Attention: Phumla Nyamza

Tel: 021 403 3852

Fax: 086 504 6848

28 Pages

From: WWF (Laura Tyrer)

Tel: 011 262 9460

WWF South Africa
World Wide Fund For Nature
Reg. No: 003-226 NPO
VAT NO: 4820122481
Web: www.wwf.org.za

Head Office:
Millennia Park
16 Stellentia Avenue
STELLENBOSCH 7600
Private Bag X2
DIE BOORD 7613
Tel: +27 21 888 2800
Fax: +27 21 888 2888

Gauteng Office:
Pinmill Farm
Ground Floor, Block F
164 Katherine Street
SANDOWN 2031
Postnet Suite 436
Private Bag X9
BENMORE 2010
Tel: +27 11 262 9460
Fax: +27 11 262 9461

WWF for a living planet®

for attention: Joint Committees Climate Change Public Hearings
Portfolio Committee on Water and Environmental Affairs
Portfolio Committee on Science and Technology
Portfolio Committee on Rural Development and Land Reform
Portfolio Committee on Agriculture, Forestry and Fisheries
Portfolio Committee on Energy
Portfolio Committee on Tourism
Select Committee on Land and Environmental Affairs

Honourable Members

WWF's verbal submission to the Joint Committees Climate Change Public Hearings will cover South Africa's role in dealing with Climate Change, both domestically and internationally, including the nature of the response strategies we need to develop within our country, and contributions to inform our negotiating position at the upcoming Copenhagen talks.

WWF is helping to articulate a vision of people-centred low carbon development, a response to climate change which we believe combines advancing national social and economic development imperatives, and addressing the need to mitigate and adapt to climate change. Such an approach holds the potential of creating jobs, widespread social upliftment, resolving challenges around depleting resources, and achieving cuts in greenhouse gas emissions. For example, this includes targets like 15% of our electricity being supplied from renewable energy technologies by 2020, and water security programmes involving restoration of key catchments, river systems, improved wetland management. Strategies for social and ecological adaptation could be pursued through public works programmes, and investments that result in social, carbon, and ecosystem benefits.

Herewith executive summaries of the following WWF research reports, providing the global context for this low carbon vision, and which you may find useful in your deliberations:

- *Arctic Feedbacks Report*: the latest scientific findings on the state of Arctic ice, and a risk assessment of the global consequences, being runaway climate change.
- *Ecofys Carbon Budget*: a study working out the carbon constraints within which humans need to operate to limit global warming to below 2°C. A key component would be a carbon tax.
- *Climate Solutions II*: motivates the urgency of reindustrialisation to create low carbon development, and the potential this holds for positive social impacts and returns on investment.

WWF supports the South African lead agent in working for an inclusive, fair and effective treaty agreement to come out of the Copenhagen negotiations, with ambitious binding targets and strong democratic, implementation mechanisms.

Thank you for the opportunity to present to the Joint Committees Climate Change Public Hearings.

ECOFYS

Ecofys Germany GmbH
Am Wassermann 36
50829 Köln
Germany

W: www.ecofys.de
T: +49 (0) 221 270 70 100
F: +49 (0) 221 270 70 011
E: info@ecofys.de

Sharing the effort under a global carbon budget

Niklas Höhne
Sara Moltmann

24 August 2009

Commissioned by:
WWF International

PECSDE082855
PECPDE083519

Executive summary

Stringent global greenhouse gas emission reductions by all sectors and all countries will be necessary to keep global average temperature increase below 2°C. This report gives an overview of different methods to share the effort of reducing greenhouse gas emissions between countries to reach a given global carbon budget by 2100 in line with the 2°C limit.

First, we defined the carbon budget, which is the amount of tolerable global emissions over a period of time. Afterwards, we divided the available emission rights among countries according to different rules. To be consistent with the 2°C limit, for this report we assume CO_2eq emissions will have to be reduced by 30% compared to 1990 levels by 2030. By 2050 global emissions excluding those from land-use change and forestry (LUCF) need to be reduced by 80% compared to 1990. This leads to an emission budget of roughly 1800 GtCO_2eq between 1990 and 2100 excluding LUCF. Further, we assume that emissions from LUCF remain constant at about 4 GtCO_2 until 2010 and decline to zero by between 2010 and 2020. LUCF will become a stable net sink of emissions afterwards. By 2030 LUCF will remain at -4 GtCO_2. The global emission budget including LUCF will, thus, be about 1600 GtCO_2eq. This is the budget between 1990 and 2100. Until today and because mankind has already increased its global emissions substantively since 1990, the remaining net cumulative budget between 2009 and 2100 is limited to 870 GtCO2eq. This translates to an allowable global annual emission on average for the next 91 years of no more than 9.5 GtCO_2eq, or about 20% of today's annual net global emissions.

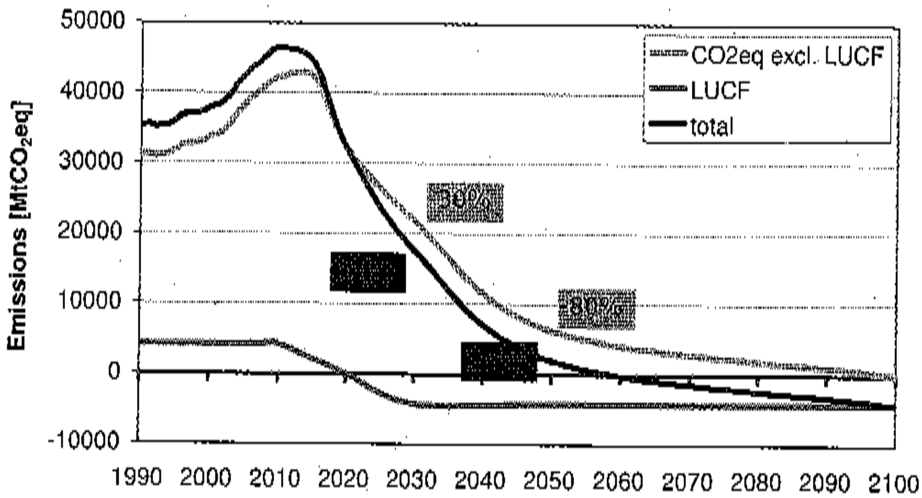


Figure 1. Possible global GHG emissions pathway between 1990 and 2100 according to a global carbon budget of about 1800 Mt CO_2eq (excl. LUCF) and 1600 Mt CO_2eq (incl. LUCF)

Under this strict emission budget, delay in reductions of only 5 years has significant consequences. Starting absolute global emission reductions around the year 2015 requires global average annual emissions reductions of about 5%, which already is very ambitious. Starting absolute global reduction in 2020 requires a global annual reduction of 8% after 2020.

The requirements to reach this are very stringent (see Figure 2). This is also reflected by the resulting target of about 0.5 tCO_2eq per capita as global average in 2050. In

2020 the average per capita emissions are around 9 tCO_2eq per capita for Annex I and 3-5 tCO_2eq per capita for non-Annex I.

We have shared the global emission budget using three methodologies, which are currently under discussion:

- Greenhouse Development Rights (GDRs): All countries need to reduce emissions below their business as usual path based on their responsibility (cumulative emissions) and capacity (GDP). Only emissions and GDP of the population above a development threshold account towards responsibility and capability.
- Contraction and Convergence (C&C): The targets for individual countries are set in such a way that per capita emission allowances converge from the countries' current levels to a level equal for all countries within a given period, here until 2050.
- Common but Differentiated Convergence (CDC): As above, targets are set so per capita emissions for all countries converge to an equal level over the period 2010 to 2050. For developed (Kyoto Protocol Annex I) countries' per capita emission allowances convergence starts immediately. For individual non-Annex I countries' per capita emissions convergence starts from the date when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average.

Generally, the Greenhouse Development Rights approach (GDRs) allows negative emissions where required reductions based on capacity and responsibility are larger than business as usual emissions. Contraction and Convergence (C&C) and Common But Differentiated Convergence (CDC) allow only very low but not negative emission levels. Therefore, Annex I emission targets go to -60% in 2020 under the GDRs, while the other approaches require around -40%.

