring in water flow formation areas Inventory of water ecosystems, organization of a complex ecological monitoring of significant areas	Scientific research and education Improvement of ecological education in schools and higher educational institutions Dissemination of information on the state of the environment Developments for application of progressive ways and technologies related to fishery and pisciculture	Legislative deficiencies in wild ecosystems protection Shortage of financial resources for natural reserve management National ecological network not created Absence of transboundary biosphere reserves
Water ecosystems fish resources	Water deficiency and deterioration of its quality Increased degradation of water ecosystems, disappearance of particular lake, river and coastal ecosystems					Shortage of financial resources Insufficient regional coordination Aral Sea and Amu-darya delta lakes not included in list of water consumers

Table 9.5 Adaptation strategies in the forests and forestry sector

Sector	Action/ consequences	Adaptation strategies and measures				Obstacles to implementation
Forests and forestry	Increased fragmentation of arid forest ecosystems Reduction of juniper ranges Disappearance of *tugai* forests and field-protective forestation Decrease in desert forest productivity	Improvement of legislation and the system of forestry management Development and adoption of a Forestry Code Development and adoption of a National Programme and programmes for field-protective forestation Setting quota for forestry	Enhancement of forestry activity effectiveness Use of scientific recommendations and international experience Consideration of climatic changes in the planning of new planting areas	Increase of personnel potential Obligatory forestry education for supervising officials of the branch System if continuous upgrade of personnel qualifications	Development of applied research on demand production and close correlation between forestry and production Selection of forest trees resistant to pests and disease, heat and drought	Insufficient financial resources Underestimate of Climate Change impact on forest ecosystems Insufficient methods for assessment of impact of climatic parameters on forest ecosystems

Table 9.6. Adaptation measures in the gas, oil, transport and construction, planning, and the household sectors.

Sector	Action/ consequences	Measures	Obstacles to implementation
Oil and gas sector **Transport**	Natural decrease of oil, gas condensate and oil products, miscalculations in assessment of natural decrease of oil products	Use of upgraded climatic information in assessment of natural decrease of oil products and natural gas, in assessment of fuel and lubricating material use Development of specialized climatic zoning and new approaches to the register of climatic factors Production and import of equipment and materials in accordance with hot climate	Underestimate of impact of Climate Change on economic sectors Shortage of methods for assessing impact of climatic parameters on economic sectors Absence of necessary statistical data on economic sectors Absence of necessary financial resources
Construction, planning, energy supply and household	Overuse of material, technical and energy resources Increase of energy use for ventilation and air-conditioning Emergence of new heat islands in towns Increased frequency of emergency situations in cold water supply systems	Upgrade normative documents including climatic parameters once every 10 years Improve and adopt town planning and architecture with a view to reducing heat load (use new technologies and materials, landscaping, shading of building, etc) Improve the planning of industrial areas and vehicular communications with a view to reducing heat islands in towns Improve the system of recording cold and hot water consumption in communal household	

Chapter 9 sources:

1. This chapter has been written by Natalya Akinshina and Azamat Azizov of National University of Uzbekistan.
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III

Climate Politics

Chapter 10
United Nations Climate Convention

10.1 International cooperation for the environment

The origins of present day international co-operation on environment and sustainable development go back to the late 1960s, when Sweden took the initiative to place the issue of environment on the agenda of the United Nations. The background was an increasing awareness in the scientific community about the serious nature of the negative environmental side-effects of the technological and scientific advances after the Second World War. The initiative also reflected a realization that environmental problems did not stop at national borders, nor did regional cooperation suffice to deal with them. Sweden thus proposed that a global United Nations Conference be convened to increase awareness about the implications of this situation among governments and the public at large and to identify those problems which could only, or best, be solved through international co-operation.

The United Nations Conference on the Human Environment convened on 5 June 1972 in Stockholm. This day in June is now yearly celebrated as the World Environment Day. The motto of the Conference was "Only One Earth," a revolutionary concept for its time. The conference was attended by 113 countries at the ministerial level and by representatives of many international organisations.

In the 1980s Sweden took up the recommendation of the Stockholm Conference to convene another conference on the human environment. This time, on the advice of the Brundtland Commission, a shift in emphasis was proposed to clearly underline the relationship between environment and development. In 1989 the UN General Assembly decided to convene in 1992 the United Nations Conference on Environment and Development (UNCED).

In spite of the progress generated through the processes set up in Stockholm, the global conditions were much worse in 1992. World population had increased by 1.7 billion to more than 5 billion. Almost 500 million acres of trees had been lost in the preceding 20 years. Chemical substances had damaged the ozone layer and deserts were rapidly expanding. The climate change problems had also begun to receive serious attention.

In contrast to Stockholm, the Rio Conference was a summit, attracting some 120 Heads of State of Government. Altogether, 178 countries participated. In an

Box 10.1. Conventions and their structure

Rules for global conventions are legally binding agreements, containing commitments by states, which make part of international law. How a convention is set up, supervised and ratified, as well as how states join a convention and leave it is today regulated in the so-called 1969 Vienna Convention. Conventions that are considered part of customary law becomes binding to all states, and conventions are thus a forceful part of international law. The

United Nation Secretary General serves as the depositary of international conventions.

Global conventions are the results of extensive, often several year long, negotiations between many, often up to some 100, states. After the negotiators have come to an agreement the text of the convention is signed by representatives of the governments and later ratified by the legislative organs of each signatory state, most often the parliament. When the specified number of ratifications have been reached the convention enters into force.

Today more than 200 global conventions are in place. Each convention is governed by a Conference of the Parties (COP) which meets regularly. It is serviced by a Secretariat which handles the legal procedures, e.g. to oversee that the participating states follow binding commitments, and a secretariat that work with the practical implementation. The undertakings in the conventions are often amplified by special Protocols that contain more detailed and, at times, binding commitments. Very often further resources, such as technical committees, research laboratories, etc., are set up to work with the issues of the convention, such as monitoring, forecasting, etc. The secretariats and other mechanisms of the global conventions are normally financed through obligatory contributions by the parties according to a scale of assessment of the United Nations.

important change of direction, the United States which had played a leading role 20 years before, this time took a defensive position. The Conference became a success. It adopted three documents, the Rio Declaration, Agenda 21, and the Statement of Forest Principles. It also adopted two global conventions, the Convention on Climate Change and the Convention on Biological Diversity.

During the period described, from the 1960s to today more than 200 global conventions have been set in place. *Conventions* are legally binding instruments, containing commitments by States. They have to be ratified by the legislative organs of each signatory state. Each convention is governed by a Conference of the Parties (COP) and is serviced by a secretariat. (The Climate Convention secretariat is located in Bonn, Germany.) UNEP (UN Environmental Programme) has a special role in many cases to provide administrative and other kinds of support. The undertakings in the conventions are often amplified by special protocols that contain more detailed and, at times time bound, commitments.

10.2 The climate issue

At the Rio conference, two global conventions were opened for signature, the *UN Framework Convention on Climate Change* (UNFCCC) and the *UN Convention on Biological Diversity* (CBD). This was followed a few years later by the *UN Convention to Combat Desertification* (UNCCD). As the perception of global threats to the environment became stronger in the 1980s, the climate change issue came increasingly into focus. Several international conferences were held, and towards the end of the decade, UNEP and WMO (World Meteorological Organisation) took an initiative that had a major impact on subsequent events. They created jointly the *Intergovernmental Panel on Climate Change* (IPCC), which issued its first assessment report in 1990. The Panel is composed of the world's most competent climate scientists, but it has also sought to incorporate representatives of governments and experts in the social sciences. It has to be recognized though, that it is in the framework of natural science that the Panel has commanded greatest authority. The purpose of the Panel has not been to carry out research on its own, but to monitor and evaluate existing research, adding its own conclusions and presentations for policy makers.

In this respect, the Panel has been very successful. Under the guidance of its first Chairman, the Swedish scientist Bert Bolin, the assessment reports of IPCC have greatly influenced the climate negotiations and been instrumental in launching the Framework Convention on Climate change (FCCC). The IPCC first assessment report appeared in the autumn of 1990. It stated that the process of global warming, created by what was known as the enhanced greenhouse effect through the accumulation of carbon dioxide and other greenhouse gases in the atmosphere, could lead to an increase of temperature in the Earth's atmosphere by 1.5 to 4.5 degrees centigrade towards the end of the 21st century. The IPCC statements carried great authority as the mainstream opinion by the great majority of climate experts. Up to the present five Assessments Reports (AR) have been issued, the latest, AR5 in 2013-14. Already since the second assessment report, that appeared in 1995-96, IPCC concluded that there was now beyond doubt a human impact on climate was caused by the increased emissions of greenhouse gases since the beginning of industrialization.

Governments demonstrated that they took global warming seriously by engaging in the negotiations on the Climate Convention. These were concluded in May 1992 after a surprisingly rapid negotiation, which was closely linked to the preparation of the 1992 Rio Conference on Environment and Development. During the Rio Conference 153 states signed the Convention, which entered into force in early 1994, after ratification by the required 50 states. The commitments

Box 10.2. The United Nations Framework Convention on Climate Change (UNFCCC)

The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

The idea is that, as they are the source of most past and current greenhouse gas emissions, industrialized countries are expected to do the most to cut emissions on home ground. They are called Annex I countries and belong to the Organization for Economic Cooperation and Development (OECD). They include 12 countries with "economies in transition" from Central and Eastern Europe. Annex I countries were expected by the year 2000 to reduce emissions to 1990 levels.

Industrialized nations agree under the Convention to support climate change activities in developing countries by providing financial support for action on climate change-- above and beyond any financial assistance they already provide to these countries. A system of grants and loans has been set up through the Convention and is managed by the *Global Environment Facility,* GEF. Industrialized countries also agree to share technology with less-advanced nations.

The UNFCCC entered into force on 21 March 1994. Today, it has near-universal membership. The 195 countries that have ratified the Convention are called Parties to the Convention.

Source: http://unfccc.int/essential_background/convention/items/6036.php

of the Convention were to a large extent of a procedural nature, but for the industrialised countries, known in Convention language as Annex I states, there was a commitment in principle to stabilize greenhouse gas emissions at 1990 levels by the end of the decade.

10.3 The climate negotiations and the Kyoto Protocol

At the first Conference of the Parties, COP-1, held in Berlin in 1995, it was decided that these commitments were not sufficient or adequate, and a separate negotiation was launched with the aim of reaching agreement on a Protocol with more precise commitments for Annex I states, within specified timeframes. In Berlin it was also confirmed that the process would not introduce any new commitments for developing countries, reflecting the principle of common but differentiated responsibilities. The decision became known as the *Berlin Mandate*, and it opened a period of intense negotiation up to December 1997, when the third Conference of the Parties after a difficult session concluded the *Kyoto Protocol*, named after the Japanese city where the Conference was held.

Figure 10.1. The Kyoto conference. An unidentified Australian member of the World Wide Fund for Nature (WWF) delegation covers his face with a paper bag to show his shame over his own country's disappointing proposal. The event took place during a press conference at the COP3 conference on global warming in Kyoto, Japan, Monday, Dec. 1, 1997. However the 10-day meeting resulted in an agreement on a protocol for measures to halt global warming. (Photo: Koichi Yamada/ Pressens Bild.)

The Kyoto Protocol introduces commitments of a new nature for industrialised countries, giving a much more concrete legally binding character than the Convention itself. It thus contains provisions for follow-up and compliance, which open the way for a real legal regime. However, it was not possible in the short time available to agree on all details in the Protocol, and therefore important negotiations continued in the period after Kyoto, leading up to the sixth Conference of the Parties in the Hague in November 2000. The main quantitative commitments in the Kyoto Protocol relate to the period 1990-2010, or rather to an end point defined as an average of the years 2008/2012. Industrialised countries committed themselves to reduce emissions of greenhouse gases during the period with an average of 5.2 percent. The European Union commitment was -8%, that of USA -7% and that of Japan -6%. The commitments were based on a principle of equal effort, taking into account previously undertaken reductions and more general economic considerations.

The agreement would not have been possible without the perspective of softening the commitments with elements that would make it easier to achieve the targets. These refer mainly to the so-called flexible mechanisms, that is, a system of crediting emission reductions achieved abroad through co-operation on such projects as improving efficiency in power plants through what is known as Joint Implementation (JI) or through trading in emission reductions. Negotiations on these rules, which could also apply to developing countries, has been part of the so-called Clean Development Mechanism (CDM).

The three Kyoto mechanisms, *International Emissions Trading, Joint Implementation*, and the *Clean Development Mechanism*, allow for flexibility in the implementation of the emission reduction efforts. Another element of further negotiations were the rules relating to *sinks and reservoirs*, based on the fact that the ground, and in particular growing forests, absorb carbon. This carbon cycle is still not well-known, and therefore the rules were restrictive during the first commitment period. Nevertheless, a well-designed system could help sustainable forest management. The arguments around the mechanisms and the rules on sinks have centred around the risk that they would make it too easy to reach the Kyoto targets and thus reduce the credibility of the Kyoto Protocol, and in particular the strong signal effect it has had on actors on the global market, that governments are really taking the greenhouse effect seriously.

The European Union has underlined that there must be no loopholes in the system, whereas the United States and others have emphasised the need for an efficient market-based system, reflecting the principle of cost-effectiveness. Still the new Bush administration declared that the United States would not ratify the Kyoto Protocol. The EU under the Swedish Presidency reacted strongly and stated that the Union and its members would go along with ratification anyway, expecting that other Annex I parties would join in such a way that the required target for entry into force would be met.

At the resumed Conference of Parties, COP-6 in Bonn, a political agreement was reached which will enable countries such as Japan, Canada, and Russia to begin their ratification process. However the agreement meant some weakening of the Kyoto targets in introducing more flexibility in the calculations of sinks and the use of the mechanisms. This was a reasonable price to pay for saving the Kyoto process. Furthermore, important decisions were taken with regard to support for developing countries including assistance for adaptation to climate change.

A number of remaining technical details were finally settled at COP-7 in Marrakesh in October 2001. This first Conference of the Parties in an African country also took important further steps on linkages to the other global conventions, and on transfer of technology and capacity-building in favour of developing countries. The Kyoto Protocol finally enter into force in 2005 after the Russian Federation had signed. Australia ratified the Kyoto Protocol in 2007, while Canada, as more conservative government took power, left the Kyoto protocol in 2011. At the same time the Russian Federation and Japan announced that it would not take on new responsibilities for reduction of emissions of GHGs.

It is not surprising that negotiations have been difficult. Measures to respond to climate change go straight into the heart of our industrial civilization, involving basic questions related to transports or energy. Important economic and social interests are at stake, and the complexity of the regime is daunting. The climate issue makes concrete a number of the more general aspects involved in the discussions and negotiations on sustainable development, and it is sometimes very difficult to see the way forward. Nevertheless it is encouraging that the international community over a short period of time has managed to seriously tackle a long-term survival issue in a serious manner.

10.4 Implementing the Kyoto Protocol

The Kyoto protocol states that by 2010 (as the average of the 2008-2012 window), the parties should have decreased their CO_2 emission by an average of 5.2% as compared to the chosen base year of 1990. The commitments were unevenly distributed and for the European Union members it was -8%, for the USA -7% and Japan -6%. The Kyoto protocol entered into force on the 16th of February 2005 after the Russian Federation had ratified the protocol as one of more than 150 States. Thereby countries, representing the requested 55% of the 1990-emission of CO_2, had ratified the protocol, which was made a precondition for its entering into force. The USA, at the time responsible for about 35% of the global CO_2-emission, was and is the only major state, which has not ratified the protocol. Later China, after considerable increase of energy use, has become the second largest emitter of GHGs in the world. Neither USA nor China have joined the Protocol.

At the COP-11 in Montreal, Canada in 2005, a sanction system was outlined making the Climate Convention close to becoming a real global legal regime. The COP in Montreal also was the first Meeting of the Parties to the Kyoto Protocol (MOP1).

The first commitment period of the Kyoto Protocol thus started in 2005 and was concluded in 2012. 37 industrialized countries and the European Community (the European Union-15, made up of 15 states at the time of the Kyoto negotiations) committed themselves to binding targets for GHG emissions. The targets applied to the four greenhouse gases carbon dioxide, methane, nitrous oxide and sulphur hexafluoride, and two groups of fluorinated gases, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). The six GHGs are translated into CO_2 equivalents, CO_2eq, in determining reductions in emissions.

The then 15 EU member states had agreed on a reduction in CO_2 emissions of 8% by 2008-2012 compared to the 1990 base line. These obligations were subsequently distributed among the member states with variations from reductions of e.g. 21% (Germany and Denmark) and 15-27% (Spain, Greece and Portugal). The 10 new member states from 2010 got between 6% and 8% reduction targets relative to the 1990-base line. As these countries have seen a profound economic restructuring over the 1990s with closure of a number of energy consuming industries, this reduction has been met – and more so – by this very economic restructuring.

The Protocol was in great danger to be cancelled after this first commitment period, but at the 17th Conference of the Parties (COP17) in Durban, Republic of South Africa, in 2011 governments agreed to a second term of the Kyoto Protocol. The agreement came into force in January 2013. The 194 parties to the UN's Nations Framework Convention on Climate Change took almost an entire extra day to thrash out the agreement. The launch of the much-anticipated *Green Climate Fund*, after a year of waiting, was also announced. This, and the Kyoto Protocol extension, falls under a new set of decisions known as the *Durban Platform*.

The following year at the COP18 in Doha, Qatar, an agreement was reached to extend the Protocol to 2020 and to set a date of 2015 for the development of a successor document, to be implemented from 2020. The outcome of the Doha talks has received a mixed response. The Kyoto second commitment period applies to about 15% of annual global emissions of greenhouse gases. The countries joining a second commitment period of the Protocol were Australia, the EU, Croatia, Iceland, Liechtenstein, Monaco, Norway and Switzerland. Major emitters such as China, the USA, Russia, India, Japan, Brazil, Canada, Mexico, Indonesia, South Korea and South Africa announced politically binding reduction targets to be achieved by 2020 under the Climate Convention, but not as part of the Protocol. No targets have so far been agreed for the second commitment period. The European Union has however announced its goal is to reduce GHG emission by 20%, counted from 2012 as the base line year, to 2020.

10.5 The European Union Climate policy

The European Union has from the early stages of Climate negotiations been a forerunner in climate policies. The European Commission took its first climate-related initiatives in 1991, when it issued the first Community Strategy to limit carbon dioxide emissions and improve energy efficiency. From the first Climate Convention Conference of Parties (COP) in Berlin 1995 the EU countries, then 15 of them, negotiated together as a single actor. Today the number have increased to 28, to which should be added the four countries which work together with the Union as members of the European Economic Area, EEA. In 1997 at the

Kyoto COP3, the EU was at the forefront to develop the Protocol and implemented it forcefully the following years as the EU Emission Trading Scheme.

EU leaders have committed themselves to transform Europe into a highly energy-efficient, low carbon economy. The EU has set itself targets for reducing its greenhouse gas emissions progressively up to 2050. To achieve this the Union has introduced a series of Directives and Regulations related to the climate issue on energy production, industry, mobility etc. The policy is described in the European Climate Change Programme (ECCP), the Emissions Trading Scheme (ETS), the National Emission Ceilings (NEC) Directive, and the Carbon Capture and Storage (CCS) Directive. A second European Climate Change Programme (ECCP II) was launched in October 2005.

With the exception of carbon dioxide trading, legislation in this area is rather weak and development is mostly promoted through policy actions and support programmes. There is, however, the Council Directive on limiting carbon dioxide emissions by improving energy efficiency (SAVE), and the Communication from the Commission called Energy Efficiency in the European Community – Towards a strategy for the rational use of energy.

A number of Directives concern energy use and efficiency. These include

- Directive 2001 on the electricity production from renewable energy sources
- Directive 2002 on the energy performance of buildings,
- Directive 2004 on the promotion of cogeneration in power plants
- Communication 2007 on reduction of CO_2 emissions from cars to 120 g/km by 2012

In 2007 the European Council adopted an energy policy for Europe, aiming at saving energy and promoting climate-friendly energy sources. EU leaders set a firm target of cutting 20% of the EU's greenhouse gas emissions by 2020. In addition it says that the EU is willing to increase this goal up to 30% if the US, China and India make similar commitments. EU leaders also set a binding overall goal of 20% for renewable energy sources by 2020, compared to the 6,5% in 2011. A binding minimum target of 10% for the share of biofuels in overall transport petrol and diesel consumption by 2020 was also set.

This is together the so-called 20-20-20 strategy to be achieved by the year 2020:

- 20% reduction of emissions
- 20% renewable energy
- 20% increased energy efficiency

In the climate and energy policy framework for 2030, the European Commission proposes that the EU set itself a target of reducing emissions to 40% below 1990 levels by 2030. For 2050, EU leaders have endorsed the objective of reducing Europe's greenhouse gas emissions by 80-95% compared to 1990 levels as part of efforts by developed countries as a group to reduce their emissions by a similar degree.

The European Commission have developed adaptation strategies to help strengthen Europe's resilience to the inevitable impacts of climate change. It says that reigning in climate change carries a cost, but doing nothing would be far more expensive in the long run. Moreover, investing in green technologies that cut emissions will also boost the economy, create jobs and strengthen Europe's competitiveness.

The fight against climate change is increasingly being reflected in other policy areas. To further advance this "mainstreaming" process, the EU has agreed that at least 20% of its €960 billion budget for the 2014-2020 period should be spent on climate change-related action. This is on top of climate finance from individual EU Member States. This budget marks a major step forward in transforming Europe into a clean and competitive low-carbon economy. As the world's leading donor of development aid, the EU also provides substantial funding to help developing countries tackle climate change. It gave just over €7.3 billion in "fast start" financing to developing countries over 2010-2012 and is continuing to provide climate finance every year.

10.6 A global climate agreement

From the beginning of the Climate Convention the goal was to establish a global agreement on reduction of emissions of greenhouse gases. This turned out to be very difficult. An agreement in the United Nations Conventions requires consensus. To arrive to a consensus between more than 190 states is not easy. It is enough that two or three have different interests and see themselves as unable to agree. These are typically states whose economy is very much dependent on fossil fuel trading and/or use and see themselves as unable to follow a proposed reduction.

The first serious efforts to forge a global agreement are connected to the development of the Kyoto Protocol. However several main emitters did not take part in the Protocol and the Protocol itself got weaker as the negotiations of it was concluded by 2005.

A series of COPs then led up to the COP15 in Copenhagen in 2009. The Copenhagen Conference raised climate change policy to the highest political level.

Figure 10.3 COP15 in Copenhagen 2009. President Barack Obama briefs European leaders, including British Prime Minister Gordon Brown, French President Nicolas Sarkozy, EU President Swedish Prime Minister Fredrik Reinfeldt, German Chancellor Angela Merkel, European Union Commission President Jose Manuel Barroso, and Danish Prime Minister Lars L. Rasmussen, following a multi¬lateral meeting at the United Nations Climate Change Conference in Copenhagen, Denmark, Dec. 18, 2009. Photo by Pete Souza.

Close to 115 world leaders attended making it one of the largest gatherings of world leaders ever outside UN headquarters in New York. More than 40,000 people, representing governments, nongovernmental organizations, intergovernmental organizations, faith-based organizations, media and UN agencies attended. A global agreement was meticulously prepared and expectations were high to have it adopted. In spite of the presence of world leaders, including US President Obama, EU leaders among them Angela Merkel and Nicolas Sarkozy, and European Union Commission President Jose Manuel Barroso, the agreement failed and many felt a great disappointment. Instead the so-called *Copenhagen Accord* was signed. The Accord contained several key elements in which the views of governments converged. Most importantly it included the long-term goal of limiting the maximum global average temperature increase to no more than 2 degrees Celsius above pre-industrial levels, subject to a review in 2015. There was, however, no agreement on how to do this in practical terms. It was far from a protocol.

At the following COP-16 in Cancun, Mexico, the Copenhagen Accord was formalized to become the *Cancun Agreement*, including the development of new

Figure 10.4 Peoples Climate March New York 21st of September 2014

reporting rules to significantly improve the transparency of developing country emissions and actions.

After the disappointment with the Copenhagen COP the international community had to find a new starting point. It was created at the COP 17 in Durban, South Africa, in 2011. First of all after tough talks a number of member states agreed to establish a second commitment period of the Kyoto Protocol (2013-2020). Secondly the meeting agreed to start a new process for a global agreement applicable to all Parties to be signed by 2015 at the COP21 in Paris and to take effect from 2020.

This so called *Durban Platform for Enhanced Action* (ADP) has since then been the main focus for international climate policy development. It was in focus at the Rio+20 Meeting in 2012 on Sustainable Development where the document *The Future We Want* was the main document. At the COP 19 in Warsaw 2013 member states agreed to announce nationally determined contributions for the post-2020 period well in advance of the Paris COP. At the COP20 in Lima in 2014 work was done to elaborate the elements of the new global agreement. Most importantly rules on how all countries can submit contributions to the new agreement during the first quarter of 2015 were set. These Intended Nationally Determined Contributions (INDCs) will form the foundation for climate action post 2020 when the new agreement will take effect.

A most remarkable extra meeting, the UN Climate Summit, supported this process. On the 23rd of September 2014 the UN Secretary General Ban Ki-Moon gathered world leaders from government, finance, business, and civil society to New York with the intention to "ask these leaders to bring bold announcements and actions to the Summit that will reduce emissions, strengthen climate resilience, and mobilize political will for a meaningful legal agreement in 2015".

The meeting was supported by an enormously large manifestation, *Peoples Climate March*, on the streets of New York as a hundred thousand people marched to support the Climate meeting, together with similar manifestations in hundreds of cities around the world. New commitments, new ideas, and new financing for significant actions to address the challenge of climate change dominated the announcements made by more than 100 Heads of State and Government and leaders from the private sector and civil society. Most remarkable is that several institutional investors, including large asset managers and pension funds, announced that they will reduce the carbon footprint of US$ 100 billion of institutional investments by *divesting in fossil fuel companies*. We may have come to a stage where investing in a fossil fuel based economy is a risk rather than an asset. May be this is a precondition for success in combatting climate change. (http://www.un.org/climatechange/summit/).

