Resolution urging the Retirement Board of the San Francisco Employees' Retirement System to divest from publicly-traded fossil fuel companies.

Attachments:

1. "Turn Down the Heat," The Potsdam Institute
   http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

2. "Fourth Assessment Report ," Intergovernmental Panel on Climate Change (IPCC)
   https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

3. 2004 Climate Action Plan for San Francisco
   http://www.sfenvironment.org/download/2004-climate-action-plan-for-san-francisco

4. "Living with a Rising Bay," San Francisco Bay Conservation and Development Commission
   www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf

5. Copenhagen Accord of 18 December 2009
   http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf

6. "Unburnable Carbon," the Carbon Tracker Initiative
   www.carbontracker.org/wp-content/uploads/downloads/2012/08/Unburnable-Carbon-Full1.pdf

7. "Oil and Carbon Revisited," HSBC Global Research
   http://www.hsbcnet.com/hsbc/research

8. "Do the Investment Math: Building a Carbon-Free Portfolio," the Aperio Group investment management firm
   https://www.aperiogroup.com/system/files/documents/building_a_carbon_free_portfolio_0.pdf

9. San Francisco Employees' Retirement System (SFERS) Retirement Board's Social Investment Policy
   http://sfers.org/

Executive Summary

1. "Turn Down the Heat," The Potsdam Institute
http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

Turn Down the Heat

Why a 4°C Warmer World Must be Avoided

THE WORLD BANK

Executive Summary

4° Turn Down the Heat

Why a 4°C Warmer World Must be Avoided

November 2012

A Report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics

THE WORLD BANK

Executive Summary

This report provides a snapshot of recent scientific literature and new analyses of likely impacts and risks that would be associated with a 4° Celsius warming within this century. It is a rigorous attempt to outline a range of risks, focusing on developing countries and especially the poor. A 4°C world would be one of unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on ecosystems and associated services. But with action, a 4°C world can be avoided and we can likely hold warming below 2°C.

Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3°C above the preindustrial climate. Even with the current mitigation commitments and pledges fully implemented, there is roughly a 20 percent likelihood of exceeding 4°C by 2100. If they are not met, a warming of 4°C could occur as early as the 2060s. Such a warming level and associated sea-level rise of 0.5 to 1 meter, or more, by 2100 would not be the end point: a further warming to levels over 6°C, with several meters of sea-level rise, would likely occur over the following centuries.

Thus, while the global community has committed itself to holding warming below 2°C to prevent "dangerous" climate change, and Small Island Developing states (SIDS) and Least Developed Countries (LDCs) have identified global warming of 1.5°C as warming above which there would be serious threats to their own development and, in some cases, survival, the sum total of current policies—in place and pledged—will very likely lead to warming far in excess of these levels. Indeed, present emission trends put the world plausibly on a path toward 4°C warming within the century.

This report is not a comprehensive scientific assessment, as will be forthcoming from the Intergovernmental Panel on Climate Change (IPCC) in 2013–14 in its Fifth Assessment Report. It is focused on developing countries, while recognizing that developed countries are also vulnerable and at serious risk of major damages from climate change. A series of recent extreme events worldwide continue to highlight the vulnerability of not only the developing world but even wealthy industrialized countries.

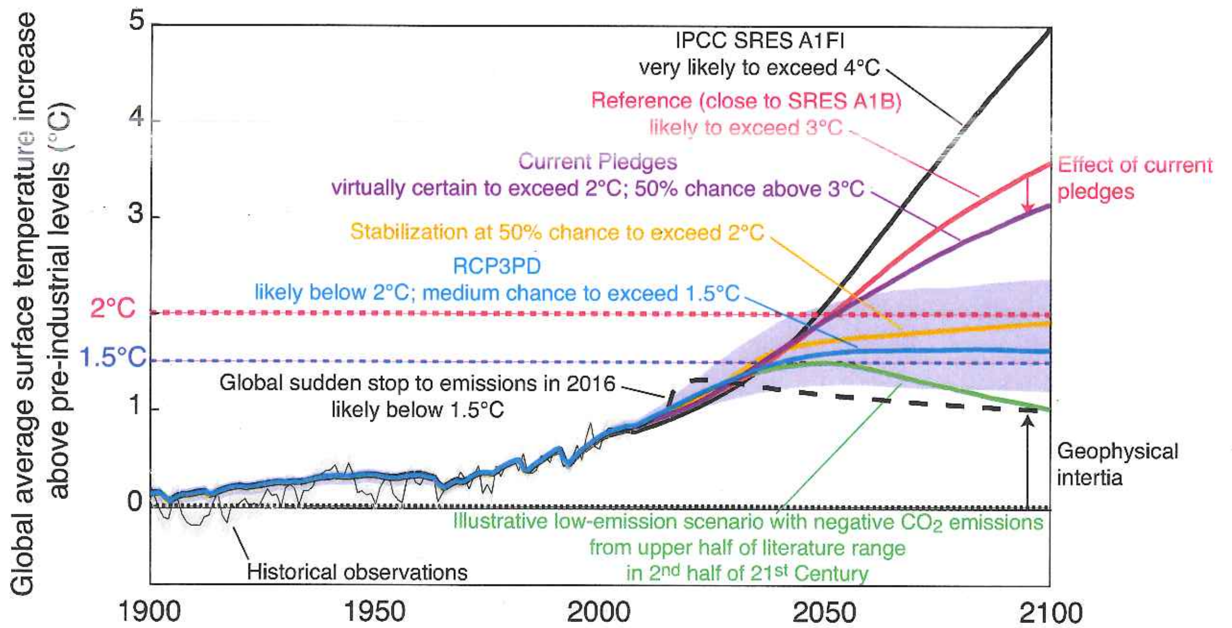
Uncertainties remain in projecting the extent of both climate change and its impacts. We take a risk-based approach in which risk is defined as *impact multiplied by probability*: an event with low probability can still pose a high risk if it implies serious consequences.

No nation will be immune to the impacts of climate change. However, the distribution of impacts is likely to be inherently unequal and tilted against many of the world's poorest regions, which have the least economic, institutional, scientific, and technical capacity to cope and adapt. For example:

- Even though absolute warming will be largest in high latitudes, the warming that will occur in the tropics is larger when compared to the historical range of temperature and extremes to which human and natural ecosystems have adapted and coped. The projected emergence of unprecedented high-temperature extremes in the tropics will consequently lead to significantly larger impacts on agriculture and ecosystems.
- Sea-level rise is likely to be 15 to 20 percent larger in the tropics than the global mean.
- Increases in tropical cyclone intensity are likely to be felt disproportionately in low-latitude regions.
- Increasing aridity and drought are likely to increase substantially in many developing country regions located in tropical and subtropical areas.

A world in which warming reaches 4°C above preindustrial levels (hereafter referred to as a 4°C world), would be one of

Figure 1: Median estimates (lines) from probabilistic temperature projections for two non-mitigation emission scenarios (SRES A1FI and a reference scenario close to SRESA1B), both of which come close to, or exceed by a substantial margin, 4°C warming by 2100. The results for these emission scenarios are compared to scenarios in which current pledges are met and to mitigation scenarios holding warming below 2°C with a 50% chance or more. A hypothetical scenario is also plotted for which global emissions stop in 2016, as an illustrative comparison against pathways that are technically and economically feasible. The spike in warming after emissions are cut to zero is due to the removal of the shading effect of sulfate aerosols. The 95% uncertainty range (shaded area) is provided for one scenario only to enhance readability. See (Rogelj et al., 2010; Hare et al., 2011; Schaeffer et al., 2012) for scenarios and modeling methods.



unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on human systems, ecosystems, and associated services.

Warming of 4°C can still be avoided: numerous studies show that there are technically and economically feasible emissions pathways to hold warming likely below 2°C (Figure 1). Thus the level of impacts that developing countries and the rest of the world experience will be a result of government, private sector, and civil society decisions and choices, including, unfortunately, inaction.

Observed Impacts and Changes to the Climate System

The unequivocal effects of greenhouse gas emission-induced change on the climate system, reported by the IPCC's Fourth Assessment Report (AR4) in 2007, have continued to intensify, more or less unabated:

- The concentration of the main greenhouse gas, carbon dioxide (CO_2), has continued to increase from its preindustrial concentration of approximately 278 parts per million (ppm) to over 391 ppm in September 2012, with the rate of rise now at 1.8 ppm per year.
- The present CO_2 concentration is higher than paleoclimatic and geologic evidence indicates has occurred at any time in the last 15 million years.
- Emissions of CO_2 are, at present, about 35,000 million metric tons per year (including land-use change) and, absent further policies, are projected to rise to 41,000 million metric tons of CO_2 per year in 2020.
- Global mean temperature has continued to increase and is now about 0.8°C above preindustrial levels.

A global warming of 0.8°C may not seem large, but many climate change impacts have already started to emerge, and the shift from 0.8°C to 2°C warming or beyond will pose even greater challenges. It is also useful to recall that a global mean temperature increase of 4°C approaches the difference between temperatures today and those of the last ice age, when much of central Europe and the northern United States were covered with kilometers of ice

Observed Climate Changes and Impacts

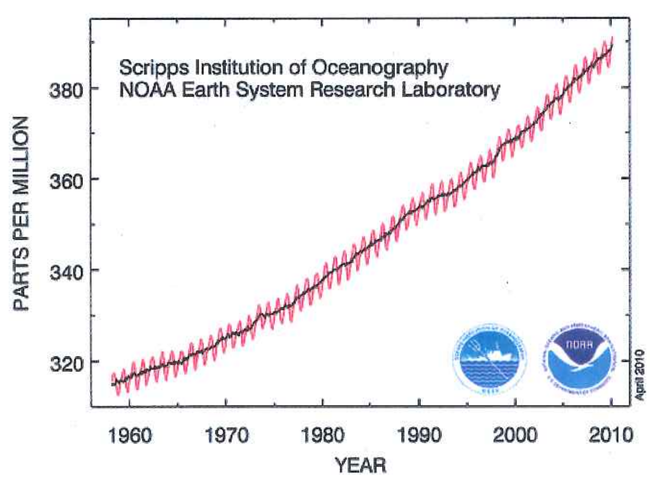
There is a growing and well-documented body of evidence regarding observed changes in the climate system and impacts that can be attributed to human-induced climate change. What follows is a snapshot of some of the most important observations. For a full overview, the reader is referred to recent comprehensive reports, such as *State of the Climate 2011*, published by the American Metrological Society in cooperation with National Oceanic and Atmospheric Administration (NOAA) (Blunden et al. 2012).

The Rise of CO_2 Concentrations and Emissions

In order to investigate the hypothesis that atmospheric CO_2 concentration influences the Earth's climate, as proposed by John Tyndall (Tyndall 1861), Charles D. Keeling made systematic measurements of atmospheric CO_2 emissions in 1958 at the Mauna Loa Observatory, Hawaii (Keeling et al. 1976; Pales & Keeling 1965). Located on the slope of a volcano 3,400 m above sea level and remote from external sources and sinks of carbon dioxide, the site was identified as suitable for long-term measurements (Pales and Keeling 1965), which continue to the present day. Results show an increase from 316 ppm (parts per million) in March 1958 to 391 ppm in September 2012. Figure 1 shows the measured carbon dioxide data (red curve) and the annual average CO_2 concentrations in the period 1958–2012. The seasonal oscillation shown on the red curve reflects the growth of plants in the Northern Hemisphere, which store more CO_2 during the boreal spring and summer than is respired, effectively taking up carbon from the atmosphere (Pales and Keeling 1965). Based on ice-core measurements,[2] pre-industrial CO_2 concentrations have been shown to have been in the range of 260 to 280 ppm (Indermühle 1999). Geological and paleo-climatic evidence makes clear that the present atmospheric CO_2 concentrations are higher than at any time in the last 15 million years (Tripati, Roberts, and Eagle 2009).

Since 1959, approximately 350 billion metric tons of carbon (or GtC)[3] have been emitted through human activity, of which 55

Figure 1: Atmospheric CO_2 concentrations at Mauna Loa Observatory.



2 The report adopts 1750 for defining CO_2 concentrations. For global mean temperature pre-industrial is defined as from mid-19th century.

3 Different conventions are used are used in the science and policy communities. When discussing CO_2 emissions it is very common to refer to CO_2 emissions by the weight of carbon—3.67 metric tons of CO_2 contains 1 metric ton of carbon, whereas when CO_2 equivalent emissions are discussed, the CO_2 (not carbon) equivalent is almost universally used. In this case 350 billion metric tons of carbon is equivalent to 1285 billion metric tons of CO_2.

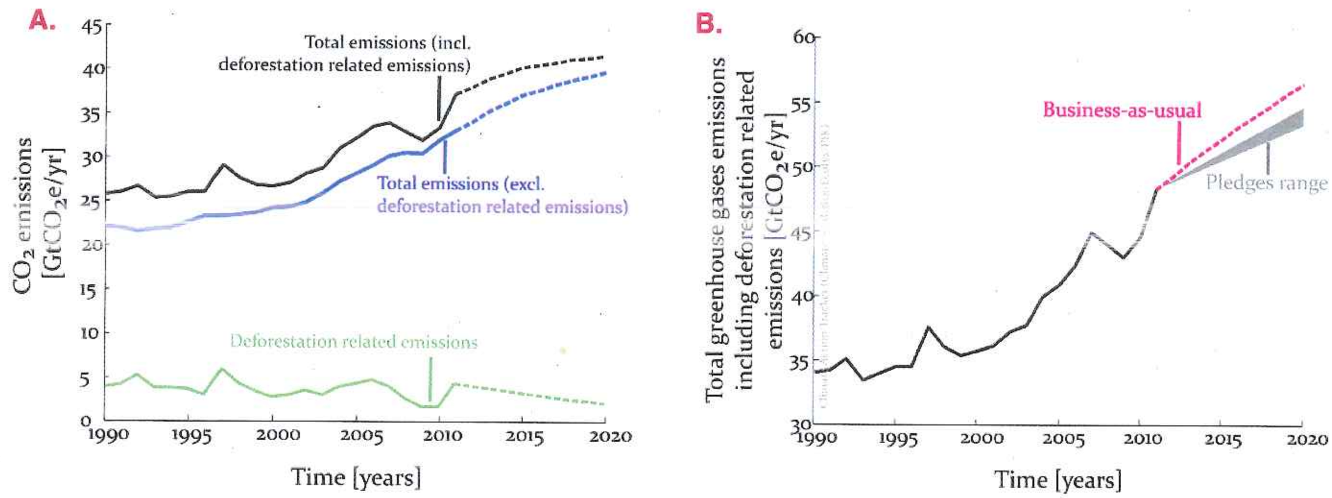


Figure 2: Global CO_2 (a) and total greenhouse gases (b) historic (solid lines) and projected (dashed lines) emissions. CO_2 data source: PRIMAP4BIS[a] baseline and greenhouse gases data source: Climate Action Tracker[b]. Global pathways include emissions from international transport. Pledges ranges in (b) consist of the current best estimates of pledges put forward by countries and range from minimum ambition, unconditional pledges, and lenient rules to maximum ambition, conditional pledges, and more strict rules.

a https://sites.google.com/a/primap.org/www/the-primap-model/documentation/baselines
b http://climateactiontracker.org/

percent has been taken up by the oceans and land, with the rest remaining in the atmosphere (Ballantyne et al. 2012). Figure 2a shows that CO_2 emissions are rising. Absent further policy, global CO_2 emissions (including emissions related to deforestation) will reach 41 billion metric tons of CO_2 per year in 2020. Total greenhouse gases will rise to 56 $GtCO_2e$[4] in 2020, if no further climate action is taken between now and 2020 (in a "business-as-usual" scenario). If current pledges are fully implemented, global total greenhouse gases emissions in 2020 are likely to be between 53 and 55 billion metric tons CO_2e per year (Figure 2b).

Rising Global Mean Temperature

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) found that the rise in global mean temperature and warming of the climate system were "unequivocal." Furthermore, "most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" (Solomon, Miller et al. 2007). Recent work reinforces this conclusion. Global mean warming is now approximately 0.8°C above preindustrial levels.[5]

The emergence of a robust warming signal over the last three decades is very clear, as has been shown in a number of studies. For example, Foster and Rahmstorf (2011) show the clear signal that emerges after removal of known factors that affect short-term temperature variations. These factors include solar variability and volcanic aerosol effects, along with the El Niño/Southern oscillation events (Figure 3). A suite of studies, as reported by the IPCC, confirms that the observed warming cannot be explained by natural factors alone and thus can largely be attributed to anthropogenic influence (for example, Santer et al 1995; Stott et al. 2000). In fact, the IPCC (2007) states that during the last 50 years "the sum of solar and volcanic forcings would likely have produced cooling, not warming", a result which is confirmed by more recent work (Wigley and Santer 2012).

Increasing Ocean Heat Storage

While the warming of the surface temperature of the Earth is perhaps one of the most noticeable changes, approximately 93 percent of the additional heat absorbed by the Earth system resulting from an increase in greenhouse gas concentration since 1955 is stored

4 Total greenhouse gas emissions (CO_2e) are calculated by multiplying emissions of each greenhouse gas by its Global Warming Potential (GWPs), a measure that compares the integrated warming effect of greenhouses to a common base (carbon dioxide) on a specified time horizon. This report applies 100-year GWPs from IPCC's Second Assessment Report, to be consistent with countries reporting national communications to the UNFCCC.

5 See HadCRUT3v: http://www.cru.uea.ac.uk/cru/data/temperature/ and (Jones et al. 2012).

2. "Fourth Assessment Report ," Intergovernmental Panel on Climate Change (IPCC) https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

Climate Change 2007:
Synthesis Report

Synthesis Report

An Assessment of the Intergovernmental Panel on Climate Change

This underlying report, adopted section by section 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.

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3

Climate change and its impacts in the near and long term under different scenarios

3.1 Emissions scenarios

There is *high agreement* and *much evidence*[9] that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. Baseline emissions scenarios published since the IPCC Special Report on Emissions Scenarios (SRES, 2000) are comparable in range to those presented in SRES (see Box on SRES scenarios and Figure 3.1).[10] *{WGIII 1.3, 3.2, SPM}*

The SRES scenarios project an increase of baseline global GHG emissions by a range of 9.7 to 36.7 $GtCO_2$-eq (25 to 90%) between 2000 and 2030. In these scenarios, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond. Hence CO_2 emissions from energy use between 2000 and 2030 are projected to grow 40 to 110% over that period. *{WGIII 1.3, SPM}*

Studies published since SRES (i.e. post-SRES scenarios) have used lower values for some drivers for emissions, notably population projections. However, for those studies incorporating these new population projections, changes in other drivers, such as economic growth, result in little change in overall emission levels. Economic growth projections for Africa, Latin America and the Middle East to 2030 in post-SRES baseline scenarios are lower than in SRES, but this has only minor effects on global economic growth and overall emissions. *{WGIII 3.2, TS.3, SPM}*

Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. *{WGIII 3.2, TS.3, SPM}*

Available studies indicate that the choice of exchange rate for Gross Domestic Product (GDP) (Market Exchange Rate, MER or Purchasing Power Parity, PPP) does not appreciably affect the projected emissions, when used consistently.[11] The differences, if any, are small compared to the uncertainties caused by assumptions on other parameters in the scenarios, e.g. technological change. *{WGIII 3.2, TS.3, SPM}*

Scenarios for GHG emissions from 2000 to 2100 in the absence of additional climate policies

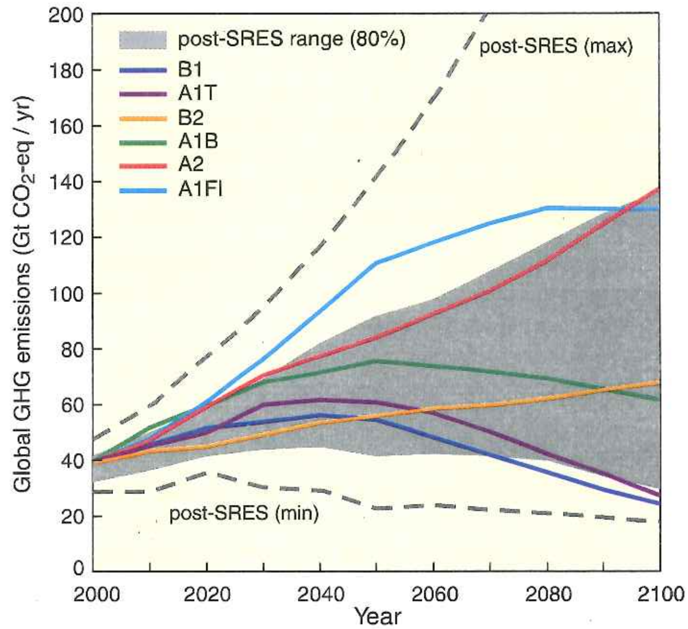


Figure 3.1. *Global GHG emissions (in $GtCO_2$-eq per year) in the absence of additional climate policies: six illustrative SRES marker scenarios (coloured lines) and 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. {WGIII 1.3, 3.2, Figure SPM.4}*

SRES scenarios

SRES refers to the scenarios described in the IPCC Special Report on Emissions Scenarios (SRES, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. The SRES scenarios do not include additional climate policies above current ones. The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments. *{WGI 10.1; WGII 2.4; WGIII TS.1, SPM}*

The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B). B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy. B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change. No likelihood has been attached to any of the SRES scenarios. *{WGIII TS.1, SPM}*

[9] Agreement/evidence statements in italics represent calibrated expressions of uncertainty and confidence. See Box 'Treatment of uncertainty' in the Introduction for an explanation of these terms.