Negative emission allowances (below 100% of base year) do not mean that the respective countries have to mitigate everything domestically. This is just a method of illustrating the equitable emissions allocations under this methodology. In reality it means that industrialised countries have to substantially support reducing emissions in developing countries via the carbon market, technology and/or funding etc.

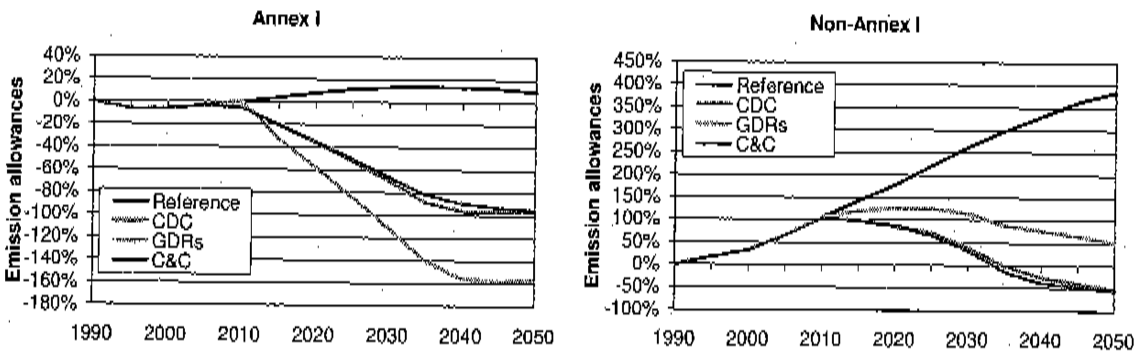


Figure 2. Development of emission allowances for Annex I countries and Non-Annex I countries between 1990 (0%) and 2050 under the effort sharing approaches CDC, GDRs and C&C

Developing countries in general and economies in transition (EITs) have more room to grow under GDRs than under the other approaches. The main reasons for this are the relatively low per capita emissions combined with limited financial capacity.

Least Developed Countries (LDCs) are almost all exempt from emission reduction requirements under GDRs, while under C&C they are granted little more allowances than their reference emissions until 2020 and face reduction obligations after 2025. Under CDC they face reductions after 2030.

Cumulative emissions per capita vary considerably under C&C and CDC for Annex I and non-Annex I. For GDRs some non-Annex I countries are even granted higher per capita cumulative emissions than some countries of Annex I.

Under GDRs, non-Annex I countries are allowed to increase their total emissions and peak until 2025 and then need to reduce them to roughly today's level in 2050 (about 50% above 1990). Under C&C and CDC there is less room for growth and their emissions need to be at a third of today's emissions (half of 1990's emissions). This is particularly reflected in the case of China and India. Both countries would be entitled under GDR to grow their emissions by 10% and even 240%, respectively, by 2050 compared to 1990, while being required to reduce by more than 70% and about 2-7% in the same period under the other two models.

Climate Solutions 2:
Low-Carbon Re-Industrialisation

A report to WWF International based on the Climate Risk Industry Sector Technology Allocation (CRISTAL) Model

Executive Summary

Climate Risk

Climate Risk Pty Ltd provides specialist professional services to business and government on risk, opportunity and adaptation to climate change.

Climate Risk

WWF

Climate Risk Pty Limited (Australia)
Sydney + 61 2 8243 5767
Brisbane + 61 7 3040 1621
www.climaterisk.net

Climate Risk Europe Limited
London: + 44 752 506 8331

This report was prepared by:

Dr. Karl Mallon
karl@climaterisk.com.au

Dr. Mark Hughes
mark@climaterisk.com.au

Sean Kidney
sean@climaterisk.net

Climate Solutions 2: Low-Carbon Re-Industrialisation

This report was commissioned by:

WWF-Australia
Level 13, 235 Jones Street
Ultimo NSW 2007
Australia
Tel: + 61 2 9281 5515
Fax: + 61 2 9281 1060

ISBN: 978-0-9804343-8-5

For WWF International correspondence:

Dr. Stephan Singer
Director, Global Energy Policy Program
WWF International
c/o WWF European Policy Office
168 Avenue de Tervueren
Brussels 1150
Belgium
Tel: + 32 2 743 8817
ssinger@wwfepo.org

Executive Summary

Re-Industrialising to a Low-Carbon Economy

This report models the ability of low-carbon industries to grow and transform within a market economy. It finds that runaway climate change is almost inevitable without specific action to implement low-carbon re-industrialisation over the next five years. The point of no return is estimated to be 2014.

Climate Solutions 2 recognises that every industry has constraints on its ability to grow caused by limitations of resources, technology, capital and the size and skills of its workforce.

These limits are measurable and make it possible to calculate, with considerable sophistication, the speed required to re-industrialise the energy and non-energy sectors to create a low-carbon economy in time to prevent runaway climate change.

Climate Solutions 2 accesses historical data and uses a variety of models to reach its conclusions. Two scenarios have been considered in this report:

- Emissions cuts of 63% relative to 1990 levels; and
- Emissions cuts of 80% relative to 1990 levels.

Under both scenarios, every key low-carbon resource and industry must be under their maximum rate of development by 2014. For the 63% reduction scenario, each of these resources and industries must grow at between 22% and 26% every year until they reach a scale that provides reasonable certainty of achieving the necessary global emissions levels by the mid-century.

In the second scenario, there is a significantly better chance of avoiding warming of 2°C if emissions levels are 80% below 1990 levels by 2050. However, to achieve this outcome requires the re-industrialisation process to commence immediately with growth rates of between 24% and 29% every year until deployment scale has been achieved. In addition, emissions abatements from the forestry and energy efficiency sectors must be at the upper end of what is technically possible.

The good news is that the resulting economies of scale from these low-carbon revolutions will create major long-term savings and returns when compared to the business-as-usual trajectory, especially in the energy sectors.

Where We Are Now

Higher Atmospheric Greenhouse Gas Levels than Expected

The current level of carbon dioxide in the atmosphere is 386 ppm (parts per million) while the total greenhouse gases are estimated to be 463 ppm (Tans 2009). This is precariously close to the approximate 475 ppm upper limit (for greenhouse gases) that current literature predicts makes it possible to return to a stable 400 ppm (Meinshausen 2006). Beyond this level, runaway climate change grows increasingly likely. At present, the rate of increase in atmospheric carbon dioxide has not yet begun to slow and, in fact, may be accelerating.

The Development of Low-Carbon Industry is Too Slow

This report clearly identifies that the key constraint to meeting emissions levels needed to prevent dangerous climate change is the speed at which the economy can make the transformation to low-carbon resources, industries and practices. Today, only three out of 20 industries are moving sufficiently fast enough.

There are Less Than Five Years to get Low-Carbon Re-Industrialisation Underway

To avoid major economic disruption, the report's modelling indicates that world governments have a window that will close between now and 2014. In that time they must establish fully operational, low-carbon industrial architecture. This must drive a low-carbon re-industrialisation that will be faster than any previous economic and industry transformation.

Carbon Trading Schemes, Alone, are Not a Sufficient Solution

By itself, an emissions trading scheme will not promote the growth of important but initially higher-cost technologies. A comprehensive plan for low-carbon industrial development is an integral part of the solution. If this window is missed then economically disruptive "command-and-control" style government intervention will be necessary to focus industrial production on the climate change challenge.

How to Achieve a Low-Carbon Economy

The Industries that will Lead the Way

Clean energy generation, energy efficiency, low-carbon agriculture and sustainable forestry must lead the transformation to a low-carbon economy. It is important to note that solutions that extract and store carbon from the atmosphere and biosphere, such as biomass energy production with carbon capture and storage (CCS), have not been used as part of the suite of resources in this report but are likely to be required at some stage if constraints on fuels can be resolved.

Rapid Expansion of Clean Industries

This report's modelling shows that to get key industries to a sufficient scale of deployment, from 2010 they will need to grow by 22% every year in the minus 63% scenario and by 24% every year in the minus 80% scenario to achieve the necessary cuts on 1990 levels. The scale of this re-industrialisation cannot be underestimated. Every year of delay will increase the level of growth required and increase costs.

