CICERO Report 2001:2

The state of climate research and climate policy

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Tittel: The state of climate research and climate policy **Forfatter(e):** Asbjørn Torvanger, Knut H. Alfsen, Hans H. Kolshus og Linda Sygna CICERO Report 2001: 2 90 sider **Finansieringskilde:** CICERO **Prosjekt:** Program 2 **Prosjektleder:** Asbjørn Torvanger **Kvalitetsansvarlig:** Asbjørn Torvanger **Nøkkelord:** klimaforskning, IPCC, effekter av klimaendring, klimapolitikk, Kyotoprotokollen **Sammendrag:** Formålet med rapporten er å gi en oversikt over status for klimaforskningen og internasjonale klimaforhandlinger per mai 2001. Rapporten presenterer en samling av fakta basert på rapporter fra FNs klimapanel (IPCC), diverse rapporter fra CICERO og en del andre kilder. Rapporten er organisert som en samling lysark med kommentarer som forklarer bakgrunnen, innholdet i hvert lysark, samt relasjonen til andre sider av klimaforskning og klimapolitikk. Arbeidet er utført på oppdrag av Norsk Hydro ASA. **Språk:** Engelsk	**Title: The state of climate research and climate policy** **Author(s):** Asbjørn Torvanger, Knut H. Alfsen, Hans H. Kolshus and Linda Sygna CICERO Report 2001: 2 90 pages **Financed by:** CICERO **Project:** Program 2 **Project manager:** Asbjørn Torvanger **Quality manager:** Asbjørn Torvanger **Keywords:** climate research, IPCC, climate change impacts, climate politics, Kyoto Protocol **Abstract:** The aim of the report is to give an overview of the state of climate research and international climate policy negotiations until May 2001. The report presents a collection of factual information based on reports from the Intergovernmental Panel on Climate Change (IPCC), various reports from CICERO, and a number of other sources. The report is organized as a collection of slides with comments that explain the background, the contents of each slide, and their relation to other aspects of climate research and policy. The report was commissioned by Norsk Hydro ASA. **Language of report:** English
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Preface

This report has been commissioned by Norsk Hydro ASA and written in the period February to May 2001. The aim of the report is to give an overview of the state of climate research and international climate policy negotiations until May 2001. The report presents a collection of factual information based on reports from the Intergovernmental Panel on Climate Change (IPCC), various reports from CICERO, and a number of other sources compiled by the CICERO team of authors. This is an updated version of a similar report that was produced for Norsk Hydro ASA in March 1997 (CICERO Report 1997:5). The report is organized as a collection of slides with comments that explain the background, the contents of each slide, and their relation to other aspects of climate research and policy.

We hope that this report will provide a useful overview of climate change issues for everyone that is interested in what happens to our global climate. We thank Jan Fuglestvedt for valuable comments, and Lynn Nygaard and Tone Veiby for excellent language and editing assistance.

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1. Introduction

The aim of this report is to give an overview of the state of the science of climate change research and the state of the international climate policy negotiations. The report is an updated version of CICERO Report 1997:05.

The Kyoto Protocol was adopted in December 1997, but has not yet entered into force since not enough countries have ratified the Protocol. Even if the future of the Kyoto Protocol is more uncertain than ever, a number of countries have made preparations to implement the Protocol, in particular through initiatives to establish national and regional emission trading systems. A Summary for Policymakers of the third assessment report by the UN Intergovernmental Panel on Climate Change (IPCC) was released in the spring of 2001.[1] The full reports are scheduled for release later this year. In the area of regional climate change impacts, a number of research projects have contributed new insights, not the least the research project RegClim in Norway.

Chapter 2 gives an overview of the climate system and the climate history of the Earth. The main message is that indications of a man-made global warming are stronger than ever before, and also that the warming trend has been particularly notable over the last decade. The next chapter presents the newest scenarios for global man-made greenhouse gas emissions, followed by an analysis of necessary emission reductions to stabilize atmospheric concentrations of greenhouse gases. The scenarios show the large span between low-emission futures and high-emission futures, and how the specific outcomes depend on the major driving forces. Stabilization of atmospheric concentrations of greenhouse gases under a doubling of pre-industrial concentrations would require global emission reductions in the region of 70% over some decades. Based on these scenarios, the newest IPCC estimates of future climate trends are given, after which future climate trends for Norway based on the RegClim project are presented. The upper estimate of global temperature increase is higher than earlier (5.8 ^{o}C) because of lower projected sulfur emissions (cooling effect). The RegClim results predict a warmer and wetter future for Norway. The range of climate change impacts and adaptation is the topic of chapter 4, first at the global level and then at the national level in Norway. Climate change impacts are not likely to be dramatic at the global level, but there can be substantial differences between regions and various human activities. Some impacts are likely to be beneficial, but others could be significantly negative for vulnerable regions, in particular for some developing countries with little capacity to adapt to climate change. Moving onto the policy arena in chapter 5, we briefly describe the climate policy negotiations from the Climate Convention from 1992 until the Kyoto Protocol from 1997, and the negotiations from 1998 onwards to fill in the missing details of the Protocol.[2] In the next section we focus on the status of the negotiations after the failure of the sixth Conference of the Parties to the Climate Convention (COP6) in The Hague in November 2000, and emphasize the land use change and forestry issues and rules for the Kyoto mechanisms that turned out to be the crunch issues. In chapter 6 we include an overview of important Parties' negotiation positions after the conference in The Hague, and link this to a presentation of structural features within countries that explain different emission levels and abatement costs and how they affect national positions. Another important determining factor for a country's position is its anticipation of and concern about future costs related to climate change impacts. The next section presents some results from analyses of how implementation of the Kyoto Protocol will affect the markets for fossil fuels, which is of particular interest for Norway as a large oil- and gas-exporter. For Norway, the costs resulting from reduced oil and gas wealth are greater than the sum of emission abatement costs and projected expenses from purchasing emission quotas in other countries. In chapter 7, the main features of some initiatives for domestic and regional emission trading systems, policies and measures within the EU to reduce greenhouse gas emissions, and green certificates to stimulate renewable energy sources are described. Furthermore a discussion of important challenges for Norwegian climate policy

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[1] United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) set up IPCC jointly in 1988.

[2] The official name of the Climate Convention is United Nations Framework Convention on Climate Change (UNFCCC).

is offered, showing Norway's dependency on the Kyoto mechanisms. Finally, in chapter 8 we analyze the prospects for the climate policy negotiations and the Kyoto Protocol, focusing on the setback of the negotiations after the USA's pronounced skepticism to the Kyoto Protocol, and look into burden sharing aspects of future climate policy agreements. Given the large differences in national circumstances and income levels among the countries of the world, future negotiations face substantial challenges with respect to designing agreements that balance both efficiency and fairness considerations.

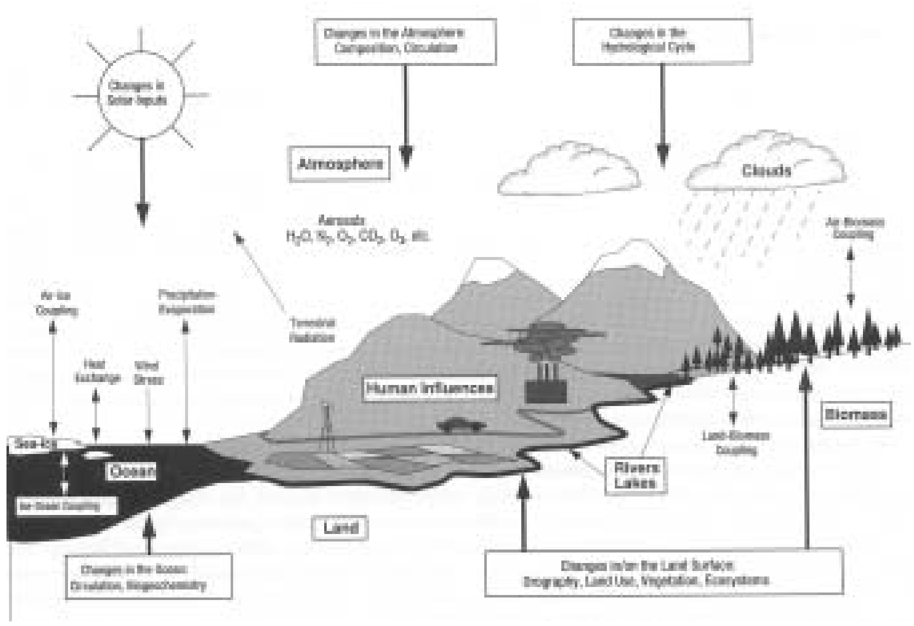
2. The climate system and climate history of the Earth

2.1 The climate system

The climate in a given region is determined by the probability distribution (the average and the variability) of the weather. Key parameters include average values of temperature, precipitation and wind, as well as extreme values of these and other parameters.

Slide 2.1. Climate change: Driving forces

Climate change: Driving forces



Source: IPCC (2001a)

The climate of the Earth is produced by the interaction between a large number of sub-systems, of which the most important are *the atmosphere, the oceans, the cryosphere (ice and snow), the biosphere, and the lithosphere (rock and soil)*. Energy and matter are exchanged between these systems, causing chemical reactions to take place and thus altering the composition of the sub-systems. These processes operate on a number of time scales, from the very slowest geological time scales to more short-term changes due to bio-physical processes. The non-linear interactions within and between the sub-systems make it very difficult to predict the climatic effects of changes in one or more of the driving forces of the climate system.

The driving forces are partly *external* to the climate system and partly *internal*. Strictly external driving forces behind the climate system include solar output, variations in the orbit of the Earth and geological processes such as continental drift and volcanic activity. Effects from the forces are enhanced or diminished through internal feedback processes related to weathering of rock, changes in ocean currents and the albedo of the Earth's surface, biological changes on the surface of the Earth, and the atmosphere. Human impacts work particularly through these last two mechanisms: changes in the atmosphere and land use changes.

Slide 2.2. Climate change: Driving forces on many time scales

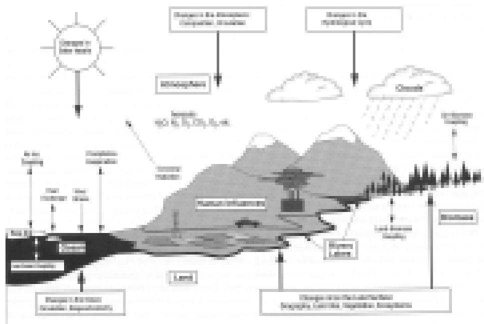
Climate change: Driving forces on many time scales

External forces:

- Variations in solar output (all time scales)
- Variations in the orbit of the Earth (relatively slow)
- The form and positions of the continents (slow)
- Vulcanic activity (all time scales)

Internal forces and feedbacks:

- Changes in the Earth's albedo (all time scales)
- Changes in the Earth's biosphere (all time scales)
- Changes in the composition of the atmosphere*:*
  - gases (fast and relatively slow)
  - particles (fast)
  - clouds (fast)

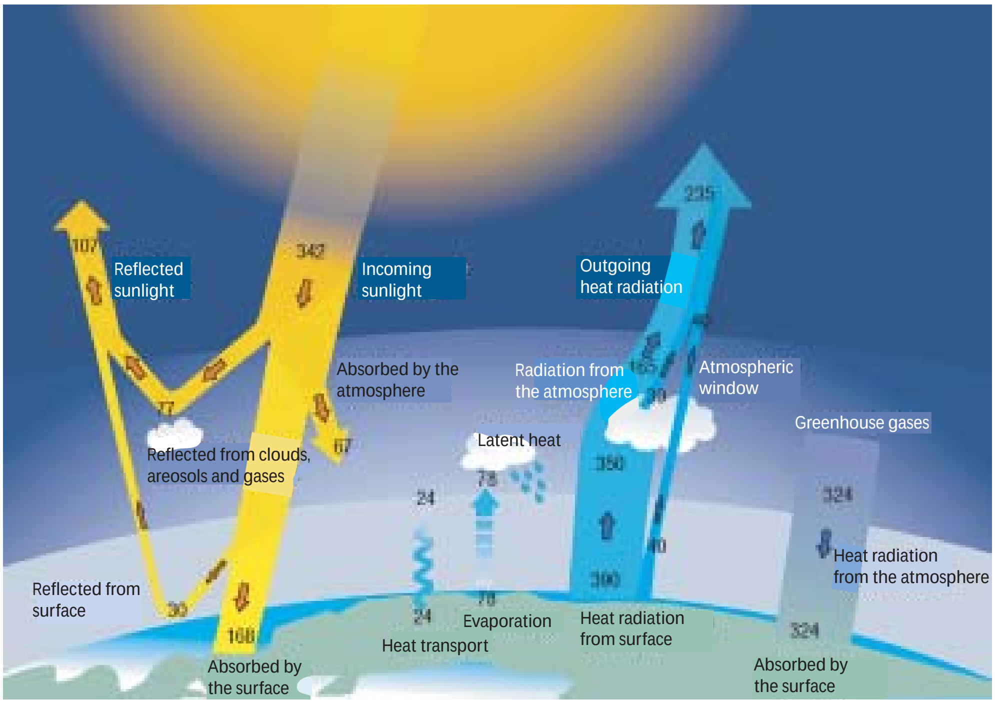


Source: IPCC (2001a) and CICERO

The so-called greenhouse effect, i.e. the trapping of heat from the Earth by radiative active gases in the atmosphere, has been operating on Earth since the atmosphere was first formed. The *natural greenhouse effect* – caused by the presence of water, carbon dioxide and other greenhouse gases in the atmosphere – leads to a 34 ^{o}C higher average temperature on Earth than otherwise would have been the case. Life on Earth as we know it thus depends on the operation of the greenhouse effect. However, since the industrial revolution mankind has enhanced the concentration of greenhouse gases in the atmosphere –carbon dioxide in particular. The increase has been very rapid and is leading to the *enhanced greenhouse effect.*

Slide 2.3. Radiative balance

Radiative balance



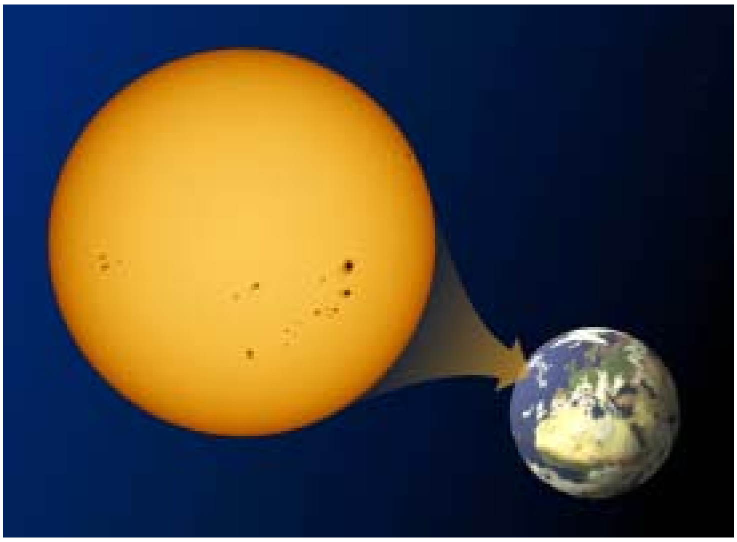
Source: NILU

Changes in land use affect the carbon cycle through changes in vegetation respiration and storage of carbon in soils, as well as the albedo of the Earth, thus altering the amount of solar radiation reflected back into space. Changes in the composition of the atmosphere lead to changes in the greenhouse effect. This effect works by letting short-wave radiation from the sun through the atmosphere but inhibits the long-wave heat radiation from the Earth. For a stable surface temperature, the energy received through short-wave solar radiation must balance the outgoing long-wave heat radiation. An increase in the concentration of greenhouse gases in the atmosphere must therefore be balanced by an increased surface temperature.

The most important greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). The enhanced greenhouse effect – caused by increased emissions of CO_2, CH_4, and N_2O, and by emissions of new chemicals such as the PFC and HFC gases since the industrial revolution some 200 years ago – leads to an increase in the natural greenhouse warming and may induce man-made climate change.

Slide 2.4. Climate change and the sun: How important?

Climate change and the sun:
How important?



Source: NASA

Among the important driving forces for climate change are solar variations. The sun is probably more active now than it was 250 years ago. The total increase in solar irradiance is of 0.2–0.5%. This increase has contributed to the surface warming of the Earth, but not as much as the growth in greenhouse gas concentrations.

The ultraviolet radiation from the sun has perhaps increased by 3% over the same period. This may have an indirect effect on the climate through changes in the chemistry of the atmosphere, and ozone generation in particular.

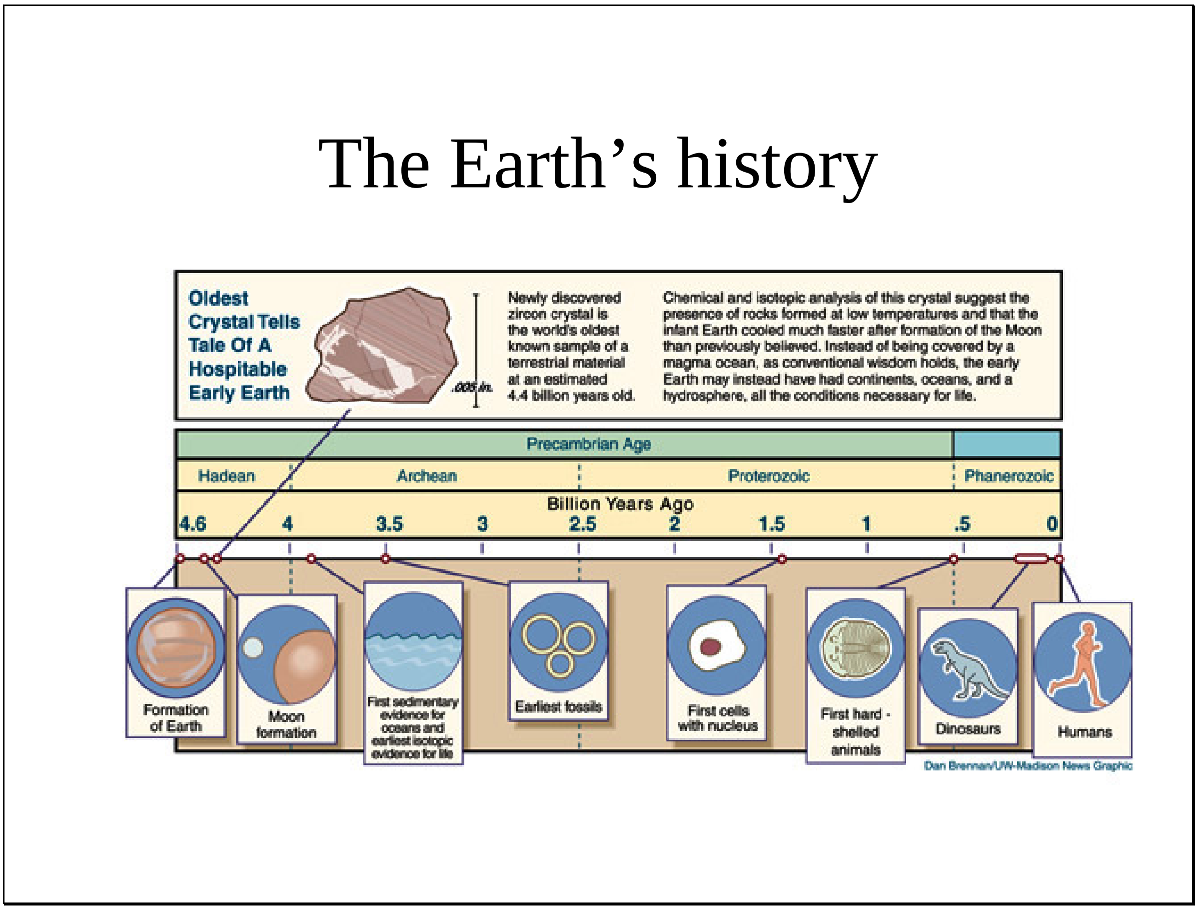
Long-term variations in the solar wind and interplanetary magnetic field can have an indirect effect on the climate through the influence of the magnetic field on cosmic rays reaching the atmosphere. A stronger magnetic field will shield the atmosphere from some of the cosmic rays that otherwise would have reached the atmosphere of the Earth. The rays can in turn have an effect on the cloud formation, and through this have a climatic effect. Some studies indicate that the solar magnetic field has increased by 230% since 1901 and 40% since 1964. The physical mechanisms and the potential importance of this indirect effect of changes in solar output remain to be fully explored. The current status is summarized by the IPCC as follows: "Mechanisms for the amplification of solar effects on climate have been proposed, but currently lack a rigorous theoretical or observational basis" (IPCC, 2001a).

2.2 Climate history and variations

We believe the Earth to be approximately 4.6 billion years old. This is a time span that is difficult to grasp. Human history represents only a brief moment on this scale, and possible human-induced changes in the Earth's climate appear to be only an insignificant perturbation from this perspective. Still, to us it matters.

Throughout its history, the Earth has experienced huge climate changes. Today, we believe that the Earth has gone through four or five “ice houses,” and a similar number of “hot houses.” During the “ice house” periods, the Earth has experienced a more or less regular coming and going of ice ages, long intervals with a very cold and mostly dry climate punctuated with intermediate periods with much less ice. During the “hot house” periods, the climate was warm, much warmer than today, with no or very little ice to be found at the Earth’s surface.

Slide 2.5. The Earth’s history

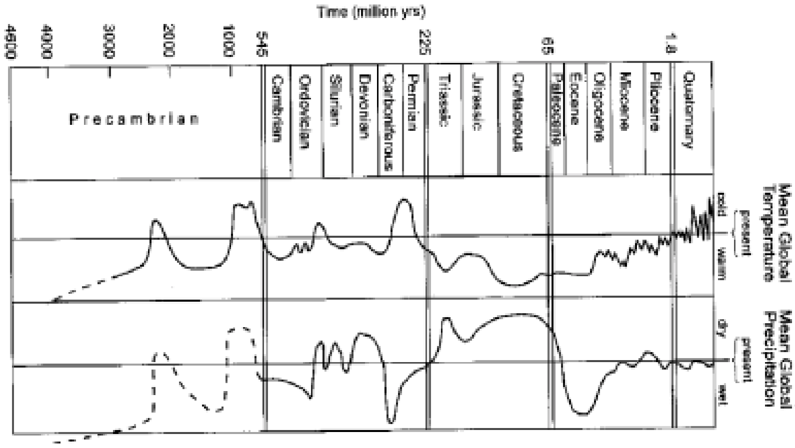


These changes, although large, have still been limited to a range that has allowed life to develop and evolve for almost 4 billion years. And this is despite the fact that the external forcing from the sun has increased by approximately 30% over the time period. The reason for this successful balance between a deeply frozen snowball Earth and a boiling inferno is to be found in the many feedbacks within the climate system.

Today, the Earth is in an “ice house” period.

Slide 2.6. Climate history: Four or five ice age periods

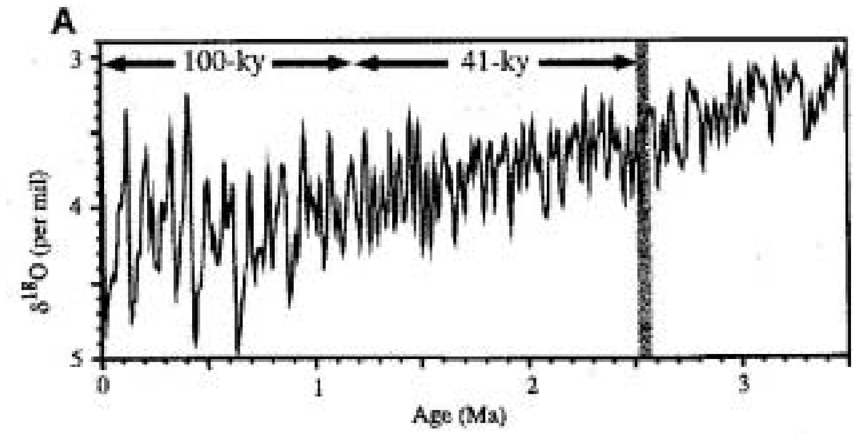
Climate history: Four or five ice age periods



Source: L.A. Frakes (1979)

Slide 2.7. Ice ages in the last ice house period (2.5. million years)

Ice ages in the last ice house period (2.5 million years)

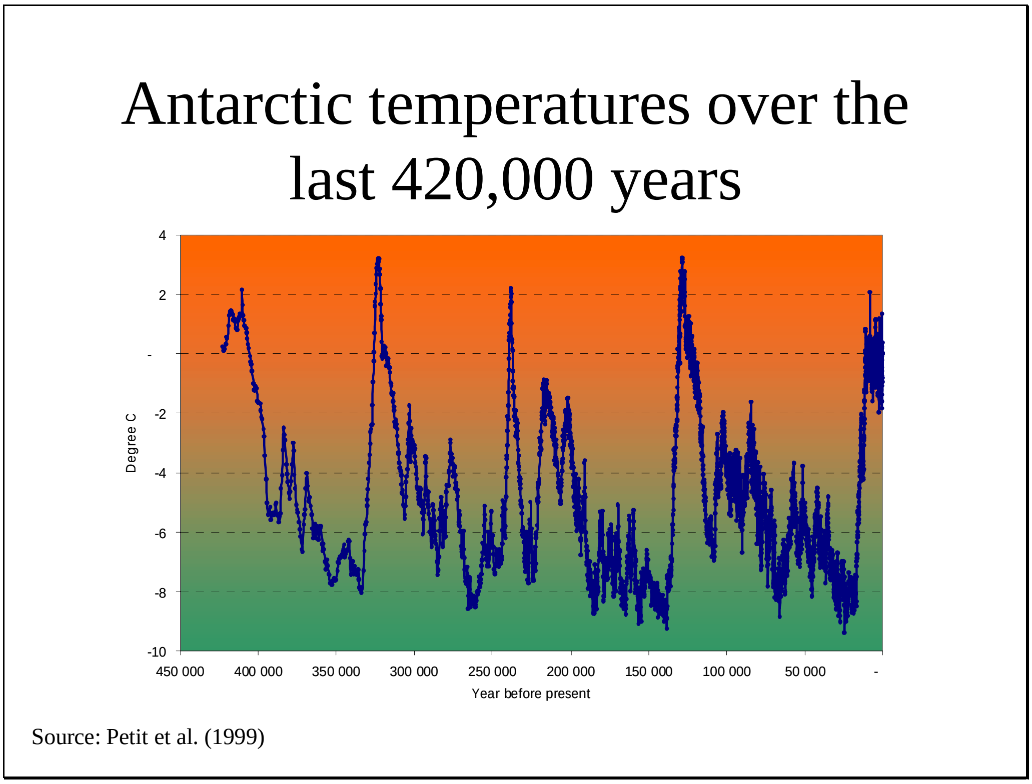


Source: Clark et al. (1999)

The current "ice house" period started approximately 3 million years ago, and the Earth has experienced several dozen ice ages since then. It is speculated that this "ice house" was set off when South and North America collided and the oceanic currents changed more or less to today's configuration.

In the beginning, the ice ages were rather short and lasted for approximately 40,000 years. Lately, they have tended to be colder and to last longer: approximately 100,000 years with rather short intermediate periods of some 10 to 20,000 years. The coming and going of the individual ice age is governed by small changes in the Earth's orbits that act as triggers and are amplified by internal feedback in the climate system linked to the concentration of greenhouse gases such as CO_2 and CH_4 in the atmosphere. The last ice age ended approximately 10,000 years ago. Normally we would then expect to be on the brink of a new ice age. However, fortunate circumstances with respect to changes in the orbit of the Earth have produced a longer intermediate period this time. Thus we foresee a period of 40 to 50,000 years before the next ice age. The issue of anthropogenic climate change is only a short episode within this rather long current intermediate period, but still it matters to us.