It appears that finally the forces supporting a global climate agreement finally will be the stronger and the result will come in Paris in 2015.

Chapter 10 sources:

This chapter includes excerpts from Chapter 23 of the book *Environmental Science* of the Baltic University Programme Authored by Bo Kjellén, http://www.balticuniv.uu.se/index.php/boll-online-library#environmental-science; as well as excerpts from Chapters 10 and 11 in the book *Environmental Management volume 1 Environmental Policy - Legal and Economic Instruments* of the Baltic University Programme authored by Børge Klemmensen and Lars Rydén. http://www.balticuniv.uu.se/index.php/boll-online-library/826-em-1-environmental-policy-legal-and-economic-instruments-. It also includes information from the European Union websites on Climate Policies http://ec.europa.eu/clima/policies/brief/eu/

A series of excerpts from the UNFCCC COPs websites have also been used.

Chapter 11
Uzbek national policies to combat climate changes

11.1. Implementing the international conventions

In view of the escalating necessity of the world community to counteract a coming climate crisis, the Republic of Uzbekistan acts as an active participant of several international conventions, agreements and projects. In addition, the struggle against global climate change also offers business opportunities. It is also obvious that a climate change policy is a necessary component of a strategy of sustainable development and economic growth.

The Republic of Uzbekistan signed the UN Framework Convention on Climate Change (UNFCCC) in 1993 and approved the Kyoto Protocol in 1999. Within the limits of the Kyoto Protocol a market for trading emission quotas of GHG has already formed. The trade in emission rights is an element of the Clean Development Mechanism (CDM) of the Kyoto Protocol and thus can at least partly be financed as *Green technologies* in the Protocol. The Executive Council of UNFCCC has so far registered 14 such projects from the Republic Uzbekistan. Uzbekistan has a leading position not only among countries of Eastern and Central Europe and the CIS, but also universally. It is on the 8th place in the annual reduction of emissions and 19th place in the world by number of registered Green technologies projects.

Several projects have been carried out or are in the planning. One project concerns *Uzbekneftegaz* recycling of casing-head gases to reduce the volumes of gases which is burnt and thus gives rise to CO_2 emissions, on the deposit Ko‘kdumaloq. Two more projects, also at *Ko‘kdumaloq* on the recycling of natural gas and gas condensate, have been carried out. Feasibility reports have been written for two more investment projects, now confirmed by the government, on recycling casing-head gases on deposits in Northern SHo‘rton, Garmiston, Qumchi, and SHakarbuloq. The average annual volume of utilized gas in these areas is 690 million m^3. Further projects at Southern Kemachi, Kruk, western Kruk, Northern O‘rtabuloq, and Umid concern an average annual volume of the utilized gas of 934 million m^3. These projects are included in the Program About priorities of development of the industry of the Republic Uzbekistan in 2011-2015.

Uzbekistan signed the United Nations Convention to Combat Desertification (UNCCD) in 1994 and ratified it in 1995. It is effective since 1996. It is of course of special significance in Uzbekistan, since the country includes 60% desert. Desertification is understood as degradation of the soil in arid, semi-arid and dry sub-humid areas as a result of action of various factors, including climate change and human activities.

Since 1995, Uzbekistan is also a party to the Convention on Biological Diversity (CBD). Present projects address the country's efforts in implementing the CBD Strategic Plan during 2011-2020 at the national level. Projects aimed at developing measurable goals in biodiversity conservation and its sustainable use, to ensure the preservation of products and services provided by ecosystems, and addressing the challenges and opportunities for adaptation and strengthening of resilience of ecosystems to climate change.

11.2 The laws of Uzbekistan support Climate Change policy

The implementation of the UN conventions on climate change, desertification and biodiversity are backed up by the laws of Uzbekistan.

To implement the Proceeding from the requirements UNCED, decisions regarding problems in the field of Climate Change (CC), climate risk management (CRM) and struggle against desertification, several provisions of the *Law «About Nature Protection»* can be used: Maintenance of the population with the current and emergency information on changes in a surrounding environment and forecasts of its condition (item 30); Ecological insurance (item 36); Provision provides «insurance … on a case of the damage which has grown out of pollution of the surrounding environment and deterioration of natural resources».

The law *About water and water use* can be applied for the regulation of CC, CRM and the struggle against desertification. This law include provisions on establishing water intake limits; providing planning of water use and water consumption for needs of agriculture; Realization of urgent measures under the prevention and liquidation of the acts of nature caused by waters harmful influence; fixing the requirement, that at planning of use of waters the data of state water cadastre (SWC), water economic balances (WEB), and schemes of complex use and protection of waters (CUPW).

The laws *About protection of atmospheric air, About protection and flora use, About protection and use of fauna* can also be applied for the regulation of CC, CRM and the struggle against desertification.

The Parliament of the Republic of Uzbekistan has enacted over one hundred laws and decrees on environmental protection and the use of natural resources and energy. These refer to Sustainable Use of Energy; Nature Protection; Water and Water Use; and the Protection of Air.

Interventions aiming to reform macroeconomic policies, reorganize the energy market and the pricing structure, strengthen the commercial and legal framework of investments, and formulate national strategies of energy conservation and introduction of effective technologies into economic sectors and the social sector are required in future.

11. 3 Implementing the UN Convention on desertification

Uzbekistan State Hydrometeorolgical Institute has, in partnership with UNEP, developed a National program to combat desertification to meet the obligations of the convention on desertification. This convention, as opposed to UNFCCC and the Kyoto Protocol, is closest to problems CC, CRM and the struggle against desertification. In particular, the Convention obliges its Parties to:

- “develop a strategy and to establish priorities, within the limits of plans and strategy … on struggle against desertification and softening of consequences of a drought (item 5-b),
- “properly strengthen «corresponding existing laws», and in cases of absence of those - «by means of the edition of new laws and formation of a long-term policy and programs of actions (item 5-e).
- “encourage coordination of activity for achievement of its purposes, and directly names UNCED and Biodiversity Convention (BC) (item 8-1).

The largest attention in the Convention is given to the possible creation, formation and informing the public. This should include full participation of local population at all levels, especially women and youth, in cooperation with non-governmental and local organisations. It should aim to propagate the corresponding knowledge and experience; adaptation of ecologically comprehensible technology and traditional methods of conducting agriculture to modern social and economic conditions. It should also prepare the demanded administrative personnel and the employees responsible for gathering and the analysis of data, for distribution and use of the information, concerning the early prevention of arid conditions, etc.

The acts which give a possibility to combat desertification and arid conditions in Uzbekistan are the laws «About Nature Protection», «About water and to water use», «About protection of atmospheric air», «About protection and flora use», «About protection and fauna use», «About protected natural territories», «About Forest» (from April, 15th, 1999) and others.

11.4 National participation in the UNFCCC

The First National Communication of the Republic of Uzbekistan on the implementation of the UN Framework Convention on Climate Change was presented at the Fifth Conference of Parties (COP) to the Convention in Bonn in 1999.

The key element in the First National Communication was a register of gases having direct and indirect greenhouse effect that do not fall under the Montreal Protocol. The register was compiled in conformity with the 1996 Revised Handbook of the Intergovernmental Panel on Climate Change (IPCC). The national register contained an inventory of greenhouse gas sources (GHG) and their emission in the two benchmark years 1990 and 1994. An essential component of the National Communication was a long-term forecast of GHG emission for the period until 2010, guidelines for activities aiming to reduce GHG emission, and a list of interventions in this sector.

The Second National Communication of the Republic of Uzbekistan on the implementation of the UN Framework Convention on Climate Change was published in 2008.

Climate data are used in the construction, design, and planning of municipal economy; in transport sector, oil and gas industry, in hardware facilities operation, planning of the light and food industry production process, etc.

The task of assessment of the economic sectors vulnerability to Climate Change is complicated and complex as the Climate Change leads to a set of both favourable and unfavourable impacts on economic spheres that are frequently interrelated with each other. Climate Change impact on economic sectors is considered by the normative documents that defines standard climate parameters or various types of zoning. By evaluating how Climate Change impacts these parameters, it is possible to identify Climate Change related trends in economic sectors.

Construction and communal economy design and planning use such data as duration of the cold (heating) and hot seasons, temperature of the coldest and hottest days, number of days with the temperature over and below a specified criteria etc. In the oil and gas industry and transportation sector climatic zones as well as actual temperatures are applied for recording of climatic factor.

11.5 Capacity Building to Assess Technological Requirements

The institutional structure of the national system for Convention implementation in Uzbekistan and collaboration with international agencies was presented in the First National Communication of the Republic of Uzbekistan on UNFCCC.

In 2000 the Government of Uzbekistan placed direct responsibility for implementing the UNFCCC under the Chief Administration for Hydrometeorological Institute of the Republic of Uzbekistan (Glavhydromet). A relevant Secretariat has been established at Glavhydromet as a permanent body vested with the further implementation of national commitments of Uzbekistan under the Convention.

The scheme of co-ordination of national implementing agencies and their collaboration with international institutions is presented in Fig. 11.1 In the course of implementation of the UNDP/GEF Project 'Uzbekistan: Country Study on Climate Change, Phase 2' teams of national experts have been formed to identify priority requirements of economic sectors in Uzbekistan aiming to reduce GHG emission and mitigate the negative impact of climate change as well as to analyse climatic vulnerability and design interventions of adaptation to climate change. One of the tasks addressed by the experts was to look for solutions of specific sector problems related to technology transfer. National expert teams were comprised of leading professionals from various sectors and departments well versed in the issues of technological modernization and energy conservation in electric power engineering, oil and gas sector, construction materials industry, municipal thermal power engineering, forestry and agriculture as well as research institutions working in the areas of climate studies, hydrology, agro-climatology and environmental pollution monitoring.

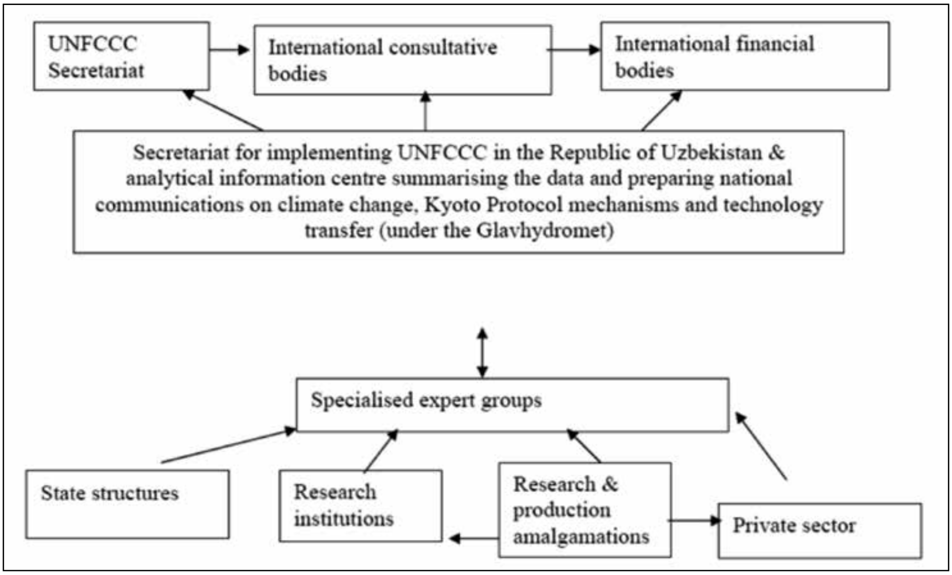

Figure 11.1 Scheme of collaboration of national and international institutions

Thus, implementation of the Project "Uzbekistan: Country Study on Climate Change, Phase 2' helped to improve the qualifications of national experts in addition to available experts on GHG inventory, adaptation interventions and mitigation of the impact of climate change. It should be noted that the development of the institutional structure is largely determined by acceleration of technology transfer under the UNFCCC and the Kyoto Protocol. This is explained by the fact that the development of the logistical capacity in technology transfer is viewed in Uzbekistan within the context of establishment of a more flexible and constructive body for implementing the tasks and meeting commitments of both the Convention itself and the Kyoto Protocol. In order to meet these commitments and introduce better technologies a national interdepartmental body should be established, which will coordinate and manage the solution of these issues. Such a body may be established in the initial phase with the support of international financial institutions such as the GEF (Global Environmental Facility) and the UNDP.

The establishment of such a body will help co-ordinate activities of all line national agencies and promote an effective transfer, dissemination and application of environmentally friendly technologies.

11.6 Building Information Capacity

Although removal of information barriers is an important factor in the transfer and replication of more advanced technologies, at present Uzbekistan lacks a system of selection and dissemination of information on environmentally friendly technologies. This is only done within the framework of projects on climate change. The leading role belongs to Glavhydromet, which has access to the international climatic and technological databases via Internet and other means of communication. Besides that, it has close contacts with relevant governmental, research and engineering agencies in this area.

At the same time, higher public awareness of energy conservation policies using information systems and electronic mass media may have a significant effect on energy conservation in the country.

In order to build the capacity for technology information dissemination in Uzbekistan the establishment of well-developed information systems and their connection to regional and international networks through specialised agencies and information companies is required. Equally important is to raise public awareness of climate change issues, sustainable use of fuel and energy resources, and a wider use of renewable energy sources.

11.7 Barriers to Introducing New Technologies

The transfer of many types of technology requires high qualifications from a wide range of managers as well as engineering and production specialists. They should have the correct idea of the national economic and environmental conditions, be able to assess technological requirements, know the possibilities and peculiarities of technology transfer, and be able to arrange exchange of the required data among national producers and international donors.

Unfortunately, most city and provincial khokimiyats lack skilled experts specialising in climate change and technology transfer.

In the course of making an inventory and preparing the First National Communication as well as in connection with the implementation of the energy efficiency project in municipal heat supply, a number of training workshops and courses on various aspects of climate change, assessment of vulnerability of natural climatic resources and economic peculiarities of environmental projects were conducted, which were attended by young experts from various public institutions. However, when project implementation should be done the expert teams are usually disbanded. Apart from that, skilled professionals tend to leave their positions in the public sector for private companies because of low salaries. For this reason human capacity development in Uzbekistan encounters difficulties. Thus, targeted activities aiming to develop human capacity, improve the educational system, build research and technical capacity of educational establishments, improve their curricula and promote regional and international co-operation are of high priority in Uzbekistan.

The transfer of technologies in Uzbekistan may encounter logistical, legal, social, psychological, economic, financial, technological and information barriers. This leads to a limited capability to assimilate innovations. This will require additional analysis in each specific case.

At the same time, Uzbekistan has a large potential for economically effective interventions to mitigate the impact of climate change. Barriers of a general nature identified in the course of analysis are listed in Table 11.1.

11.8 Mitigation, Adaptation, and National Development Plans

The main conditions for mainstreaming Climate Change into national development planning are

- to prioritize needs so that adaptation and mitigation measures are comparable with national development priorities
- to consider risks associated with Climate Change

According to the assessment study, the first condition is in place in Uzbekistan; the second condition is so far implemented 'unconsciously' through a 'forced' adaptation to water and land resources deficits, irrigated lands and natural pasture degradation, and high rates of population growth.

The urgent undertaking of mitigation measures is a vital necessity given that currently the economy of the country is a high energy consuming process.

Despite being an energy self-sufficient country, Uzbekistan still has many problems that impact (directly or indirectly) the energy self-sufficiency and entail an increase in greenhouse gases emissions. More than 30% of equipment in the energy sector is out-of-date and of low efficiency. The high losses in current systems of energy production, transportation, transmission and distribution to consumers result in high levels of fuel cost per unit and greenhouse gases emissions.

Therefore, the goal of intensive industrial development can be achieved only by improving the current situation in the energy sector. Reconstruction and modernization of the existing energy production facilities, introduction of new tech-

Table 11.1 Barriers to technology transfer and ways to remove them.

#	Barriers	Possible solutions
1	Economic situation: • limited public resources for purchasing equipment abroad • lack of national currency conversions • state subsidies to energy consumption • low paying capacity of enterprises & population • non-involvement of national banks in technology transfer	• extension of grants & easy credits; expansion of operational programmes of multilateral financing institutions • improvement of the economic situation in the country; acquisition of government permissions on currency operations • inclusion of the actual cost of energy resources into the national financial turnover • raising public awareness and introducing energy conservation interventions • involvement of national banks in project formulation and implementation
2	Peculiarities of the fuel and energy sector: • lack of national energy consumption standards • lack of domestic production of power engineering equipment • low prices on organic fuel	• formulation of standards and norms of energy resources consumption and technological equipment efficiency • development of joint production enterprises • formulation of pricing policies reflecting the actual costs of energy supply; introduction of taxes on GHG emission
3	Lack of awareness: • lack of access to technological information • low public awareness of the necessity of energy conservation and emission reduction • lack of information among investors on the potential technology market in Uzbekistan	• development of a system of specialised information services • intensification of public awareness interventions related to climate change issues as well as mitigation of the impact of and adaption to climate change • in-depth assessment of the country's technological requirements and activities within the framework of the projects selected for specific investors; development of consulting services in enterpreneurial activity
4	Lack of skilledprofessionals in energy conservation and efficiency	• targeted development of human capacity and training of specialists for the public and private sectors

nologies are to be the principal measures that will allow more effective fuel utilization. That is why a new assessment of the technology should be implemented with use of state-of-the-art approaches and detailed economic analysis of costs and benefits of introducing new technologies in connection with the national sustainable development policy.

A new technological need assessment will facilitate making appropriate decisions with respect to the mitigation measures and policy, accelerate technology transfer and proper legislation development in the energy and non-energy sectors and will serve as a basis for renovation of the National Strategy of Greenhouse Gases Emissions.

Overall energy saving capacity in the Republic is estimated to be 23 million tons of reference fuel per year, realization of which will enable the reduction of greenhouse gas emissions more than by 40 million tons in CO_2 equivalent every year. This has allowed Uzbekistan as a Party not included in Annex I, to use the Clean Development Mechanism to support its own efforts to increase fuel consumption efficiency and undertake Climate Change mitigation activities.

Launching the activities under the CDM, namely, the establishment of the Interdepartmental Council and CDM Designated National Authority (DNA), conduction of several training programmes were a powerful incentive for the development of the mitigation measures. The projects containing mitigation measures that were submitted for funding under the CDM have been already developed within the sectorial programs in the Republic. CDM has mainstreamed Climate Change mitigation activity in Uzbekistan.

Therefore, to stimulate activity on adaptation to Climate Change, similar efforts should be undertaken, especially on strengthening capacity. At present, the main barriers to commencing this activity are the fragmented actions, lack of coordination at the national level, lack of funding and the fact, that many decision makers are unfamiliar with Climate Change problem and the methods of adaptation to its negative consequences.

To start the mainstreaming process, that is, to create a united flow of actions on Climate Change adaptation in the country, it is necessary to build capacity at all levels:

- by increasing awareness of Climate Change issues amongst decision makers and in the agencies directly related to socio-economic development, environment protection, health etc.;
- by creating a non-departmental coordination body charged with the responsibility for addressing adaptation issues in order to strengthen coordination and work out joint strategies and measures;

- by involving the agencies/organizations as well private business;
- by improving the legislative-regulatory process to support adaptation measures, especially in respect of effective land and water consumption;
- by increasing public awareness on the vital necessity of undertaking adaptation measures, rational land and water resources usage by waging public awareness campaigns on a continuous basis.

The main barriers and constraints to the above activities are as follows:
- all adaptation measures implemented in the country are economically forced in so far Climate Change problem has low priority;
- lack of financial assistance/support from donors for strengthening the institutional structure for better impact assessment, analysis of adaptation measures and support of adaptation actions;
- lack of expertise working in the adaptation area and insufficient awareness at all levels;
- uncertainty of the climate predictions in time and space – the assessments differentiated by territory and time are required for economic evaluation of adaptation measures and making appropriate decisions;
- lack of differentiated social and economic data, methods for assessing the impact and developing and undertaking the relevant measures at local levels; these measures being successful would show the public the benefits of adaptation measures and encourage the introduction of the adaptation technologies, thereby, attracting small business.

To summarize the above, there is a necessity for designing a project on adaptation capacity building with final/fundamental goal being to establish an Expert Unit for development of adaptation measures. There is also a necessity to design and implement a project on assessment of Climate Change impact on social and economic situation in the country with a focus on the most vulnerable social and economic sectors.

At the international level, it is necessary to establish the leverages for "encouraging" adaptation activities in the developing countries, possibly through training programmes on adaptation projects development with inclusion of the economic effectiveness issues and the methods of economic evaluation; ad hoc workshops for decision makers; demonstration projects on adaptation technologies introduction, etc.

11.9 Mitigation programmes

A National Strategy on Greenhouse Gas Emissions Reduction was approved in 2000. Here general statements and requirements towards the current national policy for mitigation measures are presented. The strategy should, however, be updated to take into account new needs, priorities, levels of technology development and effectiveness of the measures for reducing GHG emissions. All these enable reduced emissions at lower cost. The need for an energy efficiency and conservation strategy is acknowledged. Today we have both high levels of waste in the current systems for energy distribution and consumption, and a need to place the sector on a more market-based footing.

A *National Programme on Renewable Energy Sources Use* has also been developed. Uzbekistan possesses a significant potential for renewables and the programme recommends projects on utilization of solar power energy, small hydro power energy, use of wind power, and biomass energy. Solar energy use for supplying households and governmental agencies with hot water and electricity is considered as the most realistic.

The *National Energy Programme* and the *National Energy Saving Programme* have both been developed but not adopted; they are presently revised to take into account modern opportunities and needs in the following directions:

- enhancement of the legislative and regulatory basis for rational energy and natural resources use;
- preservation of energy self-sufficiency through developing domestic energy resources;
- partial decentralization of energy production sector;
- mitigation of unfavourable energy sector impact on environment through increases in performance index and the ratio of renewable energy sources to total energy use;
- increase in efficiency of oil processing and quality of oil products;
- persistent development of coal industry and the attraction of investments to increase effectiveness of coal production; and
- restructuring of the public electricity and heat production sector; modernization of central heating infrastructure and development of renewables for the purposes of heating and hot water supply.

At the present time the *Integrated Programme of Technical Modernization and Development of Leading Industrie*s is under way, and contains the specific measures for development, technical re-equipment and modernization of the key industries (energy, oil and gas industry, gold production and chemical industry, ferrous and non-ferrous metallurgy, construction materials) and attraction of foreign funds to these industries.

11.10 Adaptation programmes

The key problems caused by Climate Change in Uzbekistan are many: salinization and degradation of agricultural lands; scarcity and pollution of water resources, insufficient supply of safe drinking water, loss in biodiversity of all ecosystems, desertification, contamination of food, and air contamination in big cities and industrial centres. A number of programmes and projects addressing these problems are being developed in Uzbekistan. They are included in the "Strategy for Improvement of Living Standards of the People of Uzbekistan 2005-2010", which plays an important role in increasing adaptation capacity.

The *Land Reclamation Programme for 2008-2012* addresses the problem of construction and reconstruction of main, inter-district and on-farm collectors with the total length of more than 3,500 km and more than one thousand ameliorative wells, reconstruction of the drainage system with total length of 7 600 km. Provision of modern equipment to firms of contractors and water management organizations via leasing and the Composite List of Priority Investment Projects includes projects on rational water consumption and increase in water supply.

The *Programme of Action on Environmental Protection for 2008-2012* envisages resettlement of the people living in landslide, mudflow and flood prone areas. Currently it is necessary to prepare the recommendations on risk reduction for planning organizations and decision makers, to expand the specialized monitoring of snow avalanches, mudflows and high mountain lakes prone to bursting and also to improve the methods of disaster forecasting.

The *National Strategy and Action Plan for Conservation of Biodiversity* envisages the creation of a number of protected natural territories and centres on breeding animals and plants that are about to become extinct. The commitments of Uzbekistan on the fulfilment of the Convention on Biological Diversity include development of measures stimulating protection and sustainable development of the components of biodiversity. The most important task for the future is identification and monitoring of the most important components of biodiversity – species and ecosystems under threat of extinction as a result of severe anthropogenic impact.

The *Programme of Action on Improvement of Ecological and Socio-Economic Situation in the Aral Sea Basin (2003-2010)* anticipates such measures as the development of a legislative base to support water supply, improvement of monitoring system, scientific research, implementation of the adaptation related projects, that is reconstruction of irrigation and drainage systems, creation of managed lake systems, expanding access of the population living on the vulnerable territories to clean potable water etc.

The project Restoring and creating of forests on the Jambay and Zaamin forest farms prepared within the framework of the Second National Communication, can serve as a demonstration project in forestry.

Programme on public health protection and prevention for 2004-2008 aims at preventing dangerous diseases (HIV, tuberculosis, malaria), improvement of nutrition and provision of modern medical equipment as well as medical and sanitary care to rural population. The access of urban and rural population to clean potable water supplies and sanitation is being expanded, Measures are being undertaken on the reconstruction and expanding water supply systems in many settlements in the Republic of Karakalpakstan, Khorezm, Samarkand, Navoi and Bukhara provinces and in Tashkent City.

Such economic sectors as oil and gas sector, transport, construction and municipal service being the sources of greenhouse gases, in turn, are affected by Climate Change impact and also need adaptation measures. For instance, the rise in temperature leads to an increase in natural losses and making errors during the receipt, transportation, storage and distribution of oil products. The rise in temperature also leads to increased energy consumption due to air-conditioning, as new urban islands of heat can possibly appear, and heat emergency situations become more frequent. Developing and undertaking adaptation measures in the oil and gas sector, transport, construction and municipal sector can be considered as ideas for project proposals but nothing is being done.