Should re-industrialisation be delayed until 2014, low-carbon industries would need to sustain an annual growth rate of about 29% to have a greater than 50% chance of avoiding 2°C of global warming. This upper rate appears to be the limit of plausible sustained industrial growth, so further delays will tip the probability in favour of runaway climate change and its consequences.

Stable Investment Environments

Low-carbon re-industrialisation will require each government to create a secure, long-term investment environment to allow for major increases in the scale of production and installation of low-carbon technologies. This includes technologies and resources that will take two or more decades to reach commercial viability.

Investing in a Low-Carbon Economy — Costs and Returns

Long-Term Investment

Transforming to a low-carbon economy will require substantial investment in resources and infrastructure. Many of these investments will eventually become commercially viable in their own right.

The investment required to cover the additional cost of renewable energy relative to fossil fuel energy is about US$6.7 trillion in the minus 63% scenario and US$7.0 trillion in the minus 80% scenario. If the ongoing costs of CCS out to 2050 are also included, these costs would be increased by as much as US$10 trillion.

The modelling indicates that annual expenditure will peak at around US$375 billion a year in the minus 63% scenario and US$400 billion a year for the minus 80% scenario by 2025 and then start to decline. With sufficient up-front capital, energy efficiency measures will be cost-effective immediately or over a very short time period. Forest and CCS initiatives will require ongoing funding.

Since global agreements on emissions and carbon pricing are not yet in place, this report takes the conservative stance of applying no carbon pricing for the minus 63% or minus 80% scenarios.

Tipping Point into Profit

Within the period from 2013 to 2049, the average production cost of each renewable energy technology around the world is forecast to become cheaper than energy produced from their fossil fuel competition. In countries with high energy prices, this renewable energy cross-over will occur soonest.

Returns on Investment

Government, industry and institutional investors can expect to see the benefits of their investment in transforming the energy sector from 2013. This is the point when the first of the renewable energy technologies starts to outperform the current fossil fuel, business-as-usual model.

The scale of renewable energy savings from 2013 to 2050 is expected to be in excess of US$41 trillion for the minus 63% scenario and US$47 trillion for the minus 80% scenario.

Implications for Government, Industry and Investment

This report indicates that to avert runaway climate change, an international agreement on greenhouse emissions must be augmented by a program to rapidly develop a broad suite of low-carbon industries. This program must develop all low-carbon energy sectors concurrently – even those not initially profitable – and on an unprecedented scale. This means that:

- The private sector must be prepared for a massive scale-up of the low-carbon sector and not stand in the way of this transformation. It must deliver cost reductions through economies of scale.
- The investment community must commit tens of trillions of dollars, but can be rewarded with secure substantial long-term returns.
- Governments must create a stable long-term investment environment that fosters a secure market for all low-carbon industries and their investors.

Explanation of Major Findings

The Implications of an Upper Limit to Industrial Growth

A central axiom of the modelling in this report is that there are real-world limits to the rates at which companies and their industries can grow. In the energy sector, growth rates of less than 5% are typical. In the new, renewable energy sector, only a few industries have been able to sustain growth rates above 20% for long periods.

The real-world constraints to industrial growth include access to skilled people, access to resources, access to plant and machinery for manufacturing, installation and operation, and access to capital for both manufacturing and projects. Rapid growth can be just as hazardous for a company and industry as inadequate growth. Therefore, it is important when modelling the growth of low-carbon industries to establish a plausible upper limit of growth for companies and industries participating in a very rapid low-carbon re-industrialisation.

This upper limit reflects the point at which companies are likely to either fail due to excessive growth or turn away opportunities in order to maintain stability.

In this report, 30% annual average growth is considered to be the upper limit of sustained industry growth in a free market. Beyond this limit, the delivery of consistent growth is not plausible.

Under a "command and control" scenario – typically only observed during times of war – it may be possible to achieve annual growth rates slightly beyond 30% by forcing the reallocation of resources. However, since most renewable energy industries rely on specialised skills, equipment and materials, any benefits obtained by such forced resource reallocation are likely to be limited.

The 30% upper limit to industry growth used in this report reveals a very limited window of opportunity and, therefore, very little margin for policy error. Initially, delays in establishing low-carbon industries can be compensated by increases in the growth rate. However, at some stage these delays will no longer be able to be recovered by growth rate increases (when they reach their upper limit) and this will inevitably lead to delays in delivering

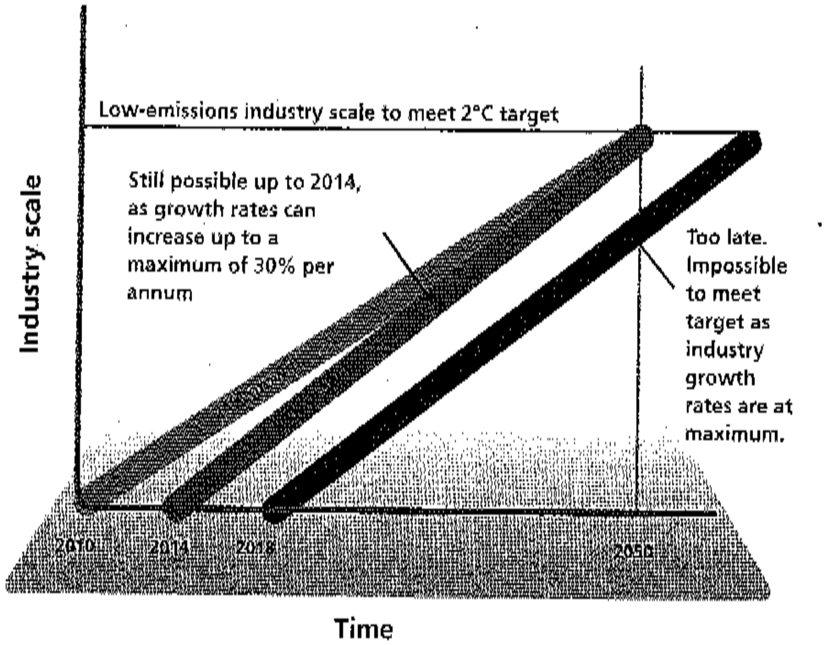


Figure 1: Missing the target. This schematic diagram illustrates that initial delays can be made up by increased growth rates. However, when the upper limits to growth are reached, further delays result in a shortfall in deployment in later years.

the low-carbon outcomes (see Figure 1). The consequence of such delays will be a failure to meet the cumulative and annual emissions reduction objectives needed to prevent runaway climate change.

The modelling indicates that it is still possible to achieve emissions levels that are 80% below 1990 levels by 2050. Reaching these levels creates a high probability of avoiding global warming of 2°C. To achieve an 80% reduction by 2050 requires immediate low-carbon industrial development growth rates of 24% every year until large-scale deployment has been achieved. At the same time, countries must maximise all plausible emissions abatement opportunities in the forestry sector and boost the adoption of energy efficiency measures.

This report finds that if re-industrialisation across all low-carbon sectors – including clean energy, forestry and agriculture – does not get underway until after 2014, then the probability of exceeding 2°C of warming and the risks of runaway climate change occurring will exceed 50%.

For all emissions abatement scenarios examined in this report, it is assumed that there are no major changes in population growth, GDP growth or fundamental lifestyle choices. If such activities were curtailed over the long-term, the low-carbon industry growth rate requirements reported here may be eased somewhat.

The Inadequacy of Trading/Carbon Price Alone

Should the development of low-carbon industries be unduly delayed, the constraints on industrial growth will create a situation where industrial production cannot respond to price signals from the market. That is, despite an increasing price for carbon, the industries most able to provide abatement at those prices will not be sufficiently developed or able to grow fast enough to meet the demand. They will be constrained by shortages of skills, materials and production output.

One foreseeable cause of delay is the exclusive use of price-based mechanisms like emissions trading. These mechanisms support the development of least-cost industries first, essentially fostering a sequential industrial development process.

This report compares a sequential development scenario with a concurrent development scenario. The comparison reveals that for the sequential approach, emissions levels in 2050 are more than double those in the concurrent case when using the same industry growth rates (see Figure 2).

Even if price-based mechanisms like emissions trading were accompanied by policies that ensured the sequential development of low-carbon industries, there would still be a need for investment in the early stages of development. Figure 3 shows that even for high carbon prices there is still a cost shortfall for low-carbon energy generation relative to that of fossil fuels that would need to be met by investment of some kind.