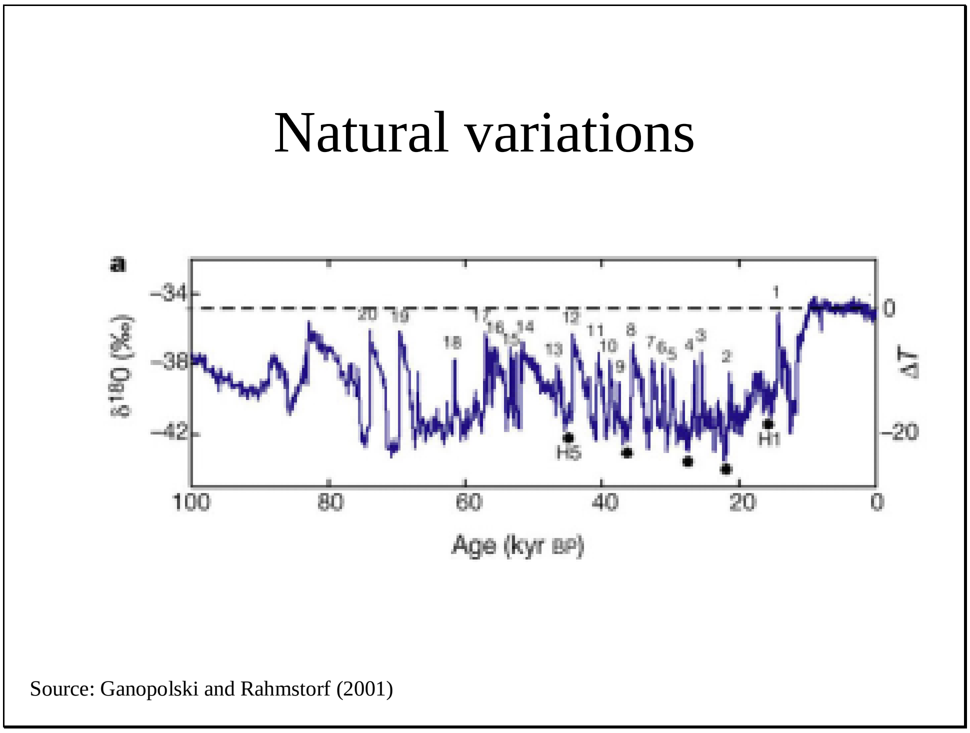
Slide 2.8. Antarctic temperatures over the last 420,000 years



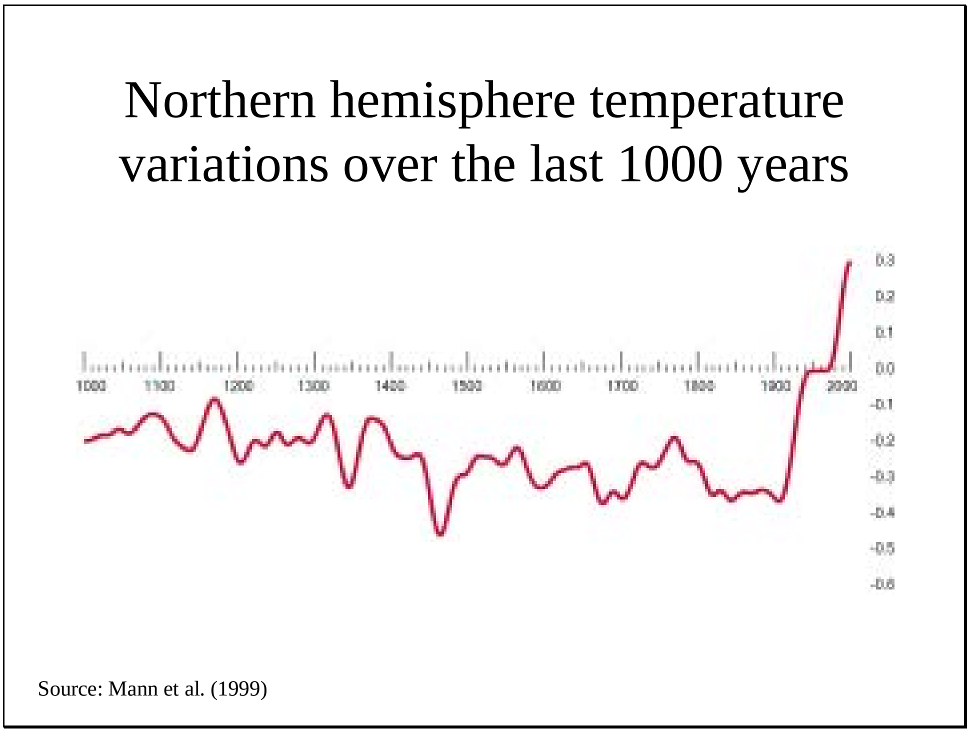
Measurements from ice cores drilled at the Russian-French Antarctic research station Vostok allow us to get a fairly detailed picture of the temperature development in this region over the last 420,000 years. What we find is a pattern where the temperature gradually falls during an ice age, then to be followed by a rapid rise in temperature, leading to a relatively short intermediate period (interstadial).

History shows us that the climate may vary considerably as a result of natural causes. **Slide 2.9** shows abrupt climate changes in our region as recorded in Greenland ice-core data. We find changes in annual mean temperatures of more than 10 ^{o}C over a few decades triggered by rapid change in the North Atlantic current. After the end of the last ice age 10,000 years ago, this huge variability has disappeared. It is during this much calmer period that we as a species have established our civilization, built cities and developed to where we are today. Thus, our civilization has never experienced climate variability as it was during the last ice age and before. The potential reoccurrence of this variability is an important aspect of the climate problem. There are probably threshold values for the anthropogenic forcing of the climate, which if exceeded, will trigger instabilities in the ocean current, and hence in the climate, similar to those observed during the last ice age.

Slide 2.9. Natural variations

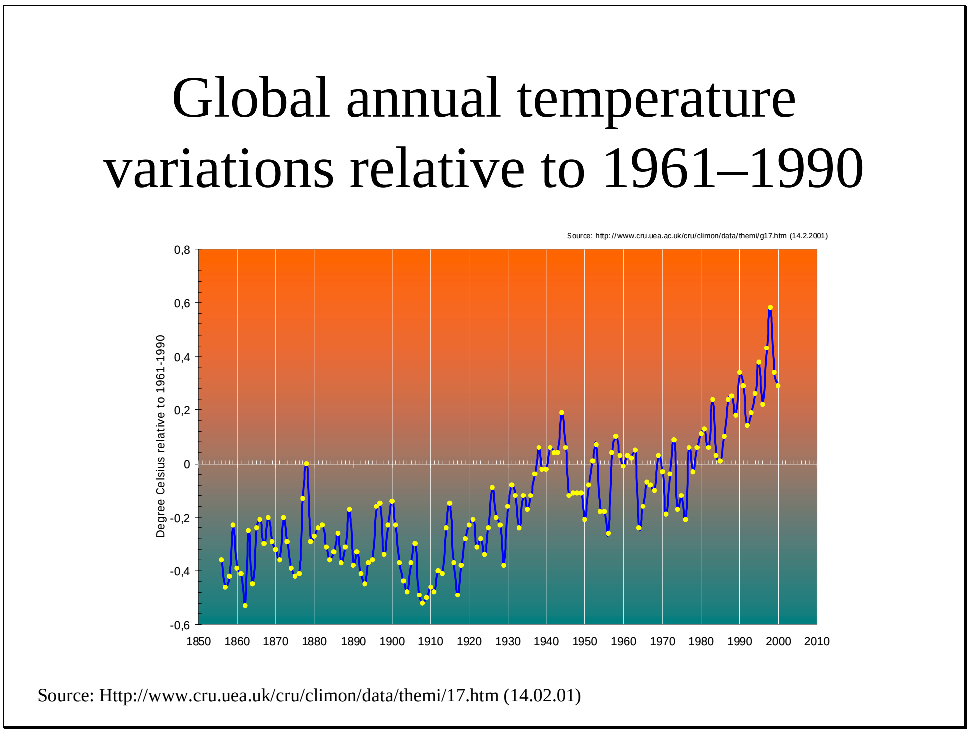


Slide 2.10. Northern hemisphere temperature variations over the last 1000 years



The temperature variations over the last 1000 years can be inferred from a number of proxy indicators such as tree ring or sedimentation measurements, etc. The picture that emerges for the Northern hemisphere depicts a long-term cooling trend (more or less in accordance with what we expect to happen as a result of orbital variations) punctuated by two periods of rapidly increasing temperatures. The first period is from approximately 1910 to 1945, and the second period starts in 1976 and is still in progress.

Slide 2.11. Global annual temperature variations relative to 1961-1990



It is only for the last 150 years that we have a reasonably reliable instrumental record of global changes in the average annual temperature variations. **Slide 2.11** shows in more detail the annual variations and the two warming periods from 1910 to 1945 and from 1976, together with a slight cooling period between the end of the first period and the start of the second period. While the warming from 1920 to 1945 can be explained by predominantly natural driving forces (solar variation and variations in volcanic activity), the effects of emissions of greenhouse gases dominate in the period from 1976.

At the beginning of this century, the global mean temperature was some 0.6 ^{o}C higher than at the beginning of the last century. Year 2000 was the fifth warmest year on record, beaten only by 1999, 1998, 1997, 1995, and 1990. The ten warmest years have all been since 1983, and eight of them since 1990. Year 2000 was the twentieth consecutive year with a mean annual temperature above the 1961–1990 norm.

2.3 Changes in the concentration of greenhouse gases

The most important driving force behind the recent rapid increase in global temperature is probably the enhanced greenhouse effect. The most important greenhouse gases are listed in **Slide 2.12**.

Slide 2.12. Greenhouse gases

Greenhouse gases

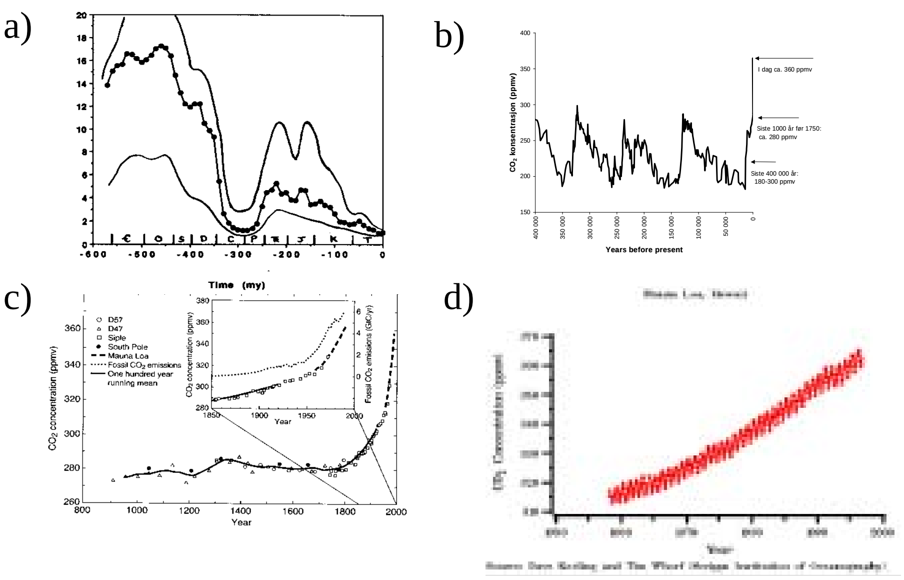
The main greenhouse gases

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)	Anthropogenic sources	Global warming potential (GWP)*
Carbon-dioxide	CO2	280 ppmv	358 ppmv	50-200	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH4	700 ppbv	1720 ppmv	12-17	Fossil fuels Rice paddies Waste dumps Livestock	21**
Nitrous oxide	N2O	275 ppbv	312 ppmv	120-150	Fertilizer industrial processes combustion	310
CFCs	CFC12	0	503 pptv	102	Liquid coolants Foams	125-152
HCFCs	HCFC-22	0	105 pptv	13	Liquid coolants	135
Perfluorocarbon	CF4	0	110 pptv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF6	0	72 pptv	1 000	Production of magnesium	23 900

Source: IPCC (1996a)

Slide 2.13. CO_2 concentration in earlier times

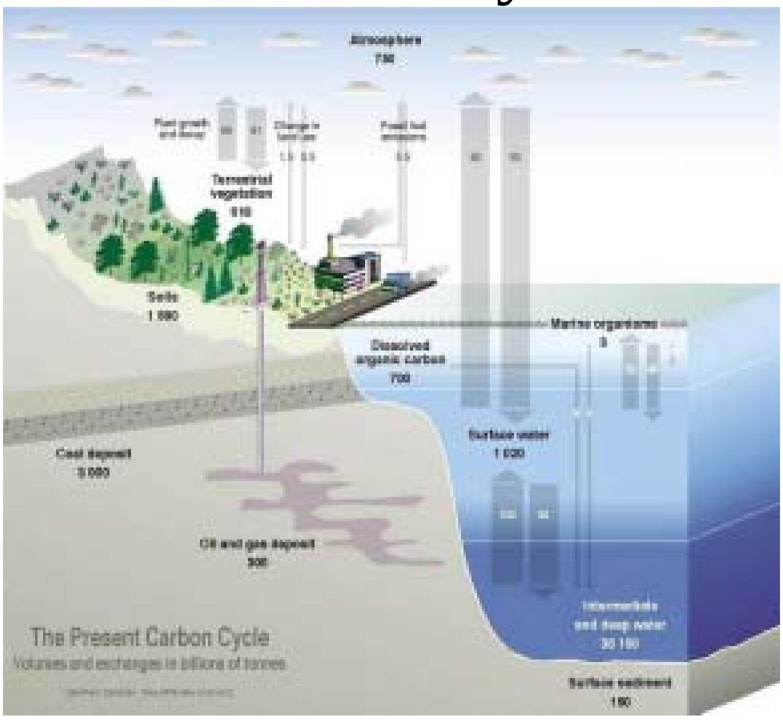
CO_2 concentration in earlier times



Half a billion years ago, the CO_2 concentration in the Earth's atmosphere was probably some 15 times higher than today, see panel *a* of the figure. Then, 300 million years ago, the landscape was changed dramatically through plant growth, which reduced the CO_2 concentration substantially. Panel *b* shows the CO_2 concentration over the last four ice ages, obtained by measurements from ice cores from the Antarctic. During this period, the concentration level was between 180 and 280 ppmv. Only during the last 100 years has this level been exceeded (panels *c* and *d*). Panel *b* gives a perspective of where we are heading the next 100 years in relation to the "normal" background level.

Slide 2.14. The carbon cycle

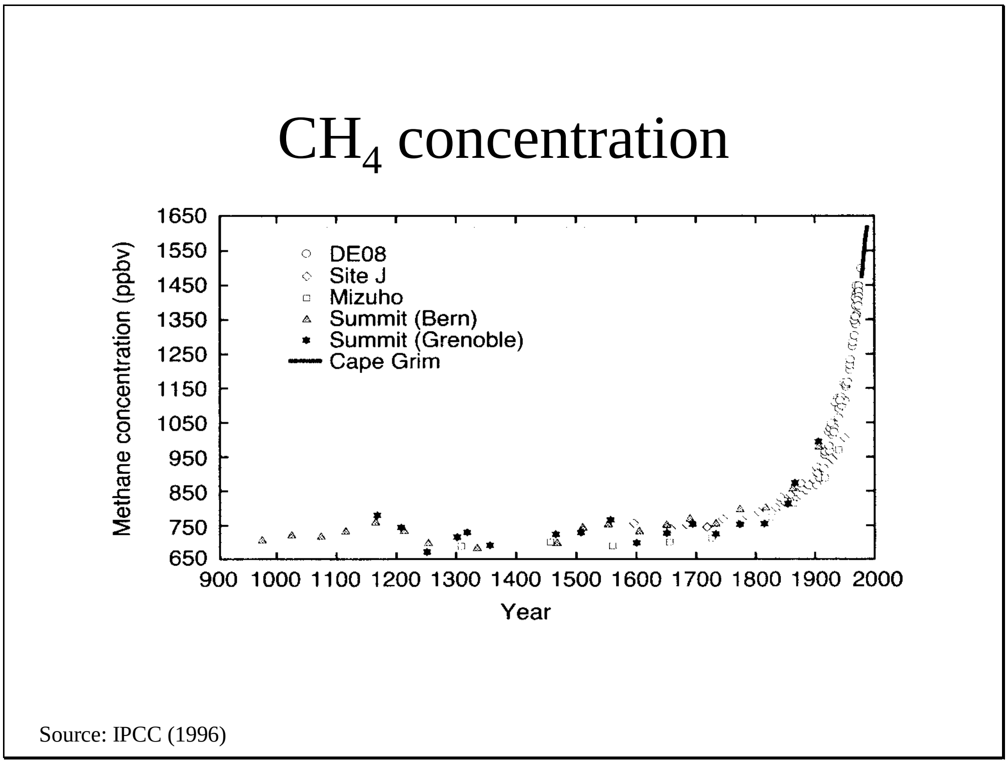
The carbon cycle



Source: Grid-Arendal (2001) and IPCC (1996)

The CO_2 concentration in the atmosphere is the result of exchanges of carbon between several reservoirs. The man-made flux of carbon to the atmosphere is small compared to the natural fluxes between the reservoirs, but these are more or less compensated by return flows. Thus, since the anthropogenic emission of carbon is a one-way stream, it over time leads to the increased concentration of CO_2 in the atmosphere, as has already been observed (approximately 30% from a pre-industrial level).

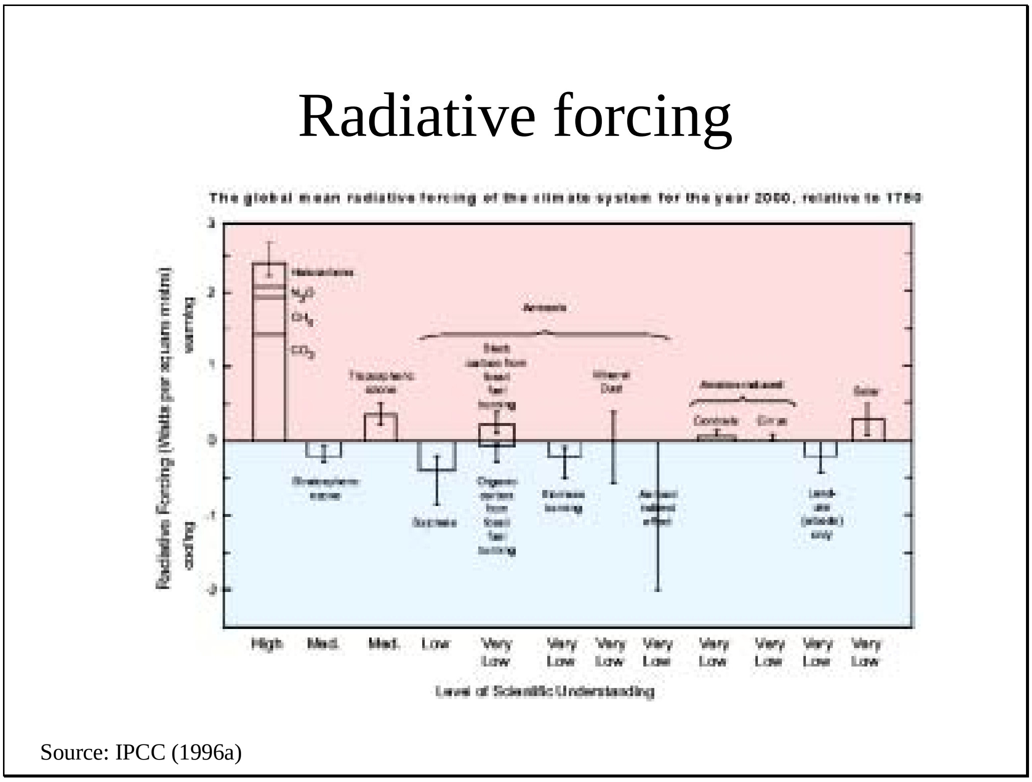
Slide 2.15. CH_4 concentration



Also the concentration of CH_4 has increased substantially since the industrial revolution.

2.4 Radiative forcing and Global Warming Potentials

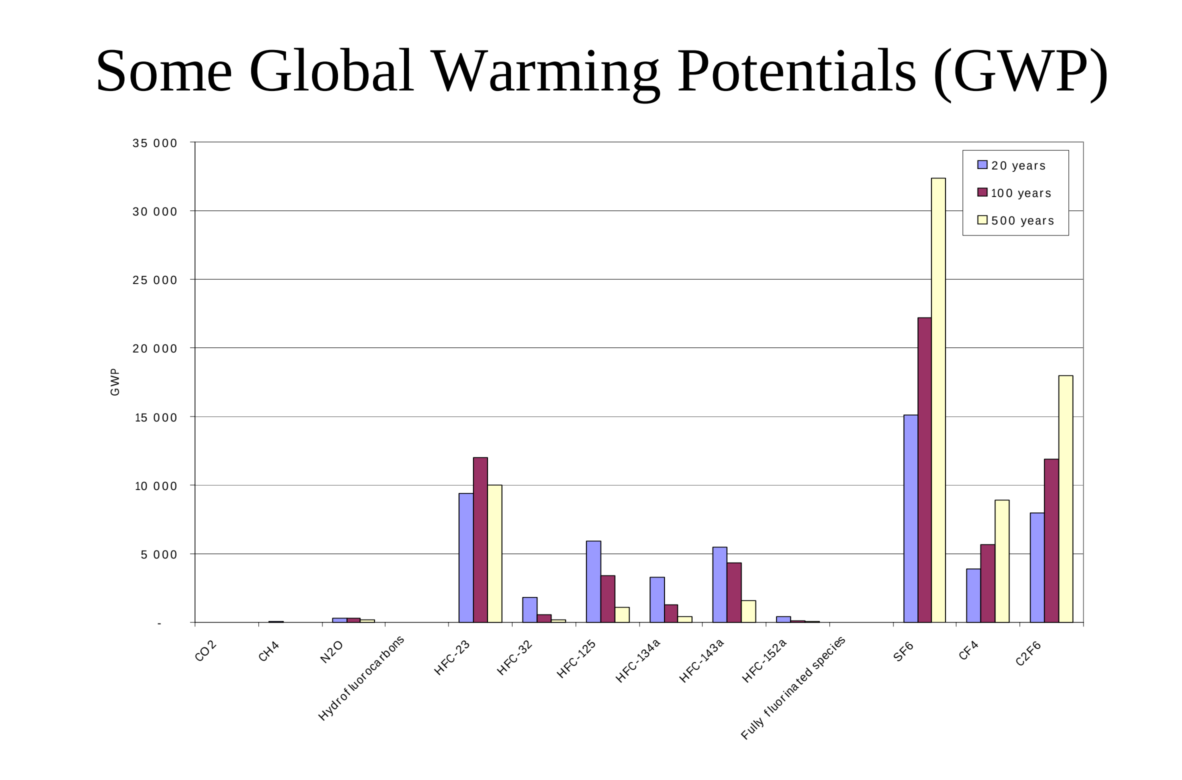
Slide 2.16. Radiative forcing



"Radiative forcing" is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth–atmosphere system. A positive radiative forcing indicates a trapping of energy in the atmosphere and thus has a heating effect.

Changes in the composition of the atmosphere, surface characteristics of the Earth, and solar radiation since 1750 have changed the radiation balance of the atmosphere, as shown in **Slide 2.16**. The slide also gives a rough indication of the confidence level associated with the different factors. The dominating role of CO_2 and other greenhouse gases at the far left of the slide and the relative high scientific certainty associated with these warming effects is particularly noteworthy. The greatest uncertainty is associated with the indirect effects of aerosols, e.g. their impact on cloud formation and the cloud effects on the radiative forcing.

Slide 2.17. Some Global Warming Potentials (GWP)



Source: IPCC (1996a)

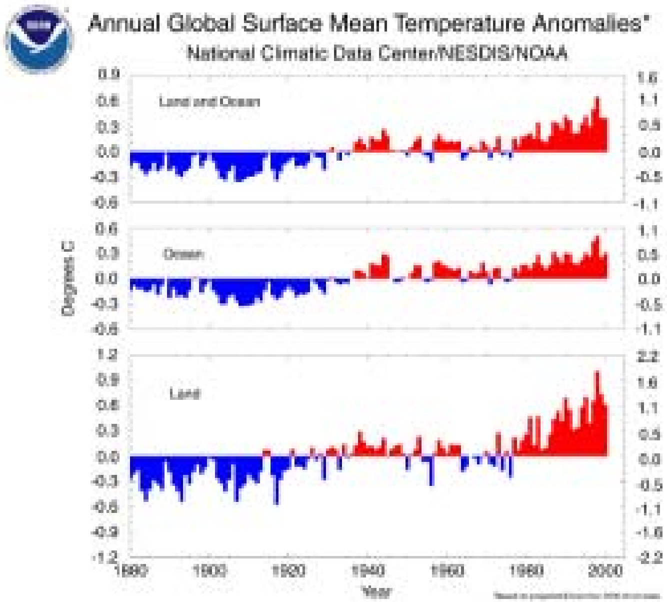
By integrating the radiative effect of a unit of a greenhouse gas over a certain time horizon – conventionally chosen as 20, 100 or 500 years – it is possible to get a rough measure of the warming potential of that gas. It is also the convention to normalize the warming potential such that the warming potential of *CO_2 is equal to one* (i.e. all gases are compared to CO_2 when assessing their warming potentials). The extreme high values of some of the fully fluorinated species and also some of the ethers and halogenated ethers are noteworthy in this respect.

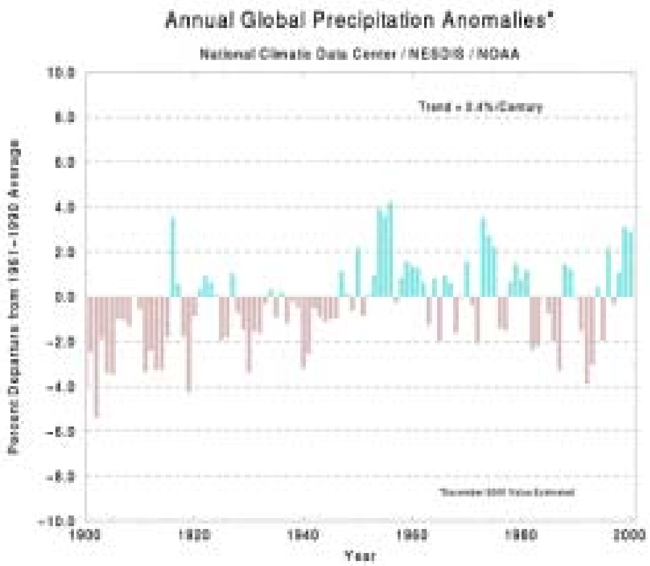
2.5 Observed climate change: Is it man-made?

Observed and inferred changes in mean temperature have been depicted in earlier slides. **Slide 2.18** (left panel) shows a breakdown of temperature changes over land and oceans. As expected, the increase has been larger over land areas than over oceans, due to the greater thermal inertia of the oceans. In addition to changes in the global mean temperature, we have also observed changes in precipitation.