The *Regional Environmental Action Plan for Central Asia (REAPCA*) addresses air and water pollution; land degradation; waste management and degradation of mountain ecosystems. Regional Cooperation for Sustainable Mountain Development in Central Asia addresses the organization and coordination of integrated research of the mountain territories based on the monitoring system data. For this purpose a Regional Mountain Centre in Central Asia was established.

As previous experience has shown, not all measures come to the stage of implementation. The success rate of regional programmes stems from insufficient coordination and conflict of interests between the countries at the very early stages of the regional programmes development. Within the framework of the national capacity building for implementation of three global environmental conventions (UNFCCC, CCD and CBD), project proposals were prepared on development of the programme for sustainable development and rational use of deserted pastures and on the development of desertification and drought monitoring system and computer information system for early warning against drought.

Also many financial and organizational barriers hinder the integration of adaptation measures into national development planning. These include incomplete realization of developed and approved national development plans; lack of long-term targeted development programmes in the agricultural sector; weak regional cooperation in trans boundary water use; absence of the indicators of the national strategy of sustainable development for long-term prospect (main indicators have been developed up to 2010); and lack of targeted research in adaptation and mitigation, especially in terms of economic aspects, hampers decision making and attraction of investments.

11.11 A national strategy of Sustainable Development and Climate Change

At the present time, the programmes and plans promoting adaptation and mitigation, are fragmentary and lack financial support. International funds will be necessary support. All the above listed activities, under implementation or prepared for implementation, will not solve all existing problems. An integrated approach and consolidation of efforts is required. We need a National Action Plan on Climate Change, which would include both adaptation to Climate Change and mitigation of its causes, to integrate all efforts undertaken by the country to achieve the general goal: to reduce the risk of negative consequences for different socio-economic sectors. In order to persuade politicians to take all above indicated factors into account in the long-term planning, these factors should be scientifically substantiated.

The national strategy of sustainable development includes the goals of social, economic and environmental policy. To gradually achieve these goals we need to

- ensure high living standards of the population under the conditions of sustainable social and economic growth based on the structural and institutional reforms;
- create a socially-oriented market economy in the constitutional state, that is integrate the world economic system;
- overcome the consequences of the Aral Sea crisis and improve the strained ecological situation in other territories of the Republic;
- conserve and improve the environment; and
- rationalise land use and water consumption and implement effective utilization of other natural resources with the purpose of their conservation for future generations.

The measures of forced adaptation and mitigation developed and implemented in Uzbekistan are of a multilateral nature. They include relevant technological application, enhancement of management system and increased public awareness. All of them promote sustainable development, increased resilience to negative Climate Change consequences, contribute to reduction of greenhouse gases emissions and facilitate implementation of the National programmes. However, the majority of them remain at the stage of planning and only a few of them have come to the stage of implementation.

For mainstreaming all Climate Change related activities undertaken or planned in the country should be identified and coordinated. The projects containing these activities, which have not been adopted by the Government should be comprehensively analysed and revised if necessary, and then submitted for approval. The programmes that are being implemented and developed should be reinforced and/or revised in order to be in line with the National strategy of sustainable development. The revision of the programmes, their integration or abolishment should be implemented regularly taking into consideration new possibilities, which arise and the priority needs of the country. All of this can be addressed within the project "Integration of vulnerability and adaptation to Climate Change into sustainable development policy planning and implementation."

A peculiarity of the country is the absence of trade-offs between development priorities and the actions required to deal with Climate Change. The Second National Communication has shown that the adaptation priorities including management of risks associated with Climate Change overlap with the national development priorities including the policy and actions on increased living standards of the population and sectorial development programs.

In the water recourses, agricultural, ecosystems and public health sectors the necessity of undertaking urgent measures is obvious, as anthropogenic impact on these sectors has reached a critical point. The Government of Uzbekistan has passed new decrees and regulations including urgent measures to stabilize the ecological situation and line agencies have prepared the sectorial, inter-sectorial and national development programs and plans.

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Chapter 12
Policy Instruments to implement Climate Actions

12.1 Policy instruments

When states or regional and local authorities have adopted a policy to reduce the emissions of greenhouse gases the work to implement this starts. Some measure to achieve the reductions may be obvious. State-owned facilities such as power plants may be changed to use less fossil fuels. The conditions for import of fossil fuels may be changed. But in general very many other actors than the state or authorities themselves need to be involved in the changes to make them happen. Authorities thus need means to influence these other actors, which may be the citizens, but also the private sector, companies, investors, and other authorities. These means are the policy instruments.

Policy instruments are tools used by the policy-makers in their attempts to alter society. They address societal processes to change them according to the intention of their policies. Technically, policy instruments are a set of techniques used by the executive power of a country, the governmental or local and regional authorities. Public policy instruments are generally divided into three classes:

- regulations,
- economic means, and
- information/moral suasion.

Regulation, also called command-and-control instruments, comprises a range of direct regulations such as standards, bans, permits, zoning, use restrictions, etc. Direct regulations are institutional measures aimed at directly influencing the environmental performance of polluters by regulating processes or products used, by abandoning or limiting the discharge of certain pollutants, and/or by restricting activities to certain times, areas, etc. Within the OECD countries, regulation has traditionally been the most commonly used policy instrument in environmental protection.

The second approach is the application of *economic instruments* to create environmentally appropriate behaviour. The main economic instruments could be categorized as:

- charges and taxes (effluent charges, product charges, tax differentiation),
- subsidies,
- deposit-refund systems,
- market creation (emissions trading, liability), and
- financial enforcement incentives (non-compliance fines, performance bonds).

Economic policy instruments involve either the handing out or the taking away of material resources. In other words, economic instruments make it cheaper or more expensive to pursue certain actions.

The third approach is *information* and moral suasion aiming at changing an agent's behaviour on a voluntary basis. This could be accomplished via education, transfer of knowledge, training, persuasion, recommendation, and negotiation. One important instrument in this category is voluntary agreements between governmental agencies and private enterprises. This type of policy instrument is likely to gain importance in the future.

Each type of policy instrument has its strengths and weaknesses. Regulations are most suited to effectively prevent hazards and irreversible effects. Furthermore, regulations frequently provide polluters with incentives to develop technology. Provided that there is effective enforcement, these instruments are able to achieve the desired environmental goals. The point is that enforcement is often problematic, because of the great number of control, administrative requirements, staff, legal procedures in case of non-compliance, and so on. A second drawback is that command-and-control instruments tend to become weakened by bargaining and negotiation between representatives of the polluters and the environmental authorities. Thirdly, regulations are expensive for society in that they are often not efficient in economic terms.

Economic instruments, such as environmental taxes and charges, minimize total abatement costs in that they constitute a permanent incentive to reduce pollution. Furthermore, they provide a source of revenue. However, a number of problems and uncertainties arise in connection with the use of these instruments. First of all, the rate of charges and taxes are not always set at a level that assures effectiveness in environmental terms. Secondly, charges and taxes may be inappropriate for controlling hazardous substances if the time lag is too long before use of the substances is curtailed. The best way to control these substances is by means of direct regulations and bans. Thirdly, there are distributive implications which must be taken into consideration when economic instruments are used. For instance, energy taxes may have negative effects on poorer households.

Voluntary agreements also have their pros and cons. On the one hand they offer flexibility and transparency. On the other hand, control by environmental authorities over actual implementation is minimal.

In real life policy instruments tend to come in packages. For example, regulations are almost always followed by some kind of information. Moreover, the application of policy instruments tend to require some kind of organisational arrangements, such as authorities, legal bodies, etc. The existing organisation partly determines what is possible to do.

The choice of policy instruments is also connected to an "administrative culture" that is quite different if the command and control or information and suasion dominate. What we see is that the shift towards prevention approaches and sustainability requires that governments use instruments such as negotiation with stakeholders and joint agreements and action plans to a much larger extent than traditionally, both within the governmental offices, that is, between sectorial ministries, and between authorities and other stakeholders in society. This is even more apparent on the local level, where often the municipalities are not economically strong enough to implement a policy and thus need to agree with other actors, especially the business sector, to achieve practical results.

12.2 The policy-makers: From politicians to citizen organisations

In a parliamentarian democracy *parliaments* have the authority to legislate, tax the people, and appoint the government. It is the parliament that constitutes the core of policy-making as the elected members of parliament shape the policy of the country, including environmental policy.

The 1970s saw a considerable increase in interest and concern for environmental issues in society. As a result several political parties with environmental protection as the major political programme were created, the Green parties. In the beginning these were small and were not elected to the parliament. Still they were influential and their influence is still increasing. Later a number of EU countries had green parties in the parliaments. In the 1980s the German Green party was taking a place in the government as the first green party to achieve this. In Sweden this did not happen until 2014.

The *government* has the task to execute and implement the policies decided by the parliament. This is carried out by the responsible minister and his or her ministry. It was not until the 1980s that the environment was given its own portfolio, a special minister. In Sweden, e.g., the Ministry of Environment and

Energy was established in 1986. Since the new government in 2014 Sweden has a Ministry of Environment and Climate.

The ministries establish their special agencies, *authorities*, with special tasks within a defined area. The Environmental Protection Agencies (EPA) were established in many countries after the Stockholm conference for the environment in 1972, in some countries even before that. The EPAs play crucial roles for protecting the environment by providing scientific research, co-ordinating comprehensive point-source abatement programmes, and controlling separate companies and prosecuting those who do not comply. Today EPAs are present in almost all industrialised countries.

The profile of EPAs typically from the 1980s and 1990s focus increasingly on research and the provision of information. The agencies also perform multi-year assessments of the environmental situation, reports which provide the background for action programmes which are developed on major areas of concern, including climate protection. Also the new EU member states in Central and Eastern Europe soon established their own EPAs. The European Union European Environmental Agency, EEA, with location in Copenhagen, is the main actor for climate protection measures within the EU.

The conditions and the prerequisites for *local and regional authorities* vary greatly. The Nordic countries have a long tradition of local self-government. Municipalities and counties are financially strong and they have already carried out investments in environmental infrastructure, such as sewage treatment plants, district heating and waste management. Municipalities in the Nordic countries are responsible for environmental issues on local level. The counties are solely responsible for regional environmental issues. Regardless of the range of responsibilities resting with municipalities in different countries, one thing they have in common is that they work close to citizens and close to the problems and needs within their territory.

In this landscape of actors not only the authorities have a place. Also *NGOs, citizens' organisations*, such as WWF or Nature Protection Associations, are very active. They influence the public policy by pushing authorities to improve their policies, making campaigns, and issuing reports. The situation and roles of NGOs are very different in different countries. In general they are well respected and are important with high membership numbers in Western Europe and e.g. the USA. This also means they have a fairly good economy and have the resources to establish their own agenda and e.g. projects for investigation of climate or other environmental effects.

Media has a key role in a democratic society as it makes public the policies of authorities, and provide an arena to discuss and criticises this policy. Media in the best case also have an important role in informing and educating the readers as new information on the environment becomes available. They also inform about events and actions taken in other countries and areas of the world and effects of e.g. climate change. It is up to the readers then to draw conclusions as to what should happen in their own country.

Science is an important actor as basic facts on climate change comes from research. Often it is concerned with general knowledge and then researchers may be located anywhere in the world, but it is equally important to get to know what is happening in each country for which local scientific institutions have a responsibility.

Finally the individual citizens have a role in this landscape of policy implementation. Individuals choose how to heat their homes, how to travel, how to consume, how to eat and so forth, each of these actions have an impact on GHG emissions and climate change. Individuals may also be politically active and at least they are so when they vote for political representations in a democracy. The choice of the individual is dependent on regulations, prices and information and thus policy instruments reach out to the citizens.

12.3 Regulation – three cases

An important part of the implementation process is the process of legal decisions on permits to conduct an activity that is (potentially) harmful to the environment, and the following control that decisions and in general legal regulations are respected.

The decisions on permits are taken either by the local authorities or by special courts. The supervision of environmental performance is often divided between authorities, and often very different in different countries. The local and regional authorities, the environmental protection agencies or special authorities are in charge for different areas. Very often the local authorities both on the county and municipal level, are responsible for various kinds of control, for example for permits for industries and, water management, agriculture and so on.

There is in some countries a discussion on how to balance the need for inspection and control with information/consulting. Companies and other organisations for which environmental regulations importantly influence their activities may often fail to follow these regulations only because of lacking competence. The controlling authorities, hopefully with much larger knowledge and experience, have in this situation a possibility to help in many ways: monitoring schemes, proper changes in the production processes, needed investments, etc. Small companies that do not have a special person responsible for environmental matters especially need help. A consulting function is often a very good way to improve performance and may not necessarily prevent the inspection function.

The number of laws and regulations related to emission of GHG and in particular CO_2 is vast in many countries. Here we will only give as example a three cases from the European Union. It should be noted that the EU Directives should be implemented in the national legislation of all member states before a given time period. The three cases refers to co-generation power plants, energy performance of buildings and CO_2 emissions from cars and vans.

Cogeneration. Directive 2004/8/EC of the European Parliament on the promotion of cogeneration says that Member States must ensure that the origin of electricity produced from high-efficiency cogeneration can be guaranteed according to objective, transparent and non-discriminatory criteria laid down by each Member State. Member States must ensure that the guarantee of origin of the electricity enables producers to demonstrate that the electricity they sell is produced from high-efficiency cogeneration.

Cogeneration is a technique allowing the production of heat and electricity in a single process. There is considerable unexploited potential for cogeneration in the Member States. Moreover cogeneration reduces losses on the electrical grid because cogeneration installations are usually closer to the consumption point. Electricity/heat cogeneration installations can achieve energy efficiency levels of around 90%. Electricity production from cogeneration accounted for 11% of total electricity production in the EU in 1998. The development of cogeneration could avoid the emission of 127 million tonnes of CO_2 in the EU in 2010 and 258 million tonnes in 2020.

There are already examples of regulatory developments in some Member States, such as Belgium (green certificates and cogeneration quotas), Spain (new decree on the sale of cogeneration electricity) or Germany (new law on cogeneration).

Energy efficiency of buildings. Buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU. While new buildings generally need less than three to five litres of heating oil per square meter per year, older buildings consume about 25 litres on average. Some buildings even require up to 60 litres. Currently, about 35% of the EU's buildings are over 50 years old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5% to 6% and lower CO_2 emissions by about 5%.

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislation when it comes to reducing the energy consumption of buildings. Under the Energy Performance of Buildings Directive:

1) energy performance certificates are to be included in all advertisements for the sale or rental of buildings
2) EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect
3) all new buildings must be nearly zero energy buildings by 31 December 2020
4) EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.)
5) EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings

The Member States are responsible for drawing up the minimum standards. They will also ensure that the certification and inspection of buildings are carried out by qualified and independent personnel.

CO_2 emissions for cars and vans. Road transport contributes about one-fifth of the EU's total emissions of carbon dioxide, and increased by nearly 23% between 1990 and 2010; without the economic downturn growth could have been even bigger. Transport is the only major sector in the EU where greenhouse gas emissions are still rising. Light-duty vehicles - cars and vans - produce around 15% of the EU's emissions of CO_2.

Following up on a European Commission strategy adopted in 2007, the EU has put in place a comprehensive legal framework – COM/2007/0019 final – to reduce CO_2 emissions from new light duty vehicles. The legislation sets binding emission targets for new car and van fleets. As the automotive industry works towards meeting these targets, average emissions are falling each year.

For cars, manufacturers are obliged to ensure that their new car fleet does not emit more than an average of 130 grams of CO_2 per kilometre by 2015 and 95g by 2021. This compares with an average of almost 160g in 2007 and 132.2g in 2012. In terms of fuel consumption, the 2015 target is approximately equivalent to 5.6 litres per 100 km of petrol or 4.9 l/100 km of diesel. The 2021 target equates approximately to 4.1 l/100 km of petrol or 3.6 l/100 km of diesel.

For vans the mandatory target is 175 g CO_2/km by 2017 and 147g by 2020. This compares with an average of 203g in 2007 and 180.2g in 2012. In terms of fuel consumption, the 2017 target is approximately equivalent to 7.5 litres per

100 km of petrol or 6.6 l/100 km of diesel. The 2020 target equates approximately to 6.3 l/100 km of petrol or 5.5 l/100 km of diesel.

12.4 Using Economic Instruments to control climate impacts

Economic instruments are applied to change behaviour by economic incentives. There are several reasons to use economic instruments. First a good deal of the natural environment, such as the air, is a "common good", i.e. it has no owner. There is then a risk of exploitation. The state comes in to play the role of the owner to protect this common good. It may do this by charging a fee for its use. In other cases there is no possibility of charging for the use of a service, for example street lighting. But it costs something to provide it. In order to cover the costs the public has to collect a tax. Thirdly, and more importantly, environmental consequences of human activities are diffuse, wide-ranging, piece-meal and often dangerous only in the long term.

An example is the release of CO_2 from power generation causing a climate impact, but those suffering from the climate change are often far away from the polluter. Taxation may be a means of controlling the emission. But not only direct emissions of CO_2 may be controlled by economic instruments. For example nutrients are on the list since the production of especially nitrogen but also phosphorus has a considerable energy costs and typically fossil fuels are used in the production. Taxation may reduce emissions. Some of these impacts are regulated by regulatory policy instruments. In other cases an original economic approach is replaced by a regulatory one. An example is provided by agriculture. Here the use of fertilizer and pesticides were first regulated via a quota-system and by quality requirements or outright ban on certain products, but later taxation was used instead.

Often, regulatory policy instruments are not sufficient. There is a limit to in how much detail you can regulate an activity. The resources needed for detailed control would be impossible. This is especially true for diffuse sources and/or diffuse and long-term effects. Further, the direct regulation approach does not promote changes and innovation very well. In these cases economic instruments are more efficient.

The damaging effects of emissions exemplified above, remain external to the cost-calculations in companies and hence are not included in the prices of the products. This is where the economic instruments may play an important role. Such instruments can "internalize" the costs of this type of environmental impact by assigning a tax to each unit of exhaust, to each kg of fertilizer and to

Box 12.1 The German Energy Transition: Nuclear Phase-Out and Climate Protection
Energiewende – Atomausstieg und Klimaschutz

Energiewende is the transition by Germany to an energy portfolio dominated by renewable energy, energy efficiency and sustainable development. The final goal is the abolition of coal and other non-renewable energy sources.

Piecemeal measures often have only limited potential, so a timely implementation for this transition requires multiple approaches in parallel. Energy conservation and improvements in energy efficiency thus play a major role. An example of an effective energy conservation measure is improved insulation for buildings; an example of improved energy efficiency is cogeneration of heat and power. Smart electric meters can schedule energy consumption for times when electricity is available inexpensively. Households producing their own solar electricity thus can sell their surplus for a long-term guaranteed given price.

The Energiewende was started with the decision to out phase nuclear energy by the year 2021, and at the same time reduce emissions of greehouse gases.

each ton of CO_2. Such taxes will make the prices go up. Thereby they will create a dynamic (or continuous) incentive to innovate, to substitute or – at least – to try to reduce the use of the environmentally damaging products or methods to avoid paying or reduce the amount of the tax to be paid. There are, in other words, some "social costs" of human activities, which are not automatically brought "into the equation". The economic instruments, i.e. taxation, provide a way to internalize these costs into the private calculations. In this way private and social costs are added and thereby make the prices "tell the truth" about the environmental costs of a given commodity or service.

Quite a few environmental policy principles have been developed over the recent years and most notably since 1987, when the Brundtland Commission Report *Our common Future* was published. For the economic instruments, the polluter pays principle is the oldest, the most widely recognized principle, included in legislation across the globe. It was adopted in the 1st EU Environmental Action Programme back in 1973 and included in the EU Treaty of 1992/93, Art. 174/EC. It was also included in the UNCED-Rio-Declaration from 1992. The key issue is, what should be included to fulfil this principle, i.e. when can the polluter be said to have paid (all the costs of his/her activity)? Like most other areas we have here witnessed a historical development, changing the notion and the understanding of the polluter pays principle as to what should be included for full cost coverage. The main distinction goes between environmental fees/charges and environmental taxes.

Charges are defined as the payment which should cover the proven expenses for handling waste or providing a resource such as water. The companies responsible for these services are in many EU-countries run by, or owned by, the municipality. Also these activities are linked to the climate change. Solid waste on landfill causes emission of methane, a strong greenhouse gas. Non-treated wastewater will cause biological degradation and CO_2 emission. Good management of waste and water will reduced climate impact. The costs are in many EU countries rather high and increasing, especially with the more recent serious demands on solid waste management, as landfilling of organic waste is severely restricted.

12.5 Taxation on energy and carbon dioxide emissions

Environmental taxes have become increasingly popular with most governments in recent years. With the first and the second "oil crises" in 1974 and 1979 respectively an increase of petrol tax was introduced to halt a rise in, or to reduce, the petrol consumption. At the same time a shift from oil-based to coal-based power generation was initiated. These taxes were not originally founded on environmental concerns; it came firmly on the agenda with the 1987 Brundtland Report and the Rio summit in 1992.

Environmentally related taxes or fees are of several kinds. They include:

- Emission charges or fees, e.g. on emitted CO_2.
- Non-compliance fees when exceeding permitted emissions.
- Product taxes on products causing an environmental impact, such as fertilizers.
- Product charges on petrol.
- Taxes for land-filling of waste.

The most direct form of environmental taxes is when a cost is charged on emissions. The taxation is done to stimulate the reduction of emissions. Charges for SO_x emissions should be compared to the cost of abatement. In this case it is rather cheap to remove the SO_x from the flue gases and, at least in several countries, the taxes are more expensive. This means that the taxation have been a rather efficient economic instrument to improve environmental protection.

An IPPC licence (integrated permit) usually gives the right to a company to emit a defined amount of each substance from its activity. If these amounts are exceeded the consequences is in the first place a non-compliance fee. It is an economic instrument with the purpose of reducing the likelihood of exceeding the allowed amount. The non-compliance fee is often progressive, that is, the first few kg or m^3 are less costly and the additional kg or m^3 cost more.

Taxes may also be put on products, which will cause environmental impact. Most typical is the charge on petrol, but there are several other taxes. Artificial fertilisers have a tax in Sweden, related to their nitrogen content. In this case it has been clearly shown that the use of fertilisers is dependent on the level of this tax. A EU Commission's policy is that the amount of biodegradable municipal waste in landfill should be reduced. A main reason is to remove methane emissions from landfills. Composting and subsequent use for soil improvement or biogas production are the preferred ways.

The tax on landfill has again proved to be a very efficient instrument to promote a long series of projects to reduce landfilling. An important option is solid waste incineration, which is increasing in Europe. The taxes on landfilling have also stimulated the establishment of a market for recycled materials, such as paper, glass and scrap metal. This has, in a very considerable way, changed waste management in the European Union and in other parts of the world.

Energy taxes are by far the oldest types of environmental taxes. Energy taxation has been a main instrument for a number of purposes, the most important being:

- to reduce oil dependency.
- to reduce emission caused by power production.
- to reduce car traffic.
- to increase fiscal revenues.

Energy taxation is implemented for petrol and in general for fossil fuels for cars, for oil used for heating purposes, for gas and coal used for the same purposes, as well as for electricity. Energy taxation has not been introduced for international traffic, neither by boat nor by air. This is becoming an increasingly serious drawback in efforts to reduce carbon dioxide emissions.

Taxes are decided on nationally. They thus vary considerably, but all member states in the European Union have energy taxes. There have been efforts to harmonise energy taxes, and even more so, that there are carbon dioxide taxes, in the European Union. Energy taxes are fairly high.

The EU-directive 2003/96/EC of 2003 sets minimum rates of taxation for motor fuel, motor fuel for industrial or commercial use, heating fuel and electricity. The levels of taxation applied by the Member States must not be lower than the minimum rates set in the Directive. These taxes will apply to and affect private households and private transportation, including the costs for commuting. The same is true about waste and water taxes, which are applied in a number of member states, but with widely different amounts among its members.

Of the price on petrol about 2/3 is tax, a normal level for western European countries. The state income from energy taxation is considerable. In 2013 the Swedish petrol taxation totalled 24 billion SEK (2.5 billion Euro). About 2/3 of all environmental tax revenue is coming from energy taxation. Fuel for commercial use, i.e. non-car-related use, is making up about 6-8% of the household taxation. That is true also for the fuel used for producing heat and electricity.

The overall trend for the OECD-countries as well as for the EU-15 is a relative decrease in fuel taxation rate from 1998 and onwards, while the trend for the USA has been a decrease from 1994. The USA fuel taxation rate, at some 40% of the average for all OECD-countries, is in addition by far at the lowest level of all nations.

A different case is Australia. In 2012 the Australian Federal government introduced a carbon price of $23AUD per tonne of emitted CO_2eq on selected fossil fuels consumed by major industrial emitters and government bodies such as councils. It is estimated that the Australian scheme had cut carbon emissions by as much as 17 million tonnes due to this taxation. On July 17, 2014, this changed with a new right-wing government. The Abbott government passed repeal legislation through the senate, and Australia became the first nation to abolish a carbon tax.

Regrettably there is today globally more subsidies for supporting the use of fossil fuels than taxation, e.g. fishing industry and much of agriculture is often subsidized as a way to support them economically.

What effects do the environmental taxes have? Have they moved the burden of paying costs for environmental impact to the polluter? Do they reduce environmental impact? It seems clear that environmental taxation never or very seldom makes the polluter pay for an environmental cost. The victim still has to take care of the cost of pollution. The main effect of environmental taxes has thus been to reduce emissions, rather than to compensate the victim for his/her costs for the damages the emissions may cause. Good environmental taxes are set in such a way that it is more profitable to avoid emissions than to pay the fees. In these cases the income from taxation decreases. This is caused by price elasticity. Price elasticity is how much consumption changes with the price. It is for prices with a high degree of elasticity that the tax really contributes to changed behaviour. For commodities with less price elasticity, such as energy, the tax provides more of an income for the state than an incentive for changed behaviour in the society.