[10] Baseline scenarios do not include additional climate policies above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion. Emission pathways of mitigation scenarios are discussed in Topic 5.

[11] Since the TAR, there has been a debate on the use of different exchange rates in emissions scenarios. Two metrics are used to compare GDP between countries. Use of MER is preferable for analyses involving internationally traded products. Use of PPP is preferable for analyses involving comparisons of income between countries at very different stages of development. Most of the monetary units in this report are expressed in MER. This reflects the large majority of emissions mitigation literature that is calibrated in MER. When monetary units are expressed in PPP, this is denoted by GDP_{PPP}. {WGIII SPM}

3.2 Projections of future changes in climate

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 (Figure 3.2). *{WGI 10.3, 10.7; WGIII 3.2}*

Since the IPCC's first report in 1990, assessed projections have suggested global averaged temperature increases between about 0.15 and 0.3°C per decade from 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections. *{WGI 1.2, 3.2}*

3.2.1 21st century global changes

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. *{WGI 10.3}*

Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emissions scenarios. Table 3.1 shows best estimates and *likely* ranges for global average surface air warming for the six SRES marker emissions scenarios (including climate-carbon cycle feedbacks). *{WGI 10.5}*

Although these projections are broadly consistent with the span quoted in the TAR (1.4 to 5.8°C), they are not directly comparable. Assessed upper ranges for temperature projections are larger than in the TAR mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. For the A2 scenario, for example, the climate-carbon cycle feedback increases the corresponding global average warming at 2100 by more than 1°C. Carbon feedbacks are discussed in Topic 2.3. *{WGI 7.3, 10.5, SPM}*

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. Model-based projections of global average sea level rise at the end of the 21st century (2090-2099) are shown in Table 3.1. For each scenario, the mid-point of the range in Table 3.1 is within 10% of the TAR model average for 2090-2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions.[12] The sea level projections do not include uncertainties in climate-carbon cycle feedbacks nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. Therefore the upper values of the ranges given are not to be considered upper bounds for sea level rise. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003, but these flow rates could increase or decrease in the future. If this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios shown in Table 3.1 would increase by 0.1 to 0.2m.[13] *{WGI 10.6, SPM}*

Table 3.1. *Projected global average surface warming and sea level rise at the end of the 21st century. {WGI 10.5, 10.6, Table 10.7, Table SPM.3}*

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) These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity, and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs) as well as observational constraints.

b) Year 2000 constant composition is derived from 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 WGI 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.

[12] 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 3.1 if it had treated uncertainties in the same way.

[13] For discussion of the longer term see Sections 3.2.3 and 5.2.

3.2.2 21st century regional changes

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. ***{WGI 8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}***

Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean (near Antarctica) and northern North Atlantic, continuing recent observed trends (Figure 3.2 right panels). *{WGI 10.3, SPM}*

Snow cover area is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions. Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. *{WGI 10.3, 10.6, SPM; WGII 15.3.4}*

It is *very likely* that hot extremes, heat waves and heavy precipitation events will become more frequent. *{SYR Table 3.2; WGI 10.3, SPM}*

Based on a range of models, it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea-surface temperatures. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period. *{WGI 3.8, 9.5, 10.3, SPM}*

Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns, continuing the broad pattern of observed trends over the last half-century. *{WGI 3.6, 10.3, SPM}*

Since the TAR there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high-latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, Figure 3.3), continuing observed patterns in recent trends. *{WGI 3.3, 8.3, 9.5, 10.3, 11.2-11.9, SPM}*

3.2.3 Changes beyond the 21st century

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. ***{WGI 10.4, 10.5, 10.7, SPM}***

If radiative forcing were to be stabilised, keeping all the radiative forcing agents constant at B1 or A1B levels in 2100, model experiments show that a further increase in global average temperature of about 0.5°C would still be expected by 2200. In addition, thermal expansion alone would lead to 0.3 to 0.8m of sea level rise by 2300 (relative to 1980-1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. *{WGI 10.7, SPM}*

Atmosphere-Ocean General Circulation Model projections of surface warming

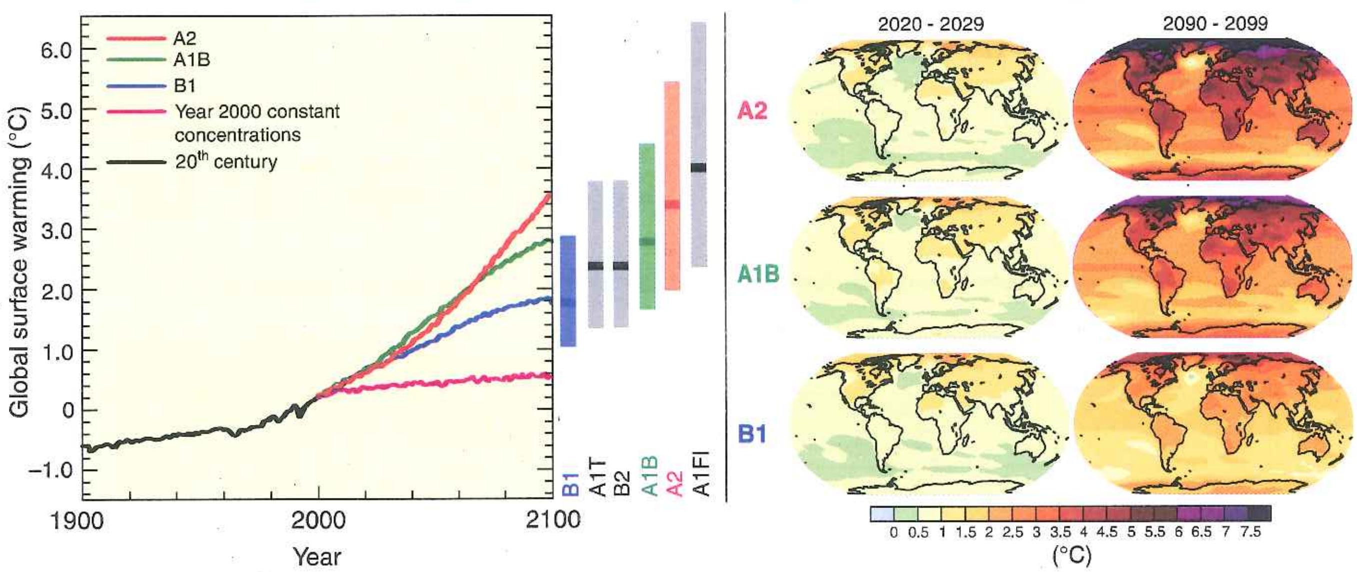


Figure 3.2. Left panel: *Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the SRES scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. The orange line is for the experiment where concentrations were held constant at year 2000 values. The bars in the middle 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 relative to 1980-1999. The assessment of the best estimate and* likely *ranges in the bars includes the Atmosphere-Ocean General Circulation Models (AOGCMs) in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints.* ***Right panels:*** *Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999. The panels show the multi-AOGCM average projections for the A2 (top), A1B (middle) and B1 (bottom) SRES scenarios averaged over decades 2020-2029 (left) and 2090-2099 (right). {WGI 10.4, 10.8, Figures 10.28, 10.29, SPM}*

Multi-model projected patterns of precipitation changes

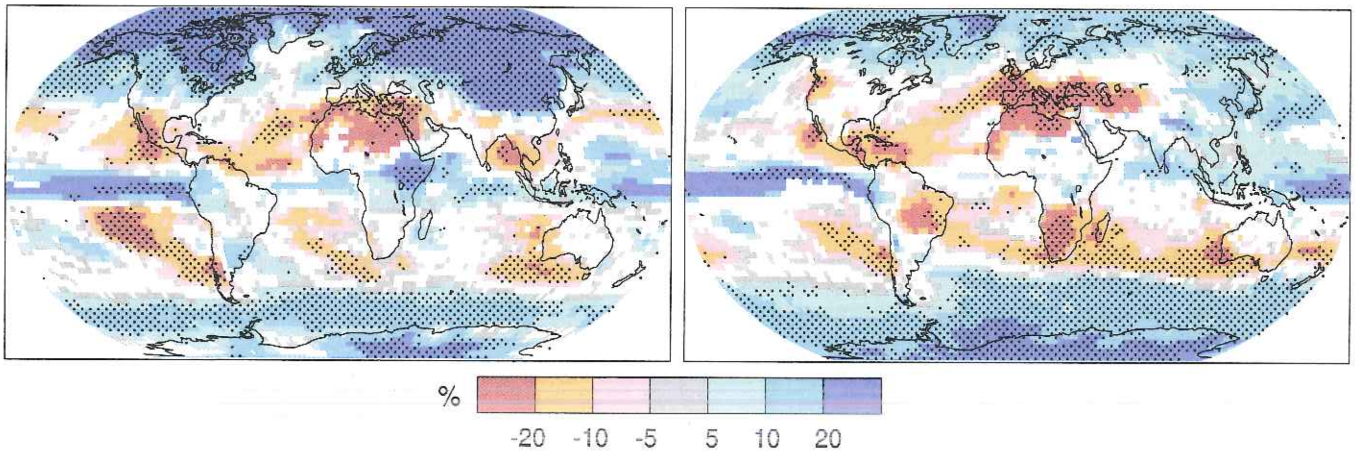


Figure 3.3. Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {WGI Figure 10.9, SPM}

Contraction of the Greenland ice sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest ice mass losses increase with temperature more rapidly than gains due to increased precipitation and that the surface mass balance becomes negative (net ice loss) at a global average warming (relative to pre-industrial values) in excess of 1.9 to 4.6°C. If such a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7m. The corresponding future temperatures in Greenland (1.9 to 4.6°C global) 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. *{WGI 6.4, 10.7, SPM}*

Dynamical processes related to ice flow – which are not included in current models but suggested by recent observations – could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude. *{WGI 4.6, 10.7, SPM}*

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. *{WGI 10.7, SPM}*

Both past and future anthropogenic CO_2 emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for the removal of this gas from the atmosphere. *{WGI 7.3, 10.3, Figure 7.12, Figure 10.35, SPM}*

Estimated long-term (multi-century) warming corresponding to the six AR4 WG III stabilisation categories is shown in Figure 3.4.

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

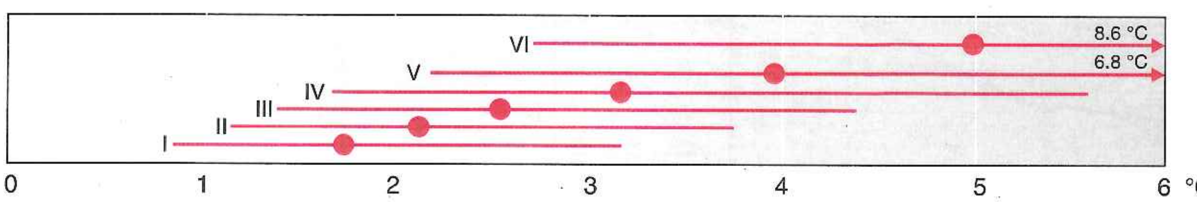


Figure 3.4. Estimated long-term (multi-century) warming corresponding to the six AR4 WG III stabilisation categories (Table 5.1). The temperature scale has been shifted by -0.5°C compared to Table 5.1 to account approximately for the warming between pre-industrial and 1980-1999. For most stabilisation 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 850 ppm 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 5.1), the equilibrium temperature may be reached earlier. {WGI 10.7.2}

3.3 Impacts of future climate changes

More specific information is now available across a wide range of systems and sectors concerning the nature of future impacts, including some fields not covered in previous assessments. *{WGII TS.4, SPM}*

The following is a selection of key findings[14] regarding the impacts of climate change on systems, sectors and regions, as well as some findings on vulnerability[15], for the range of climate changes projected over the 21st century. Unless otherwise stated, the confidence level in the projections is *high*. Global average temperature increases are given relative to 1980-1999. Additional information on impacts can be found in the WG II report. *{WGII SPM}*

3.3.1 Impacts on systems and sectors

Ecosystems

- The resilience of many ecosystems is *likely* to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, ocean acidification) and other global change drivers (e.g. land-use change, pollution, fragmentation of natural systems, over-exploitation of resources). *{WGII 4.1-4.6, SPM}*
- Over the course of this century, net carbon uptake by terrestrial ecosystems is *likely* to peak before mid-century and then weaken or even reverse[16], thus amplifying climate change. *{WGII 4.ES, Figure 4.2, SPM}*
- 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 (*medium confidence*). *{WGII 4.ES, Figure 4.2, SPM}*
- For increases in global average temperature exceeding 1.5 to 2.5°C and in concomitant atmospheric CO_2 concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply. *{WGII 4.4, Box TS.6, SPM}*

Food

- Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1 to 3°C depending on the crop, and then decrease beyond that in some regions (*medium confidence*). *{WGII 5.4, SPM}*
- At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1 to 2°C), which would increase the risk of hunger (*medium confidence*). *{WGII 5.4, SPM}*
- Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1 to 3°C, but above this it is projected to decrease (*medium confidence*). *{WGII 5.4, 5.5, SPM}*

Coasts

- Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas (*very high confidence*). *{WGII 6.3, 6.4, SPM}*
- By the 2080s, many millions more people than today are projected to experience floods every year due to sea level rise. The numbers affected will be largest in the densely populated and low-lying megadeltas of Asia and Africa while small islands are especially vulnerable (*very high confidence*). *{WGII 6.4, 6.5, Table 6.11, SPM}*

Industry, settlements and society

- The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring. *{WGII 7.1, 7.3, 7.4, 7.5, SPM}*
- Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. *{WGII 7.2, 7.4, 5.4, SPM}*

Health

- The health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrhoeal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone in urban areas related to climate change; and the altered spatial distribution of some infectious diseases. *{WGI 7.4, Box 7.4; WGII 8.ES, 8.2, 8.4, SPM}*
- Climate change is projected to bring some benefits in temperate areas, such as fewer deaths from cold exposure, and some mixed effects such as changes in range and transmission potential of malaria in Africa. Overall it is expected that benefits will be outweighed by the negative health effects of rising temperatures, especially in developing countries. *{WGII 8.4, 8.7, 8ES, SPM}*
- Critically important will be factors that directly shape the health of populations such as education, health care, public health initiatives, and infrastructure and economic development. *{WGII 8.3, SPM}*

Water

- Water impacts are key for all sectors and regions. These are discussed below in the Box 'Climate change and water'.

[14] Criteria of choice: magnitude and timing of impact, confidence in the assessment, representative coverage of the system, sector and region.

[15] Vulnerability to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts.

[16] Assuming continued GHG emissions at or above current rates and other global changes including land-use changes.

Climate change and water

Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanisation. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows in regions supplied by meltwater from major mountain ranges (e.g. Hindu-Kush, Himalaya, Andes), where more than one-sixth of the world population currently lives. *{WGI 4.1, 4.5; WGII 3.3, 3.4, 3.5}*

Changes in precipitation (Figure 3.3) and temperature (Figure 3.2) lead to changes in runoff (Figure 3.5) and water availability. Runoff is projected with *high confidence* to increase by 10 to 40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and South-East Asia, and decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration. There is also *high confidence* that many semi-arid areas (e.g. the Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production and health. Regionally, large increases in irrigation water demand as a result of climate changes are projected. *{WGI 10.3, 11.2-11.9; WGII 3.4, 3.5, Figure 3.5, TS.4.1, Box TS.5, SPM}*

The negative impacts of climate change on freshwater systems outweigh its benefits (*high confidence*). Areas in which runoff is projected to decline face a reduction in the value of the services provided by water resources (*very high confidence*). The beneficial impacts of increased annual runoff in some areas are *likely* to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk. *{WGII 3.4, 3.5, TS.4.1}*

Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. The resulting increased flood risk poses challenges to society, physical infrastructure and water quality. It is *likely* that up to 20% of the world population will live in areas where river flood potential could increase by the 2080s. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development. Increased temperatures will further affect the physical, chemical and biological properties of freshwater lakes and rivers, with predominantly adverse impacts on many individual freshwater species, community composition and water quality. In coastal areas, sea level rise will exacerbate water resource constraints due to increased salinisation of groundwater supplies. *{WGI 11.2-11.9; WGII 3.2, 3.3, 3.4, 4.4}*

Projections and model consistency of relative changes in runoff by the end of the 21st century

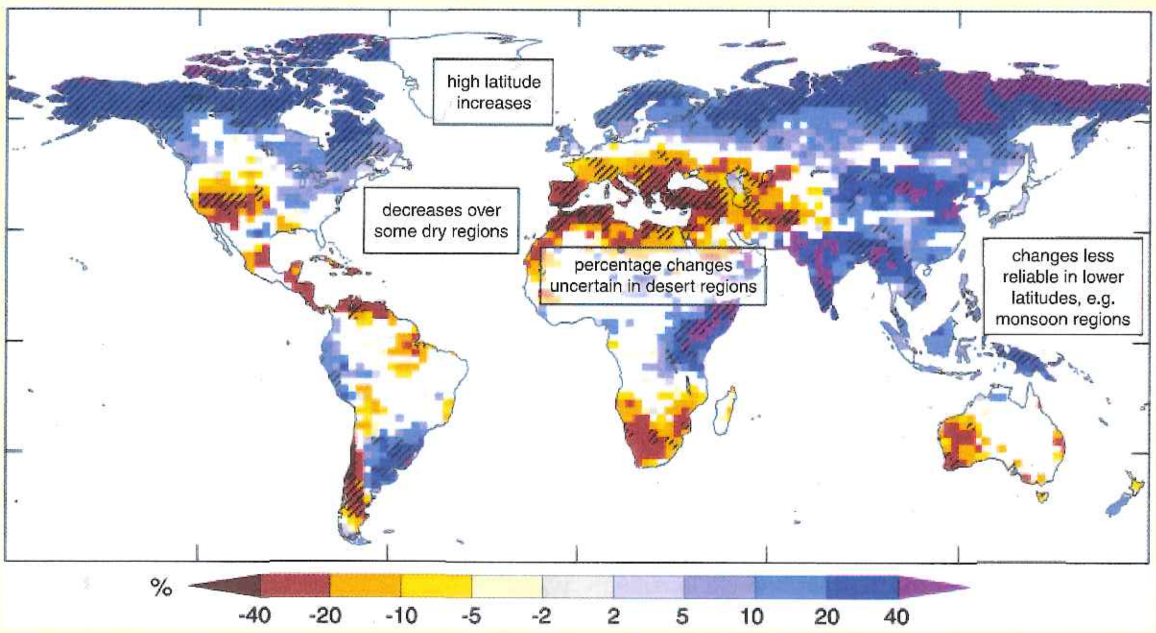


Figure 3.5. *Large-scale relative changes in annual runoff (water availability, in percent) for the period 2090-2099, relative to 1980-1999. Values represent the median of 12 climate models using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. The quality of the simulation of the observed large-scale 20th century runoff is used as a basis for selecting the 12 models from the multi-model ensemble. The global map of annual runoff illustrates a large scale and is not intended to refer to smaller temporal and spatial scales. In areas where rainfall and runoff is very low (e.g. desert areas), small changes in runoff can lead to large percentage changes. In some regions, the sign of projected changes in runoff differs from recently observed trends. In some areas with projected increases in runoff, different seasonal effects are expected, such as increased wet season runoff and decreased dry season runoff. Studies using results from few climate models can be considerably different from the results presented here. {WGII Figure 3.4, adjusted to match the assumptions of Figure SYR 3.3; WGII 3.3.1, 3.4.1, 3.5.1}*