Slide 2.18. Temperature and precipitation

Temperature and precipitation

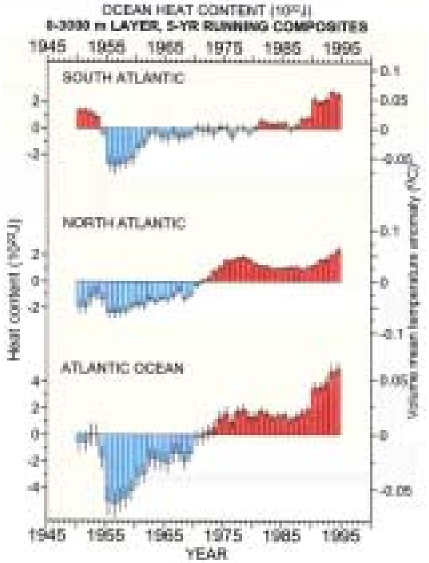


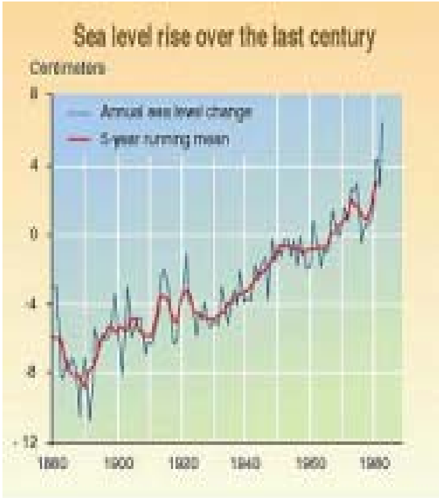


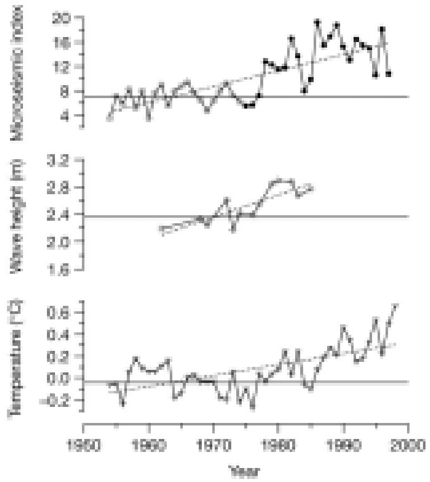
Source: National Climate Data Center/NESDIS/NOAA

Slide 2.19. The ocean

The ocean





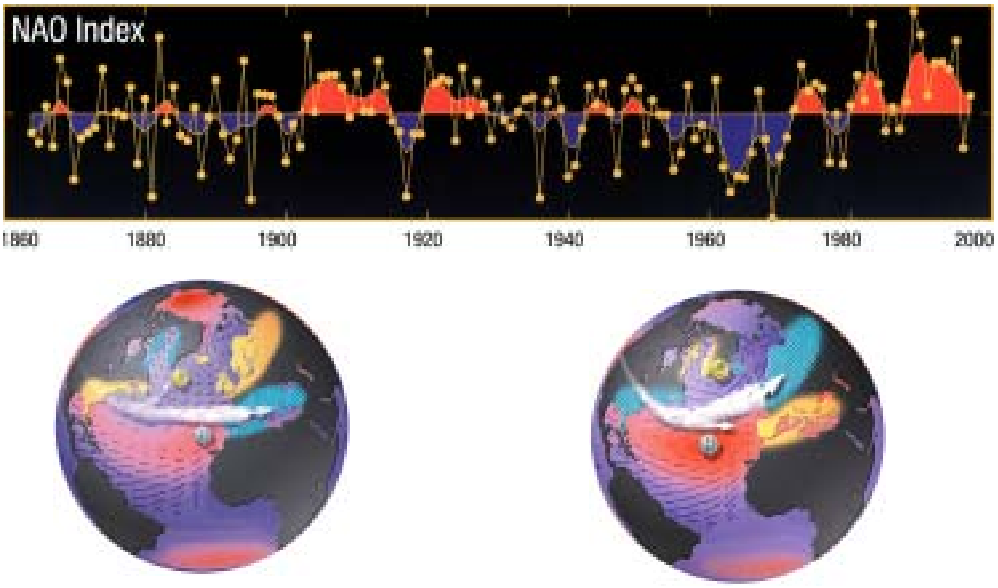


Source: Levitus et al. (2000), IPCC (1996), Grid Arendal (2001), Grevemeyer, I., R. Et al. (2000)

Other observations also indicate that the climate is changing. Thus the ocean temperature down to approximately 3000 m has been increasing. The left panel of **Slide 2.19** shows observations from the Atlantic. As a result of increased temperature, the water mass expands and the sea level increases (middle panel). Finally, increased wind has increased the wave heights in the North Atlantic as measured directly or as inferred from the measurement of micro-seismic events.

Slide 2.20. NAO and our local climate

NAO and our local climate

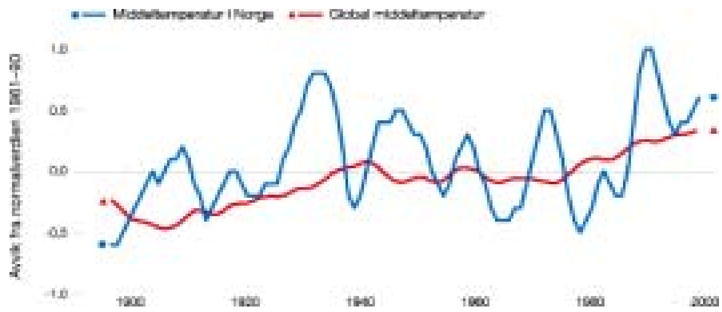


Source: NOAA/NILU-RegClim

Changes in the regional or local level will differ considerably from global changes due to topographical features, ocean currents and other local or regional features and processes. In our region, we find that the regional climate is strongly coupled to the so-called North Atlantic Oscillation index (NAO). The index measures the pressure difference between the Icelandic low pressure and the high-pressure region near the Azores. A low NAO index during the winter season implies that the low-pressure systems coming across the Atlantic take a southern course, exposing Norway to cold polar air masses. A high NAO index results in a more northern path for the low-pressure systems, with warm and moist air dominating over Norway. We see from the slide that during the periods with global warming (1910–1945 and 1976–), we tend to have a high NAO index.

Slide 2.21. Temperature development in Norway

Global and Norwegian mean temperature 1900-1999



Slide 2.21 shows a comparison between the development in global mean temperature (red curve) and the temperature in Norway (blue curve) over the least century relative to the mean value of the period 1961–1990.

Slide 2.22. Ocean currents

Ocean currents

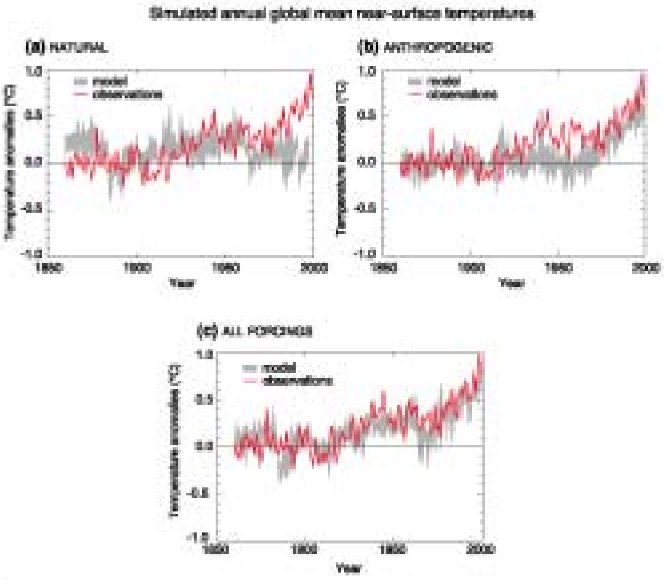
Source: GRID Arendal

We also see changes in ocean processes like the thermohaline circulation in the North Atlantic. The deep-water formation taking place in the North Atlantic has been significantly reduced over the last few decades. This may lead to changes in the ocean currents and in the heat transport that takes place because of them.

Previous huge natural climate variations during the last ice age were probably caused by such changes in the ocean current. Continued increasing man-made climate change may trigger a new period of climatic instability. This is a much more dire scenario than a gradually warming world, and reinforces the importance of the Precautionary Principle in the context of climate change.

Slide 2.23. Does human activity have an effect on our climate?

Does human activity have an effect on our climate?



Source: IPCC (2001a)

Are the observed climate changes man-made? The IPCC concludes that there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. **Slide 2.23** shows one piece of evidence in the form of three model simulations of global mean temperatures over approximately the last 150 years. In the upper left hand panel, natural driving forces drive the model simulations only. In the upper right hand panel, only anthropogenic forces (greenhouse gases) are included, while the lower panel combines both types of forces. The agreement with the observed temperature changes (red curve) is convincing only when anthropogenic forces are included.

2.6 The debate about IPCC

In the climate debate, scientists tend to be classified into one of two categories: Those who tend to accept the findings of IPCC, and those who, for various reasons, are critical to the conclusions of IPCC. The criticisms broadly follow two dimensions: (1) a concern about procedural practices in the IPCC where the skeptics tend to claim that certain disciplines, and regions are not properly represented among the many hundreds of lead authors, contributing authors, or reviewers, and (2) a disagreement about the underlying science of climate change. The following section offers comments on each of these dimensions.

Procedural matters and fair representation

While there certainly are bound to be some unfortunate omissions or biased selections along some of these dimensions, it is still a fact that the IPCC process is by far the most open and all-inclusive assessment process undertaken in the scientific community. Over time, the IPCC has also included representatives from ever more disciplines as the climate relevant research from these disciplines has increased, and efforts are undertaken to include more of the non-English literature in the assessment process. All in all, it is difficult to understand the accusation that the IPCC assessment process is a highly politicized process, all the more so since some of the critics clearly represent business interests themselves (e.g. the Global Climate Coalition).

Scientific disagreements

Those who disagree with the IPCC about the science of climate change can in turn be roughly divided into two groups. One group criticizes the basic scientific facts and observations, while the other group proposes alternative hypotheses concerning one or more less well-known mechanisms at work in the climate system.

Among those who are skeptical to basic scientific facts and observations, we find a group of individuals who are skeptical to the reliability and representativeness of the temperature measurements and the corrections they are subject to due to the use of different measurement instruments, urban heat island effects and so on. Others are critical to the methods used for measuring the CO_2 content of the atmosphere, while some doubt the well-established radiative properties of the greenhouse gases. While no scientific fact is foolproof and immune to improvement, it is fair to say that the majority of criticisms raised in this category are based on rather simple misunderstandings of the underlying physics of climate change. An exception is the criticism based on disagreements between surface temperature measurements and measurements carried out by satellites since the late 1970s. While the two time series measure two different things (surface temperatures and temperatures in the lower troposphere) and the gap between the measurement series has narrowed over time due to corrections of the satellite data, it still remains an unexplained difference which gives cause for concern about our understanding of the energy transport in the lower troposphere.

The most serious criticism of IPCC comes from those proposing alternative hypotheses about key physical mechanisms in the climate system. The mechanisms are related to transport and condensation of humidity in the upper troposphere/lower stratosphere under climate change, hypotheses about the indirect effects of solar activity on the flux of cosmic rays and cloud formation, and concern about our ability to model ocean currents in a realistic manner. The IPCC explicitly acknowledges that we lack an understanding of these mechanisms, and there is no disagreement about the need to research these areas further. Still, the IPCC does not advocate that we should disregard what we know about the effect of greenhouse gases on climate development in view of the uncertainties with regard to the mentioned mechanisms, while the skeptics are more inclined to question our understanding of the effects of e.g. greenhouse gases in view of the mentioned uncertainties. The final conclusion on this is a political question where the IPCC seems to favor a proactive stance where governments should formulate climate policy on the best available information, while some of the skeptics seem to advocate a wait and see attitude.

In all of this, it is important to foster a sound understanding of the scientific process as a dialog where new elements are constantly emerging and where no final truth is ever going to be achieved. On this fluid background, we are nevertheless forced to make decisions that are going to affect our and future generations for a long time to come.

Slide 2.24 Uncertainties

Uncertainties

This we know:	This is likely to happen:	This is uncertain:
• We have a *natural* greenhouse effect due to greenhouse gases and clouds in the atmosphere. The most important greenhouse gases are H_2O, CO_2, CH_4 og N_2O • Since pre-industrial times, the concentrations of CO_2, CH_4 and N_2 have increased by 31%, 151% and 17%, respectively. The increases are due to man-made emissions and have led to an *enhanced* greenhouse effect. • Observed climatic changes over the last century include: ✓ Increased global mean temperature by 0.4–0.8 °C. The five warmest years after 1860 have all occurred after 1990.	• Man-made emissions of greenhouse gases have contributed to the observed climate change. • With today's growth in emissions we can expect the following climate changes by year 2100: ✓ Global increases in mean temperatures of 1.4–5.8 °C ✓ Sea level rise: 10–90 cm (continuing for many hundred years) ✓ More precipitation in wet areas and less in already dry areas	• Strong and rapid climate change has occurred in earlier times, and we are uncertain what triggers this kind of instability, and when. • There is uncertainty with regard to how global warming will manifest itself at a regional and local level. • There is still great uncertainty with regard to: ✓ Feedback effects, particularly associated with water vapor and clouds. ✓ Cooling effects of particles ✓ Indirect effects of solar variability. ✓ The effects of global warming on strong storms. ✓ Changes in ocean currents

Source: IPCC (2001a)

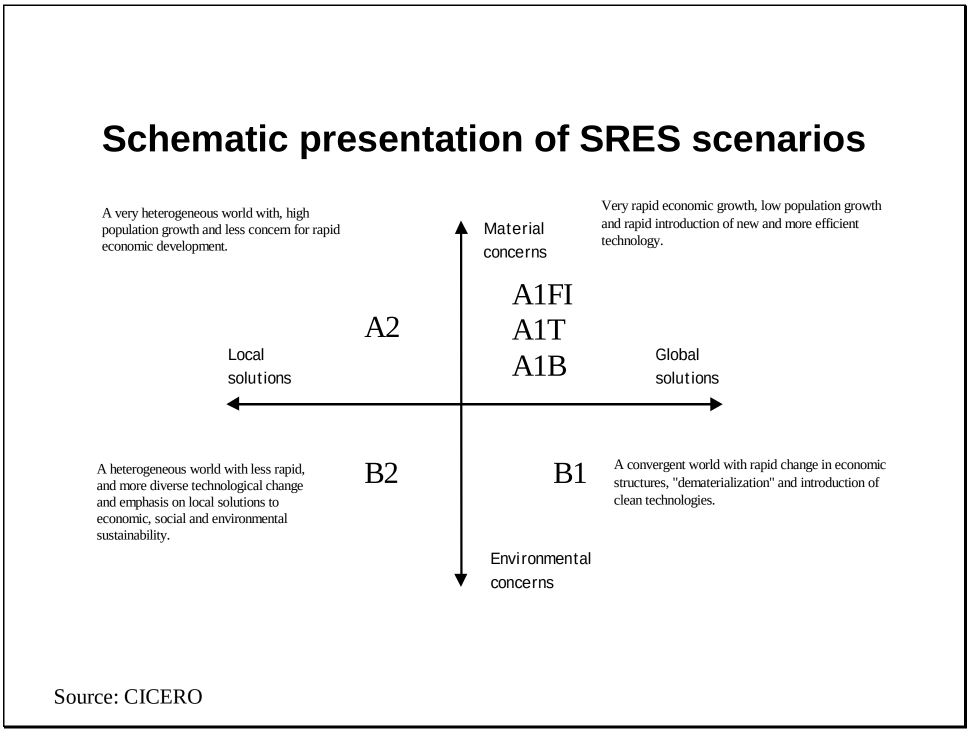
3. Future climate change

3.1 Scenarios for global anthropogenic greenhouse gas emissions

A scenario is a description of how future development may evolve. Scenarios integrate qualitative storylines and quantitative formulations based on modeling. A set of emission scenarios can therefore contribute to understanding future developments of complex and integrated systems. Emission scenarios are important both for scientific assessments and policy makers, and are based on a set of assumptions, theories, and relations between central driving forces.

Working Group III of the IPCC was in 1996 given the responsibility for developing a Special Report on Emission Scenarios (SRES), and the report was completed in 2000. The development of the new SRES scenarios started with a review and analysis of literature on existing global and regional scenarios. The formulation of four different *storylines* – called A1, A2, B1 and B2 – was a central part of the process. The storylines represent different paths with respect to economic, technical, social and environmental development. The *A1* scenarios (A1FI, A1T and A1B) describe a world with rapid economic growth, low population growth and rapid introduction of new and more efficient technology. Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. The *A2* scenario describes a very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local conditions, high population growth, and less concern for rapid economic development. The *B1* scenario is characterized as a world with rapid change in economic structures, “dematerialization,” and introduction of clean technologies. The emphasis is on global solutions to environmental and social sustainability, including concerted efforts for rapid technology development, dematerialization of the economy, and improving equity. The *B2* scenario describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is again a heterogeneous world with less rapid, and more diverse technological change, but a strong emphasis on community initiative and social innovation to find local, rather than global solutions. **Slide 3.1** shows a schematic presentation of the new SRES scenarios.

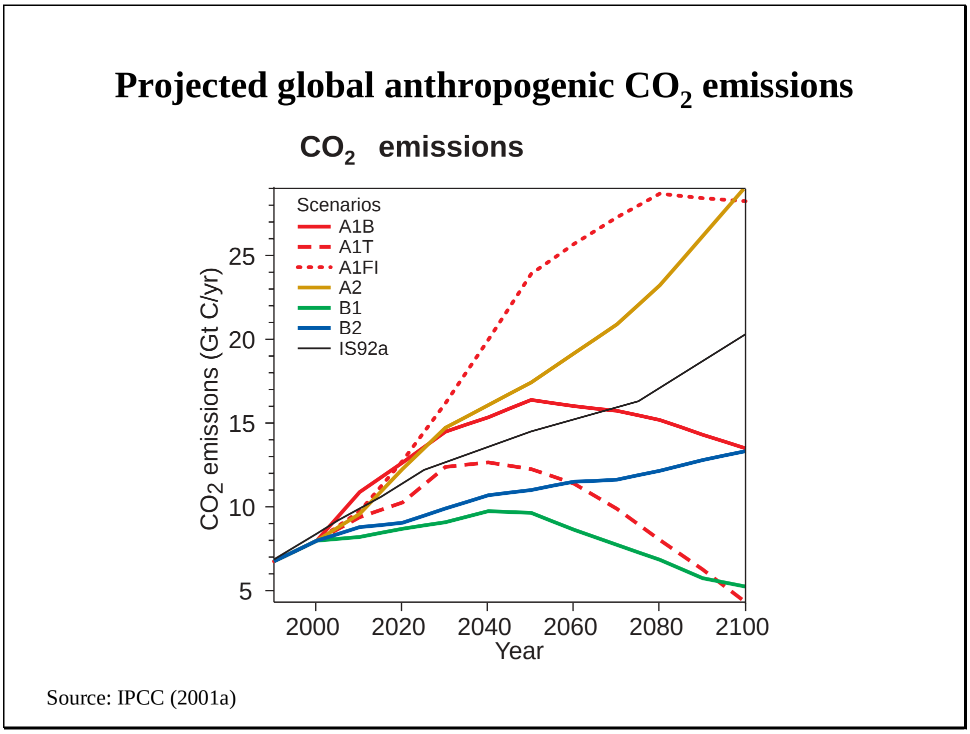
Slide 3.1. Schematic presentation of SRES scenarios



Six models were used to quantify these storylines, and 40 scenarios were developed altogether. All variants of a storyline were put together into a "family" of scenarios. The model-run that best represents each of the various storylines is called a *marker scenario*, and there are six such marker scenarios. There is one each from A2, B1, and B2, and three from A1. The three marker scenarios from A1 represent different developments with respect to energy technologies, but the other driving forces are assumed to be identical. A1FI is based on an intensive use of fossil fuels, A1T is based on other energy sources than fossil fuels, and A1B represents a balanced use of all energy sources (Nakicenovic, 2000).

Since assumptions and events vary among the scenarios, they represent different future developments. It is therefore not surprising that the scenarios depict emissions that vary substantially. The emissions of CO_2 have had and still have the largest impact on the increase in the greenhouse effect (see Slide 2.16). The future emissions of this gas are therefore particularly important and interesting. **Slide 3.2** shows that the emissions of CO_2 can vary between 6 and 29 billion tons carbon in 2100. Marker scenario A2 will have the highest emissions, important driving forces being high population growth, and high energy and carbon intensity.

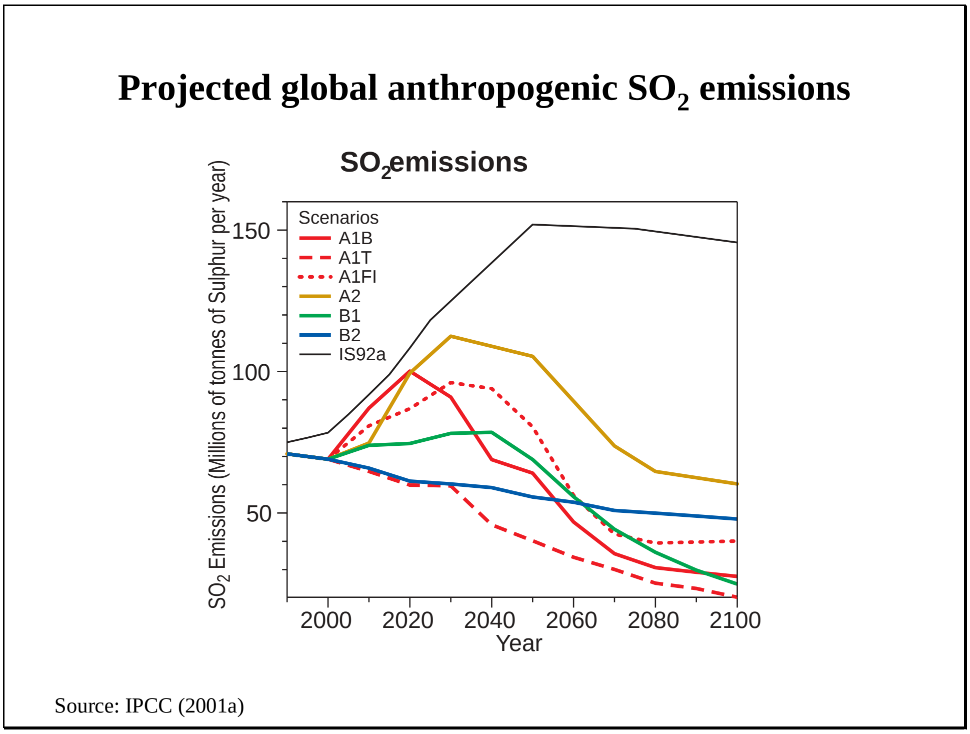
Slide 3.2. Projected global anthropogenic CO_2 emissions



The emissions of methane (CH_4) also contribute significantly to the increased greenhouse effect, and the main sources are agriculture, waste treatment, and production of fossil fuels. The emissions of CH_4 are projected to vary between 240 and 890 million tons in 2100. The 1990 level was 310 million tons, so the scenarios predict a range of outcomes spanning from a small decrease in emissions to an increase of almost 300%. The third most important contribution to the increased greenhouse effect is the emissions of nitrous oxide (N_2O). Emissions of N_2O stem from agriculture, waste treatment, and industrial processes. The emissions of N_2O are expected to stabilize at around 6-7 million tons N in 2100, the exceptions being the A2 and A1FI scenarios. These scenarios both reach about 16.5 million tons N in 2100.

While CO_2, CH_4 and N_2O contribute to the increased greenhouse effect (and the warming), SO_2 has a cooling effect through the formation of particles and clouds. The future emissions of this gas are therefore particularly important. **Slide 3.3** shows that emissions of SO_2 can vary between 20 and 60 million tons of sulfur in 2100. Compared to the former set of emission scenarios from IPCC, the IS92 scenarios, the new set of emission scenarios has significantly lower SO_2 emissions. The reduction is due to structural changes in the energy system as well as concerns about local and regional air pollution. This is the most striking difference between the new SRES scenarios and the IS92 scenarios.

Slide 3.3. Projected global anthropogenic SO_2-emissions



3.2 Necessary emissions reductions for stabilizing concentrations

The ultimate goal of the Climate Convention, as stated in Article 2, is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." This should be taken as a starting point when discussing reductions of emissions. Stabilization of *emissions* is not enough to stabilize the *concentrations* at the same rate. If CO_2 emissions are stabilized at the current emission level, the concentration in the atmosphere will still increase for at least two hundred years as a result of the long adjustment time.

Stabilization scenarios illustrate implied rates of CO_2 emission that would result in various stable CO_2 concentration levels. These have been projected using a similar methodology to that applied in the analysis of emissions scenarios. **Slide 3.4** shows WRE (**W**igley, **R**ichels and **E**dmonds) trajectories that follow CO_2 concentrations consistent with the IS92a scenario beginning in 1990 that branch off to reach constant CO_2 concentrations of 450, 550, 650, 750 and 1000 ppmv (Wigley et al., 1996).[3] The implied CO_2 emissions are projected by two fast carbon cycle models, Bern-CC and ISAM. The ranges represent effects of different model parameterizations and assumptions. The results for the reference cases are not substantially different from those presented in the Second Assessment report (SAR). However, the range based on alternative model parameterizations is larger than that presented in the SAR, mainly due to the range of simulated terrestrial CO_2 uptake.

When discussing emission and stabilization scenarios, it is interesting to look into the reserves and resources of fossil fuels.[4] **Slide 3.5** shows carbon in oil, gas, and coal reserves and resources with

[3] The concentration of CO_2 in the atmosphere will increase by 1 ppmv if 2.123 PgC is emitted as a pulse to the amosphere. However, there will be a slow delay of this CO_2 pulse due to uptake by the ocean and biosphere.

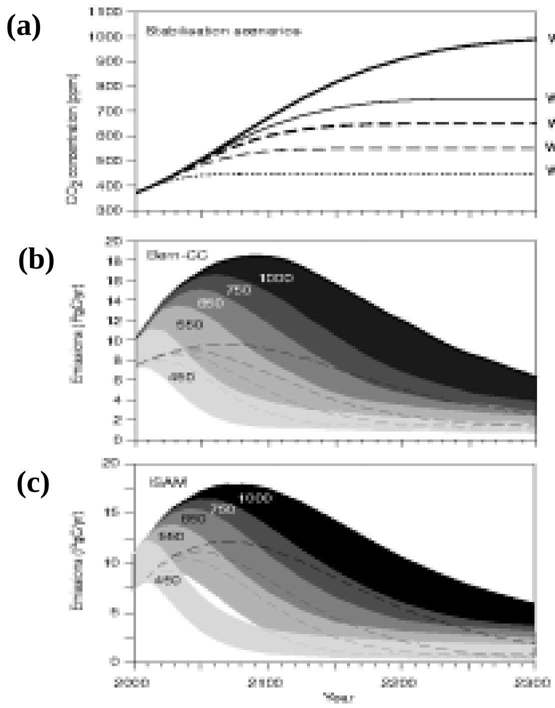
[4] Reserves are those occurrences that are identified and measured as economically and technically recoverable with current technologies and prices. Resources are those occurrences with less certain geological and/or economic characteristics, but which are considered potentially recoverable with foreseeable technological and economic developments. The resource base includes both categories. On top of that, there are additional

historic fossil fuel carbon emissions 1860–1998, and with cumulative carbon emissions from two SRES scenarios and three IPCC Third Assessment Report (TAR) stabilization scenarios until 2100. The figure shows that there are abundant fossil fuel resources that will not limit carbon emissions during the 21st century. However, compared to the relatively large coal and unconventional oil and gas deposits, the carbon in proven conventional oil and gas reserves, or in conventional oil resources, is much less than the cumulative carbon emissions associated with stabilization of carbon dioxide at levels of 450 ppmv or somewhat higher. These resource data may imply a change in the energy mix and the introduction of new sources of energy during the 21st century. The choice of energy mix and associated investment will determine whether, and if so, at what level and cost, greenhouse concentrations can be stabilized. Currently most energy sector investments are directed at discovering and developing more conventional and unconventional fossil resources.

Slide 3.4. Stabilization scenarios

Stabilization scenarios

Panel **(a)** shows the assumed trajectories of CO_2 concentration (WRE scenarios: Wigley *et al.*, 1996) and panels **(b)** and **(c)** show the implied CO_2 emissions, as projected with two fast carbon cycle models, Bern-CC and ISAM. The ranges represent effects of different model parameterizations and assumptions. For each model, the upper and lower bounds (corresponding to low- and high-CO_2 parameterizations respectively) are indicated by the top and bottom of the shaded area. Alternatively, the lower bound (where hidden) is indicated by a hatched line.



Source: IPCC (2001a)

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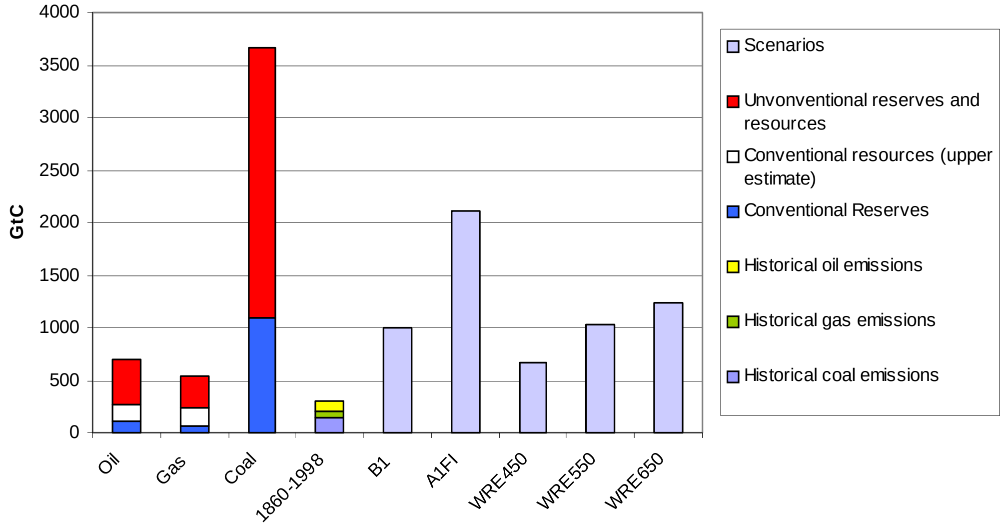
quantities with unknown certainty of occurrence and/or with unknown or no economic significance in the foreseeable future, referred to as "additional occurrences" (IPCC, 1996b). Examples of such unconventional fossil fuel resources include tar sands, shale oil, other heavy oil, coal bed methane, deep geopressured gas, gas in acquifers, etc.