Taxation and fees have reduced pollution and the material flows in our societies. The countries in Europe are slowly moving from waste societies to recycling societies. Important incentives in this process are taxation of resources, fees on landfill, markets on recycled material, regulation on end-of-life of products including producers' responsibility. These economic policy instruments have had an influence on the price of the products and stimulated environmentally better behaviour. However we are still waiting for a strong reduction of the use of fossil fuels.

Box 12.2 CO_2 taxation

Environmental taxes and charges are the most widely used market-based instrument for environmental policy in Europe, despite current interest in trading schemes. They are generally seen as the most cost-effective instruments for environmental improvements.

While attempts to introduce a CO_2/energy tax at the EU level have failed, CO_2 taxes have been widely adopted in the Member States. The first CO_2 tax was levied in Finland in 1990, and there are now CO_2 taxes in all EU countries. These taxes are often an additional tax levied on some energy carriers, not always differentiated according to their carbon content, and with many exemptions.

As an example the Swedish taxation for heating fuels, per ton CO_2 is high for households and service (114 € in 2011) and low for sectors subject to international competition and carbon leakage = industry, agriculture and heat production in combined heat and power plants (CHP). In 2011 outside EU ETS 34 €, within EU ETS 0 € industry, 8 € for CHP. Energy tax for industry within EU ETS used to fulfil EU minimum tax levels. As a result there are today very few Swedish households heating their homes with fossil fuel. The normal is district heating, heat pumps or bio pellets.

12.6 Taxation on car and car driving

A number of economic instruments have been introduced for car traffic. These have been motivated in at least three different ways:

- Cars should pay their costs for investments in infrastructure.
- Cars traffic should be moved over to public transport.
- Cars traffic should pay for their environmental impacts.

The economic instruments include energy tax on petrol, registration tax (accis), and road tax.

Petrol taxes started already in the 1970's in many western European countries, motivated by the search for means to ease the energy-dependency after the so-called oil price crisis. When this after a few years had lost much of its impetus, the petrol taxes had at the same time become an important income for the state. It was then convenient to be able to "rename" it "environmental". Still, the effect in terms of reducing or keeping the use of petrol stable was there and an effect along the ideas behind the environmental taxation therefore realized.

The registration tax on new cars is also counted as an environmental tax. This tax varies very much across the countries with Norway and Denmark having by far the highest level of that tax in all EU, making up 40% of all environmental taxes in Denmark.

The EU-commission Directive supports a gradual shift of registration tax for a CO_2-based taxation system for passenger cars, with the least CO_2-emitting car models receiving the biggest tax rebate. As transportation is increasing and in all countries responsible for a substantial increase in energy consumption and hence in CO_2 emission.

Subsidies are as economic instruments the opposite of charges. While charges correspond to the 'stick', subsidies constitute the 'carrot' in the carrot and stick metaphor. Subsidies could be either direct or indirect. A direct subsidy is for example when a state partially finances an investment, which the state considers important. As an example state subsidies have been used for stimulating the change of heating equipment for individual houses. Thus in Sweden the state pays a constant subsidy to those who change from direct electric heating or an oil-fuelled boiler to an environmentally better heating mode, such as district heating, pellet-fuelled boiler or heat pump. The Swedish and Norwegian governments also offers a subsidy for buying a so-called "green car". A green car is a car which has been labelled environmentally better by the road authority, for having low fuel consumption or being an electric car, a hybrid car or a car using ethanol or biogas as fuel. The green car subsidy is very high in Norway, which has the highest percentage of electric cars in Europe. An electric car in Norway have additional advantages, such as being allowed to use the bus lane in rush hours and free parking spaces.

An indirect subsidy is a reduction of costs for a certain activity. For example tax reduction may be offered to a company which invests in a region of the country, which is in need of working places. In Central and Eastern Europe it appears that indirect subsidies, such as tax reduction, are more commonly used, for stimulating investments asked for by the authorities.

12.7 Emission trading

Tradable pollution permits are an alternative to setting emissions standards or using pollution fees. The tradable pollution permits involves the establishment of a trading system for the "right to pollute". It may be used among those living along a coast or a river, which has the capacity to adsorb a certain amount of exhausts, or more commonly among those emitting pollutants to the air in a region. It is also called "cap and trade" or a "bubble". It is a way to use market forces for environmental purposes.

Already at the COP3 in Kyoto Al Gore, who represented USA, required that emission trading was going to be used for implementing the Kyoto obligations. But in the USA neither the Kyoto Protocol nor emission trading was accepted by the Senate. However in the European Union this was done and a large scale effort for implementing emission trading was started. The EU Emission Trading Scheme (EU-ETS) is the first multi-national emission-trading and the largest trading scheme in the world.

EU-ETS is an internal EU-emission trading system among the 28 EU member states. In addition four non-EU members – Norway, Iceland, Liechtenstein, and Switzerland – have joined the scheme. It can be considered as a forerunner for the global emission trading scheme, foreseen in the Kyoto Protocol, but never realized. Now EU-ETS is prepared to become an integrated part of a future global system.

The principle of the ETS is to help make sure, that CO_2 emission reductions take place at installations or companies, where these savings can be made at the lowest costs. The ETS does that by providing a framework or a marketplace for buying and selling allowances for emissions. In this way those able to make savings for low costs can go further than they need to meet their own target and sell the allowances via the ETS to those which need high investments to meet their target. These last types of installations will then buy allowances to cover what would otherwise bring them into exceeding their number of allowances, and face penalties.

During the first committeemen period the EU-ETS issued allocation of emission allowances to 11,500 energy intensive industrial companies and installations across EU, like electrical power plants, oil refineries, iron and steel plants as well as factories e.g. making cement, glass, bricks and pulp and paper. Together they account for about half of the total CO_2 emissions within the EU. Each of these 11,500 energy intensive installations receives an emission allowance when the trading begins. The allowances were first negotiated between the EU member states. Then the national allowances were distributed between the listed installations. This way to distribute allowances is commonly called “grandfathering”, since it is decided on from “above”, rather than bought, for example in an auction of emission rights. The allocation of allowances is based on a National Allocation Plan (NAP), made by each member state and specifying for each installation the number of tons of CO_2 emissions allocated. The national plans are then checked and approved by the EU-Commission. A most important criterion for allowances allocated in the NAP is that it allows for that state to fulfil its obligation towards the Kyoto Protocol. This will for most member states eventually mean, that the allowances in total will have to be smaller than the total present emission, as most member states have obliged themselves to bigger or smaller reductions.

In the Second Trading period, 2013-20, a detailed regulation of which companies should take part has been agreed by the Commission. In general, companies are required to participate in the ETS if the total thermal input of their combustion installations is 20 MW or higher. The total rated thermal input is the sum of the rated thermal inputs of a company's various installations. For the period 2013-2016 emissions from aviation – air flights within the EU as well as European Economic Area – has also been included. The goal is to include all sectors, e.g. also traffic and agriculture and all important GHGs.

The ET scheme has disadvantages in as much as it does not lead to any CO_2-emission reduction, neither short term nor long term. On the contrary, it leads to the use of a quota in the short term which should only have been used later in accordance with the actual economic development within the country, possessing it or – may be – never been used at all. This is why this Kyoto Protocol ET-scheme has been named "trading warm air", i.e. trading emission reductions which are not real or nothing at all. There are different demands for a maximum amount of a total quota to be sold to make sure that a country is not, in the short term, selling so much that it will get in trouble fulfilling its own obligation towards the Protocol later, when it has eventually had got the economy better under way.

To lead to a meaningful exchange of emission rights it is estimated that a minimum price of some 30 Euros per tonne is needed. At present the cost of one tonne of CO_2 is much lower, around 1 Euro/tonne, and thus the EU-ETS is not effective. It is perceived that there is at present too many emission rights available to make the EU ETS effective.

The EU Commission is running a registry hub to be able to monitor that the trading and transfer of allowances are in line with the directive, while the member states will operate an electronic registry of allowances to be able to follow the transfers of allowances. The member states collect allowances, which have to be given up by the installations in accordance with the allocation plan, and distribute allowances to new installations. It's also the member state responsibility to collect the data that each installations is obliged to produce currently on its CO_2 emission to prove that it stays within the allowances received. Finally, the member states will make a report annually to the EU Commission on the operation of the system, including the emission data collected.

The Norwegian Consultancy *Point Carbon* is the trading point within the EU ETS. In the early phases of the trading it reported during 2006 the total turnover of emission rights was 22.5 billion euros and 1.6 billion tonnes of CO_2. The reported carbon trading is to a large extent financially motivated and corresponds only partly to actual reductions. Equally the projects are partly CDM projects, which neither corresponds to emission reductions within the European Union, although they are included in the Kyoto obligations. Thus some reformation of the EU ETS is needed to improve the system.

12.8 Financial instruments – Environmental investments

Most environmental actions requires funding. Financing environmental policy has become an important component in the economy of many countries. Most CEE and OECD countries spend some 1-2% of their GDP for environmental investments yearly. Public expenditures include building and upgrading of wastewater treatment plants, energy plants, improving infrastructure, and setting off land for nature protection areas. Private investments include all kinds of technical developments as well as equipment for abatement of pollution. Where does the money come from and how are the investments justified? Private investments to reduce pollution are often required by legal regulation of emissions. The company has to choose between paying charges and reducing emissions, which then often requires investment in abatement equipment. But increasingly environmental investments are made since they are profitable as such.

Investments as part of waste minimisation (e.g. lower energy and water consumption, and thus costs) and cleaner production schemes often have a short time for return of investments, between six and 30 months. This is a so-called win-win situation. Both the environment and the economy win.

Providers of water, energy, waste management and bus transport, often municipally owned companies, are funded by charges on the services they provide. As an example the Stockholm Water company, entirely run on charges from their almost one million customers, have a yearly budget of 3 billion SEK (Euro 320 million), and is regularly investing to expand wastewater treatment and expand infrastructure. But in general water companies often do not have enough income and are partly financed through taxes. This is even more typical for municipal bus companies.

Not all companies and municipalities are able to set aside resources for environmental investments, even if this is required by law. Financing of environmental investments from municipalities' own resources is unusual, except for revenues from user fees (charges on water, energy and waste management). Various economic instruments are thus used by the authorities to help the process. These include trading permits, subsidies including those via special environmental funds, damage compensation, and finally banking. Poland established its National Fund for Environmental Protection and Water Management quite early, 1989. It is today a major instrument to finance environmental investments, through so-called soft loans (low credit rate, long mortgage times) and subsidies. Similar funds exist on the county and municipal levels.

On a global scale environmental investments in developing countries, where it is often most needed, cannot be carried by the countries on a sufficient scale.

Thus *international financing tools* have been constructed. The largest is today the Global Environmental Facility, GEF, in Washington DC. This fund is investing some 10 billion USD yearly in climate protection projects. The World Bank also provides e.g. soft loans for environmental projects. Costs might be considerable.

Lately we have seen several cases where risk capitalists, as well as e.g. pension funds, have removed investments in fossil fuels companies – this is called *divestment*. The reason is that these investments are seen as risky. The market for fossil fuels are weaker, the costs for extracting fossils are increasing and risky, e.g. in the case of fracking. If this trend is continuing we will see a change away from fossils because of market mechanisms. We are then approaching a low carbon economy.

Chapter 12 sources:

This chapter includes excerpts from Chapter 22 of the book *Environmental Science* of the Baltic University Programme, http://www.balticuniv.uu.se/index.php/boll-online-library#environmental-science; as well as excerpts from Chapters 10 in the book *Environmental Management volume 1 Environmental Policy - Legal and Economic Instruments* of the Baltic University Programme authored by Børge Klemmensen and Lars Rydén. http://www.balticuniv.uu.se/index.php/boll-online-library/826-em-1-environmental-policy-legal-and-economic-instruments-. It also includes information from the European Union websites on Climate Policies http://ec.europa.eu/clima/policies/brief/eu/

IV

A Sustainable Energy System

Chapter 13
Steps towards a low carbon economy – Energy efficiency

13.1 Energy efficiency is a bridge to a low carbon economy

The Earth is warming, oil reserves are running out, our way of life is unsustainable. For years, environmentalists have been lecturing us to reduce our carbon footprint or suffer the consequences. A world survey concluded that climate change will account for a 5 to 20% loss in Gross World Product within the next 30 years. But reducing our use of carbon doesn't have to mean a rejection of capitalism or turning our backs on the niceties of modern life. From driving electric cars to producing ethanol from waste products, controlling carbon change is in fact creating new economic opportunities.

Energy efficiency is finally a common sense term. Nowadays almost everyone knows that using energy more efficiently saves money, reduces the emissions of greenhouse gasses which cause climate change phenomena, and lowers dependence on imported fossil fuels like oil, gas and coal.

When we consider energy supply, energy efficiency is again the natural first step. By eliminating wasteful consumption and losses in the supply chain, we are actually increasing capacity of existing systems by creating so called 'negawatts', i.e. enabling supply of more customers without additional investments into energy generation and distribution capacities.

Therefore, whether we consider supply or demand side of an energy system, energy efficiency is always the first thing to do.

However, after this step one should think of what follows!

We are living in a fossil age at the peak of its strength. Almost 90% of all primary energy used nowadays comes from fossil fuels and nuclear. This is due to phenomenal increase in use of fossil fuels as a consequence of rapid development of emerging economies. Competition for securing resources for fuelling further economic development is increasing, price of fuels will increase and geopolitical conflicts will become more likely as the availability of fossils fuels would gradually decline.

Evidently we are living in a rapidly changing word facing a multitude of challenges caused by these processes of endless change, technological as well as geopolitical. One consequence is growing complexity which has huge impact

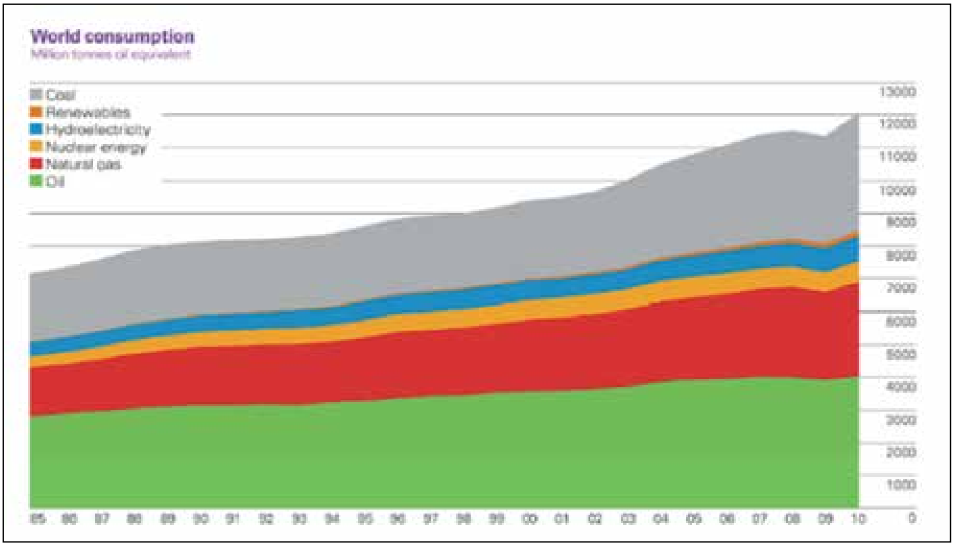

Figure 13.1. Trends in world energy consumption, (Source: 2011 BP Statistical Review of World Energy).

on society which requires adequate policy response and timely implemented actions. The policy space that climate change happily occupied for 5 to 10 years has temporarily been superseded by other issues, like economic growth and bank recapitalization. We read so often there is lack of leadership, lack of money, and so many challenges that are confronting us at the same time. The bandwidth of political leaders is restricted, and short term approach focusing mostly on the mandate at hand increases vulnerability of national economies which are dependent on fossil fuel imports. Small nations and small economies will be first to suffer if caught unprepared in the midst of the struggle for resources among the large players. Here it is where energy efficiency has a potential to lead toward the natural second step – transition from fossil age into a bio-age!

13.2 Pillars of the low carbon society

Fossil age still has some 100 years to go, but should we wait until the last moment before we make a switch? Population is increasing, urbanization is increasing, price of oil will be increasing, and eventually it will run out. The economies that delay transition to low carbon society, especially if dependent on import of fossil fuels, are risking major upheavals.

The transition policies should be crafted now - and implementation should follow without delay. This of course entails a major shift in economies, and consequently there will be winners and losers. The losers in this shift of focus would be the existing pro-status-quo groups, lobbying to postpone changes. The winners may not even exist yet, which is why the ongoing political debates are unbalanced because the losers know they will lose and fight back now, but future winners still don't put up equally strong arguments.

The fusion of Internet, information and communication technologies (ICT) and renewable energy sources (RES) enables development of nations toward a low carbon society.

There are 5 basic pillars of the low carbon society:

1. *Energy efficiency*: all energy losses must be either eliminated or minimized in accordance with best available technologies;
2. *Renewable energy sources*: solar, wind, hydro, geothermal, biomass, ocean waves and tides – their falling costs make them increasingly competitive;
3. *Buildings as active consumers*: Buildings that generate most of their energy needs from locally available renewable energy sources (The concept prosumers referring to units which both produce and consume energy is increasingly used).
4. *Electro mobility*: Electric vehicles, once deployed on a large scale, will serve both as means of transportation but also as energy storage units throughout the city;
5. *Developing smart energy cities*: An integrated effort of improving social, economic, environmental systems in cities, with energy infrastructure transformed first, as an enabler of further developments.

When these five pillars come together, they make up an indivisible sustainable development platform – an emergent system, whose properties and functions are qualitatively different than the sum of its parts.

Interconnectedness between the pillars creates cross-industry relationships, a system called *distributed energy generation* in which millions of existing and new businesses and homeowners become energy players to the advantage of final beneficiaries – the citizens. The citizens (people) are the foundation of the approach. Transition towards low carbon society must be consensual, involves change of behaviour and life style, thus people participation is essential.

13.3 Towards Energy Efficient Oil & Gas Sector

Hydrocarbons have played one of the most crucial roles in economic history by fuelling globalization and industrialisation. Today, oil and natural gas form a key lifeline of the global economy, contributing to a 56.6% share in global energy consumption (BP, 2014). Further, in spite of the recent worldwide thrust provided to the renewable sector, International Energy Agency's (IEA) (2014) World Economic Outlook for 2040 projects that oil and gas will remain the single largest energy source throughout the projection period, as developing countries experience growth. In particular, transport, heating, and cooking energy requirements will largely continue to be powered by oil and natural gas.

The continued dominance of hydrocarbons in the energy mix can be explained by the presence of a lock-in of fossil fuel energy systems. This carbon lock-in has occurred globally through the systemic co-evolution of technology and institutions, thus creating a Techno-Institutional Complex of high fossil fuel intensity. Such a lock-in is among the biggest barriers to climate change mitigation and sustainability.

As with any fossil fuels, Green House Gases (GHGs) that emanate from the use of hydrocarbons can be curbed by discouraging the use of the fuel. In theory, some form of resource taxation on the oil and gas industry would discourage fuel extraction and therefore oil and gas use. Several countries already tax crude oil extraction, primarily to raise revenues for the state rather than to curb emissions. A more direct way to curb emissions would involve the imposition of a Pigouvian tax on carbon. However, carbon taxes would apply on emissions from the use of other fossil fuels too, and would also apply on fossil fuel consuming industries.

This brief instead suggests short-term policy measures to reduce emissions from the extraction and transformation industry itself, i.e. the supply side. The extraction and transformation industry, after all, is a major energy consumer - most of which is met by the use of fossil fuels. IEA (2013) reveals that in 2011, in Million Tonnes of Oil Equivalent (MTOE), 6.9% of the total energy produced by the oil and gas industry was consumed by the industry itself.

There is thus a case for the reduction of GHG emissions from the hydrocarbons supply industry. To this extent, the improvement of energy efficiency within the industry could lead emission reductions. IEA (2014) shows that efficiency measures account for about half of cumulative CO_2 emissions savings, with the share being even higher in the short term. While the largest efficiency savings in 2040 come from end-use sectors, energy supply – including power plants, refineries and oil and gas extraction – is responsible for 9% of cumulative savings.

The cost to implement policies directed towards increasing energy efficiency might be steep, but it can be offset by the positive spill-over effects of decreased emissions that will come from reduced fuel consumption.

While many oil and gas companies are already pursuing sustainability initiatives, there is room for policy intervention through standardisation of best practices. A few broad themes are discussed below.

13.4 Energy carrier system

Energy carrier systems of renewable sources have become widely used due to world's need to reduce the fossil fuel consumption and consequently greenhouse effect. However, the energy density of these systems is much lower than fossil fuels or nuclear fission. Besides, energy outlooks (IEA, 2011) show that energy demand around the world will continue its increasing trend. In turn, the wide scale construction of power plants based in fossil fuel cannot continue due to negative environmental effects.

Also, the latest accident in reactor nr 3 of the Fukushima Daiichi Nuclear Power Station in Japan in consequence of the March 11 in 2010 earthquake and tsunami increased the fear of radiation effects and the discussion about nuclear safety. Thus, it is relevant to provide an up-to-date assessment of the global sustainability of current and future energy carrier systems for electricity supply based on fossil fuel and renewable energy sources. It includes the analysis of energy carrier systems based on fossil fuels: coal, natural gas and oil and on renewable ones: wind, solar photovoltaic, geothermal, hydro, hydrogen, ocean (wave and tidal power), and nuclear.

The sustainability assessment of an energy conversion process into electrical energy is carried out in technological, economic, environmental and social dimensions. A solid basis for a state-of-the-art interdisciplinary assessment using data obtained from the literature supports the sustainability comparison. Thus, indicators that best describe the technologies and that are related to each of the abovementioned dimensions are defined to quantify the sustainability of energy carrier systems. These indicators are:

- efficiency of electricity generation,
- lifetime,
- energy payback time,
- capital cost,
- electricity generation cost,
- greenhouse gases emissions during full life cycle of the technology,
- land requirements,
- job creation and social acceptance.

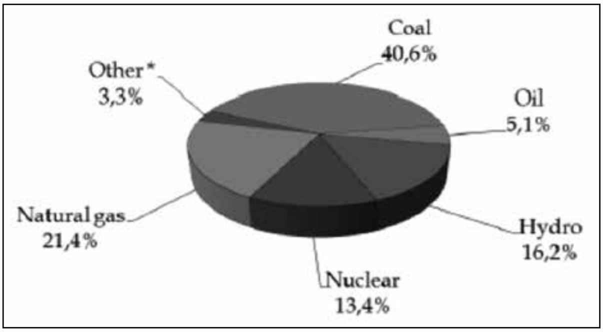

Figure 13.2 2009 World energy source share of electricity generation. Other: wind, solar photovoltaic, geothermal, biofuels and waste, and heat. (Source: IEA, 2011)

A criteria based on membership functions is exposed in order to determine a global sustainability index that quantifies how sustainable each energy carrier system is. The multi criteria analysis is performed considering different weighting functions applied to sustainability indexes in order to assess, today and in the near future, energy carrier systems that should be used in the mix of energy conversion systems to electricity.

There are different types of energy carrier systems for conversion into electricity. The world energy source share of electricity generation in 2009 is shown in Fig. 13.3 (IEA, 2011). Energy carrier systems are subdivided in renewable energy sources (wind, solar photovoltaic, geothermal, hydro, hydrogen and ocean) and fossil fuel (coal, natural gas and oil). Among these renewable energy sources, the wind and solar photovoltaic energies carrier systems are those with higher growth. Nowadays, nuclear energy can be considered as "an almost" renewable energy because new generation's nuclear plants can reuse uranium and its derivatives. Thus, this energy carrier system is included into renewable section. Their advantages, disadvantages and capture technology are presented. The installed power, worldwide production and perspective of future increase are quantified for each energy carrier system.

13.5 Decreasing carbon content of energy

The carbon content of the energy is decreasing as alternative non-fossil based resources are increasingly introduced in the energy system. Such a change has been going on since a long time. Fig. 13.3 shows data from 1960-2000 for USA, European Union, Japan and Sweden. In all cases is the carbon content (in gram C; may also be shown as CO_2 emissions) per MJ decreasing. Most of this is due to the introduction of nuclear power. In Sweden 12 reactors were built during this

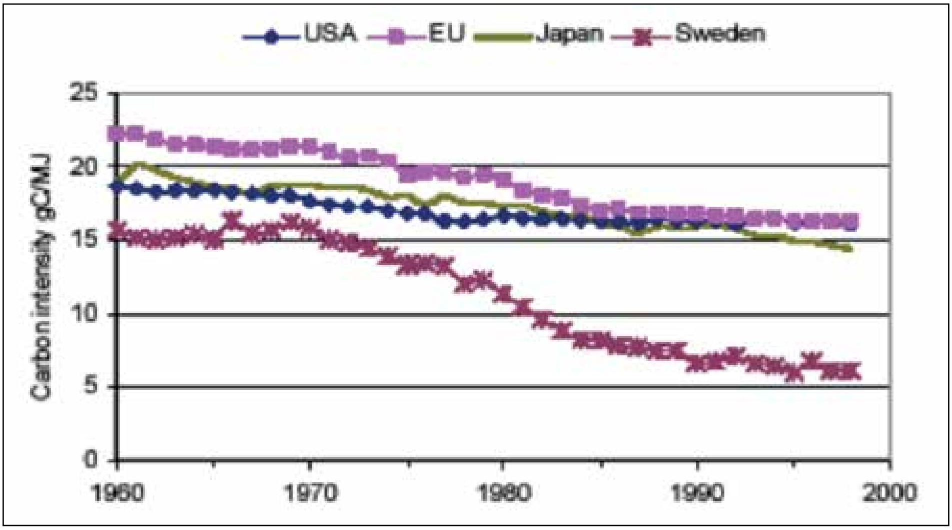

Figure 13.3 Carbon content of energy supply in USA, Japan, Sweden and the European Union. (Source: Chalmers University of Technology)

period and the country after this had the highest amount of nuclear electricity per capita in the world. Also a considerable increase in the use of biomass occurred. As a result the carbon content of the energy supply went from about 15 g C/MJ to about 6 g C/MJ, a decrease of 60%.