Investment and Returns

Changes in energy prices, driven by economies of scale, will be an intrinsic component of low-carbon re-industrialisation. For example, currently renewable energy technologies generally cost more than fossil fuel-based energy and are, therefore, priced out of the market. However, once renewable energy technologies are driven to larger scales, this situation reverses.

Since the fuels for renewable technologies (i.e. biomass, wind, sun, etc.) are obtained at zero or low cost, the core cost stems from building plants to extract that energy. Empirical evidence provides a reliable guide to the decline of future costs.

By contrast, fossil fuel costs are likely

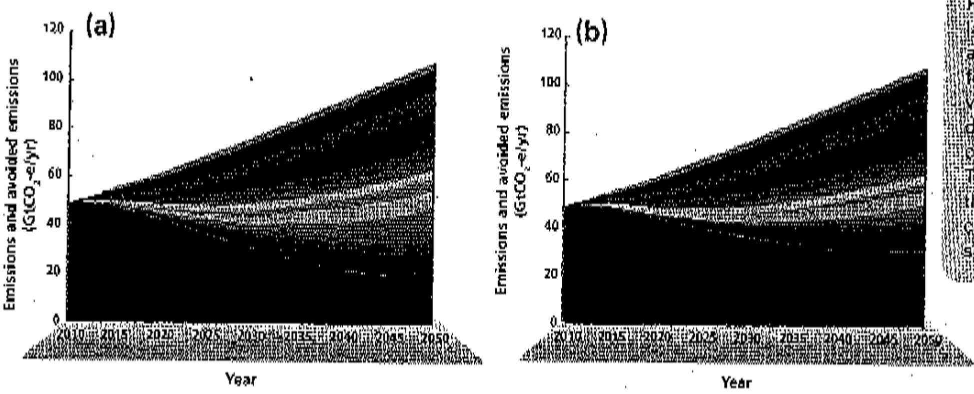


Figure 2: There is a large difference in the abatement outcomes for (a) concurrent versus (b) sequential development of low-carbon industries. This figure illustrates the difference in the case of the minus 63% scenario.

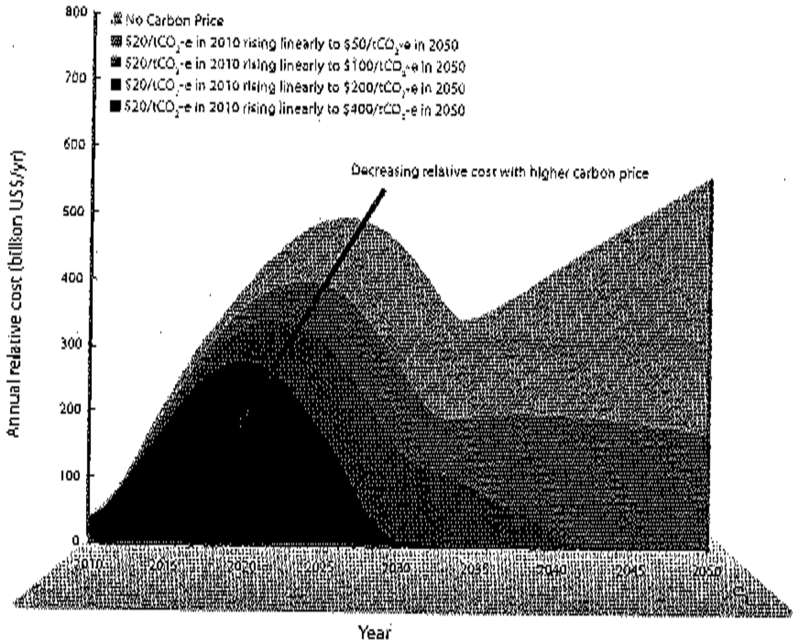


Figure 3: The impact of various carbon prices on the annual cost of low-emissions energy generation industries relative to fossil fuels in the minus 63% scenario. This annual relative cost approximates the amount of investment required for all low-carbon energy generation industries (including CCS). This figure shows that even high carbon prices do not overcome the interim cost-shortfall of low-carbon energy generation.

to increase in price due to rising fuel extraction costs and the cost of managing greenhouse gas pollution. *Climate Solutions 2* assumes that fossil fuel prices will increase by 2% every year but does not include a cost of carbon.

In this report, the point at which the first renewable energy industries, such as wind and small hydro power, start to create net savings is 2013 (assuming no retardation of learning rates). By 2049, all major renewable resources will be able to provide energy at, or below, those costs projected in the business-as-usual scenario. The final resources projected to cross the viability line are wave and ocean energy generation.

In many countries with higher energy prices, the savings will start being realised much earlier.

This presents a long-term investment picture in which short-term price support to achieve economies of scale is repaid with long-term returns from the cost savings (see Figure 4). This type of investment and return profile is most appropriate for institutional and pension fund investments. It may also lend itself to the use of "climate bonds" – structured by governments, investors and industry specifically to support this process.

Conclusions

The current trajectory of global greenhouse gas emissions is on course to trigger tipping elements that are forecast to unlock runaway climate change.

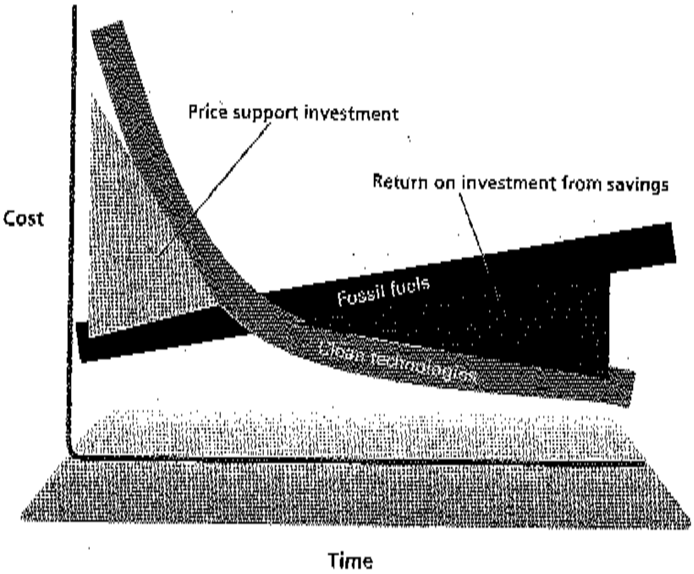


Figure 4: Short-term price support for renewable energy technologies to achieve economies of scale will result in long term cost savings.