Slide 3.5. Reserves, resources and emissions

Reserves, resources and emissions



Carbon in oil, gas and coal reserves and resources compared with historic fossil fuel carbon emissions 1860-1998, and with cumulative carbon emissions from two SRES scenarios (B1 and A1FI represent the two extremes) and three TAR stabilization scenarios up until 2100. Data for reserves and resources are shown in the left hand columns. Unconventional oil and gas includes tar sands, shale oil, other heavy oil, coal bed methane, deep geopressured gas, gas in acquifers, etc. Gas hydrates (clathrates) that amount to an estimated 12,000 GtC are not shown. The scenario columns show both SRES reference scenarios as well as scenarios that lead to stabilization of CO_2 concentrations at a range of levels.

Source: Modified from IPCC (2001c)

3.3 Future climate trends at a global level

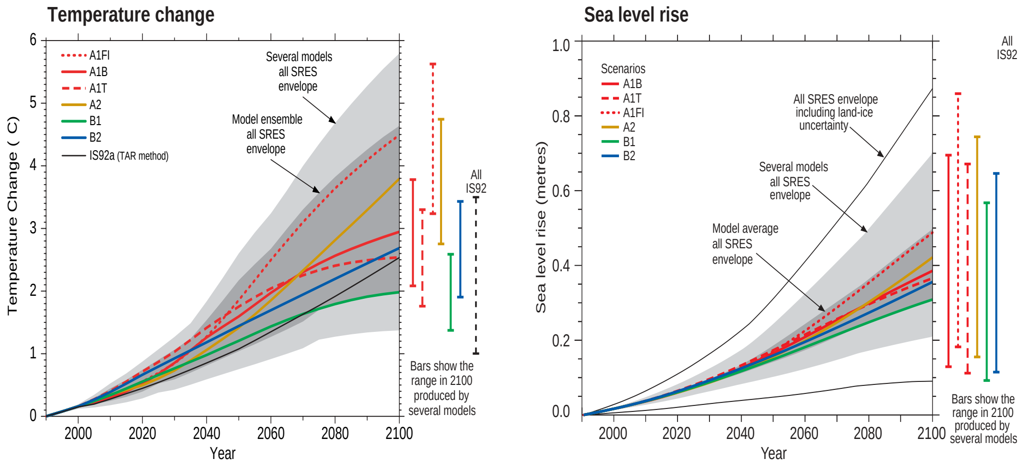
For more than two centuries humans have tried to model climate and climate variability. Since Svante Arrhenius's early projections in 1896, the field of climate simulations has evolved extensively. The climate models available today describe complicated processes and feedbacks, including hydrology, biology, ocean currents, sea ice, and clouds (see **Slide 2.1**).

Based on the range of SRES emission scenarios and extensive study on climate models, IPCC has projected the globally averaged surface air *temperature* to increase by 1.4 to 5.8 ºC by 2100 relative to 1990 (see **Slide 3.6**). The climate sensitivity is likely to be in the range of 1.5 to 4.5 ºC (an estimate unchanged from the two former IPCC Assessment Reports).[5] IPCC (1996a) projected a lower temperature change, with a range from 1.0 to 3.5 ºC, based on the former IS92 scenarios. The higher projected temperature and the wider range are due primarily to the lower projected sulfur dioxide emissions (cooling effect) in the SRES scenarios relative to the IS92 scenarios.

[5] Climate sensitivity usually refers to the long-term (equilibrium) change in global mean surface temperature following a doubling of atmospheric CO_2 (or equivalent CO_2) concentration ranging from 1.5 to 4.5 ºC.

Slide 3.6. The global climate of the 21st century

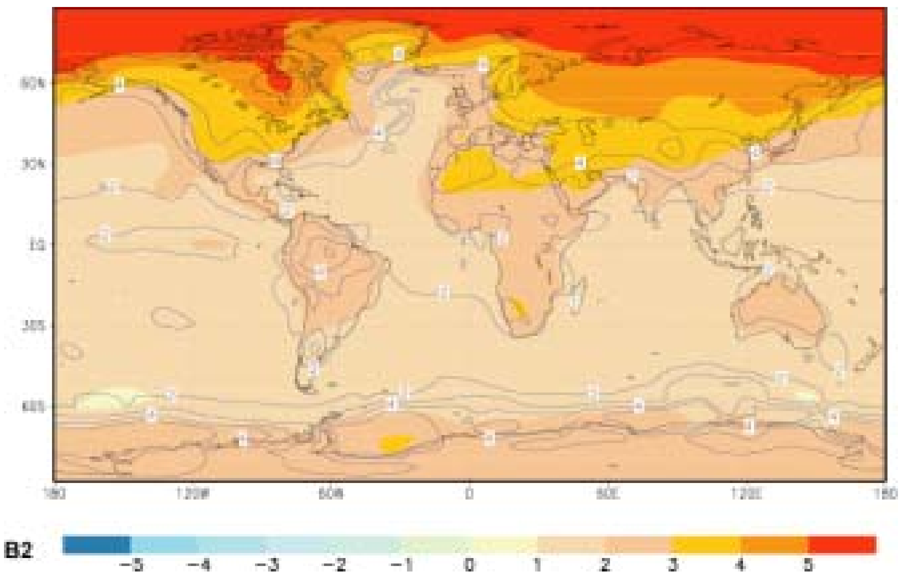
The global climate of the 21st century



Source: IPCC (2001a)

Slide 3.7. Temperature change (°C)

Temperature change (°C)



Source: IPCC (2001a)

If we look back a hundred years, the temperature change has been between 0.4 and 0.8 ºC. It is therefore *very likely* that the projected rate of warming will be much larger than what we have experienced during the 20th century.[6] **Slide 3.7** shows the geographical response in temperature change for the SRES scenario B2, where projected global average surface temperature increase by 0.9-3.4 ºC. Land areas at high latitudes are likely to warm more rapidly than the global average.

The warmer weather will amplify the observed retreat of glaciers and ice caps world wide through the 21st century. In the Northern hemisphere, the snow cover and sea-ice is expected to decrease further. In the Antarctic, on the other hand, the ice sheet is expected to increase as a result of increased precipitation.

The sea temperature, through terminal expansion, and the contribution from melting glaciers and ice caps determine the magnitude of *sea level* rise. Models have projected the globally averaged sea level to rise 0.09 to 0.88 meters by 2100. The sea level projections are lower than the ones presented in SAR primarily due to improved models that give less weight to ice sheets and glaciers. The projections show a continued increase both in warming and sea level rise well beyond 2100.

The projections conducted by IPCC indicate that the warming will vary by region, and be accompanied by increases and decreases in *precipitation*. Global average precipitation is projected to increase during the 21st century. However, there are large regional differences especially between the northern and southern hemispheres. It is *likely* that precipitation will increase over northern mid- to high latitudes and Antarctica during winter.[7] At lower latitudes, there are both regional increases and decreases over land areas. Generally the variability in precipitation will increase on all continents.

A large-scale and possibly irreversible effect resulting from climate change may be the slowing or possibly complete shut-down of the ocean circulation that transports warm water to the North Atlantic. Although current projections using climate models do not project a complete shut-down of the *thermohaline circulation* by 2100, beyond this period, the thermohaline circulation could completely, and possibly irreversibly, shut down in either hemisphere if the changes in radiative forcing are large enough and exist over a long enough period.

In addition to the changes in the average weather, the IPCC expects changes in the variability of climate and changes in the frequency and intensity of some *extreme climate* phenomena. **Slide 3.8** depicts the projected changes in some extreme weather and confidence levels.[8]

[6] In the Summary for Policymakers and in the Technical Summary from the Third Assessment Report (TAR) from IPCC, the following words have been used to indicate the confidence level: *virtually certain* (greater than 99% chance that a result is true); *very likely* (90–99% chance); likely (66–90 % chance); *medium likelihood* (33–66% chance); *unlikely* (10–33% chance); *very unlikely* (1–10% chance); *exceptional unlikely* (less than 1 % chance).

[7] See footnote 5.

[8] See footnote 5.

Slide 3.8. Projected changes in extreme weather and climate events

Projected changes in extreme weather and climate events

- Higher maximum temperatures and more hot days over nearly all land areas (*very likely*).
- Higher minimum temperatures, fewer cold days and frost days over nearly all land areas (*very likely*).
- Reduced diurnal temperature range over most land areas (*very likely*).
- Increase of heat index i.e. temperature and humidity over land areas (*very likely*).
- More intense precipitation events (*very likely*).
- Increased summer continental drying and associated risk of drought (*likely*).
- Increase in tropical cyclone peak wind intensities (*likely*).
- Increase in tropical cyclone mean and peak precipitation intensities (*likely*).

Source: IPCC (2001a)

Since SAR, the scientific community has managed to reduce some of the uncertainties through a wider range of detection techniques, separation of forced signals from internal variability, and multi-signal studies. Multi-signal studies address whether simulated response to a particular forcing agent is consistent with observations. All such studies conclude that anthropogenic greenhouse gases are likely to have made a substantial contribution to the 20th century warming (IPCC, 2001a). Despite improvements since TAR, there still are uncertainties, including the following:

Slide 3.9. Remaining uncertainties

Remaining Uncertainties

- Discrepancies between the vertical profile of temperature change in the troposphere seen in observations and models.
- Large uncertainties in estimates of internal climate variability from models and observations.
- Considerable uncertainty in the reconstructions of solar and volcanic forcing.
- Large uncertainties in anthropogenic forcing are associated with the effects of aerosols.
- Large differences in the response of different models to the same forcing.

Source: IPCC (2001a)

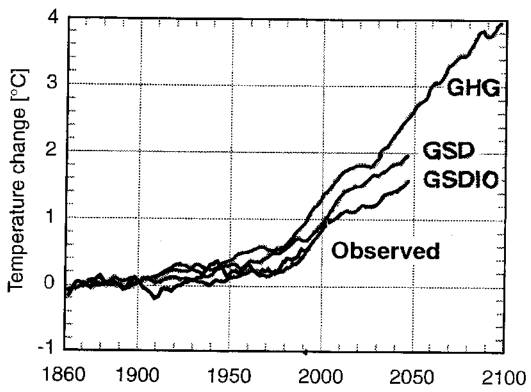
The accuracy of estimates of the magnitude of human induced warming continues to be limited by uncertainties in estimates of internal variability, natural and anthropogenic radiative forcing, and the climate response to external forcing.

3.4 Future climate trends nationally: the case of Norway

RegClim (Regional Climate Development under Global Warming) is a multi-institutional project aimed at estimating probable changes in the regional climate in Northern Europe. The large coarse-resolution general circulation models (GCMs) are not capable of predicting regional climate because of the low geographical resolution of the simulation. Therefore, one important component of the project involves the statistical and dynamical downscaling of results from the global models to produce regional climate change scenarios for Norway.

Slide 3.10. Changes in global average temperature

Changes in global average temperature



Scenarios: GHG (greenhouse gasses); GSD (greenhouse gasses and direct effect of aerosols); and GSDIO (greenhouse gasses, direct and indirect effects of aerosols and the effects of ozone.

Source: Fleichter (1999)

The first round of regional climate predictions is based on results from a climate model from the Max Planck Institute (MPI). **Slide 3.10** shows the model runs with future scenarios for forcing agents as input: “GHG” includes all greenhouse gases; “GSD” includes the greenhouse gases and direct effects from aerosols; “GSDIO” includes the greenhouse gases, the direct and indirect effects of aerosols and the effects of ozone in the troposphere. The scenarios GHG and GSD give rise to larger temperature increases. RegClim bases its runs on the GSDIO scenario since this scenario better fits the observations. In the future, RegClim will make use of additional models and scenarios of forcing agents.

The first RegClim scenario includes seasonal and inter-annual variability and probable changes in severe weather conditions, which are defined by high wind speeds, large precipitation amounts and extreme sea levels. The projections are given as differences between the average climate from 1980 to 2000 and from 2030 to 2050. Given the input scenario, Norway can expect a warmer and wetter climate, with potentially more strong winds and more frequent storms along some part of the coastline. Average annual temperature is expected to increase by 0.2–0.5 °C each decade, and average annual precipitation is expected to increase by almost 10%. However, the RegClim results indicate that climate change will manifest itself differently across Norway (RegClim 2000) (see **Slide 3.11**).

Slide 3.11. Regional estimated changes in temperature and precipitation from 2000 to 2050

Regional estimated changes in temperature and precipitation from 2000 to 2050

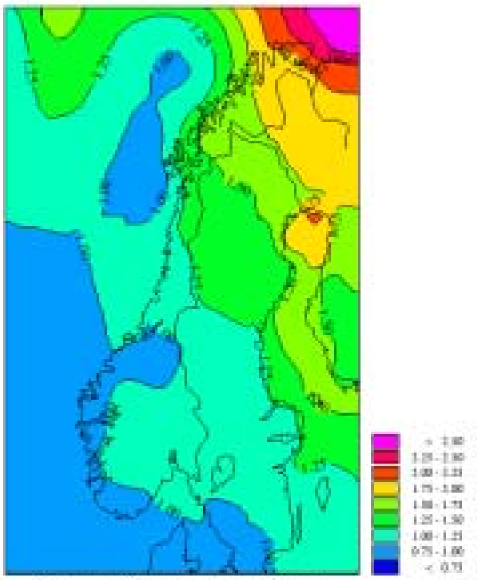
		Temperature change (°C)	Precipitation change (mm/day)	Precipitation change (percent)
Northern Norway	whole year	1,6	0,3	7,8
	spring	1,4	0,2	5,0
	summer	1,2	0,1	1,5
	autumn	1,7	0,8	18,2
	winter	**2,0**	0,2	5,2
Western Norway	whole year	1,0	0,8	13,5
	spring	0,9	0,1	1,2
	summer	0,7	1,0	18,2
	autumn	1,1	1,5	23,5
	winter	1,2	0,6	9,3
Eastern Norway	whole year	1,1	0,2	4,3
	spring	1,0	-0,1	-4,1
	summer	0,6	0,1	1,7
	autumn	1,3	0,3	6,9
	winter	1,3	0,4	13,1

Source: RegClim (2000)

The greatest changes are expected in the autumn and winter, with milder temperatures and increased precipitation. Northern Norway will experience the greatest winter temperature increases, and generally the changes will be greater inland than in coastal areas. The western part of Norway is expected to receive substantially more rainfall, especially during summer and autumn, whereas Eastern Norway will experience more winter rainfall. Eastern parts may even experience a decline in precipitation during spring. The following maps show the regional distribution of a variety of different climate parameters (**Slides 3.12–3.16**).

Slide 3.12. Estimated change in average temperature (Jan. –Dec.) from 2000 to 2050

Estimated change in average temperature (Jan.-Des.) from 2000 to 2050



Change in Temperature Jan-Dec (C)

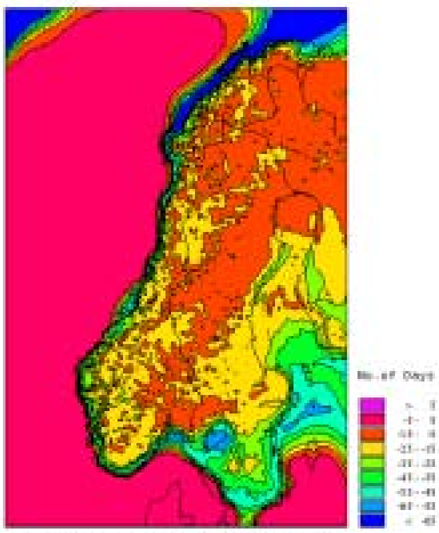
Annual average temperature increase of 0.2-0.5 °C per decade

Source: RegClim (2000)

There are large regional differences in temperature estimates. The temperature increase is expected to be greater inland compared to areas along the coast. Especially high temperature increases are expected in the region of Svalbard/Barents Sea.

Slide 3.13. Changes in the length of the winter season from 2000 to 2050

Changes in length of the winter season from 2000 to 2050



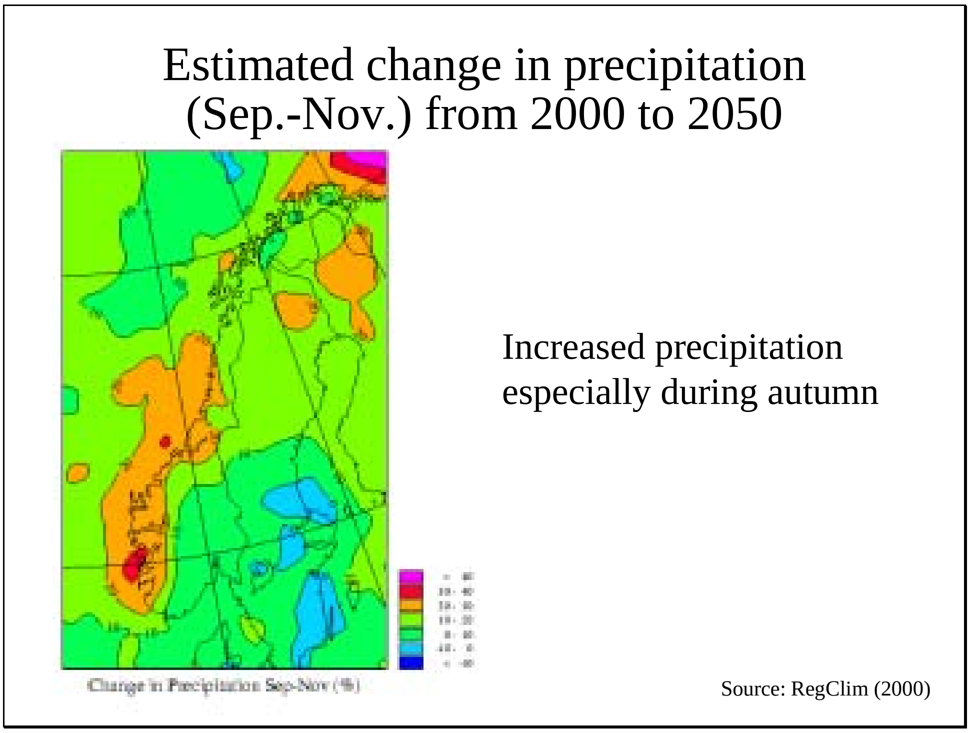
Change in length of the winter (Tmean<0)

Shorter winter season

Source: RegClim (2000)

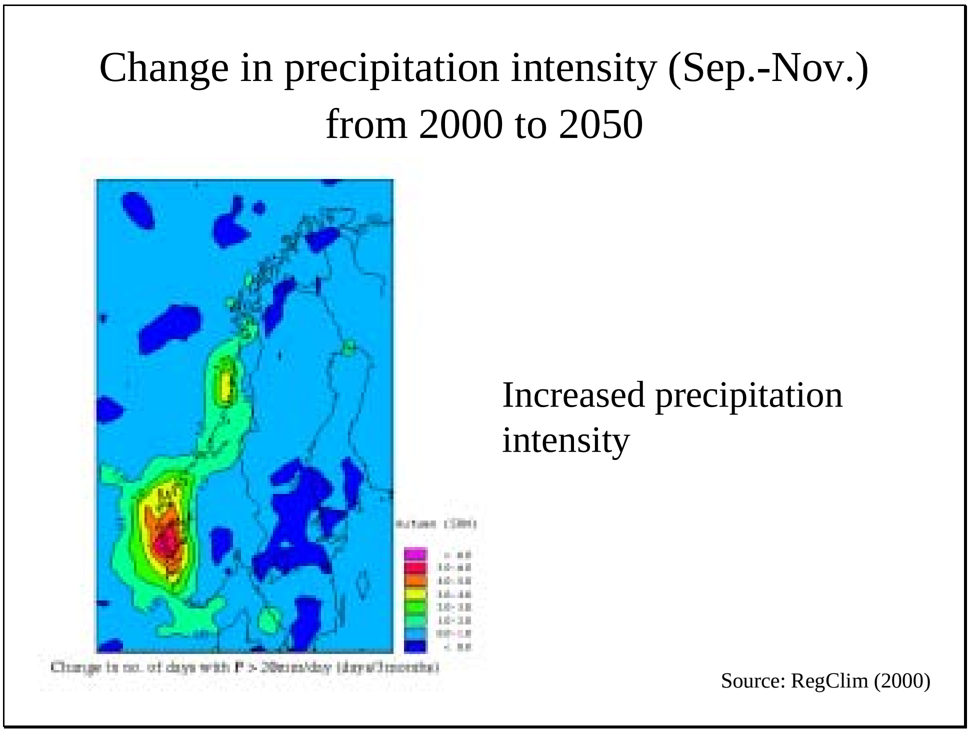
It is especially the minimum temperatures during winter that are expected to increase resulting in a shortening of the cold season. **Slide 3.13** shows that the number of days with a mean temperature lower than 0 °C will be reduced by 25–35 along the coast. The reduction in winter days inland will be more moderate with 15–25 days.

Slide 3.14. Estimated change in precipitation (Sept.–Nov.) from 2000 to 2050



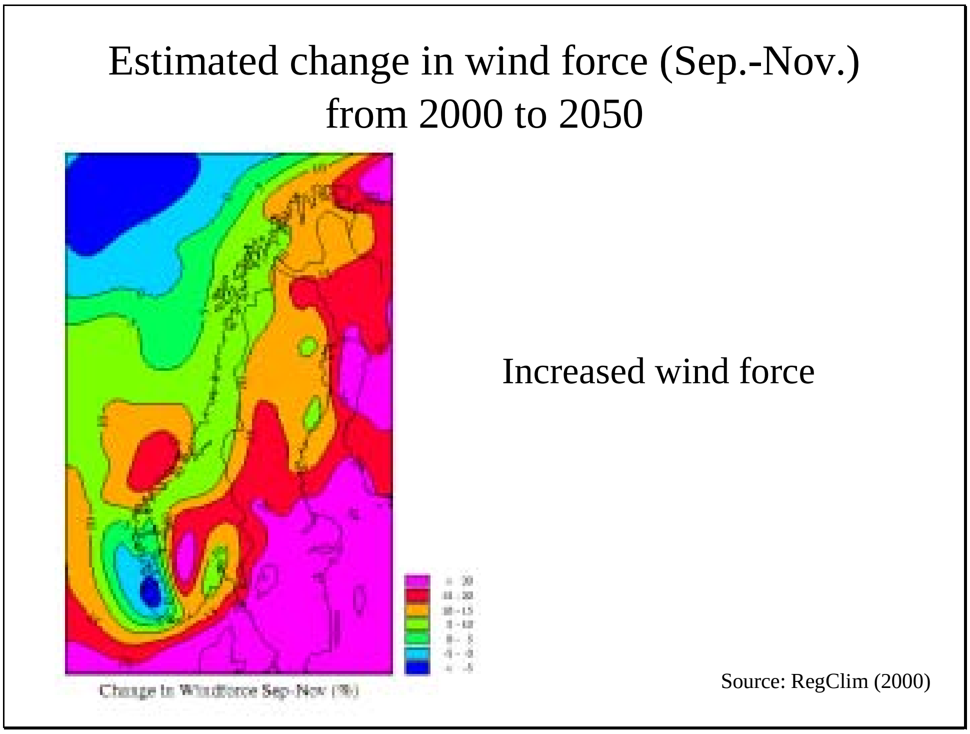
Precipitation will increase most during autumn, especially along the western coast (20–30 %) and in the Svalbard/Barents Sea region.

Slide 3.15. Change in precipitation intensity (Sept.–Nov.)



The increased precipitation does not necessarily relate to increased days with precipitation, but rather to increased intensity. There is expected to be 5–6 more days with more than 20 mm precipitation during the autumn along the western coast, particularly in Hordaland.

Slide 3.16. Estimated change in wind force (Sept.-Nov.) from 2000 to 2050



The wind force is expected to increase most places in Norway during the autumn and winter. This increase is expected to be largest in Langfjella and along the coast of Møre and Trøndelag and in the Barents Sea east of Finnmark. The smallest increase can be found along the western coast south of Bergen and east of Lindesnes. The number of storms will increase to some extent, especially along the coast of Møre and Trøndelag.

Most models show a weakening of the thermohaline circulation of the northern hemisphere, which contributes to a reduction of the surface warming in the North Atlantic. Whether a reduced Gulf Stream may mitigate or offset a warming effect in Norway is highly important for climate development in our areas. One hypothesis indicates that oceans bordering our coast will be covered by ice during large parts of the winter season. However, this must be regarded as highly speculative. Today we have limited knowledge about how the ocean currents behave with global warming.

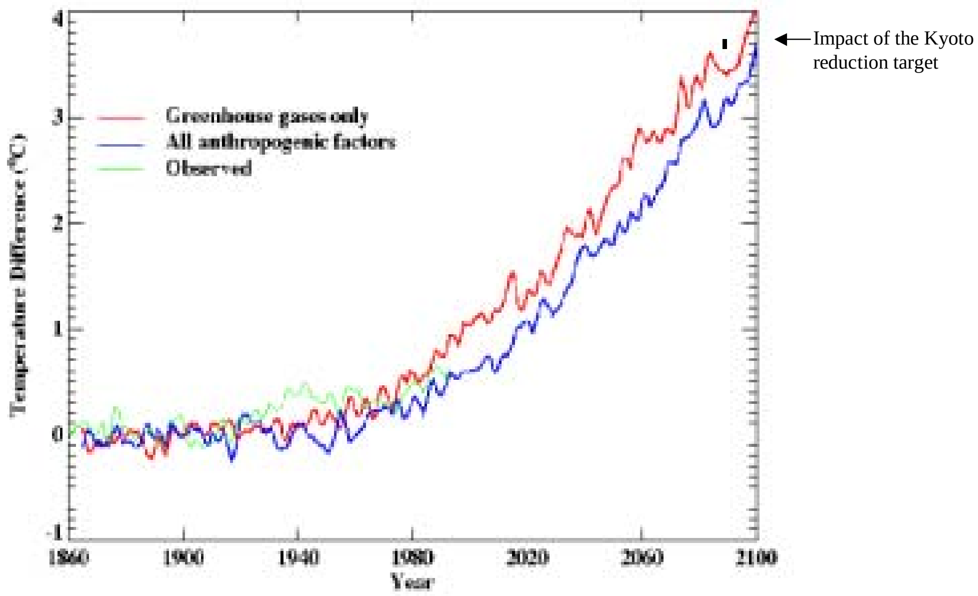
4. Climate change impacts

4.1 Global impacts and adaptation

Global mean surface temperature increases and rising sea level from the thermal expansion of the ocean are projected to continue for hundreds of years after the stabilization of greenhouse gas concentrations, owing to the long timescales on which the deep ocean adjusts to climate change. According to **Slide 4.1,** the target reduction of 5.2% negotiated in the Kyoto agreement is nowhere near sufficient to level out future temperature development. Therefore, any strategies designed to cope with climate change should focus, in addition to emission reductions, on impacts of and adaptation to climate change, climate variability, and extreme events.

Slide 4.1. Impact of the Kyoto Protocol

Impact of the Kyoto Protocol



Source: Hadley Centre for Prediction and Research, UK Met. Office

Both natural and human systems are more or less sensitive to changes in climate, including mean climate characteristics, climate variability, and the frequency and magnitude of extreme events. The effects may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2001b). However, potential damage to systems from climate change and climate vulnerability, including extreme events, may be reduced through adaptation and coping strategies. System vulnerability is therefore determined by the magnitude and rate of climate variation to which a system is exposed, the system's sensitivity and its adaptive capacity (see **Slide 4.2**).

A system capable of adapting to climate change has the potential to reduce the adverse impacts of climate change and enhance beneficial impacts. **Slide 4.3** shows various adaptation types and examples. In natural systems, adaptation is reactive. In human systems, on the other hand, adaptation can also be anticipatory.

Slide 4.2. Sensitivity, adaptability and vulnerability

Sensitivity, adaptability and vulnerability

- *Sensitivity* is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.
- *Adaptive* capacity is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, take adventage of opportunities, or cope with the consequences.
- *Vulnerability* is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.