Also in the other countries expansion of nuclear power was a main reason for the reduced carbon content of the energy supply. Japan expanded to more than 40 reactors and NP was also built in USA and EU, especially France, with almost 50 reactors, and Germany, with 17 reactors.

Nuclear power is, however, in the long run not a good solution of the sustainability challenge. Even if it is not emitting GHG during the use phase, there is a considerable carbon debt during the building phase. In addition the storage of waste fuel remains a problem due to its long time radiation, and finally uranium is a non-renewable resource. One may add that the investment in NP today is not profitable on a private market and all existing projects are supported by states. Although many are planned, the only reactors built at present are two in Finland.

The challenge today is to avoid an increase in the carbon content of the energy supply when the nuclear power sector is continually shrinking. This has not been possible in Japan as all its reactors were closed during a very short time after the Fukushima disaster. Japan was forced to increase its import of fossil coal. A similar negative reaction on nuclear power occurred in Germany, which decided

Figure 13.4 Barsebäck Nuclear Power Plant in southern Sweden. This power plant's two reactors were closed in 1999 and 2005. (Photo: Bengt Oberger)

on its "Energiwende", (energy transition) also a result of the political (and popular) reaction to the Fukushima disaster. The decision was taken to close all 17 nuclear reactors before 2022. 8 reactors have been closed at the moment. The intention is to replace this energy sector with renewables but it takes time. During 2012 and 2013 the carbon content increased and some lignite fired power plants, which were closed, will most likely be opened again. Still the German carbon emission has started to decline in 2014. The sectors of wind and solar as well as biogas have expanded dramatically but from a low level.

Sweden closed two of its 12 reactors in 1999 and 2005 as a result of a political decision to phase out nuclear power. Most likely two more reactors will be closed before 2018, as these approach the end of its technical life length. In this case there has been no increase of carbon in the energy supply since the renewables have been well developed in parallel.

13.6 Tackling the energy intensity of the economy

An important part of the road to the carbon free economy is to reduce the *energy intensity* of the economy. This is mostly the result of improved energy efficiency. Energy intensity is often measured and reported as kg of oil equivalents (o.e.) per GDP, Gross Domestic Product in the currency of the country or in USD or Euros. Here we see dramatically different values for the countries in the world. In the western industrialised states we typically have between 100-200 kg o.e./1 000 Euros. This corresponds to about 0.100 to 0.200 tonnes of CO_2 per 1000 USD. The average value for the world was 0.612 tonnes of CO_2 per 1000 USD (2011 statistics) as reported by the US Energy Information Administration (EIA).

The energy intensities of the economies in the world is slowly decreasing. The world-wide values were 0.706 tonnes of CO_2 per 1,000 USD in 1990 and 0.612 in 2011, a decrease of 13% in 20 years. However in the fossil fuel dependent Central and Eastern European countries the values are much higher. For Uzbekistan the carbon intensity of the economy was in Uzbekistan 10,229 in 1992, a value which had decreased to 5,313 in 2011, a decrease of almost 50%. Still it is close to 10 times larger than in the industrialised EU.

The development of the energy intensity over the 30 years from 1980 to 2010 is shown in Fig. 13.5 and 13.6. We typically see a 50% decrease over the period. It may be simply understood as a shift form an industry-based economy to a service oriented economy, using less physical resources per unit of economic output.

The decrease of resource use per economic output is called *decoupling*! Looking at detail of energy use in the western European countries it is typically slowly increasing or rather constant after about 1990. Energy use in the housing sector is decreasing while energy use in the transport sector is increasing. However the economic growth continues much faster than the slow increase of energy consumption. We have *relative decoupling*, not a total decease of energy use, then it would be absolute decoupling. It is clear that energy efficiency is the most straightforward way to become a low carbon economy.

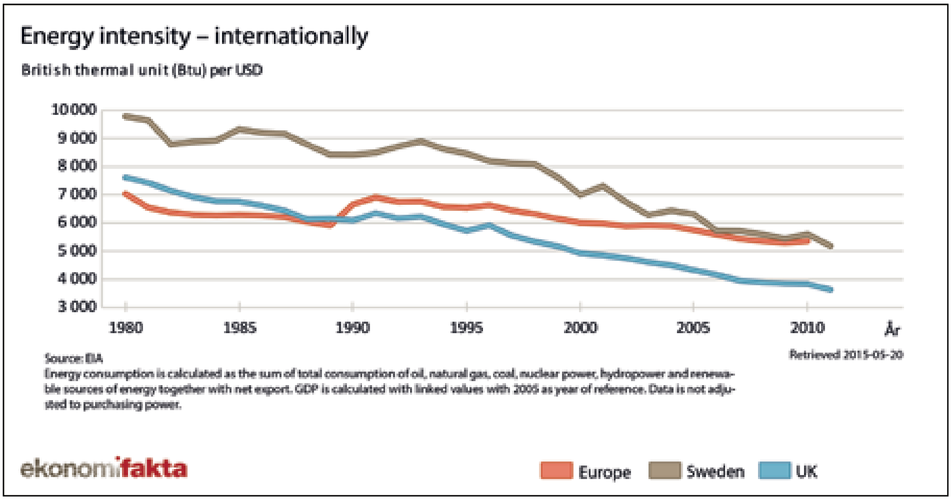

Figure 13.5 Energy intensity of the economy for EU (red) UK (blue) and Sweden (brown) in British thermal units (BTU) per USD. (Source EIA, http://www.ekonomifakta.se/sv/Moduler/Diagram/Energi/Energieffektivisering/Energiintensiteten/?backdrop=emf&print=y&from1520=&to1520=&columns1520=,1,2,3,)

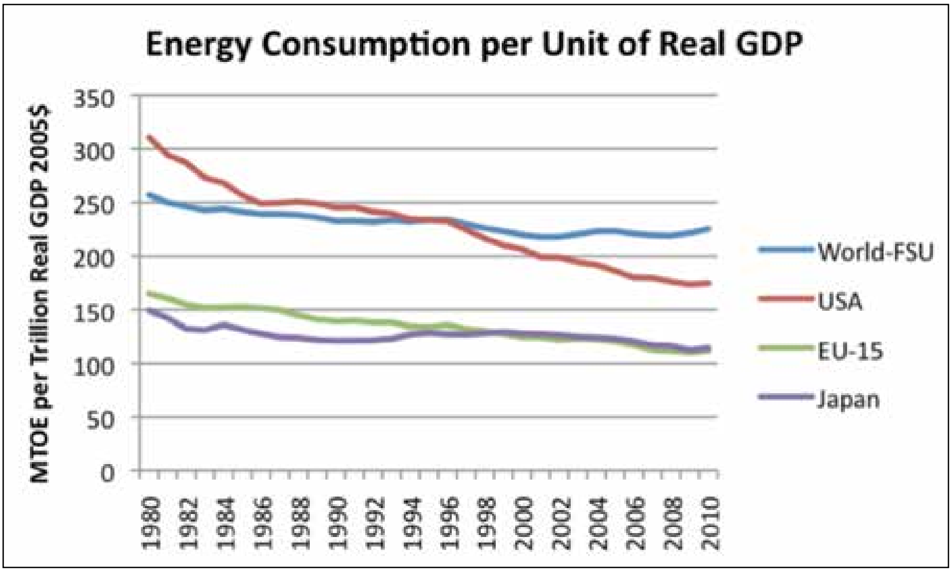

Figure 13.6 Energy consumption per unit of real GDP. Source: Gail Tverberg Is it really possible to decouple GDP Growth from Energy Growth? http://ourfiniteworld.com/2011/11/15/is-it-really-possible-to-decouple-gdp-growth-from-energy-growth/

13.7 Financial concerns in a low carbon economy

Each industrial sector is dependent on capital to develop. Thus capitalists or so-called risk capitalists are important players in the development of the energy sector. If they do not want to invest money in the sector it will not develop.

The original difficulties to find money for developing renewable energy resources has now started to decline. Investments in wind power in particular is considered a good business. Often solar PV is considered also as good investment. In the same time some capitalists slowly start to see investments in the fossil fuel sector as risky. There is a concern for accidents (such as in the Gulf of Mexico for deep sea drilling) or non-acceptable environmental consequences (Gulf of Mexico event, but also e.g. the fracking industry in the US). Finally if the costs of carbon dioxide emission are increasing, e.g. by new taxes, the investments in the fossil fuel sector will be less profitable.

At present the oil, coal and gas sector is extremely established with its flow of capital and longtime links between the different companies and individuals. Thus the changes possible will not be very rapid. Still we see some very large pension funds decreasing investments in the gas and oil sector, and some even replace their capital to other objects than the large oil and gas companies. This movement of capital is called *divestment*.

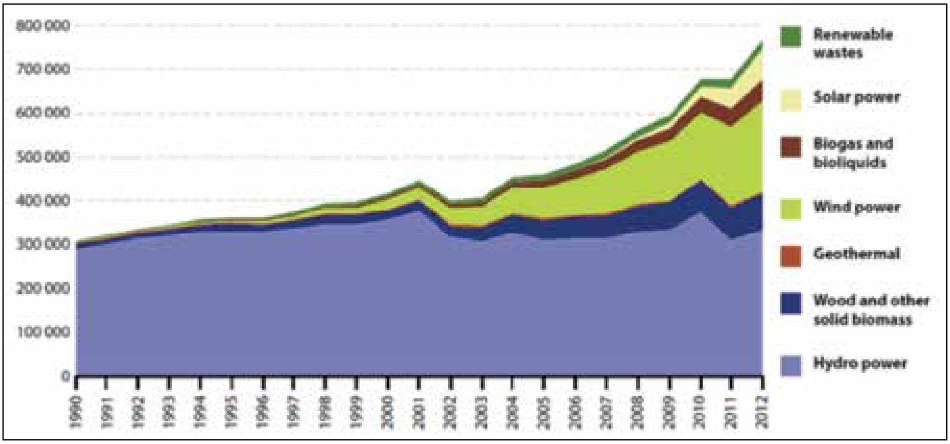

Figure 13.7 Gross electricity generation from renewable energy sources, EU-28 Europe 2020 indicators - climate change and energy November 2014. (Source: http://ec.europa.eu/eurostat/statistics-explained/images/f/fb/Gross_electricity_generation_from_renewable_energy_sources%2C_EU-28_Fig_11.PNG)

The gross electricity generation from renewable energy sources in the EU-28 shows a rather large increase in wind power (Fig. 13.7) as well as in the other technologies. This increase leads to more jobs in renewable energy industry. To this should be added a plethora of new employment options: The retrofitting of residential and commercial buildings to improve energy efficiency is increasing. Other "green" jobs are connected to e.g. smarter and 'greener' technologies, integrated water resources management, ecosystem services accounting, and ecosystem-based adaptation to climate change and opportunities in the fields of housing and spatial planning. Some statistics are collected in Table 13.1.

A carbon-free economy has the potential to be greener and better for both employment possibilities and the environment. The road to a carbon free economy, as we have seen, has been going on since the 1960s, even if the rate of change is slow. We may see it as a new transformation of societies, from agricultural

Table 13.1 Jobs in the renewable energy industry in the EU

Year	Employees
2005	230.000
2006	300.000
2007	360.000
2008	400.000
2009	550.000

based economies to industrialised societies and later serviced-based societies and finally to carbon free economies, where the new energy systems, based on renewables, are in the centre of the change.

Chapter 13 sources:

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Sector 13.4. Brief "Towards an Energy Efficient Oil and Gas Sector" for Global Sustainable Development Report (GSDR). Saahil Parekh and Siddharth Singh, The Energy & Resources Institute (TERI) 2015, 5 p.

Sector 13.5-13.7 Main text Lars Rydén. Some main sources:

http://vmisenergy.com/category/real-gdp/

http://ourfiniteworld.com/2011/11/15/is-it-really-possible-to-decouple-gdp-growth-from-energy-growth/

Data mostly from EIA as given in the graphs.

Energy intensity statistics is available at the International Energy Statistics US Energy Information Administration (EIA): The energy intensity of the economy in tons of CO2/1000 USD. http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=91&pid=46&aid=31&cid=r3,&syid=1990&eyid=2011&unit=MTCDPUSD

Chapter 14
Technologies for saving energy

14.1 Saving Electric Energy

Strategic Choices. In the power industry, energy efficiency involves getting the most usable energy out of the fuels. At its best, energy efficiency improvements in the power industry can lead to postponing – or altogether avoiding – the construction of new power plants. The efficient generation of power is only one way a power plant can pursue energy efficiency. New technologies, applied to the storage of energy and the transmission of energy, contribute to energy efficiency. For instance, the copper wires used in typical transmission lines lose a percentage of the electric energy passing through them because of resistance, which causes some of the electric energy to turn into heat.

But “superconducting” materials have no resistance, and if they are used to transmit electricity in the future, very little of the electric energy will be lost.

Energy storage can also make an electric utility system operate more efficiently. The most familiar way to store electricity is using batteries, but many other technologies have been developed, ranging from pumping water uphill to trapping electrical current in superconducting wire loops.

Unlike other energy sources like natural gas, fuel oil, or gasoline, which are held in large storage tanks until they are needed, most of the electricity is generat-

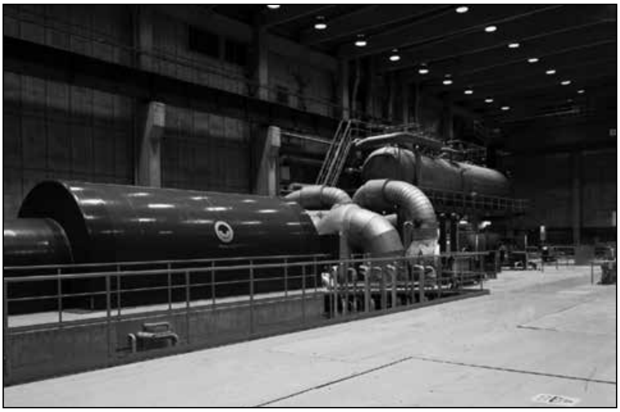

Figure 14.1 Cogeneration. Combustion for heat production may be coupled to electricity generation in turbines, as in this turbine hall. When the hot steam is pressed through the turbines electricity is generated. The steam is cooled to temperatures appropriate for the district heating system. With this combined system efficiency is close to the theoretical maximum. (Photo: Kjell-Arne Larsson).

ed at the moment it is needed. To meet changing electrical demands, some power plants must be kept idling in case they are needed. These plants are known as spinning reserves, and they waste energy. During times of high electrical demand, inefficient power plants may be brought on-line to provide extra power, and the transmission system may be stretched to near its limit, which also increases transmission energy losses. On the other hand, the inability to store excess electricity during periods of low demand can force utilities to operate power plants at less than full power, which is usually less efficient.

Energy storage allows excess electricity to be stored during slack times and used during periods of high demand. Energy storage can also help electric utilities to make the best use of intermittent energy sources, like wind and solar power. Another way for utilities to meet these changing energy demands is to locate smaller power sources close to the customers that need the power. This concept, called *distributed generation*, helps take the load off of transmission lines and, because the electricity travels only short distance before it is used, there is little or no energy lost in the transmission of the electricity.

Power Factor Improvement. Power factor quantifies the reaction of alternating current (AC) electricity to various types of electrical loads. Inductive loads,

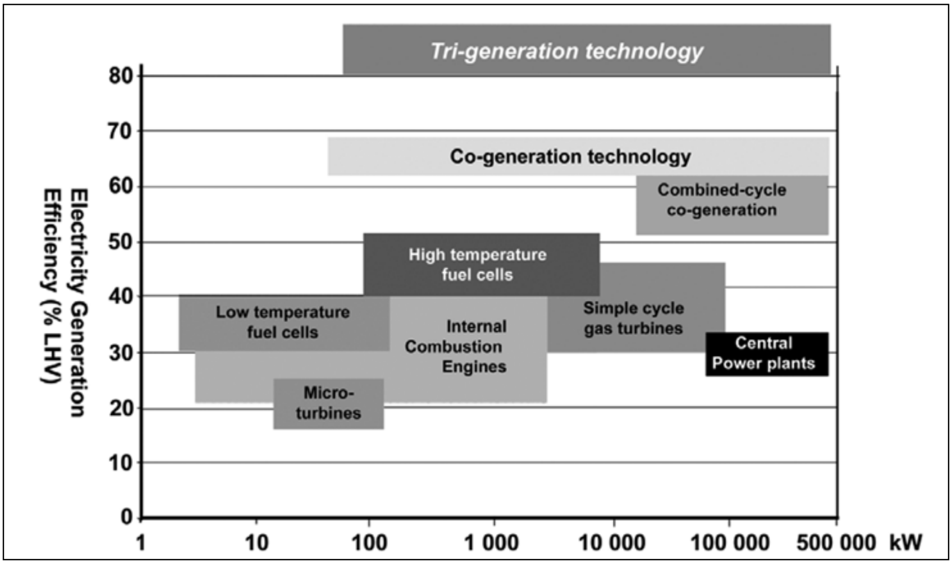

Figure 14.2 Trigeneration technology. Comparison of the over-all energy efficiency between different electricity generation technologies. (Source: Adapted from brochure: Trigeneration, EPA Combined Heat and Power Partnership, 1999).

as found in motors, drives and fluorescent lamp ballasts, cause the voltage and current to shift out of phase. Electrical utilities must then supply additional power, measured in kilovolt amps (kVA), to compensate for phase shifting.

The total power requirement constituents can be broken down into the resistive, also known as the real component, and reactive component. Useful work performance comes from the resistive component, measured in kilowatts (kW) by a wattmeter. The reactive component, measured in reactive kilovolt amps (kVAR), represents current needed to produce the magnetic field for the operation of a motor, drive or other inductive device but performs no useful work, and does not register on measurement equipment such as the watt meter. The reactive components significantly contribute to the undesirable heating of electrical generation and transmission equipment formulating real power losses to the utility.

The power factor derives from the ratio of real, usable power (kW), to apparent power (kVAR). Mathematically, the power factor is expressed as:

$$PF = kW/kVAR$$

As an example consider a 480 volt 3-phase system with an assumed load and instrument readings as follows: the ammeter indicates 200 amps and wattmeter reads 120 kW. The power factor of the load can be expressed as follows:
The apparent power for a 3-phase circuit is given by the expression:

$$kVA = E \text{ x } I \text{ x } \sqrt{3}/1000 = 480\text{volts x } 200\text{amps x } 1{,}73/\ 1000 = 166{,}08\text{kVA}$$

Therefore: $PF = kW/kVA = 120/166{,}08 = 0{,}7224 = 72{,}25\%$

From the above example it is apparent that by decreasing the power drawn from the line (kVA) the power factor can be increased. Preventive measures involve selecting high-power-factor equipment. For example, when considering lighting, only high-power factor ballasts should be used for fluorescent and high intensity discharge (HID) lighting. The power factor of so-called normal-power factor ballasts is notoriously low, on the order of 40 to 55%.

When induction motors are being selected, the manufacturer's motor data should be investigated to determine the motor power factor at full load. Some motor manufacturers have introduced premium lines of high-efficiency, high-power-factor motors. In some cases, the savings on power factor alone can justify the premium prices charged for such motors. Motors should also be sized to operate as closely as possible to full load, because the power factor of an induction motor suffers severely at light loads. Power factor decreases because the inductive component of current that provides the magnetising force, necessary for motor operation, remains virtually constant from no load to full load, but the in-phase current component that actually delivers work varies almost directly with motor loading.

14.2 Level out peaks in the demand profile

Load Factor Improvements. Load factor is defined as the ratio of the average kilowatt load over a billing period to the peak demand. For example, if a facility consumed 800,000 kWh during a 30-day billing period and had a peak demand of 2,000 kW, the load factor is:

Load Factor = (800,000kWh/720hrs)/2,000kW = 0.55 or 55%

The user will obtain the lowest electric cost by operating as close to a constant load as possible (load factor 100%). The closer a plant can approach this ideal situation, the lower the monthly demand charge will be. The key to a high-load factor and corresponding lower demand charge is to even out the peaks and valleys of energy consumption.

In order to level out peaks in the demand profile, it is necessary to reduce loads at peak times. Consequently it is necessary to identify the various loads that could be reduced during periods of high demand. Approaches that could be considered are:

1) *Stagger Start-Up Loads* – If a high-peak load is determined to result from the simultaneous start-up of several loads, such as might occur at the beginning of a shift, consideration can be given to staggering start-up of equipment to span two or more demand intervals.
2) *Reschedule Loads* – Peak demands are usually established at particular times during the day shift. A review of the operating schedule may show that individual loads can be rescheduled to other times or shifts to even out demand. This technique can provide significant gains at little or no cost. For example, operation of an electric oven might be rescheduled to the evening shift if the oven is not needed full-time. Another example is conducting routine testing of the fire pump during periods when peak demands are not likely to occur.

3) *Increase Local Plant Generation* – When some electricity is generated by the plant, plant generation can be temporarily increased to limit demand. In some

cases, any venting of excess low-pressure steam from the turbo-generator for short periods may represent a lesser penalty than the increased demand charge.

4) *Install Automatic Demand Control* – The power demand controller automatically regulates or limits operation in order to prevent set maximum demands from being exceeded. The type of controller best suited for a plant operation is that which will predetermine the demand limit and the demand interval.

The overall usage of power is constantly monitored from the power company meter, the power usage of all the controlled loads is also monitored. By having this information the controller can calculate when an overrun of the desired demand limit will occur. The controller will delay any demand threatening to exceed the demand limit to allow time for loads to "level out".

14.3 Saving Thermal Energy – Boilers

Thermal energy services in an industry consist of the supply of heating and cooling to an industrial process. A boiler is a device where energy extracted from some type of fuel is converted into heat that is distributed to needed places (to do useful work). In the process, the carrying media (circulating water or steam) gives up the heat and is cyclically reheated again and again.

Carnot cycle. An ideal model of a boiler operation is based on the Carnot cycle. The Carnot cycle is defined as two reversible isothermal and two reversible adiabatic processes. Heat is added to the cycle during the isothermal process at

Figure 14.3 Boilers. Boilers, mostly for providing hot water, are basic in most energy systems. In smaller or medium sized industries, residential areas or large buildings, boilers in the size of 100-1,000 m³ with output energy of 10-500 MW are common. The proper maintenance and use of boilers is important for energy efficiency. Further improvement is possible by using a cogeneration equipment in the scale proper – also small equipment are available – to produce both heat and power (electricity). (Photo: iStockphoto).

high temperature, TH. Then follows an adiabatic process producing work as the working fluid is expanded to a lower pressure. During the next isothermal stage, heat is rejected to the low temperature reservoir at TL. During the last phase the working fluid is adiabatically compressed to finish the cycle.

The Carnot cycle is the most efficient cycle for the given low and high temperatures. Its efficiency is given by:

$\eta = 1 - (T_l/T_H)$

The efficiency of a real boiler is always lower than this ideal Carnot efficiency. The boiler efficiency can be improved and maintained through proper maintenance and monitoring of operation. Some performance improvements are easily achieved. They are all dependent on proper maintenance or operation procedures.

Adjustment of air-to-fuel ratio. For each fuel type, there is an optimum value for the air/fuel ratio. The air/fuel ratio is the ratio of combustion air to fuel supplied to the burner. For natural gas boilers, this is 10% excess air, which corre-

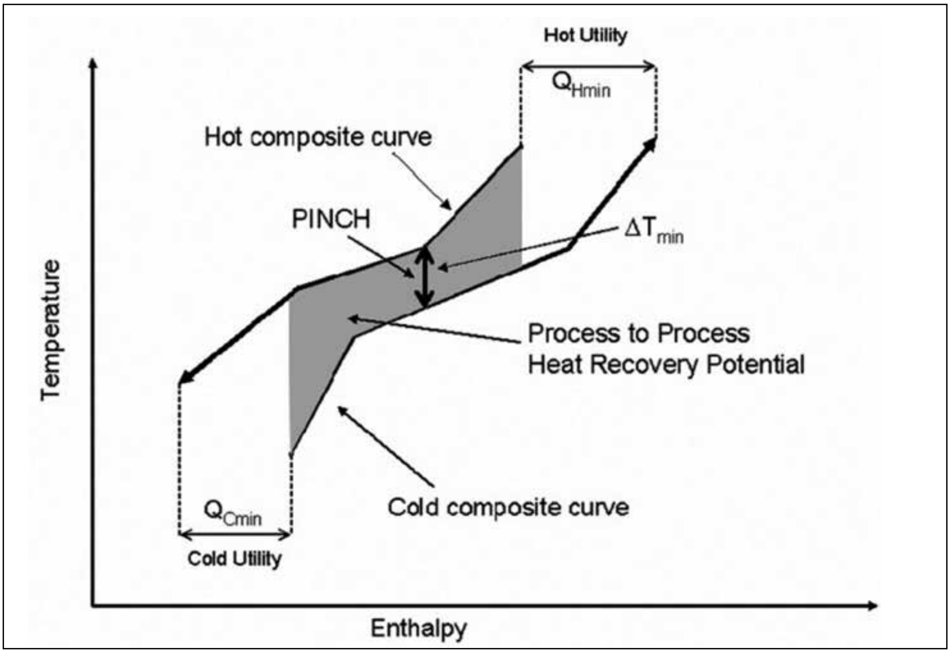

Figure 14.4 Pinch Analysis. Composite Curve diagram (Source: Adapted from Cheresources, 2004]. http://www.cheresources.com/pinchtech1.shtml)

sponds to 2.2% oxygen in the flue gas. For coal-fired boilers, the values are 20% excess air and 4% oxygen.

