UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101-3140

REGIONAL ADMINISTRATOR

August 20, 2009

Peter E. Slaiby
Shell Alaska General Manager
Shell Exploration & Production, Inc.
3601 C Street, Suite 1000
Anchorage, Alaska 99503

Dear Mr. Slaiby:

This letter is in response to your August 4, 2009, letter to me raising concerns about EPA's processing of Shell's air permits for exploratory drilling in the Chukchi Sea and the Beaufort Sea. EPA recognizes your concerns and I want to reiterate that the Agency is working diligently on the permits. EPA and Shell share the common goal to have in place, as expeditiously as possible, legally defensible Outer Continental Shelf (OSC) / Prevention of Significant Deterioration (PSD) permits. Additionally, I have directed my staff to treat the Shell permitting efforts as the highest priority. Timely permit issuance is dependent upon the permit applicant submitting the necessary information to us in a timely and collaborative manner. As described below, project reconfigurations and late submittals on Shell's part have created a challenge for EPA.

Chukchi Sea Permit Application. Shell submitted its initial permit application for the Chukchi permit in December 2008. EPA sent two incompleteness determinations to Shell, dated January 16, 2009, and March 12, 2009, identifying additional information that was needed to process the permit application. Shell's formal submittal in response to the second incompleteness determination was submitted to EPA on May 18, 2009. Not until this submission did Shell conclusively define the ambient air boundary for the proposed activity. Because the air quality impact analysis is dependent upon the ambient boundary, Shell's timing in deciding the boundary significantly impeded the Agency's permit work. Although the application was still incomplete in other aspects after the May 18 submittal, EPA continued to work on the permit while continuing to reiterate our requests for additional information. After May 18, Shell submitted updated information on emissions to reflect changes in the project configuration and other aspects of the operation in support of requests for additional operational flexibility. Shell finally submitted the necessary background air quality data on July 27, 2009, along with other information requested related to your submittals under the Endangered Species Act. We issued a completeness determination for the Chukchi permit application on July 31, the date I committed to in my July 27, 2009, letter to you. EPA will be issuing a public notice for the proposed Chukchi Sea permit on August 20, 2009.

Beaufort Sea Permit Application. Your letter is not accurate regarding the Agency's response to the Beaufort Sea permit application. EPA issued a partial incompleteness determination letter on July 29, 2009, as I committed to doing in my July 27, 2009, letter to you. The determination was made following ongoing technical discussions with Shell and it specified additional information that was necessary to complete specified sections of the permit. Missing information included key elements such as an updated emission inventory and associated updates to the Best Available Control Technology (BACT) analyses, modeling and a potential to emit inventory for all regulated New Source Review (NSR) pollutants. We also expressed concern about the adequacy of ambient monitoring data. We met again with Shell's consultants on July 29, provided them with a signed copy of the letter, and discussed the permit issues with them at length. The timing for issuance of the Beaufort Sea permit depends on how quickly Shell submits the necessary missing information. We anticipate being able to issue a public notice for the proposed permit within approximately 10 weeks after we receive all of the necessary information from Shell. We continue to work on the project in the meantime and anticipate building on the work carried out for the Chukchi Sea permit, however there are additional requirements in the area of the Beaufort Sea that is subject to onshore area regulations. I look forward to our August 25th meeting to discuss the schedule for public notice of the Beaufort permit.

Permit writing resources and staffing. In an effort to expedite processing of Shell's permit applications, EPA has devoted considerable resources towards the Shell permits at the expense of other high priority Agency work. Although we do have staffing limitations, the permit applications are not processed by a "one person technical expert approach." Rather, there is a designated lead permit writer for each permit, who is supported by a team of Agency technical, legal, managerial and administrative personnel from within Region 10 and at EPA Headquarters. Additionally, EPA staff continue to consult with other federal agencies.

We appreciate your noting that the Alaska Department of Environmental Conservation (ADEC) has offered their assistance, and we do seek their assistance as appropriate. We have, for example, advised Shell that we will accept Shell's regional emissions inventory, derived from State-developed databases for sources they regulate, for the Beaufort Sea application if ADEC approves it. Nonetheless, there are limitations on how much EPA can rely on assistance from the State. The Beaufort Sea Exploration plan includes activity in areas subject to federal jurisdiction both more and less than 25 miles from the state's seaward boundaries. Accordingly, both the corresponding onshore area regulations and the federal regulations apply to the proposed activity. Pursuant to the federal regulation, the State does not have the authority to issue the permits in this instance, and EPA has an independent responsibility to carry out the development of permit terms and conditions.

Response to Comments. You expressed concern regarding the estimated time for EPA to respond to comments received on the proposed permit and offered to provide support or information necessary to respond to the public comments. As with the previous EPA OCS permits proposed for Shell, we anticipate considerable public interest in these permits and comments that raise technically and legally complex issues. I appreciate your offer to assist us in responding to the public comments; however, it is EPA's independent responsibility and obligation to consider and respond to the comments received. Throughout the public comment process Shell may certainly provide its own comments and additional information that it believes relevant to the issues that may be raised by other parties. I can assure you that we will respond to the comments and issue the final permit as expeditiously as possible.

PM2.5 issues. Your letter expressed concern about EPA's requirement to address PM2.5 in this application. The National Ambient Air Quality Standards (NAAQS) for PM2.5 were originally promulgated in 1997, and PSD permits issued by EPA or States since that date have been required to address compliance with the PM2.5 NAAQS. Until recently, EPA and States had the discretion to use PM10 as a surrogate for PM2.5 in PSD permitting. However, as of July 2008, EPA rescinded the surrogate policy for the federal PSD permitting programs, such that PSD permit applications needed to fully comply with all requirements for PM2.5 direct emissions and PM2.5 precursors (SO2 and NOx). EPA no longer utilizes the PM10 surrogate policy in any federal permitting action, including when we are implementing federal rules on the OCS that mirror the onshore PSD rules. The PSD permit application for the Chukchi project was initially submitted in December 2008 and the Beaufort application in May 2009, both well after the July 2008 effective date of EPA's PSD rulemaking. Shell's applications do indeed address emissions of PM2.5, as required. The remaining concern is the limited amount of ambient PM2.5 data; however, ambient air quality data is a requirement of PSD applications and this requirement is not unique to Shell.

Endangered Species Act (ESA) consultation. Finally you inquired as to the status of EPA's ESA consultation efforts. We are continuing our efforts related to complying with our obligations under the ESA and want to reassure you that our consultation efforts are proceeding on track. The Mineral Management Service has also consulted on Shell's oil exploration activities and serves as the lead agency for Shell's oil exploration activities and has consulted with the Services regarding the Chukchi and Beaufort Seas. EPA has had discussions with the Services regarding our specific permitting actions and we are currently researching the scientific literature for species impacts due to air quality, which we will use to formulate our determination.

As EPA is currently working on the Clean Air Act permits necessary for Shell to begin its exploratory drilling program in the Chukchi and Beaufort Seas, we also recognize that additional approvals or actions from other federal agencies are also required. For example, the Exploration Plans need to be approved, the letters of authorizations issued and the analysis completed regarding the lease sales as required by the DC Circuit Court of Appeals.

As you know, Shell's proposed exploratory drilling activity is the subject of considerable public interest. The proposed activity potentially affects a number of communities on the Alaska North Slope. We expect the Chukchi and Beaufort permits will receive careful scrutiny from a number of interested parties. EPA is working diligently to enhance coordination with affected communities and to issue technically sound, legally defensible permits as quickly as possible.

As stated above, I understand the urgency associated with these permits and assure you that the Agency is working diligently to issue technically sound, legally defensible permits in time for Shell's 2010 drilling program. We look forward to your cooperation and collaboration in the coming weeks and months as we continue our work.

Please feel free to give me a call if you any further questions.

Sincerely,

Michelle L. Pirzadeh
Acting Regional Administrator

cc: The Honorable Ken Salazar
Secretary, Department of Interior

The Honorable Lisa Murkowski
United States Senator, Alaska

The Honorable Mark Begich
United States Senator, Alaska

The Honorable Don Young
United States Representative, Alaska

The Honorable Seań Parnell
Governor, State of Alaska

Larry Hartig, Commissioner
Alaska Department of Environmental Conservation

Prevention of Significant Deterioration for PM2.5 - Increments, Significant Impact Levels and Significant Monitoring Concentrations

a.k.a. PSD for PM2.5 - Increments, Significant Impact Levels and Significant Monitoring Concentrations

RIN: 2060-AO24 (What's this?)

Docket No.: EPA-HQ-OAR-2006-0605 (What's this?)

Current Phase: Proposal (What's this?)

Abstract:
EPA is finalizing regulations under the Prevention of Significant Deterioration (PSD) program to establish new increments, significant impact levels (SILs) and a significant monitoring concentration (SMC) for fine particulate matter (particles with an aerometric diameter less than or equal to a nominal 2.5 micrometers, "PM2.5"). (More)

These regulations are consistent with section 166 of the Clean Air Act which authorizes the Environmental Protection Agency to establish regulations to prevent significant deterioration of air quality due to emissions of any pollutant for which National Ambient Air Quality Standards (NAAQS) have been promulgated. The NAAQS for PM2.5 were promulgated in 1997. To help facilitate the states' implementation of the preconstruction review permit process, this action will also establish screening tools (SILs and SMC) to determine when sources must complete analyses to satisfy specific requirements associated with the evaluation of PM2.5 impacts.

Timeline

Milestone	Date
Initiated	05/12/2006
NPRM: Sent to OMB for Regulatory Review	04/03/2007
NPRM: Received by OMB	05/22/2007
NPRM: Regulatory Review Concluded	07/03/2007
NPRM: Comment Period Open	09/21/2007
NPRM: Published in FR	09/21/2007
NPRM: Comment Period Closed	11/20/2007
NPRM: Comment Period Extension Published in FR	11/20/2007
NPRM: Comment Period Closed with Extension	01/21/2008
Final Rule: Sent to OMB for Regulatory Review	12/23/2009
Final Rule: Received by OMB	12/28/2009
Final Rule: Regulatory Review Concluded	03/18/2010
Final Rule: Published in FR	07/2010 (projected)

Potential Effects

Federal Government - other agencies
Likely to be regulated by this rule.
Likely to be involved in the implementation of this rule.

Local Governments
Likely to be regulated by this rule.
Likely to be involved in the implementation of this rule.

State Governments
Likely to be regulated by this rule.
Likely to be involved in the implementation of this rule.

Tribal Governments
Likely to be regulated by this rule.
Likely to be involved in the implementation of this rule.

Participate in This Rulemaking

Tell Us What You Think About the Gateway

Visit our discussion forum to submit your comments about the Rulemaking Gateway

More Regulatory Information

Please Note:
The Rulemaking Gateway focuses on priority rules that are currently under development. For more comprehensive regulatory information, visit the Related Links page.

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Contact us about this rule.

Learn More

Regulatory Review

Some of EPA's rulemakings undergo regulatory review (What's this?), as prescribed by Executive Order 12866 and coordinated by the Office of Management and Budget (OMB). The following list describes which of this rulemaking's stages have completed review and published in the Federal Register, if any, and provides links to the review documents where available. Consult the "Timeline" section of this Web page for the dates of each review.

- **NPRM** - This stage of the rulemaking underwent review. Click on the following link(s) to see how the rule changed as a result of review:
  - Documentation of changes made during review

- **Final Rule** - No Information Available.

Citations & Authorities

***Federal Register* Citations**

- **NPRM:** 72 FR 54112
- **NPRM Comment Period Extension:** 72 FR 65282

Code of Federal Regulations (CFR) Citation
40 CFR 52.21;40 CFR 51.166

Legal Authority
42 USC 7410;42 USC 7470-7479;42 USC 7501-7503;42 USC 7601(a)(1)

Last updated on Thursday, April 22, 2010.

Exhibit 28
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

OFFICE OF
GENERAL COUNSEL

September 9, 2008

Ms. Eurika Durr
Clerk of the Board
U.S. Environmental Protection Agency
1341 G Street NW, Suite 600
Washington, DC 20005

Re: Deseret Power Electric Cooperative, PSD Appeal No. 07-03

Dear Ms. Durr:

In consideration of the information and argument submitted in this case by the EPA Office of General Counsel (OGC) on behalf of the EPA Office of Air Radiation (OAR) and EPA Region 8, these offices believe that it is incumbent on them, in recognition of a duty of candor, to inform the Board of a recent action by the Agency that the Board may find relevant in its deliberations over the issue on which the Board granted review in this matter. OAR, Region 8, and OGC have recently learned that on April 29, 2008, EPA Region 3 issued a final approval of a Delaware State Implementation Plan (SIP) revision incorporating state regulations which include specific limitations on the rate of several pollutants, including carbon dioxide, that may be emitted by stationary generators in that state. *See* 73 Fed. Reg. 23101 (April 29, 2008); DNREC Regulation No. 1144 (January 11, 2006) (enclosed). Consistent with the arguments submitted on behalf of OAR and Region 8 in this case, these offices do not believe such action should influence the Board's decision in this case concerning a PSD permit issued prior to April 29, 2008 in another jurisdiction. *See* Response of EPA Office of Air and Radiation and Region VIII (filed March 21, 2008) at 53 n.21. Moreover, OAR is considering whether Region 3's approval of this aspect of the SIP submission was appropriate. Nevertheless, given the Board's careful review of the important issue before it in this matter, we wish to ensure that the Board is aware of this intervening activity by the Agency that the Board might consider relevant in its deliberations.

Sincerely,

Brian L. Doster

Brian L. Doster
Air and Radiation Law Office

Enclosures
cc: Counsel of Record

CERTIFICATE OF SERVICE

I hereby certify that copies of the attached letter were served on the following persons:

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Brian L. Doster

Brian L. Doster

Climate Change 2007: Synthesis Report

Summary for Policymakers

An Assessment of the Intergovernmental Panel on Climate Change

This summary, approved in detail at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Fourth Assessment Report.

Based on a draft prepared by:

Lenny Bernstein, Peter Bosch, Osvaldo Canziani, Zhenlin Chen, Renate Christ, Ogunlade Davidson, William Hare, Saleemul Huq, David Karoly, Vladimir Kattsov, Zbigniew Kundzewicz, Jian Liu, Ulrike Lohmann, Martin Manning, Taroh Matsuno, Bettina Menne, Bert Metz, Monirul Mirza, Neville Nicholls, Leonard Nurse, Rajendra Pachauri, Jean Palutikof, Martin Parry, Dahe Qin, Nijavalli Ravindranath, Andy Reisinger, Jiawen Ren, Keywan Riahi, Cynthia Rosenzweig, Matilde Rusticucci, Stephen Schneider, Youba Sokona, Susan Solomon, Peter Stott, Ronald Stouffer, Taishi Sugiyama, Rob Swart, Dennis Tirpak, Coleen Vogel, Gary Yohe

Exhibit 30
AEWC & ICAS

Introduction

This Synthesis Report is based on the assessment carried out by the three Working Groups of the Intergovernmental Panel on Climate Change (IPCC). It provides an integrated view of climate change as the final part of the IPCC's Fourth Assessment Report (AR4).

A complete elaboration of the Topics covered in this summary can be found in this Synthesis Report and in the underlying reports of the three Working Groups.

1. Observed changes in climate and their effects

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (Figure SPM.1). *{1.1}*

Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]°C[1] is larger than the corresponding trend of 0.6 [0.4 to 0.8]°C (1901-2000) given in the Third Assessment Report (TAR) (Figure SPM.1). The temperature increase is widespread over the globe and is greater at higher northern latitudes. Land regions have warmed faster than the oceans (Figures SPM.2, SPM.4). *{1.1, 1.2}*

Rising sea level is consistent with warming (Figure SPM.1). Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear. *{1.1}*

Observed decreases in snow and ice extent are also consistent with warming (Figure SPM.1). Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. Mountain glaciers and snow cover on average have declined in both hemispheres. *{1.1}*

From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has *likely*[2] increased since the 1970s. *{1.1}*

It is *very likely* that over the past 50 years: cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent. It is *likely* that: heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level[3] has increased worldwide. *{1.1}*

There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones. It is difficult to ascertain longer-term trends in cyclone activity, particularly prior to 1970. *{1.1}*

Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1300 years. *{1.1}*

Observational evidence[4] from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. *{1.2}*

Changes in snow, ice and frozen ground have with *high confidence* increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems. *{1.2}*

There is *high confidence* that some hydrological systems have also been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers and through effects on thermal structure and water quality of warming rivers and lakes. *{1.2}*

In terrestrial ecosystems, earlier timing of spring events and poleward and upward shifts in plant and animal ranges are with *very high confidence* linked to recent warming. In some marine and freshwater systems, shifts in ranges and changes in algal, plankton and fish abundance are with *high confidence* associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation. *{1.2}*

Of the more than 29,000 observational data series, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming (Fig-

[1] Numbers in square brackets indicate a 90% uncertainty interval around a best estimate, i.e. there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Uncertainty intervals are not necessarily symmetric around the corresponding best estimate.