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. *{WGII SPM}*

Examples of this new information for systems and sectors are presented in Figure 3.6. The upper panel shows impacts increasing with increasing temperature change. Their estimated magnitude and timing is also affected by development pathways (lower panel). *{WGII SPM}*

Depending on circumstances, some of the impacts shown in Figure 3.6 could be associated with 'key vulnerabilities', based on a number of criteria in the literature (magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and 'importance' of the impacts) (see Topic 5.2). *{WGII SPM}*

3.3.2 Impacts on regions[17]

Africa

- By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change. *{WGII 9.4, SPM}*
- 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. *{WGII 9.4, SPM}*
- 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 GDP. *{WGII 9.4, SPM}*
- By 2080, an increase of 5 to 8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (*high confidence*). *{WGII Box TS.6, 9.4.4}*

Asia

- By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease. *{WGII 10.4, SPM}*
- 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. *{WGII 10.4, SPM}*
- Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development. *{WGII 10.4, SPM}*
- 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. *{WGII 10.4, SPM}*

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. *{WGII 11.4, SPM}*
- By 2030, water security problems are projected to intensify in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. *{WGII 11.4, SPM}*
- 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. *{WGII 11.4, SPM}*
- 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. *{WGII 11.4, SPM}*

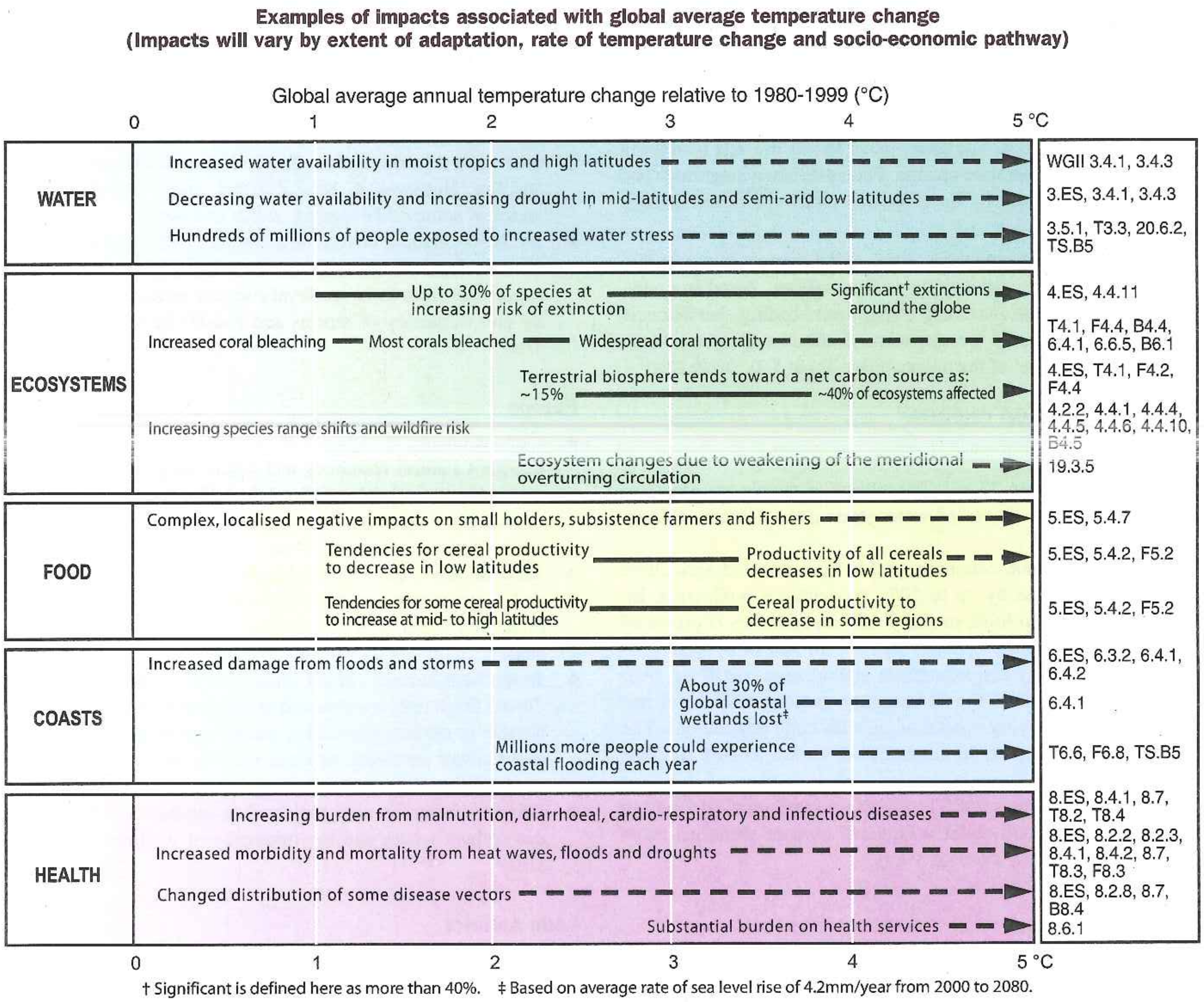
Europe

- 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). *{WGII 12.4, SPM}*
- 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). *{WGII 12.4, SPM}*
- 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. *{WGII 12.4, SPM}*
- Climate change is also projected to increase the health risks due to heat waves and the frequency of wildfires. *{WGII 12.4, SPM}*

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. *{WGII 13.4, SPM}*
- There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America. *{WGII 13.4, SPM}*
- 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 (*medium confidence*). *{WGII 13.4, Box TS.6}*
- Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation. *{WGII 13.4, SPM}*

[17] Unless stated explicitly, all entries are from WG 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 WG 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.



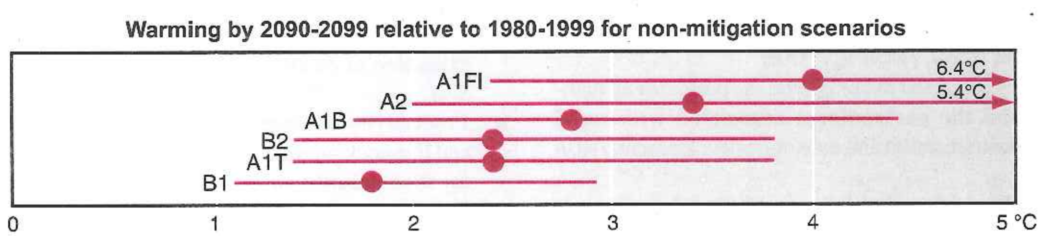


Figure 3.6. *Examples of impacts associated with global average temperature change.* ***Upper panel:*** *Illustrative examples of global impacts projected for climate changes (nd sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature 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. *The upper right panel gives the WG II references for the statements made in the upper left panel.** ***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. {WGI Figure SPM.5, 10.7; WGII Figure SPM.2; WGIII Table TS.2, Table 3.10}*

*Where ES = Executive Summary, T = Table, B = Box and F = Figure. Thus B4.5 indicates Box 4.5 in Chapter 4 and 3.5.1 indicates Section 3.5.1 in Chapter 3.

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. *{WGII 14.4, SPM}*
- 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. *{WGII 14.4, SPM}*
- 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. *{WGII 14.4, SPM}*
- Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution. *{WGII 14.4, SPM}*

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. *{WGII 15.4, SPM}*
- For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed. *{WGII 15.4, SPM}*
- Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. *{WGII 15.4, SPM}*
- In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered. {WGII 15.4, SPM}

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. *{WGII 16.4, SPM}*
- Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources. *{WGII 16.4, SPM}*
- 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. *{WGII 16.4, SPM}*
- With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands. *{WGII 16.4, SPM}*

3.3.3 Especially affected systems, sectors and regions

Some systems, sectors and regions are *likely* to be especially affected by climate change.[18] ***{WGII TS.4.5}***

Systems and sectors: *{WGII TS.4.5}*

- 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[19] 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: *{WGII TS.4.5}*

- 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. *{WGII 7.1, 7.2, 7.4, 8.2, 8.4, TS.4.5}*

3.3.4 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. *{WGI SPM; WGII SPM}*

3.3.5 Extreme events

Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems (Table 3.2). ***{WGII SPM}***

Examples for selected extremes and sectors are shown in Table 3.2.

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[18] 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.

[19] Including arid and semi-arid regions.

Table 3.2. *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. {WGII Table SPM.1}*

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 *{WGII 4.4, 5.4}*	Water resources *{WGII 3.4}*	Human health *{WGII 8.2, 8.4}*	Industry, settlement and society *{WGII 7.4}*
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 WGI 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. *{WGI 10.6}*

3.4 Risk of abrupt or irreversible changes

Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change. ***{WGII 12.6, 19.3, 19.4, SPM}***

Abrupt climate change on decadal time scales is normally thought of as involving ocean circulation changes. In addition on longer time scales, ice sheet and ecosystem changes may also play a role. If a large-scale abrupt climate change were to occur, its impact could be quite high (see Topic 5.2). *{WGI 8.7, 10.3, 10.7; WGII 4.4, 19.3}*

Partial loss of ice sheets on polar land and/or the thermal expansion of seawater over very long time scales 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. Current models project that such changes would occur over very long time scales (millennial) if a global temperature increase of 1.9 to 4.6°C (relative to pre-industrial) were to be sustained. Rapid sea level rise on century time scales cannot be excluded. *{SYR 3.2.3; WGI 6.4, 10.7; WGII 19.3, SPM}*

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. *{WGII 4.4, Figure SPM.2}*

Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century; nevertheless temperatures in the region are projected to increase. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. *{WGI 10.3, 10.7; WGII Figure, Table TS.5, SPM.2}*

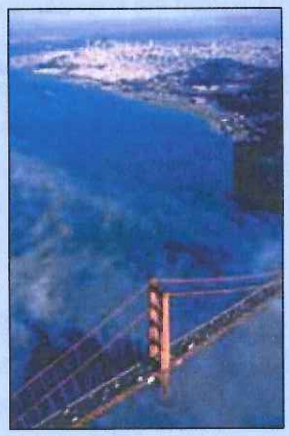
Impacts of large-scale and persistent changes in the MOC are *likely* to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation. Changes in terrestrial and ocean CO_2 uptake may feed back on the climate system. *{WGII 12.6, 19.3, Figure SPM.2}*

3. 2004 Climate Action Plan for San Francisco
http://www.sfenvironment.org/download/2004-climate-action-plan-for-san-francisco

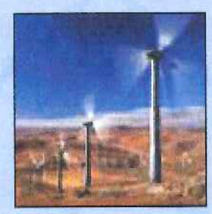
Climate Action Plan

For San Francisco

Local Actions to Reduce Greenhouse Gas Emissions






San Francisco Department of the Environment • San Francisco Public Utilities Commission

September 2004

Executive Summary

Global Warming is real. The world's leading climate scientists agree that human behavior is accelerating global warming, and that the earth is already suffering the impacts of the resulting climate change.

Climate change will affect San Francisco. It is a global problem with local impacts. Rising temperatures, rising sea level, and more frequent El Niño storms could seriously threaten the City's infrastructure, economy, health, and ecosystems with impacts such as:

- Flooded roads, threats to the sewage system and Airport infrastructure
- Increased asthma and respiratory illness due to higher ozone levels
- Threatened Bay wetlands and marine life
- Fishing and tourism industry impacts, high insurance and mitigation costs

We have a responsibility to act. San Francisco is responsible for about 9.7 million tons of CO_2 emissions per year. In 2002, the San Francisco Board of Supervisors passed the *Greenhouse Gas Emissions Reduction Resolution*, committing the City and County of San Francisco to a greenhouse gas emissions reductions goal of 20% below 1990 levels by the year 2012. The resolution also states that the Mayor and Board of Supervisors actively support the Kyoto Protocol, and calls upon national leaders to do so as well. Federal inaction makes state and local action all the more important. The development of this *Climate Action Plan*, called for in the resolution, describes what San Francisco can do in order to achieve our greenhouse gas reduction goal.

San Francisco has joined with over 500 cities around the world to participate in the *Cities for Climate Protection* (CCP) campaign, sponsored by the International Council for Local Environmental Initiatives (ICLEI). As part of the campaign, member cities have committed to: inventory their emissions of greenhouse gases; set reduction targets; develop comprehensive strategies to meet these targets; implement these emissions reduction actions; and measure the results. The criteria set by the CCP campaign have been used to define the scope and presentation of this Plan.

The *Climate Action Plan*

- Provides background information on the causes of climate change and projections of its impacts on California and San Francisco from recent scientific reports;
- Presents estimates of San Francisco's baseline greenhouse gas emissions inventory and reduction target;
- Describes recommended emissions reduction actions in the key target sectors - transportation, energy efficiency, renewable energy, and solid waste management – to meet our 2012 goal; and
- Presents next steps required over the near term to implement the Plan.

Climate Change: Causes and Impacts

Climate change is both a global and local phenomenon. The Intergovernmental Panel on Climate Change (IPCC), reports that temperatures and sea level are rising at the fastest rate in history, and are projected to continue rising (2-10 degrees Fahrenheit temperature rise, 4-36 inches sea-level rise over the next 100 years). This trend, sometimes referred to as "global warming," is seriously impacting water resources, ecosystems, human health, and the economy.

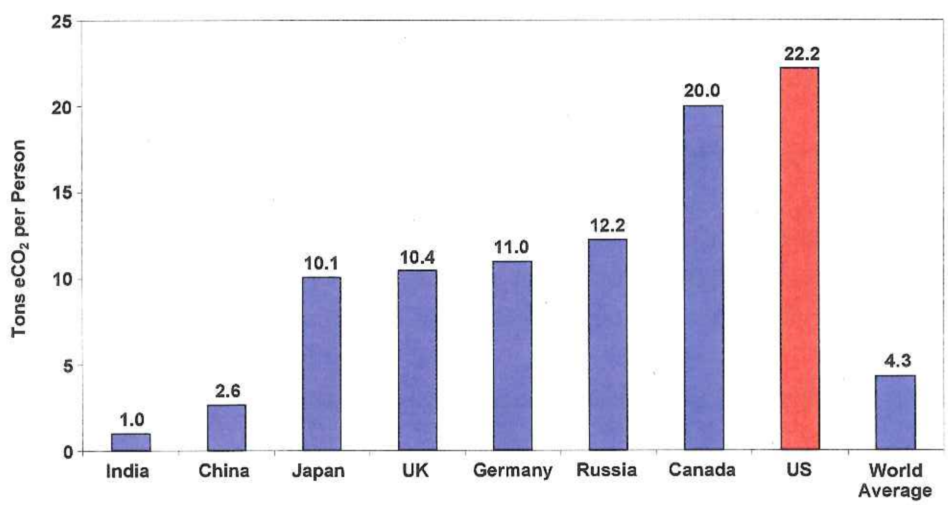
Human and Cultural Causes of Climate Change

Human behavior is accelerating climate change. The release into the atmosphere of carbon dioxide (CO_2) from the burning of fossil fuels in power plants, buildings and vehicles, the loss of carbon "sinks" due to deforestation, and methane emitting from landfills are the chief human causes of climate change. These emissions are referred to collectively as "greenhouse gases" (ghgs).

The United States has the highest per capita emissions of ghgs in the world–22 tons of CO_2 per person per year (see figure ES.1). With only five percent of the world's population, the United States is responsible for 24 percent of the world's CO_2 emissions.

California, despite its strong environmental regulations, is the second largest greenhouse-gas polluting state in the nation, and emits 2% of global human-generated emissions. Its largest contribution of CO_2 is from vehicle emissions. Clearly, more needs to be done. California has much to lose if climate change is not abated.

Figure ES.1 - Per Capita CO_2 Emissions 2001



Sources: Energy Information Administration: World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1992-2001, U.S. Census Bureau: Countries Ranked by Population: 2001

Impacts on San Francisco

San Francisco, as a coastal city surrounded on three sides by water, is extremely vulnerable to climate change. It is further at risk because the City depends on the Sierra snow pack for its water supply and for hydroelectric power. According to a joint study by the Union of Concerned Scientists and Ecological Society of America, some of the possible effects of climate change on San Francisco are:

- Sea-level rise may threaten coastal wetlands, infrastructure, and property.
- Increased storm activity together with sea-level rise could increase beach erosion and cliff undercutting.
- Warmer temperatures and more frequent storms due to El Niño will bring more rain instead of snow to the Sierras, reducing supply of water for summer needs.
- Decreased summer runoff and warming ocean temperatures will affect salinity, water circulation, and nutrients in the Bay, possibly leading to complex changes in marine life.

Such dramatic changes to San Francisco's physical landscape and ecosystem will be accompanied by financial and social impacts. Tourism would suffer, as would San Francisco's fishing industry and the regional agricultural industry, which is expected to be greatly disrupted by a warmer climate. Food costs would rise, property damage would be more prevalent, and insurance rates would increase accordingly.

The City's roads, pipelines, transportation, underground cables and sewage systems could be severely stressed or overwhelmed if rare instances of flooding or storm damage become common occurrences. Low lying areas such as San Francisco International Airport, built on a wetland, would be at high risk in the face of a rising sea level.

The environment plays a large role in some diseases carried by insects. Warming could make tick-borne Lyme disease more prevalent and could expand the range of mosquito-borne diseases such as West Nile virus. Another threat to the health of San Francisco residents is air pollution caused by higher temperatures and increased ozone levels. Neighborhoods in the Southeast of the City, where asthma and respiratory illness are already at high levels, would be especially at risk.

Existing Mandates to Curb Climate Change

The United Nations Framework Convention on Climate Change (UNFCC) process is comprised of 150 participating countries. As of June 2003, 110 countries had ratified the Kyoto Protocol, agreeing to targets and timelines for reducing their greenhouse gas emissions. The United States signed, but has not ratified the protocol.

California has set specific targets for reducing greenhouse gas emissions produced in the state.

- Senate Bill 1078 (Sher, 2002) set a Renewable Portfolio Standard (RPS) which requires electricity providers to increase purchases of renewable energy resources by 1% per year until they have attained a portfolio of 20% renewable resources.

4. "Living with a Rising Bay," San Francisco Bay Conservation and Development Commission
www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf

STAFF REPORT

Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline

Approved on October 6, 2011

SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION
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Web site: http://www.bcdc.ca.gov

habitat and water quality, maintaining flood protection, and providing public shoreline access. Shoreline vulnerability assessments can help government agencies and the public understand how existing planning and management challenges will be exacerbated by climate change and assist in developing strategies for dealing with these challenges.

The Vulnerability Assessment

Two sea level rise projections were selected as the basis for the vulnerability assessment in this report: a 16-inch (40 cm) sea level rise by mid-century and a 55-inch (140 cm) rise in sea level by the end of the century. When BCDC initiated its effort to amend the Bay Plan to address climate change in 2009, the State of California was still in the process of formulating statewide policy direction for adapting to sea level rise. In 2010 the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) developed a Sea Level Rise Interim Guidance document that advises the use of projections (relative to sea level in 2000) for the state that range from 10 to 17 inches by 2050, 17 to 32 inches by 2070, and 31 to 69 inches at the end of the century (based on work by Vermeer and Ramstorf, 2009). This document was endorsed by a resolution of the California Ocean Protection Council in 2011. The projections used in BCDC's report fall within the ranges suggested by the CO-CAT's Sea Level Rise Interim Guidance document. The CO-CAT has recognized that it may not be appropriate to set definitive sea level rise projections, and, based on a variety of factors, state agencies may use different sea level rise projections. Although the CO-CAT values are generally recognized as the best science-based sea level rise projections for California, scientific uncertainty remains regarding the pace and amount of sea level rise. Moreover, melting of the Greenland and Antarctic ice sheets may not be reflected well in current sea level rise projections. The interim guidance will be updated consistent with the National Academy of Sciences sea level rise assessment report, expected in 2012, and other forthcoming studies.

Using the two sea level rise projections, the vulnerability assessment focused on three planning areas or systems: shoreline development, the Bay ecosystem, and governance. Key sectors within each system, such as land uses or subregions of the Bay, were used to assess their sensitivity, adaptive capacity and, ultimately, their vulnerability.