Elimination of Steam Leaks. Significant savings can be realised by locating and repairing leaks in live steam lines and in condensate return lines. Leaks in the steam lines make steam to be wasted, resulting in higher steam production requirements from the boiler to meet the system needs. Condensate return lines that are leaky return less condensate to the boiler, increasing the quantity of required make-up water.

Maintenance of Steam Traps. A steam trap holds steam in the steam coil until the steam gives up its latent heat and condenses. In a flash tank system without a steam trap (or a malfunctioning trap), the steam in the process heating coil would have a shorter residence time and does not condense completely. The uncondensed high-quality steam would then be lost from the steam discharge pipe to the flash tank.

High Pressure Condensate Return Systems. As steam loses its heat content it is condensed into hot water, called condensate. A sudden reduction in the pressure of a pressurised condensate will cause the condensate to change phase into steam, more commonly called flashing. Flash tanks are often designed into a pressurised return system to allow flashing and to remove non-condensable gases from the steam. The resulting low-pressure steam in the flash tank can often be used as a low-temperature heat source. A more efficient alternative is to return the pressurised condensate directly to the boiler through a high-pressure condensate return system.

Conversion of boilers. An important means to improve energy management is to change boilers using oil to other fuels, such as gas or biofuels. This conversion reduces GHG emissions per output energy. By replacing the burners and changing the burner configuration the efficiency of the boiler can be greatly improved. Thus a more complete combustion of the fuel with right temperature, and a better distribution of the flue gases in the boiler can be achieved. The better distribution of gases will increase the overall heat transfer as well as prevent “hot spots” in the neighbourhood of the burner orifice that causes extensive formation of nitrogen oxides.

Fluidised bed combustion (FBC) has emerged as a viable alternative boiler design that has significant advantages over conventional firing system and offers multiple benefits. FBC boilers can burn fuel with a combustion efficiency of over 95% irrespective of ash content, and an overall efficiency of 84% (plus or minus 2%). High heat transfer rate over a small heat transfer area immersed in the bed result in overall size reduction of the boiler. FBC boilers can be operated efficiently with a variety of fuels. Air emissions can be reduced as SO_2 formation is minimised by the addition of limestone or dolomite for high sulphur coals or oil, while a low combustion temperature eliminates NO_x formation. Finally by operating the fluidised bed at elevated pressure, it can be used to generate hot pressurised gases to power a gas turbine. This can be combined with a conventional steam turbine to improve the efficiency of electricity generation and give a potential fuel savings of at least 4%.

14.4 Heat recovery systems and pinch technology

Heat recovery systems are installed to make use of some of the energy which otherwise would be lost to the surroundings. The systems use a hot media leaving the process to preheat other, or sometimes the same, media entering the process. Thus energy otherwise lost does useful work. Ventilation, process exhaust and combustion equipment exhaust are the major sources of recoverable energy. Regardless of the amount or temperature of the energy discharged, recovery is impractical unless the heat can be effectively used somewhere else. Also, the recovered heat must be available when it is needed.

Heat recovery uses *heat exchangers*. Heat exchangers have been improved considerably in recent years, both for exchanges in gas and liquid phase. Heat exchangers are used in a great many processes. Heat extracted from indoor air ventilated to the outdoors is used to heat the incoming air. This is a very important part of heat recovery. In modern buildings the air is exchanged once every hour and some 25% of the heat used to heat buildings is lost in ventilation. Heat exchangers are also used to recover heat from exhausts flue gases.

Pinch Technology. The design of a new process, or the optimisation of an existing process, is a complex task, due to interactions between the unit operations that make up the process. These interactions force the designer not to consider each unit operation individually, but the whole process system as a whole. This is especially important for analysis and optimisation of heat recovery systems.

Pinch technology presents a simple methodology for systematic analysis of processes and the surrounding utility systems with the help of the first and second laws of thermodynamics.

The first law of thermodynamics provides the energy equation for calculating the enthalpy changes (ΔH) in the process streams passing through a heat exchanger. The second law stipulates that heat energy only may flow in the direction of warm to cold, whereby the direction of the flow of heat is determined. This prohibits "temperature crossovers" of the warm and cold stream profiles through the exchanger. The warm stream can only be cooled to, and the cold stream heated to a temperature defined by the "temperature approach" of the heat exchanger. This temperature approach is the minimum allowable temperature difference (ΔT_{min}) in the stream temperature profiles. The temperature level at which ΔT_{min} is observed in a process is referred to as the “pinch point”.

The steps of a pinch analysis are:

1. Identification of hot, cold and utility streams in the process. Hot streams are those that must be cooled or are available to be cooled. Cold streams are those that must be heated. Utility streams are used to heat or cool process streams. A hot utility may be steam, hot water, flue gases etc. A cold utility may be cooling water, air, refrigerant etc.
2. Thermal data calculation. From the supply temperature (T_S°C), the target temperature (T_T°C) and the heat capacity flow rate (CP kW/°C) of each stream the potential enthalpy change (ΔH) of the streams are calculated.
3. Selection of the initial ΔT_{min} value. A minimum heat transfer driving force must always be allowed for a feasible heat transfer design. In mathematic terms, at any point in an exchanger $T_H - T_C \geq \Delta T_{min}$, where T_H is the hot stream temperature and T_C the cold stream temperature.
4. Construction of composite curves. Composite curves consist of temperature-enthalpy profiles of heat availability in the process (the hot composite curve) and heat demands (the cold composite curve). We can then build the curves of hypothetical heat exchangers overlapping these hot and cold composite curves so that they are separated by a minimum temperature difference. The final horizontal overlapping of the composite curves is the maximum amount of energy that can be recovered and the enthalpy in

intervals not overlapping represent the enthalpy requirements that cannot be fulfilled with process streams and thus are the minimum required cooling and heating utilities for the process.

By applying the pinch analysis methodology to a complex process system the task of optimising the heat flows in the process system is greatly facilitated. In order to maximise energy recovery and minimise the energy (both heating and cooling) requirement an appropriate heat exchanger network is required. With the use of pinch analysis the design of the heat exchanger network becomes very systematic and methodical.

14.5 Heat pumps

Heat pumps function by moving (or pumping) heat from one place to another. A heat pump takes heat from a heat source outside and pump it inside. Heat pumps use electricity to operate pumps that alternately evaporate and condense a refrigerant fluid to move that heat. In the heating mode, heat pumps are far more "efficient" at converting electricity into usable heat because the electricity is used to move heat, not to generate it.

The most common type of heat pump – an air-source heat pump – uses outside air as the heat source during the heating season and the heat sink during the air-conditioning season. Water-to-water heat pumps work the same way, except that the heat source/sink is the ground, ground water (geothermal heat pumps), or a body of surface water, such as a lake (surface water heat pumps). For large installations geothermal or surface water based heat pumps are the most common.

The efficiency or coefficient of performance (COP) (a ratio calculated by dividing the total heating capacity provided by the heat pump by the total electrical input) of water-to-water heat pumps is significantly higher than that of air-source heat pumps because the heat source is warmer during the heating season and the heat sink is cooler during the cooling season. Ground-source heat pumps are also known as geothermal heat pumps.

Ground-source heat pumps are environmentally attractive because they deliver so much heat or cooling energy per unit of electricity consumed. Water-to-water heat pumps connected to geothermal sources and low temperature, below 100 ^{o}C,

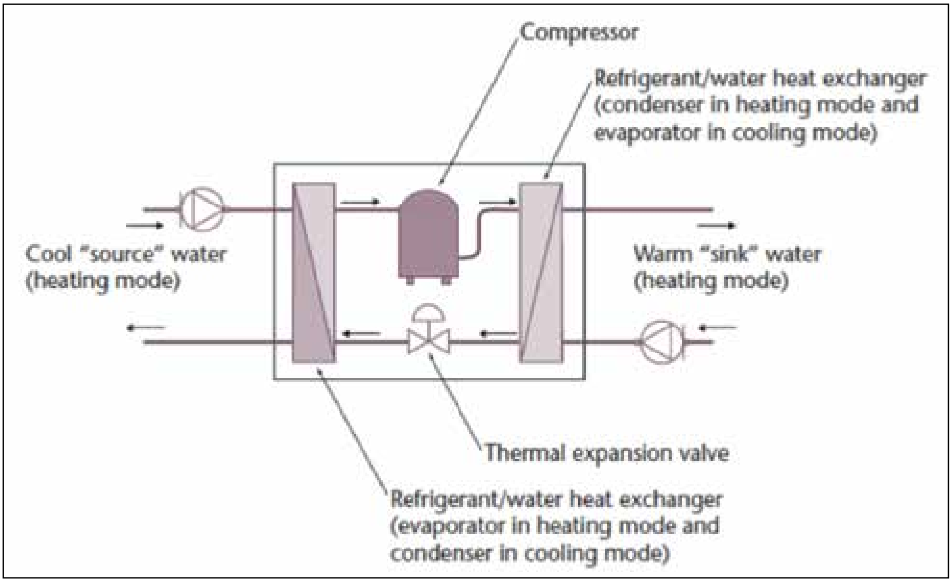

Figure14.5 Geothermal heat pump (Source: adapted from U.S. DOE, 2003).

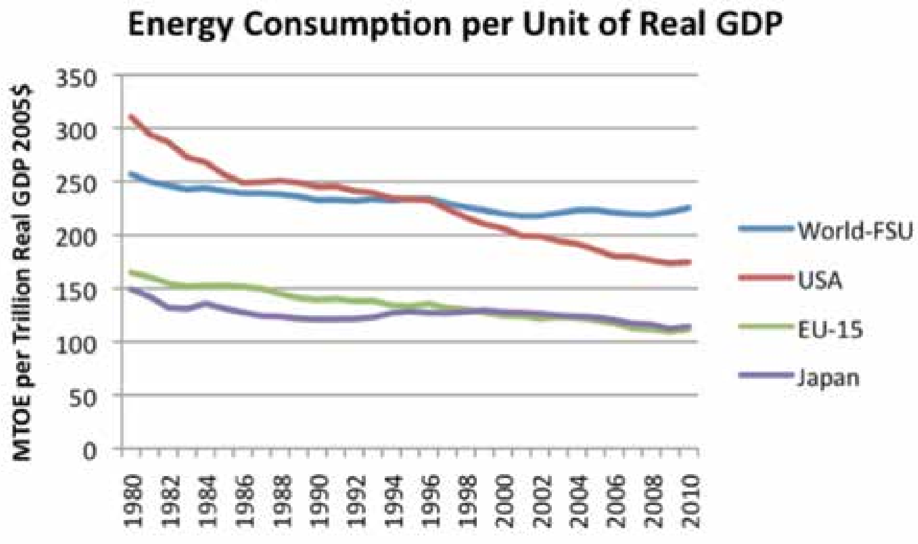

Figure 14.6 Using heat pumps. This large industrial heat pump is taking its heat from the flue gases from waste combustion at Vattenfall, Uppsala Energy. In the process the gas condenses and the heat extracted is transferred to the district heating system. In other large-scale applications heat is extracted from sewage water or surface water. The chilled water may be used for district cooling. Most heat pumps are smaller and used for individual homes. (Photo: Kjell-Arne Larsson).

loads typically have COPs in the range of 2.5 to 3.2. The best ground-source heat pumps are more efficient than high-efficiency gas combustion, even when the source efficiency of the electricity is taken into account.

Insulation. Although not generally viewed as a part of the mechanical design system, insulation is an important part of every piece of equipment or building where any transfer of fluids or gases takes place and that their temperature is required to be different than that of ambient air. Properly insulated pipes, tanks and other equipment can save substantial amounts of energy.

There are several opportunities in the industrial sector to realise energy savings by installing insulation in manufacturing facilities. Good insulation design and installation are very important in terms of performance and energy efficiency.

It is essential to determine the most appropriate type and thickness of insulation for specific applications. The most cost-effective approaches involve insulating pipes and tanks.

Other obvious measures include covering surfaces of hot liquids – also water – and dimensioning the equipment correctly. Large pipes and tanks leak more heat to the surroundings than smaller, as diffusion is proportional to the surface area.

14. 6 Saving Thermal Energy – Cooling Systems

Choosing the Right Source of Cold Temperature. For process cooling it is always best from the standpoint of energy conservation to use the lowest form of energy first. That is, for a piece of equipment or a process that is air cooled, first use outside air (an economizer) if the outside air temperature is low enough. The next step, in appropriate climates, would be to use direct evaporative cooling. This is a process in which air passing through water droplets (a swamp cooler) is cooled, as energy from the air is released through evaporation of the water. Evaporative cooling is somewhat more energy intensive than the economizer but still provides some relatively inexpensive cooling. The increase in energy use is due to the need to pump water.

Indirect evaporative cooling is the next step up in energy use. Air in a heat exchanger is cooled by a second stream of air or water that has been evaporatively cooled, such as by a cooling tower and coil. Indirect evaporative cooling may be effective if the wet-bulb temperature is fairly low. The wet-bulb temperature is the temperature indicated by a thermometer for which the bulb is covered by a film of water. As the film of water evaporates, the bulb is cooled. High wet-bulb temperatures correspond to higher air saturation conditions. For example, dry air

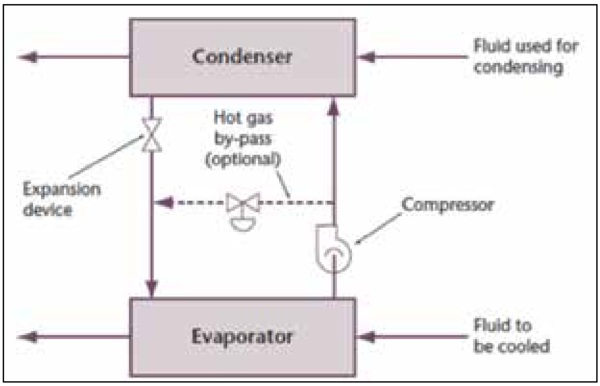

Figure 14.7. Vapour-compression re-frigeration system. (Source: Perry and Green, 1984).

Figure 14.8. Insulation. Energy efficiency requires that pipelines are well-insulated. (Photo: Waska Williams Jr. – North Slope Borough)

has the ability to absorb more moisture than humid air, resulting in a lower, wet-bulb temperature.

Indirect evaporative cooling involves both a cooling tower and swamp cooler, so more energy will be used than for the economizer and evaporative cooling systems because of the pumps and fans associated with the cooling tower. However, indirect cooling systems are still less energy intensive than systems that use a chiller. The final step would be to bring a chiller on line. Many plants have chillers that provide cooling for various plant processes. Chillers consist of a compressor, an evaporator, an expansion valve, and a condenser.

Cooling towers dissipate heat by evaporation of water that is trickling from different levels of the tower. Usually the water is sprayed into the air, so the evaporation is easier. Cooling towers conserve water, prevent discharge of heated water into natural streams and also avoid treating large amount of makeup water.

There are three types of cooling towers widely used today: mechanical forced-draft towers, induced draft towers and hyperbolic towers. Mechanical forced-draft is designed to provide an air supply at ground level and at amounts that are easily controlled by fans. In case of induced-draft towers the fan is mounted on the top of the tower. This arrangement improves air distribution and less make-up water is needed. The hyperbolic tower is based on the chimney effect. The effect of the chimney eliminates the need for fans that are necessary for both induced-draft and mechanical forced-draft cooling towers.

Absorption Refrigeration. Packed absorption liquid chillers are used to produce chilled liquid for air-conditioning and industrial refrigeration processes. The chillers are usually powered by low-pressure steam or hot water, which can be supplied by the plant boiler or by waste heat from a process.

In the absorption cycle, two distinct chemicals are used and the cycle is driven by heat. The most common absorption system fluids are water as the volatile fluid and lithium bromide brine as the absorber fluid.

Mechanical Refrigeration. Refrigeration machines provide chilled water or other fluid for both process and air conditioning needs. Of the three basic types of refrigeration systems (mechanical compression, absorption, and steam jet), mechanical compression is the type generally used. The other two have application only in special situations.

The mechanical compression refrigeration system consists of four basic parts; compressor, condenser, expansion device, and evaporator. A refrigerant, with suitable characteristics, is circulated within the system. Low-pressure liquid refrigerant is evaporated in the evaporator (cooler), thereby removing heat from the warmer fluid being cooled. The low-pressure refrigerant vapour is compressed to a higher pressure and a correspondingly higher saturation temperature. This higher pressure and temperature vapour is condensed in the condenser by a cooling medium such as cooling tower water, river water, city water, or outdoor air. The higher pressure and temperature refrigerant liquid is then reduced in pressure by an expansion device for delivery to the evaporator.

District Cooling. By connecting to a trigeneration power plant delivering district cooling, an industry may cover its need for process or facility cooling in an energy and environmentally efficient manner. This is becoming increasingly used in e.g. restaurants and other services where cold rooms are used. It is obvious that just as with district heating, environmentally it is advantageous with a central facility that can be run with optimal efficiency, be well regulated, and equipped with proper environmental protection.

Insulation. Just as with heating systems, cooling systems need to be properly insulated. Insulation is an important part of every piece of equipment or building where any transfer of fluids or gases takes place and that their temperature is required to be different than that of ambient air. Properly insulated pipes, tanks and other equipment can save substantial amounts of energy. Good insulation design and installation are very important in terms of performance and energy efficiency. It is essential to determine the most appropriate type and thickness of insulation for specific applications.

Chapter 14 sources:

Lennart Nilsson, from Chapter 6 in *Cleaner Production – Technologies and Tools for Resource Efficient Production* of the Baltic University Programme http://www.balticuniv.uu.se/index.php/boll-online-library/827-em-2-cleaner-production-technologies-and-tools-for-resource-efficient-production

Chapter 15
Energy Management

15.1 Basics of resource management

Management, which literally means "handling" (from *manus* = hand in Latin), usually refers to a process which is planned and carried out according to a set procedure. Management of energy resources and use is thus a question of how to be aware of the energy resources one has access to, to know what they are and how they are used, and then to change this situation to the better for the organisation in which you are responsible for energy use. This may in the simplest case be personal or for a household, but more often it refers to a company, may be an industry, a municipality or even a country.

Business has since at least the 1960s a culture of management and education of management and a wealth of methods and tools for management. This most often refers to the management of financial resources – money – but to the field of economic management we need to add the management of personnel, i.e. human resources, and the management of material resources. Energy management is part of management of physical or material resources.

Most management systems are built on the so-called "Plan-Do-Check-Act" quality management model introduced by Deming in the USA in the 1950s. This model puts great emphasis on the concept of continuous improvement. In the following we will explain and discuss the requirements of an efficient energy management system according to the basic *Deming Cycle* (Fig. 14.1) as applied in industries, municipalities etc.

Management systems have today been standardised though agreements between countries and business representatives all over the world. Best know is the ISO organisation (ISO= International Organization for Standardization). ISO standards have been globally agreed and it is possible to get a certificate that an ISO standard has been implemented and properly audited in the organization. The first ISO standards were the quality standards in the series ISO 9001. Soon thereafter followed the ISO 14001 standards for Environmental Management Systems, EMS. Energy management standards, which are much more recent, are in the series ISO 50001. However there are many other standards, some of them are local or national. They are also developed by and are part of an organization

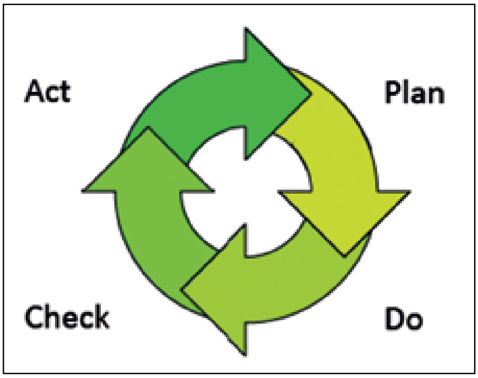

Figure 15.1 The Deming cycle

and may also be audited and offer a certificate. The reasons for this is that to fully implement an ISO standard is quite requiring and also expensive. It may be worth it but perhaps it is good so start with something simpler.

To improve resources management an organisation needs to focus not only on what happens but also on why it happens. Over time, the systematic identification and correction of system deficiencies leads to better environmental and overall organizational performance.

Most organisations apply *Total Quality Management* (TQM) principles to some of their operations and activities. An effective Management System is built on TQM concepts. TQM was mostly developed in the USA, though the Japanese were the first to visualize its benefits and apply it successfully. They found that if management and employees solved problems together, everyone was committed to the solution. TQM differs from traditional quality improvement techniques in several ways. Most important is that it focuses on system problems. Statistical methods are used to find the reasons for problems, and active employee involvement is required. TQM uses new and alternative methods to improve an organisation's performance while involving all hierarchical levels of staff – from top-management to frontline workers. Environmental Management and Energy Management Systems are at best part of Total Quality Management.

15.2 Energy management in the industrial sector

Large energy-intensive industries are the first which need to adopt a system of energy management. However it is not always done. In a project administered by the Swedish Energy Authority from 2007 much experience has been gained how to work in practice with energy management. The project, called PFE, recruited

100 industrial companies in the first round. To attract them into the project the participating companies were relieved from part of energy taxation (0.5 Euro per MWh). Requirements were simple: They all had to introduce an energy management system, map energy use and improve their energy efficiency.

This is how it was carried out: One or perhaps several individuals in the company were assigned the responsibility to work with energy management. Ideally the whole company from the Director to every single worker should be informed about the project and also get some professional *education* in the energy field. It should be clear that *the project is promoted by the leadership* of the company. In this way the managers who will walk around and photograph, measure and talk to all employees will be welcome wherever they go.

The first big part of the management procedure is *mapping energy use*. This is done by looking into every room and process: photograph, measure and talk to most people. Both heat and electricity used should be included, if possible also cooling. This part will take a long time. It requires measurements as far as possible, in the terms of kWh used per day for each purpose. Some uses may be difficult to measure - e.g. the energy dissipated from a badly insulated tubing or heat used for big rooms - while others may be measured exactly, especially electricity used for lighting, motors, fans etc.

Secondly the managers comes up with *energy efficiency proposals*. For each proposal a list of advantages and drawbacks and calculations should be made. *Calculations* should include both potential energy savings and needed financial investments. Together with energy price the managers should be able to estimate time for return of investment.

Based on this list the industrial staff decides on a *number of projects*. Finally the projects are implemented and then evaluated. After that the first round of the management cycle is complete.

One example is the Swedish company *Sandvik Materials Technology* factory in Sandviken in mid Sweden. It is a fairly large working place with 9,000 employees producing special steel products with an annual turnover of 17,700 billion SEK, this is close to EUR 2 billion. This factory had a history of environmental management; thus some knowledge and experience was already at hand. They were certified according to the EMS 14001 in 1999, had an integrated permit (IPPC EU Directive) from 2002 and joined the PFE project in 2005.

Two engineers got responsibility for carrying out the energy management. They spent almost a whole year to map energy use in the factory. In the end 52 projects were implemented, which took 2 years to do. The cycle was thus about three years, which is normal.

Primary improvements in the project included:

- Temperature adjustments
- Heat recovery
- New valves (to control flows)
- Insulation
- Changed routines
- New lighting
- Toilets (not being lit 24 hours, but just when used)

Secondary improvements caused by these changes were e.g.

- Reduced water use (which is also saving energy and money)
- Decreased fire risks
- Less air pollutants
- Less noise

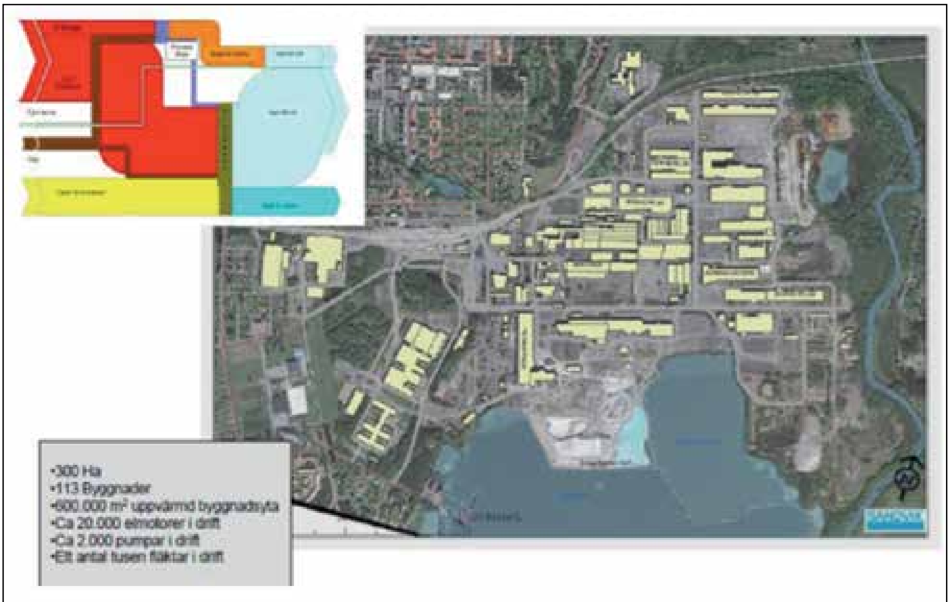

Figure 15.2 Sandviken Materials Technology, Sweden, where one of the PFE energy management project was run. The photo shows the industry facilities of 300 ha, 113 buildings, 600,000 m^2 surface area. There are a total of 20,000 electric motors, 2,000 pumps, and several thousand fans.

As a result of the projects the reduction of energy use was 19,304 MWh /year. A number of further projects are under planning. When they have been carried out it is foreseen that energy consumption will decrease with another 32,942 MWh /year.