Source: IPCC (2001b)

Slide 4.3. Types of adaptation to climate change

Types of adaptation to climate change

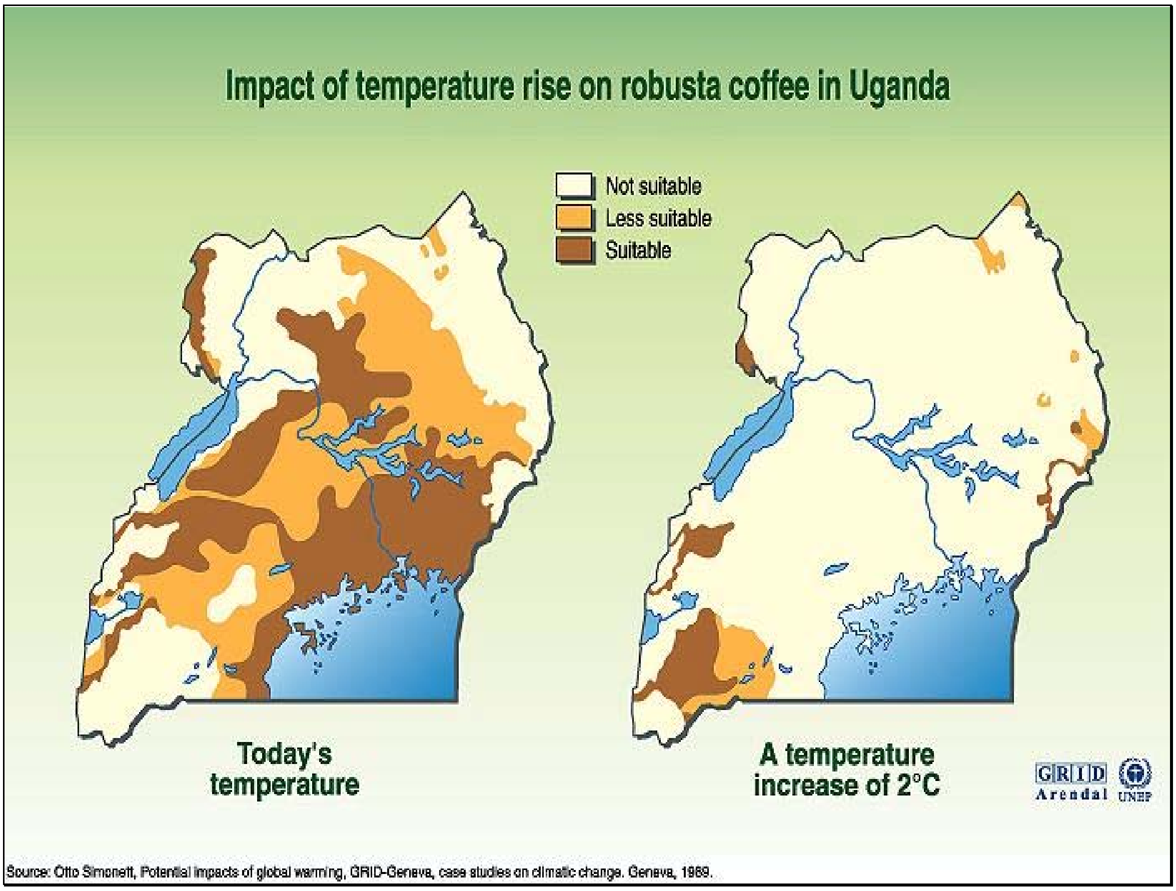
		Anticipatory	Reactive
Natural systems			•changes in lenght of growing season •changes in ecosystem compostition •wetland migration
Human systems	Private	•purchase of incurance •construction of house on stilts •redesign of oil-rigs	•changes in farm practices •changes in insurance premiums •purchase of air-conditioning
	Public	•early-warning systems •new building codes, design standards •incentives for realocation	•compensatory payments, subsidies •enforcement of building codes •beach nourishment

Source: IPCC (2001b)

Relying on reactive adaptation to climate change may incur substantial ecological, social and economic costs. Many of these costs may be avoided if policies, programs and measures containing anticipatory adaptation to climate change are implemented. Natural systems are especially vulnerable to climate change due to their limited adaptive capacity. We know there are various constraints to achieving the potential for adaptation also within human systems. The private and public incentives for adaptation may be limited by institutional conditions and various sources of market failure. The ability of human systems to adapt depends on factors such as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities.

Many developing countries are particularly vulnerable to climate change because of limited adaptive capacity due to widespread poverty, recurrent drought, inequitable land distribution, and dependence on rainfed agriculture. The agricultural sector is important both in terms of local and national food security and highly needed export earnings. If the farmers fail to harvest the anticipated amount of yields, this may have large implications not only for the small-scale farmer, but also for the national economy. As a result, these countries are more vulnerable to climate change and extreme weather events. To exemplify the vulnerability concept, we include a study from Uganda (**Slide 4.4**).

Slide 4.4. Impact of temperature rise on robusta coffee in Uganda



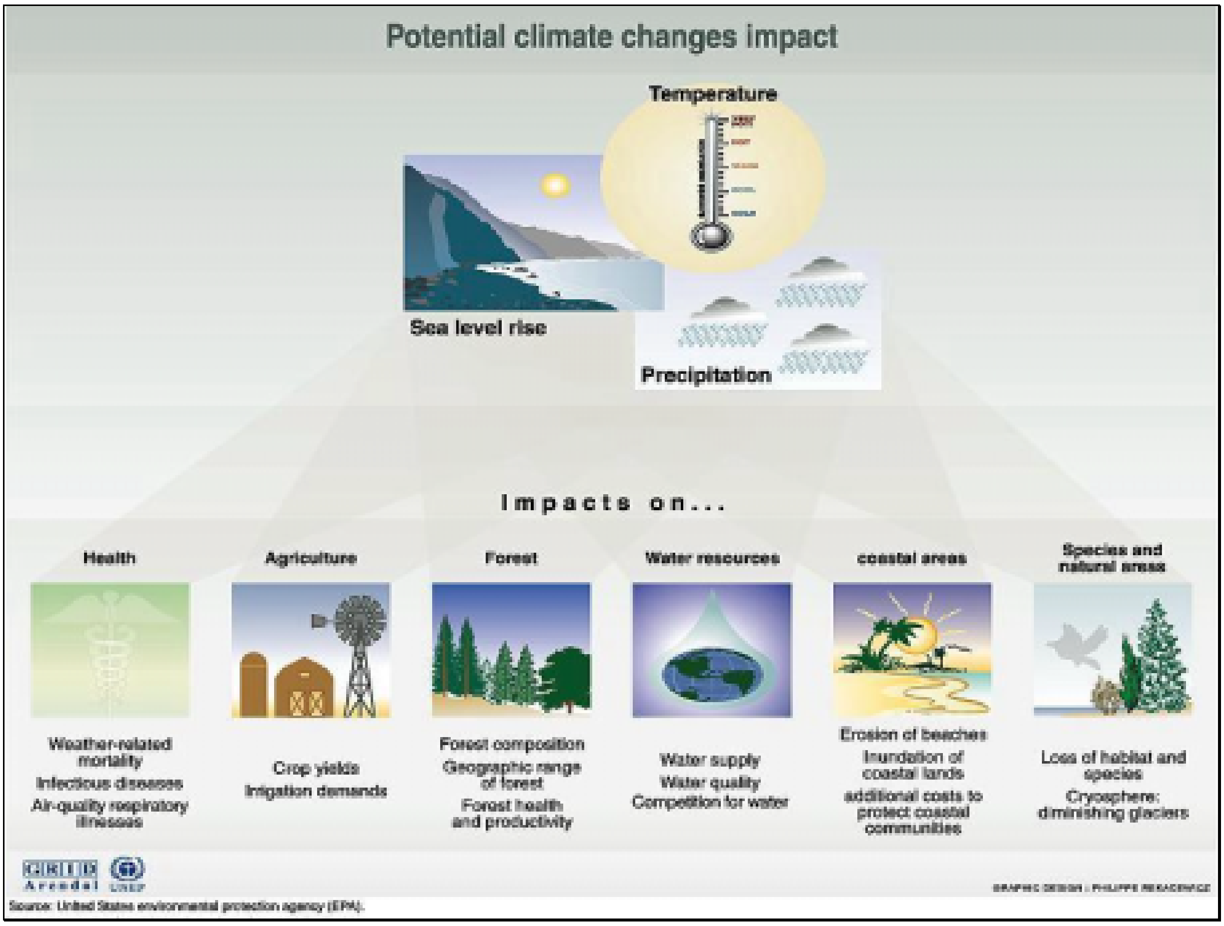
Uganda depends heavily on coffee production, both in terms of employment and foreign exchange earnings. With a projected temperature increase of 2 ^{o}C, the areas suitable for growing robusta coffee will be dramatically reduced. Only the colder regions will be able to maintain the production. The adaptation capacity will determine how seriously affected a country like Uganda will be due to climate change.

Enhancement of adaptive capacity both for human and natural systems will reduce the vulnerability of sectors and regions to climate change, including variability and extremes. In addition, reduced vulnerability may promote sustainable development and equity.

4.2 Global impacts on human systems and ecological sectors

Climate change and climate variability will potentially have wide-ranging effects on the natural environment, as well as on human societies and economies. According to **Slide 4.5** many human systems are sensitive to climate change.

Slide 4.5. Potential climate changes impact



Human health and a wide range of ecosystems and socio-economic sectors will most likely be affected by the projected changes in temperature, precipitation, and sea level, and related indirect effects.

Regional studies indicate that increases in temperature have already affected a diverse set of physical and biological systems in many parts of the world. Examples include the shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of mid- to high-latitude growing seasons, poleward and altitudinal shifts of plant and animal ranges, declines in some plant and animal populations, and earlier flowering of trees, emergence of insects, and egg laying in birds (IPCC, 2001b). According to WG I, the rate of warming is going to be greater than the global average over most land areas, and most pronounced at high latitudes in winter.

We do not currently have sufficient climatic or biological data to quantify potential impacts related to changes in precipitation. However, there is emerging evidence that some social and economic systems have been affected by the recent increasing frequency of floods and drought in some areas. Future projections show increasing precipitation globally, although there will be large regional distributional differences between the northern and southern hemisphere as indicated in chapter 3.3.

Sea level rise is referred to as an indirect effect of climate change. Sea level rise will be particularly critical for small island states and low-lying costal areas. A sea level rise of 5 mm per year over the next 100 years will result in enhanced coastal erosion, loss of land, dislocation of people, increased risk of damage from storm surges, saltwater intrusion into freshwater resources, and so on (IPCC, 2001b). A range of impacts may have high environmental, economic and social costs.

The IPCC expects extreme events to increase in frequency and/or severity during the 21st century as a result of changes in the mean and/or variability of climate. With respect to temperature, there is a very high level of confidence that daytime maximum and minimum temperatures will increase, accompanied by an increased frequency of hot days. [9] Projections indicate with high confidence that heat waves will become more frequent, while the number of cold waves and of frost days will decline (IPCC, 2001b). The warmer weather during summer may potentially be particularly critical in some urban areas during the summer. The frequency and magnitude of extreme low temperature events, on the other hand, are projected to decrease in the future. This will have both positive and negative effects. With respect to precipitation, the projected increase in intensity in some regions may have substantial impacts on water quality, loss of land, pollution, erosion and so on. Whether there will be an increase in storm activity is more uncertain. Projections indicate with medium confidence that the intensity of mid-latitude storms and the frequency of hail and lightening are expected to increase (IPCC, 2001b). Historically, human societies and natural systems have proven vulnerable to climate extremes though damage, hardship, and death caused by events such as draught, floods, heat waves, avalanches, and windstorms. Most likely the impacts of climate extremes will fall disproportionately on the poor parts of the world.

What the potential impacts will be of a weakening or a shut-down of the ocean thermohaline circulation is highly uncertain. Such major changes may have impact on deep-water oxygen levels and carbon uptake by oceans and marine ecosystems, and might reduce warming over parts of Europe.

Adverse global impacts listed in TAR are projected from models and studies and include the following:

Slide 4.6. Adverse impacts on human systems

Adverse impacts on human systems

- A general reduction in potential crop yields in most tropical and sub-tropical regions for most projected increases in temperature.
- Decreased water availability for populations in many water scarce regions, particularly in the sub-tropics.
- An increase in the number of people exposed to vector-borne diseases (e.g. malaria) and water-borne diseases (e.g. cholera) and increase in heat stress mortality.
- A widespread increase in the risk of flooding for many human settlements from both increased heavy precipitation events and sea-level rise.
- Increased energy demand for space cooling due to higher summer temperatures.

Source: IPCC (2001b)

[9] In the TAR Summary for Policymakers from Working Group II (IPCC, 2001b), the following words have been used where appropriate to indicate judgmental estimates of confidence: *very high* (95% or greater), *high* (67–95%), *medium* (33–67%), *low* (5–33%), and *very low* (5% or less).

However, there are also projected beneficial impacts due to climate change and these include the following:

Slide 4.7. Beneficial impacts on human systems

Beneficial impacts on human systems

- Increased potential crop yields in some regions at mid-latitudes for increases in temperature of less than a few degrees Celsius.
- A potential increase in global timber supply for appropriate managed forests.
- Increased water availability for populations in some water scarce regions, for example in parts of South East Asia.
- Reduced winter mortality in mid- and high-latitudes.
- Reduced energy demand for space heating due to higher winter temperatures.

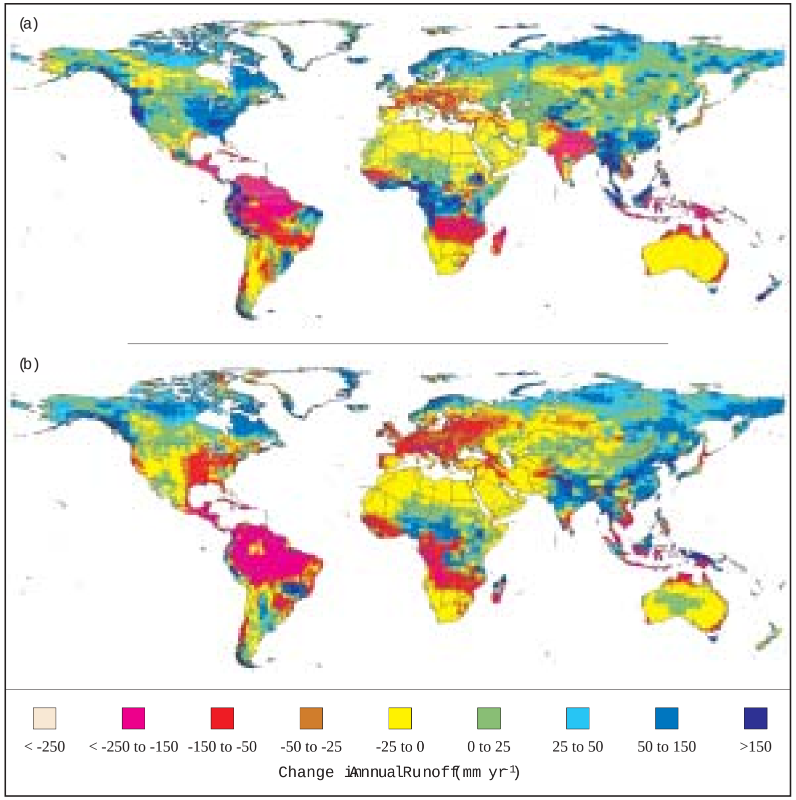
Source: IPCC (2001b)

4.3 Water resources

One third of the world's population lives in countries that are water stressed. Projections indicate that this number will increase to around 5 billion by 2025 due to population growth and increased demand. Slide 4.8 shows projected changes in average annual water runoff by 2050, relative to average runoff for 1960–1990. The changes largely follow projected changes in precipitation, and therefore the level of evaporation is assumed to be unchanged. Areas most vulnerable to domestic water shortages include those where access to water is already limited. Areas in the high latitudes and Southeast Asia will experience increased runoff. Central Asia, the area around the Mediterranean, southern Africa, and Australia, on the other hand will experience decreases in runoff in the future (IPCC, 2001b).

Slide 4.8. Changes in average annual water runoff by 2050.

Changes in average annual water runoff by 2050



Source: IPCC (2001a)

Impacts of climate change – including direct effects such as changes in temperature, precipitation and sea levels – and indirect effects such as floods, evaporation, and higher water temperature will influence the availability and quality of freshwater around the world. This will exacerbate periodic and chronic shortfalls of water, especially in arid and semi-arid areas. The same areas are experiencing rapid population growth, urbanization, financial problems, and lack of human capital.

4.4 Food Security

Changes in temperature, precipitation, length of the growing season, and timing of extreme events will have an effect on agricultural production. Recent studies strengthen the conclusion from SAR (IPCC, 1996b) that "global agricultural production could be maintained relative to baseline production" for a growing population under 2xCO_2 equilibrium climate conditions. In a food security perspective, however, the regional distributional effects are of vital interest. Global agricultural production could be maintained, regardless of how the regional distribution changes. Middle to high latitudes may experience increases in productivity, depending on crop type, the seasonality of precipitation, etc. In contrast, there are several countries in the tropics and subtropics – where some crops are near their maximum temperature tolerance and dry conditions dominates – yields are likely to decrease (IPCC, 2001b). The number of malnourished people amounted to 800 million in 1998 (IPCC, 1998). Many of these people are found in environmentally, economically and socially stressed areas. **Slide 4.9** lists some of the potential impacts on food security resulting from climate change, including confidence levels.

Slide 4.9. Climate change impacts on food security

Climate change impacts on food security

- Both positive and negative responses for mid-latitude crops when adaptation is included (*medium confidence*).
- A general reduction in potential crop yields in most tropical and sub-tropical regions (*medium confidence*).
- Income from agricultural production will increase in developed countries and there will be smaller or negative changes in developing regions (*medium confidence*).

Source: IPCC (2001b)

4.5 Biodiversity

Climate change will influence the geographical location of the ecological systems and the mix of species that they contain. Based on model simulations of vegetation distribution, large shifts of vegetation boundaries into higher latitudes and elevations can be expected (IPCC, 1998). Many species have rather restricted climatic niches and are unable to migrate due to fragmentation of the landscape, soil differences, or topography. These species are particular vulnerable to changes in climate.

Many ecosystems are already under stress from human induced activities such as land-use change, deposition of pollutants, harvesting, grazing by livestock, and others. Climate change and variability constitute an additional pressure that could endanger some ecosystems and species. Species already classified as critically endangered will be lost, and species labeled endangered or vulnerable will become much more rare (IPCC, 2001b). Many important costal ecosystems, such as coral reefs, mangrove, and sea grass beds are vulnerable to rising temperatures and accelerated sea level rise.

Slide 4.10. Climate change impacts on biodiversity

Climate change impacts on biodiversity

- Substantial ecosystem or biome movement (*high confidence*).
- Loss of critical endangered species (*high confidence*).
- Poleward movement of the southern and northern boundaries of fish distributions (*medium confidence*).
- Increased net primary productivity in most systems due to increased CO_2 concentration (*high confidence*).
- Decreased net primary productivity in arid or semi-arid areas (*medium confidence*).
- Forests will replace some wetlands, and areas with permafrost will be disrupted (*high confidence*).

Source: IPCC (2001b)

4.6 Human health

Global climate change will have diverse impacts on human health – some positive, but most negative (IPCC, 2001b). Many of the world's known vector-borne, food-borne and water-borne infectious diseases are sensitive to changing climatic conditions (**Slide 4.11**).

Slide 4.11. Spread of major tropical vector-borne diseases

Spread of major tropical vector-borne diseases

Disease	Vector	Population at risk (million)[1]	Number of people currently infected or new cases per year	Present distribution	Likelihood of altered distribution
Malaria	Mosquito	2,400[2]	300-500 million	Tropics and Subtropics	Highly likely
Schistosomiasis	Water snail	600	200 million	Tropics and Subtropics	Very likely
Lymphatic Filariasis	Mosquito	1 094[3]	117 million	Tropics and Subtropics	Likely
African Trypanosomiasis (Sleeping sickness)	Tsetse fly	55[4]	250 000 to 300 000 cases per year	Tropical Africa	Likely
Dracunculiasis (Guinea worm)	Crustacean (Copepod)	100[5]	100 000 per year	South Asia, Arabian Peninsula, Central-West Africa	Unknown
Leishmaniasis	Phlebotomine sand fly	350	12 million infected, 500 000 new cases per year[6]	Asia, Southern Europe Africa, Americas	Likely
Onchocerciasis (River blindness)	Black fly	120	17.5 million	Africa, Latin America	Very likely
American Trypanosomiasis (Chagas disease)	Triatomine bug	100[7]	18 million	Central and South America	Likely
Dengue	Mosquito	1,800	10-30 million per year	All Tropical countries	Very likely
Yellow Fever	Mosquito	450	more than 5 000 cases per year	Tropical South America Africa	Likely

1. Top three entries are population-prorated projections, based on 1989 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Ranque, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

Highly likely · Very likely · Likely · Unknown

GRID Arendal UNEP

Source: Climate change 1995, Impacts, adaptations and mitigation of climate-change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Source: GRID Arendal/UNEP

Studies show that the geographic range of potential transmission of malaria and dengue will show a net increase given the projected climate change. Assessment of potential impacts of changes in temperature and precipitation suggests that large areas will experience increased risk due to expansion of the areas suitable for malaria transmission.

More frequent and stronger floods are likely to have health effects through increased risk of drowning, diarrhea, and respiratory diseases and, in developing countries, hunger and malnutrition. There are also other direct effects from climate change that are critical to human health such as periods with either extremely hot or extremely cold weather. If heat waves occur more frequently and with increased intensity, the risk of death and illness will increase, especially among the elderly and the urban population.

Slide 4.12. Climate change impacts on human health

Climate change impacts on food security

- Both positive and negative responses for mid-latitude crops when adaptation is included (*medium confidence*).
- A general reduction in potential crop yields in most tropical and sub-tropical regions (*medium confidence*).
- Income from agricultural production will increase in developed countries and there will be smaller or negative changes in developing regions (*medium confidence*).

Source: IPCC (2001b)

4.7 National climate change impacts: the case of Norway

As an affluent country situated in high latitudes, Norway is often assumed to benefit from warmer global temperatures. In fact, the possibility of milder winters and warmer summer temperatures gives many people the misconception that climate change will be unproblematic for Norway, unless the warm ocean currents of the North Atlantic Current change. Sea-level rise associated with climate change is generally disregarded as a problem in Norway, despite the potential impacts on some municipalities. However, recent results from RegClim (see section 3.4) show that Norway can expect a warmer but also wetter climate, with potentially stronger winds and more frequent storms along some part of the coastline. The RegClim results also indicate that climate change will manifest itself differently across Norway. As a country covering many degrees of latitude, with an extensive coastline and a mountainous terrain, Norway may be more vulnerable to climate change in some regions than others.

A preliminary review of the literature on potential climate impacts in Norway reveals that a number of sector-, region-, and species-specific studies have been carried out over the past decade. However, there has been no comprehensive synthesis and analysis of socio-economic impacts of climate change in Norway. Therefore, Center for Climate and Environmental Research (CICERO) recently organized a workshop on climate impacts in Norway, which gathered experts from various fields, to discuss the state of knowledge and, if possible, say something about potential impacts in various sectors (Sygna and O'Brien 2000). Sectors that are most vulnerable to potential changes in temperature, precipitation, and the frequency and magnitude of extreme events are listed below, including potential effects.

Slide 4.13. Vulnerable sectors in Norway (1)

Vulnerable sectors in Norway (1)

Transport

Climate related events: flooding; fog; landslides; avalanches; warm winters; storms; frost heave.

Consequences: variable driving conditions; less predictability; cancelled and delayed airplanes, trains, ferries and other modes of transportation; higher maintenance costs.

Hydropower

Climate related events: increased runoff; changing flood regimes; warmer winters.

Consequences: increased electricity production; reduced predictability; reduced dam safety; lower demand for electricity during winter.

Source: CICERO

Slide 4.14. Vulnerable sectors in Norway (2)

Vulnerable sectors in Norway (2)

Fisheries

Climate related events: warmer ocean; change in ocean currents; melting of inland ice; more freshwater in fjords;

Consequences: increased fish production; change in species composition; movement of fish species to colder areas; introduction of new species; incidents of pests and algae blooming more frequent.

Agriculture

Climate related events: longer growing season; CO_2 fertilization; erosion.

Consequences: increased production; change in frequency of pests, changes in water availability; loss of agricultural land.

Source: CICERO

Compared to many other countries, especially less developed countries (as commented in chapter 4.1), Norway is relatively robust with respect to climate change and climate variability. We are not particularly vulnerable to sea level rise, Norway is one of the wealthiest countries in the world, and we are used to bad weather. However the RegClim results show that climate change will not occur evenly across the country. In addition, some regions, sectors, ecosystems and social groups within Norway are more vulnerable to climate change than others. Some sectors of society will be capable of adapting to changing climatic conditions; others will be more marginalized and increasingly vulnerable. Regardless of the aggregate resilience to climate change, climate change is of concern for Norway in that it has implications for regional recreational opportunities, income, employment, and demographic distribution.

5. The status of climate policy negotiations

5.1 The negotiation process up to the Climate Convention in 1992

Throughout the 1980s, there was an increasing concern among the natural scientists that the changes in the atmosphere's chemical composition could result in climate changes. A series of international meetings and conferences were arranged on this topic. The United Nations Environmental Program (UNEP) and the World Meteorological Organization (WMO) responded by founding a working group whose first task was to propose an international agreement. The scientific progress was rapid during this period, mainly due to the Intergovernmental Panel of Climate Change (IPCC). In 1990, the UN's General Assembly established a negotiation committee (International Negotiation Committee for the Framework Convention on Climate Change, INC/UNFCCC) as a response to the working group's proposal. The INC's mandate was to draw up proposals for a convention or other binding international agreement that could be a first step towards solving the climate problem. The INC had five sessions between February 1991 and May 1992. These meetings brought together negotiators from more than 150 states. The result was a proposal for a convention, the United Nations Framework Convention on Climate Change (UNFCCC).

The proposed convention was signed by 155 states at the Rio conference in June 1992. More states have signed it since then. The UNFCCC entered into force in March 1994, 90 days after the 50th state had ratified it. The main events concerning the establishment of the UNFCCC are shown in **Slide 5.1.**

Slide 5.1. Processes prior to the UNFCC

Processes prior to the UNFCCC

- 1980s — Increased concern for human-induced climate changes
- 1990 — UN's General Assembly establishes a negotiation committee (INC)
- 1991-1992 — More than 150 states participate in 5 rounds of negotiations
- May 1992 — The INC proposes a climate convention (UNFCCC)
- June 1992 — Top meeting in Rio. The proposed climate convention is signed by 155 states
- March 1994 — The UNFCC enters into force

Source: CICERO

5.2 The Climate Convention

The United Nations Framework Convention on Climate Change (UNFCCC) is ambitious since it defines targets for the concentration of greenhouse gases in the atmosphere. The ultimate goal of the Climate Convention, as stated in Article 2, is to achieve *"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."* The UNFCCC is not clear on how high these concentrations can be, nor does it indicate how the objective of stabilization is to be met. The most important contribution of the UNFCCC was therefore probably the mere acknowledgement of the climate problem. **Slide 5.2** describes some of the main features of the UNFCCC. Central features include the following:

Slide 5.2. Main features of the Climate Convention

Main features of the Climate Convention

Main goal:	Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system
Precautionary:	The precautionary principle is acknowledged
Groups of countries:	Annex I, Annex II, and developing countries
Responsibility:	The industrialized countries have historical responsibility
Commitments:	Annex I countries are recommended to stabilize emissions at 1990 level within year 2000
Institutions:	Secretariat Conference of the Parties (COP) Subsidiary Body on Implementation (SBI) Subsidiary Body on Scientific and Technological Advice (SBSTA)

Source: CICERO

1. The UNFCCC acknowledges the *precautionary principle*.

2. The UNFCCC distinguishes three main groups of countries: The industrialized countries, including those countries with economies in transition, are listed in Annex I to the UNFCCC. Annex II lists only those countries that were members of the OECD when the UNFCCC was established in 1992. The third group of countries mentioned is developing countries.

3. The UNFCCC places the main responsibility on the rich countries (Annex I countries). It is pointed out that these countries have a special responsibility to set an example since they account for the most of the accumulated historical emissions of greenhouse gases.

4. The UNFCCC established important institutions for the future work. The Conference of the Parties (COP), where all Parties participate, is the highest body of the UNFCCC. The first COP took place in Berlin in March 1995, and the most recent was COP6 in The Hague in November 2000. The secretariat conducts necessary coordination and ensures the flow of information. The COP is supported by two sub-committees, SBI (Subsidiary Body on Implementation) and SBSTA (Subsidiary Body on Scientific and Technological Advice).

The UNFCCC does not imply commitments of any kind that would significantly reduce the global emissions of greenhouse gases (GHG). On the contrary, it has been clear that the UNFCCC, as it was decided at the Rio Conference, was primarily meant to form the basis for an international agreement that can ensure emission reductions. An important part of this has been that the countries, by ratifying the UNFCCC, acknowledge the climate problem, and that they participate in the COPs. The Parties have certain commitments that ensure that the work of implementing measures is initiated.