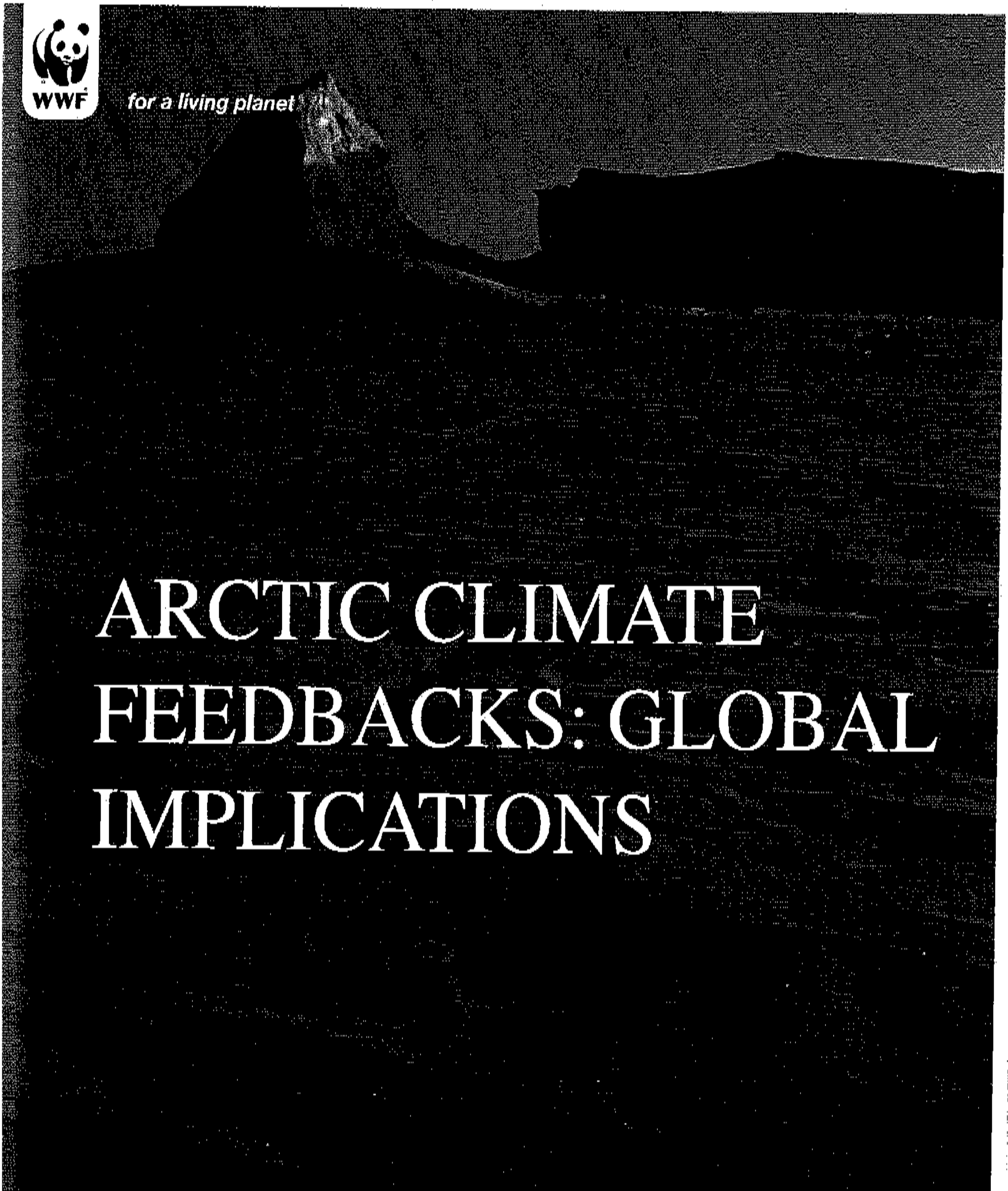
However, a small but rapidly closing window of opportunity remains to prevent this eventuality. This window is defined by the time needed to develop and deploy low-carbon industries at a scale that will prevent a 2°C rise in global temperatures. In order to proceed through this window of opportunity, the process of low-carbon re-industrialisation must be at full speed no later than 2014.

Beyond 2014, this report finds that there is a "point of no return", where market-based mechanisms cannot be expected to meet the abatement requirement. At this point, the probability of runaway climate change is considerably greater than the probability of keeping the global average temperature from rising more than 2°C.

This finding has important policy implications and opportunities.

- Policy implications: 24 critical low-carbon resources and industries will be needed to meet the required emissions target. This implies that schemes such as carbon pricing and trading – which foster development of one technology after another, with least-cost technologies being activated first – are not sufficient by themselves. Instead, international policy is required to simultaneously drive the worldwide ramping up of the full suite of low-carbon industries and practices identified in this report.

- Opportunities: The good news is that the resources, technologies and industries required for the transformation are all available; the rates of growth are plausible and the trillions of dollars of investment required are within the capacity of the institutional investment sector.



ARCTIC CLIMATE FEEDBACKS: GLOBAL IMPLICATIONS

OVER THE PAST FEW DECADES, the Arctic has warmed at about twice the rate of the rest of the globe. Human-induced climate change has affected the Arctic earlier than expected. As a result, climate change is already destabilising important arctic systems including sea ice, the Greenland Ice Sheet, mountain glaciers, and aspects of the arctic carbon cycle including altering patterns of frozen soils and vegetation and increasing methane release from soils, lakes, and wetlands. The impact of these changes on the Arctic's physical systems, biological systems, and human inhabitants is large and projected to grow throughout this century and beyond.

"Human-induced climate change has affected the Arctic earlier than expected"

In addition to the regional consequences of arctic climate change are its global impacts. Acting as the Northern Hemisphere's refrigerator, a frozen Arctic plays a central role in regulating Earth's climate system. A number of critical arctic climate feedbacks affect the global climate system, and many of these are now being altered in a rapidly warming Arctic. There is emerging evidence and growing concern that these feedbacks are beginning to accelerate global warming significantly beyond the projections currently being considered by policymakers. Recent observations strongly suggest that climate change may soon push some systems past tipping points, with global implications. For example, the additional heat absorbed by an increasingly ice-free Arctic Ocean in summer is already accelerating local and regional warming and preventing sea ice from recovering. There is also a concern that arctic feedbacks may increase regional or global warming significantly enough that it would alter other climate feedbacks.

"There is emerging evidence and growing concern that arctic climate feedbacks affecting the global climate system are beginning to accelerate warming significantly beyond current projections"

While the important role of the Arctic in the global climate system has long been recognized, recent research contributes much to the understanding of key linkages, such as the interactions between the Arctic Ocean and the atmosphere. At the same time, the science assessing the growing regional and global consequences of arctic climate impacts is rapidly maturing. In combination, these growing insights sharpen our awareness of how arctic climate change relates to global average warming, and what level of global warming may constitute dangerous human interference with the climate system. Avoiding such interference by stabilising atmospheric greenhouse gases at the necessary levels is the stated objective of the United Nations Framework Convention on Climate Change. Global feedbacks already arising from arctic climate change suggest that anything but the most ambitious constraints on greenhouse gas concentrations may not be sufficient to avoid such interference. This points to the need to continually incorporate the latest science in determining acceptable limits.

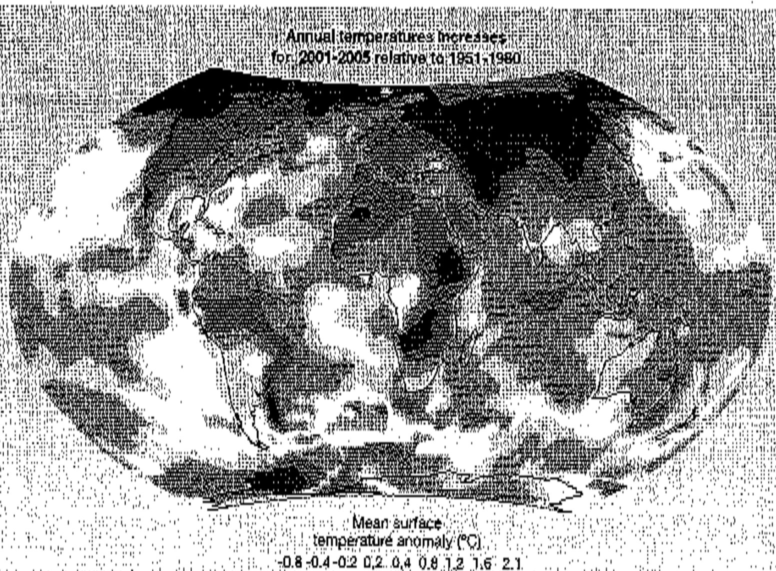
"Global feedbacks already arising from arctic climate change suggest that anything but the most ambitious constraints on greenhouse gas concentrations may not be sufficient to avoid dangerous interference with the climate system"

Climate change in the Arctic is affecting the rest of the world by altering atmospheric and oceanic circulation that affect weather patterns, the increased melting of ice sheets and glaciers that raise global sea level, and changes in atmospheric greenhouse gas concentrations (by altering release and uptake of carbon dioxide and methane). This report provides a comprehensive and up-to-date picture of why and how climate change in the Arctic matters for the rest of the world and is thus relevant for today's policy decisions regarding reductions in atmospheric greenhouse gases. In particular, the report describes the most recent findings regarding major arctic feedbacks of global significance for coming decades.

IN SUM, important aspects of the global climate system, which directly affect many people, are already seeing the effects of arctic climate change. This assessment of the most recent science shows that numerous arctic climate feedbacks will make climate change more severe than indicated by other recent projections, including those of the IPCC 2007 assessment. Some of these feedbacks may even interact with each other. Up-to-date analyses of the global consequences of arctic change highlight the need for ongoing critical review of the thresholds of dangerous human interference with the climate system, and demand increased rigour to stay below these thresholds through an ambitious global effort to reduce atmospheric greenhouse gases.