Sandviken Materials Technology was one out of a total of 100 energy intensive companies which took part in the PFE under the Swedish Energy Authority. All of them made a complete energy use mapping; all introduced a certified energy management system. A total of 1,247 projects were carried out which reduced the total electricity consumption in the 100 companies by 1.47 TWh. Investments totalled 708 M SEK (about Euro 70 M) and reduced energy costs were 400 MSEK (about Euro 40 M) annually. This means that average return of investments was 1.5 year. Tax reductions totalled 150 MSEK annually, that is much less than the reduced energy costs. A second group of 94 industrial companies joined the PFE in 2012. The Energy Authority counts PFE as a means to not only reduce energy consumption and emissions but in general to improve environmental performance.

15.3 Cleaner Production as a management approach

Production in a factory may be improved tremendously by Cleaner Production, CP. It is a method for environmental management which is very important also for energy efficiency. Cleaner Production intends to improve the eco-efficiency in companies by the implementation of technical or organisational actions. This means that CP measures should reduce the negative effects to the environment, reduce operating costs and resource and energy use. Cleaner Production works with process integrated - preventive - methods instead of End-of-Pipe solutions. The five basic Principles of CP are

- *Input-Substitution*; use of less hazardous raw-, auxiliary- or operating materials and use of operating materials with a longer life-time.
- *Good Housekeeping*; increasing the Material and Energy efficiency with actions in the process. Try to fetch the "Low hanging fruits" first, such as reducing losses due to leakage. It is important with training of employees.
- *Internal Recycling*; closing of Material and Energy Loops (Water, Solvents,…) and Cascading of Material and Energy streams.
- *Technological Optimisation*/Change
- *Optimisation of the Product*

It is clear that in the example described above - Sandvikens Material Technology – many of the projects in the first round may be listed as "low hanging fruits".

These are simple actions which still contributed to energy reduction. They included being careful with heating and lighting in the rooms of the industry, as well as adjusting the flows of e.g. hot and cold water or solvents.

A study on a *beverages factory* in Austria will illustrate some of the possibilities when working with CP methods. In their case use of water was central. They did the following:

1. Started to monitor water use carefully.
2. Installed valves to close water when not used.
3. Fix “low hanging fruits” (leaks etc)
4. Reuse of wastewater (down-classing of water) was introduced.
5. Recirculation of cooling water after cooling (closed cooling water system)
6. Recirculation of process water (after specific purification)
7. Redesign of processes (e.g. introducing counter current rinsing)

The changes made were carried out in cooperation with the engineering faculty at the University of Technology in Graz and took several years. Counted over the whole period the use of water decreased almost tenfold. It led to reduced water costs, reduced costs for waste water cleaning and management, reduced use of chemicals, reduced energy cost, and reduced personnel costs. Of course it was also profitable economically.

Also the *pulp and paper industry* was a classical user of huge volumes of water. Introduction of CP methods in the 1990s in the development of this industry branch has had dramatic results in improving its performance. In particular the recycling of process water has been important. A difficulty, which was solved, was to remove manganese in the process water before it could be fed back to the process. In addition to the reduced water consumption other steps in this industry has been to use black liquor for energy purposes. Black liquor originates from lignin and hemi-cellulose in the wood; it has about 50% of the energy content of the wood. This has almost made pulp production energy independent, although some factories prefer to make biodiesel from black liquor and sell.

It should also be mentioned that the use of a large amounts of recycled paper (from external recycling) has reduced virgin forest use significantly. The production of recycled paper uses about 40% less energy compared to paper from wood. A paper fibre may be recycled about 6 times. This corresponds to a total of 2.5 times less energy.

15.4 Energy management in the housing sector

Buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU. Many older buildings are not at all efficiently heated and in addition uses coal, oil or gas. While new built houses are more energy efficient and use a larger share of renewable energy the older buildings have a huge need for retrofitting and energy improvements. Such improvements not only reduced energy consumption and CO_2 emissions but also reduce costs.

Energy Service Companies have been operating within the energy sector for buildings for many years and recognise the challenges that housing organizations face and the need for change. They take a comprehensive view of a building's carbon footprint, identify the areas where improvements can be made and implement practical, engineered solutions to reduce energy consumption and carbon emissions. The benefits are immediate, including reduced costs, improved building comfort and legislative compliance.

The most established management system is called Energy Performance Contracting (EPC). EPC owes its success to a new form of reducing financial risks when investing in improved energy performance. An EPC overcomes the need for upfront capital investment by the owner of buildings by guaranteeing the costs to be covered until reduced energy costs have covered the investments. You may say that the EPC works as a bank for the project.

An EPC works in four stages, more or less as in a typical Plan-Do-Check-Act cycle:

Figure 15.3 A pulp and paper factory in Sweden.

1. *Prestudy* in which the opportunities for a real project is evaluated. If it is favourable the owner of the buildings and the EPC company sign a contract for a project planning phase.
2. *Project development*. Here the company in some detail outlines which projects are possible, the energy savings for each of them, the economic investments and saving for each of them and finally the educational needs. If the owner wants to continue a contract for carrying out the job is signed.
3. *Implementation phase*. The agreed actions are carried out and education of personnel made. Some typical actions include improved windows and doors, sometimes improved insulation of walls and roof; improved circulation of hot water, adjustments of circulation pumps, better control of heat exchangers, sometimes improvement of tubing; improved ventilation with heat exchangers.
4. *Evaluation*. Energy and financial savings are monitored. If the project has been financed by the owner payment is due. If it is not, the house owner pays the old energy costs until the costs for the project has been covered. It is normally the EPC company that takes the risk, if savings are less then foreseen.

Thereafter the owner reap the cost savings. A long series of EPC have been carried out in all of EU as part of the European Energy Service Initiative. Experiences are very good. Many case studies are found in the EU-ESCO report. (See sources for this chapter, where also 60 examples from Sweden are found.) On the average in the apartment house sector 22% reduction of energy use was achieved. In industry buildings the reduction was 55%.

It should be added that much can also be achieved by the individuals living in the houses. Adjustment of temperature, careful use of equipment and careful use of lighting are typically dependent of the inhabitants rather than the house owner.

15.5 Energy management in the local community

Energy management in a municipality focus on the sources of energy at least as much as the use of energy. Reasons are that a high dependency of imported fossil energy resources makes the municipality dependent on external factors and reduces energy safety. If more of the energy needs are covered by local sources the municipality is less vulnerable and more sustainable.

A successful change from a classical situation with much imported fossil energy resources to a “post-oil” situation requires that the municipality set up an office for this purpose, have management personnel, and take the typical steps to improve its situation as described.

Figure 15.4 Energy Performance Contacting, EPC. Good practice example Norrtälje municipality 7 buildings, 11,000 m^2 Contracted 2003. Energy savings 36% (Source: http://www.european-energy-service-initiative.net/se/goda-exempel/paa-engelska-eesi.html)

The first task is typically to map the energy sources available in the local region. This may be a very wide array of energy types. In Uppsala, Sweden, a first not too comprehensive mapping could locate 18 different sources of renewable energy. Some of them are

- *Electricity* Sun/Wind/Streaming water for electricity, solar cells for PV electricity, wind power, new technologies.
- *Heat*: Biomass, solar panels for heating, heat pumps, new technologies.
- *Fuels*: Biodiesel, ethanol, wood chips, pellets, biogas.

When starting to use new energy forms the municipality may either be cooperating with an energy company or create one themselves. There are several strategies possible. The creation of local energy supply is itself a strategy; it is called *distributed generation*. Another possibility is upscaling. E.g. if many houses in the municipality is connected to a district heating network and stop individual heating, it is *upscaling*. One may also include the strategy of waste management here. Use of organic waste collected by the municipality for waste incineration or for production of biogas is another form of upscaling as well as a local energy supply.

There are many reason for a municipality to start to improve energy management. These include support local development and new jobs; to combat climate change; to create social capital and promote sustainable development. Experience confirms the conclusion that this can be achieved.

There are many good examples: From 1992 the small town of *Güssing* in Austria became self-sufficient with regards to electricity, heating, and transportation within eleven years. In addition, more than 60 new companies and over 1,500 new “Green Jobs” were created; the share of commuters to other regions fell to 40%. Since Güssing generated more “green” energy than the region needed, the

Figure 15.5 A housing area in Vauban Freiburg, Germany.

value added to the region by selling surplus energy was over 28 million USD per year. Finally, greenhouse gas emissions were reduced by over 80%. Güssing achieved this with a tight cooperation between an energy company created by an engineer from the town connected to the University to Technology in Vienna. Local energy was mainly developed from the forest resources and bioenergy.

Another success story to be retold regards the neighbourhood of *Vauban in Freiburg* in Germany. Its green city initiative has attracted green businesses to locate there. About 1,500 green companies employ some 10,000 people, mostly in the solar energy sector. 50% of the electricity is produced by co-generation units that also provide heat through district heating systems. Solar energy is very visible around Freiburg. Currently 12.3 MW of solar capacity is in place, producing over 10 million kilowatt-hours annually. There are 5 medium sized wind turbines installed on the hills around the city producing 14 million kWh every year.

15.6 The ISO 50001 Energy Management System

ISO 50001 is an internationally recognised energy management system which may be audited and certified. It is in operation since 2012. ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management. As the other management systems it consists of a continuous cycle of planning, implementing, reviewing and improving the processes and actions that an organisation undertakes to meet its environmental targets and requirements.

ISO 50001:2011 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works, and
- Continually improve energy management.

Like other ISO management system standards, certification to ISO 50001 is possible but not obligatory. Some organizations decide to implement the standard solely for the benefits it provides. Others decide to get certified, to show external parties they have implemented an energy management system. ISO, however, does not perform certification. There are other (accredited) companies which do that.

Due to the fact that ISO standards are intended to be applicable in many or even all parts of the world, they are kept very general. Organisations that implement an ISO 50001 can thus adapt their management systems, MS, exactly to their needs. Organisations that do not have significant environmental impacts themselves may focus their MS on the environmental performance of suppliers, while organisations with significant environmental impacts may focus on operating more environmentally friendly.

This great flexibility means that two different management systems cannot be compared, though they both have to meet the requirements set by the standard setting organisation. An outside observer must be able to understand what an MS is trying to achieve. Certification of a MS means that the organizational structures required have been established and that the MS is designed to achieve continuous improvement. ISO 50001 requires organisations to commit themselves to compliance with applicable environmental legislation. As environmental legislation differs widely from country to country, there is a range in level of difficulty to achieve national environmental compliance.

It should be underlined that when a company have a certified management system in place it does not mean that certain results have been reached. It rather

Figure 15.6 Improved energy management, may reduce the use of fossils in the future. Coal power plant in Datteln (Germany) at the Dortmund-Ems-Kanal. Photo: Arnold Paul cropped by Gralo.

means that a system of improvement is in place and that the company will perform better, but may presently be not at all good.

The challenge of responding to a MS standard is on the agenda of organisations in both the public and private sectors and their environmental stakeholders. Customers, governments, communities, public interest groups and others may ask for ISO 14001 or ISO 50001 certification to ensure that the organisation's environmental responsibilities are being managed in an organised and serious way. However, developing an MS that meets the ISO requirements is a very ambitious undertaking, and obtaining certification of an MS requires additional effort and cost – especially if an outside registrar audits and verifies that it meets the requirements.

As most organisations implementing a MS seek monetary benefits, a main concern is always: is it an investment or just a cost? The answer depends on the approach taken and on the goals set.

Some of the numerous benefits of an energy management system have already been described in the previous paragraphs. Since energy costs money it is obvious that economic advantages are on top. To this should be added the reduction of GHG emissions, which may as well cost, and to an extent reduced vulnerability, better training of personnel, and often better working conditions in the company.

External costs mainly occur during the process of implementation of a MS and possibly also on further external coaching of the improvement process after certification. These external costs include:

- Outside staff training.
- Consultant fees.
- In-house training and specialized training costs.
- Certification costs.
- Internal manpower costs.
- Investment costs for improving energy performance.

Usually the implementation of a MS results in more benefits than costs. In any case, in order to help prevent unpleasant surprises, the potential costs of implementation need to be evaluated before the process starts.

At present there are very few EMS experts in Eastern Europe. At the same time, the need for experts who can assist organisations in the EMS implementation process is growing and most organisations in Eastern Europe cannot afford to hire experts from other EU member states or elsewhere. Another major problem is the lack of national accreditation in Eastern European countries. The result is that certification is conducted by expensive certification bodies from the UK or Germany.

Chapter 15 sources:

Main text Lars Rydén

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Chapter 16
Renewable energy systems and energy futures

16.1 The characteristics of C-free energy sources

The characteristics of various C-free energy sources for the production of electricity, heat and fuels are reviewed here and compared, where appropriate, with those of nuclear energy and fossil fuels. Passive solar energy – in the form of day-lighting and passive heating, ventilation and cooling driven by passive ventilation with cool outside air – is the simplest, most reliable and often the least expensive form of renewable energy. Its incorporation into buildings is treated as a reduction in energy demand rather than as energy supply. However, active methods of collecting solar energy (PV modules and solar thermal collectors) are treated as renewable energy supply and so form part of the discussion here.

Renewable energy markets, investments, industries, and policies have experienced rapid changes in recent years. The global economic recession, felt most acutely in Europe, was expected to decrease the installed capacity of these energy carrier systems. However, the three-month long oil spill in the Gulf of Mexico and the incident in nuclear power station in Japan caused extensive damage and welfare of people in these regions. It has led us to rethink and promote the use of renewable energy carrier systems.

The greatest potential for C-free electricity involves solar and wind, with biomass playing a potentially important supplementary role. Electricity can be generated from sunlight using either PV modules or using mirrors to concentrate sunlight by a factor of 600-2000, producing steam that in turn is used in a steam turbine, so-called Concentrated Solar Power, CSP.

PV modules can use either un-concentrated sunlight or sunlight concentrated by a factor of 20-550. Both solar thermal and concentrating PV systems require that mirrors or modules track the sun at all times, and so are applicable only in arid or semi-arid parts of the world (where clouds are rare), but the annual solar irradiance on sun-tracking modules is about 30 per cent greater than for an optimally oriented fixed module. An advantage of concentrating solar thermal power (CSP) is that heat can be stored overnight, allowing 24-hour-per-day generation of electricity and some ability to vary the electricity production with demand.

An advantage of concentrating PV compared to conventional PV is that much smaller quantities of expensive semi-conductor materials are needed, thereby allowing highly efficient multi-junction modules using rare elements to provide a large share of future electricity requirements. Fluorescent dye (also called quantum dot) concentrators, currently under development, offer the possibility of concentrating both direct and diffuse sunlight without the need for a sun-tracking system. There is a large potential to generate electricity using building-integrated PV panels. Costs for both CSP and PV power should soon be attractive in regions with high solar irradiance.

Wind energy is currently the lowest-cost form of C-free energy that can be exploited on a large scale, and for this reason is experiencing the greatest rate of growth of C-free sources of energy. By combining widely dispersed wind farms with various storage techniques, base-load or dispatchable electricity can be produced from the wind. The most promising parts of the world for wind energy are in middle and high latitudes, and in some low-latitude regions with steady trade winds.

A variety of other renewable energy sources for the generation of electricity – geothermal, hydro and marine – could be locally important, although the first two are not entirely free of GHG emissions and geothermal energy can be replenished only at a very slow rate (through upward conduction of heat from the earth's interior).

16.2 Wind and solar photovoltaic energy

Wind turbines are used for the conversion of wind's kinetic energy into mechanical energy and then into electricity. This form of energy produces no emissions or contamination during the system operation.

World Wind Energy Association (WWEA) (2011) states that wind energy has reached 196.630 GW of worldwide installed capacity and 430 TWh of produced energy (2.5% of the global consumption of electricity). This sector shows a fast growth rate among the renewable energy carrier systems, but in 2010 has showed the lowest growth rate value (23.6%) since 2004 due to the international economic situation. Although, the wind sector had a turnover of 40 billion Euro and employed 670,000 persons worldwide.

The distribution of the total installed capacity has changed since 2009, as China became number one in total installed capacity (44.7 GW), dethroning the United States of America (USA) with 40.2 GW. Also, China is now the centre of the international wind industry, adding 18.9 GW within one year, accounting for more than 50% of the world market for new wind turbines. The growth rate in European countries shows stagnation in Western ones but a strong growth in a number of Eastern European countries (Romania, Bulgaria, Turkey). Nevertheless, Germany keeps its number one position in Europe for installed capacity with 27.2 GW, followed by Spain with 20.6 GW. The highest shares of wind power in electricity supply can be found in three European countries: Denmark (21%), Portugal (18%) and Spain (16%).

WWEA predicts further substantial growth of wind sector in China, India, Europe and North America. Based on the current growth rates, this agency expects by 2015 a global wind capacity of 600 GW and more than 1,500 GW by the year 2020.

The solar photovoltaic (PV) technology is a method of converting solar radiation into electricity through the photovoltaic effect. It is an environmentally friendly energy carrier system by its ability to operate noiseless and emitting no greenhouse gases.

The Renewable Energy Policy Network for the 21st Century (REN21) reported a strong growth and investment in the PV sector, more than doubling in 2010 (REN21, 2011). Its capacity was added in more than 100 countries during that year, ensuring that PV remained the world's fastest growing power-generation technology.

The nominal worldwide installed capacity of PV systems in 2010 was about 40 GW – more than seven times the capacity in place five years earlier. Just only in 2010, 17 GW of capacity was added worldwide. This value represents an increase of 9.7 GW comparing with the installed PV power in 2009. The number of utility-scale PV plants continues to rise, accounting for almost 25% of total global PV capacity.

Technology cost reductions in solar PV led to high growth rates in manufacturing, and cell manufacturing continued its shift to Asia.

The PV market is dominated by the European Union (EU) countries (accounting for 80% of the world total) and particularly by Germany, which owns almost of half of global market (44%) and installed more PV in 2010 (7.4 GW) than the entire world did the previous year. The rank is followed by Spain, Japan and Italy.

16.3 Capacity of Wind and Solar Energy Resources in Uzbekistan

Unfortunately, the existing network of actinometric and meteorological stations of Uzbekistan does not provide sufficient information for fully assessing the ca-

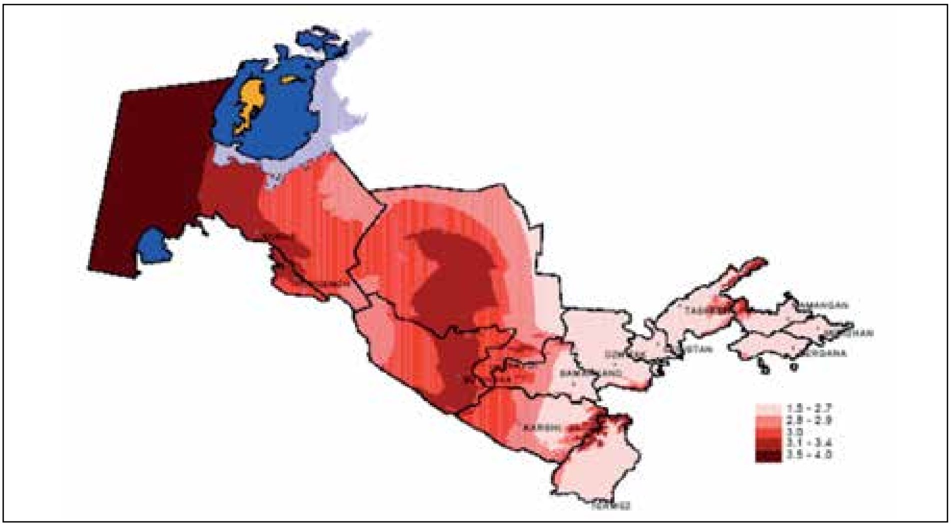

Figure 16.1 Average annual wind velocity in Uzbekistan (m/sec).

pacity of the wind and solar energy resources at any point of its territory. However, it permits to assess the general availability of such resources in various parts of the country.

Based on an analysis of the territorial distribution of statistical characteristics of wind velocity as well as the shape of the distribution curve at various stations, areas have been identified, within which the wind velocity regime and the wind energy resources may be considered uniform.

The North-west of the country and the Aral Sea littoral area, with an average wind velocity constituting 4 to 6 m/sec, are the richest in wind energy resources. In the greater part of the plains the registered average wind velocity is from 3 to 4 m/sec, and the specific capacity of the wind current reaches 150 W/m^2. In the foothills and low mountains the average wind velocity does not exceed 2-3 m/sec (see Fig. 16.1), and specific capacity is no more than 100 W/m^2. In some high-mountain areas stronger winds occur as well as in some foothill areas (at the exit from mountain valleys strong winds are observed, but they are rare).

An analysis of the territorial distribution of statistical characteristics of daily amounts of direct and aggregate solar radiation (Fig. 16.2) permits to identify four areas in Uzbekistan (plains, foothills, mountains and low-mountain depressions) with uniform solar energy resources.

Plains are the richest in solar energy resources. Daily amounts of direct solar radiation vary there from 8-10 MJ/ m^2 in winter to 28-30 MJ/ m^2 in summer, and

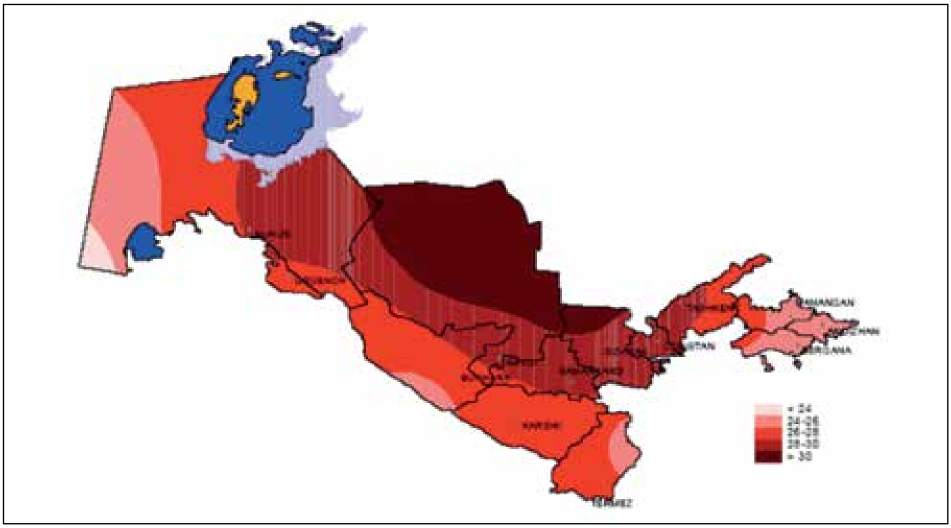

Figure 16.2 Daily amounts of direct solar radiation in Uzbekistan (MJ/m^2 in July).

daily amounts of aggregate radiation from 7-8 MJ/ m^2 to 25-28 MJ/ m^2. Duration of sunshine constitutes 10 to 12 hours in summer.

Foothills have somewhat smaller solar energy resources. Daily amounts of direct solar radiation there achieve 25-27 MJ/m^2 in summer, and daily amounts of aggregate radiation reach 24-27 MJ/m^2. Duration of sunshine is 10 to 12 hours, as in the plains. Mountain territories are not uniform as regards their radiation regime. Intensity of solar radiation in the mountains is very high, but duration of sunshine is 10 to 15 per cent less than in the plains due to greater cloudiness. Given the best conditions of shading and cloudiness, average daily amounts of direct and aggregate solar radiation in the mountains constitute 26-27 MJ/m^2 in summer. Duration of sunshine does not exceed 10 hours.

Low-mountain depressions receive the smallest amounts of solar radiation. Daily amounts of direct solar radiation there do not exceed 25 MJ/m^2 in summer, and daily amounts of aggregate radiation are no more than 25-27 MJ/m^2. Duration of sunshine in the depressions varies between 3.3-4.0 hours in winter and 11.0-11.5 hours in summer.

The richest wind energy resources are in the north-west of Uzbekistan (Karakalpakstan and Khorezm). Wind facilities with an initial operating speed of 5 m/sec can function there. On the contrary, solar energy facilities will function less efficiently there due to high cloudiness and a higher concentration of water steam in the atmosphere.

The central desert areas are sufficiently rich in both wind and solar energy resources. Wind-driven facilities with an initial speed of up to 3 m/sec can operate with idling of no more than 50 per cent of operation time. Solar energy facilities can operate with utmost efficiency there. In summer their capacity exceeds 800 MJ/m^2 per month both in facilities using direct solar radiation and in collectors operating on aggregate radiation.

In winter they can generate up to 200 MJ/m^2 per month. Foothills are less rich in both wind and solar energy resources. The average wind velocity is down to 2.0-2.5 m/sec, and therefore wind-driven facilities will operate with long idle periods in most of the foothill territory. Exceptions are some areas situated predominantly at the exit from mountain valleys (near the towns of Yanghiyer and Bekabad and the Charvak water reservoir where the wind regime is characterised, on the one hand, by repeated strong winds, and on the other hand, by long periods of quiet weather. In those areas it would be wise to use wind-driven facilities together with solar ones. Besides that, it will be necessary to ensure a possibility of accumulating energy in periods of strong winds. Solar energy resources in the foothills are also somewhat smaller than in the plains. Nonetheless, its generation reaches 800 MJ/m^2 per month in summer and 150 MJ/m^2 in winter. The foothills are very suitable for using the solar energy.

Mountain areas vary greatly in the amounts of both wind and solar energy. In vast open mountain valleys an average wind velocity is no more than 2.0-2.5 m/sec. Wind-driven facilities will operate with idle time constituting more than 65 per cent of total time. Solar facilities will operate more efficiently than in the plains and foothills. In summer they will generate up to 750 MJ/m^2 per month.

In closed intra-mountain depressions an average wind velocity does not exceed 1.5 m/sec. It is rather inefficient to use wind-driven facilities. As for solar facilities, they will operate with the least efficiency as compared to the rest of the territory of Uzbekistan. In summer months their energy generation does not exceed 650 MJ/m^2. However, solar facilities can serve as a good addition to traditional energy sources.