1. Shoreline Development

Residents, businesses and entire industries that currently thrive on the shoreline will be at risk of flooding by the middle of the century, and probably earlier, if nothing is done to protect, elevate or relocate them. A 16-inch rise (relative to sea level in 2000) would potentially expose

281 square miles of Bay shoreline to flooding, and a 55-inch rise would potentially expose 333 square miles to flooding. If no adaptation measures were taken, a 55-inch rise in sea level would place an estimated 270,000 people in the Bay Area at risk from flooding, 98 percent more than are currently at risk. The economic value of Bay Area shoreline development (buildings and their contents) at risk from a 55-inch rise in sea level is estimated at $62 billion—two-thirds of all the estimated value of development vulnerable to sea level rise along California's entire coastline. In those areas where lives and property are not directly vulnerable, the secondary and cumulative impacts of sea level rise will affect public health, economic security and quality of life. Additionally, changes in climate may cause increased storm activity, which in combination with higher sea level, may cause even greater flooding. It is expected that extreme storm events will cause most of the shoreline damage from flooding.

Shoreline development located in an area potentially exposed to a 100-year high water event in 2000 could be potentially exposed to regular tidal inundation by mid-century, not taking existing and planned shoreline protection into account. Approximately half of that development is residential, totaling 103 square miles. Over 128 square miles of residential development is at risk of flooding by the end of the century. Where residents are not directly at risk of flooding, access to important services such as commercial centers, health care, and schools would likely be impeded by flooding of the service centers or the transportation infrastructure that links them. Rising sea levels could impact the delivery of petroleum products, electricity, and drinking water to Bay Area residents and businesses. Dealing with this range of impacts will be more difficult for low-income residents because they have less financial flexibility and fewer resources to pursue alternative housing and transportation.

Populations may suffer if wastewater treatment is compromised by inundation from rising sea levels, given that a number of treatment plants discharge to the Bay. Impaired water quality and higher temperatures can result in algal blooms and a higher potential for the spread of water-born disease vectors.

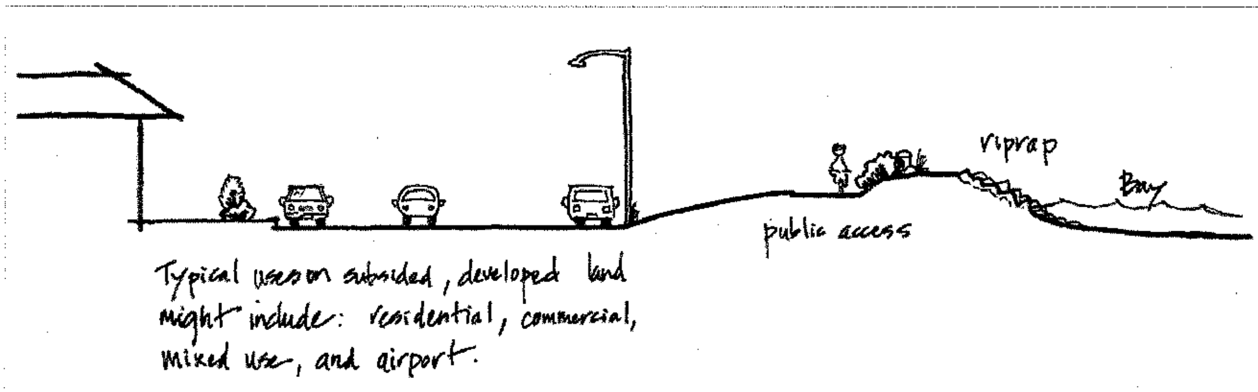
Large commercial and industrial areas are at risk of flooding, especially in San Francisco, Silicon Valley, and Oakland. Approximately 72 percent of each of the San Francisco and Oakland Airports is at risk from a 16-inch sea level rise and about 93 percent of each is at risk from a 55-inch sea level rise, which could disrupt as many as 30 million airline passengers annually and approximately one million metric tons of cargo. Flooding of highway segments in the regional transportation network could disrupt the movement of goods from ports, which

Shoreline Protection

San Francisco Bay and the shoreline support some of the densest urban development in the United States as well as ample open space and some of the most extensive tidal wetland habitats (Figure 1.6). Shoreline development, public safety, and the Bay ecosystem are at risk from current flooding and increased future flooding and storm activity. Public infrastructure and shoreline development that are critical to the region's health, safety and welfare will require protection. Wetlands must be sustained to continue providing important habitat and healthy functioning of the Bay ecosystem as well as flood protection and carbon sequestration. A variety of shoreline features and development exist around the Bay, some of which are more vulnerable than others, and all present unique challenges for protection and adaptation to sea level rise[3]. Discovering ways to protect shoreline development and wetlands is one of the major challenges in adapting to future sea level rise.

Figure 1.20 Typical Section: Subsided Land with Structural Shoreline Protection

Source: BCDC



Sea level rise and flooding on the Bay shoreline will lead to a greater risk of erosion, causing local governments and landowners to evaluate protection techniques and strategies. Currently, static structures or structural protection, such as seawalls, riprap revetments and levees, are the most common form of protection against flooding and erosion along the shoreline (Figures 1.20-1.22). Although expensive, these structures are attractive options because the engineering

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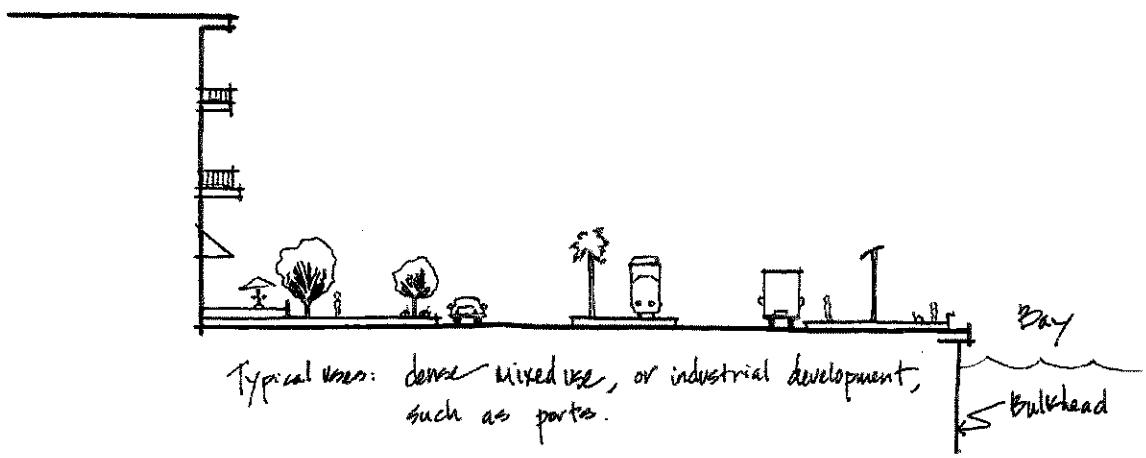
[3] A series of figures showing typical shoreline conditions are included to further an understanding of the variety of shoreline conditions discussed here and in future chapters.

standards for their design and implementation are fully developed and widely used (BCDC 1988a, Smits et al. 2006). Static structures on the edge of a dynamic Bay shoreline can result in erosion of adjacent tidal flats or marshes and eventually the flood protection itself (Williams 2001, Lowe and Williams 2008, Schoellhammer et al. 2005, Smits et al. 2006, Heberger et al. 2008).

Figure 1.21 Typical Section: Urban Shoreline with Bulkhead

Source: BCDC

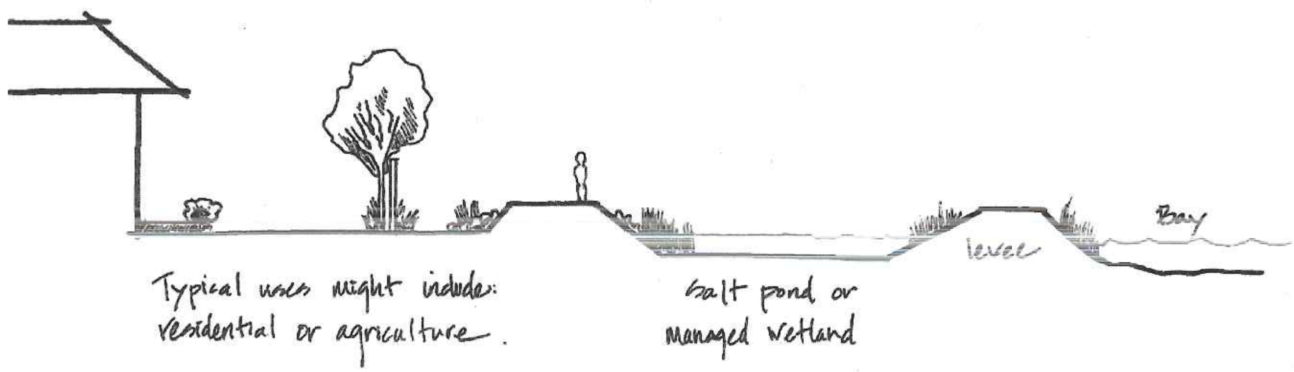


Construction and maintenance of shoreline protection typically requires fill in the Bay (BCDC 1988a). From 1978 to 1987, BCDC authorized nearly 300,000 cubic yards of fill for shoreline protection, most of which was used to construct riprap revetments (BCDC 1988a). Many of these revetments degraded tidal flats that provide important habitat to birds and dissipate wave energy. Thus, residential communities and infrastructure on the shoreline, as well as the Bay ecosystem, may be significantly impacted by the cumulative effect of additional engineered structures along the Bay shoreline to address sea level rise.

Both the construction and maintenance cost of protection structures increases over time, particularly as sea level rises and the damaging effect of storms increases. Since 1990, the construction cost of a waterside levee rose to approximately $1,500 per linear foot, a 320 percent increase, and seawalls are even more expensive at approximately $5,300 per linear foot (Heberger et al. 2008). Maintenance costs range from 1-15 percent of the construction cost per year over the life of the project, which does not include the cost of damages to public safety, infrastructure, or the ecosystem (Heberger et al. 2008).

Figure 1.22 Typical Section: Wetlands and Levees

Source: BCDC



The Pacific Institute reports that statewide the cost of protecting against a 55-inch rise in sea level using static structures would be $14 billion. This cost estimate assumes that, throughout the Bay, levees are sufficient to provide shoreline protection. However, the existing shoreline protection is a mix of levees, riprap and bulkheads or seawalls. Evaluating the full cost of protection measures on the Bay shoreline requires a full assessment of existing structures, both in terms of the level of flood protection and the resistance to erosion under sea level rise projections. In many cases, the wave energy will be sufficient that local governments may desire the additional protection of a seawall, which is far more expensive. Furthermore, Bay levees are constructed, in many cases, using loosely compacted Bay mud that are often insufficient to support the additional weight of material required for retrofitting (URS 2005, PWA 2005). This deficiency is offset, to a degree, because the cost estimate is based on areas potentially exposed to sea level rise and flooding irrespective of whether current protection exists—a more risk-averse approach. Considering that there are multiple types of shoreline protection other than levees, and, that where existing levees cannot be raised, they may require replacement with an alternative method of protection, the Pacific Institute's cost estimate for the Bay is probably low.

Providing structural shoreline protection may actually increase vulnerability by encouraging development in flood-prone areas directly behind the structure and giving those who live behind the structure a false sense of security (Heberger et al. 2008, Smits et al. 2006, United Nations 2004). In areas of the Netherlands, as progressively larger protection structures were built, development behind the structures intensified and populations in those areas increased. The protection structures completely eliminated water circulation in several estuaries, which were ultimately abandoned as functioning ecosystems (Smits et al. 2006). Large areas of the Mississippi Delta are being considered for restoration, in part, to restore previous wave attenuation benefits and help avoid repetition of the devastating impacts caused by Hurricane Katrina, a tragic example of relying too heavily on shoreline protection structures (Day et al. 2007). Loss of this ecosystem benefit is just one of the reasons for ambitious tidal wetland restoration efforts in the Bay-Delta estuary (Save the Bay 2007). While sedimentation and tidal wetlands alone may not completely protect against flooding and erosion (Jongejan 2008), early adaptation of existing development, prevention of new development in flood prone areas, and the flood protection benefit of tidal wetlands can help reduce the cost of adaptation.

The *San Francisco Bay Plan* (Bay Plan) requires a design review process for engineering projects, such as major shoreline protection works on fill. The Bay Plan also includes policies to guide the Commission decisions regarding compensatory mitigation for unavoidable adverse impacts resulting from projects in the Bay. Approving structural shoreline protection on a project-by-project basis may create additional, cumulative adverse impacts to Bay habitat. Analysis of these cumulative impacts and potential planning approaches that will minimize them are needed. Both the USGS and the USACE are currently investigating regional and local effects of shoreline inundation and flooding, respectively, in the South Bay. Additional analysis can provide local governments and landowners with adequate information for designing erosion control and shoreline protection (Knowles 2008, USACE 2008).

Summary and Conclusions

The planet is getting warmer and there is broad scientific consensus that human release of GHGs is driving this change. Greenhouse gases that naturally reside in the earth's atmosphere, absorb heat emitted from the earth's surface and radiate heat back to the surface—a natural process called the "greenhouse effect." The planet is now warming at an accelerated rate due largely to the rapid release greenhouse gases into the atmosphere since industrialization. Temperatures in California are projected to rise between 1.8°F and 5.4°F (1°C and 3°C) by mid century and between 3.6°F and 9°F (2°C and 5°C) by the end of the century. As air temperatures warm, the oceans warm, glaciers and ice sheets melt, causing sea level to rise.

A range of sea level rise projections has been estimated, but they may not adequately reflect future contributions from ice-sheet melt. The estimates for this analysis are based on higher GHG emissions scenarios. Choosing a higher scenario is a more risk-averse approach to protecting public safety. Two sea level rise scenarios were selected for analysis: a 16-inch (40 cm) sea level rise by mid-century and a 55-inch (140 cm) rise in sea level by the end of the century. These scenarios are generally consistent with other state SLR estimates.

Extreme storm events will cause most shoreline damage from flooding. Changes in climate may increase storm activity, which, in combination with higher sea level, will result in more frequent and extensive flooding. The data used for this analysis reflects storm activity, but does not include wave activity. With the 16-inch projection, 180,000 acres (281 square miles) of shoreline are potentially exposed to more flooding or permanent inundation by mid-century and 213,000 acres (332 square miles) are at risk from a 55-inch sea level rise at the end of the century.

Structural shoreline protection can hold floodwaters back from the shoreline. Incorporating both engineering and ecosystem elements can be used to in some cases to mitigate some of the impacts of structural shoreline protection (Lowe and Williams 2008).

Cumulative impacts of structural shoreline protection can have far reaching adverse impacts to the Bay ecosystem. Because structural shoreline protection requires long-term maintenance and can have unintended adverse impacts, it should be seen as only one of several adaptation options for a shoreline area (BCDC 1988a, BCDC 1988b, Smits et al. 2006).

5. Copenhagen Accord of 18 December 2009
http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf

Decision -/CP.15

The Conference of the Parties,

Takes note of the Copenhagen Accord of 18 December 2009.

Copenhagen Accord

The Heads of State, Heads of Government, Ministers, and other heads of the following delegations present at the United Nations Climate Change Conference 2009 in Copenhagen: [*List of Parties*]

In pursuit of the ultimate objective of the Convention as stated in its Article 2,

Being guided by the principles and provisions of the Convention,

Noting the results of work done by the two Ad hoc Working Groups,

Endorsing decision x/CP.15 on the Ad hoc Working Group on Long-term Cooperative Action and decision x/CMP.5 that requests the Ad hoc Working Group on Further Commitments of Annex I Parties under the Kyoto Protocol to continue its work,

Have agreed on this Copenhagen Accord which is operational immediately.

1. We underline that climate change is one of the greatest challenges of our time. We emphasise our strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities. To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis ofequity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. We recognize the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse effects and stress the need to establish a comprehensive adaptation programme including international support.

2. We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity. We should cooperate in achieving the peaking of global and national emissions as soon as possible, recognizing that the time frame for peaking will be longer in developing countries and bearing in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries and that a low-emission development strategy is indispensable to sustainable development.

3. Adaptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa. We agree that developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries.

4. Annex I Parties commit to implement individually or jointly the quantified economy-wide emissions targets for 2020, to be submitted in the format given in Appendix I by Annex I Parties to the secretariat by 31 January 2010 for compilation in an INF document. Annex I Parties that are Party to the Kyoto Protocol will thereby further strengthen the emissions reductions initiated by the Kyoto Protocol. Delivery of reductions and financing by

developed countries will be measured, reported and verified in accordance with existing and any further guidelines adopted by the Conference of the Parties, and will ensure that accounting of such targets and finance is rigorous, robust and transparent.

5. Non-Annex I Parties to the Convention will implement mitigation actions, including those to be submitted to the secretariat by non-Annex I Parties in the format given in Appendix II by 31 January 2010, for compilation in an INF document, consistent with Article 4.1 and Article 4.7 and in the context of sustainable development. Least developed countries and small island developing States may undertake actions voluntarily and on the basis of support. Mitigation actions subsequently taken and envisaged by Non-Annex I Parties, including national inventory reports, shall be communicated through national communications consistent with Article 12.1(b) every two years on the basis of guidelines to be adopted by the Conference of the Parties. Those mitigation actions in national communications or otherwise communicated to the Secretariat will be added to the list in appendix II. Mitigation actions taken by Non-Annex I Parties will be subject to their domestic measurement, reporting and verification the result of which will be reported through their national communications every two years. Non-Annex I Parties will communicate information on the implementation of their actions through National Communications, with provisions for international consultations and analysis under clearly defined guidelines that will ensure that national sovereignty is respected. Nationally appropriate mitigation actions seeking international support will be recorded in a registry along with relevant technology, finance and capacity building support. Those actions supported will be added to the list in appendix II. These supported nationally appropriate mitigation actions will be subject to international measurement, reporting and verification in accordance with guidelines adopted by the Conference of the Parties.

6. We recognize the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests and agree on the need to provide positive incentives to such actions through the immediate establishment of a mechanism including REDD-plus, to enable the mobilization of financial resources from developed countries.

7. We decide to pursue various approaches, including opportunities to use markets, to enhance the cost-effectiveness of, and to promote mitigation actions. Developing countries, especially those with low emitting economies should be provided incentives to continue to develop on a low emission pathway.

8. Scaled up, new and additional, predictable and adequate funding as well as improved access shall be provided to developing countries, in accordance with the relevant provisions of the Convention, to enable and support enhanced action on mitigation, including substantial finance to reduce emissions from deforestation and forest degradation (REDD-plus), adaptation, technology development and transfer and capacity-building, for enhanced implementation of the Convention. The collective commitment by developed countries is to provide new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010 – 2012 with balanced allocation between adaptation and mitigation. Funding for adaptation will be prioritized for the most vulnerable developing countries, such as the least developed countries, small island developing States and Africa. In the context of meaningful mitigation actions and transparency on implementation, developed countries commit to a goal of mobilizing jointly USD 100 billion dollars a year by 2020 to address the needs of developing countries. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance. New multilateral funding for adaptation will be delivered through effective and efficient fund arrangements, with a governance structure providing for equal representation of developed and developing countries. A significant portion of such funding should flow through the Copenhagen Green Climate Fund.

9. To this end, a High Level Panel will be established under the guidance of and accountable to the Conference of the Parties to study the contribution of the potential sources of revenue, including alternative sources of finance, towards meeting this goal.

10. We decide that the Copenhagen Green Climate Fund shall be established as an operating entity of the financial mechanism of the Convention to support projects, programme, policies and other activities in developing countries related to mitigation including REDD-plus, adaptation, capacity-building, technology development and transfer.