[2] Words in italics represent calibrated expressions of uncertainty and confidence. Relevant terms are explained in the Box 'Treatment of uncertainty' in the Introduction of this Synthesis Report.

[3] Excluding tsunamis, which are not due to climate change. Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[4] Based largely on data sets that cover the period since 1970.

Exhibit 30
AEWC & ICAS

Changes in temperature, sea level and Northern Hemisphere snow cover

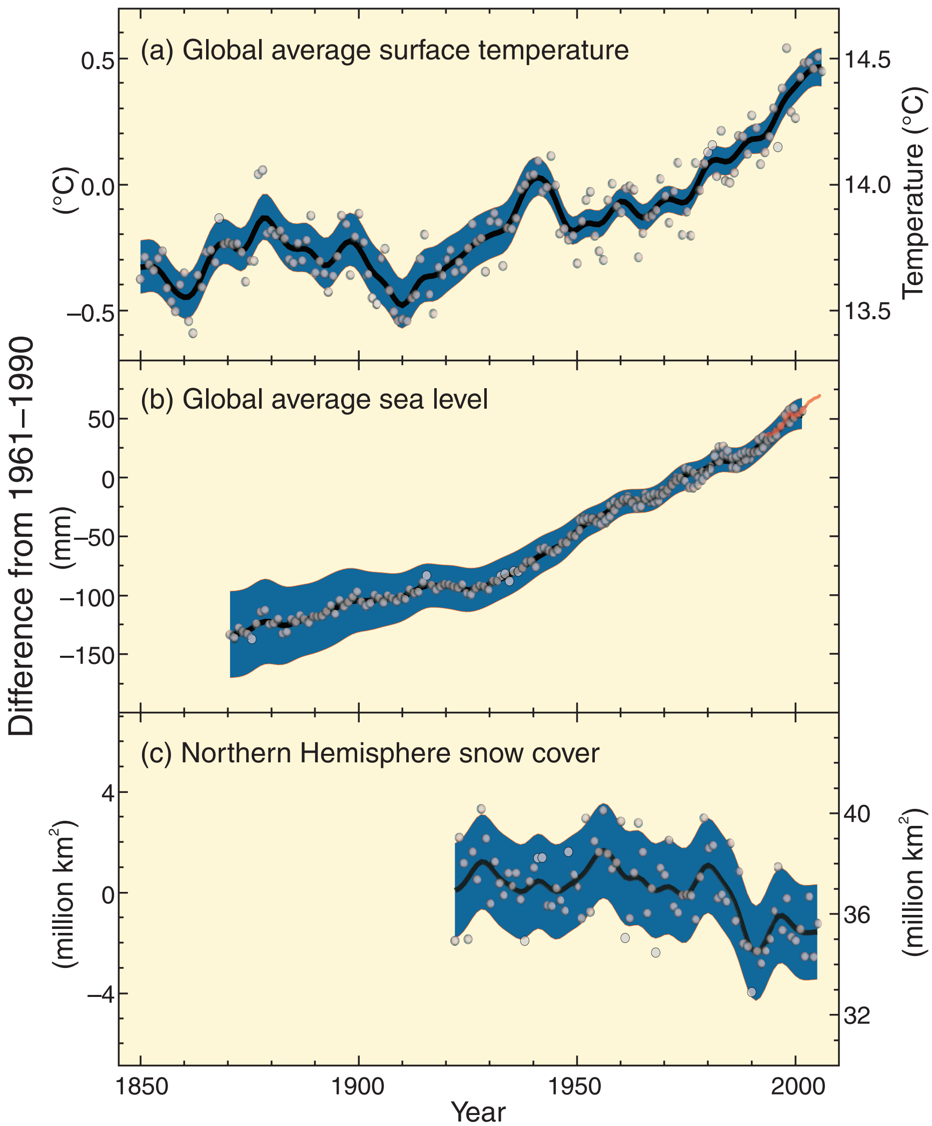

Figure SPM.1. *Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {Figure 1.1}*

ure SPM.2). However, there is a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries. *{1.2, 1.3}*

There is *medium confidence* that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers. *{1.2}*

They include effects of temperature increases on: *{1.2}*

- agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests
- some aspects of human health, such as heat-related mortality in Europe, changes in infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes
- some human activities in the Arctic (e.g. hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports).

Exhibit 30
AEWC & ICAS

Changes in physical and biological systems and surface temperature 1970-2004

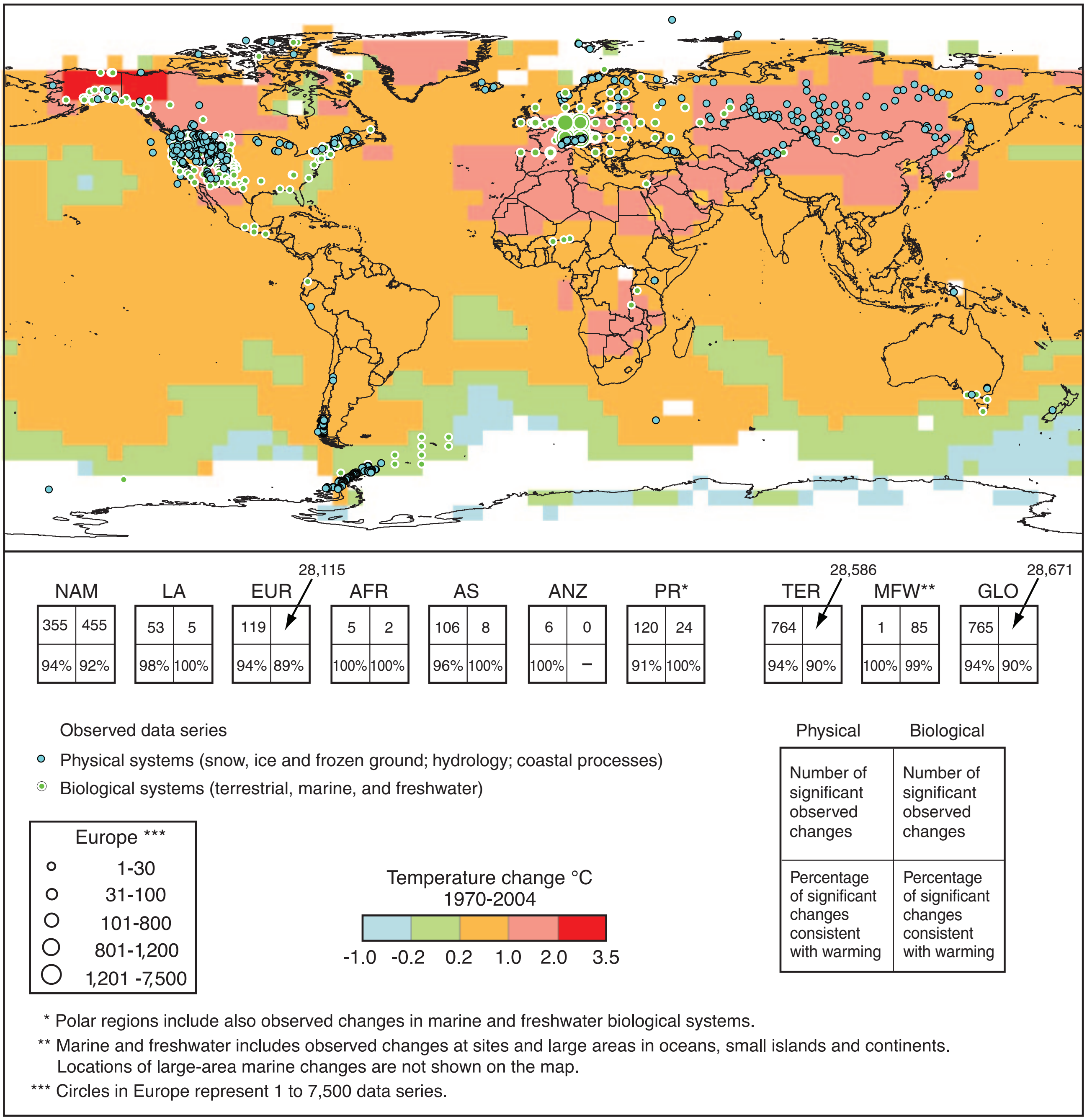

Figure SPM.2. *Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which about 70 are new since the TAR) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 × 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, EUR, AFR, AS, ANZ, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFW) systems. Locations of large-area marine changes are not shown on the map. {Figure 1.2}*

Exhibit 30
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2. Causes of change

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system. *{2.2}*

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Figure SPM.3).[5] *{2.1}*

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000. *{2.1}*

Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. *{2.2}*

Atmospheric concentrations of CO_2 (379ppm) and CH_4 (1774ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. CH_4 growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N_2O concentration is primarily due to agriculture. *{2.2}*

There is *very high confidence* that the net effect of human activities since 1750 has been one of warming.[6] *{2.2}*

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations.[7] It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (Figure SPM.4). *{2.4}*

During the past 50 years, the sum of solar and volcanic forcings would *likely* have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales. *{2.4}*

Global anthropogenic GHG emissions

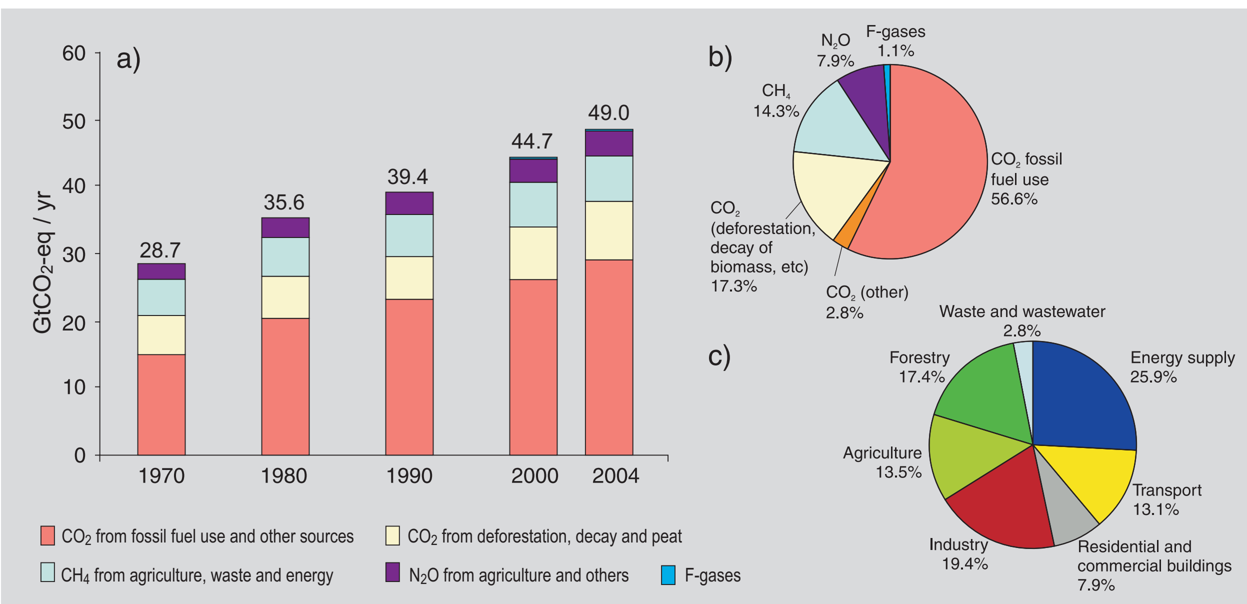

Figure SPM.3. *(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.[5] (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalents (CO_2-eq). (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation.) {Figure 2.1}*

[5] Includes only carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6), whose emissions are covered by the United Nations Framework Convention on Climate Change (UNFCCC). These GHGs are weighted by their 100-year Global Warming Potentials, using values consistent with reporting under the UNFCCC.

[6] Increases in GHGs tend to warm the surface while the net effect of increases in aerosols tends to cool it. The net effect due to human activities since the pre-industrial era is one of warming (+1.6 [+0.6 to +2.4] W/m²). In comparison, changes in solar irradiance are estimated to have caused a small warming effect (+0.12 [+0.06 to +0.30] W/m²).

[7] Consideration of remaining uncertainty is based on current methodologies.

Exhibit 30
AEWC & ICAS

Global and continental temperature change

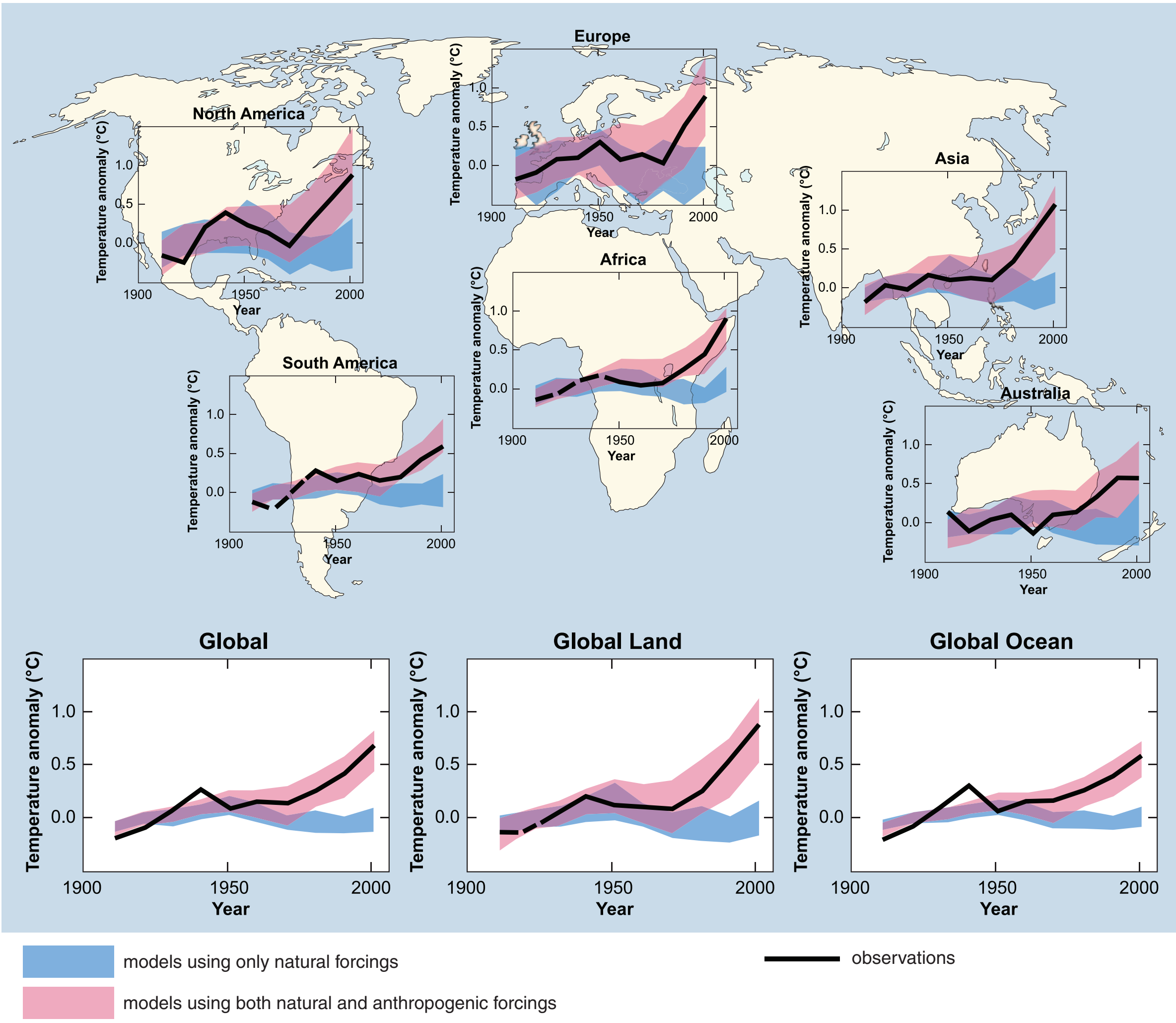

Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for the period 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5 to 95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5 to 95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {Figure 2.5}*

Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate. *{2.4}*

Human influences have: *{2.4}*

- *very likely* contributed to sea level rise during the latter half of the 20th century
- *likely* contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- *likely* increased temperatures of extreme hot nights, cold nights and cold days
- *more likely than not* increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.