Annex I countries are committed to implementing certain measures. Article 4.2b of the UNFCC states that: "…each of these Parties shall communicate…detailed information on its policies and measures…with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol." This is the most concrete text on emission reductions in the UNFCCC. Annex II countries also have a special commitment to finance the developing countries' reporting, and assist developing countries that are particularly vulnerable for climate changes. Annex II countries must also take steps to arrange for transfer of technology to other Parties, especially developing countries. The UNFCCC has been ratified by 186 countries as of the 7th of September 2000.

5.3 Negotiations leading up to the Kyoto Protocol

The first Conference of the Parties (COP1) was arranged in Berlin in March/April 1995. The Parties' implementation of the UNFCCC was summarized and some important decisions were made.

One such important decision was to initiate a pilot phase for joint implementation (JI) of climate measures up to year 2000. JI entails cooperation between two or more Parties to fulfill their national commitments to reduce GHG emissions. This separates the commitment of each country from the implementation of measures. No credits were to be given for GHG reductions in this pilot phase. To distinguish the activities in the pilot phase from a fully developed JI mechanism, they were called "Activities Implemented Jointly" (AIJ).

Slide 5.3. The Berlin-Mandate

Berlin-mandate:

Acknowledges that the commitments to reduce emissions under the UNFCC are not sufficient.

Will start a process towards a negotiation process that should lead to GHG emission reductions in Annex I countries after 2000.

Quantified and time-scheduled emission targets for 2005, 2010 and 2020, and necessary measures and means were to be decided.

In accordance to the Parties' differentiated responsibilities, respective capacities, and different economic structures and resource bases.

The process shall be conducted in "the Ad Hoc Group on the Berlin Mandate" (AGBM) where all parties could participate, and finalized in 1997 at COP3.

Source: CICERO

The so-called Berlin mandate was adopted at this first COP (COP1). The Berlin mandate calls for the initiation of a negotiation process that should lead to GHG emission reductions in Annex I countries after 2000. The negotiations were to be finalized before COP3 in December 1997. The negotiations took place through "the Ad Hoc Group on the Berlin Mandate" (AGBM) in which all Parties could participate. Quantified and time-scheduled emission targets, and necessary measures and means were to be decided. Both the UNFCCC and the Berlin mandate state that these decisions should be made in accordance to the Parties' differentiated responsibilities and respective capacities. **Slide 5.3** describes the main features of the Berlin mandate. COP2 took place in Geneva in July 1996, where the USA came out with clear support of the newly released second report from IPCC and stated that countries should take on binding commitments to reduce their emissions of greenhouse gases. There was widespread support for flexibility in terms of a basket approach of gases and the opportunity to use JI and emissions trading to meet national reduction commitments. Another important issue was equal or differentiated reduction commitments.

5.4 The Kyoto Protocol

The Kyoto Protocol was adopted in Kyoto, Japan, at COP3 in December 1997 after a number of meetings in the AGBM. The final text was a result of intense negotiations where the "big four" – USA, EU, Japan and G77/China (developing countries) – had the most influence. The entry-into-force provision of the Protocol not only requires ratification by 55 Parties, but also employs a "double trigger" that specifies that ratifying Annex-I Parties must also represent at least 55% of the total Annex-I CO_2 emissions in the year 1990. USA alone represents 36% of CO_2 emissions in Annex I in 1990. As of March the 19th of 2001, 84 Parties have signed the Kyoto Protocol, but only 33 have ratified it. Romania is the only country with commitments to reduce emissions that have ratified the Protocol. Those that have ratified the Kyoto Protocol are mainly small island states, some Latin American countries, and former Soviet Union republics. The main components of the Kyoto Protocol are described below and summarized in **Slide 5.4**

- The industrialized countries are to reduce their aggregate GHG emissions by 5.2% in the period 2008–2012 compared to base year 1990. Each country's commitment is defined in an Annex B to the Kyoto Protocol. Annex B is an updated version of industrialized countries as defined in Annex I of the Climate Convention and consists of OECD countries and economies in transition to a market economy. The developing countries do not have any commitments to reduce their emissions in this first commitment period.

- Six gases or groups of gases are included in the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorcarbons (PFC), and sulfur hexafluoride (SF_6).

- The reduction targets are differentiated between countries and varies between +10% for Iceland and –8% for the EU, most countries with economies in transitions (Russia and Ukraine are exceptions as they have 0%), New Zealand, and Switzerland. The USA has –7% whereas Norway has +1%. See **Slide 5.5** for details on the burden sharing.

- The Kyoto Protocol also includes the possibility for countries to participate in a "bubble." Their overall emission reductions must be in accordance with the Kyoto Protocol, but the burden can be distributed within the "bubble." The EU has formed such a "bubble" where the internal burden sharing ranges from +27% for Portugal to –21% for Denmark and Germany, and –28% for Luxembourg. See **Slide 5.6** for details of the EU burden sharing.

- Three mechanisms for cooperation on emission reductions across country borders are introduced: international emissions trading (IET, referred to here as simply "emissions trading"), Joint Implementation (JI) and the Clean Development mechanism (CDM). These mechanisms are often referred to as flexibility mechanisms, or simply as the Kyoto mechanisms. The most important motivation is to increase cost-effectiveness by reducing the countries' costs of fulfilling the required emissions reductions. Emissions trading and JI can only occur among Annex I countries, whereas the CDM can take place between countries with and without emissions targets. See **Slide 5.7** and the text for further details on the mechanisms, where also domestic emission trading is included. The Protocol states that private entities (agents) may participate in the CDM and that legal entities may participate in JI, whereas private entities are not mentioned in relation to emissions trading.

Slide 5.4. Main features of the Kyoto Protocol

Main features of the Kyoto Protocol

Industrialized countries are to reduce their aggregate GHG emissions by 5.2% in the period 2008–2012 compared to the base year 1990.

Differentiated reduction targets ranging from –8 to +10%.

Possibility to participate in a “bubble” to jointly reduce emissions.

Six gases or groups of gases are included: CO_2, CH_4, N_2O, HFC, PFC, and SF_6.

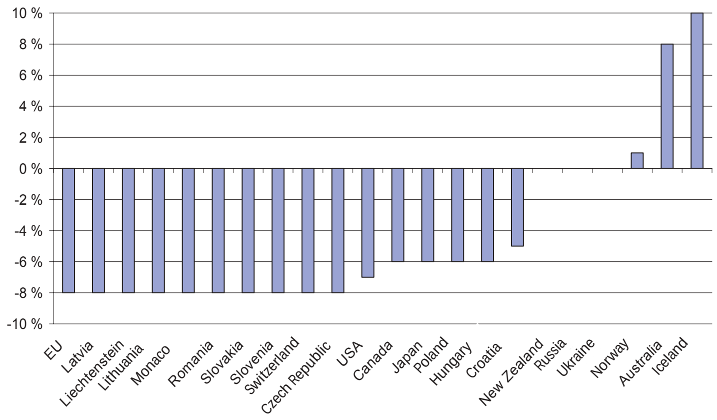
There is an opening for including sequestration of CO_2 in forests and soils.

Three flexible mechanisms are specified: International emissions trading (IET), Joint Implementation (JI), and the Clean Development mechanism (CDM).

Source: CICERO

Slide 5.5. Differentiated reduction targets

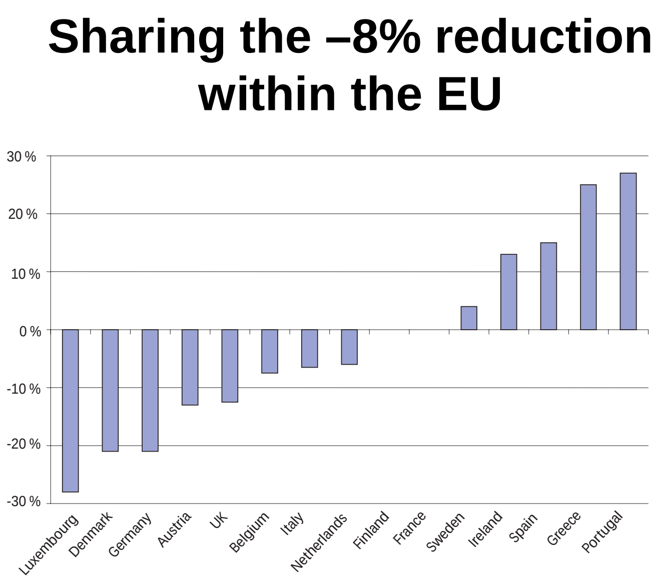
Differentiated reduction targets



Source: CICERO

Slide 5.7 summarizes the main features of the Kyoto mechanisms as defined in the Kyoto Protocol. JI and the CDM differ from emissions trading in that they are project-based. JI involves cooperation between Annex I countries only. One country (the investor country) funds, and possibly also conducts emissions reduction projects in another (the host country). JI will draw on the experience from the four-year pilot phase, "Activities Implemented Jointly" (AIJ), which was established at the Berlin Conference in 1995. AIJ did not result in carbon credits, and operated with relatively open criteria. The difference between JI and emissions trading is that under JI, the host country transfers emissions reduction units to the investor country based on an agreed-upon and verified estimate of the emissions reduction units determined by the JI project, while under emissions trading, quotas are transferred based on an agreed price (Holtsmark and Alfsen, 1998).

Slide 5.6. Sharing the –8% reduction within the EU



Source: CICERO

The CDM is one of the most interesting components of the Kyoto Protocol since it is the only direct manner in which non-Annex I countries are involved in emission abatement measures. It is also highly relevant because certified emissions reductions were to be obtained from the year 2000 to achieve compliance for the first commitment period. The purpose of the CDM is, as stated in Article 12 of the Kyoto Protocol, to *"to assist Parties not included in Annex I in achieving sustainable development and…to assist Parties included in Annex I in achieving compliance with their quantified emission limitation."* The CDM will require the creation of an Executive Board whose powers, composition and relation to COP/MOP will be decided by the COP.[10] The CDM will be open for private or public entities of investor and host nations to participate in project activities that result in certified emissions reductions and in the acquisition of these. Further, a share of the proceeds from project activities is to be used to cover administrative expenses and to assist developing countries that are particularly vulnerable to climate change to meet adaptation costs (Dessus, 1998). One of the main questions concerning the CDM is whether carbon sequestration from land use, land-use change, and forestry (LULUCF) will count as official GHG reductions. This is discussed in section 5.6.

[10] MOP is Meeting Of the Parties to the Kyoto Protocol.

Slide 5.7. Mechanisms for greenhouse gas emissions trading

Mechanisms for greenhouse gas emissions trading

Mechanism	Unit	Participants	Features
Domestic emissions trading	Quota	Firms and other national agents	Link to international emissions trading
International emissions trading	Quota Assigned amount unit (AAU)	Annex B countries (industrialized countries); private agents?	Supplementarity
Joint Implementation	Credit Emission reduction unit (ERU)	Annex B countries (industrialized countries); private agents?	Supplementarity Monitoring and verification
Clean Development Mechanism	Credit Certified emission reductions (CER)	Annex B countries (industrialized countries) and non-Annex B countries (developing countries)	Supplementarity Monitoring and verification Tax as share of proceeds

Source: CICERO

5.5 The status of negotiations on the Kyoto Protocol

The Kyoto Protocol left a number of challenging issues unresolved, with the common understanding that these issues would have to be negotiated later. The main issues are rules for the Kyoto mechanisms, accounting for sources and sinks for greenhouse gases from land use changes and forestry, and funding mechanisms and capacity building in developing countries (particularly those that are the most vulnerable to climate changes or to negative side effects of climate policy measures undertaken in industrialized countries). At the fourth conference of the Parties to the Climate Convention (COP4) in Buenos Aires, Argentina, 1998, the “Buenos Aires Plan of Action” was adopted. The aim of the plan was to finalize negotiations on remaining issues by COP6 in The Hague, the Netherlands, in November 2000.

The President of COP6, the Dutch minister of environment Mr. Pronk, suspended the conference because the Parties were not able to find acceptable compromises on a number of important issues. The last couple of days of the negotiations were focused on a compromise proposal submitted by Mr. Pronk, the so-called “Pronk paper”. Plans were made to resume the conference in May in Bonn, where meetings of the subsidiary bodies to the Climate Convention should take place, but the plans were postponed at the request of the American delegation because the new Bush administration wanted more time to prepare for these negotiations. Thus the conference will resume in Bonn 16–27 July 2001. In the meantime, Parties have met at several occasions to try to bridge differences, but without much progress so far. Mr. Pronk put a new compromise proposal on the table in April 2001, containing particular efforts to bridge the differing views on including Land Use, Land-Use Change and Forestry (LULUCF) projects, which we refer to as “the second Pronk paper”.

An overview of the most important negotiation issues in The Hague is shown in **Slide 5.8**. Even though substantial difficulties in the negotiations remain, progress on number of issues was noted. Rules for reporting and handling of information are more or less finalized. The USA backed off from its earlier position to demand early participation by developing countries to commit to reducing their greenhouse gas emissions. The USA also retreated from its proposal to have a very wide definition of applicable carbon stock changes related to forestry, land use and land use change, and now seems to accept a more limited approach. The EU took a step away from its proposal to have a concrete capping (capping) on the use of the Kyoto mechanisms.[11] Finally, progress was observed in terms of transfer mechanisms to developing countries to help them cope with climate change and side effects of climate policies in industrialized countries.

Slide 5.8. The most important negotiation issues after COP6 in The Hague in November 2000

The most important negotiation issues after COP6 in the Hague in November 2000

Issues	**Negotiation status**
Rules for the Kyoto mechanisms	Disagreement on a quantitative ceiling on the use of the mechanisms. Disagreement on nuclear power and large hydropower projects.
Emissions trading	Disagreement on taxing.
Joint implementation	Disagreement on taxing.
Clean Development Mechanism	Disagreement on forestry projects.
Accounting for sources and sinks related to land use change and forestry	Different views on what forestry, land use and land use change activities that are acceptable to include.
Funding mechanisms and capacity building in developing countries	Uncertain if the funding package proposed by Mr. Pronk is acceptable to developing countries.
Enforcement of the Kyoto Protocol	Progress has been made, but differences remain as to choice of sanctions.
Information and reporting	Only details remain to negotiate.

Source: CICERO

Article 17 of the Kyoto Protocol states that Parties may participate in emissions trading for the purpose of fulfilling their commitments, and that “any such trading shall be supplemental to domestic actions.” In relation to the Kyoto mechanisms, the EU has proposed a capping on purchasing and selling quotas, referring to Article 6 on Joint Implementation and Article 17 on emissions trading in the Kyoto Protocol that state that the acquisition of emissions reduction units and trading must be supplemental to domestic action. Further arguments for this proposal include the necessity of providing strong enough incentives for developing new, efficient green technologies at the domestic level and reducing the flow of so-called hot air from Russia and Ukraine.[12]

In the case of emissions trading, the EU’s proposal suggests that net acquisitions of quotas, which are called Assigned Amount Units (AAUs), must not exceed the higher of two ceilings:

- Five percent of the average of its base year emissions and its number of AAUs, or
- Fifty percent of the difference between its annual actual emissions in any year of the period from 1994 to 2002 and its number of AAUs.

[11] The EU’s comment from 25 November 2000 to Mr. Pronk’s paper states: “Each Annex I Party shall meet its commitments primarily through domestic action since 1990. This means that use of the mechanisms under Article 6, 12 and 17 shall not exceed reductions achieved through domestic actions as reported in national communications and reviewed under Article 8. Compliance with this principle will be assessed by the enforcement branch of the compliance committee on the basis of qualitative and quantitative information.”

[12] The background for hot air is the Kyoto Protocol target of the same emissions in 2008-12 as 1990 for these countries. Hot air refers to a surplus of quotas resulting from the economic recession in these countries after 1990, whereby emissions of carbon dioxide are strongly reduced and not likely to reach 1990 levels by 2010. Consequently, there is likely to be a large volume of quotas for export that do not result from any climate policy measures.

The EU proposal also includes a limit on net transfers, as it states that net transfers of AAUs must not exceed 5% of the average of its base year emissions and its number of AAUs. However, the ceiling may increase if a party carries out domestic abatement, at least in the same amount as they are exporting permits. In such situations there will be no limits on their export.

The Umbrella Group, which includes the USA and Norway, strongly opposed the ceiling (capping) proposal, claiming that this would be a *de facto* renegotiation of the Kyoto Protocol, and that the cost-effectiveness potential of the Kyoto mechanisms would be severely harmed. Most developing countries sympathized with EU's view, but some opposed the idea of a ceiling on the mechanisms.

The Pronk paper states "Annex I Parties shall meet their emission commitments primarily through domestic action since 1990. Compliance with this principle will be assessed by the facilitative branch of the compliance committee on the basis of qualitative and quantified information, reported in national communications and reviewed under Article 8." Apparently Mr. Pronk has tried to strike a balance between the positions of the EU and the USA, but the compromise seems closer to the USA's position than the EU's.

The Pronk paper expresses concern that a strong and enforceable compliance regime is not sufficient to prevent Parties from overselling quotas. To meet this challenge, Annex B Parties must retain a portion of their assigned amounts in their national registries for the specified period, equal to 70% of their assigned amounts, or the portion determined on the basis of emissions or projected emissions. This means that only up to 30% of the assigned amount can be traded as quotas between countries.

Developing countries (the G77/China group) wanted taxes on emissions trading and JI similar to that on the CDM, as stated by the Kyoto Protocol. The proposed tax would cover administrative expenses and assist developing countries that are particularly vulnerable to climate change impacts. The industrialized countries opposed a tax on emissions trading and JI. In his compromise proposal, Mr. Pronk proposed that emissions trading and JI would be later taxed unless industrialized countries raise at least 1 billion USD annually by 2005 for two funds that would support developing countries in their adaptation to climate change efforts, capacity building, technical support and technology transfer. Another controversial issue relates to project types, where a few Parties favor including nuclear power and large hydropower projects, whereas many Parties disagree.

In terms of forestry, land use, and land use changes, the USA, Canada and Japan argued for including a wide range of changes in the carbon stock from forestry activities, land use changes, and land use, e.g. change in soil carbon due to agriculture practices. This would imply that some countries could count a substantial contribution from carbon sinks toward meeting their Kyoto Protocol target, thus reducing the need for abating energy-related emissions. The EU, Norway, and most developing countries opposed this view and argued that the Kyoto Protocol targets would be undermined given such liberal rules. Furthermore, incentives for developing new green technologies would be weakened, particularly if liberal rules also applied to the CDM, which would lead to a large volume of cheap forestry quotas from developing countries.

Some progress in the negotiations on funding mechanisms and capacity building for developing countries was observed. However, there is significant uncertainty whether developing countries are willing to accept the compromise proposal forwarded by Mr. Pronk. He proposed establishing an adaptation fund and a convention fund under the Global Environmental Facility. At least 1 billion USD annually would be transferred from industrialized countries to the funds. Many developing countries are also skeptical to the linkage to the Global Environment Facility due to its close relation with the World Bank.

There is somewhat less controversy surrounding the design of a compliance system for enforcing the Kyoto Protocol. The EU and small island states wanted strict sanctions in case of non-compliance with the Protocol. The USA and Canada wanted milder sanctions.

5.6 Land Use, Land-Use Change and Forestry.

When discussing emission reductions, the focus has primarily been on reducing the consumption of fossil fuels. But Land Use, Land-Use Change and Forestry (LULUCF) activities are also important. Estimates show that LULUCF activities have contributed to about 30% of the increase in the CO_2 concentration in the atmosphere. This is primarily a result of land-use changes and deforestation in tropical areas. But the forest is also important as a sink as it houses about half of the carbon stored in terrestrial ecosystems. The potential for cheap emissions reductions within LULUCF activities is large, and it could to some extent protect the tropical forests. The uncertainty connected with LULUCF activities is also large, and there is some fear that such activities could undermine the aim of reducing emissions from fossil fuels in Annex I countries. **Slide 5.9** describes the most important articles in the Kyoto Protocol concerning LULUCF activities.

- Article 2.1 encourages Annex I countries to protect or increase their sinks. This includes promotion of sustainable forest management, afforestation, and reforestation.
- Article 3.3 states that net changes in GHG emissions by sources and removals by sinks as a result of direct human-induced land-use change and forestry, limited to afforestation, reforestation, and deforestation since 1990 shall be included in the national climate accounts.
- Article 3.4 states that the COP shall decide upon modalities, rules and guidance as to how, and which, additional human-induced activities within LULUCF can be included (for instance activities related to agriculture).
- Article 6.1 encompasses Joint Implementation, which opens for emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or *enhancing anthropogenic removals by sinks* of GHG in any sector of the economy.

Slide 5.9. Articles in the Kyoto Protocol concerning LULUCF

Articles in the Kyoto Protocol concerning LULUCF

Article 2.1	promotion of sustainable forest management, afforestation and reforestation.
Article 3.3	afforestation, reforestation and deforestation activities since 1990
Article 3.4	additional human-induced activities within LULUCF can be included.
Article 6.1	Joint Implementation through enhancing anthropogenic removals by sinks

Source: CICERO

The treatment of LULUCF projects for project-level mitigation under Article 12 on the CDM remains debated. This is to a large extent based on the text in the Kyoto Protocol, as Article 12 has no explicit mention of “source” or “sink.” Some claim that since there is no explicit reference to LULUCF activities, they are not included. But given the broad coverage of forestry activities in other articles in the Kyoto Protocol, it seems unlikely that it was intentionally left out of Article 12.

Slide 5.10. Challenges/difficulties concerning LULUCF

Challenges/difficulties concerning LULUCF

Difficulties in measuring and verify carbon sequestration

The issue of permanence

Increased land conflicts

Problem of leakage

Environmental effects

Source: CICERO

One of the problems of including LULUCF activities in the implementation of the Kyoto Protocol is that the Protocol lacks vital definitions of what forests, afforestation, reforestation, and deforestation are. A special report from the IPCC on LULUCF was completed in the spring of 2000 to aid decision-makers on such issues. But the problems and challenges of including LULUCF activities do not stop there. **Slide 5.10** highlights some of these other main difficulties.

- How should the carbon sequestration be measured and verified? The uncertainties in measuring such change are large, especially concerning the carbon content in roots and the soil.
- The issue of permanence is vital, as the forest in principle should stand forever if its emission reductions are to be considered permanent. This is easier in the energy sector because reduced emission one year does not imply higher emissions at a later stage. This cannot be guaranteed for LULUCF activities because the accumulated carbon can be released as a result of, e.g., changing ownership, government policies, climatic factors, and fires.
- Measures within forestry, such as tree plantations or national parks, can lead to additional conflict. Such forest areas will be tied up for a long time, thus reducing the alternative uses significantly.
- Another possible problem is the issue of leakage. Protecting one area can lead to increased pressure in a different area. If this other area is deforested, the net climate effect could be zero.
- Tree plantations can come in conflict with, e.g., the Biodiversity Convention. The environmental effects of such activities must therefore be considered.

Some concern has been expressed over the possibility that LULUCF activities may come in conflict with other agreements, for instance the Biodiversity Convention. Obviously, not every “forest” project considered for its carbon benefits will be able to deliver the same amount of socio-economic and other environmental benefits. In fact, some previous attempts to reduce forest loss have led to unanticipated adverse effects. Financial incentives offered to encourage reforestation in Costa Rica prompted some landowners to cut down native forests to clear land for new trees. Foresters in Chile have been criticized for planting radiata pine over large areas without diversifying to other species, and for making room for plantations by removing existing native forests (Goldberg, 1999).

It is clear that the issue of LULUCF activities represents several challenges, and it is one of the unresolved "crunch" issues in climate negotiations. LULUCF activities have a central part in the second proposal issued by Mr. Pronk (the second Pronk paper). It is especially Article 3.4 that has led to heated discussions as to what additional human-induced activities within LULUCF can be included. Mr. Pronk suggests a "three-tiered" proposal for accounting under Article 3.4 LULUCF activities that seeks to strike a balance between several considerations (including quality of sinks and scientific basis). The proposal states that Parties that choose to make use of the provisions of Article 3.4 must adhere to the following:

- *First tier.* Forest management credited 100% up to the level of Article 3.3 debit, with a cap of 30 Mt CO_2 times five, if total managed forest since 1990 compensates for this debit.
- *Second tier*. Forest management beyond first tier – apply 85% discount.
- *Third tier*. Agricultural management (cropland management, grazing land management, and revegetation): apply "net-net" accounting compared to the base year level (i.e. carbon stock changes in the commitment period minus five times the carbon stock changes in the base year).

Mr. Pronk further suggests some boundary conditions for LULUCF accounting for the first commitment period.

- The sum total of:
    1. the second and third tier under Article 3.4; and
    2. emissions reduction units (ERUs) resulting from LULUCF project activities under Article 6; and
    3. certified emissions reductions (CERs) resulting from LULUCF project activities under Article 12; is not to exceed 50% of a Party's emission reduction target, for Annex I
- is not to exceed 50% of a Party's emission reduction target, for Annex I Parties whose Kyoto target in Annex B is less than 100 (i.e. 0.5 x ((100-Kyoto target)/100) x base year emissions x 5, and
- is not to exceed 2.5 % of a Party's base year emission times 5, for Annex I Parties whose Kyoto target in Annex B is equal to or greater than, 100.

5.7 Capacity building in developing countries

Capacity building in developing countries is regarded as very important as it is a way of including developing countries. The framework for capacity building activities was negotiated at COP6 based on a text forwarded to the COP by the subsidiary bodies at their thirteenth session. The framework sets out the scope and provides the basis for action on capacity building. The objective of capacity-building is to assist developing countries in building, developing, strengthening, enhancing, and improving their capabilities to achieve the objective of the UNFCCC through the implementation of the provisions of the Convention and the preparation for their effective participation in the Kyoto Protocol process. There are several guiding principles and approaches for the framework. The framework is guided and informed by a number of articles in the Convention (articles 4.1, 4.3, 4.4, 4.5, 4.7 and others) and in the Kyoto Protocol (articles 10c, 10d, 10e and 11). Capacity building activities should build on work already undertaken by developing countries, as well as on the work undertaken with support from multilateral and bilateral organizations. The capacity building needs already identified should continue to be comprehensively and promptly addressed to promote sustainable development. Capacity building must be country-driven, addressing the specific needs and conditions of developing countries and reflecting their sustainable development strategies, priorities, and initiatives. Capacity building is a continuous, progressive and iterative process, the implementation of which should be based on the priorities of developing countries. It should be undertaken in an effective, efficient,

integrated and programmatic manner, taking into consideration the specific national circumstances of developing countries.
The least developed countries and small island states are among the most vulnerable to extreme weather events and the adverse effects of climate change. They are particularly vulnerable as they also have the least capacity to cope with and adapt to the adverse effects of climate change. The needs and priority areas for capacity building in these countries include the following (UNFCC, 2000):

a) Strengthening existing and, where needed, establishing new national climate change secretariats or focal points;

b) Developing an integrated implementation program that takes into account the role of research and training in capacity building;

c) Developing and enhancing technical capacities and skills to carry out and effectively integrate vulnerability and adaptation assessments into sustainable development programs;

d) Strengthening existing and, where needed, establishing new national research and training institutions;

e) Strengthening the capacity of meteorological and hydrological services;

f) Enhancing public awareness.

5.8 Reporting systems

The issue of reporting is not controversial in the climate negotiations, and it seems that agreement will be reached fairly easily. In accordance with articles 4 and 12 of the Convention, Parties are to submit to the secretariat national greenhouse gas inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. These inventory data are provided in the national communications under the Convention by Annex I and non-Annex I Parties. In addition, Annex I Parties submit annual national greenhouse gas inventories with data for their base year (in most cases 1990) and up to the second to last year prior to the year of submission.

Starting in 2000, Annex I Parties must follow the revised UNFCCC reporting guidelines, adopted at COP5, in preparing their inventories. According to these guidelines, Annex I Parties must use a common reporting format for reporting their annual greenhouse gas data. Also at COP5, Parties adopted, for a two-year trial period covering the inventory submissions due in 2000 and 2001, guidelines for the technical review of the greenhouse gas inventories submitted by Annex I Parties.

5.9 Enforcement of the Kyoto Protocol

A compliance system is required to ensure that the Kyoto Protocol can be enforced. The Parties must be monitored to certify that they honor their commitments to the Protocol in accordance with the rules adopted for the Kyoto mechanisms. So far, the Parties have agreed to establish a Compliance Committee comprising two branches, one facilitative branch and one enforcement branch, see **Slide 5.11**.

The tasks of the facilitative branch are to give assistance to individual Parties and make recommendations on questions of implementation, in particular with reference to minimizing adverse effects from actions taken and from climate change impacts on other Parties, especially developing country Parties, estimation and reporting of greenhouse gas emissions, demonstration of compliance, reporting of measures to mitigate climate change, transfer of technologies to developing countries, climate research, education and training programs, and provision of additional financial resources to developing countries to meet their commitments under the Climate Convention and the Kyoto Protocol. There is a provision for an expedited procedure with respect to the Kyoto mechanisms.