Arctic Climate Change

The Arctic climate feedbacks that are the focus of this report are taking place in the context of rapid and dramatic climate change in the Arctic. Rising temperatures, rapidly melting ice on land and sea, and thawing permafrost are among the sweeping changes being observed. The following is a brief summary of these changes that define the starting point for the discussion of arctic climate feedbacks and their implications for the world.



Source: Hansen, J., et al. *Global Temperature Changes*, Proc. Natl. Acad. Sci. 103. 2006.

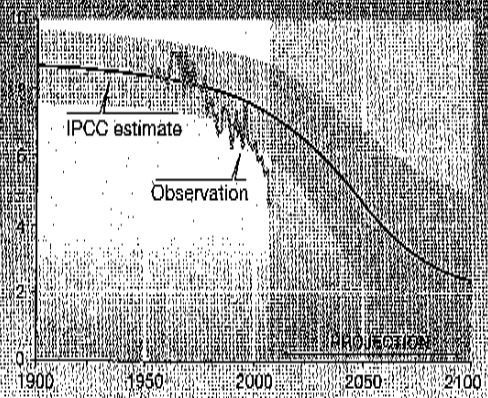
Air temperatures rising

Arctic air temperatures have risen at almost twice the rate of the global average rise over the past few decades. This "arctic amplification" of global warming is largely a result of reduced surface reflectivity associated with the loss of snow and ice, especially sea ice. The year 2007 was the warmest on record in the Arctic. Recent research has concluded that this warming contains a clear human "fingerprint". Precipitation is also increasing in the Arctic, and at a greater rate than the global average, an expected result of human-caused warming.

Sea ice declining

Sea ice extent has decreased sharply in all seasons, with summer sea ice declining most dramatically — beyond the projections of IPCC 2007. Nearly 40 per cent of the sea ice area that was present in the 1970s was lost by 2007 (the record low year for summer sea ice), and ice-free conditions existed in 2008 in both the Northeast and Northwest passages for the first time on record. Sea ice has also become thinner. Thick ice that persists for years (multi-year ice) has declined in extent by 42 per cent, or 1.5 million square kilometres, about the size of Alaska, between 2004 and 2008 alone. As this multi-year ice is replaced by young ice, arctic sea ice is becoming increasingly vulnerable to melting.

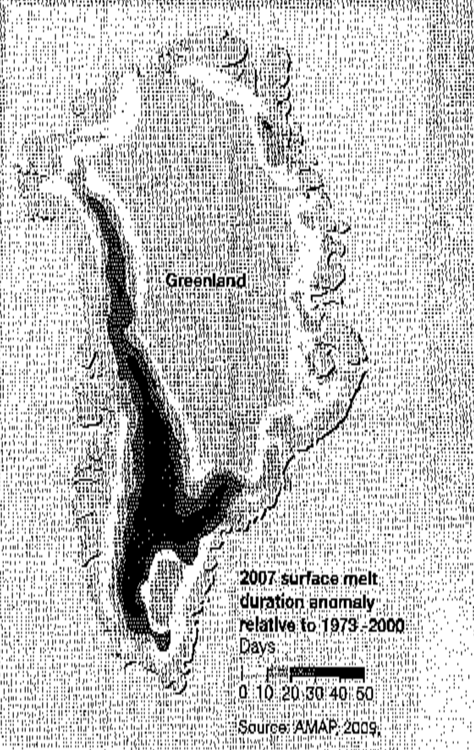
Minimum arctic summer sea-ice extent
Million square kilometres

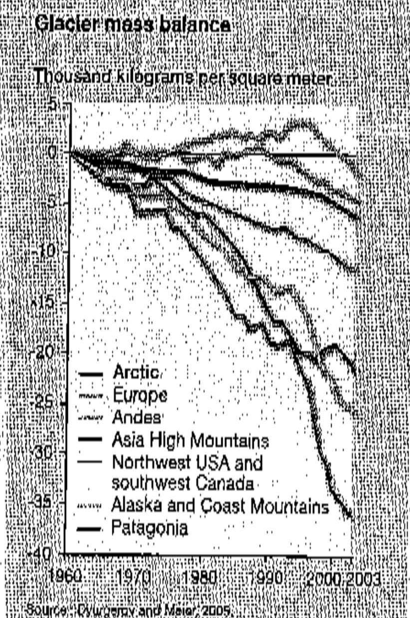


Source: Max Planck Institute for Meteorology.

Greenland Ice Sheet melting

The loss of ice from the Greenland Ice Sheet has increased in recent years and is more rapid than was projected by models. The faster flow of glaciers to the sea appears to be responsible for much of the increase in mass loss. In addition, melting on the surface of the ice sheet has been increasing, with 2007 melting being the most extensive since record keeping began. The area experiencing surface melt was 60 per cent larger than in 1998, the year with the second-largest area of melting in the record.





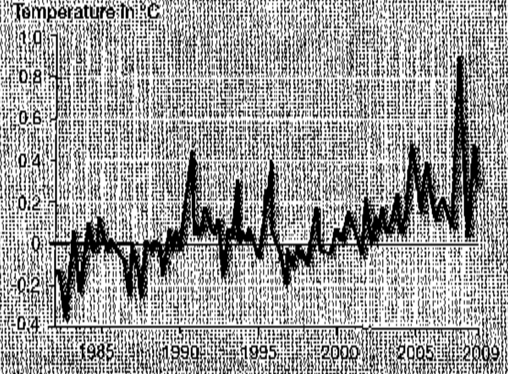
Glacier retreat accelerating

Glacier mass loss has been observed across the Arctic, consistent with the global trend. Some glaciers are projected to completely disappear in the coming decades. Alaska's glaciers are shrinking particularly rapidly. Until recent years, glaciers in Scandinavia were reported to be increasing in mass while those on Svalbard showed no net change as increased winter snowfall outpaced or equalled summer melting in those areas. This has reversed in recent years, with glaciers in both Scandinavia and on Svalbard now clearly losing mass.

Ocean surface warming

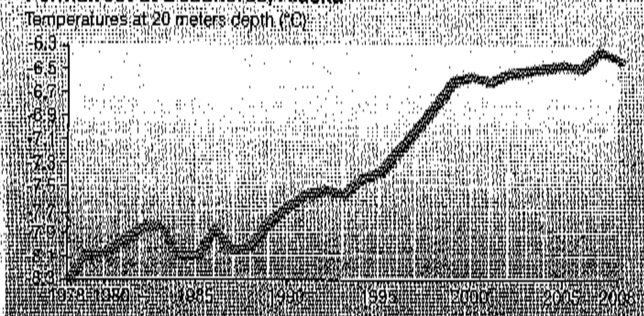
Consistent with the rapid retreat of sea ice, the surface waters of the Arctic Ocean have been warming in recent years, because declining sea-ice cover allows the water to absorb more heat from the sun. In 2007, some surface water ice-free areas were as much as 5°C higher than the long-term average. The Arctic Ocean has also warmed as a result of the influx of warmer water from the Pacific and Atlantic oceans.

Arctic Ocean surface temperatures



Source: NOAA 2009

Permafrost at Deadhorse, Alaska



Source: US Climate Impact Report 2009

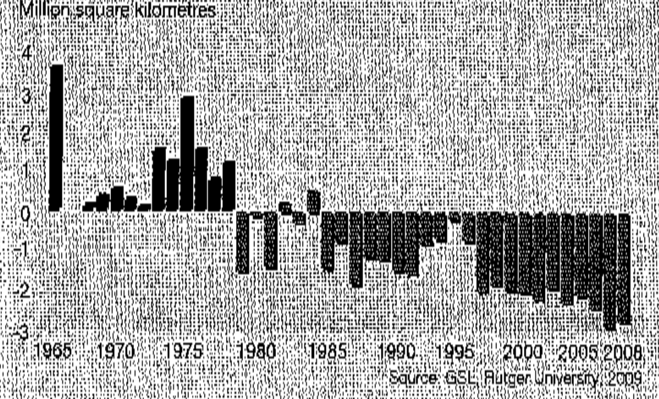
Permafrost warming and thawing

Permafrost has continued to warm and to thaw at its margins. The depth of the active layer, which thaws in the warm season, is increasing in many areas. Degrading permafrost is significantly affecting wetlands. Projections show widespread disappearance of lakes and wetlands even in formerly continuous permafrost zones.