Anthropogenic warming over the last three decades has *likely* had a discernible influence at the global scale on observed changes in many physical and biological systems. *{2.4}*

Spatial agreement between regions of significant warming across the globe and locations of significant observed changes in many systems consistent with warming is *very unlikely* to be due solely to natural variability. Several modelling studies have linked some specific responses in physical and biological systems to anthropogenic warming. *{2.4}*

More complete attribution of observed natural system responses to anthropogenic warming is currently prevented by the short time scales of many impact studies, greater natural climate variability at regional scales, contributions of non-climate factors and limited spatial coverage of studies. *{2.4}*

Exhibit 30
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3. Projected climate change and its impacts

There is *high agreement* and *much evidence* that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. *{3.1}*

The IPCC Special Report on Emissions Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25 to 90% (CO_2-eq) between 2000 and 2030 (Figure SPM.5), with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range.[8,9] *{3.1}*

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century (Table SPM.1, Figure SPM.5). *{3.2.1}*

For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios. *{3.2}*

The range of projections (Table SPM.1) is broadly consistent with the TAR, but uncertainties and upper ranges for temperature are larger mainly because the broader range of available models suggests stronger climate-carbon cycle feedbacks. Warming reduces terrestrial and ocean uptake of atmospheric CO_2, increasing the fraction of anthropogenic emissions remaining in the atmosphere. The strength of this feedback effect varies markedly among models. *{2.3, 3.2.1}*

Because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise. Table SPM.1 shows model-based projections

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

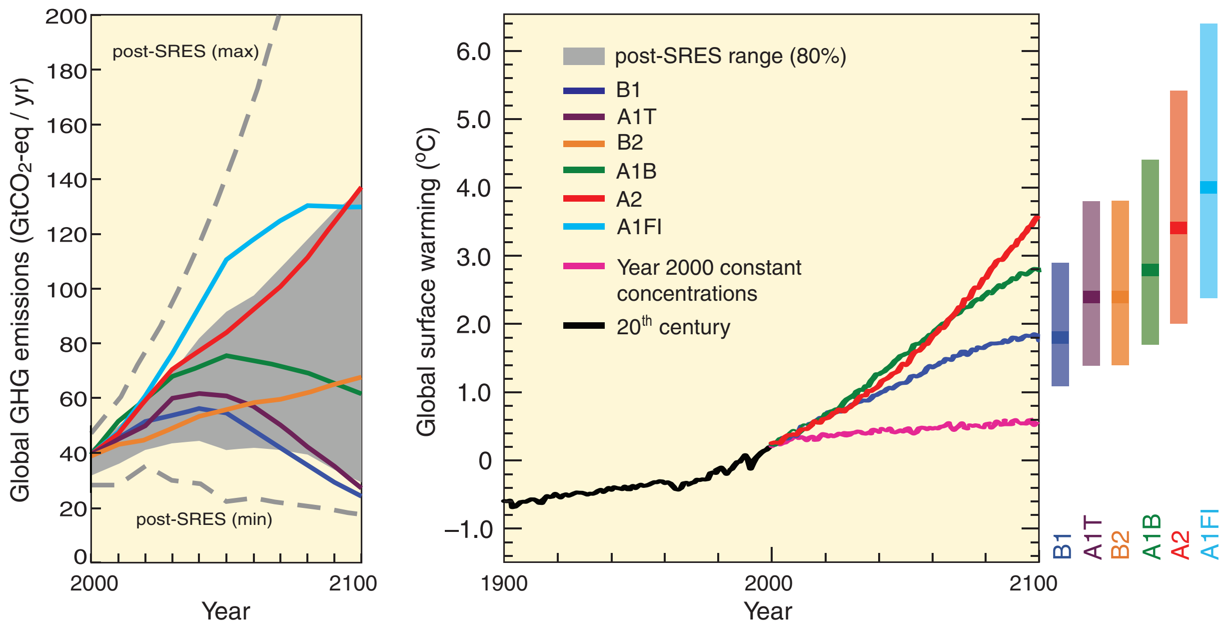

Figure SPM.5. ***Left Panel:*** *Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases.* ***Right Panel:*** *Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the* likely *range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999. {Figures 3.1 and 3.2}*

[8] For an explanation of SRES emissions scenarios, see Box 'SRES scenarios' in Topic 3 of this Synthesis Report. These scenarios do not include additional climate policies above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

[9] Emission pathways of mitigation scenarios are discussed in Section 5.

Exhibit 30
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Table SPM.1. *Projected global average surface warming and sea level rise at the end of the 21st century. {Table 3.1}*

Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Notes:
a) Temperatures are assessed best estimates and *likely* uncertainty ranges from a hierarchy of models of varying complexity as well as observational constraints.
b) Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only.
c) All scenarios above are six SRES marker scenarios. Approximate CO_2-eq concentrations corresponding to the computed radiative forcing due to anthropogenic GHGs and aerosols in 2100 (see p. 823 of the Working Group I TAR) for the SRES B1, AIT, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1550ppm, respectively.
d) Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899 add 0.5°C.

of global average sea level rise for 2090-2099.[10] The projections do not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise. They include a contribution from increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, but this could increase or decrease in the future.[11] *{3.2.1}*

There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and sea ice. ***{3.2.2}***

Regional-scale changes include: *{3.2.2}*

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends (Figure SPM.6)
- contraction of snow cover area, increases in thaw depth over most permafrost regions and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century
- *very likely* increase in frequency of hot extremes, heat waves and heavy precipitation
- *likely* increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation and temperature patterns
- *very likely* precipitation increases in high latitudes and *likely* decreases in most subtropical land regions, continuing observed recent trends.

There is *high confidence* that by mid-century, annual river runoff and water availability are projected to increase at high latitudes (and in some tropical wet areas) and decrease in some dry regions in the mid-latitudes and tropics. There is also *high confidence* that many semi-arid areas (e.g. Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. *{3.3.1, Figure 3.5}*

Studies since the TAR have enabled more systematic understanding of the timing and magnitude of impacts related to differing amounts and rates of climate change. ***{3.3.1, 3.3.2}***

Figure SPM.7 presents examples of this new information for systems and sectors. The top panel shows impacts increasing with increasing temperature change. Their estimated magnitude and timing is also affected by development pathway (lower panel). *{3.3.1}*

Examples of some projected impacts for different regions are given in Table SPM.2.

[10] TAR projections were made for 2100, whereas the projections for this report are for 2090-2099. The TAR would have had similar ranges to those in Table SPM.1 if it had treated uncertainties in the same way.

[11] For discussion of the longer term, see material below.

Geographical pattern of surface warming

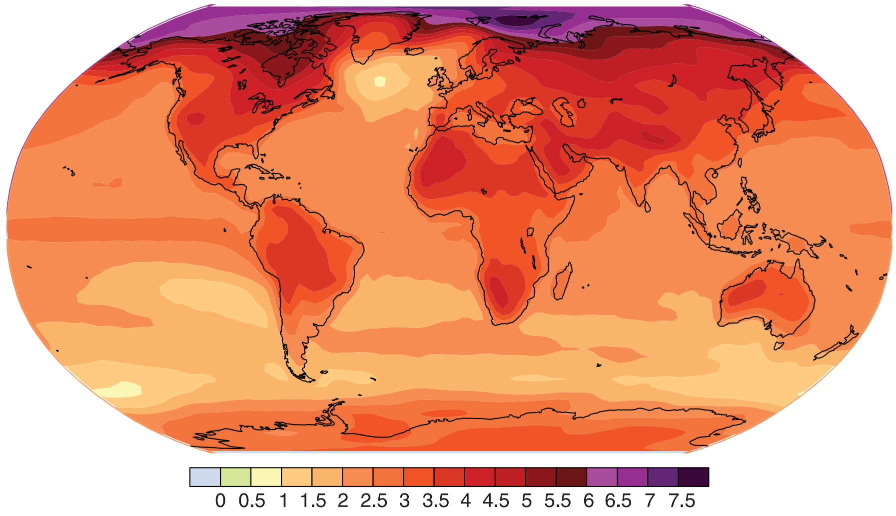

Figure SPM.6. *Projected surface temperature changes for the late 21st century (2090-2099). The map shows the multi-AOGCM average projection for the A1B SRES scenario. Temperatures are relative to the period 1980-1999. {Figure 3.2}*

Some systems, sectors and regions are *likely* to be especially affected by climate change.[12] *{3.3.3}*

Systems and sectors: *{3.3.3}*

- particular ecosystems:
  - terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
  - coastal: mangroves and salt marshes, due to multiple stresses
  - marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- water resources in some dry regions at mid-latitudes[13] and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture in low latitudes, due to reduced water availability
- low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events
- human health in populations with low adaptive capacity.

Regions: *{3.3.3}*

- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of low adaptive capacity and projected climate change impacts
- small islands, where there is high exposure of population and infrastructure to projected climate change impacts
- Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.

Within other areas, even those with high incomes, some people (such as the poor, young children and the elderly) can be particularly at risk, and also some areas and some activities. *{3.3.3}*

Ocean acidification

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units. Increasing atmospheric CO_2 concentrations lead to further acidification. Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century. While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent species. *{3.3.4}*

[12] Identified on the basis of expert judgement of the assessed literature and considering the magnitude, timing and projected rate of climate change, sensitivity and adaptive capacity.

[13] Including arid and semi-arid regions.

Exhibit 30
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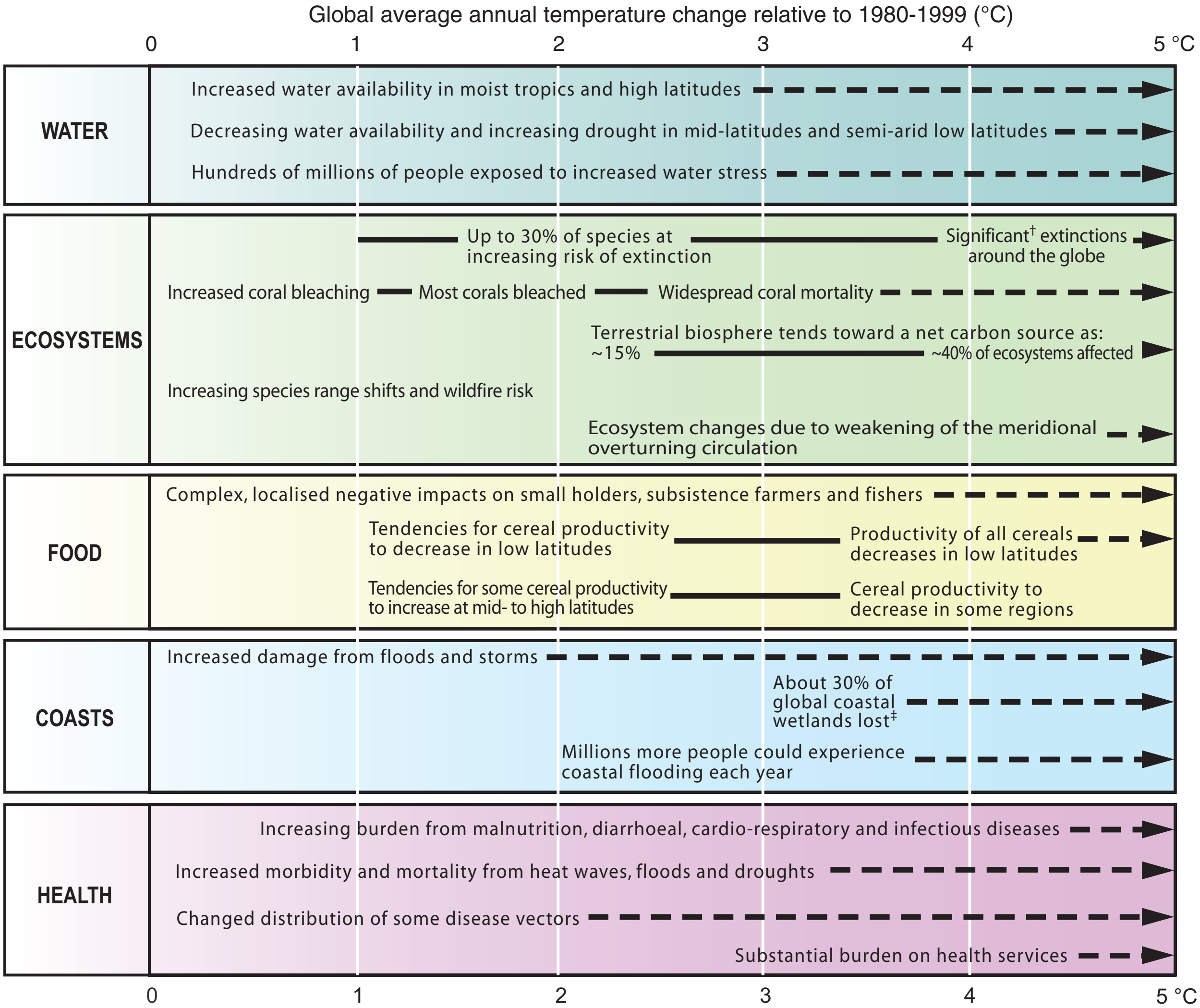
Examples of impacts associated with global average temperature change
(Impacts will vary by extent of adaptation, rate of temperature change and socio-economic pathway)



† Significant is defined here as more than 40%. ‡ Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.

Warming by 2090-2099 relative to 1980-1999 for non-mitigation scenarios

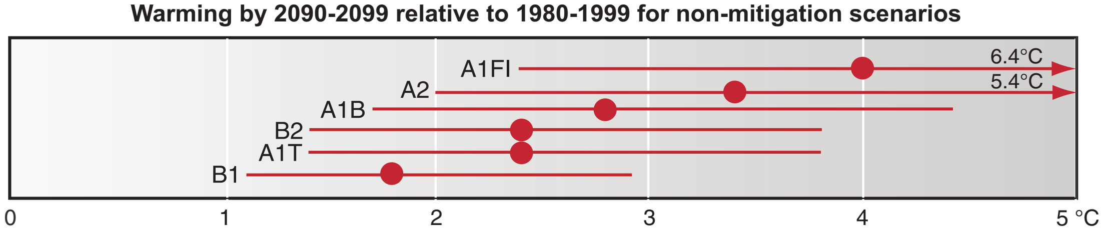


Figure SPM.7. *Examples of impacts associated with projected global average surface warming.* ***Upper panel:*** *Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are* high. ***Lower panel:*** *Dots and bars indicate the best estimate and* likely *ranges of warming assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. {Figure 3.6}*

Exhibit 30
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Table SPM.2. *Examples of some projected regional impacts. {3.3.2}*

Africa	• By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change. • By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition. • Towards the end of the 21st century, projected sea level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5 to 10% of Gross Domestic Product (GDP). • By 2080, an increase of 5 to 8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (TS).
Asia	• By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease. • Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. • Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development. • Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle.
Australia and New Zealand	• By 2020, significant loss of biodiversity is projected to occur in some ecologically rich sites, including the Great Barrier Reef and Queensland Wet Tropics. • By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. • By 2030, production from agriculture and forestry is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in some other regions. • By 2050, ongoing coastal development and population growth in some areas of Australia and New Zealand are projected to exacerbate risks from sea level rise and increases in the severity and frequency of storms and coastal flooding.
Europe	• Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods and more frequent coastal flooding and increased erosion (due to storminess and sea level rise). • Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emissions scenarios by 2080). • In southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. • Climate change is also projected to increase the health risks due to heat waves and the frequency of wildfires.
Latin America	• By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. • There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America. • Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones, soybean yields are projected to increase. Overall, the number of people at risk of hunger is projected to increase (TS; *medium confidence*). • Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation.
North America	• Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources. • In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. • Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts. • Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.

continued...

Exhibit 30
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***Table SPM.2.** continued...*

Polar Regions	• The main projected biophysical effects are reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators. • For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed. • Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. • In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered.
Small Islands	• Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. • Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources. • By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods. • With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.

Note:
Unless stated explicitly, all entries are from Working Group II SPM text, and are either *very high confidence* or *high confidence* statements, reflecting different sectors (agriculture, ecosystems, water, coasts, health, industry and settlements). The Working Group II SPM refers to the source of the statements, timelines and temperatures. The magnitude and timing of impacts that will ultimately be realised will vary with the amount and rate of climate change, emissions scenarios, development pathways and adaptation.

Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems. *{3.3.5}*

Examples for selected extremes and sectors are shown in Table SPM.3.

Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilised. *{3.2.3}*

Estimated long-term (multi-century) warming corresponding to the six AR4 Working Group III stabilisation categories is shown in Figure SPM.8.

Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7m if global average warming were sustained for millennia in excess of 1.9 to 4.6°C relative to pre-industrial values. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar land ice extent and 4 to 6m of sea level rise. *{3.2.3}*

Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and gain mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. *{3.2.3}*

Estimated multi-century warming relative to 1980-1999 for AR4 stabilisation categories

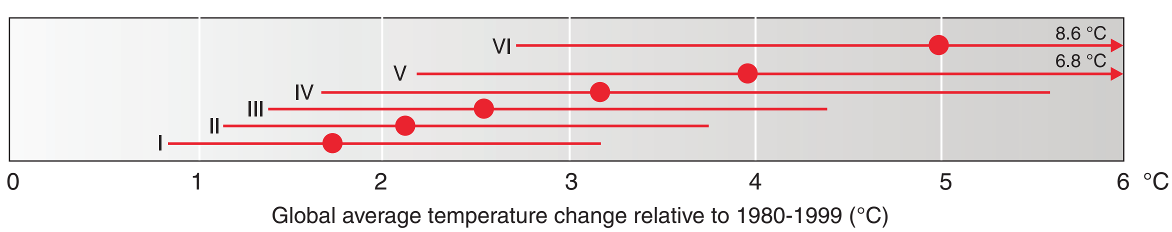

***Figure SPM.8.** Estimated long-term (multi-century) warming corresponding to the six AR4 Working Group III stabilisation categories (Table SPM.6). The temperature scale has been shifted by -0.5°C compared to Table SPM.6 to account approximately for the warming between pre-industrial and 1980-1999. For most stabilisation levels global average temperature is approaching the equilibrium level over a few centuries. For GHG emissions scenarios that lead to stabilisation at levels comparable to SRES B1 and A1B by 2100 (600 and 850ppm CO_2-eq; category IV and V), assessed models project that about 65 to 70% of the estimated global equilibrium temperature increase, assuming a climate sensitivity of 3°C, would be realised at the time of stabilisation. For the much lower stabilisation scenarios (category I and II, Figure SPM.11), the equilibrium temperature may be reached earlier. {Figure 3.4}*

Exhibit 30
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Table SPM.3. *Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one.* {Table 3.2}

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See Working Group I Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d) In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. *{3.4}*

Partial loss of ice sheets on polar land could imply metres of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded. *{3.4}*

Climate change is *likely* to lead to some irreversible impacts. There is *medium confidence* that approximately 20 to 30% of species assessed so far are *likely* to be at increased risk of extinction if increases in global average warming exceed 1.5 to 2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40 to 70% of species assessed) around the globe. *{3.4}*

Based on current model simulations, the meridional overturning circulation (MOC) of the Atlantic Ocean will *very likely* slow down during the 21st century; nevertheless temperatures over the Atlantic and Europe are projected to increase. The MOC is *very unlikely* to undergo a large abrupt transition during the 21st century. Longer-term MOC changes cannot be assessed with confidence. Impacts of large-scale and persistent changes in the MOC are *likely* to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO_2 uptake may feed back on the climate system. *{3.4}*

4. Adaptation and mitigation options[14]

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood. *{4.2}*

Societies have a long record of managing the impacts of weather- and climate-related events. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. Moreover, vulnerability to climate change can be exacerbated by other stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS. *{4.2}*

Some planned adaptation to climate change is already occurring on a limited basis. Adaptation can reduce vulnerability, especially when it is embedded within broader sectoral initiatives (Table SPM.4). There is *high confidence* that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios. However, comprehensive estimates of global costs and benefits of adaptation are limited. *{4.2, Table 4.1}*

Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies. *{4.2}*

A range of barriers limits both the implementation and effectiveness of adaptation measures. The capacity to adapt is dynamic and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology. Even societies with high adaptive capacity remain vulnerable to climate change, variability and extremes. *{4.2}*

Both bottom-up and top-down studies indicate that there is *high agreement* and *much evidence* of substantial economic potential for the mitigation of global GHG emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels (Figures SPM.9, SPM.10).[15] While top-down and bottom-up studies are in line at the global level (Figure SPM.9) there are considerable differences at the sectoral level. *{4.3}*

No single technology can provide all of the mitigation potential in any sector. The economic mitigation potential, which is generally greater than the market mitigation potential, can only be achieved when adequate policies are in place and barriers removed (Table SPM.5). *{4.3}*

Bottom-up studies suggest that mitigation opportunities with net negative costs have the potential to reduce emissions by around 6 $GtCO_2$-eq/yr in 2030, realising which requires dealing with implementation barriers. *{4.3}*

[14] While this Section deals with adaptation and mitigation separately, these responses can be complementary. This theme is discussed in Section 5.

[15] The concept of '**mitigation potential**' has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of 'market mitigation potential' and 'economic mitigation potential'.

Market mitigation potential is the mitigation potential based on private costs and private discount rates (reflecting the perspective of private consumers and companies), which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake.

Economic mitigation potential is the mitigation potential that takes into account social costs and benefits and social discount rates (reflecting the perspective of society; social discount rates are lower than those used by private investors), assuming that market efficiency is improved by policies and measures and barriers are removed.

Mitigation potential is estimated using different types of approaches. ***Bottom-up studies*** are based on assessment of mitigation options, emphasising specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged. ***Top-down studies*** assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

Exhibit 30
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Table SPM.4. *Selected examples of planned adaptation by sector. {Table 4.1}*

Sector	Adaptation option/strategy	Underlying policy framework	Key constraints and opportunities to implementation (Normal font = constraints; *italics = opportunities*)
Water	Expanded rainwater harvesting; water storage and conservation techniques; water re-use; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; *integrated water resources management; synergies with other sectors*
Agriculture	Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	Technological and financial constraints; access to new varieties; markets; *longer growing season in higher latitudes; revenues from 'new' products*
Infrastructure/ settlement (including coastal zones)	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; *integrated policies and management; synergies with sustainable development goals*
Human health	Heat-health action plans; emergency medical services; improved climate-sensitive disease surveillance and control; safe water and improved sanitation	Public health policies that recognise climate risk; strengthened health services; regional and international cooperation	Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; *upgraded health services; improved quality of life*
Tourism	Diversification of tourism attractions and revenues; shifting ski slopes to higher altitudes and glaciers; artificial snow-making	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	Appeal/marketing of new attractions; financial and logistical challenges; potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use); *revenues from 'new' attractions; involvement of wider group of stakeholders*
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations, e.g. permafrost areas	Financial and technological barriers; availability of less vulnerable routes; *improved technologies and integration with key sectors (e.g. energy)*
Energy	Strengthening of overhead transmission and distribution infrastructure; underground cabling for utilities; energy efficiency; use of renewable sources; reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	Access to viable alternatives; financial and technological barriers; acceptance of new technologies; *stimulation of new technologies; use of local resources*

Note:
Other examples from many sectors would include early warning systems.

Future energy infrastructure investment decisions, expected to exceed US$20 trillion[16] between 2005 and 2030, will have long-term impacts on GHG emissions, because of the long lifetimes of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in investment patterns, although the net additional investment required ranges from negligible to 5 to 10%. *{4.3}*

[16] 20 trillion = 20,000 billion = 20×10^{12}

Comparison between global economic mitigation potential and projected emissions increase in 2030

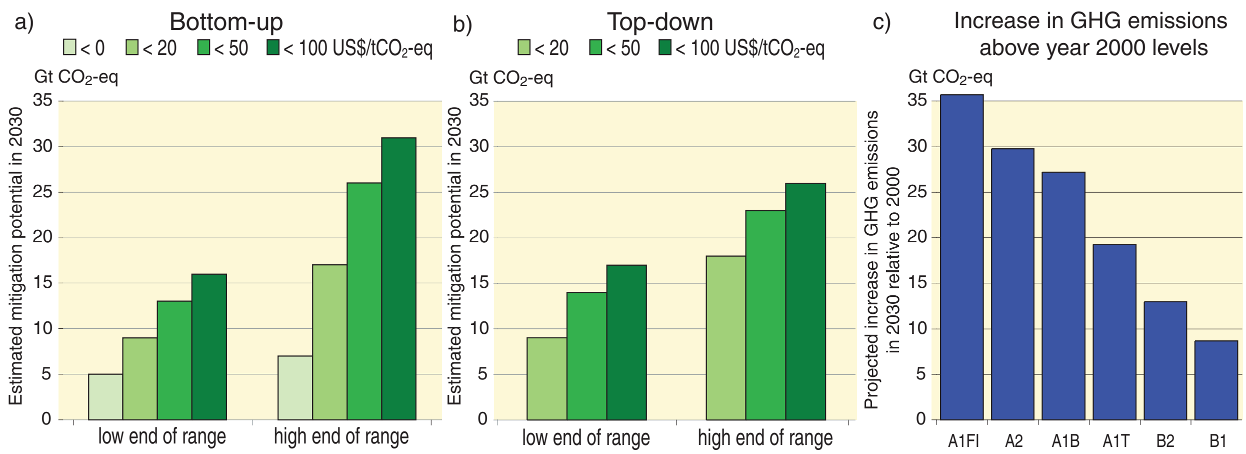

Figure SPM.9. *Global economic mitigation potential in 2030 estimated from bottom-up (Panel a) and top-down (Panel b) studies, compared with the projected emissions increases from SRES scenarios relative to year 2000 GHG emissions of 40.8 GtCO$_2$-eq (Panel c). Note: GHG emissions in 2000 are exclusive of emissions of decay of above ground biomass that remains after logging and deforestation and from peat fires and drained peat soils, to ensure consistency with the SRES emission results. {Figure 4.1}*

Economic mitigation potentials by sector in 2030 estimated from bottom-up studies

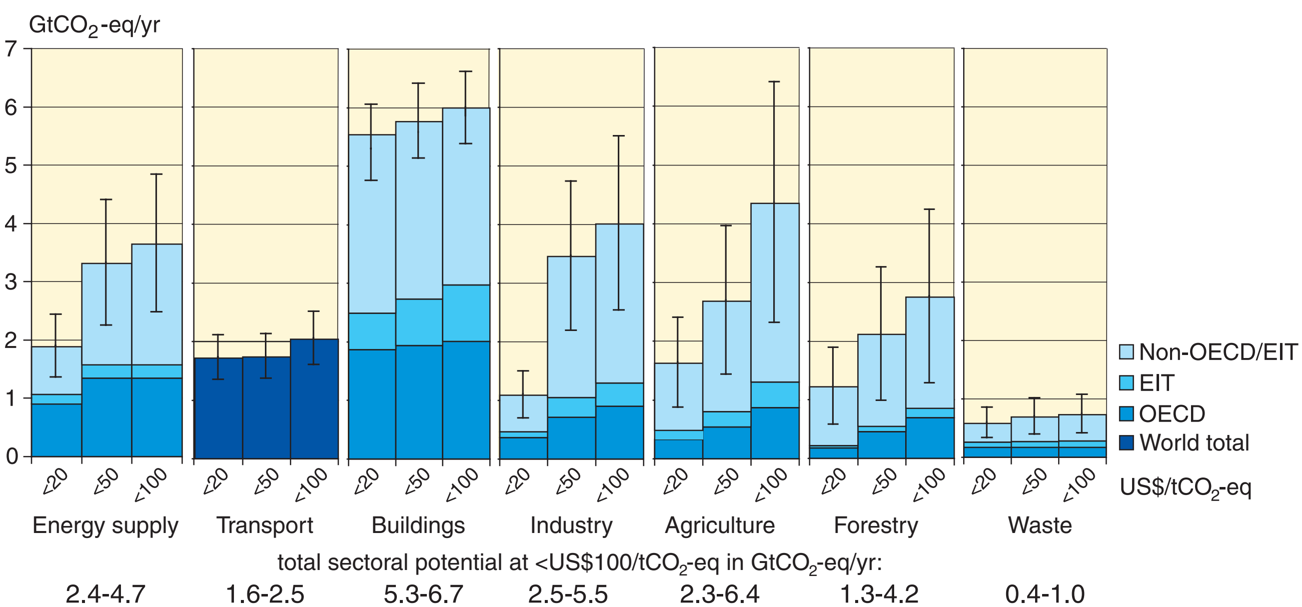

Figure SPM.10. *Estimated economic mitigation potential by sector in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. The potentials do not include non-technical options such as lifestyle changes. {Figure 4.2}*

Notes:

a) The ranges for global economic potentials as assessed in each sector are shown by vertical lines. The ranges are based on end-use allocations of emissions, meaning that emissions of electricity use are counted towards the end-use sectors and not to the energy supply sector.

b) The estimated potentials have been constrained by the availability of studies particularly at high carbon price levels.

c) Sectors used different baselines. For industry, the SRES B2 baseline was taken, for energy supply and transport, the World Energy Outlook (WEO) 2004 baseline was used; the building sector is based on a baseline in between SRES B2 and A1B; for waste, SRES A1B driving forces were used to construct a waste-specific baseline; agriculture and forestry used baselines that mostly used B2 driving forces.

d) Only global totals for transport are shown because international aviation is included.

e) Categories excluded are: non-CO$_2$ emissions in buildings and transport, part of material efficiency options, heat production and co-generation in energy supply, heavy duty vehicles, shipping and high-occupancy passenger transport, most high-cost options for buildings, wastewater treatment, emission reduction from coal mines and gas pipelines, and fluorinated gases from energy supply and transport. The underestimation of the total economic potential from these emissions is of the order of 10 to 15%.

Table SPM.5 *Selected examples of key sectoral mitigation technologies, policies and measures, constraints and opportunities. {Table 4.2}*

Sector	Key mitigation technologies and practices currently commercially available. *Key mitigation technologies and practices projected to be commercialised before 2030 shown in italics.*	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities (Normal font = constraints; *italics = opportunities*)
Energy supply	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas); *CCS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics*	Reduction of fossil fuel subsidies; taxes or carbon charges on fossil fuels	Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; renewable energy obligations; producer subsidies	*May be appropriate to create markets for low-emissions technologies*
Transport	More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; *second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries*	Mandatory fuel economy; biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels; road and parking pricing	Effectiveness may drop with higher incomes
		Influence mobility needs through land-use regulations and infrastructure planning; investment in attractive public transport facilities and non-motorised forms of transport	*Particularly appropriate for countries that are building up their transportation systems*
Buildings	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycling of fluorinated gases; *integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar photovoltaics integrated in buildings*	Appliance standards and labelling	Periodic revision of standards needed
		Building codes and certification	*Attractive for new buildings*. Enforcement can be difficult
		Demand-side management programmes	Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	*Government purchasing can expand demand for energy-efficient products*
		Incentives for energy service companies (ESCOs)	*Success factor: Access to third party financing*
Industry	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies; *advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture*	Provision of benchmark information; performance standards; subsidies; tax credits	*May be appropriate to stimulate technology uptake.* Stability of national policy important in view of international competitiveness
		Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertiliser application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; *improvements of crop yields*	Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilisers and irrigation	*May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation*
Forestry/ forests	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; *tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change*	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement	Constraints include lack of investment capital and land tenure issues. *Can help poverty alleviation*
Waste	Landfill CH_4 recovery; waste incineration with energy recovery; composting of organic waste; controlled wastewater treatment; recycling and waste minimisation; *biocovers and biofilters to optimise CH_4 oxidation*	Financial incentives for improved waste and wastewater management	*May stimulate technology diffusion*
		Renewable energy incentives or obligations	Local availability of low-cost fuel
		Waste management regulations	Most effectively applied at national level with enforcement strategies

Exhibit 30
AEWC & ICAS

A wide variety of policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and sectoral context (Table SPM.5). *{4.3}*

They include integrating climate policies in wider development policies, regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, and research, development and demonstration (RD&D). *{4.3}*

An effective carbon-price signal could realise significant mitigation potential in all sectors. Modelling studies show that global carbon prices rising to US$20-80/t$CO_2$-eq by 2030 are consistent with stabilisation at around 550ppm CO_2-eq by 2100. For the same stabilisation level, induced technological change may lower these price ranges to US$5-65/t$CO_2$-eq in 2030.[17] *{4.3}*

There is *high agreement* and *much evidence* that mitigation actions can result in near-term co-benefits (e.g. improved health due to reduced air pollution) that may offset a substantial fraction of mitigation costs. *{4.3}*