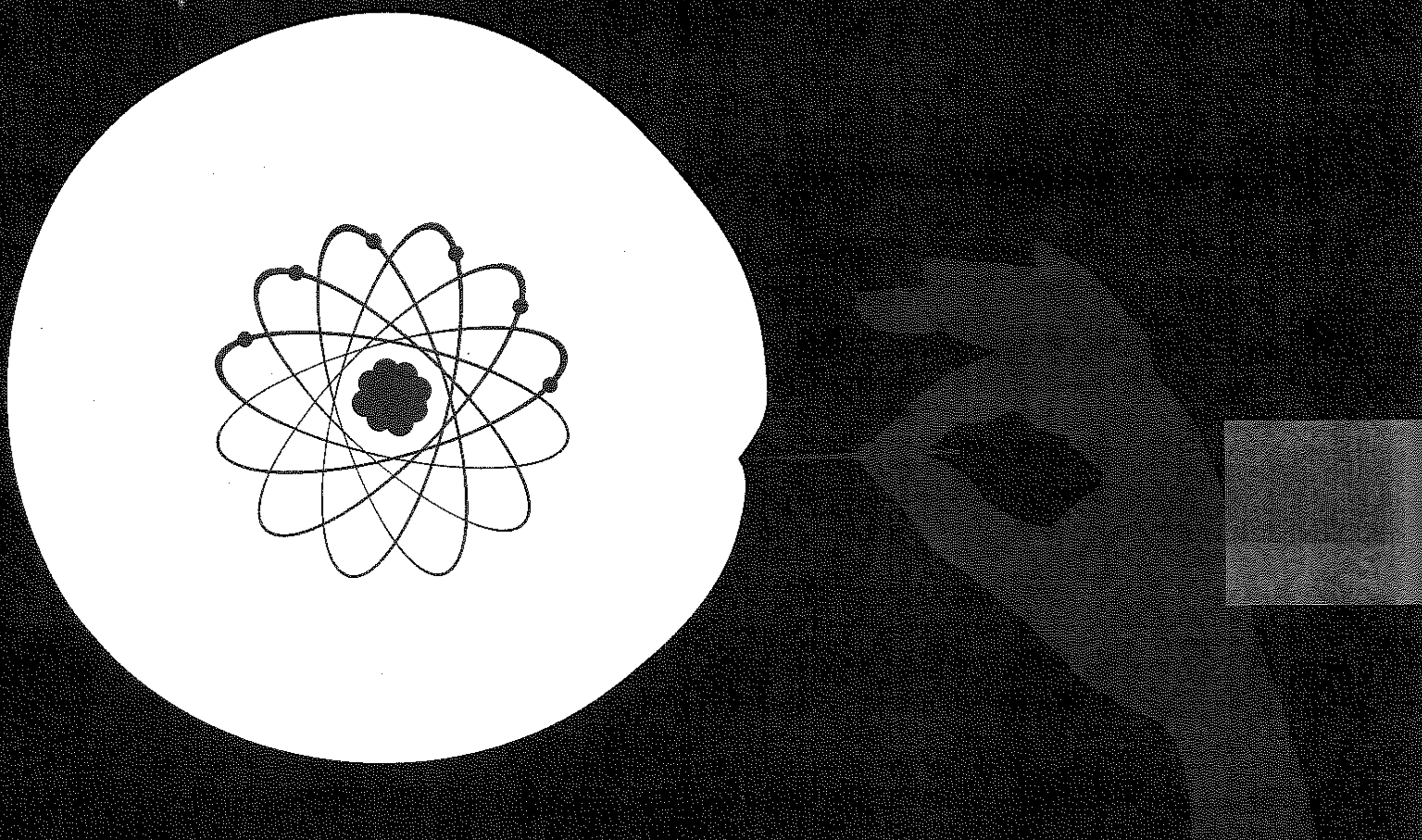
11. In order to enhance action on development and transfer of technology we decide to establish a Technology Mechanism to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities.

12. We call for an assessment of the implementation of this Accord to be completed by 2015, including in light of the Convention's ultimate objective. This would include consideration of strengthening the long-term goal referencing various matters presented by the science, including in relation to temperature rises of 1.5 degrees Celsius.

Carbon Tracker Initiative

6. "Unburnable Carbon," the Carbon Tracker Initiative
www.carbontracker.org/wp-content/uploads/downloads/2012/08/Unburnable-Carbon-Full1.pdf

Unburnable Carbon – Are the world's financial markets carrying a carbon bubble?



Carbon Tracker Initiative

About Carbon Tracker

The Carbon Tracker initiative is a new way of looking at the carbon emissions problem. It is focused on the fossil fuel reserves held by publically listed companies and the way they are valued and assessed by markets. Currently financial markets have an unlimited capacity to treat fossil fuel reserves as assets. As governments move to control carbon emissions, this market failure is creating systemic risks for institutional investors, notably the threat of fossil fuel assets becoming stranded as the shift to a low-carbon economy accelerates.

In the past decade investors have suffered considerable value destruction following the mispricing exhibited in the dot.com boom and the more recent credit crunch. The carbon bubble could be equally serious for institutional investors – including pension beneficiaries - and the value lost would be permanent.

We believe that today's financial architecture is not fit for purpose to manage the transition to a low-carbon economy and serious reforms are required to key aspects of financial regulation and practice firstly to acknowledge the carbon risks inherent in fossil fuel assets and then take action to reduce these risks on the timeline needed to avoid catastrophic climate change.

Carbon Tracker's goal is to prevent a carbon crash by:

- Working with capital market regulators and investors to assess systemic climate change risks and propose practical measures to minimise these risks to market stability and the operation of an orderly market.
- Revisiting the way fossil fuel companies are valued including the accounting treatment of fossil fuel-based reserves to ensure that carbon limits are fully integrated;
- Evaluating the concentration risk facing key global markets which are currently over-weight fossil fuels (such as the UK), and how indices, benchmarks and tracking products can be reformed to protect investors
- Improving the quality and utility of disclosures required by regulators and listings authorities to ensure that future carbon risks associated with fossil fuel reserves are fully dealt with to enable investors to make informed decisions;
- Updating the way fossil fuel companies are brought to the capital markets by investment banks;

We believe the regulatory regimes covering the capital markets need realigning to provide transparency for investors on the assumptions behind valuing unburnable carbon. With the global economy following the fortunes of the financial sector, it is essential to create capital markets which are robust enough to deliver an economy which can prevent dangerous climate change. Unless a more long-term approach is required by regulators, the shift in investment required to deliver a low carbon future will not occur.

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Executive Summary

Global carbon budget

Research by the Potsdam Institute calculates that to reduce the chance of exceeding 2°C warming to 20%, the global carbon budget for 2000-2050 is 886 $GtCO_2$. Minus emissions from the first decade of this century, this leaves a budget of 565 $GtCO_2$ for the remaining 40 years to 2050.

Global warming potential of proven reserves

The total carbon potential of the Earth's known fossil fuel reserves comes to 2795 $GtCO_2$. 65% of this is from coal, with oil providing 22% and gas 13%. This means that governments and global markets are currently treating as assets, reserves equivalent to nearly 5 times the carbon budget for the next 40 years. The investment consequences of using only 20% of these reserves have not yet been assessed.

Global warming potential of listed reserves

The fossil fuel reserves held by the top 100 listed coal companies and the top 100 listed oil and gas companies represent potential emissions of 745 $GtCO_2$. This exceeds the remaining carbon budget of 565 $GtCO_2$ by 180 $GtCO_2$.This means that using just the listed proportion of reserves in the next 40 years is enough to take us beyond 2°C of global warming. On top of this further resources are held by state entities. Given only 20% of the total reserves can be used to stay below 2°C, if this is applied uniformly, then only 149 of the 745 $GtCO_2$ held by listed companies can be used unabated. Investors are thus left exposed to the risk of unburnable carbon. If the 2°C target is rigorously applied, then up to 80% of declared reserves owned by the world's largest listed coal, oil and gas companies and their investors would be subject to impairment as these assets become stranded.

The carbon intensity of stock exchanges

The top 100 coal and top 100 oil & gas companies have a combined value of $7.42 trillion as at February 2011. The countries with the largest greenhouse gas potential in reserves on their stock exchanges are Russia, (253 Gt CO_2), the United States, (156.5 Gt CO_2) and the United Kingdom, (105.5 Gt CO_2). The stock exchanges of London, Sao Paulo, Moscow, Australia and Toronto all have an estimated 20-30% of their market capitalisation connected to fossil fuels.

London – a green capital?

The UK has less than 0.2% of the world's coal, oil and gas reserves, and accounts for around 1.8% of global consumption of fossil fuels. Yet the CO_2 potential of the reserves listed in London alone account for 18.7% of the remaining global carbon budget. The financial carbon footprint of the UK is therefore 100 times its own reserves. London currently has 105.5 $GtCO_2$ of fossil fuel reserves listed on its exchange which is ten times the UK's carbon budget for 2011 to 2050, of around 10 $GtCO_2$. Just one of the largest companies listed in London, such as Shell, BP or Xstrata, has enough reserves to use up the UK's carbon budget to 2050. With approximately one third of the total value of the FTSE 100 being represented by resource and mining companies, London's role as a global financial centre is at stake if these assets become unburnable en route to a low carbon economy.

Transferring risk to the markets

In addition to the coal, oil and gas reserves of established companies, new fossil fuel companies continue to list on exchanges to raise capital through share issues, in order to fund further exploration and development. Recently London has seen Glencore, Vallar/Bumi and Vallares list on its exchange with no consideration by the regulators of potential systemic risks to financial markets of the increased exposure to climate change risk. In addition, former state-owned companies are coming to the markets, bringing huge carbon reserves to western investment portfolios (e.g. Indian and Monglian coal mining companies).

The asset owners response

We believe investors need to respond to this systemic risk to their portfolios and the threat it poses of a carbon bubble bursting. Our research poses the following questions for asset owners:

- Which capital markets regulators are responsible for oversight of systemic risks and protecting your investments from systemic climate change risk?
- To what extent are you exposed to markets which have higher than average exposure to fossil fuels and are more prone to the stranding of assets?
- Are conventional fossil fuel-heavy indices still appropriate performance benchmarks for your portfolios?
- Are your asset allocation decisions based on obsolete data regarding the full risks facing fossil fuel reserves and what proportion of your investments may be unburnable carbon?

The reporting challenge

Corporate disclosure of carbon risks has improved markedly over the past decade, but arguably the most material climate change risk remains hidden from most reports issued by fossil fuel companies. For these companies, it is not the scale of operational emissions that is the strategic challenge, but the emissions associated with their products which are currently locked into their reserves. The potential carbon footprints of reserves are material numbers which are not transparent. The long-term viability of these businesses rests on their future ability to extract and sell carbon, rather than their past emissions. For investors to gain a greater understanding of these risks, a change of mindset is required to consider the scale of the systemic risk posed by fossil fuel reserves. This will require moving beyond annual reporting of last year's emissions flows to more forward-looking analysis of carbon stocks. This is a logical step as carbon reporting becomes mainstream and integrated with financial analysis.

The regulator's responsibility

The recent financial crisis has shown that capital markets were not-self-regulating and required unprecedented intervention; regulators were not monitoring the biggest systemic risks and so missed key intervention points. Listing authorities will need to take greater responsibility for reviewing the provision of information on embedded carbon by quoted companies. They need to ensure that taking the capital markets as a whole, systemic risks posed by the carbon asset bubble are addressed. Further regulation, guidance, and monitoring are needed to shift practices across the exchanges.

Do the maths

It's a simple formula:

Company-level: Reserves x carbon factor = carbon dioxide potential.
Exchange-level: Sum of company carbon dioxide potentials = Exchange total.
Global-level: Sum of exchange totals > Global carbon budget.

Today, these numbers do not add up. Moreover those responsible for the stability of financial markets have not yet started to collect this data or assimilate it into their risk models. It's time that asset owners and capital market regulators made sure they did.

Recommendations:

Regulators should:

- Require reporting of fossil fuel reserves and potential CO_2 emissions by listed companies and those applying for listing.
- Aggregate and publish the levels of reserves and emissions using appropriate accounting guidelines.
- Assess the systemic risks posed to capital markets and wider economic prosperity through the overhang of unburnable carbon
- Ensure financial stability measures are in place to prevent a carbon bubble bursting.

Introduction

This research provides the evidence base which confirms what we have long suspected – that there are more fossil fuels listed on the world's capital markets than we can afford to burn if we are to prevent dangerous climate change. Having satisfied that curiosity, this report marks a new phase of dealing with the implications for the investment world.

The missing element in creating a low carbon future is a financial system which will enable that to happen. Political will, technology and behaviour change all play their part, but finance will be critical to tackling climate change. This analysis demonstrates why a greater focus on changing the financial system is required to align it with emissions reduction objectives.

The global nature of capital markets means that fossil fuel reserves are distributed very differently in terms of ownership compared to their physical location. This places the responsibility for financing the development of fossil fuel reserves in industrialising countries with western investors.

Now is the time to move into the second generation of investor action on climate change, which tackles the system that is locked into financing fossil fuels. Climate change poses a great threat to the global economy and it is not unrealistic to expect regulators responsible for assessing new systemic risks to address the carbon bubble.

The goal now is for regulators to send clear signals to the market that cause a shift away from the huge carbon stockpiles which pose a systemic risk to investors. This is the duty of the regulator – to rise to this challenge and prevent the bubble bursting.

Mark Campanale & Jeremy Leggett

Acknowledgements

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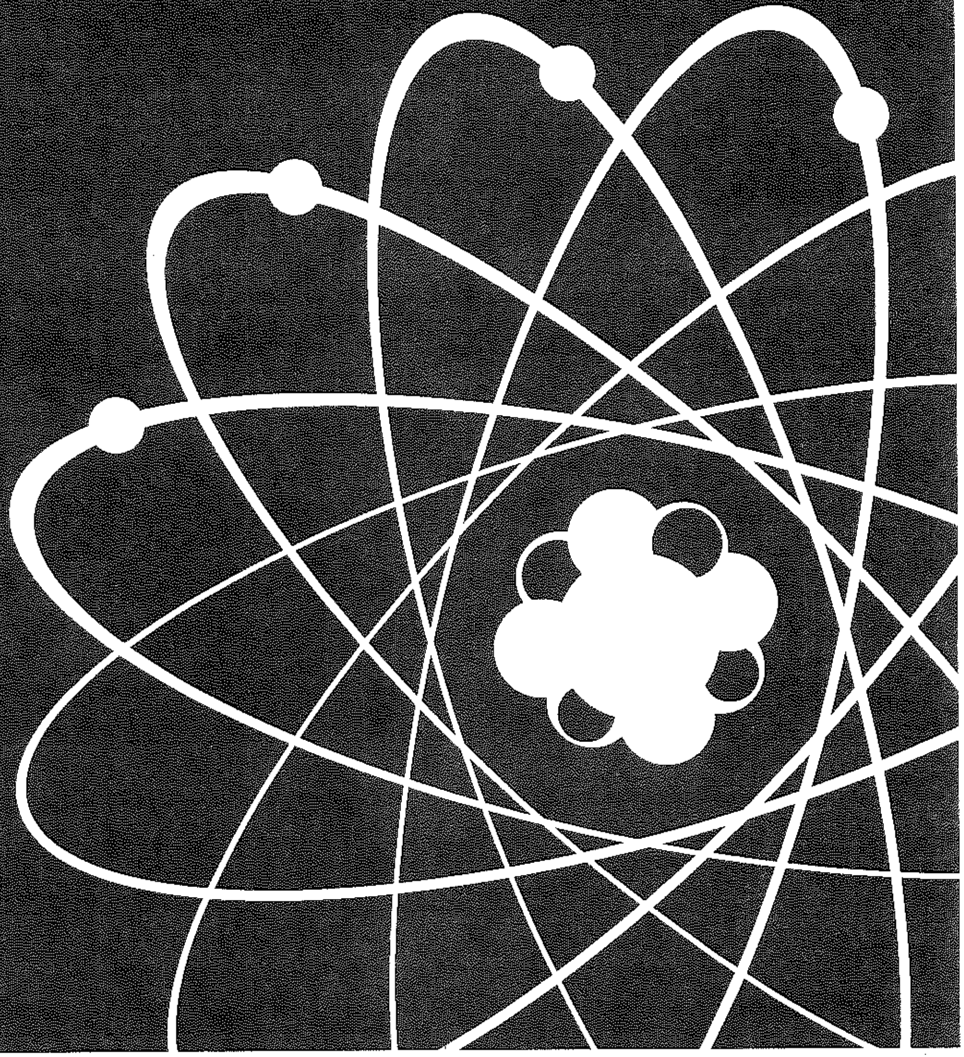
Part A:
The Analysis



1. The global carbon budget

The Cancun Agreement in December 2010 captured an international commitment to limit global warming to two degrees Celsius (°C) above pre-industrial levels. It also noted the potential need to tighten this target to 1.5°C.[1] This agreement provides a reference point against which global emissions scenarios can be compared to assess whether the world is on track to achieve the two degrees target. We are focused on how the world's financial markets are aligned with this pathway as it is clear a shift to a low carbon economy needs capital markets to rise to this challenge.

The Potsdam Climate Institute has calculated a global carbon budget for the world to stay below 2°C of warming. This uses probabilistic climate change modelling to calculate the total volume of carbon dioxide (CO_2) emissions permitted in the first half of the 21st century to achieve the target. This revealed that to reduce the chance of exceeding 2 °C warming to 20%, the global carbon budget for 2000 -2050 is 886 $GtCO_2$.[2] (N.B. All emissions are expressed in carbon dioxide only, rather than the equivalent of the full suite of greenhouse gases.)

What have we already used since 2000?

By 2011, the global economy has already used up over a third of that 50 year budget in the first decade alone. Calculations of global emissions published in Nature indicate 282 $GtCO_2$ have already been emitted in the first decade of this century from burning fossil fuels, with land use change contributing a further 39 $GtCO_2$.[3] This leaves a budget of around 565 $GtCO_2$ for the remaining 40 years to 2050. This budget could be further contracted if a position is adopted to limit global warming to 1.5°C or even lower.

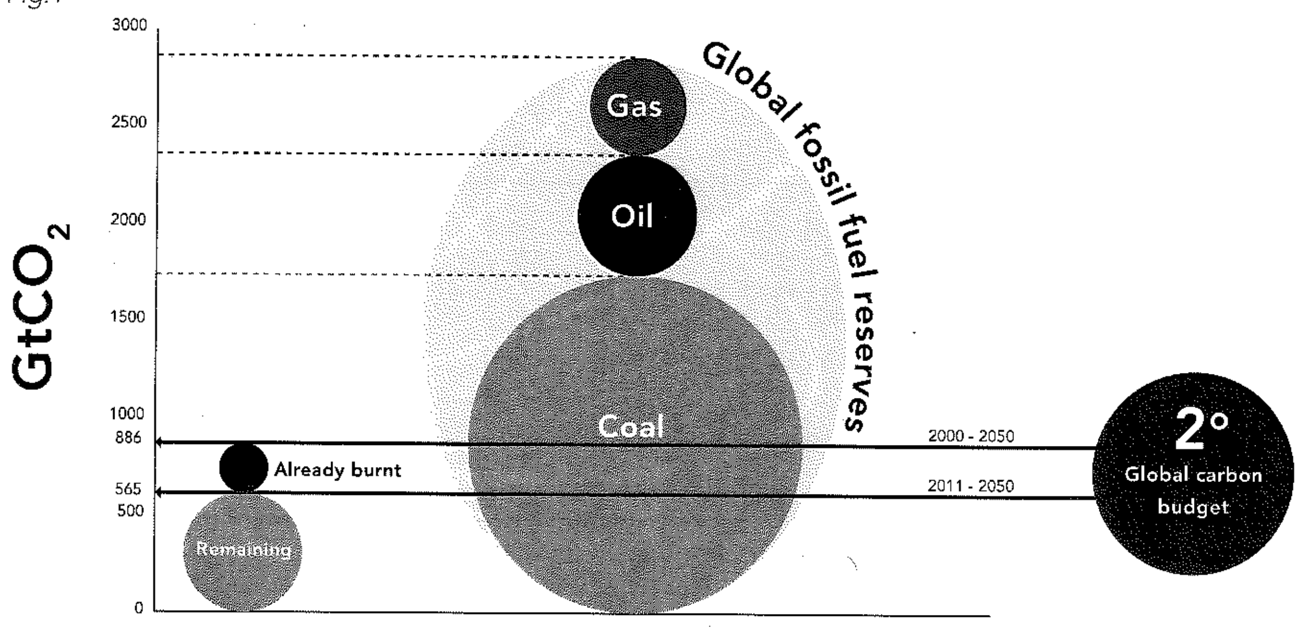
What are the potential emissions from global fossil fuel reserves?

The Potsdam Climate Institute also calculated the total potential emissions from burning the world's proven fossil fuel reserves (coal, oil and gas). This is based on reserve figures reported at a country level and UNFCCC emissions factors for the relevant fossil fuel types. Oil was split into conventional and unconventional types, whilst coal was split into three different bands to reflect the range of carbon intensity.