Declining snow, river and lake ice

Snow cover extent has continued to decline and is projected to decline further, despite the projected increase in winter snowfall in some areas. The lengthening of the snow-free season has a major impact in accelerating local atmospheric heating by reducing the reflectivity of the surface. Ice cover duration on rivers and lakes has continued to decline. This is especially apparent in earlier spring ice break-up.

Anomalies in Northern Hemisphere Snow Cover



Source: GSL, Rutger University, 2009

Key Findings of this Assessment

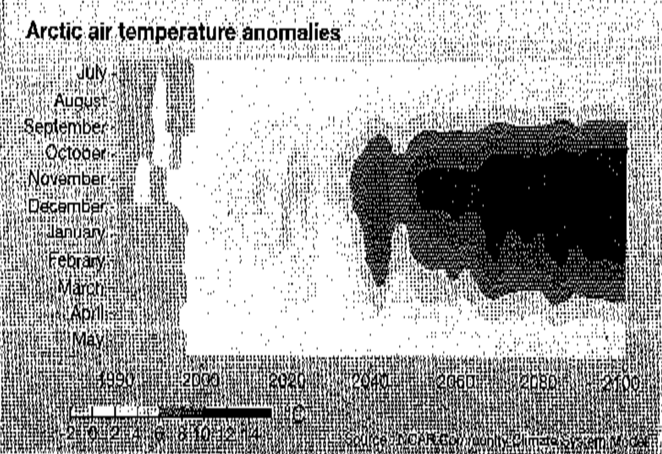
■ Amplification of global warming in the Arctic will have fundamental impacts on Northern Hemisphere weather and climate.

(Chapter 1: Atmospheric Circulation Feedbacks)

■ **Reduced sea ice amplifies warming.** Reduced sea ice cover is already amplifying warming in the Arctic earlier than projected. This amplification will become more pronounced as more ice cover is lost over the coming decades.

■ **Amplified warming spreads over land.** Amplified atmospheric warming in the Arctic will likely spread over high-latitude land areas, hastening degradation of permafrost, leading to increased release of greenhouse gases presently locked in frozen soils, leading to further arctic and global warming.

■ **Weather patterns are altered.** The additional warming in the Arctic will affect weather patterns in the Arctic and beyond by altering the temperature gradient in the atmosphere and atmospheric circulation patterns. It may also affect temperature and precipitation patterns in Europe and North America. These changes will affect agriculture, forestry and water supplies.



The global ocean circulation system will change under the strong influence of arctic warming.

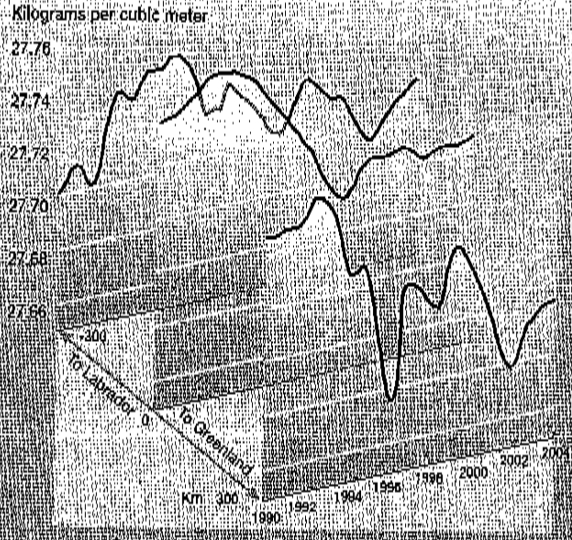
(Chapter 2. Ocean Circulation Feedbacks)

Changes in ocean circulation matter to people. From dramatic climate shifts to decade-to-decade climatic fluctuations, the oceans contribute to Earth's varying climate.

A changing Arctic can modify ocean circulation globally. By causing atmospheric changes that affect the ocean outside the Arctic, and through the direct ocean circulation connection between the Arctic Ocean and the global ocean, changes in the Arctic can alter the global ocean circulation.

The Arctic Ocean connections are changing. The Arctic Ocean is connected to the global ocean through the Atlantic and the Pacific Oceans. Water flowing into the Arctic Ocean from both the Pacific and Atlantic has warmed over the past decade. Although there has been an increase in freshwater input into the Arctic Ocean from melting ice and increased precipitation and river flows, so far there are few indications of an increase in freshwater export from the Arctic. Changes in temperature and salinity and their effects on density are among the concerns because of their potential to alter the strength of the global ocean circulation.

Potential density of Labrador Sea water at 200-800 m depth



Source: Yashayaev, I., *Progress in Oceanography*, Vol 73, 2007

Global ocean circulation will not change abruptly, but it will change significantly, in this century. There are only few indications that changes in the global overturning circulation are already occurring. However, it is likely that the circulation strength will change in the future. This assessment supports the IPCC 2007 projection of a 25 per cent average reduction of the overturning circulation by 2100.

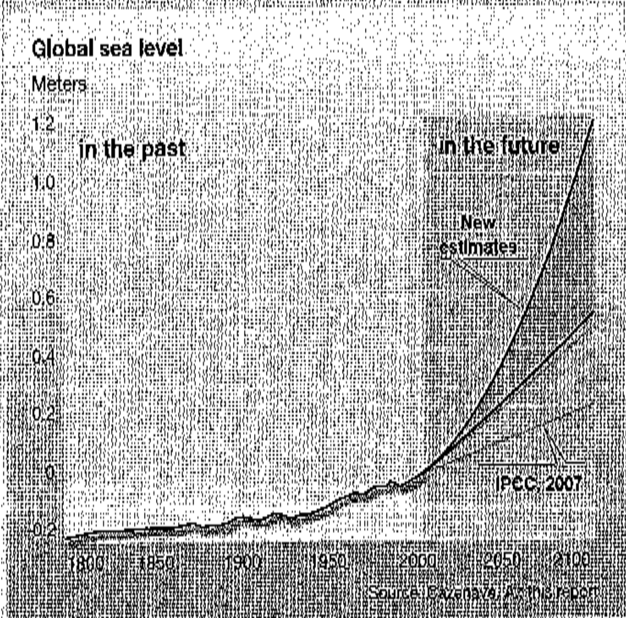
People are affected not only by changes in ocean circulation strength, but also by changes in circulation pathways. This assessment highlights the potential for currents in the North Atlantic Ocean to alter their paths. Different ocean currents transport waters with different characteristics, supporting different ecosystems. Therefore, changes in ocean circulation pathways will affect fisheries and other marine resources.

■ The loss of ice from the Greenland Ice Sheet has increased and will contribute substantially to global sea level rise.

(Chapter 3, Ice Sheets and Sea-level Rise Feedbacks)

■ **Sea-level rise is accelerating.** Sea level has been rising over the past 50 years, and its rate of rise has been accelerating. The rate of rise in the past 15 years is about double that of the previous decades.

■ **Thermal expansion and melting of land-based ice are driving sea-level rise.** Ocean warming and increased water inputs from melting glaciers and ice sheets are the primary contributors to sea-level rise. Over the past 15 years, thermal expansion, glacier melting and ice sheet mass loss have each contributed about one-third of the observed sea-level rise.



■ **The ice sheets are melting.** The ice sheets on Greenland and Antarctica are melting into the ocean faster than expected. Melt rates are sensitive to climate and are accelerating as both land and ocean temperatures rise.

■ **Ice sheet melt will be the major contributor to future sea-level rise.** With ongoing warming, ice sheet melting is projected to continue irreversibly on human timescales and will be the primary contributor to sea-level rise far into the future, well beyond this century.

■ **Sea level will rise more than previously expected.** Sea level will rise more than 1 metre by 2100, even more than previously thought, largely due to increased mass loss from the ice sheets. Increases in sea level will be higher in some areas than in others. Low-lying coastal areas around the world are at particular risk.