There is *high agreement* and *medium evidence* that Annex I countries' actions may affect the global economy and global emissions, although the scale of carbon leakage remains uncertain.[18] *{4.3}*

Fossil fuel exporting nations (in both Annex I and non-Annex I countries) may expect, as indicated in the TAR, lower demand and prices and lower GDP growth due to mitigation policies. The extent of this spillover depends strongly on assumptions related to policy decisions and oil market conditions. *{4.3}*

There is also *high agreement* and *medium evidence* that changes in lifestyle, behaviour patterns and management practices can contribute to climate change mitigation across all sectors. *{4.3}*

Many options for reducing global GHG emissions through international cooperation exist. There is *high agreement* and *much evidence* that notable achievements of the UNFCCC and its Kyoto Protocol are the establishment of a global response to climate change, stimulation of an array of national policies, and the creation of an international carbon market and new institutional mechanisms that may provide the foundation for future mitigation efforts. Progress has also been made in addressing adaptation within the UNFCCC and additional international initiatives have been suggested. *{4.5}*

Greater cooperative efforts and expansion of market mechanisms will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness. Efforts can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD&D programmes; adopting common policies; implementing development-oriented actions; or expanding financing instruments. *{4.5}*

In several sectors, climate response options can be implemented to realise synergies and avoid conflicts with other dimensions of sustainable development. Decisions about macroeconomic and other non-climate policies can significantly affect emissions, adaptive capacity and vulnerability. *{4.4, 5.8}*

Making development more sustainable can enhance mitigative and adaptive capacities, reduce emissions and reduce vulnerability, but there may be barriers to implementation. On the other hand, it is *very likely* that climate change can slow the pace of progress towards sustainable development. Over the next half-century, climate change could impede achievement of the Millennium Development Goals. *{5.8}*

5. The long-term perspective

Determining what constitutes "dangerous anthropogenic interference with the climate system" in relation to Article 2 of the UNFCCC involves value judgements. Science can support informed decisions on this issue, including by providing criteria for judging which vulnerabilities might be labelled 'key'. *{Box 'Key Vulnerabilities and Article 2 of the UNFCCC', Topic 5}*

Key vulnerabilities[19] may be associated with many climate-sensitive systems, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets and modes of oceanic and atmospheric circulation. *{Box 'Key Vulnerabilities and Article 2 of the UNFCCC', Topic 5}*

[17] Studies on mitigation portfolios and macro-economic costs assessed in this report are based on top-down modelling. Most models use a global least-cost approach to mitigation portfolios, with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs are given for a specific point in time. Global modelled costs will increase if some regions, sectors (e.g. land use), options or gases are excluded. Global modelled costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues. Significant progress has been achieved in applying approaches based on induced technological change to stabilisation studies; however, conceptual issues remain. In the models that consider induced technological change, projected costs for a given stabilisation level are reduced; the reductions are greater at lower stabilisation level.

[18] Further details may be found in Topic 4 of this Synthesis Report.

[19] Key vulnerabilities can be identified based on a number of criteria in the literature, including magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and 'importance' of the impacts.

Exhibit 30
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The five 'reasons for concern' identified in the TAR remain a viable framework to consider key vulnerabilities. These 'reasons' are assessed here to be stronger than in the TAR. Many risks are identified with higher confidence. Some risks are projected to be larger or to occur at lower increases in temperature. Understanding about the relationship between impacts (the basis for 'reasons for concern' in the TAR) and vulnerability (that includes the ability to adapt to impacts) has improved. *{5.2}*

This is due to more precise identification of the circumstances that make systems, sectors and regions especially vulnerable and growing evidence of the risks of very large impacts on multiple-century time scales. *{5.2}*

- ***Risks to unique and threatened systems.*** There is new and stronger evidence of observed impacts of climate change on unique and vulnerable systems (such as polar and high mountain communities and ecosystems), with increasing levels of adverse impacts as temperatures increase further. An increasing risk of species extinction and coral reef damage is projected with higher confidence than in the TAR as warming proceeds. There is *medium confidence* that approximately 20 to 30% of plant and animal species assessed so far are *likely* to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C over 1980-1999 levels. Confidence has increased that a 1 to 2°C increase in global mean temperature above 1990 levels (about 1.5 to 2.5°C above pre-industrial) poses significant risks to many unique and threatened systems including many biodiversity hotspots. Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. Increasing vulnerability of indigenous communities in the Arctic and small island communities to warming is projected. *{5.2}*
- ***Risks of extreme weather events.*** Responses to some recent extreme events reveal higher levels of vulnerability than the TAR. There is now higher confidence in the projected increases in droughts, heat waves and floods, as well as their adverse impacts. *{5.2}*
- ***Distribution of impacts and vulnerabilities.*** There are sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change. There is increasing evidence of greater vulnerability of specific groups such as the poor and elderly not only in developing but also in developed countries. Moreover, there is increased evidence that low-latitude and less developed areas generally face greater risk, for example in dry areas and megadeltas. *{5.2}*
- ***Aggregate impacts.*** Compared to the TAR, initial net market-based benefits from climate change are projected to peak at a lower magnitude of warming, while damages would be higher for larger magnitudes of warming. The net costs of impacts of increased warming are projected to increase over time. *{5.2}*
- ***Risks of large-scale singularities.*** There is *high confidence* that global warming over many centuries would lead to a sea level rise contribution from thermal expansion alone that is projected to be much larger than observed over the 20th century, with loss of coastal area and associated impacts. There is better understanding than in the TAR that the risk of additional contributions to sea level rise from both the Greenland and possibly Antarctic ice sheets may be larger than projected by ice sheet models and could occur on century time scales. This is because ice dynamical processes seen in recent observations but not fully included in ice sheet models assessed in the AR4 could increase the rate of ice loss. *{5.2}*

There is *high confidence* that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change. *{5.3}*

Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed. There are barriers, limits and costs, but these are not fully understood. Unmitigated climate change would, in the long term, be *likely* to exceed the capacity of natural, managed and human systems to adapt. The time at which such limits could be reached will vary between sectors and regions. Early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs. *{5.2, 5.3}*

Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts. *{5.3, 5.4, 5.7}*

In order to stabilise the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilisation level, the more quickly this peak and decline would need to occur.[20] *{5.4}*

Table SPM.6 and Figure SPM.11 summarise the required emission levels for different groups of stabilisation concentrations and the resulting equilibrium global warming and long-

[20] For the lowest mitigation scenario category assessed, emissions would need to peak by 2015, and for the highest, by 2090 (see Table SPM.6). Scenarios that use alternative emission pathways show substantial differences in the rate of global climate change.

Exhibit 30
AEWC & ICAS

term sea level rise due to thermal expansion only.[21] The timing and level of mitigation to reach a given temperature stabilisation level is earlier and more stringent if climate sensitivity is high than if it is low. *{5.4, 5.7}*

Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilised, for any of the stabilisation levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. The eventual contributions from Greenland ice sheet loss could be several metres, and larger than from thermal expansion, should warming in excess of 1.9 to 4.6°C above pre-industrial be sustained over many centuries. The long time scales of thermal expansion and ice sheet response to warming imply that stabilisation of GHG concentrations at or above present levels would not stabilise sea level for many centuries. *{5.3, 5.4}*

There is *high agreement* and *much evidence* that all stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialised in coming decades, assuming appropriate and effective incentives are in place for their development, acquisition, deployment and diffusion and addressing related barriers. *{5.5}*

All assessed stabilisation scenarios indicate that 60 to 80% of the reductions would come from energy supply and use and industrial processes, with energy efficiency playing a key role in many scenarios. Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. Low stabilisation levels require early investments and substantially more rapid diffusion and commercialisation of advanced low-emissions technologies. *{5.5}*

Without substantial investment flows and effective technology transfer, it may be difficult to achieve emission reduction at a significant scale. Mobilising financing of incremental costs of low-carbon technologies is important. *{5.5}*

***Table SPM.6.** Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] {Table 5.1}*

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

[21] Estimates for the evolution of temperature over the course of this century are not available in the AR4 for the stabilisation scenarios. For most stabilisation levels, global average temperature is approaching the equilibrium level over a few centuries. For the much lower stabilisation scenarios (category I and II, Figure SPM.11), the equilibrium temperature may be reached earlier.

Exhibit 30
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CO_2 emissions and equilibrium temperature increases for a range of stabilisation levels

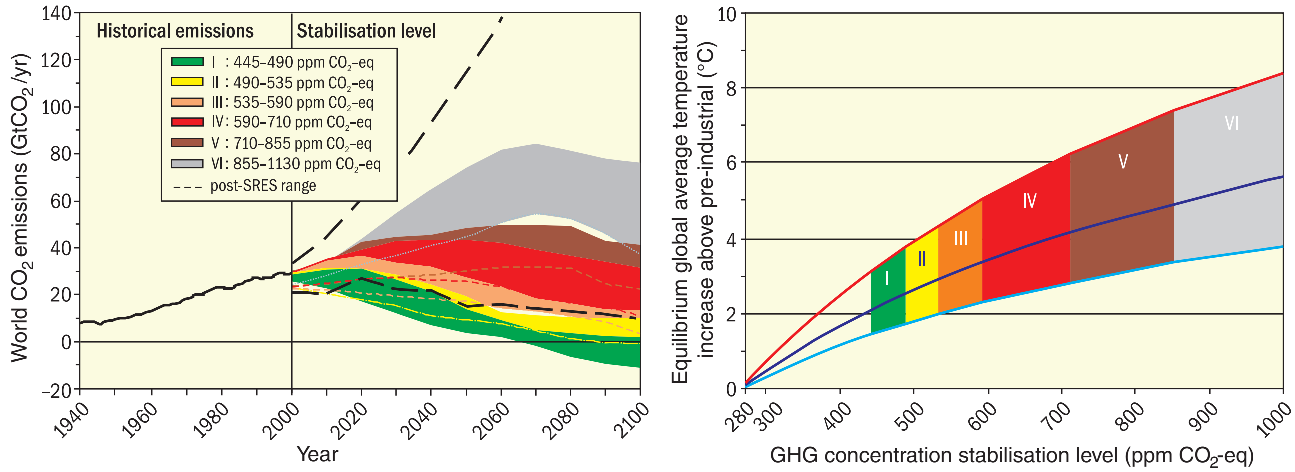

Figure SPM.11. *Global CO_2 emissions for 1940 to 2000 and emissions ranges for categories of stabilisation scenarios from 2000 to 2100 (left-hand panel); and the corresponding relationship between the stabilisation target and the* likely *equilibrium global average temperature increase above pre-industrial (right-hand panel). Approaching equilibrium can take several centuries, especially for scenarios with higher levels of stabilisation. Coloured shadings show stabilisation scenarios grouped according to different targets (stabilisation category I to VI). The right-hand panel shows ranges of global average temperature change above pre-industrial, using (i) 'best estimate' climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of* likely *range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of* likely *range of climate sensitivity of 2°C (blue line at bottom of shaded area). Black dashed lines in the left panel give the emissions range of recent baseline scenarios published since the SRES (2000). Emissions ranges of the stabilisation scenarios comprise CO_2-only and multigas scenarios and correspond to the 10th to 90th percentile of the full scenario distribution. Note: CO_2 emissions in most models do not include emissions from decay of above ground biomass that remains after logging and deforestation, and from peat fires and drained peat soils. {Figure 5.1}*

The macro-economic costs of mitigation generally rise with the stringency of the stabilisation target (Table SPM.7). For specific countries and sectors, costs vary considerably from the global average.[22] *{5.6}*

In 2050, global average macro-economic costs for mitigation towards stabilisation between 710 and 445ppm CO_2-eq are between a 1% gain and 5.5% decrease of global GDP (Table SPM.7). This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points. *{5.6}*

Table SPM.7. *Estimated global macro-economic costs in 2030 and 2050. Costs are relative to the baseline for least-cost trajectories towards different long-term stabilisation levels. {Table 5.2}*

Stabilisation levels (ppm CO_2-eq)	Median GDP reduction[a] (%)		Range of GDP reduction[b] (%)		Reduction of average annual GDP growth rates (percentage points) [c,e]	
	2030	2050	2030	2050	2030	2050
445 – 535[d]	Not available		< 3	< 5.5	< 0.12	< 0.12
535 – 590	0.6	1.3	0.2 to 2.5	slightly negative to 4	< 0.1	< 0.1
590 – 710	0.2	0.5	-0.6 to 1.2	-1 to 2	< 0.06	< 0.05

Notes:
Values given in this table correspond to the full literature across all baselines and mitigation scenarios that provide GDP numbers.
a) Global GDP based on market exchange rates.
b) The 10th and 90th percentile range of the analysed data are given where applicable. Negative values indicate GDP gain. The first row (445-535ppm CO_2-eq) gives the upper bound estimate of the literature only.
c) The calculation of the reduction of the annual growth rate is based on the average reduction during the assessed period that would result in the indicated GDP decrease by 2030 and 2050 respectively.
d) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.
e) The values correspond to the highest estimate for GDP reduction shown in column three.

[22] See Footnote 17 for more detail on cost estimates and model assumptions.

Exhibit 30
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Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity and attitudes to risk. *{5.1}*

Impacts of climate change are *very likely* to impose net annual costs, which will increase over time as global temperatures increase. Peer-reviewed estimates of the social cost of carbon[23] in 2005 average US$12 per tonne of CO_2, but the range from 100 estimates is large (-$3 to $95/t$CO_2$). This is due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates. Aggregate estimates of costs mask significant differences in impacts across sectors, regions and populations and *very likely* underestimate damage costs because they cannot include many non-quantifiable impacts. *{5.7}*

Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that they are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or stabilisation level where benefits exceed costs. *{5.7}*

Climate sensitivity is a key uncertainty for mitigation scenarios for specific temperature levels. *{5.4}*

Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay. *{5.7}*

[23] Net economic costs of damages from climate change aggregated across the globe and discounted to the specified year.

Exhibit 30
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Arctic Council

Arctic Marine Shipping Assessment 2009 Report

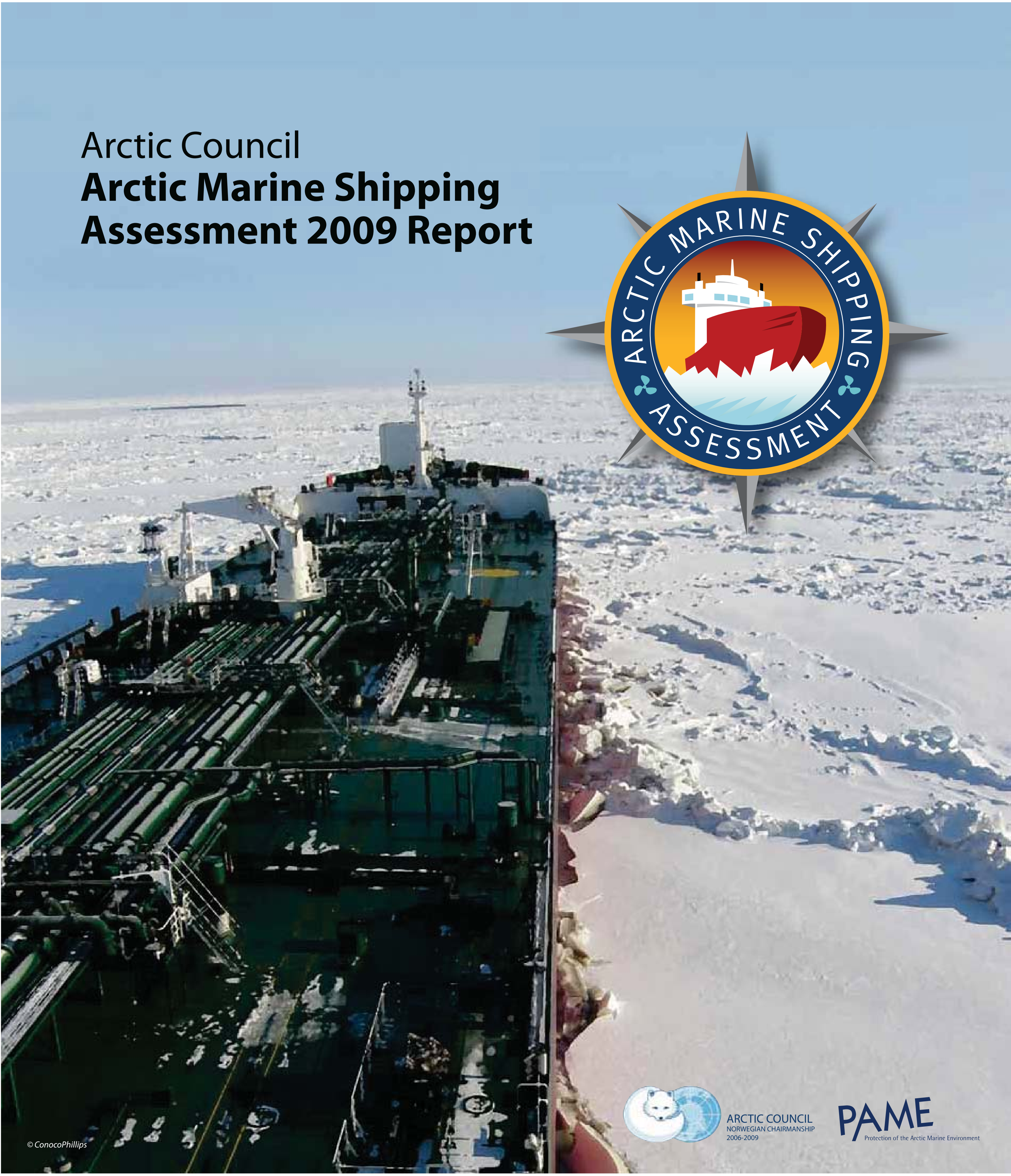


Exhibit 31
AEWC & ICAS

Interestingly, the five smallest September ice-covered areas for the Arctic Ocean during the modern satellite record (1979-2008) have occurred in the five most recent seasons (2004-2008). Map 2.2 shows the sea ice coverage derived from satellite at the time of minimum extent of Arctic sea ice on September 16, 2007.