The total CO_2 potential of the earth's proven reserves comes to 2795 $GtCO_2$. 65% of this is from coal, with oil providing 22 % and gas 13%. This means that governments are currently indicating their countries contain reserves equivalent to nearly 5 times the carbon budget for the next 40 years. Consequently only one-fifth of the reserves could be burnt unabated by 2050 if we are to reduce the likelihood of exceeding 2°C warming to 20%.

Comparison of the global 2°C carbon budget with fossil fuel reserves CO_2 emissions potential

Fig.1



2. Global reserves of coal, oil and gas

The global distribution of fossil fuels reserves creates energy superpowers and consequently produces energy security issues for other nations, especially as political risk and catastrophic events ratchet up energy prices. The top ten countries for each of the three fossil fuels are shown below, with additional data for countries with major stock exchanges.

Fig.2

OIL

Country	Reserves (bbl)	% world
Saudi Arabia	264.6	17.9%
Canada	176.5	12.0%
Venezuela	172.3	11.7%
Iran	137.6	9.3%
Iraq	115	7.8%
Kuwait	101.5	6.9%
UAE	97.8	6.6%
Russia	74.2	5.0%
Libya	44.3	3.0%
Kazakhstan	39.8	2.7%
		82.9%
UK	3.1	0.2%
India	5.8	0.4%
China	14.8	1.0%
US	28.4	1.9%
World		**1476.4**

GAS

Country	Reserves (tn cm)	% world
Russia	44.38	23.7%
Iran	29.61	15.8%
Qatar	25.37	13.5%
Turkmenistan	8.1	4.3%
Saudi Arabia	7.92	4.2%
US	6.93	3.7%
UAE	6.43	3.4%
Venezuela	5.67	3.0%
Nigeria	5.25	2.8%
Algeria	4.5	2.4%
		76.8%
UK	0.29	0.2%
India	1.12	0.6%
China	2.46	1.3%
World	**187.49**	

COAL

Country	Reserves (tn cm)	% world
US	238308	28.9%
Russia	157010	19.0%
China	114500	13.9%
Australia	76200	9.2%
India	58600	7.1%
Ukraine	33873	4.1%
Kazakhstan	31300	3.8%
South Africa	30408	3.7%
Poland	7502	0.9%
Brazil	7059	0.9%
		91.5%
UK	155	0.02%
World	**826001**	

Source: BP Statistical Review of World Energy 2010[4]

The UK is a major global finance centre, but a relatively small country in terms of geographic size, which has less than 0.2% of the world's fossil fuel reserves. The rapidly industrialising economies of India and China have significant reserves of coal, but not oil and gas.

These reserves are split between those that are still owned by governments (National Oil Companies – NOCs), and those that are assets licensed to the private sector (International Oil Companies – IOCs). A number of state enterprises, particularly in the BRICS economies, are raising finance internationally via capital markets, in order to develop their coal and oil reserves. This trend is leading to a steady transfer of parts of the national companies to international investors.

The scale of the reserves held by these companies means that even a partial listing - such as Coal India in 2010 - can result in a significant addition of potential carbon emissions to the private sector and thus to the transfer of climate risk to the pension funds of ordinary citizens.

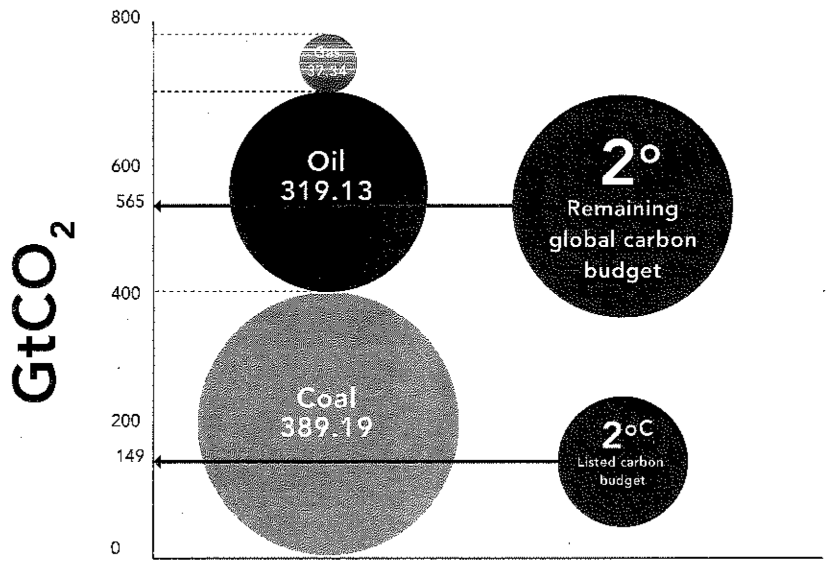
The figures used here are the proven reserves (i.e. those which have a 90% certainty of being extracted).[5] Companies also have probable (50% chance of being extracted) and possible (10% chance of being extracted)

3. Do listed fossil fuel reserves take us to unburnable carbon?

We estimate the fossil fuel reserves held by the top 100 listed coal companies and the top 100 listed oil and gas companies represent potential emissions of 745 $GtCO_2$. This exceeds the remaining carbon budget of 565 $GtCO_2$ by 180 $GtCO_2$. The potential emissions from listed fossil fuel reserves show that just over half the carbon comes from coal reserves, whilst only 5% is attributable to gas.

Carbon dioxide emissions potential of listed fossil fuel reserves

Fig.3



'using just the reserves listed on the world's stock markets in the next 40 years would be enough to take us beyond 2°C of global warming.'

This has profound implications for the world's energy finance structures and means that using just the reserves listed on the world's stock markets in the next 40 years would be enough to take us beyond 2°C of global warming. This calculation also assumes that no new fossil fuel resources are added to reserves and burnt during this period – an assumption challenged by the harsh reality that fossil fuel companies are investing billions per annum to find and process new reserves. It is estimated that listed oil and gas companies had CAPEX budgets of $798 billion in 2010.[6] In addition, over two-thirds of the world's fossil fuels are held by privately or state owned oil, gas and coal corporations, which are also contributing even more carbon emissions.

Given that only one fifth of the total reserves can be used to stay below 2°C warming, if this is applied uniformly, then only 149 of the 745 $GtCO_2$ listed can be used unmitigated. This is where the carbon asset bubble is located. If applied to the world's stock markets, this could result in a repricing of assets on a scale that would dwarf past profit warnings and revaluation of reserves. This situation persists because no financial regulator is responsible for monitoring, collating or interpreting these risks.

How quickly would we reach unburnable carbon if emissions continue business as usual?

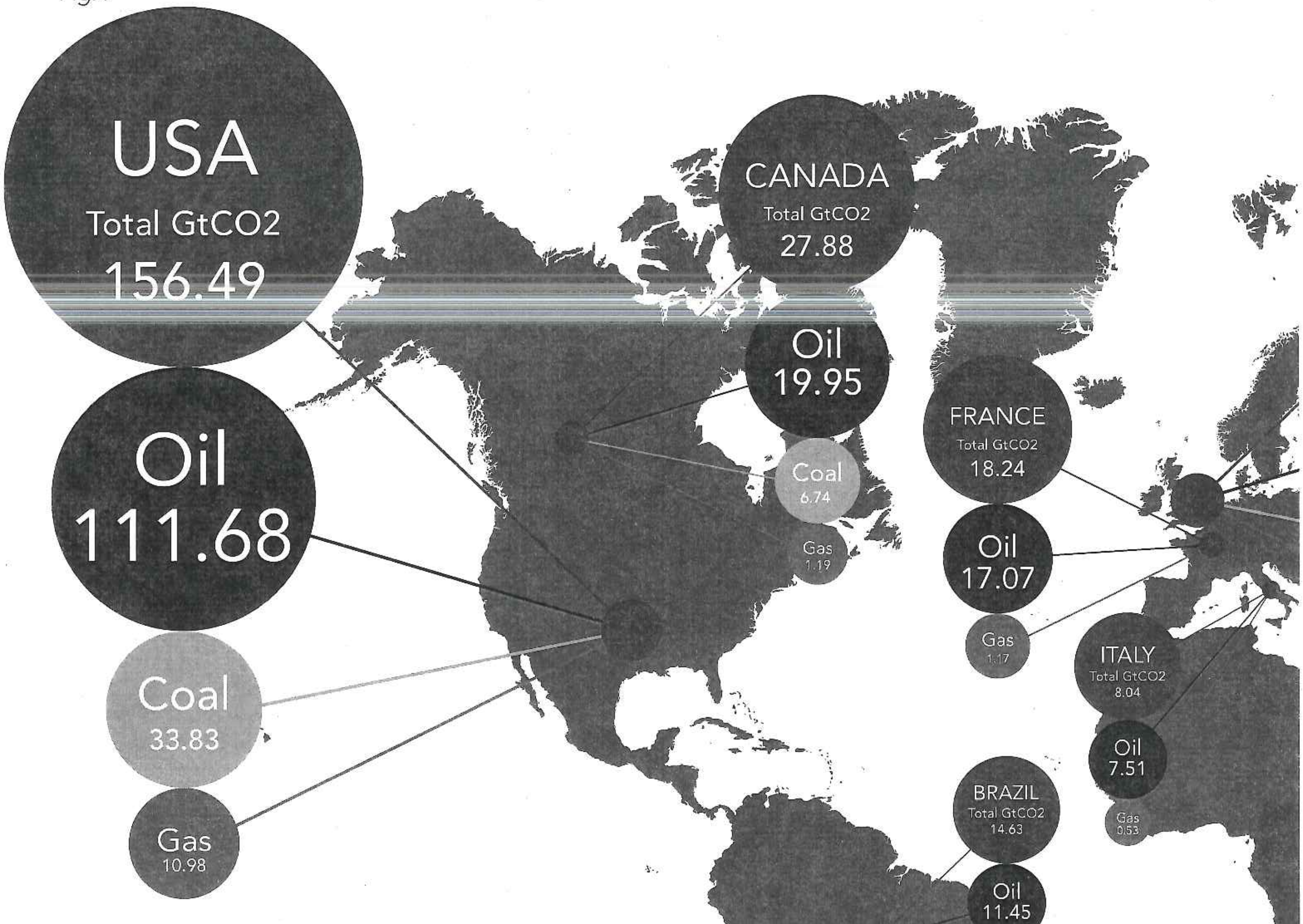
According to the latest IEA projections of energy-related fossil fuel CO_2 emissions, unburnable carbon will be reached in just 16 years if energy consumption continues unfettered.[7] This is based on global annual energy emissions increasing from 30.12 $GtCO_2$ in 2011 to 37.58 $GtCO_2$ in 2027, totalling 570.11 $GtCO_2$ over the period.

Where are these reserves listed?

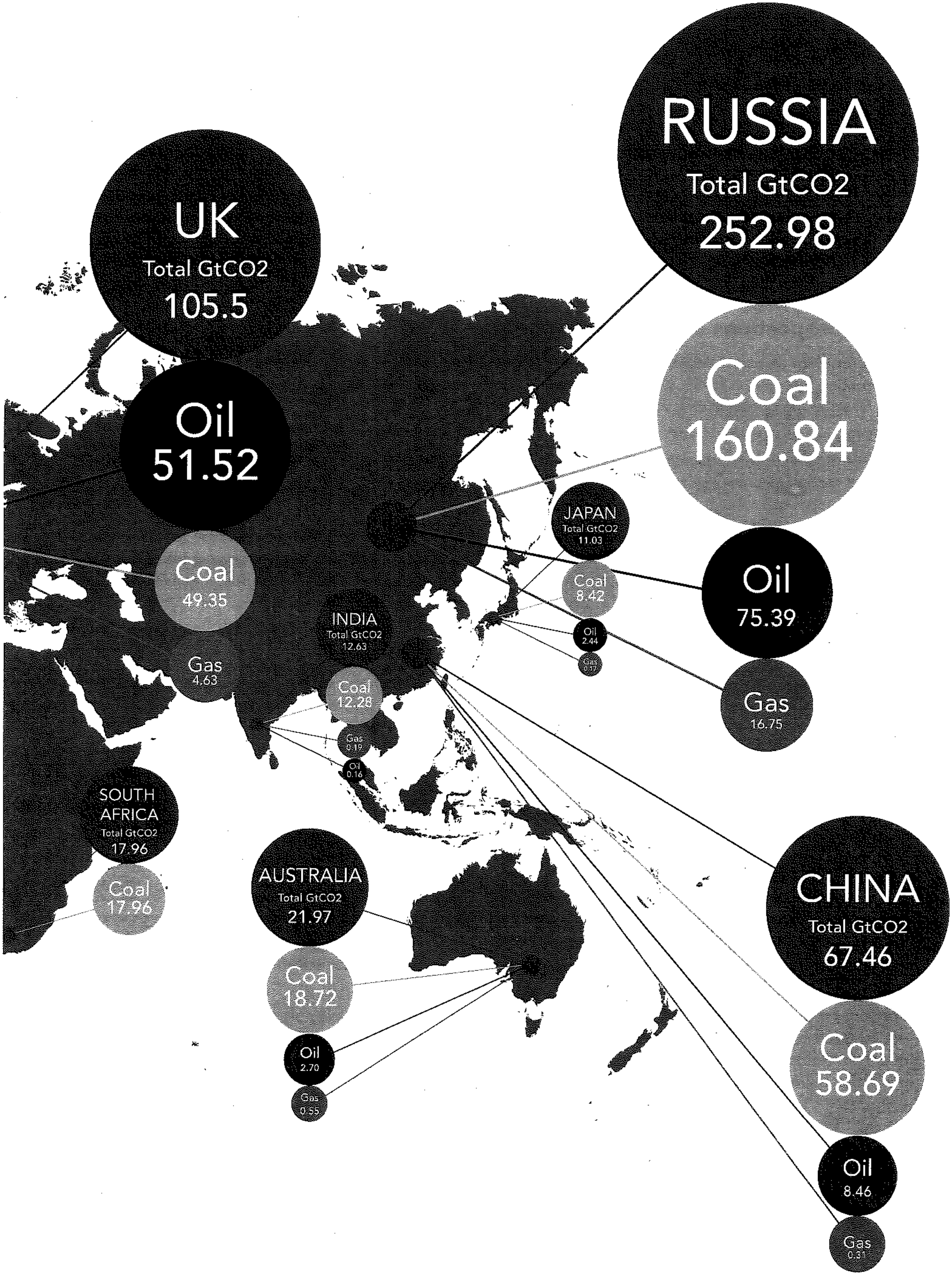
The following map shows the carbon dioxide emissions potential of the reserves that are listed in each country, broken down by the three types of fossil fuel. Russia, the US, the UK and China dominate the picture. However some exchanges, for example US and France, are skewed towards oil reserves, whilst Russia, China, Australia and South Africa are concentrated in coal reserves. This is in stark contrast to the limited fossil fuel reserves in the UK and the limited oil reserves in the US.

Distribution of fossil fuel reserves between stock exchanges

Fig.4



Country	Coal	Oil	Gas	Total
INDONESIA	5.15	-	-	**5.15**
GREECE	4.56	-	-	**4.56**
SPAIN	-	2.96	0.29	**3.25**
SINGAPORE	3.21	-	-	**3.21**
THAILAND	2.55	0.33	0.12	**3.0**
NORWAY	-	2.23	0.25	**2.48**
GERMANY	1.94	-	0.05	**1.99**
ARGENTINA	-	1.68	0.12	**1.8**
KOREA	-	1.56	-	**1.56**
AUSTRIA	-	1.02	0.06	**1.08**
CZECH REPUBLIC	1.07	-	-	**1.07**
NETHERLANDS	0.62	-	-	**0.62**
SWEDEN	-	0.47	0.00	**0.47**
COLOMBIA	-	0.35	0.01	**0.36**
MEXICO	0.26	-	-	**0.26**
HUNGARY	-	0.19	0.01	**0.2**
CROATIA	-	0.17	-	**0.17**


RUSSIA
Total GtCO2
252.98
Coal
160.84
Oil
75.39
Gas
16.75
UK
Total GtCO2
105.5
Oil
51.52
Coal
49.35
Gas
4.63
JAPAN
Total GtCO2
11.03
Coal
8.42
Oil
2.44
INDIA
Total GtCO2
12.63
Coal
12.28
Gas
0.19
Oil
0.16
SOUTH AFRICA
Total GtCO2
17.96
Coal
17.96
AUSTRALIA
Total GtCO2
21.97
Coal
18.72
Oil
2.70
Gas
0.55
CHINA
Total GtCO2
67.46
Coal
58.69
Oil
8.46
Gas
0.31

How much of each exchange's market capitalisation is based upon these reserves?

It is difficult to produce accurate figures due to the involvement of diversified mining companies who also extract metals and minerals other than coal. It would exaggerate the proportion of the market capitalisation linked to fossil fuels if, for example, the whole figure for Rio Tinto or BHP Billiton were included. If a conservative estimate is used which reduces the contribution from mining companies, then we believe 20 - 30% of the market capitalisation is linked to fossil fuel extraction in on the Australian, London, MICEX, Toronto and Sao Paulo exchanges. Paris, Shanghai, Hong Kong and Johannesburg are currently less exposed with less than 10% market capitalisation linked to fossil fuel extraction.

What proportions of global reserves are listed?

The companies assessed here represent the majority of listed reserves, with companies below this threshold contributing less than 0.15 $GtCO_2$ each to the total. These top 200 coal, oil and gas extraction companies are equivalent to the potential emissions from:

- 20% of global coal reserves
- 50% of global conventional oil reserves
- 12% of global unconventional oil reserves
- 10% of global gas reserves.

Combined, these top 200 companies are equivalent to around 27% of the global proven fossil fuel reserves, in terms of their carbon dioxide emissions potential. Oil therefore has a much higher representation on the financial markets. The low proportion of gas listed reflects the concentration of reserves in Russia and the Middle East, where oligarchs and National Oil Companies (NOCs) are dominant.

An unmitigated disaster?

Energy and emissions predictions often include potential solutions such as carbon capture and storage (CCS) which would allow some fossil fuels to be burnt with a much lower rate of carbon emissions. Viable CCS would certainly provide some extra carbon budget in the medium term. However it could only be applied to power generation by coal and gas, leaving the entire oil-based transport system unmitigated. It is also worth noting that even fossil fuel companies believe commercial application is at least a decade away and doesn't appear to be getting much closer. This means that the global carbon budget may be used up before CCS can even start to make a contribution. Cleaner combustion technologies will also stretch the budget, but will not address the fundamental problem.

Unconventionals

The figure for unconventional oil is artificially low, we believe, due to Canadian accounting practices which result in oil sands reserves not being booked upon discovery. Instead, they are only reported under Canadian rules once production is believed to be 'imminent'. The Canadian stock exchanges in particular may therefore have some hidden CO_2 potential as a result.

There has recently been more interest in unconventional gas deposits, for example shale gas, which are also not included in these figures and have a higher carbon factor than traditional gas. The current limited treatment of unconventionals suggests the reserve figures may be even higher and more carbon intensive, cancelling out mitigation gains.