With a reference to the Kyoto targets and requirements for the Kyoto mechanisms, the tasks of the enforcement branch are to assess non-compliance and decide on questions of implementation that can potentially lead to application of adjustments and sanctions.

The second Pronk paper suggests that the two branches of the Compliance Committee comprise one member from each of the five UN regional groups, one member from the group of small island states, two members from Annex I countries, and two members from non-Annex I countries, altogether 10 representatives. Decisions are to be made by consensus. If consensus is not possible, there should be a three-fourths majority vote. Furthermore the paper proposes that excess emissions from a Party's assigned amount can be subtracted in the subsequent commitment period with a penalty rate added. The penalty rate is a type of interest rate for delays that give Parties incentives to comply. The penalty rate is set at 1.1 for exceeding assigned emissions by less than 1% for the subsequent commitment period (which means that the excess emissions must be covered by an additional 10% reduction), to be increased to 1.5 for exceeding emissions by between 1% and 8%, and 2.0 for exceeding emissions by 8% or more. A Party not in compliance must provide a compliance action plan explaining how to meet the commitments in the subsequent period, to be approved by the enforcement branch. A Party that is not able to satisfactorily demonstrate that it has a surplus in terms of meeting the national Kyoto target and the methodological and reporting requirements for the Kyoto mechanisms can have its eligibility to transfer and acquire emissions suspended. With respect to the CDM, there will be no eligibility requirements for developing countries. Mr. Pronk favors the adoption of a formal agreement on compliance that supplements the Kyoto Protocol.

Slide 5.11. Proposed compliance system for the Kyoto Protocol

Proposed compliance system for the Kyoto Protocol

- Compliance Committee with:
  - Facilitative branch
  - Enforcement branch
- The second Pronk paper proposal for sanctions in case of non-compliance: subtraction of excess emissions in subsequent commitment period:
  - Penalty rate of 1.1 if excess emissions are less than 1% of assigned amount (excess emissions plus 10%)
  - Penalty rate of 1.5 if excess emissions are between 1% and 8% of assigned amount
  - Penalty rate of 2.0 if excess emissions are 8% or more of assigned amount

Source: CICERO

6. The status of the Parties' negotiation positions after the meeting in The Hague

6.1 Factors determining countries' positions

To understand the different countries' positions in the climate negotiations, one has to consider a number of factors. Some countries may not be clear on where they stand because they are uncertain of how they stand to gain or lose from the Kyoto Protocol. But a country can also be reluctant to take positions for tactical reasons. Generally speaking, the many types of uncertainties concerning both costs and benefits from measures of reducing GHG emissions will make clear positions more difficult. The most important factors determining a country's position in climate negotiations are shown in **Slide 6.1.**

Slide 6.1. Factors determining countries' positions

Factors determining countries' positions

- Expected costs of reducing the GHG emissions in the country. Such costs will depend on a number of factors, including economic structure and trade patterns, energy system, energy efficiency, the extent to which measures have been implemented, and the specific details of the Kyoto Protocol.
- Expected costs of future climate changes in the country.
- Positions of other countries. It will be easier to get a country to stretch further if it expects other countries to do likewise. However, the benefits of free riding when other countries implement measures can be large.
- Political conditions and culture/lifestyle in the country. One example is the US resistance against taxes in environmental policies and other areas.

Source: CICERO

Slide 6.2 gives another perspective on countries and groups of countries' positions in international climate policy negotiations. The countries are divided along two dimensions, where the first is vulnerability to climate change impacts, and the second is costs associated with climate policy measures. Along both dimensions, a country's anticipated vulnerability can be just as important as cost estimates. The Parties are divided into three main groups similar to the negotiations leading up to the Kyoto Protocol, "the Umbrella Group", "EU and friends", and G77/China. The "Umbrella Group" comprises Australia, Canada, Iceland, Japan, New Zealand, Norway, the Russian Federation, Ukraine, and the United States. "EU and friends" comprise, in addition to the EU, Switzerland and 8 Central and East European Countries (CEE). There seems to be a good correlation between the positions countries have chosen in the negotiations and their anticipated vulnerability to climate change impacts and to estimated national costs related to climate policy measures (see Slide 6.2).

Slide 6.2. Interests of countries according to degree of vulnerability to climate change impacts and to climate policy costs

Interests of countries according to degree of vulnerability to climate change impacts and to climate policy costs

Vulnerability to climate change impacts* **Costs due to climate policy measures**	**Less vulnerable to climate change impacts**	**Vulnerable to climate change impacts**
Low costs	USA EU Most of "umbrella" group [Ambitious targets if high concern about climate change]	AOSIS Most of G77/China [Ambitious targets, but industrialized countries must take the first steps]
High costs	Norway [Ambitious targets if high concern about climate change, but realizes this will be costly]	OPEC [Slow down policy measures; more concerned about cost of measures than cost of climate change impacts]

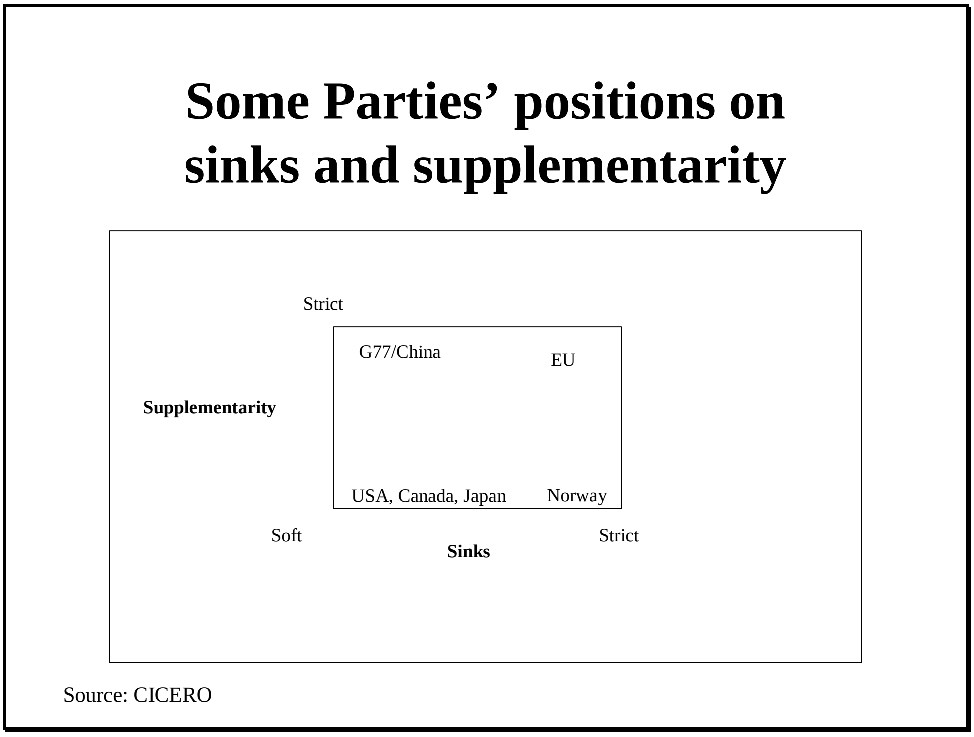
* Note that AOSIS-countries and OPEC-countries are members of G77/China, and that USA and Norway are members of the umbrella group (AOSIS is the Alliance of Small Island States).

Source: CICERO

6.2 The positions of the most important Parties

Slide 6.3 shows some Parties' positions on supplementarity with respect to the Kyoto mechanisms (emissions trading, JI, and the CDM), and on sinks. The EU and most developing countries supported a strict interpretation of the requirement that trading with the Kyoto mechanisms shall be supplemental to domestic mitigation actions. As mentioned above, the EU proposed a quantified capping on buying and selling quotas. The Umbrella Group – which includes the USA, Canada, Japan and Norway – wanted a soft interpretation of supplementarity and no capping on trade. In terms of sinks, the USA, Canada and Japan wanted soft rules, implying that a large volume of carbon sequestration from forestry, agriculture practices, and land use changes could be credited toward the Kyoto targets, whereas the EU, Norway and most developing countries favored stricter rules for inclusion of sinks, at least for the first Kyoto period 2008–12.

Slide 6.3. Some Parties' positions on sinks and supplementary related to the Kyoto mechanisms



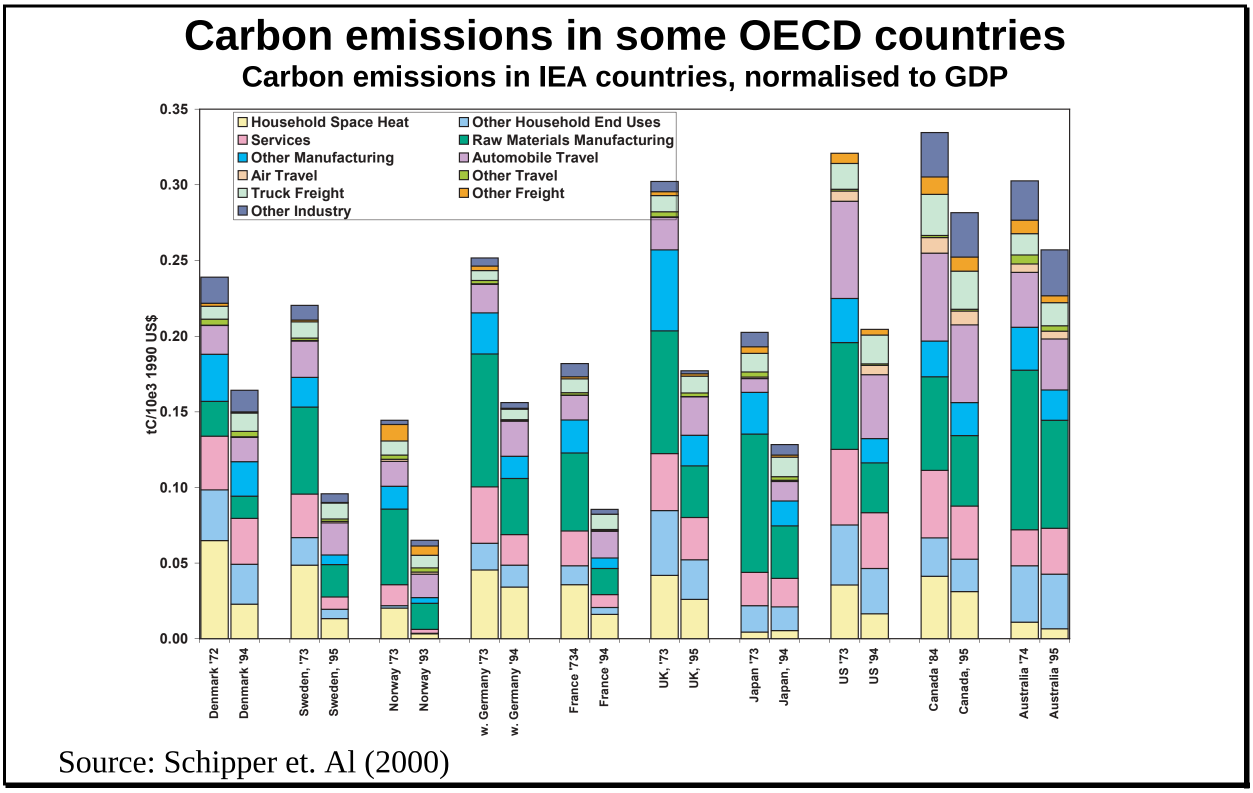
There is also disagreement on sanctions in case of non-compliance with the Kyoto Protocol commitments. The EU and the small island states wanted strict sanctions in the form of fees, whereas the USA and Canada wanted milder sanctions.

In terms of funding mechanisms and capacity building in developing countries, Mr. Pronk proposed the establishment of an adaptation fund and a convention fund. The adaptation fund would be financed by a share of proceeds on the CDM equal to 2% of the CDM credits generated by a project. The other fund would be financed through a not yet specified transfer of the initial assigned amount to OECD countries (Annex II) to the registry of the fund. These units can be bought by industrialized countries as part of emissions trading under Article 17 of the Kyoto Protocol. The developing countries (G77/China) in their comments to Mr. Pronk's paper propose that a much higher share of the CDM credits generated by a project should finance the adaptation fund, namely 9%. This group of countries furthermore proposes that the convention fund be named "the Special Fund" and be managed by a UN specialized body, such as UNEP, instead of the GEF. The total funding of these funds should by year 2005 reach one billon USD annually as an average for the period 2000–2005 to avoid applying a levy on emissions trading and JI.

6.3 Reasons for different emissions within the OECD countries

There are large variations in how much CO_2 the industrialized countries emit, both relative to population numbers and income level (i.e. gross domestic product). It is clear that energy is utilized more efficiently in the OECD countries compared to former communist countries. The emissions per capita are not higher than in these former communist countries, despite income levels being much higher in the OECD countries. **Slide 6.4** shows the carbon emissions in some countries relative to GDP. It is clear that the carbon intensities (carbon emissions divided by GDP) have decreased significantly in some countries. France, Norway, and Sweden have nearly halved their carbon intensities from 1973 to 1993/95. Countries such as Australia, Canada and Denmark have also reduced their carbon intensities, but not to the same extent as the countries mentioned above.

Slide 6.4. Carbon emissions in some OECD countries



Australia's high CO_2 emissions can partly be explained by energy-intensive sectors, such as the chemical industry and production of iron, steel and non-iron metals. Another factor is that nearly all electricity in Australia is produced by coal-fired power plants. Australia also has a large transport sector.

The high CO_2 emissions in Canada and the USA can also be explained by the high energy consumption in the transport sector. The generally high income levels combined with low taxes on energy consumption can account for the large emissions. The energy consumption in the transport sector is especially high, as the taxes on fuels are very low. Canada has a very energy intensive industry sector, the main sectors being chemical industry and paper industry. The US industry is not as energy intensive as the Canadian industry, but the USA still has higher CO_2 emissions than Canada. This is because over 50% of the electricity in the USA is produced by coal-fired power plants. Canada's power production on the other hand, is based mainly on hydropower and coal is less important.

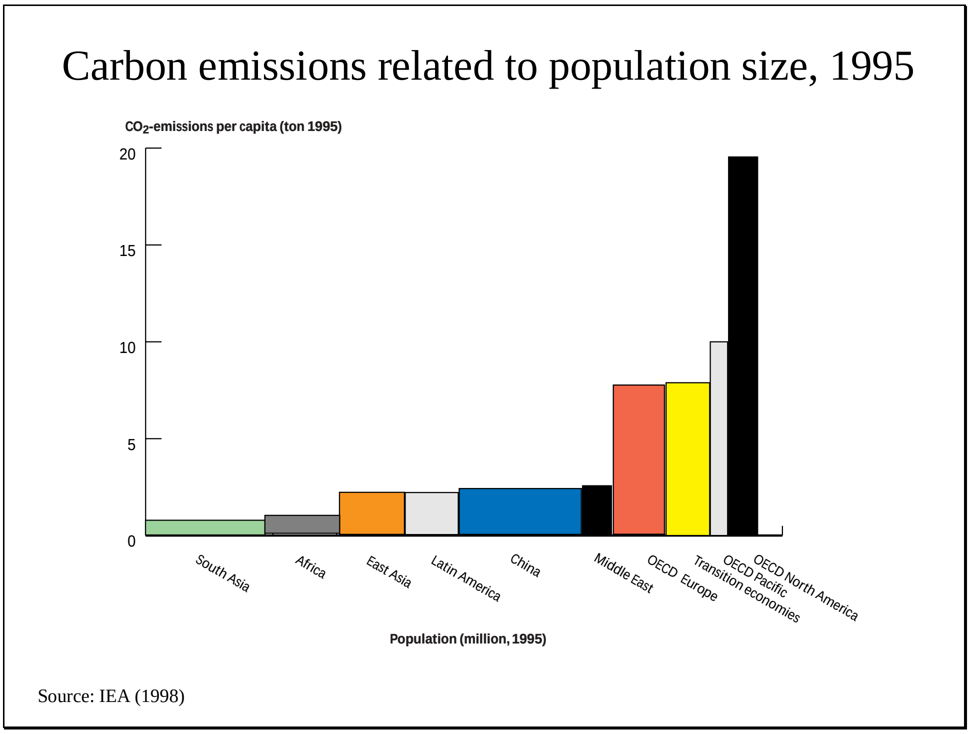
Both Norway and Sweden have high energy consumption per capita, but still relatively low emissions of CO_2. The most important explanation for this is the hydropower-based power sector in these countries, and nuclear power in Sweden. The UK and Germany do not have a particular energy intensive industry structure. An explanation for their relatively high emissions is that over half of their electricity production is from coal-fired power plants. Oil, gas and nuclear power are important for Japanese energy production. Nuclear power has an important role in France. Approximately 80% of the electricity is France is based on nuclear power plants, whereas 14% is based on hydropower.

6.4 Distribution of global CO_2 emissions

The Kyoto Protocol acknowledges the historical responsibility of the industrialized countries as they account for the bulk of atmospheric build-up of CO_2 concentrations. The previous slide showed that carbon intensities vary between countries. **Slide 6.5** shows that the CO_2 emissions per capita also vary sustantially, especially if developed countries are compared to developing countries. The North American OECD countries (the USA and Canada) have emissions close to 20 tons CO_2 per capita.

Corresponding figures for Latin America, Africa and South Asia are 2.4, 1.0 and 0.7 tons CO_2 per capita. The 5% of the global population living in the USA and Canada, account for more than 25% of the global carbon emissions. China, on the other hand, accounts for about one-fifth of the global population, but only 14% of global carbon emissions.

Slide 6.5. Carbon emissions related to population size, 1995



6.5 Emission reduction costs

A number of options can be adopted in response to the increasing concentration of greenhouse gases in the atmosphere. These options include (i) measures to eliminate or reduce greenhouse gas emissions, and ii) measures to offset emissions, for instance through the enhancement of sinks. There have been numerous studies on the costs of reducing CO_2 emissions, and the estimates span over a wide range. Some studies estimate losses at several percent of GDP, whereas others question whether there will be any losses at all. Significant differences and uncertainties surround specific quantitative estimates of the costs of mitigation options. The possible explanations for disagreement are many: choice of methodologies, underlying assumptions, emission scenarios, policy instruments, base year, and others. The SAR described two categories of approaches to estimating costs: bottom-up approaches, which build on assessments of specific technologies and sectors, and top-down modeling studies, which proceed from macroeconomic relationships. These two approaches lead to differences in the estimates of costs, which have been narrowed since the SAR. Even if these differences were resolved, other uncertainties would remain (See **Slide 6.6**).

The cost estimates for Annex B countries to implement the Kyoto Protocol vary between studies and regions, and depend strongly upon the assumptions regarding the use of the Kyoto mechanisms and their interactions with domestic measures. The great majority of global studies reporting and comparing these costs use international energy-economic models. Nine of these studies suggest the following GDP impacts:

1) Annex II countries: In the absence of emissions trading among Annex B countries, the majority of global studies show reductions in projected GDP of about 0.2 to 2% in 2010 for different Annex II regions. With full emissions trading among Annex B countries, the estimated

reductions in 2010 are between 0.1 and 1.1% of projected GDP. Models whose results are referred to here assume full use of emissions trading without transaction cost. Results for cases that do not allow Annex B trading assume full domestic trading within each region. Models do not include sinks or non-CO_2 greenhouse gases. They do not include the CDM, negative cost options, ancillary benefits, or targeted revenue recycling.

The models show that the Kyoto mechanisms are important in controlling risks of high costs in a number of countries, and thus can complement domestic policy mechanisms. Similarly, they can minimize risks of inequitable international impacts and help to level marginal costs. The global modeling studies reported above show national marginal costs of meeting the Kyoto targets ranging from about US$20/tC up to US$600/tC without trading, and from about US$15/tC up to US$150/tC with Annex B trading. The cost reductions from these mechanisms may depend on the details of implementation, including the compatibility of domestic and international mechanisms, constraints, and transaction costs.

2) Economies in transition: For most of these countries, GDP effects range from negligible to a several percent increase. This reflects opportunities for energy efficiency improvements not available to Annex II countries. Under assumptions of significant energy efficiency improvements and/or continuing economic recessions in some countries, the assigned amounts may exceed projected emissions in the first commitment period. In this case, models show increased GDP due to revenues from trading assigned amounts. However, for some economies in transition, implementing the Kyoto Protocol will have similar a impact on GDP as for Annex II countries.

Slide 6.6. Emissions reduction costs

Emission reduction costs

- Options that eliminate or reduce greenhouse gas emissions, and options that offset emissions, for instance through the enhancement of sinks.
- Bottom-up approaches and top-down modeling studies.
- Numerous studies and the cost estimates span over a wide range.
- The range of cost estimates has been narrowed since the SAR.
- The cost estimates for Annex B countries depend strongly on the assumptions regarding the use of the Kyoto mechanisms, and their interactions with domestic measures.
- In the absence of emissions trade among Annex B countries, the majority of global studies show reductions in projected GDP of about 0.2 to 2% in 2010 for different Annex II regions.
- With full emissions trading among Annex B countries, the estimated reductions in 2010 are between 0.1 and 1.1% of projected GDP.

Source: IPCC (2001c)

6.6 The Kyoto Protocol and the fossil fuel markets

To the extent that international environmental agreements seek to lower emissions related to energy use, which is the case for the Kyoto Protocol, their implementation affects energy markets and prices. The fossil fuel markets are especially interesting as emissions of carbon dioxide, and thereby combustion of fossil fuels, have to be reduced. Bartsch and Müller (2000), Holtsmark and Mæstad (2000), and Kolshus et al. (2000), among others, have shown that implementation of the Kyoto

Protocol is likely to have significant impacts on the fossil fuel markets and energy prices. The results from such studies will naturally vary according to different assumptions on central issues such as choice of policy tools, the use of the Kyoto mechanisms, technological development, and modeling techniques. The effects after the Kyoto Protocol's first commitment period are more uncertain because decisions concerning ambition level of emissions reductions and country participation must be made.[13]

The study by Holtsmark and Mæstad (2000) applies a numerical model of the fossil fuel markets and includes a global oil market, a global coal market, and three regional gas markets (North America, Asia, and Europe including Russia). The model should be considered as an analytical tool that can be used to obtain information about important mechanisms and some orders of magnitudes. However, it is not intended as a forecasting device. The consequences for the fossil fuel markets depend on the policies that are employed to reach the emission targets. Particular attention is devoted to the role of international emissions trading. Three different trading regimes are compared: free emissions trading, no emissions trading, and the EU proposal on limits on the acquisition and transfer of emission permits. Some of the key findings are described below and summarized in **Slide 6.7.**

- The Kyoto Protocol will significantly reduce coal demand, but it will not lead to very large reductions in oil and gas demand. In the industrialized countries, coal demand is reduced by some 34–44%, oil demand by 5–7%, and gas demand by 2–3% (relative to the business-as-usual scenario for 2010).

- Demand reductions are generally smaller with free international emissions trading, because substantial amounts of hot air then will be released on the market.

- Emissions trading generally leads to more abatement in Eastern Europe and less abatement in North America.

- The EU capping proposal will be non-binding for buyers of emission permits, but will significantly constrain the sale of emissions permits from Eastern Europe. The amount of hot air released on the market is reduced by some 65%.

- The EU capping proposal causes a rise in the international permit price from 15 to 23 USD per ton CO_2.

- There is less substitution from oil to gas in Western Europe than in other regions. While oil demand in Western Europe declines by 4–6%, gas demand is reduced by 4–8%.

- Western Europe is a net importer of emission permits with low permit prices (free trade) and a net exporter with high permit prices (the EU proposal). Thus, a gradual "liberalization" of international emission trading might first lead to lower fuel demand, then to higher fuel demand in Western Europe.

- The producer prices of fossil fuels do not fall dramatically. The coal price falls by 7–9%, the oil price drops by 2–3%, while the European gas price falls by 3–5%. Oil and gas prices decline most without emissions trading because less hot air then is released on the market. See **Slide 6.8** for details on the impacts on producer prices in 2010 under three different cases: free emissions trading, no emissions trading, and trading within limits.[14]

[13] See for instance Kolshus et al. (2000).
[14] "Trading within limits" is identical with the EU capping proposal described in chapter 5.5.

Slide 6.7. Key findings from a study on the Kyoto Protocol and the fossil fuel markets

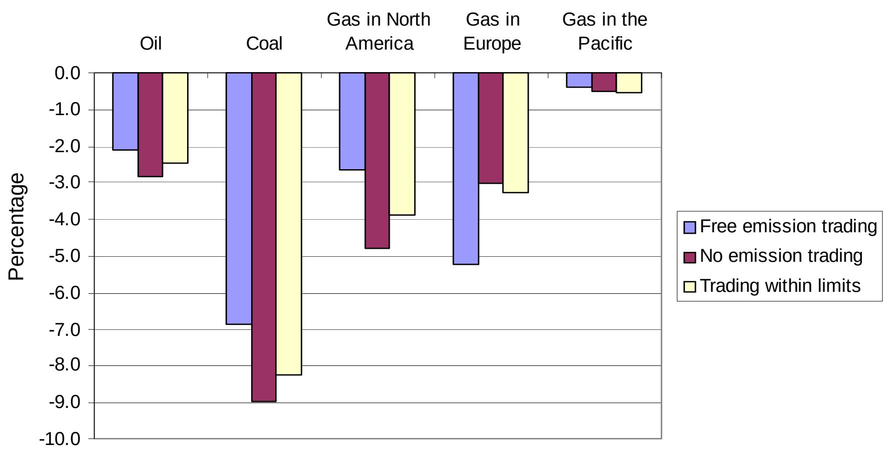
Key findings of a study on the Kyoto Protocol and the fossil fuels markets

- Significant reductions in coal demand, less impact on oil and gas demand.
- Demand reductions are generally smaller with free international emission trading.
- Emissions trading generally leads to more abatement in Eastern Europe and less abatement in North America.
- The EU capping proposal increases the international permit price from 15 to 23 USD per ton CO_2.
- Producer prices of fossil fuels do not fall dramatically.

Source: Holtsmark and Mæstad (2000)

Slide 6.8. Impacts on the producer prices in 2010

Impacts on producer prices in 2010



Source: Holtsmark and Mæstad (2000)

7. National and regional initiatives

This chapter presents an overview of national and regional climate policy measures with a focus on emissions trading initiatives. In addition, climate policies and measures within the EU and green certificates to stimulate renewable energy sources are mentioned.

7.1 National emissions trading systems

Norway
In October 1998, a Quota Commission for Norway was appointed as part of a political compromise at the Norwegian parliament to propose a domestic emissions trading system for Norway. The idea was to design a domestic emissions trading system that would be an important part of implementing the Kyoto Protocol in Norway from year 2008. According to the mandate for the commission, the system should at least encompass sectors that are exempted from the carbon tax, but consider how the remaining sectors could be included in the system. The commission should emphasize quota allocation criteria. The report was finalized in December 1999.[15] The main features of the report are shown in **Slide 7.1**.

Slide 7.1. Main features of the domestic emissions trading system for Norway proposed by the Quota Commission

Main features of the domestic emissions trading system for Norway proposed by the Quota Commission.

1. A broad domestic system including 90% of emissions of the six Kyoto greenhouse gases.
2. Quota obligations from 2008 as part of implementing the Kyoto Protocol.
3. Sinks for carbon dioxide are included.
4. Quotas can be banked and freely used within the period.
5. Firms must pay the full market price for quotas (minority view that most quotas should be free).
6. If free quotas are used, their sale should be restricted.
7. New firms must buy all the quotas they need.
8. The obligation to obtain quotas can be on producers, distributors, or consumers.
9. All agents should be allowed to participate in international emissions trading.

Source: CICERO.

The Quota Commission stated that emissions trading could be combined with carbon taxes at the domestic level, but that a domestic quota system could easily be linked to international emissions trading. The remaining 10% of greenhouse gas emissions would be too difficult and costly to include in the quota system.

A majority of 6 members of the committee recommended that all firms pay full market price for quotas according to the Polluter Pays Principle. A minority of 2 members of the committee recommended that firms that are exempted from the carbon tax should receive free quotas, whereas a

[15] NOU 2000:1.

different minority of 2 members of the committee argued that allocation of free quotas was outside the mandate of the commission. The commission furthermore proposed that if free quotas are allocated, some of these should be non-tradable such that the firm that received those quotas can only use them. A majority of 6 felt that free quotas would reduce the danger of some firms going out of business due to climate policy. On the other hand, non-tradable quotas would reduce incentives to make production more effective and reduce emissions of greenhouse gases. A minority of 5 therefore proposed that some of the free quotas should be tradable to improve incentives for abating emissions.