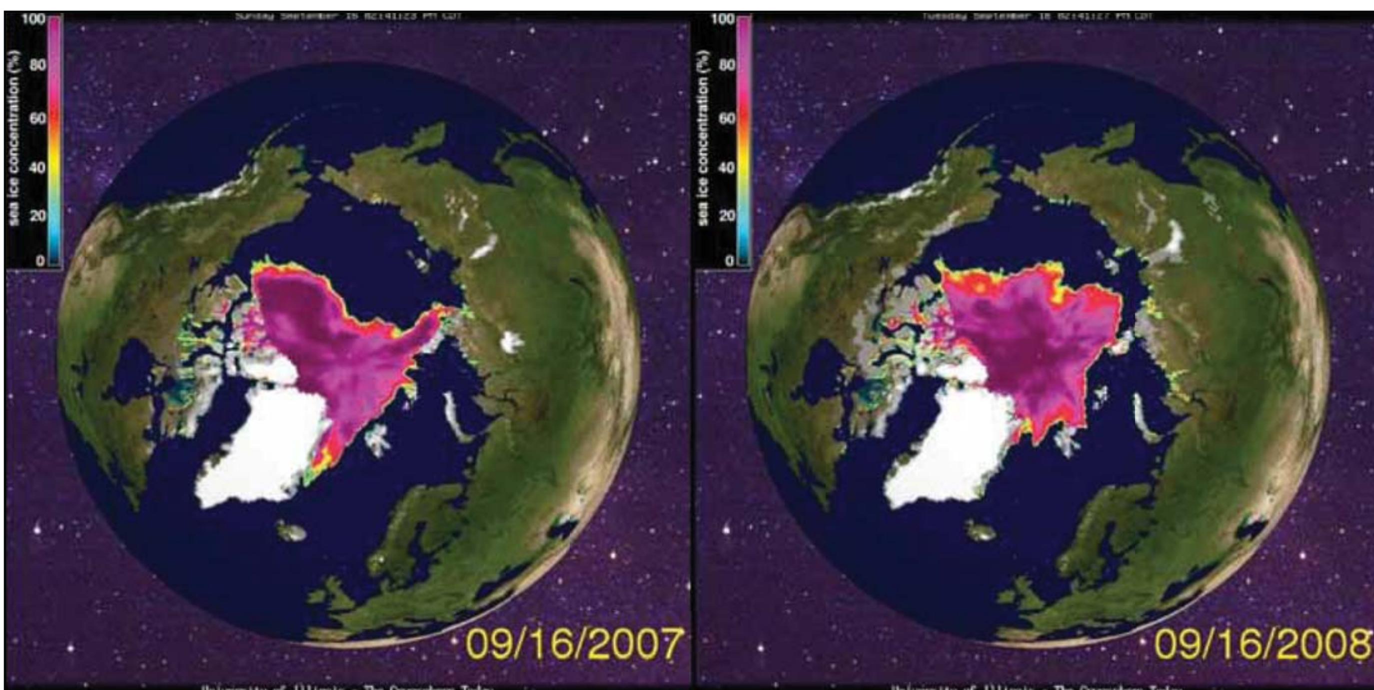
This snapshot represents the minimum coverage of Arctic sea ice in the satellite era of observations. Striking are several notable features: the largely ice-free areas across the Russian Arctic coastal seas (north of the Eurasian coast), except for a small region in the western Laptev Sea; an ice edge that has retreated north of Svalbard and well north in the Beaufort and Chukchi seas; several ice-free passages through the Canadian Archipelago; and a large area of the central Arctic Ocean that previously has not been observed open or without even a thin ice cover.

These extraordinary changes in the summer ice cover of the Arctic Ocean, represented by a single, iconic satellite image for September 16, 2007, are major factors in the potential lengthening of the navigation season in regional Arctic seas, particularly in the summer. It should be noted though that during the same timeframe, the Fram Strait contained more ice than normal, underscoring the regional variability of sea ice extent.

Arctic Climate Impact Assessment

The ACIA, approved by the eight Arctic countries, was called for by the Arctic Council and the International Arctic Science Committee. The assessment found that the Arctic is extremely vulnerable to observed and projected climate change and its impacts. The Arctic is now experiencing some of the most rapid and severe climate change on earth. During the 21st century, climate change is expected to accelerate, contributing to major physical, ecological, social and economic changes, many of which have already begun. Changes in Arctic climate will also affect the rest of the planet through increased global warming and rising sea levels. Of direct relevance to future Arctic marine activity, and to the AMSA, is that potentially accelerating Arctic sea ice retreat improves marine access throughout the Arctic Ocean.

The assessment confirmed, using a wealth of current Arctic research, that declining Arctic sea ice is a key climate change indicator. During the past five decades the observed extent of Arctic sea ice has declined in all seasons, with the most prominent retreat in summer. While the ACIA models have now been surpassed by more capable GCMs, each of the five GCMs used in the ACIA did project a continuous decline in Arctic sea ice coverage throughout the 21st



Map 2.2 Satellite images of summer sea ice cover. *Source: University of Illinois – The Cryosphere Today*

Exhibit 31
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Earth's climate is changing, with the global temperature now rising at a rate unprecedented in the experience of modern human society. These climate changes, including increases in ultraviolet radiation, are being experienced particularly intensely in the Arctic. Because the Arctic plays a special role in global climate, these changes in the Arctic will also affect the rest of the world. It is thus essential that decision makers have the latest and best information available regarding ongoing changes in the Arctic and their global implications.

The Arctic Council called for this assessment and charged two of its working groups, the Arctic Monitoring and Assessment Programme (AMAP) and the Conservation of Arctic Flora and Fauna (CAFF), along with the International Arctic Science Committee (IASC), with its implementation. An Assessment Steering Committee was charged with the responsibility for scientific oversight and coordination of all work related to the preparation of the assessment reports.

This assessment was prepared over the past five years by an international team of over 300 scientists, other experts, and knowledgeable members of the indigenous communities. The report has been thoroughly researched, is fully referenced, and provides the first comprehensive evaluation of arctic climate change, changes in ultraviolet radiation, and their impacts for the region and for the world.

The scientific results reported herein provided the scientific foundation for the Arctic Climate Impact Assessment (ACIA) synthesis report, entitled "Impacts of a Warming Arctic", released in November 2004.

AMAP Arctic Monitoring and Assessment Programme

CAFF Conservation of Arctic Flora and Fauna

IASC

CAMBRIDGE
UNIVERSITY PRESS
www.cambridge.org
ISBN 0-521-86509-3
9 780521 865098

ARCTIC CLIMATE IMPACT ASSESSMENT

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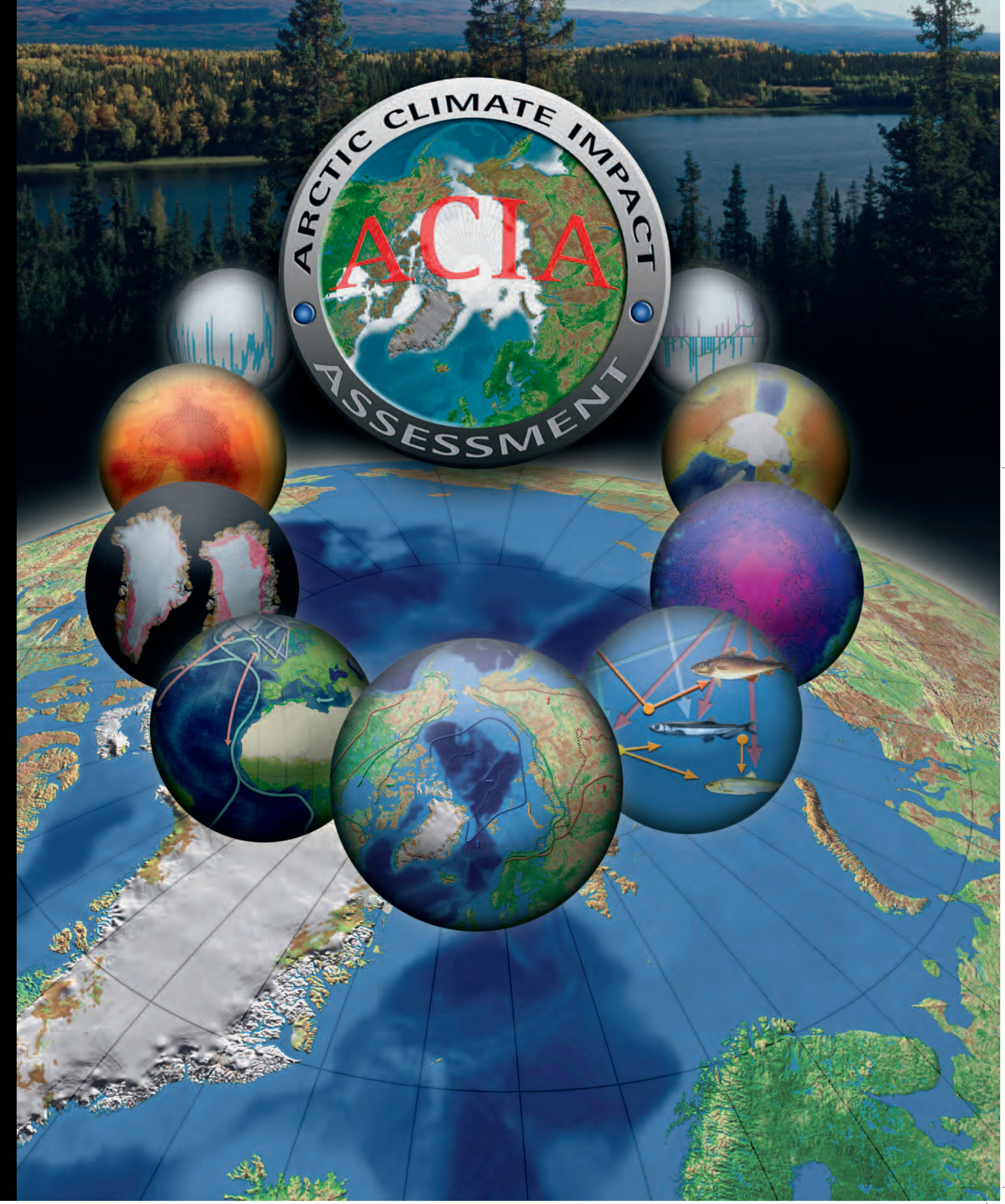
ARCTIC CLIMATE IMPACT ASSESSMENT



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Weather has also changed over the last half century. Seasons are now less consistent. For example, higher temperatures have become more common during autumn and winter, sometimes creating mid-winter fog, a new phenomenon. At the same time, lower temperatures in the summer have also become more common. Daily changes are now more extreme. It is relatively common for the temperature to change from -35 ºC one day to 0 ºC the next or vice versa. Unusual swings in weather occur not just during winter. An exceptional example is the snowstorm during July 2000, which left snow covering the tundra for a day and reduced the berry crop dramatically that year. Another example includes having the least amount of precipitation recorded for the month of November during 1999 and again in 2001, 0.25 mm, or 100 times less than the average amount of precipitation recorded for that month over the last fifty years. According to Qikiktagrugmiut, the increased variability and unpredictability in weather appears to have started during the 1970s and has continued through the 1980s and 1990s and into the new century.

The relationship between weather and the Qikiktagrugmiut is more intimate than for most people in the United States. Their daily traditional activities are almost entirely dictated by the weather and other environmental conditions, such as snow depth and animal distribution. For most urban communities the concern with weather has more to do with comfort level and recreation. For the Qikiktagrugmiut, the weather determines if daily activities can be carried out safely and productively (for instance water and ice travel and being able to dry meat and fish successfully). The weather is also tied to the ability of the land to produce natural crops of fur, meat, and berries.

This disparity in how weather is perceived by the rural Alaskan communities versus the urban mainstream is apparent from watching weather forecasters across the country, including urban centers in Alaska, such as Anchorage. The premise of these forecasters is based on the urban view that "good" weather should be sunny and warm. For the Qikiktagrugmiut, however, weather is "good" if it is favorable to the country's productivity and the ability of people to access the land's resources. Thus, "good" weather may include rain in July to produce a bountiful berry crop and extremely low temperatures during early autumn so that Kotzebue Sound and the surrounding rivers and lakes freeze quickly and reliably for safe travel. These two conditions, rain and extreme low temperatures, are almost universally portrayed as "bad" weather in urban settings. In addition, the Qikiktagrugmiut's ability to cope with extreme weather events differs from that of most urban communities across the nation. Blizzards that would shut down entire cities and be portrayed as mini-disasters by the urban media are looked upon favorably by rural Alaskan communities as a means by which travel is improved (through additional snow filling in willow stands, tundra tussocks, creeks/gullies, and compacting snow cover by the associated winds), allowing greater access to the country for travel and harvesting animals. Even in the town of Kotzebue, extreme weather events have relatively little direct impact. Schools and businesses, for example, are rarely closed due to weather.

These characteristics of the people appear to show an ability to successfully adapt and live in an inherently variable local environment. The real challenge with assessing the impacts of climate change, however, is in trying to understand the interconnectedness and the wide-ranging impacts that collectively work to change the shape of the web of activities and life in this part of the world.

Some Qikiktagrugmiut live out in the country outside the communities. Their ability to travel and obtain the necessary requirements of life is dependent on the length and quality of the freeze-up and the length of the break-up, which are determined by the weather conditions during autumn and spring. In addition, many people who are at the fringes of production, the young and the elderly, depend on favorable weather to be able to participate in the limited harvesting activities available to them. Ice fishing in front of Kotzebue, for instance, supplies people with traditional autumn food (saffron cod (*Eleginus gracilis*) and smelt (*Osmerus mordax*)), and is an important social activity that binds the community and gives the elderly and young people one of their few chances during the year to harvest traditional foods. During autumns with a late freeze-up, ice fishing is limited or less productive. Thus, a single climate variable in one season disproportionately affects this segment of the population by substantially reducing their annual harvesting opportunity.

3.4.1.1. The impacts of late freeze-up

A closer look at the Qikiktagrugmiut understanding of one event and its impacts, such as late freeze-up, can show how they see consequences that are widespread and varied yet still intertwined, so that it is impossible to look at any one thing in isolation. Late freeze-up is one likely consequence of regional climate warming, and hence a relevant example for considering the impacts of climate change. To illustrate the complexity of determining whether overall changes are positive or negative and how this depends on context and perception, this section uses the example of late freeze-up and its impacts on people, spotted seals (*Phoca largha*), caribou, and red foxes (*Vulpes vulpes*). The impacts are those that the Qikiktagrugmiut would immediately associate with late freeze-up, showing both the scope of their environmental knowledge and the patterns of interconnection that they see in their surroundings. This exercise shows how the timing, quality of ice, speed of complete freezing, associated weather, and ecological effects all combine to produce the many and varied impacts of a late freeze-up.