4. Top 200 listed companies by estimated carbon reserves

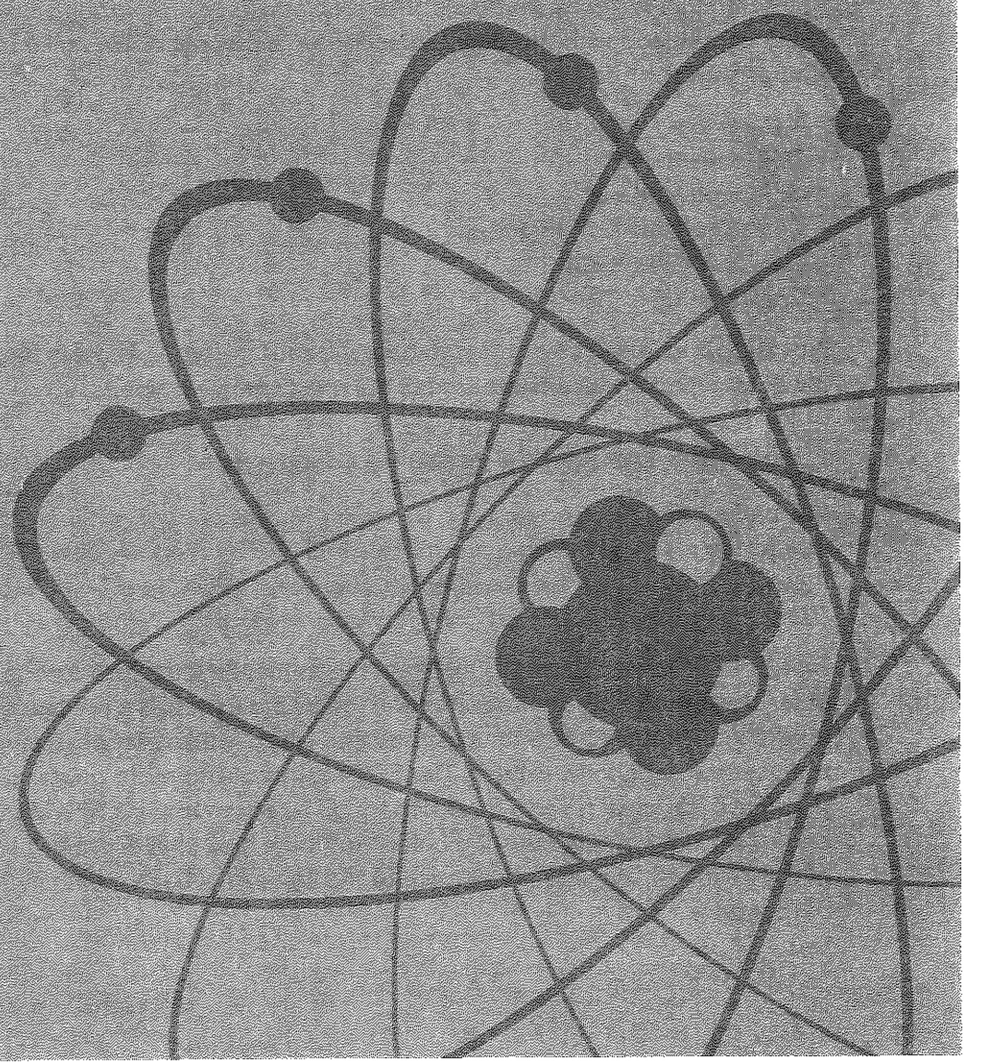
Fig.5

Rank	Coal Companies	COAL (GtCO2)	Oil & Gas Companies	OIL (GtCO2)	GAS (GtCO2)
1	Severstal JSC	141.60	Lukoil Holdings	42.59	0.97
2	Anglo American PLC	16.75	Exxon Mobil Corp.	38.14	2.89
3	BHP Billiton	16.07	BP PLC	32.68	1.92
4	Shanxi Coking Co. Ltd.	14.98	Gazprom OAO	14.87	13.96
5	Exxaro Resources Ltd.	13.37	Chevron Corp.	20.11	1.11
6	Xstrata PLC	11.60	ConocoPhillips	18.11	1.03
7	Datang International Power Generation Co. Ltd.	11.21	Total S.A.	16.90	1.12
8	Peabody Energy Corp.	10.23	Royal Dutch Shell PLC	14.11	2.09
9	Mechel OAO	8.90	Petrobras	11.45	0.17
10	Inner Mongolia Yitai Coal Co. Ltd.	7.78	Rosneft	10.70	0.08
11	China Shenhua Energy Co. Ltd.	6.91	ENI S.p.A.	7.51	0.53
12	Coal India Ltd.	6.69	Occidental Petroleum Corp.	7.36	0.22
13	Arch Coal Inc.	5.57	Bashneft	7.25	0.01
14	Rio Tinto	5.23	SINOPEC Shandong Taishan Petroleum Co. Ltd.	6.61	0.22
15	Evraz Group S.A.	4.86	Canadian Natural Resources Ltd.	4.35	0.14
16	Public Power Corp. S.A.	4.56	Devon Energy Corp.	3.77	0.42
17	Consol Energy Inc.	4.50	Suncor Energy Inc.	3.74	0.07
18	Yanzhou Coal Mining Co. Ltd.	4.46	Apache Corp.	3.32	0.33
19	Mitsubishi Corp.	4.31	Anadarko Petroleum Corp.	3.14	0.33
20	Datong Coal Industry Co. Ltd.	4.30	Hess Corp.	3.01	0.12
21	Bumi Resources	3.28	Repsol YPF S.A.	2.75	0.29
22	United Co. Rusal PLC	3.02	BG Group PLC	2.29	0.48
23	Vale SA	3.01	Marathon Oil Corp.	2.51	0.12
24	Pingdingshan Tianan Coal Mining Co. Ltd.	2.97	Inpex Corp.	2.44	0.10
25	Tata Steel Ltd.	2.96	Statoil ASA	2.23	0.25
26	Teck Resources Ltd.	2.70	BHP Billiton	1.82	0.20
27	Banpu PCL	2.55	CNOOC Ltd.	1.85	0.09
28	Sasol Ltd.	2.51	Husky Energy Inc.	1.76	0.06
29	United Industrial Corp. Ltd.	2.48	YPF S.A.	1.68	0.12
30	Polyus Gold OAO	2.47	Novatek	-	1.73
31	Alpha Natural Resources Inc.	2.29	Talisman Energy Inc.	1.47	0.19
32	Magnitogorsk Iron & Steel Works	2.20	Pioneer Natural Resources Co.	1.50	0.11
33	Raspadskaya OJSC	2.09	SK Holdings Co. Ltd.	1.56	-
34	Kuzbassenergo	2.03	Petroleum Development Corp.	-	1.51
35	RWE AG	1.94	Cenovus Energy Inc.	1.40	0.06
36	Massey Energy Co.	1.93	Nexen Inc.	1.40	0.02
37	Eurasian Natural Resources Corp. PLC	1.93	EOG Resources Inc.	0.97	0.38
38	Wesfarmers Ltd.	1.86	Noble Energy Inc.	1.04	0.12
39	Churchill Mining PLC	1.74	OMV AG	1.02	0.06
40	Idemitsu Kosan Co. Ltd.	1.58	Chesapeake Energy Corp.	0.39	0.57
41	Tata Power Co. Ltd.	1.49	Penn West Petroleum Ltd.	0.91	0.03
42	Alliance Resource Partners L.P.	1.47	Oil Search Ltd.	0.91	-
43	NACCO Industries Inc. (Cl A)	1.33	Woodside Petroleum Ltd.	0.54	0.27
44	Novolipetsk Steel OJSC	1.30	Canadian Oil Sands Ltd.	0.78	-
45	New Hope Corp. Ltd.	1.30	Imperial Oil Ltd.	0.75	0.01
46	TransAlta Corp.	1.23	Murphy Oil Corp.	0.69	0.03
47	Sherritt International Corp.	1.15	Whiting Petroleum Corp.	0.70	0.01
48	PT Bayan Resources	1.14	EnCana Corp.	0.24	0.47
49	New World Resources N.V.	1.07	Plains Exploration & Production Co.	0.67	0.04
50	Mitsui & Co. Ltd.	1.03	Newfield Exploration Co.	0.53	0.11

Table continues overleaf

Rank	Coal Companies	COAL (GtCO2)	Oil & Gas Companies	OIL (GtCO2)	GAS (GtCO2)
51	Kazakhmys PLC	0.99	Denbury Resources Inc.	0.60	0.00
52	African Rainbow Minerals Ltd.	0.95	Continental Resources Inc. Oklahoma	0.54	0.02
53	International Coal Group Inc.	0.95	Linn Energy LLC	0.49	0.03
54	Patriot Coal Corp.	0.94	Pacific Rubiales Energy Corp.	0.50	0.02
55	Aston Resources Pty Ltd.	0.93	Crescent Point Energy Corp.	0.47	0.00
56	AGL Energy	0.89	Concho Resources Inc.	0.44	0.02
57	Tokyo Electric Power Co. Inc.	0.89	Quicksilver Resources Inc.	0.36	0.08
58	Cloud Peak Energy Inc.	0.85	PTT PCL	0.33	0.12
59	CLP Holdings Ltd.	0.83	Berry Petroleum Co. (Cl A)	0.40	0.03
60	Polo Resources Ltd.	0.82	Range Resources Corp.	0.27	0.11
61	Whitehaven Coal Ltd.	0.79	Energen Corp.	0.34	0.04
62	Mongolian Mining Corp.	0.75	Enerplus Corp.	0.34	0.03
63	PT Adaro Energy	0.74	Tullow Oil PLC	0.36	0.01
64	Allete Inc.	0.72	Ecopetrol S.A.	0.35	0.01
65	Optimum Coal Holdings Ltd.	0.67	Santos Ltd.	0.19	0.17
66	ArcelorMittal	0.62	SandRidge Energy Inc.	0.33	0.03
67	Coal of Africa Ltd.	0.59	Cairn Energy PLC	0.35	0.00
68	James River Coal Co.	0.57	Arc Resources Ltd.	0.30	0.03
69	Westmoreland Coal Co.	0.56	El Paso Corp.	0.23	0.10
70	Aquila Resources Ltd.	0.53	Pengrowth Energy Corp.	0.30	0.02
71	Macarthur Coal Pty Ltd.	0.53	Lundin Petroleum AB	0.31	0.00
72	FirstEnergy Corp.	0.50	Petrobank Energy & Resources Ltd.	0.31	0.00
73	Western Coal Corp.	0.49	Baytex Energy Corp.	0.30	0.00
74	Cliffs Natural Resources Inc.	0.47	Forest Oil Corp.	0.22	0.07
75	Wescoal Holdings Ltd.	0.46	Mariner Energy	0.27	0.02
76	Walter Energy, Inc.	0.45	ATP Oil & Gas Corp.	0.24	0.01
77	Huolinhe Opencut Coal Industry Corp. Ltd.	0.41	Bankers Petroleum Ltd.	0.25	-
78	Gujarat NRE Coke Ltd.	0.40	Soco International PLC	0.25	-
79	Straits Asia Resources Ltd.	0.39	Zhaikmunai L.P.	0.22	0.01
80	Capital Power Corp.	0.38	Cimarex Energy Co.	0.18	0.05
81	Fushan International Energy Group Ltd.	0.34	Questar Corp.	0.12	0.11
82	Noble Group Ltd	0.34	GDF Suez S.A.	0.17	0.05
83	Itochu Corp.	0.34	Swift Energy Co.	0.20	0.01
84	Jizhong Energy Resources Co. Ltd.	0.30	Compania Espanola de Petroleos S.A.	0.21	-
85	Northern Energy Corp. Ltd.	0.29	PetroBakken Energy Ltd.	0.21	0.00
86	NTPC Ltd.	0.28	Premier Oil PLC	0.18	0.03
87	Prophecy Resource Corp.	0.28	Bonavista Energy Corp	0.18	0.03
88	Mitsui Matsushima Co. Ltd.	0.28	MOL Hungarian Oil and Gas Plc	0.19	0.01
89	Fortune Minerals Ltd.	0.28	SM Energy Co.	0.17	0.02
90	Black Hills Corp.	0.27	Williams Cos.	-	0.18
91	Jindal Steel & Power Ltd.	0.26	EQT Corp.	0.01	0.17
92	Grupo Mexico S.A.B. de C.V.	0.26	Oil & Natural Gas Corp. Ltd.	-	0.18
93	Gansu Jingyuan Coal Industry & Electricity Power	0.26	Global Energy Development PLC	0.17	0.00
94	Bandanna Energy Ltd.	0.25	Oil India Ltd.	0.16	0.01
95	Irkutskenergo	0.23	Venoco Inc.	0.16	0.01
96	Alcoa Inc.	0.23	INA-Industrija Nafte	0.17	-
97	Homeland Energy Group Ltd.	0.23	PA Resources AB	0.16	-
98	Neyveli Lignite Corp. Ltd.	0.19	Ultra Petroleum Corp.	-	0.16
99	Zhengzhou Coal Industry & Electric Power Co. Ltd.	0.15	Resolute Energy Corp.	0.16	0.00
100	Gujarat NRE Coking Coal Ltd.	0.12	Southwestern Energy Co.	0.00	0.16
Grand Total		**389.19**	**Grand Total**	**319.13**	**37.34**

Appendix 1: Methodology



Reserves data

Coal reserves data was provided by Raw Materials Group (RMG). More information is available at www.rmg.se Oil and gas reserves data was provided by Evaluate Energy. More information is available at www.evaluateenergy.com

The reserves data was based on the most recent reported information on proven reserves at the end of 2010. As with any snapshot analysis, ownership of reserves will continue to change and reserves will be extracted and added to a company's portfolio of assets. The research providers are leaders in their sectors and have the most complete dataset available. However, reporting of reserves and ownership in some parts of the world is not as transparent as others.

Carbon dioxide emissions factors

The formula for calculating the carbon emissions from the reserves was taken from the methodology used by the Potsdam Climate Institute. This estimates potential emissions from proven recoverable reserves of fossil fuels, according to $E = R \times V \times C \times f$, where E are the potential emissions ($GtCO_2$), R the proven recoverable reserves (Gg), V the net calorific value (TJ/Gg), C the carbon content (tC/TJ) and f a conversion factor ($GtCO_2$/tC).[44] V and C come from the IPCC Guidelines for National Greenhouse Gas Emissions Inventories.[45] The Potsdam methodology applies CO_2-only factors to the fuels, as IPCC factors for all the Kyoto gases to give CO_2-equivalent are specific to the use of the fuels. The total level of greenhouse gases will therefore be higher; however the CO_2-only data is used consistently throughout for calculating both the budgets and emissions from reserves. Care must be taken if you wish to compare these figures to CO_2e data.

Reserves classification

The fossil fuel reserves were split into six classes, again mirroring the Potsdam Institute methodology. These types correspond with the data tables for the elements which make up the carbon emissions formula. The six classes were:

- Natural Gas
- Oil Conventional
- Oil Unconventional
- Coal (Bitumous & Anthracite)
- Coal (Sub-Bitumous)
- Coal (Lignite)

Not all coal assets in the RMG database indicate the type of coal in the mine. Where this data was not available it was assumed it was bitumous coal, the most common type.

Canadian tar sands reserves figures

We believe the figures used for Canadian tar sands underestimate the reserves held by companies. This is due to the reserves booking approach stipulated by the Canadian Oil and Gas Evaluation Handbook whereby *"quantities must not be classified as reserves unless there is an expectation that the accumulation will be developed and placed on production within a reasonable timeframe."*

Typically Canadian companies interpret this as meaning that production is imminent. Given the start-stop history of tar sands projects with fluctuations in the oil price there is a precautionary approach to booking reserves. This results in companies with tar sands assets, which are known physical reserves, not always booking them due to uncertain economic viability. The SEC has produced more guidance on this topic which is starting to come through in the latest reserve reporting for US listed companies. This stipulates that unconventional reserves must be broken out from an overall oil reserves figure, and that economic viability should be based on the average of the 12-month average crude price of the first day of each month in the reporting period, rather than the end of year price.

Equity basis

Reserves, and therefore potential emissions, were attributed to each company on an equity ownership basis. Where companies still had a government interest of more than 10% only the publicly listed proportion was attributed to the stock, and therefore its exchange.

Exchange allocation

The reserves were attributed to the primary exchange of the company. For companies with dual listings the reserves were split equally between the two exchanges. This provides an indication of the primary regulator for the company. However, many companies have several listings often using depositary receipts and other mechanisms to access other markets.

Top 100 selection

The companies selected to be included in this assessment were the top 100 coal companies and the top 100 oil and gas companies, assessed on the potential carbon emissions from their reserves. There will be further fossil fuel reserves listed on the world's financial markets. However, the levels of reserves reported by these companies would not significantly affect the findings of this report. Each company beyond the top 100 coal and oil & gas companies considered here has less than 0.15 $GtCO_2$ in reserves. This extra carbon only adds to the overall volume that is listed on the world's stock markets.

Market Capitalisation

Verification of the stock listings and their market capitalisation was completed in February 2011. Obviously this will be changing on a daily basis and new listings, mergers and acquisitions and corporate restructures are occurring all the time.

Data accuracy

The approach taken is based on the best available data and provides a conservative estimate of the total reserves and potential resulting emissions attributable to listed entities and their associated stock exchanges. We believe the dataset to be of sufficient quality to test the overall hypothesis that there is sufficient carbon listed to use up the global carbon budget to 2050 and give a reasonable representation of the geographical distribution across the exchanges. We welcome comments on how to improve the analysis and suggestions of useful outputs for future versions.

7. "Oil and Carbon Revisited," HSBC Global Research
http://www.hsbcnet.com/hsbc/research

HSBC Climate Change

HSBC Global Research

Oil & carbon revisited

Value at risk from 'unburnable' reserves

- **Lowering carbon emissions could put future oil and gas developments at risk**
- **Demand effects may mean lower oil and gas prices, a greater value risk**
- **Statoil's 'unburnable' reserves amount to 17% of market capitalisation; low costs mean BG has little value at risk**

Unburnable reserves: The IEA's World Energy Outlook (2012 edition) estimated that in order to have a 50% chance of limiting the rise in global temperatures to 2°C, only a third of current fossil fuel reserves can be burned before 2050. The balance could be regarded as 'unburnable'.

Oil could deliver efficiency gains: Although coal reserves have significantly more embedded carbon than other fuels, we believe that oil demand could be reduced relatively quickly given the inefficiency of personal transport.

Gas growth slows: In a low-carbon world, defined as limiting future CO_2 emissions until 2050 to 1,440Gt, oil demand would fall post 2010. Gas demand would continue to grow but at a slower rate than currently. This means some potential oil and gas developments would no longer be needed.

Ceiling tests to assess value at risk: To assess the risk for the sector, we assume the world is already low carbon. We undertake a ceiling test on the future projects of the larger European majors we cover to assess the potential value at risk. We use USD50/b for oil and USD9/mmBtu for gas for our ceiling test. Oil and gas volumes at risk range from under 1% (BG Group) to 25% (BP). However, as a percentage, the value of reserves at risk is lower than this because they are largely undeveloped. The value impact ranges from under 1% (BG Group) to 17% (Statoil).

Price risk a material threat: Although not directly related to 'unburnable' carbon, a greater risk to the sector would be if lower demand led to lower oil and gas prices. In that case, the potential value at risk could rise to 40-60% of market cap.

Low costs are the key: Because of its long-term nature, we doubt the market is pricing in the risk of a loss of value from this issue. We think investors should focus on low-cost companies like BG; a gas bias is preferred, which would favour Shell.

25 January 2013

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aperiogroup

8. "Do the Investment Math: Building a Carbon-Free Portfolio," the Aperio Group investment management firm https://www.aperiogroup.com/system/files/documents/building_a_carbon_free_portfolio_0.pdf

THE APERIO DIFFERENCE

Do the Investment Math: Building a Carbon-Free Portfolio

As university endowments face pressure to divest stocks of companies contributing the most to climate change, much of the public discussion has focused on the looming math of the environmental impact of a carbon-based economy. As endowments decide whether or not to divest or implement screens, another kind of math is needed as part of the process: the math of portfolio analysis. (Note: this version updates an earlier paper from December 2012.)

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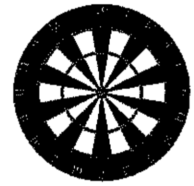
Do the Investment Math

In the past few months, a groundswell of public support has been pushing universities to divest their endowments of holdings in large fossil fuel companies. Writer and environmental advocate Bill McKibben has coined the phrase "Do the Math," referring to the dangers of rising levels of carbon dioxide in the atmosphere. This focus on the math of climate change has been catalyzed by the publication of his influential article in *Rolling Stone* magazine this past July, "Global Warming's Terrifying New Math." This has been followed up by a 21-city college campus tour encouraging carbon divestment by large endowments and pension funds.

While some endowments like that of Hampshire college have announced plans to change their investment approach, many fiduciaries sitting on endowment boards dismiss with skepticism the idea of a portfolio helping to serve environmental goals. These skeptics often claim that incorporating environmental screening, however well intentioned, simply imposes a tax on investment return. While their wariness reflects a genuine and valid desire to protect the returns earned by the endowments, outright dismissal of any screening ignores another kind of math, the kind that measures the risk to a portfolio rather than the effects of carbon dioxide on our planet.

When the idea of fossil fuel screening gets floated, the first thing an endowment committee would want to know is the impact on return, especially whether screening imposes any penalty. The research data on a wide range of social and environmental screening show no such penalty (nor any benefit either), although the results are mixed.[1] Given the lack of evidence of a return penalty, the focus then shifts to the impact of screening on a portfolio's risk, which is more predictable and easier to forecast than return. Skeptics are right when they claim that constraining a portfolio can only increase risk, but they frequently ignore the magnitude of the change in risk, which can be so minor as to be virtually irrelevant.