Strong winds of frequent repetition and an average velocity of over 5m/sec blow at open high-mountain summits and mountain passes. The capacity of the wind energy is rather high. In high-mountain areas intensity of solar radiation is sufficiently high but duration of sunshine is 10 to 15 per cent less than in the plains due to cloudiness. The idle time of solar facilities is longer than in other areas. In summer it may reach 20 to 25 per cent of daytime.

Territorial distribution of wind and solar energy is best represented in schematic maps (Fig. 16.1 and 16.2). Applied wind and solar energy characteristics showing the efficiency of operation of energy facilities in various parts of the country may be mapped in a similar way. At present Glavhydromet of the Republic of Uzbekistan is preparing for publication the "Wind and Solar Energy Cadastre of Uzbekistan', which will be published early in 2002.

16.4 Geothermal

Geothermal energy occurs in several different forms: hydrothermal, geo-pressurized, hot dry rock and magma.

Geothermal heat can be used directly to provide domestic hot water and space heating, or can be used indirectly to produce electricity by first generating steam that is used in a steam turbine. Hot dry rock systems (also known as enhanced geothermal systems (EGSs) involve (1) drilling an injection borehole, down which water will be injected; (2) fracturing the rock in the region at the bottom of the injection borehole, so that water can flow through the rock and become hot in the process; and (3) drilling an extraction borehole in the vicinity of the injection borehole, from which the heated water will be drawn. The key for geothermal energy to make a significant contribution to world energy needs is the development of hot dry rock technology. If this technology can be developed according to industry projections, geothermal energy could provide one to several 100EJ/yr for many centuries. Electricity costs of 8-10 cents/kWh might be feasible. In heating applications, the geothermal resource could be significantly extended through the use of heat pumps to extract additional heat from the already-used water that is returned to the ground.

The geothermal energy source comes from the sub-soil heat, several hundred meters below the surface. For every 100 meters deep, the temperature increases about 3 °C. It is possible to reach the water boiling point temperature (100 °C) at 3 km depth. This energy can be used for direct heating or for electricity generation by producing steam to drive a turbine. Only the latter process will be assessed in this work. In the past 25 years, the electricity production by geothermal resource has significantly grown, reaching in 2007 about 10 GW of worldwide installed capacity. By the end of 2010, total global installations came to just over 11 GW, and geothermal plants generated about 67.2 TWh of electricity during the year (REN21, 2011). However, the availability of this energy carrier system becomes scarce due to the difficulty and costs associated with sub-soil drilling at depths that allow reaching temperatures values suited to operate a turbine.

16.5 Hydropower

Hydropower is a clean, renewable and reliable energy carrier system, allowing for energy storage and subsequent use when needed, making it a highly available resource. The use of this renewable energy source is done by converting into electricity the kinetic energy contained in rivers and potential energy of water falls down a shaft. The energy conversion process requires directing the stored water to a hydraulic turbine in order to drive an electric generator. Hydro energy is a resource globally wide spread with an installed capacity of about 720 GW around the world in 2008. Since then, global hydropower production increased reaching an estimated 1010 GW.

The top countries for hydro capacity are China, Brazil, the USA, Canada, and Russia, which account for 52% of total installed capacity. Brazil and Canada generate roughly 80% and 61%, respectively, of their electricity with hydropower, while many countries in Africa, likewise Norway produce close to 100% of their grid based electricity with hydro (REN21, 2011). World spread countries continue to develop hydropower on large to small scales as well as pumped storage systems.

During the assessment of hydraulic energy resources there were 149 hydrometeorological monitoring posts on rivers, and the total watershed area under observation was 83,369 km^2. Potential hydraulic energy resources of waterways have been identified by summarising results obtained for separate areas. The metering was carried out on all rivers over 10 km long, with the exception of those drying up and periodically vanishing.

The territory under observation was divided into the following areas: a) the Ferghana Valley with an area of 17,600 km^2 within the boundaries of Uzbekistan; b) the Chirchik-Angren basin with an area of 21,100 km^2 within the boundaries of Uzbekistan; c) the South-western area including the valleys of the Zeravshan, Kashkadarya, Sherabaddarya, Surkhandarya, Sanzar and Zaaminsu rivers, with a total area of 204,400 km^2 within the boundaries of Uzbekistan; d) the lower reaches of the Amudarya River within the boundaries of Khorezm Province and Karakalpakstan, with a total area of 171,700 km^2.

Potential hydraulic energy resources of all registered rivers in the years of average water content within the boundaries of Uzbekistan have been assessed at 12.2 million kW and 107 billion kW/h (see Table 16.1).

The richest in hydraulic energy resources are Andijan, Tashkent and Ferghana provinces, and the poorest ones are Bukhara Province and Karakalpakstan. The largest hydraulic energy reserves are available in the Ferghana Valley, where 21.7 per cent of all hydraulic energy resources of Uzbekistan and concentrated. Small-

Table 16.1 Distribution of areas and potential hydraulic energy resources in Uzbekistan

Provinces	Area 000 km²	Capacity 000 kW	Energy, billions kW/h	Energy % of total	Availability of hydraulic energy resources	
					KW/km²	000 kW/h per km²
Andijan	6.2	1,971	17.3	16.2	318.0	2,800
Bukhara	122.0	648	5.7	5.3	5.3	46
Samarkand	37.7	712	6.2	5.8	18.9	165
Surkhandarya	44.7	2,886	25.2	23.6	64.5	564
Tashkent	20.1	4,079	35.7	33.4	203.0	1,775
Ferghana	11.4	962	8.4	7.8	84.5	736
Khorezm	4.6	200	1.8	1.6	43.5	392
Karakalpakstan	167.0	769	6.7	6.3	4.6	40
Total	413.7	12,231	107.0	100	29.6	259

er reserves are available in the Karadarya (19.8 per cent), Chirchik (18.6 per cent), Zeravshan (17.4 per cent) and Surkhandarya (9.8 per cent) river basins.

16.6 Wave and tidal energy

Wave and tidal energy converts the kinetic and potential energy of ocean into electricity. This renewable energy resource with high energy potential, reach around 320 GW along the European coast, which corresponds to 16% of the world total resource. However, both technologies used in the conversion of this energy are still in a development stage despite of the numerous devices and conversion techniques that are patented. Because they are in an emerging phase, there are only few technologies with commercial application and the information about its sustainability is still based on forecasts. Despite this fact, at 2010's end, an estimated total of 6 MW of wave (2 MW) and tidal stream (4 MW) capacity had been installed mostly off the coasts of Portugal and the United Kingdom. The world estimated power capacity of tidal barrage is around 500 MW capacity) in various phases of development (REN21, 2011).

16.7 Biomass

Biomass is perhaps the most complicated of the (net) C-free energy options. Complications arise from the many different possible kinds of biomass that can be used, the different forms in which biomass can be used (as solid, liquid or gaseous fuels), the variety of energy conversion processes available, the many potential end-use applications, the potential adverse and beneficial environmental impacts, social considerations through competition with land for food and impacts on the price of food crops, and uncertainties related to long-term sustainability and the impacts of climatic change during the coming century and beyond.

One of the most difficult issues with regard to biomass energy is the determination of the net energy gain using biomass. In spite of the resulting uncertainties, there are clear differences in the relative benefits of using biomass in different applications. Use of biomass as a solid fuel is superior to its conversion to liquid fuels. However, liquid fuels from biomass represent one of the few options for displacing petroleum-based fuels in the transportation sector.

The use of corn (maize) to produce ethanol is the least effective of the possible uses of biomass, and is also the least effective of the possible ways of reducing transportation energy use. Ethanol from sugarcane is substantially more attractive, as would be ethanol from lignocellulosic materials (grasses such as switchgrass or *Miscanthus*, corn stover and wood) if this technology (which is still under development) performs as projected. Direct use of woody biomass as a fuel for heating, or for subsequent gasification and use in the generation of electricity or for cogeneration, provides the greatest net energy benefit. If biomass used for electricity generation displaces coal, this would provide the largest CO_2 emission reduction per unit of biomass grown.

The use of plantation-scale biomass energy is fraught with numerous potential environmental and social problems. Its development should therefore proceed in a gradual, well-planned manner and with minimal government subsidies so as to avoid distortions that create unexpected and undesirable side-effects. Enforceable restrictions in the development of bioenergy resources will be needed so as to prevent destruction of forests or other natural areas that are better left intact.

Biomass energy could supply a significant fraction of future energy needs and at attractive costs in the long run (generally \$3-6/GJ for solid fuels, less than \$15/GJ for liquid fuels and about 5 cents/kWh for electricity). Most of this biomass will have to come from bioenergy plantations, but if existing forests are to be protected, the plantations will have to be limited to surplus agricultural and grazing lands.

Whether or not there are surplus lands in the future will depend on (1) the future human population, (2) future diet (in particular, the proportion of food energy provided by meat and the kinds of meat consumed), (3) future agricultural productivity, and (4) the future efficiency in converting animal feed into animal food products. Diet emerges as a significant factor in determining both the future potential of biomass energy and the environmental impacts associated with the food system.

16.8 Carbon capture and storage (CCS)

Capture of carbon dioxide from fossil fuel power plants would make these power stations renewable in the sense that they do not emit any carbon dioxide. CCS, however, are much less energy efficient as they have to use much of the energy for taking care of the CO_2 formed in the combustion. Using existing technologies CCS would increase fuel requirements by 11-40 per cent according to various estimates, while retrofitting existing coal-fired plants is estimated to increase fuel requirements by 43-77 per cent. With future technologies the energy penalty in new plants might be reduced to 2-12 per cent. Additional energy would be required to compress or liquefy and transport the captured CO_2 to its disposal sites. Costs are highly uncertain but are likely to be large, increasing the cost of new coal or natural gas power plants by 50-100 per cent.

Potential sites for storage of CO_2 include depleted oil and gas fields, deep saline aquifers, coal beds, sediments in the seabed and deep ocean water itself. The amount of CO_2 that can be securely stored in terrestrial sediments or coal beds is highly uncertain. Among the environmental issues associated with sequestration on land are potential leakage through the thousands of drill wells that are found in most populated regions, potential displacement of saline groundwater into freshwater groundwater supplies and mobilization of toxic elements in saline aquifers due to the increase in groundwater pH associated with CO_2 injection. Other issues are the preclusion of the future use of saline groundwater through desalination, preclusion of future mining of saline groundwater for trace elements and interference with compressed air energy storage or geothermal energy. Disposal of CO_2 in the oceans as anything more than a supplement to a major shift from fossil fuels to renewable energy sources is not acceptable.

However, burial in sub-seabed aquifers would probably pose negligible environmental risks and risks of leakage, but is also likely to be the most expensive storage option. At least 20 years of demonstration projects involving carbon capture from power plants using a variety of different types of coal, and carbon storage in a variety of different geological settings, would be required before large-scale deployment of carbon capture and storage (CCS) could begin. Another 20 years would be required before a significant fraction of the world's power plants would (through normal retirement and replacement) be equipped with CCS. Thus, even if it proves to be viable, CCS could not make a significant difference before mid-century.

Carbon sequestration could nevertheless be used as an emergency measure to accelerate the later stages in the phase-out of fossil fuel CO_2 emissions. In conjunction with the capture of CO_2 released from the use of biomass, it could create

Table 16.3 World Energy-related CO_2 Abatement (Source International Energy Agency, 2014)

CO_2 abatement	2020	2040
Energy service demand	19%	11%
End-use efficiency	46%	39%
Supply efficiency	9%	11%
Fuel and technology switching in end-uses	2%	3%
Renewables	17%	24%
Biofuels	3%	3%
Nuclear	3%	7%
CCS	1%	2%

negative CO_2 for many decades, if this is needed in order to reduce atmospheric CO_2 concentration.

It should be added that using biomass as fuel in a CCS power plant amounts to the extraction of CO_2 from the atmosphere and thus contributes to the reduction of GHG, a measure which may be necessary in the future to avoid serious climate change consequences.

16.9 The hydrogen economy

In an energy systems dominated by renewable sources, fossils will not serve as fuel. Today ethanol, biodiesel, biogas are the dominant non-fossil fuels, but in the longer term a more efficient alternative is hydrogen gas. Hydrogen has the potential to serve as an energy currency, replacing fossil fuels in all the ways in which they are used for energy today and, in combination with biomass, replacing them as a chemical feedstock. Hydrogen could be produced by electrolysis of water when solar- and wind-generated electricity are in excess, stored and later used in a fuel cell to produce electricity when there is a shortage of wind or solar power. It could also be transported from distant sunny or windy regions to demand centres. In this way, it could serve to close the spatial and temporal mismatch between intermittent renewable sources of electricity and the demand for electricity. However, much of this gap could also be closed through alternative strategies, such as long-distance high-voltage DC power transmission to link regions of good wind and solar energy with dispatchable hydroelectric facilities and electricity demand centres, and by using CAES.

The use of hydrogen in automobiles presents major challenges, particularly concerning the current high cost of fuel cells and on-board storage, as well as

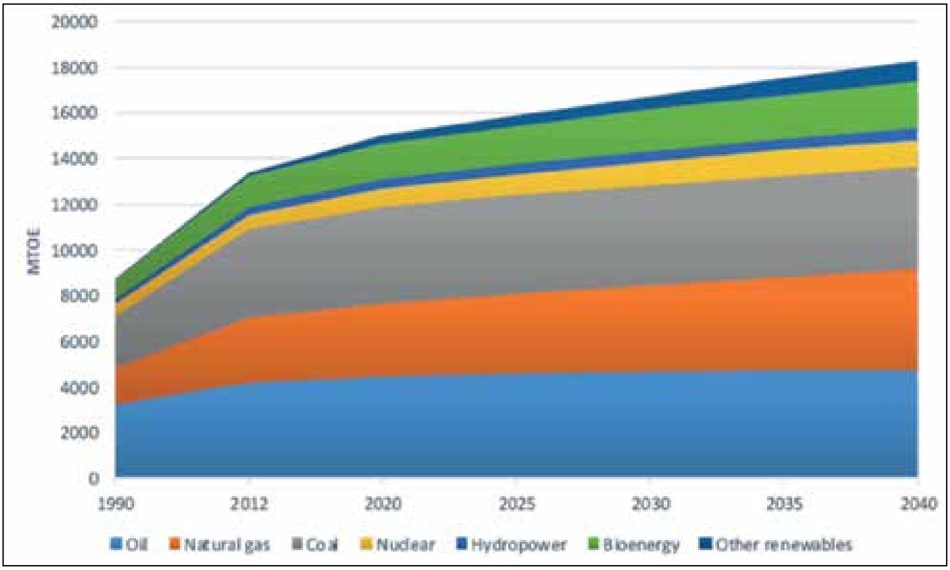

Figure 16.3 World Primary Energy Demand Projections. (Source International Energy Agency, 2014)

the difficulties of creating a whole new infrastructure to supply hydrogen fuel. Nevertheless, there are indications that the total cost of driving using hydrogen in fuel cell vehicles could become competitive with gasoline or diesel alternatives. Advanced hydrogen fuel cell vehicles are projected to be almost four times as efficient (in terms of km driven per unit of energy in the fuel tank) as current vehicles and about 1.75 times as efficient as advanced gasoline vehicles, which reduces the problem of the much greater bulk of hydrogen storage systems compared to gasoline. However, the overall effectiveness in using renewably based electricity to make hydrogen (produced by electrolysis) for subsequent use in automobiles would be only about half that of the direct use of renewably based electricity to charge batteries. Thus, the optimal solution will probably be a plug-in hybrid vehicle using on-board hydrogen in a fuel cell only to give extended driving range. Hydrogen as a transportation fuel is more promising in various niche applications, such as in railway locomotives and to power auxiliary power units in trucks.

There are also important industrial niche applications for hydrogen in a fossil fuel-free world, such as its use as a reducing agent in the manufacture of iron (in place of coke), in the manufacture of nitrogen fertilizer (in place of natural gas or coal) and in the manufacture of a variety of biomass-based chemicals (in place of petroleum).

Hydrogen is an abundant substance on the planet due to its presence in the molecule of water that covers about 70% of the earth's surface. It is a clean energy that enables the production of electricity through hydrogen fuel cells. Fuel cells are available in units of 5 to 250 kW, being more suitable for decentralized electricity production. Two types of fuel cells will be considered in the analysis of hydrogen as an energy carrier system: the phosphoric acid and solid oxide (ceramic, zirconium oxide and yttrium oxide) fuel cells. The former represents the first generation of commercial fuel cells. However, despite its good performance, such cells showed low viability. The solid oxide fuel cells have become much more attractive. With units with capacities from 5 to 250 kW, these cells are accessible to small consumers becoming suitable for decentralized production.

16.10 Renewable energy systems

Community-integrated energy systems involve centralized production of heat and possibly chilled water that are distributed to individual buildings through district heating and cooling networks. District heat networks can be coupled with large-scale underground storage of heat that is collected from solar thermal collectors during the summer and used for space heating and hot water requirements during the winter. Heat can also be supplied with biomass (as part of a biomass cogeneration system) or from geothermal heat sources. If both heat and coldness are stored, then heat pumps can be used to recharge the thermal storage reservoirs (or to directly supply heat or coldness to the district heating and cooling networks) during times of excess wind energy. This in turn permits sizing of the wind system to meet a larger fraction of total electricity demand without having to discard as much (or any) electricity generation potential during times of high wind and/or low demand. In the long run, district heating systems with cogeneration will make it easier to make the transition to a hydrogen economy, as a new infrastructure to supply hydrogen to individual buildings would not be needed.

Considering that approximately 80% of the people in developing countries who lack access to electricity live in rural areas beyond the reach of the electricity grid, rural electrification is a crucial issue in access to energy. The conventional approach to electrification has been to extend the electricity grid powered by centralized fossil fuel based power plants operated by the national utility. This is based on the model adopted in developed countries, where national governments had traditionally created such systems.

The reality in many developing countries, however, is very different, because it is financially, technologically and organizationally almost impossible to extend the central grid to all remote and rural parts of the country. Grid-connected electricity is often only available in urban areas, because of high costs for connection and subsequent power transmission losses resulting from the large distances that need to be bridged. This thus calls for off grid, decentralized solutions for energy provision, either based on existing technologies such as diesel generators or emerging renewable energy technologies (RETs), which provide access to energy beyond the public electricity grid. A diverse range of such RETs that are relevant for developing countries has emerged over the years. RETs in fact relate to two of the three (interlinked) objectives adopted in the framework of the United Nations initiative *Sustainable Energy for All*: i.e. to "ensure universal access to modern energy services" and "double the share of renewable energy in the global energy mix".

16.11 Renewable Energy Technologies (RETs) for developing countries

A broad range of RET-based applications for decentralized off-grid electrification including solar, wind, hydro- and hybrid systems has become available in recent years. For the main applications in domestic use, such as lighting and usage of electrical appliances (e.g. television, radio, mobile phones), REN21 (2010) states that the main options include the following: solar home systems (SHS) applied to individual homes, schools or hospitals; village-scale mini-grids powered by solar, wind or hybrid technologies; small-scale biomass gasifiers with gas engines; and hydropower installations on a pico-scale, micro-scale or small-scale. In addition to utilizing solar energy through SHS, also mentions two options for solar photovoltaic (PV) which create high flexibility in usage as they are easy to move and share: small solar PV applications, consisting of solar PV modules attached to a specific application, and energy boxes, consisting of a portable loading station with power outlets for creating a connection to specific applications.

When considering appropriate RETs for electrification in developing countries, it is important to define dimensions on which the choice for a specific energy system can be made, as a broad spectrum of stand-alone and mini-grid based RET applications has emerged in recent years. Selecting the best technological configuration for rural electrification from the diverse range of available options mentioned above should be done on a case-to-case basis, as the specific conditions in a geographical area determine the most effective technology solution. O'Brien et al. (2007) identify several general characteristics for selecting the appropriate RET-based solution for electrification, including the efficiency, adaptability, reparability, and ease of use of the technology, which are rather context-specific and dependent on the needs of the end-consumer. Reliability and affordability are also often mentioned as crucial aspects.

While decentralized RET-based electrification offers clear benefits from an environmental and social perspective (e.g. by avoiding emissions from fossil fuels and negative health effects from using traditional biomass fuels such as charcoal and wood for cooking and heating inside), achieving economic viability has been problematic. In addition to challenges related to financing and upscaling beyond pilot projects RETs are not yet widely adopted in developing countries due to a lack of available infrastructure for RETs, which creates high initial capital costs for RET-based electrification projects, and limits the possibilities for a wider, sustained market development. The main challenge is to achieve broad access to affordable, modern energy services in countries that lack them, and to find a mix of energy sources, technologies, policies and behaviours that avoid the negative environmental impact related to fossil fuels.

However, as RETs involve local solutions, frequently for remote communities only, national governments in developing countries might often not (be able to) play an active role in their provision at affordable price levels for poor people. This is one of the reasons that many other (non-)governmental organizations have become engaged in stimulating investments in off-grid solutions in those parts of the world that would be neglected otherwise. Through different kinds of partnerships and financing schemes, such organizations have often tried to attract the interest of the private sector while keeping costs for electricity users low. However, creating the right kind of incentives to step up investments in off-grid energy solutions and designing long-term viable business models to sustain rural electrification has been very difficult for for-profit companies.

16.12 Integrated energy scenarios for the future

Based on the observation that almost no region in the world is more than 3,000 km from regions of either good winds or semi-arid or arid regions where CSP is applicable (and most regions are no more than 2,000 km from such sites), supply scenarios consisting of the following elements are constructed (with the amounts depending on the demand scenario):

- 6,000-12,000 GW of wind energy capacity;
- 6,000-12,000 GW of CSP capacity;
- 3,000-4,000GW of BiPV or PV capacity;
- minor amounts of geothermal, biomass and additional hydroelectric generation;
- interconnection of the major renewable energy source regions and the major demand with a high-voltage DC power grid;
- retirement of all existing nuclear reactors at the end of an assumed 40-year lifespan.

Two scenarios for the supply of fuels for transportation, heating and industry are considered: a hydrogen-intensive scenario and a biomass-intensive scenario, with hydrogen produced through some combination of low-temperature electrolysis largely from wind-generated electricity and high-temperature electrolysis using CSP-generated electricity. Rates of increase in the supply of C-free energy and in C-free fuels are prescribed so as to completely eliminate fossil fuel emissions by around either 2080 or 2120, with emissions in 2050 ranging from a 15 per cent increase to an 85 per cent decrease compared to emissions in 2005 (depending on the demand scenario).

Annual material flows required to build up the renewable energy system in these scenarios are not excessive compared to current material flows, and all supply components of the system quickly become a significant net source of energy. However, water could be a significant limiting factor for the biomass-intensive scenarios. The amount of biomass required in the biomass-intensive supply scenario and the higher demand scenarios considered here is unlikely to be available unless there is a worldwide shift to diets with low meat consumption.

The CO_2 emissions produced from these scenarios are used as input to a simple coupled climate–carbon cycle model in order to calculate changes in atmospheric CO_2 concentration, global mean temperature and acidification of the oceans. The CO_2 concentration peaks at values of about 430-530 ppmv and, for the lowest emission scenario considered here (peaking at 8.4GtC/yr in 2015), global mean warming peaks at a value of 1.2-3.7 °C before slowly declining and ocean surface water pH declines by 0.13 relative to the pre-industrial value. For the highest emission scenario considered here (peaking at 11.5 GtC/yr near 2030), global mean warming peaks at a value of 1.6-4.9 °C before slowly declining and ocean surface water pH declines by 0.26 relative to the pre-industrial value. If CO_2 can be removed from the atmosphere at a rate of 1GtC/yr by 2050 through geological or biological sequestration, and the sequestration sustained at this rate, then, for the lowest emission scenario, the atmospheric CO_2 concentration, global mean warming and ocean surface water pH would return to close to present conditions by the year 2500 if there are no major releases of methane or other positive climate–carbon cycle feedbacks between now and then.

Otherwise, yet larger rates of CO_2 sequestration would be required, but there is a risk that methane emission rates could be such that countermeasures would be ineffective, causing global warming to slip beyond human control, with globally catastrophic impacts.

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UZWATER

This compendium is produced for the master level course in the UZWATER project. It consists of some newly written material as well as previously published texts extracted from freely available books, reports and textbooks on the Internet, dominated by publications from the Baltic University Programme. The sources used for each chapter is listed at the end of each chapter. The compendiums of the Uzwater project is produced exclusively for Master students free of charge at the participating Universities and is not to be sold or be freely available on the internet.

The UZWATER project is an EU TEMPUS project. It includes 8 universities in Uzbekistan and deals with university education for sustainable water managment in Uzbekistan. Uppsala University and BUP is one of the EU partners in the project. Lead partner is Kaunas University of Technology.

The main objective of the project is to introduce a Master level study program in environmental science and sustainable development with focus on water management in eight Uzbekistan universities. The curriculum of Master Programme includes Environmental Science, Sustainable Development and Water Management.

The Sustainable Development unit will include the basic methods used in Sustainability Science, in particular introduce systems thinking and systems analysis, resource flows and resource management and a series of practical tools for good resource management, such as recycling, energy efficiency, etc.

The specific objectives of the project are:

- to establish study centers at the partner universities in Uzbekistan
- to improve the capacity to train master students with expertise to address the severe environmental and water management problems of the country;
- to support the introduction and use in Uzbekistan of modern education methods, study materials, and e-learning tools;
- to encourage international cooperation at the partner universities;
- to strengthen capacities to provide guidance to authorities and the Uzbekistan society at large;
- to ensure the visibility and promotion of the Master Programme through web pages, printed material and cooperation with society;
- to ensure continuity of the Master Programme and long-term support of the project outcomes at partner universities beyond Tempus funding.

http://uzwater.ktu.lt