Impacts on humans and their way of life

The impacts of late freeze-up on humans vary widely and include better whitefish (*Coregonus* spp.) harvests, better clamming (*Macoma* spp.), better spotted seal hunting,

Exhibit 32
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better access to caribou, better arctic fox (*Alopex lagopus*) harvests, better access to driftwood, a shorter ice-fishing season, poor access to Kotzebue for people living out in the country, rough ice conditions, more danger from thin ice, and more erosion and flood problems.

- People living outside Kotzebue at remote campsites have an extended period for whitefish harvesting. Late season storm surges can reach the beach, piling porous sand across the mouth of a major harvesting river, trapping the fish behind the sand dam from where they are easily caught.
- Late season storm surges wash clams onto the beach at Sisaulik (a peninsula across the sound from Kotzebue where some of the Qikiktagrugmiut live during the summer and autumn), which can then be collected and stored in cool saltwater for many days of clambakes.
- Hunters have a longer period for using boats to hunt spotted seals, which are present in prolific numbers feeding on large schools of fish. Also, a long period of thin ice enables the seals to feed far into the sound. When the ice thickens overnight, many may try to return to open water by crawling on top of the ice, where they are easily reached by hunters now able to travel on the ice.
- Caribou hunters have a longer period in which to use boats to reach caribou (conversely snowmachine access will be delayed to later in the winter). There is, however, an increased risk during extended freeze-ups that boats will get caught in young ice and have to be abandoned for the winter. This happened during the late freeze-up of 2000.
- Arctic foxes are concentrated along the coast during the long season of open water, unable to get out onto the sea ice.
- More logs are washed up on the mud flats by late-season high water, for use by people living out in the country for their early autumn fuel supply.
- Ice for autumn fishing is missing, so the ice-fishing season is shorter in front of Kotzebue. In many cases, the ice fishers will then miss the largest runs of smelt and saffron cod, which tend to come past Kotzebue in large concentrations earlier, rather than later, in the autumn.
- People living out in the country must wait for a longer period before they can reach Kotzebue for expendable supplies such as gas, propane, medical needs and other necessities or must risk traveling under very dangerous conditions, which has caused the loss of life in some cases.
- Repeated incomplete freezing and thawing of the northern sound means that the ice that does appear can be piled up by the wind, creating very rough conditions and many obstacles to travel by snowmachine and dogs which begin once the ice freezes permanently.
- Snow can pile up on thin ice which makes such areas less likely to freeze completely and thus more dangerous once travel begins. There is often much snow on the ground during autumns with late freeze-ups because the low pressure conditions that contribute to slow ice growth are also associated with snow and storm fronts.
- Late season storm surges, unimpeded by ice, can create erosion and flood problems along the beach and road in front of Kotzebue.

Impacts on spotted seal

The impacts of late freeze-up on spotted seals include better access to inshore waters and the fishes that congregate there, better haul outs for resting, and greater risk of being trapped.

- Owing to the absence or patchiness of ice, spotted seals have increased access to the extreme inshore waters where smelt and saffron cod, and other food fishes, congregate in large numbers in early autumn. The seals force the fish into concentrated groups next to shore during the open water period, which is probably the most efficient way for them to catch the fish easily and in large numbers. Also, late freeze-up would allow seals increased access to the Noatak River, which holds large char (*Salvelinus malma*) and chum salmon (*Oncorhynchus keta*) at this time.
- Thin or patchy ice is better for hauling out on, allowing the seals to rest close to their major food source at this time of year, thus increasing the net amount of energy gained from this seasonal activity.
- Because the seals are able to haul out and breathe through the thin ice, they have a greater risk of becoming trapped too far from open water when the ice begins to thicken. Once temperatures drop well below freezing and stay there, which can happen rapidly at this time of year, the ice can become too solid and extensive for the seals to reach open water, which will force them to travel out over the ice (and in some cases over land) in order to reach the open water of the Chukchi Sea, leaving them vulnerable to starvation and predation.

Impacts on caribou

One of the impacts of late freeze-up on caribou is slower movements.

- The warm weather associated with late freeze-up makes caribou less likely to travel long distances thus slowing the autumn migration. In addition to being slowed by the warm weather and their own lack of initiative to move, extended thin ice conditions hamper movement, because the ice does not support the animals when they try to cross water bodies in their path. Although the consequences of this are unclear, they are probably many and varied, such as being forced to stay for extended periods of time on less productive ranges and increased vulnerability to predators such as wolves (*Canis lupus*) that are lighter and able to take advantage of the thin ice that is an obstacle for the caribou.

Impacts on red foxes

The impacts of late freeze-up on red foxes include better feeding and increased competition with Arctic foxes.

- A longer period of late season open water allows more storm surges to reach the shore, closing off coastal rivers with porous sand that allows large amounts of whitefish to become trapped and frozen into the ice at coastal river outlets. These provide a substantial food resource for many of the foxes along the coast. In addition, late season storms result in more sources of fox food in the form of enormous schools of baitfish and marine mammal carcasses that are deposited on the beach by the waves. Also, a longer hunting season for spotted seals and caribou by boat hunters means that more caribou gut piles and lost seals become available prior to the long period of beach foraging. Almost all foxes within the vicinity of the coast rely heavily on beach scavenging during the time around freeze-up, which also coincides with low human traffic along the coast. A particularly good year for late season beach foraging allows the foxes to accumulate critical amounts of fat to survive the long winter months ahead.
- An extended period of open water along the coast can impede the movement of arctic foxes onto the pack ice, which results in increased competition with the red foxes that rely on coastal food sources. If this occurs during a high in the four-year arctic fox population cycle, the effect is multiplied by the large numbers of arctic foxes migrating south and being stopped by the open water along the coast.

While this list of impacts arising from late freeze-up is not exhaustive, the examples indicate the interconnectedness that complicates an effort to understand the changes that occur from year to year as well as the long- and short-term effects of changes to the various combinations of environmental elements.

The challenge posed by climate change to indigenous peoples is their ability to respond and adapt to changes in the local environment, while continuing to prosper. Since the history of indigenous peoples is replete with change, it is important to ask whether they and their cultures are threatened by continued change, or whether change is just a threat to current understanding of the environment, which in any case is continually changing, slowly and on a daily basis. For example, seal hunting in leads during winter has decreased in importance and participation each year, due in part to the cultural economy's changing dependency on the seal for food and domestic utilitarian purposes, and in part to the unpredictable, and thus more dangerous, ice conditions of late. It is an activity that relies on the most extreme form of specialized knowledge of the environment that needs to be taught and learned over many years. More rapid environmental change is generally harder to adapt to. Recently, two experienced seal hunters were lost on the ice while hunting. Local interpretation of the event concluded that climate change has resulted in unusual and unpredictable ice conditions and that this must have been the cause of the tragedy, as the two men would not have had trouble traveling over ice under normal circumstances.

Even if processes are in motion that will change the entire ecosystem, whether this will result in circumstances that are not conducive to human existence, or in a new ecosystem with resources available for human consumption following some degree of adaptation, is unknown. Archaeologists have found this to have occurred in the past, with arctic societies having changed from terrestrial-based cultures to marine-based cultures and back again. The best that can be done at this point is to continue to observe, document, and discuss the changing environment and to hope that indigenous peoples will be able to adapt to whatever future environments may evolve in their traditional homelands.

3.4.2. The Aleutian and Pribilof Islands region, Alaska

The Aleut International Association (AIA) and the Aleutian and Pribilof Islands Association (APIA) prepared this summary of current observations, concerns, and plans related to climate change in their region. Michael Zacharof is President of AIA and lives on St. Paul Island in the Bering Sea. Greg McGlashan is the Tribal Environmental Programs Director on St. George Island. Michael Brubaker is the Community Services Director for APIA. Victoria Gofman is Executive Director of AIA.

There are several examples of how climate change is affecting people and communities in the Aleutian and Pribilof Islands region. The Nelson Lagoon Tribal Council has for several years been concerned about the effect of changing weather patterns on the narrow spit of sand they occupy between Nelson Lagoon (a prime nesting habitat for Steller's eider (*Polysticta stelleri*)) and the Bering Sea. The changing climate is having dramatic effects on the security of the village and the local infrastructure.

Like many Alaskan coastal communities, Nelson Lagoon has been battling the effects of winter storms for years, most notably by building increasingly strong breakwalls along the shore. The increasing violence of the storms and changing winter sea-ice patterns have exacerbated the problem, reducing sections of a structure they hoped would provide decades of protection to kindling within just a few seasons. This is because their breakwall was designed to brace the shore ice, which would in turn provide the real buffer from winter storm wave action. As the winters have been warmer over the past six years, the buffer provided by the shore ice has been lost, allowing the full force of the waves to surge against the wall and the village.

United States General Accounting Office

GAO

Report to Congressional Committees

December 2003

ALASKA NATIVE VILLAGES

Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance

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GAO-04-142

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December 2003

GAO Accountability•Integrity•Reliability

Highlights

Highlights of GAO-04-142, a report to the Senate and House Committees on Appropriations

ALASKA NATIVE VILLAGES

Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance

Why GAO Did This Study

Approximately 6,600 miles of Alaska's coastline and many of the low-lying areas along the state's rivers are subject to severe flooding and erosion. Most of Alaska's Native villages are located on the coast or on riverbanks. In addition to the many federal and Alaska state agencies that respond to flooding and erosion, Congress established the Denali Commission in 1998 to, among other things, provide economic development services and to meet infrastructure needs in rural Alaska communities.

Congress directed GAO to study Alaska Native villages affected by flooding and erosion and to 1) determine the extent to which these villages are affected, 2) identify federal and state flooding and erosion programs, 3) determine the current status of efforts to respond to flooding and erosion in nine villages, and 4) identify alternatives that Congress may wish to consider when providing assistance for flooding and erosion.

What GAO Recommends

GAO presents to Congress a matter for consideration that directs federal agencies and the Denali Commission to assess the feasibility of alternatives for responding to flooding and erosion. In addition, GAO recommends that the Denali Commission adopt a policy to guide future infrastructure investments in Alaska Native villages affected by flooding and erosion.

www.gao.gov/cgi-bin/getrpt?GAO-04-142.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Anu Mittal at (202) 512-3841 or mittala@gao.gov.

What GAO Found

Flooding and erosion affects 184 out of 213, or 86 percent, of Alaska Native villages to some extent. While many of the problems are long-standing, various studies indicate that coastal villages are becoming more susceptible to flooding and erosion due in part to rising temperatures.

The Corps of Engineers and the Natural Resources Conservation Service administer key programs for constructing flooding and erosion control projects. However, small and remote Alaska Native villages often fail to qualify for assistance under these programs—largely because of agency requirements that the expected costs of the project not exceed its benefits. Even villages that do meet the cost/benefit criteria may still not receive assistance if they cannot meet the cost-share requirement for the project.

Of the nine villages we were directed to review, four—Kivalina, Koyukuk, Newtok, and Shishmaref—are in imminent danger from flooding and erosion and are planning to relocate, while the remaining five are in various stages of responding to these problems. Costs for relocating are expected to be high. For example, the cost estimates for relocating Kivalina range from $100 million to over $400 million. Relocation is a daunting process that may take several years to accomplish. During that process, federal agencies must make wise investment decisions, yet GAO found instances where federal agencies invested in infrastructure at the villages' existing sites without knowledge of their plans to relocate.

GAO, federal and state officials, and village representatives identified some alternatives that could increase service delivery for Alaska Native villages, although many important factors must first be considered:

- Expand the role of the Denali Commission.
- Direct federal agencies to consider social and environmental factors in their cost/benefit analyses.
- Waive the federal cost-sharing requirement for these projects.
- Authorize the "bundling" of funds from various federal agencies.

Bluff Erosion at Shishmaref

Source: GAO.

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United States General Accounting Office
Washington, D.C. 20548

December 12, 2003

The Honorable Ted Stevens
Chairman
The Honorable Robert C. Byrd
Ranking Minority Member
Committee on Appropriations
United States Senate

The Honorable C.W. Bill Young
Chairman
The Honorable David R. Obey
Ranking Minority Member
Committee on Appropriations
House of Representatives

Alaska's shoreline is subject to periodic, yet severe, erosion. During these episodes, over 100 feet of land can be lost in a single storm. The state also has thousands of miles of riverbanks that are prone to annual flooding during the spring thaw. These shorelines and riverbanks serve as home to over 200 Native villages whose inhabitants hunt and fish for subsistence. Coastal and river flooding and erosion cause millions of dollars of property damage in Alaska Native villages, damaging or destroying homes, public buildings, and airport runways. Because Alaska Native villages are often in remote areas not accessible by roads, village airport runways are lifelines for many villages, and any threat to the runways either from flooding or erosion may be a threat to the villages' survival. Flooding and erosion can also destroy meat drying racks and damage food cellars, threatening the winter food supply and the traditional subsistence lifestyle of Alaska Natives.

Since 1977, the state, and in some cases the federal government, has responded to more than 190 disaster emergencies in Alaska, many in response to these problems. Several federal and state agencies are directly or indirectly involved in providing assistance for flooding and erosion in Alaska. In addition, the Denali Commission, created by Congress in 1998, while not directly responsible for responding to flooding and erosion, is charged with addressing crucial needs of rural Alaska communities,

Exhibit 33
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particularly isolated Alaska Native villages.[1] The commission is composed of a federal and a state cochair and representatives from local agencies, as well as Alaska Native, public, and private entities. For fiscal year 2003, the commission was provided with almost $99 million in federal funds to carry out its mission. The purpose of the commission is to (1) deliver the services of the federal government in the most cost-effective manner practicable; (2) provide job training and other economic development services in rural communities; and (3) promote rural development and provide infrastructure such as water, sewer, and communication systems.

The fiscal year 2003 Conference Report for the military construction appropriation bill directed GAO to study Alaska Native villages affected by flooding and erosion.[2] In response to this direction and subsequent discussions with your staff, we (1) determined the extent to which Alaska Native villages are affected by flooding and erosion; (2) identified federal and Alaska state programs that provide assistance for flooding and erosion and assessed the extent to which federal assistance has been provided to Alaska Native villages; (3) determined the status of efforts, including cost estimates, to respond to flooding and erosion in select villages seriously affected by flooding and erosion; and (4) identified alternatives that Congress may wish to consider when providing assistance for flooding and erosion of Alaska Native villages.

To address the objectives for this report, we reviewed federal and state flooding and erosion studies and project documents and interviewed federal and state agency officials and representatives from each of the nine villages. We also visited four of the nine villages. While the committee directed us to include at least six villages in our study—Barrow, Bethel, Kaktovik, Kivalina, Point Hope, and Unalakleet—we added three more—Koyukuk, Newtok, and Shishmaref—based on discussions with congressional staff and with federal and Alaska state officials familiar with flooding and erosion problems. Appendix I provides further details about the scope and methodology of our review.

Results in Brief

According to federal and state officials in Alaska, 184 out of 213, or 86.4 percent of Alaska Native villages experience some level of flooding and

[1]Pub. L. No. 105-277, tit. III, 112 Stat. 2681 (1998).

[2]H. R. Conf. Rep. No. 107-731, at 15 (2002).

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erosion, but it is difficult to assess the severity of the problem because quantifiable data are not available for remote locations. Native villages on the coast or along rivers are subject to both annual and episodic flooding and erosion. Various studies and reports indicate that coastal villages in Alaska are becoming more susceptible to flooding and erosion in part because rising temperatures cause protective shore ice to form later in the year, leaving the villages vulnerable to fall storms. For example, the barrier island village of Shishmaref, which is less than 1,320 feet wide, lost 125 feet of beach to erosion during an October 1997 storm. In addition, villages in low-lying areas along riverbanks or in river deltas are susceptible to flooding and erosion caused by ice jams, snow and glacial melts, rising sea levels, and heavy rainfall. For many villages, ice jams that form in the Kuskokwim and Yukon Rivers during the spring ice breakup cause the most frequent and severe floods by creating a buildup of water behind the jam. The resulting accumulation of water can flood entire villages. While flooding and erosion affect most Alaska Native villages, federal and state officials noted that Alaska has significant data gaps because of a lack of monitoring equipment in remote locations. This lack of baseline data makes it difficult to assess the severity of the problem.