How can this risk impact best be estimated? For analysis, we'll use a computer program called a multi-factor model, in this case the Aegis model from the company Barra. Aegis uses both industry and fundamental factors like price-earnings ratios to measure stock risk. The model generates a forecast for tracking error, which is the statistical measurement of deviation from a target benchmark like the S&P 500 or Russell 3000 for domestic stocks or the MSCI All Country World index for global stocks. Tracking error is analogous to the concept of darts thrown at a dartboard, where the bull's-eye is the benchmark return and the measurement of the dispersion of dart throws around the bull's-eye is the tracking error over a particular time frame, e.g. monthly returns over the past three years. A small or tight tracking error means the darts (each representing one monthly return) are clustered around the bull's-eye, and a large or loose tracking error means the darts are all over the board.



As an example of the impact of screening on tracking error, we'll analyze the extra risk of excluding a small sample of companies that the climate change advocates have identified as particularly harmful, the so-called "Filthy Fifteen," U.S. companies judged by As You Sow and the Responsible Endowment Coalition as the most harmful based on the amount of coal mined and coal burned as well as other metrics. To measure the impact of excluding these companies, we'll start with a broad-market U.S. benchmark, the Russell 3000, then exclude the thirteen publicly traded stocks of the Filthy Fifteen[2] and finally use the multi-factor model to create an optimized portfolio as close to the Russell 3000 as possible. Investors who want a portfolio free of the Filthy Fifteen can get a tracking error versus the Russell 3000 of only 0.14%, a very minor difference from the benchmark.

What Does Additional Tracking Error Cost the Investor?

If investors are to decide whether a tracking error of 0.14% to exclude the Filthy Fifteen seems reasonable or excessive, they need some context for what that number implies. First, tracking error has an expected value of zero, meaning that in a passive management framework a portfolio's return is just as likely to be above the benchmark as below. Second, the average expected tracking error for institutional active management is 5.0% according to a survey of large U.S. pension funds,[3] which means that investors already bear comparatively significant tracking error with their active managers. Third, in the language of statistics, tracking error is an estimate of standard deviation of returns versus a benchmark, which is in turn the square-root of variance. That means that tracking error cannot be simply added to overall portfolio risk (see Table 1). In other words, if the total market's risk is 17.67% (the Barra Aegis forecast standard deviation for the Russell 3000 as of December 31, 2012), the portfolio risk does not rise by another 0.14% to 17.81%. Instead, the impact of screening on absolute portfolio risk must be calculated using variance terms.

Table 1: Impact of Tracking Error for Exclusion of Filthy Fifteen

	Standard Deviation	Variance = (Std. Dev.)^2	Theoretical Return Penalty
Market Risk (Russell 3000)	17.6657%	3.1208%	
Tracking Error vs. R3000	0.1400%	0.0002%	
Screened Portfolio	17.6662%	3.1210%	
Incremental Risk	0.0006%		0.0002%

Source: Barra Aegis and Aperio Group

As Table 1 shows, adding 0.1400% of tracking error increases absolute portfolio risk by only 0.0006%, or about a half of one one-thousandth of a percent. In other words, the portfolio does become riskier, but by such a trivial amount that the impact is statistically irrelevant. In other words, excluding the Filthy Fifteen has no real impact on risk.

Skeptics could accurately point out that even for such a trivial amount, investors are technically bearing additional risk for which they are not compensated. Modern portfolio theory holds that any increase in risk should earn an investor a corresponding increase in return. That theoretical loss of return in this case can be measured by using historical data for the "market premium," i.e. the amount of extra return stock market investors have been paid historically for bearing extra risk. As shown in Table 1, the foregone return is 0.0002%, or two one hundredths of a basis point. Please see Appendix I for details on the calculation of the return penalty.

Having seen that excluding the Filthy Fifteen incurs virtually no risk penalty, we'll now turn to a stricter set of screens for those endowments who may want to divest a more comprehensive list of companies from an entire industry, Oil, Gas & Consumable Fuels.[4] Table 2 shows the naturally higher tracking error resulting from stricter screens.

Table 2: Impact of Tracking Error for Industry Exclusion

	Standard Deviation	Variance = (Std. Dev.)^2	Theoretical Return Penalty
Market Risk (Russell 3000)	17.6657%	3.1208%	
Tracking Error vs. R3000	0.5978%	0.0036%	
Screened Portfolio	17.6758%	3.1243%	
Incremental Risk	0.0101%		0.0034%

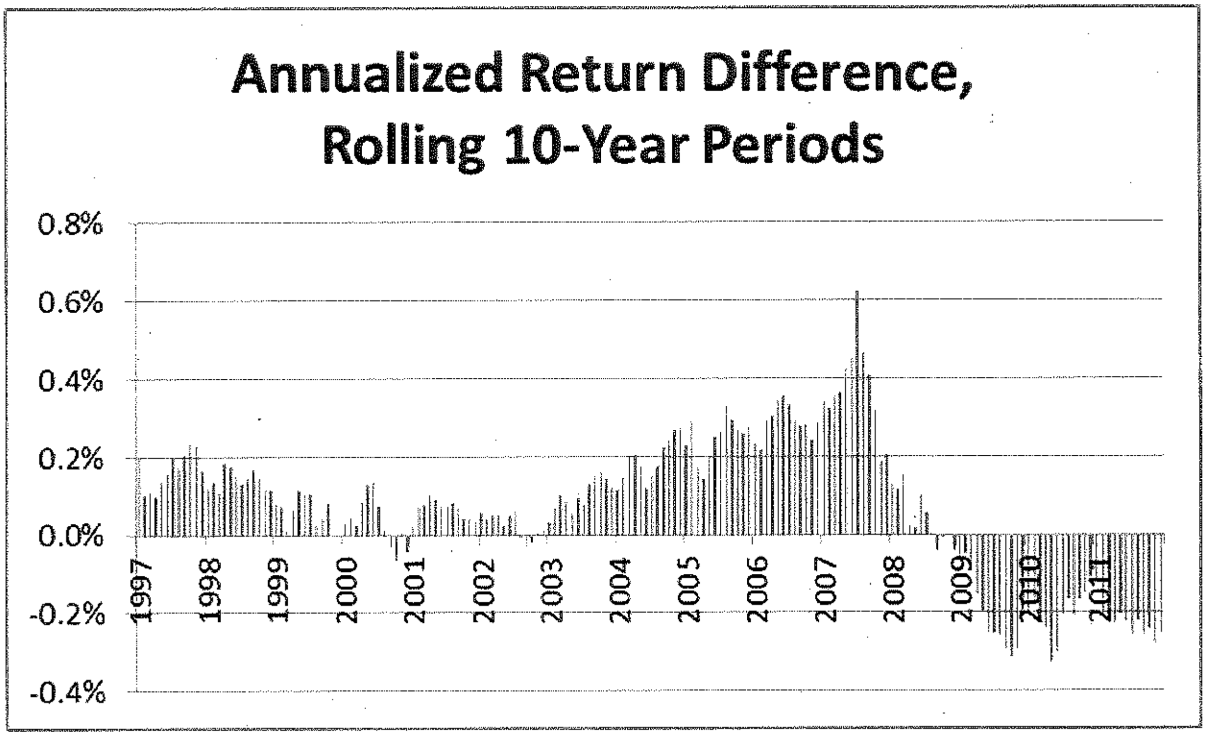
Source: Barra Aegis and Aperio Group. Numbers may not sum exactly due to rounding.

As Table 2 shows, adding 0.5978% of tracking error increases absolute portfolio risk by 0.0101%, with a theoretical return penalty of 0.0034%, or less than half a basis point. While that tracking error remains very low compared to active stock picking, the industry emphasis still means that if this industry outperforms the overall stock market, a portfolio with these exclusions will perform worse, while of course if those industries perform poorly relative to the market a screened portfolio would perform better.

The approach shown here of using a multi-factor model to manage risk in screened portfolios has been validated in a number of articles in academic finance journals that prove and explain this math in greater detail.[5] Furthermore, while this analysis shows the effects for U.S. stocks, the math looks very similar for non-U.S. and global portfolios as well. Excluding more industries increases the tracking error slightly, as presented in an earlier version of this paper, more details of which can be found in Appendix II.

Historical Back Test

The risk data discussed so far reflect estimates of future incremental impact on a portfolio's volatility. Another approach involves back testing hypothetical portfolios to see how they would have performed over different historical periods, i.e. looking backwards instead of forwards. Although such back testing should be taken with a healthy grain of salt, it can still provide at least some sense of how a screened portfolio would have performed. Using the same multi-factor Barra model used to create the portfolio shown in Table 2, the performance has been analyzed using historical return data. This screened portfolio has been optimized to track the Russell 3000 benchmark but with no stocks from Oil, Gas & Consumable Fuels. Shown below is a graph of rolling ten-year return periods from the end of 1987 through the end of 2012 for the screened portfolio, called Full Carbon Divestment. The blue bars above the 0.0% line indicate that the screened portfolio earned a higher average annual return over the trailing ten-year period, while those below the line indicate the periods for which the portfolio performed worse than the benchmark.



Return numbers show annualized return difference between Full Carbon Divestment portfolio and Russell 3000 for periods from Jan 1988 to Dec 2012.

Average Annualized 10-year Return Difference	+0.08%
Percentage of Periods Higher than R3000	73%
Percentage of Periods Lower than R3000	27%
Tracking error, current forecast	0.60%
Tracking error, historical simulation	0.78%

As the chart and table show, the average return for a 10-year rolling period over the past 25 years was slightly positive, with 73% of the ten-year periods earning higher returns. If there is no return bias, then theoretically such a screened portfolio would be expected to perform better than the benchmark only half the time. In other words, the historical data may show superior performance, but the model forecasts only risk, not any ongoing excess return. The hypothetical historical tracking error over the period was 0.78%, slightly higher than the currently forecasted 0.60%.

Summary
In deciding whether to implement any divestment, university endowments face compelling arguments on both sides. From the advocates of divestment, endowments hear about the serious environmental damage already incurred, the frightening trajectory of the math and the benefit from taking a public stance on a critical ethical issue. From the skeptics they hear that screening will adversely affect risk and return and that the goal of any endowment should be to focus exclusively on returns. The math shown in Tables 1 and 2 does support the skeptics' view that screening negatively affects a portfolio's risk and return, but it also shows that the impact may be far less significant than presumed. It's beyond the scope of this paper to judge whether endowments should implement or avoid screening, but anyone on an endowment board facing that decision should at least do the math, in this case the investment math.

Appendix I: Calculation of Theoretical Return Penalty

We can convert the uncompensated risk to a theoretical return penalty by using a simplified historical risk premium. Based on S&P 500 returns and risk (as a proxy for the U.S. stock market) from January 1926 to June 2011, we find a total market annual return of 9.88 percent versus T-bills over the same period of 3.60 percent for an excess return of 6.29 percent. From the same data set, the S&P 500 has had an annualized standard deviation of 19.14 percent, giving a simplified market Sharpe ratio of 0.33, calculated as follows: Market Sharpe ratio = (–)/ , where is return on market, is risk-free rate, and is the risk of the market as measured by standard deviation. The simplified historical market Sharpe ratio is calculated as follows: (9.88% – 3.60%) / 19.14% = 0.33. The theoretical return penalty in Table 1 is calculated as follows: 0.0005% incremental standard deviation times a Sharpe ratio of 0.33 equals 0.0002%, or two one-hundredths of a basis point in theoretical foregone return. In other words, the impact on return, according to standard portfolio theory, is virtually nonexistent for eliminating the Filthy Fifteen.

Appendix II: Screening Impact of Broader Exclusions

In an earlier version of this paper, published in December 2012, Aperio Group analyzed a broader range of industry exclusions, as listed below.

Oil, Gas & Consumable Fuels
Metals & Mining
Electric Utilities
Independent Power Producers & Energy Traders
Multi-Utilities

To avoid penalizing cleaner companies in those industries, those scored by MSCI's environmental research as receiving 100% of their revenue from environmentally sustainable businesses have been added back and made available. Table 3 shows the naturally higher tracking error resulting from stricter screens.

Table 3: Impact of Tracking Error for Broad Carbon Exclusion

	Standard Deviation	Variance = (Std. Dev.)^2	Theoretical Return Penalty
Market Risk (Russell 3000)	17.9500%	3.2220%	
Tracking Error vs. R3000	0.6900%	0.0048%	
Screened Portfolio	17.9633%	3.2268%	
Incremental Risk	0.0133%		0.0044%

Source: Barra Aegis and Aperio Group. Estimates as of November 30, 2012.

Acknowledgements

Aperio Group would like to acknowledge the help of the following people and their firms for their insights and expertise in the carbon issue and the needs of those seeking to divest their portfolios: Andrew Behar of As You Sow, Dan Apfel of The Responsible Endowment Coalition, Thomas Van Dyck, CIMA from SRI Wealth Management Group of RBC Wealth Management, Craig Muska of Threshold Group, Jeffrey R. Croteau, CFA of Prime, Buchholz & Associates, Inc. and Jamie Henn of 350.org.

Disclosure

The information contained within this presentation was carefully compiled from sources Aperio believes to be reliable, but we cannot guarantee accuracy. We provide this information with the understanding that we are not engaged in rendering legal, accounting, or tax services. In particular, none of the examples should be considered advice tailored to the needs of any specific investor. We recommend that all investors seek out the services of competent professionals in any of the aforementioned areas.

With respect to the description of any investment strategies, simulations, or investment recommendations, we cannot provide any assurances that they will perform as expected and as described in our materials. Past performance is not indicative of future results. Every investment program has the potential for loss as well as gain.

Assumptions underlying simulated back test:

- Based on Barra Aegis multi-factor risk model
- Quarterly rebalancing.
- Exclude stocks from Oil Gas & Consumable Fuels industry as defined by MSCI Barra industry for back test.
- No transaction costs or management fees included.
- Benchmark returns are simulated using underlying holdings to ensure apples-to-apples comparison.

The benchmark for back-test simulation is the Russell 3000 total return index. The simulated portfolios are actively managed, and the structure of the actual portfolios and composites may be at variance to the benchmark index. Index returns reflect reinvestment of dividends but do not reflect fees, brokerage commissions, or other expenses of investing, which can reduce actual returns earned by investors.

Performance results from back tests of particular strategies exclude any trading or management fees that would reduce the return. Furthermore, future returns for any such strategies could be worse than the results shown or the identified benchmark. Back-testing involves simulation of a quantitative investment model by applying all rules, thresholds and strategies to a hypothetical portfolio during a specific market period and measuring the changes in value of the hypothetical portfolio based on the actual market prices of portfolio securities. Investors should be aware of the following: 1) Back-tested performance does not represent actual trading in an account and should not be interpreted as such, 2) back-tested performance does not reflect the impact that material economic and market factors might have had on the manager's decision-making process if the manager were actually managing client's assets, 3) the investment strategy that the back-tested results are based on can be changed at any time in order to reflect better back-tested results, and the strategy can continue to be tested and adjusted until the desired results are achieved, and 4) there is no indication that the back-tested performance would have been achieved by the manager had the program been activated during the periods presented above.

Endnotes

[1] United Nations Environment Programme (UNEP) Finance Initiative and Mercer. 2007. Demystifying Responsible Investment Performance. http://www.unepfi.org/fileadmin/documents/Demystifying_Responsible_Investment_Performance_01.pdf. *

[2] The following companies incorporate the thirteen publicly trade stocks of the Filthy Fifteen:
Arch Coal Inc
Ameren Corp
American Elec Pwr Inc
Alpha Natural Resource
Consol Energy Inc
Dominion Res Inc
Duke Energy Corp
Consolidated Edison
Edison Intl
Firstenergy Corp
Genon Energy Inc
PPL Corp
Southern Co

[3] Based on a survey of Callan Associates, Inc., Mercer Investment Consulting and Watson Wyatt Worldwide. For details see GMO. 2007. White Paper, "What Should You Pay For Alpha?", https://www.gmo.com/NR/rdonlyres/F8E38661-0CD6-49EB-97DF-8D7B6AC32B43/1007/HowMuchPayForAlpha.pdf. *

[4] Based on the Global Industry Classification Standards developed by MSCI and Standard & Poor's.

[5] See the following articles:

Geddes, Patrick. 2012. Measuring the Risk Impact of Social Screening. *Journal of Investment Consulting* 13, no. 1: 45-53.

Jennings, William W., and Gregory W. Martin. 2007. Socially Enhanced Indexing: Applying Enhanced Indexing Techniques to Socially Responsible Investment. *Journal of Investing* 16, no. 2 (summer): 18–31.

Kurtz, Lloyd, and Dan diBartolomeo. 2011. The Long-Term Performance of a Social Investment Universe. *Journal of Investing* (fall): 95–102.

Milevsky, Moshe, Andrew Aziz, Al Goss, Jane Thompson, and David Wheeler. 2006. Cleaning a Passive Index. *Journal of Portfolio Management* 32, no. 3 (spring): 110–118.

** Any link shown above will take you to an external web site. We are not responsible for their content.*

9. San Francisco Employees' Retirement System (SFERS) Retirement Board's Social Investment Policy
http://sfers.org/

CITY AND COUNTY OF SAN FRANCISCO
EMPLOYEES' RETIREMENT SYSTEM
RETIREMENT BOARD POLICY

THE SOCIAL INVESTMENT POLICIES

The Retirement Board adopted the attached list of Social Investment Policies at the Retirement Board Meeting of September 27, 1988. As new policies are developed and adopted, they will be added to this document.

1. Corporate activities of companies whose securities are owned by the System shall be conducted in compliance with all applicable laws and regulations.	Level I	9/27/88
2. <u>Employment Standards</u> Active measures shall be taken to assure that the corporation meets fair employment standards including non-discrimination in hiring, transfer, pay and promotion, decent working facilities and conditions, and the recognition of all legal employee rights of organization and political expression.	Level I	9/27/88
3. <u>Community Relations</u> The relationship of the corporation to the communities in which it operates shall be maintained as a good corporate citizen through observing proper environmental standards, supporting the local economic, social and cultural climate, conducting acquisitions and reorganizations to minimize adverse effects and not discriminate in making loans or writing insurance.	Level I	9/27/88
4. <u>Corporate Governance and Internal Affairs</u> The Bylaws of the corporation shall be maintained to permit full expression of shareholder voting rights in corporate affairs and to prevent entrenchment of management. Executive compensation shall be fair and reasonable. Reports and data shall be made available to shareholders concerning social issues to the extent possible without jeopardizing business interests.	Level I	9/27/88

5.	MacBride Principles The corporation shall affirm and adhere to the MacBride Principles concerning operations in Northern Ireland.	Level I	2/25/92
6.	Tobacco Divestment Due to the existing litigation, proposed legislation and probable governmental restrictions relating to the Tobacco industry, the System will not invest in the equity and fixed income securities of companies manufacturing tobacco products. (See list)	Level III	10/13/98
7.	Sudan Investments The Retirement Board directed staff to engage in constructive dialogue with companies doing business in Sudan because US Congress and the State Department have found the Sudanese Government to be complicit in genocide in Darfur region.	Level II	6/13/06
8.	Sudan Investments The Retirement Board directed staff to inform companies meeting specified criteria of intention to divest. Companies will have 90 days to respond. Managers will be informed of companies meeting specified criteria and be given an opportunity to explain why they cannot achieve their mandate if required to divest. Reference Sudan – Level 3 Procedures dated 12/26/06.	Level III	11/14/06

Key:
- Level I – Shareholder Voting
- Level II – Promoting Social Rights and Interests
- Level III – Investment Restrictions

**South Africa Policy restriction at Level III was repealed on July 14, 1994.

List of Companies Involved I the Production or Wholesale Distribution of Tobacco Products:

US COMPANIES

800 –JR Cigar, Inc.
Advanced Tobacco Products
Amer Group Ltd.
American Filtrona
American Maize-Products Co.
Brooke Group Ltd.
Brown & Williamson Tobacco Corp.
Caribbean Cigar Co.
Consolidated Cigar Holdings Inc.
Dibrell Bros. Inc.
Dimon Inc.
DNAP Holding Corporation
Fortune Brand, Inc.
Future Brands Inc.
Gallaher Group PLC
General Cigar Holdings, Inc.
Holt's Cigar Holdings, Inc.
Lowes Corp
MacAndrews & Forbes Holdings, Inc.
Mafco Consolidated Group
Monk-Austin Inc.
Philip Morris Inc.
Playboy Enterprises, Inc.
Premium Cigars International, Ltd.
RJR Nabisco Holdings Corp.
Standard Commercial Corp
Swisher International Group
Tamboril Cigar Co.
Universal Corp.
UST Inc.