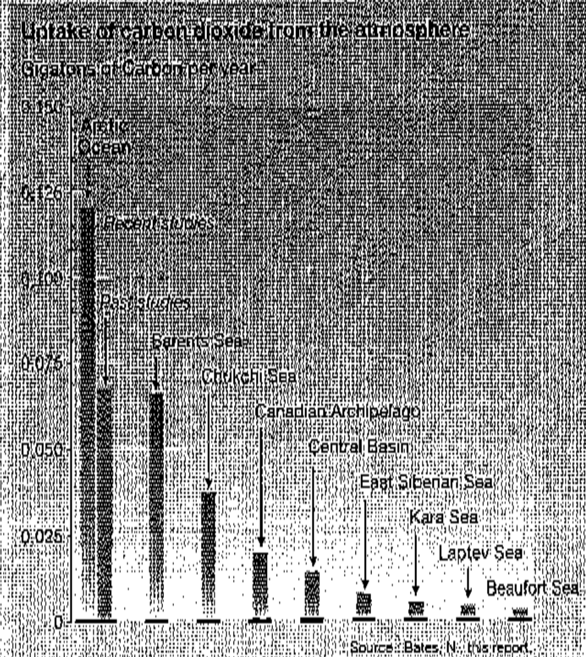
■ Arctic marine systems currently provide a substantial carbon sink but the continuation of this service depends critically on arctic climate change impacts on ice, freshwater inputs, and ocean acidification.

(Chapter 4, Marine Carbon Cycle Feedbacks)

■ **The Arctic Ocean is an important global carbon sink.** At present, the Arctic Ocean is a globally important net sink for carbon dioxide, absorbing it from the atmosphere. It is responsible for 5 to 14 per cent to the global ocean's net uptake of carbon dioxide.

■ **A short-term increase in carbon uptake by the Arctic Ocean is projected.** In the near-term, further sea-ice loss, increases in phytoplankton growth rates, and other environmental and physical changes are expected to cause a limited net increase in the uptake of carbon dioxide by arctic surface waters.

■ **In the long term, net release of carbon is expected.** Release of large stores of carbon from the surrounding arctic landmasses through rivers into the Arctic Ocean may reverse the short-term trend, leading to a net increase of carbon dioxide released to the atmosphere from these systems over the next few centuries.



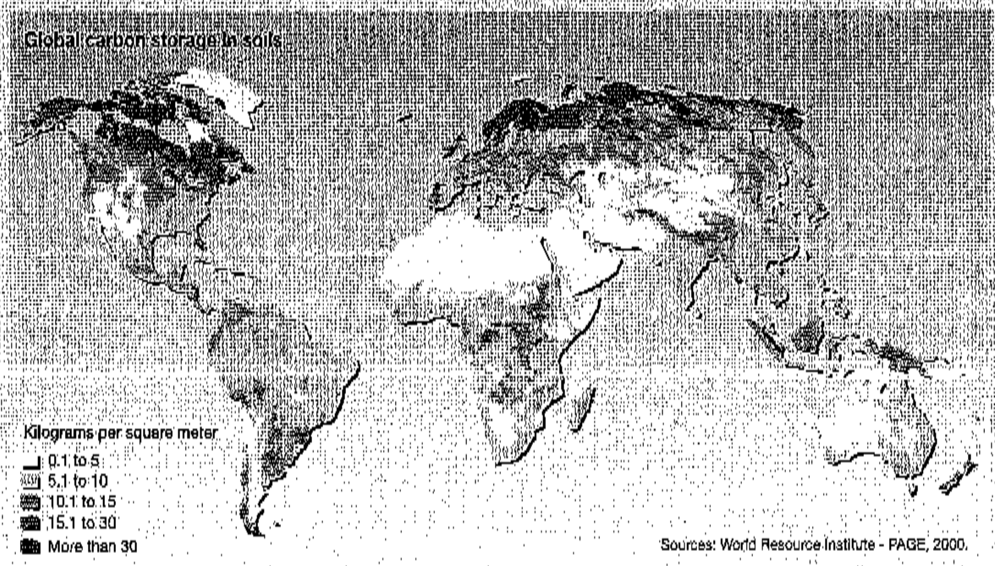
■ **The Arctic marine carbon cycle is very sensitive to climate change.** The Arctic marine carbon cycle and exchange of carbon dioxide between the ocean and atmosphere is particularly sensitive to climate change. The uptake and fate of carbon dioxide is highly influenced by physical and biological processes themselves subject to climate change impacts, such as sea ice cover, seasonal marine plant (such as phytoplankton) growth, ocean circulation and acidification, temperature effects, and river inputs, making projections uncertain.

■ Arctic terrestrial ecosystems will continue to take up carbon, but warming and changes in surface hydrology will cause a far greater release of carbon.

(Chapter 5, Land Carbon Cycle Feedbacks)

■ **Arctic lands store large amounts of carbon.** The northern circumpolar regions, including arctic soils and wetlands, contain twice as much carbon as in the atmosphere.

■ **Emissions of carbon dioxide and methane are increasing due to warming.** Current warming in the Arctic is already causing increased emissions of carbon dioxide and methane. Most of the carbon being released from thawing soils is thousands of years old, showing that the old organic matter in these soils is readily decomposed.



■ **Carbon uptake by vegetation is increasing.** Longer growing seasons and the slow northward migration of woody vegetation are causing increased plant growth and carbon accumulation in northern regions.

■ **Carbon emissions will outpace uptake as warming proceeds.** Future arctic carbon emissions to the atmosphere will outpace carbon storage, and changes in landscape will result in more of the sun's energy being absorbed, accelerating climate change.

■ The degradation of arctic sub-sea permafrost is already releasing methane from the massive, frozen, undersea carbon pool and more is expected with further warming.

(Chapter 6, Methane Hydrate Feedbacks)

■ **Large amounts of methane are frozen in arctic methane hydrates.** Methane is a powerful greenhouse gas. A large amount of methane is frozen in methane hydrates, which are found in ocean sediments and permafrost. There is more carbon stored in methane hydrates than in all of Earth's proven reserves of coal, oil and natural gas combined.

■ **Continental shelves hold most of this hydrate.** Most methane hydrates are stored in continental shelf deposits, particularly in the arctic shelves, where they are sequestered beneath and within the sub-sea permafrost. Since arctic hydrates are permafrost-controlled, they destabilize when sub-sea permafrost thaws.

■ **Thawing sub-sea permafrost is already releasing methane.** Current temperatures in the Arctic are already causing sub-sea permafrost to thaw. Thawed permafrost fails to reliably seal off the hydrate deposits, leading to extensive methane release into the ocean waters. Because of the shallow water depth of large portions of the Arctic shelves, much methane reaches the atmosphere un-oxidized (not changed to carbon dioxide). It is not yet known how much this release contributes to current global atmospheric methane concentrations. Methane is about 25 times more potent a greenhouse gas than carbon dioxide.

■ **Hydrates increase in volume when destabilized.** In addition, when methane hydrates destabilize, the methane within these hydrates increases tremendously in volume. The very high pressure that results may lead to abrupt methane bursts.

East Siberian Arctic Shelf, the most vulnerable fraction of the arctic shelf

Predicted hydrate deposits

Water depth <50 m

Source: Jacobsen et al. 2004.

■ **The most vulnerable hydrates are on the East Siberian Shelf.** The largest, shallowest, and thus most vulnerable fraction of methane deposits occurs on the East Siberian Shelf. Increased methane emissions above this shelf have been observed, but it is not yet known whether recent arctic warming is responsible for the increase in emissions.

ARCTIC CLIMATE FEEDBACKS:
GLOBAL IMPLICATIONS

Martin Sommerkorn & Susan Joy Hassol,
editors

With contributions from:
Mark C. Serreze & Julienne Stroeve
Cecilie Mauritzen
Anny Cazenave & Eric Rignot
Nicholas R. Bates
Josep Canadell & Michael Raupach
Natalia Shakhova & Igor Semiletov

Reviewed by:
David Carlson
Robert Corell

Published by
WWF International Arctic Programme
August, 2009

Cartography: GRID Arendal,
Riccardo Pravettoni in collaboration with
Laura Margueritte.
Editorial assistance: Marta Darby
Cover photo: Staffan Widstrand
Design: Ketill Berger, Film & Form