The Continuing Authorities Program, administered by the U.S. Army Corps of Engineers, and the Watershed Protection and Flood Prevention Program, administered by the Department of Agriculture's Natural Resources Conservation Service, are the principal federal programs that provide assistance for the prevention or control of flooding and erosion. However, small and remote Alaska Native villages often fail to qualify for assistance under these programs because they do not meet program criteria. For example, according to the Corps' guidelines for evaluating water resource projects, the Corps generally cannot undertake a project when the economic costs exceed the expected benefits. With few exceptions, Alaska Native villages' requests for assistance under this program are denied because the project costs usually outweigh expected benefits. Even villages that meet the Corps' cost/benefit criteria may still fail to qualify if they cannot meet cost-share requirements for the project. The Department of Agriculture's Natural Resources Conservation Service's Watershed Protection and Flood Prevention Program also requires a cost/benefit analysis similar to that of the Corps. As a result, few Alaska Native villages qualify for assistance under this program. However, the Natural Resources Conservation Service has other programs that have provided limited assistance to these villages—in part because these programs consider additional social and environmental factors in developing their cost/benefit analysis. Besides programs administered by the Corps of Engineers and the

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Natural Resources Conservation Service, there are several other federal and state programs that offer limited assistance to Alaska Native villages in responding to flooding and erosion. For example, the Federal Aviation Administration can assist with rebuilding or repairing airstrips that are affected by flooding and erosion, and the Alaska Department of Community and Economic Development provides coordination and technical assistance to communities to help reduce losses and damage from flooding and erosion. However, these programs are generally not prevention programs, but are available to assist communities in preparing for or responding to the consequences of flooding and erosion.

Of the nine villages we were directed to review, four—Kivalina, Koyukuk, Newtok, and Shishmaref—are in imminent danger from flooding and erosion and are making plans to relocate; the remaining villages are taking other actions. Kivalina, Newtok, and Shishmaref are working with relevant federal agencies to determine the suitability of possible relocation sites, while Koyukuk is in the early stages of planning for relocation. Because of the high cost of materials and transportation in remote parts of Alaska, the cost of relocation for these villages is expected to be high. For example, the Corps estimates that the cost to relocate Kivalina, which has a population of about 385, could range from $100 million for design and construction of infrastructure, including a gravel pad, at one site and up to $400 million for just the cost of building a gravel pad at another site. Cost estimates for relocating the other three villages are not yet available. The five villages not planning to relocate—Barrow, Bethel, Kaktovik, Point Hope, and Unalakleet—are in various stages of responding to their flooding and erosion problems. For example, two of these villages, Kaktovik and Point Hope, are studying ways to prevent flooding of specific infrastructure, such as the airport runway. In addition, Bethel, a regional hub in southwest Alaska with a population of about 5,471, has a project under way to stop erosion of its riverbank. The project involves repairing an existing seawall and extending it 1,200 feet to protect the entrance to the village's small boat harbor, at an initial cost estimate of more than $4.7 million and average annual costs of $374,000.

During our review of the nine villages, we found instances where federal agencies invested in infrastructure projects without knowledge of the villages' plans to relocate. For example, the Denali Commission and the Department of Housing and Urban Development were unaware of Newtok's relocation plans when they decided to jointly fund a new health clinic in the village for $1.1 million (using fiscal year 2002 and 2003 funds). While we recognize that development and maintenance of critical

Exhibit 33
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infrastructure, such as health clinics and runways, are necessary as villages find ways to respond to flooding and erosion, we question whether limited federal funds for these projects are being expended in the most effective and efficient manner. Had the agencies known of the village's relocation plans they could have explored other, potentially less costly, options for meeting the village's needs, until it is able to relocate. The Denali Commission has recognized this issue as a concern and is working on a policy to ensure that investments are made in a conscientious and sustainable manner for villages threatened by flooding and erosion. Successful implementation of such a policy will depend in part on its adoption by individual federal agencies that also fund infrastructure development in Alaska Native villages. We are recommending that the Denali Commission adopt a policy that will guide future infrastructure investments and project designs in villages affected by flooding and erosion.

The unique circumstances of Alaska Native villages and their inability to qualify for assistance under a variety of federal flooding and erosion programs may require special measures to ensure that they receive certain needed services. Federal and Alaska state officials and Alaska Native village representatives that we spoke with identified several alternatives that could help mitigate the barriers that villages face in obtaining federal services. The alternatives discussed below may be considered individually or in combination. However, adopting some of these alternatives will require consideration of a number of important factors including the potential to set a precedent for other communities and programs as well as resulting budgetary implications.

- Expand the role of the Denali Commission to include responsibility for managing a flooding and erosion assistance program, which it currently does not have.

- Direct the Corps and the Natural Resources Conservation Service to consider social and environmental factors in their cost benefit analyses for projects requested by Alaska Native villages.

- Waive the federal cost-sharing requirement for flooding and erosion programs for Alaska Native villages.

In addition, as a fourth alternative, GAO identified the bundling of funds from various agencies to address flooding and erosion problems in Alaska Native villages. While we did not determine the cost or the national policy implications associated with any of these alternatives, these costs and implications are important considerations in determining the appropriate level of federal services that should be available to respond to flooding and erosion in Alaska Native villages. Consequently, we are providing Congress with a matter for consideration that it direct relevant executive agencies and the Denali Commission to assess the feasibility of each of the alternatives, as appropriate. In addition, the Denali Commission may want to comment on the implications of expanding its role.

Background

Alaska encompasses an area of about 365 million acres, more than the combined area of the next three largest states—Texas, California, and Montana. The state is bound on three sides by water, and its coastline, which stretches about 6,600 miles (excluding island shorelines, bays and fjords) and accounts for more than half of the entire U.S. coastline, varies from rocky shores, sandy beaches, and high cliffs to river deltas, mud flats, and barrier islands. The coastline constantly changes due to wave action, ocean currents, storms, and river deposits and is subject to periodic, yet severe, erosion. Alaska also has more than 12,000 rivers, including three of the ten largest in the country—the Yukon, Kuskokwim, and Copper Rivers.[3] (See fig. 1.) While these and other rivers provide food, transportation, and recreation for people, as well as habitat for fish and wildlife, their waters also shape the landscape. In particular, ice jams on rivers and flooding of riverbanks during spring breakup change the contour of valleys, wetlands, and human settlements.

[3] The size is determined by the average rate of flow (discharge at the mouth).

Exhibit 33
AEWC & ICAS

United States Environmental Protection Agency

Office of Transportation
and Air Quality

EPA420-F-05-004
February 2005

Emission Facts

Greenhouse Gas Emissions from a Typical Passenger Vehicle

The U.S. Environmental Protection Agency (EPA) developed this series of four fact sheets to facilitate consistency of assumptions and practices in the calculation of emissions of greenhouse gases from transportation and mobile sources. They are intended as a reference for anyone estimating emissions benefits of mobile sources air pollution control programs.

Issue

Each EPA voluntary climate change program has used slightly different assumptions to translate the greenhouse gas (GHG) reductions associated with the program to the equivalent GHG emissions of a number of cars on the road. The result is that different numbers for the greenhouse gas emissions associated with a passenger vehicle have been used for different programs. The purpose of this fact sheet is to determine consistent assumptions and produce a number that is accepted for the annual GHG emissions associated with a passenger vehicle. The estimate calculated here is for vehicle emissions only, and does not include lifecycle emissions such as emissions associated with the production and distribution of fuel.

Exhibit 34
AEWC & ICAS

Recommendation

To translate GHG reductions into an equivalent number of cars off the road, annual emissions from a typical passenger vehicle should be equated to 5.5 metric tons of carbon dioxide equivalent or 1.5 metric tons of carbon equivalent.

Key steps to the calculation

There are six key steps to estimate the annual greenhouse gas emissions associated with a passenger vehicle:

1. Determining the carbon dioxide (CO_2) produced per gallon of gasoline
2. Estimating the fuel economy of passenger cars and light trucks (in miles per gallon [mpg])
3. Determining the number of miles driven
4. Determining the emissions of greenhouse gases other than CO_2 (methane [CH_4], nitrous oxide [N_2O], and hydrofluorocarbons [HFCs])
5. Estimating the relative percentages of passenger cars and light trucks
6. Calculating the resulting annual greenhouse gas emissions

Note that for the purposes of this fact sheet, representative values were chosen for each of these variables, despite the fact that in practice variation does occur in these numbers.

Step 1: Determining the CO_2 produced per gallon of gasoline

A gallon of gasoline is assumed to produce 8.8 kilograms (or 19.4 pounds) of CO_2. This number is calculated from values in the Code of Federal Regulations at 40 CFR 600.113-78, which EPA uses to calculate the fuel economy of vehicles, and relies on assumptions consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines.

In particular, 40 CFR 600.113-78 gives a carbon content value of 2,421 grams (g) of carbon per gallon of gasoline, which produces 8,877 g of CO_2. (The carbon content is multiplied by the ratio of the molecular weight of CO_2 to the molecular weight of carbon: 44/12).

Exhibit 34
AEWC & ICAS

This number is then multiplied by an oxidation factor of 0.99, which assumes that 1 percent of the carbon remains un-oxidized.[1] This produces a value of 8,788 g or 8.8 kg (19.4 lbs) of CO_2.

Step 2: Estimating the fuel economy of passenger cars and light trucks (MPG estimate)

There are two sources of data which EPA has used for the average fuel economy of passenger cars and light trucks. MOBILE6.2 (EPA's computer model for estimating emissions for highway vehicles) can calculate an average fuel economy across the fleet, based on the EPA annual Fuel Economy Trends reports. For 2003, MOBILE calculates values of 23.9 miles per gallon (mpg) for passenger cars and 17.4 mpg for light trucks. These values are weighted averages (based on vehicle age data for the fleet, including vehicles up to 25 years old) of the Fuel Economy Trends sales-weighted average fuel economy of passenger cars and light trucks for each model year. MOBILE6.2 calculates an overall average fuel economy for passenger vehicles of 20.3 mpg (weighted by vehicle miles traveled [VMT] for passenger cars and light trucks).

The Federal Highway Administration's (FHWA) "Highway Statistics 2001" gives average values of 22.1 mpg for passenger cars and 17.6 mpg for light trucks as a fleet wide average in for the year 2001 (includes all vehicles on the road in 2001). These values are obtained by dividing vehicle miles traveled by fuel use.[2] These values are used in the development of the "Inventory of U.S. Greenhouse Gas Emissions and Sinks."

Recommendation: Values were calculated using both sets of fuel economy numbers. Depending on the circumstances, use of one set of numbers or the other may be more appropriate. Generally EPA staff should use the MOBILE6 estimates. However, EPA uses the FHWA numbers in developing the National Inventory for Greenhouse Gas Emissions because they are consistent with the methodology used to develop the inventory. (Note that a small variation in the fuel economy number will not change the rough estimate of greenhouse gases derived here.)

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[1] The International Panel on Climate Change Guidelines (IPCC) recommends a fraction of carbon oxidized factor of 0.99 for all oil and oil-based products. Based on the fundamentals of internal combustion engine design and combustion, EPA is currently examining whether this fraction is higher (closer to 100 percent) for gasoline vehicles in the US.

[2] U.S. Department of Transportation, Federal Highway Administration, "Highway Statistics 2000," Washington, DC, 2001. Vehicle travel and fuel use data are kept separately for passenger cars and light trucks.

Step 3: Determining the number of miles driven

The number of miles driven per year is assumed to be 12,000 miles for all passenger vehicles.

This number is based on several sources. Calculations from EPA's MOBILE6 model show an average annual milage of roughly 10,500 miles per year for passenger cars and over 12,400 miles per year for light trucks across all vehicles in the fleet. However, these numbers include the oldest vehicles in the fleet (vehicles 25 years of age and older), which are likely not used as primary vehicles and are driven substantially less than newer vehicles. Since this calculation is for a typical vehicle, including the oldest vehicles may not be appropriate. For all vehicles up to 10 years old, MOBILE6 shows an annual average milage of close to 12,000 miles per year for passenger cars, and over 15,000 miles per year for light trucks.

FHWA's National Highway Statistics contains values of 11,766 miles for passenger cars and 11,140 miles for light trucks across the fleet. However, as with the MOBILE6 fleet-wide estimates, these numbers include the oldest vehicles in the fleet. EPA's Commuter Model uses 1997 data from Oak Ridge Laboratories for the number of cars nationally and number of miles driven which produces a value of just over 12,000 miles per year. Due to the wide range of estimates, 12,000 miles per vehicle is used as a rough estimate for calculating the greenhouse gas emissions from a typical passenger vehicle.)

Step 4: Determining the emissions of greenhouse gases other than CO_2 (N_2O, CH_4, and HFCs)

In addition to carbon dioxide, automobiles produce methane (CH_4) and nitrous oxide (N_2O) from the tailpipe, as well as HFC emissions from leaking air conditioners.

The emissions of CH_4 and N_2O are related to vehicle miles traveled rather than fuel consumption, and the emissions of CH_4, N_2O, and HFCs are not as easily estimated from a vehicle as for CO_2.[3] On average, CH_4, N_2O, and HFC emissions represent roughly 5 - 6 percent of the GHG emissions from passenger vehicles, while CO_2 emissions account for 94-95 percent, accounting for the global warming potential of each greenhouse gas. (These percentages are estimated from the EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2001.") To simplify this estimate, it is assumed that CH_4, N_2O, and HFCs account for 5 percent of emissions, and the CO_2 estimate was multiplied by 100/95 to incorporate the contribution of the other greenhouse gases.

[3] EPA is currently examining ways to better disaggregate the HFC emissions from vehicles.

Step 5: Estimating the relative percentages of passenger cars and light trucks

Because FHWA calculates fuel economy for passenger cars and light trucks separately, it is necessary to determine the relative percentage of cars and light trucks in order to derive the greenhouse gas emissions for an average passenger vehicle. (This step is not necessary when using the MOBILE6 fuel economy data because MOBILE6 already calculates a weighted average fuel economy for all passenger vehicles.) Passenger cars are assumed to make up 63.4 percent and light trucks make up 36.6 percent of the passenger vehicle fleet. These values are derived from table 6.4 (2000 data) of the "Transportation Energy Data Book: Edition 22" (published by the Center for Transportation Analysis, Oak Ridge National Laboratory), which states there are 127,721,000 passenger cars on the road and 73,775,000 light trucks (less than 8500 lbs[4]). Note that this percentage is changing over time, as light trucks now represent roughly 50 percent of annual new vehicle sales.

Step 6: Calculating the resulting annual greenhouse gases from a typical passenger vehicle

A: Using EPA MOBILE6.2 fuel economy numbers

Metric tons of CO_2e for the average passenger vehicle =

(VMT/passenger vehicle avg. MPG) x CO_2 per gallon x (100/95) /1000 =

(12,000/20.3) x 8.8 x (100/95)/1000 =

5.48 metric tons CO_2e for the average passenger vehicle (1.49 metric tons CE)

B: Using DOT fuel economy numbers

[%LDV x (LDVVMT/LDVMPG) x CO_2 per gallon x (100/95) /1000] +
[%LDT x (LDTVMT/LDTMPG) x CO_2 per gallon x (100/95) /1000] =

[0.634 x (12,000/22.1) x 8.8 x (100/95)/1000] + [0.366 x (12,000/17.6)] x 8.8 x (100/95)/1000] =

5.03 metric tons CO_2e for passenger cars and 6.32 metric tons CO_2e for light trucks (= 1.37 metric tons CE for cars and 1.72 metric tons CE for trucks) =

5.50 metric tons CO_2e for the average passenger vehicle (1.50 metric tons CE)

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[4] Vehicles over 8500 lbs are often not included in the light truck category. These vehicles are not required to meet CAFE standards. Examples of these vehicles include the Hummer and the Ford Excursion.

Recommendation: To calculate rough translations of GHG reductions into an equivalent number of cars off the road, use 5.5 metric tons of CO_2, or 1.5 metric tons of carbon equivalent. This number is rounded to the nearest tenth of a ton (using either DOT or EPA fuel economy estimates). This rough estimate will also allow for some variability in the underlying variables.

CO_2 only numbers

A: Using EPA MOBILE6.2 fuel economy numbers

Average passengerr vehicle = 5.20 metric tons CO_2e (1.42 metric tons CE)

B: Using DOT fuel economy numbers

Passenger Cars = 4.78 metric tons CO_2e (1.30 metric tons CE)
Light Trucks = 6.00 metric tons CO_2e (1.64 metric tons CE)
All passenger vehicles = 5.23 metric tons CO_2e (1.43 metric tons CE)

Recommendation: For CO_2 only estimate, use 5.2 metric tons CO_2e, or 1.4 metric tons CE

Note: These calculations and the supporting data have associated variation and uncertainty. EPA may use other values in certain circumstances, and in some cases it may be appropriate to use a range of values.

For More Information

You can access documents on greenhouse gas emissions on the Office of Transportation and Air Quality Web site at:

www.epa.gov/otaq/greenhousegases.htm

For further information on calculating emissions of greenhouse gases, please contact Ed Coe at:

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