Sweden
Sweden appointed an expert commission to produce a report on the use of the Kyoto mechanisms in Sweden. The report was finalized in April 2000. The report describes a domestic emissions trading system with many features comparable to the Norwegian proposal, but where the system should be introduced before year 2008, and with an opening for trading with other countries and using JI before 2008. After a second phase of the expert commission's work, which was initiated when the EU released its "Green paper on greenhouse gas emissions trading within the European Union" (see section 7.2), a final report was produced that proposed a much more limited domestic emissions trading system that resembles the EU's proposal. The main features of the final report are shown in **Slide 7.2**.

Slide 7.2. Main features of a proposed domestic emissions trading system for Sweden

Main features of a proposed domestic emissions trading system for Sweden.

1. The system covers energy-related carbon dioxide emissions in transport, households, and industries that are not exposed to competition from abroad.
2. Industries that are paying less than the full carbon tax are exempted until 2008.
3. The quotas are auctioned and replace present carbon taxes.
4. There should be tough sanctions on non-justified emissions.
5. JI and the CDM can be employed.
6. Sinks are not included.
7. The European Economic Cooperation-countries (of which Norway is one) are allowed to participate in emissions trading within the EU.

Source: CICERO.

Denmark
A quota system for the Danish electricity-producing sector was introduced in the spring of 2000. Carbon dioxide quotas are allocated for free based on historical emissions. The quotas can be traded with other countries. A tax equal to 40 DKK per ton of carbon dioxide is levied on emissions that surpass available quotas.

The United Kingdom
The British industry established an Emission Trading Group in 1999 that includes representatives from industry and the government. The group recommended an emissions trading system as an alternative to a climate tax intended for introduction in April 2001. The aim of the emissions trading proposal is to achieve the British climate target in cost-effective manner and keep British industries from losing their competitive edge compared to other countries. The system should induce more firms to take on

an active role and produce trading experience that will later prove valuable. The proposal contains details on allocation of quotas and rules that secure fairness, transparency, monitoring, and verification. The aim is to have the system operative from April 1, 2001.

7.2 Emissions trading within the EU

The EU has proposed an emissions trading system within the union in its “Green Paper on Greenhouse Gas Emissions Trading within the European Union” to be established by 2005. The system only covers CO_2 emissions from the energy sector, the iron and steel industry, refineries, chemical industry, glass, ceramics and building materials, and paper and pulp, which altogether accounted for about 45% of the EU’s CO_2 emissions in 1997. The other five greenhouse gases from the Kyoto protocol are completely excluded from the system. Such a limited system is simple but realistic since member states are at very different levels in implementing climate policies. The system should be flexible such that member states can choose to participate or not, and have the option to later leave the system for a period. A major concern for the EU is to harmonize market conditions in different member states to achieve a “level playing field.” Because of this, the emissions trading system must be supplemented with other measures in non-participating sectors. Possible measures in these sectors include command and control, technical minimum standards, taxes, or voluntary agreements. Different quota allocations options are discussed, such as whether quotas should be free or auctioned, whether each member state should allocate the quotas, or whether this should be a task for the EU, but these issues remain unresolved.

7.3 Other climate policy initiatives

EU policies and measures to reduce GHG emissions

The European Commission has acknowledged that actions by both member states and the European Community need to be reinforced if the EU is to succeed in reducing its emissions of GHGs by 2008–2012. The Commission launched in June 2000 the European Climate Change Programme (ECCP), the goal of which is to identify and develop all the necessary elements of an EU strategy to implement the Kyoto Protocol. The ECCP is preparing a range of additional EU-level policies and measures to cut GHG emissions as well as an emissions trading scheme. The focus is on the energy, transport, and industry sectors, but the scope may be broadened later to encompass sectors such as agriculture, forestry, and waste. Some of the proposed policies and measures on climate change are as shown below.

Energy sector

- Increased use of combined heat and power
- Capture and disposal of CO_2 in underground reservoirs
- Promotion of more efficient and cleaner fossil fuel conversion technologies
- Energy efficiency in the electricity and gas supply industries
- Improvement of building/lighting efficiency
- Public procurement of energy-efficient end-use technologies

Industrial sector

- Improvement in energy efficiency standards for electrical equipment
- Improvement in efficiency standards for industrial processes
- Development of an EC-wide policy framework for emissions trading
- Development of a framework for voluntary agreements

Transport sector

- Improved emission and fuel standards, new technologies and fuels
- European campaign for more fuel-efficient driver-behavior
- Transport pricing and economic instruments for aviation

The EU has initiated several programs as part of its policies and measures approach. Some examples of these programs are shown below.

1. The **Campaign for Take-Off** will run for 5 years, from 1999 to 2003, and is meant to act as a catalyst for the development of key renewable sectors.

2. **ALTENER** is the EU non-technological program aimed at promoting the use of renewable energy sources within the Union.

3. The **SAVE** (Specific Action for Vigorous Energy Efficiency) took a non-technological approach to energy efficiency, complementing existing technology-based programs. This initiative has been extended with **SAVE II**.

4. **THERMIE** is a demonstration component of the Non-Nuclear RTD Program and supports the demonstration and application of innovative energy technologies and provides for the enhanced dissemination of information.

Green certificates

Green certificates are a new policy tool aimed at increasing the share of renewables in electricity production. Instead of regulating producers, the electricity consumers are obliged to use a minimum share of renewables. Since renewables at the outset are not competitive with conventional electricity production, this is comparable to levying a tax on electricity consumption. In political terms this seems to be less controversial than paying large subsidies to, for instance, new windmills. This share is likely to increase over time. An efficient market for supplying different renewable energy sources can be established through green certificates, but the total electricity supply market will not be efficient due to the direct regulation of a minimum share of renewables, regardless of a higher production price for this “green” electricity. A physical market for electricity is combined with a financial market for green certificates. Green certificates are issued to the producers of renewable energy by a certification authority according to production. In the physical market, there is only one price for electricity, but consumers also have to buy green certificates equivalent to the specified percentage of their electricity use. An authority is given the responsibility of verifying that the commitments of the consumers are met. Demand and supply in the certificate market generates the price of green certificates. Transaction costs can be saved if the distributors of electricity take on the task of meeting the percentage share of renewables, and add the additional cost to the electricity bills of consumers. The price of the certificates can vary significantly due to variability in the production of for example wind energy.

A variant of green certificates called “Green labels” was introduced in the Netherlands in 1998 with the aim of increasing the share of renewables from 3.2% in 2000 to 10% by 2020. Under this system, consumers buy green electricity at a higher price directly from producers, and no electricity exchange is involved. The Netherlands has plans to transform this system into a system with green certificates. There are plans to introduce green certificates in Denmark with the aim of increasing the share of renewables to 20% by 2003. Today the share of wind energy is 9%, and other renewables account for 1–2%. In addition there are plans to introduce green certificates within the EU

Green certificates differ from emissions trading since they only aim at increasing the share of renewables. However, this policy tool may be part of a strategy to implement the Kyoto Protocol since expansion of renewable energy production can save consumption of fossil fuels. Renewable energy projects both achieve more “green” electricity production and reduce emissions of greenhouse gases.

7.4 Norwegian climate policy

According to the latest projections, Norwegian emissions of climate gases will increase by 24% from 1990 until 2010. The sectors that contribute most to this growth are oil and gas production and transportation. Norway's Kyoto target is +1% compared to 1990. This means that Norway has to reduce its expected 2010 emissions by around 12 Mt CO_2-equivalents. If the plans for five gas-fired power plants are realized, projected climate gas emissions will increase by up to 7 Mt CO_2-equivalents. Thus up to 19 Mt CO_2-equivalents must be reduced compared to business as usual in 2010 to meet the Kyoto target.

These reductions must be carried out domestically or by employing emissions trading or JI with other industrialized countries, or the CDM with developing countries. The Norwegian Pollution Control Authority has produced an inventory of abatement measures and ranked them according to increasing cost per ton of CO_2 equivalent (SFT, 2000). This marginal abatement cost curve shows that about 11 Mt CO_2 can be abated for a price that is less than the highest carbon tax at present, which is a tax of 406 NOK per ton of CO_2 on gasoline. Thereafter the marginal cost increases steeply. Assuming a quota price of 15 USD per ton of CO_2-equivalent at the international market, equivalent to around 140 NOK per ton of CO_2-equivalent, Norway should abate 5 Mt CO_2 domestically and buy 7 Mt CO_2 quotas at the international market to minimize its cost of meeting the Kyoto target. If all gas-fired power plants are built, quotas of 14 Mt CO_2-equivalents must be bought on the international market. This shows that Norway is dependent on buying a substantial amount of quotas from other countries, and particularly so if gas-fired power plants are built and their emissions have to be accounted for. Furthermore, this shows the importance of a well-functioning market for the Kyoto mechanisms with as few restrictions as possible and low transaction costs, to make the quota cost as low as possible and reduce the Norwegian implementation cost of the Kyoto target. **Slide 7.3** illustrates the potential cost saving of free quota trade through some results from a study by Kolshus, Torvanger and Malvik (2000) on Norway's cost of implementing the Kyoto target given different emission trading scenarios. The three scenarios shown are free trade, EU capping (limited trading), and no trade. The results show the cost-saving potential of free trade, where the national cost (abatement cost plus quota cost) is reduced by 26% compared to the case of no trade. The cost in the EU capping case is between the two other cases, but closer to no trade. Norway might not be able to buy as many quotas as it would choose to minimize the national implementation cost of the Kyoto Protocol. **Slide 7.4** lists some factors that might restrict Norway's choice in this respect.

The largest cost related to a climate policy for Norway, however, stems from Norway's role as a large exporter of oil and gas. **Slide 7.5** is taken from Kolshus et al. (2000) and shows the costs related to a reduced oil and gas wealth compared to the abatement cost and quota expenses from Slide 7.3. We see that the expected costs from a reduced oil and gas wealth are from 15 to 18 times greater than the combined domestic abatement cost and cost from purchasing quotas.

Slide 7.3. Quotas and abatement in Norway under the Kyoto Protocol

Quotas and abatement in Norway under the Kyoto Protocol

Cost (million USD)	Free trade	EU capping	No trade
Quota import (mt)	5.3	2.5	-
MAC (USD/t CO_2-eq.)	15.1	23.4	31.2
Domestic reduction (mt CO_2-eq.)	4.2	7.1	9.6
Quota cost (million USD)	80.0	58.5	-
Abatement cost of domestic reductions (million USD)	32.3	87.3	150.8
Total cost (million USD)	112.3	145.8	150.8

Source: Kolshus, Torvanger and Malvik (2000)

Slide 7.4. Potential risks related to large-scale use of the Kyoto mechanisms

Potential risks related to large-scale use of the Kyoto mechanisms

1. The Kyoto Protocol states that use of the mechanisms should be supplemental to domestic abatement.

2. Large-scale use of the mechanisms can be difficult for political reasons since Norway would be exposed to criticism from many Parties to the Kyoto Protocol.

3. Some type of quantitative (or qualitative) restrictions on the use of the mechanisms might still be adopted by the Parties.

4. The cost of quotas from the Kyoto mechanisms might be underestimated due to large uncertainty and potentially large transactions costs, particularly for the CDM.

Source: CICERO.

Slide 7.5. Total cost for Norway under the Kyoto Protocol

Total costs for Norway under the Kyoto Protocol

Costs (million USD)	Free trade	EU capping	No trade
Quota and abatement	112	146	151
Revenue loss	2,046	2,264	2,418
Total costs	2,158	2,410	2,569

Source: Kolshus, Torvanger and Malvik (2000)

At the domestic level, Norway should as soon as possible develop a long-term climate policy strategy where the Kyoto Protocol is the first stage to give industry and other actors a stable long-term policy environment and sufficient time for developing their strategies. This must be done well before the first Kyoto target year 2008. All Parties to the Kyoto Protocol must demonstrate progress in meeting their targets by 2005. Furthermore, given the uncertainty with respect to the future of the Kyoto Protocol, Norway should develop a policy for an international climate policy where the Kyoto Protocol does not enter into force, for instance as part of a European “Kyoto light” with many participating countries from other regions of the world where the EU is in the lead. With regard to this political uncertainty, such a climate policy strategy should be flexible and able to handle different climate policy futures. The strategy should also be able to handle different technology futures given the vital role of technological progress in meeting the climate change challenge and the uncertainty surrounding future technologies and their prices. Norway could spend some of its oil money on long-term research and development programs for green, energy-efficient and carbon-low or carbon-free technologies, which are likely to meet a growing market both domestically and on the world market in the decades to come. This could give Norway a competitive edge and move us from oil production to green energy production in the future. One obvious possibility is to build on Norway’s competence in marine technologies (including our gas- and oil technology on the continental shelf). As part of such a strategy, technologies for extracting and storing carbon dioxide in stable geological structures (for instance empty oil wells) could be worth exploring, at least as part of a temporary solution in moving to a low-carbon energy system in the future.

8. Prospects for climate policy and the Kyoto Protocol

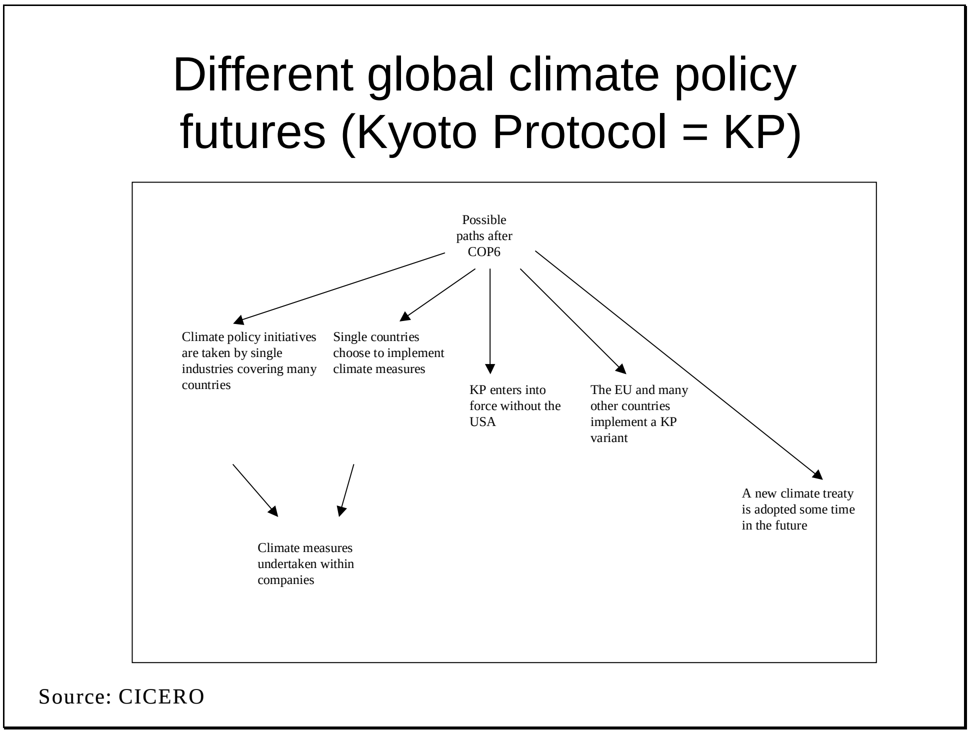
8.1 Prospects for the negotiations on the Kyoto Protocol

The uncertainty of the future of the Kyoto Protocol is larger than ever before due to President Bush’s decision to withdraw American support and not ratify the Protocol. This is a provocative stance for the

EU and a number of other countries that have invested a lot in the Kyoto Protocol. Many countries, including Japan, Russia and Canada, have criticized Bush's decision. This is a serious situation for the Protocol. If the Americans stick to this position, there are only two options left for COP6 in July. Either the USA must come up with an alternative approach, or those countries supporting implementation of the Protocol must move on without the USA.

The first option seems difficult for many reasons. First, a new initiative from the USA would probably deviate significantly from the present protocol in terms of targets and the role of developing countries, which would raise fierce opposition from many Parties. This would be totally unacceptable to many countries because of the resources invested in the Protocol, particularly for the EU. Second, this would *de facto* imply that negotiations must start more or less from scratch. This would be time-consuming and take place in a negotiation environment that would be far from supportive of a constructive dialog. The Climate Convention, which the USA has ratified, could still serve as a negotiation platform since it entered into force in 1994. However, there is a wide gap between the sound principles for long-term management of the climate system in the Convention and practical steps and commitments toward meeting those principles.

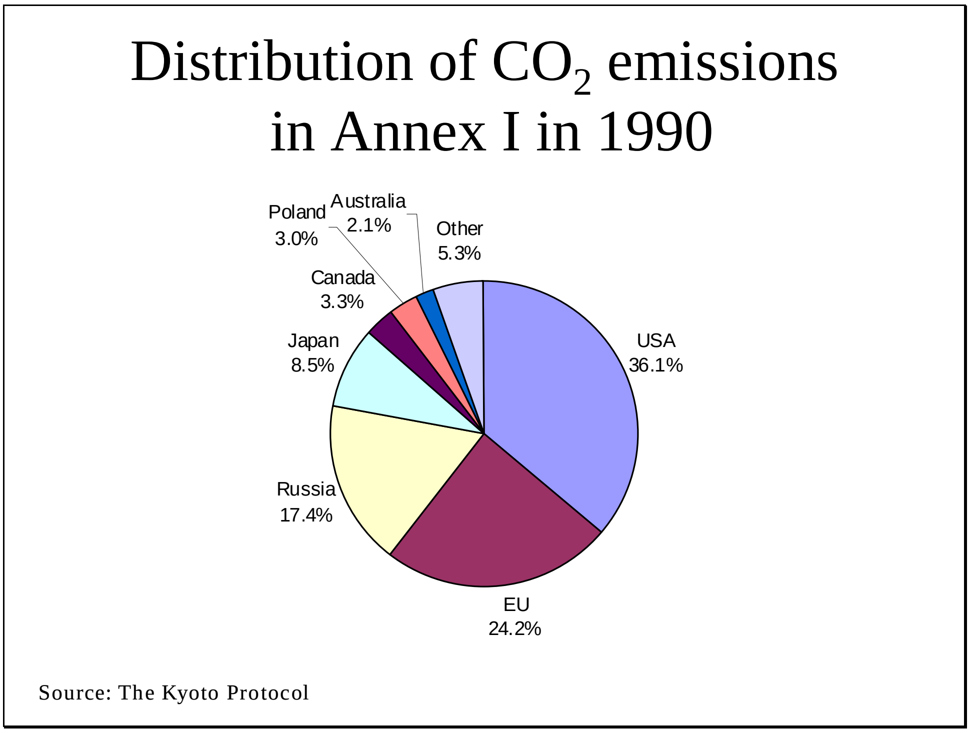
Slide 8.1. Different climate policy futures (Kyoto Protocol=KP)



Slide 8.1 shows the main paths for a climate policy regime that are possible after COP6 bis in July 2001. The EU, with support from many other countries, may choose to implement the Kyoto Protocol without the participation of the USA. Most countries are likely to follow the Europeans in that case. The countries that would be most likely to follow the USA would be Australia, Canada and New Zealand. Formally, the Protocol could enter into force without the USA if most other countries ratify. The Protocol must be ratified by Annex I countries that together represent at least 55% of CO_2 emissions within this group in 1990 (see **Slide 8.2** for an overview of the emission shares of the largest Annex I countries). However, if the support for the Protocol is too weak to have it enter into force, the EU and other collaborating countries may settle for an agreement similar to the Kyoto Protocol within this region, where most of the relevant features of the Protocol are kept. In both cases, the USA would be a free-rider to abatement efforts of other countries. This would be a difficult starting point for the collaborating countries due to USA's political importance at the global level, and due to the USA being the largest emitter of climate gases both in absolute terms and in per capita terms (aside from a few small countries). Furthermore, at least in the short term, this could mean a loss of competitive

edge for European industries compared to the USA. However, the USA risks being isolated both among industrialized countries, and its relations with developing countries could be seriously harmed. Since the collaborating countries would have to develop new and energy-efficient energy technologies, this could in the longer run give them a competitive edge compared to American industries with weaker environmental and climate-policy incentives. The markets for green technologies are expected to grow at a fast rate during the next decades, as environmental and climate demands increase. Thus the USA might later be forced to follow suit. When American shareholders discover that they lose money invested in American companies compared to European companies, they will pressure the American administration to change its climate policy.

Slide 8.2. Distribution of CO_2 emissions in Annex I in 1990



Another possibility is that single countries choose to carry out national climate policy targets whatever the choice of (most) other countries. Furthermore, industries covering many countries might choose to collaborate and implement a type of environmentally sound business strategy if they expect this to give them a valuable green image in the market and in public opinion. Another incentive could be in terms of developing green technologies that would be profitable in a relatively short time. For the same reasons, large (multinational) companies may choose proactive climate strategies.

Whatever the fate of the Kyoto Protocol we are convinced that a global climate treaty will eventually emerge as long as the signs of man-made climate change and following negative impacts for most countries become more and more clear. Thus the present dilemma of a stall at the political arena and new and stronger evidence of global man-made warming can only be temporary. A main challenge is to prevent most countries from becoming so discouraged by the lack of progress in international climate agreements that they only focus on adaptation policies, where they receive most of the benefits regardless of the policy choice of other countries. Such a scenario could mean a fast-paced climate change with many negative consequences, particularly to the detriment of vulnerable developing countries, such as low-lying island states that are vulnerable to sea level rise.

8.2 Prospects for Norway

As a small open economy, Norway is very dependent on the climate policies and economic policies of our main trading partners. Norway will most likely further approach the EU and participate in EU-led climate initiatives if the USA backs out of the climate process. Whatever Norway chooses our oil and gas wealth will be reduced as long as a substantive climate policy is carried out at the international level.

8.3 Burden sharing in future climate policy agreements

A challenging task faced by negotiators in their efforts to develop new climate policy treaties is how to divide the burden of abatement between countries in future agreements, especially between industrialized countries and developing countries. While the richer countries in the North are responsible for the bulk of emissions, the poorer countries in the South are expected to bear the brunt of harmful impacts. Moreover, the South has to struggle with how to continue to develop if they take on commitments to limit their emissions of greenhouse gases.

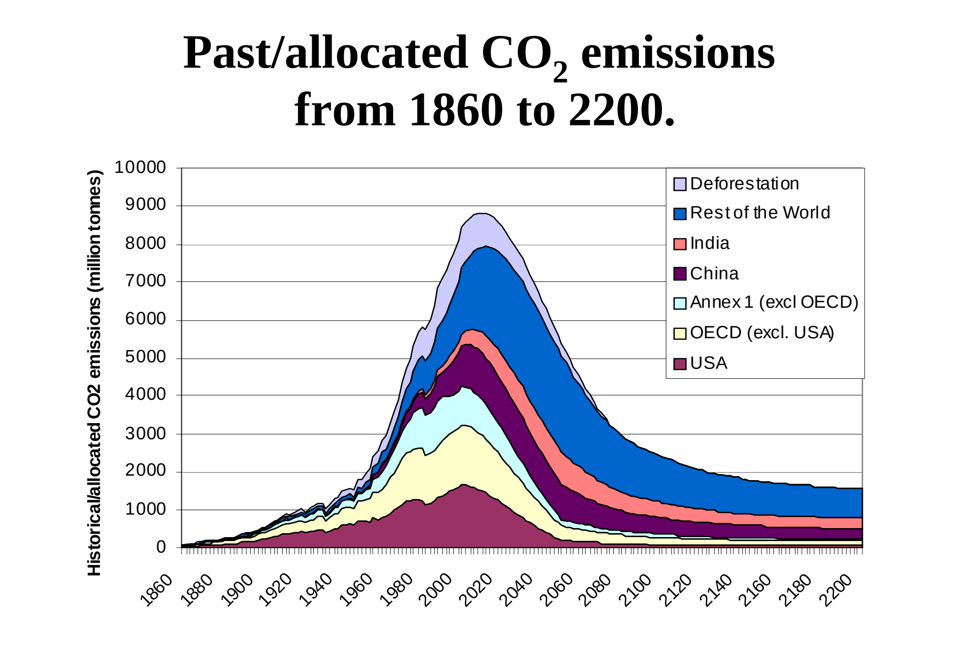
Two main burden-sharing principles are the “grandfathering” approach, where abatement targets are based on past emissions, and the per capita approach, where national targets are based on each citizen receiving an equal entitlement to emissions. Strictly speaking, the grandfathering principle favors the North by “rewarding” countries with historically high emissions and “punishing” countries that are in the process of development. In contrast, a pure per capita approach would allow developing countries to increase their emissions drastically and would require industrialized countries to reduce their emissions to a much lower level than today.

The Kyoto Protocol may represent an important political achievement but its expected impact on the climate is marginal at best. The agreement is nowhere near sufficient for stabilizing or reducing the concentration of greenhouse gases in the atmosphere, partly because developing countries have not committed to reducing their emissions in this round, and partly because the time horizon so far is only until 2012. Future climate negotiations must therefore contain more ambitious targets as well as the participation of developing countries. Let us consider some approaches to burden sharing from the literature that addresses this challenge.

In an attempt to realize this aim, the Global Commons Institute (GCI) has proposed that emission entitlements be allocated on a per capita basis. The basic idea behind the method, called “contraction and convergence” (C&C), is that we need a long-term, global agreement on controlling the total emission budget of CO_2 and on how this budget should be fairly divided between all countries. The emission budget will be consistent with a given concentration of CO_2 in the atmosphere by 2100. C&C defines a formula for allocating future tradable CO_2 quotas for all countries based on a gradual transition to per capita shares. The parameters can be changed and the results can easily be illustrated graphically. **Slide 8.3** shows the results based on a global emissions budget that gives a CO_2 concentration that does not exceed a 450 ppmv limit for atmospheric concentration of CO_2. A 450 ppmv limit for atmospheric CO_2 concentration is at the very lower end of SRES scenarios from TAR. The allocated emission quotas per capita to each country are to become identical over time, to converge. In this case, the convergence year is set to year 2050. Until that time, the developed countries’ allocated emission quotas will be reduced gradually. It is clear that the emissions of CO_2 in 1990 were at a good 6 gigatons (GtC), while the peak of about 9 GtC is projected to be reached around 2015. For atmospheric concentrations not to exceed 450 ppmv, the industrialized countries must reduce their emissions significantly. It is also clear that developing countries will increase their emissions and become responsible for a much higher share of the global emissions in, e.g., 2070 than in 2000.

Bartsch and Müller (2000), in a study of implications of the Kyoto Protocol for the global oil market, develop a burden-sharing method for future climate policy treaties based on a mix of the grandfathering and the per capita rules. Each citizen is given one vote for one of these principles and is assumed to vote for the principle that results in the most emission quotas for his/her country. When the votes are summed up over nations on a global scale and the two principles weighted according to the number of votes, the authors find that the per capita weight is 0.75 and the grandfathering weight is 0.25. Consequently, developing countries would be given an enormous number of climate gas quotas that they would be able to sell to industrialized countries. This would lead to a large transfer of money from North to South.

Slide 8.3 Past/allocated CO2 emissions from 1860 to 2200



Source: Kolshus (2000)

While the burden sharing in the Kyoto Protocol to a large extent is based on past emissions (1990), the actual targets are the outcome of negotiations where both the Parties' different willingness to take on commitments and specific national circumstances played a role. It is now becoming clear that in the long run a more systematic approach to the issue of burden sharing will be imperative. In a joint project with the Netherlands Energy Research Foundation (ECN), CICERO has recently concluded a project that explores issues of burden sharing. The specific objective of this project was to develop a useful tool for negotiators in the next round of climate policy negotiations, that is, for agreeing on reduction commitments after the Kyoto Protocol period ending in 2012. After exploring relevant fairness principles, burden-sharing rules, and availability of data, a multi-sector convergence approach is developed. This approach is based on the per capita principle, but rather than first setting overall per capita based national targets, it sets standards on a sector basis and adjusts them over time so that per capita emissions in each sector become more alike on an international basis. Seven economic sectors are specified: power production, households, transportation, industry and manufacturing, service, agriculture, and waste. Each sector is allocated a non-binding emission target in per capita terms. For the base year 2010, a global sector emission standard is set equal to the world average per capita emissions of that sector. Thereafter an annual percentage reduction norm per sector is set so that all countries converge to the same national per capita emission level in some year, e.g. 2100. Some implications of the approach are found from calculating national costs for the second budget period (2013–17) for all industrialized countries. The results show that this approach can serve as a sound basis for facilitating future policy negotiations on differentiating emission limitation targets among a large variety of countries.

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