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THE °CLIMATE GROUP

This is part of THE CLEAN REVOLUTION

CLIMATE SCIENCE

PART III: FUTURE CLIMATIC IMPACTS

Insight Briefing | Analyzing the issues that matter to the Clean Revolution

ABOUT

This briefing is the third in a series of non-technical papers on key climate science issues. Along with its companion briefings, it aims to increase awareness of climate science in advance of the publication of the Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC), from September 2013. This briefing looks at future climatic impacts as a result of a warming world. Other briefings in the series cover the 'fundamentals' of climate science, observed climatic impacts, short-lived climate pollutants and the IPCC report production process.

KEY POINTS

- Due to the amount of emissions already released and the inertia in the climate system, warming of between 1.14-1.19°C above the pre-industrial average is almost certain by 2030
- Beyond 2030 the amount of warming depends on the action taken today to reduce emissions
- Current national policies and global emission trajectory put the world on the path to at least 3°C of warming above the pre-industrial average with a possibility of 4°C or more by 2100
- Scientists are concerned that important thresholds in the climate and other natural systems could be reached before or at 2°C of warming (i.e. below the level currently considered 'safe' within the policy and business communities)
- 4°C of warming would have devastating consequences in terms of extreme temperatures, impact on agriculture, biodiversity and human health by 2100
- Uncertainty surrounding climatic and other natural system tipping points adds increased risk and uncertainty to future impacts
- To avoid 2°C or more of warming requires peaking global emissions by or before 2020, followed by rapid rates of reduction of between 3.7-9.0% a year. The earlier the reductions begin the better

INTRODUCTION

The preceding briefings in this series looked at the 'fundamentals' of climate change and the physical impacts that have already been observed as a result of a warming world. But what of the future? For businesses and governments, this is one of the most critical questions as they make policy and investment decisions. Climate science plays a vital role in assisting decision-makers with this challenge. Through the use of climate models, they have access to a range of scenarios (and hence options) based on the actions we take today and over the coming decades.

This briefing provides an overview of possible future impacts. It looks at: the potential temperature increase; the impacts from 2°C and 4°C of warming; possible tipping-points that could result in non-linear changes; and the kind of emission reductions the world needs to take to avoid the worst impacts of climate change.

BOX 1. THE ROLE, IMPORTANCE AND LIMITATIONS OF CLIMATE MODELING

"Prediction…", as the physicist and Nobel Laureate, Nils Bohr remarked, "… is very difficult, especially if it is about the future." This is certainly true of predictions relating to future climate impacts. Not only is the climate system hugely complex and chaotic by nature, but so too is the global political and economic system that determines the extent to which we emit greenhouse gases. Making predictions of future climate change therefore depends not only on understanding how the climate works, but also upon assumptions about actions the world takes (or does not take) to reduce emissions.

That there is uncertainty in the results from the computer models used by climate scientists to 'look' into the future is therefore a given. But this does not make these models or their results invalid. Calibration using 'back- or hind- casting' techniques to replicate past climates provides confidence that models can reasonably forecast future changes given a set of known parameters. And assumptions about growth rates, population changes and energy use are used in economic modeling all the time without fanfare.

In a complex system, however, it is impossible to predict its future trajectory. In economics this is understood and nobody expresses surprise when model predictions are wrong. What matters is the use of the models to establish why this is – because doing so generates more and more insight into the factors that matter (as they are revealed one by one). This in turns gives a better chance of defining the limits of future possibilities, helping to inform decision making in the face of irreducible uncertainty.

Modeled climate predictions may not be perfect, but in an imperfect world they provide the best – and indeed only – tool for looking into and planning for what will invariably be a warmer future.

FUTURE TEMPERATURE INCREASE

Future climate change and its impacts will depend upon the level of temperature increase that ultimately occurs over the coming decades and centuries. A certain amount of warming is already unavoidable due to the amount of GHGs already released into the atmosphere and the inertia of the climate system. Scientists estimate that a further 0.34-0.39°C of warming will occur by 2030 even if emissions were reduced to zero today. This would bring total temperature increase by 2030 to between 1.14-1.19°C above the pre-industrial mean.[1]

Beyond 2030, the temperature increase depends on the emission trajectory from today. Scenario modeling used in the IPCC's 2007 Assessment Report suggested a broad range from 1.1-6.4°C by 2100 depending on the rate of economic growth, climate sensitivity of the atmosphere and a range of other socio-economic assumptions.[2] More recent modeling (which has been used for the 5th Assessment Report) indicates a 1.3-6.1°C range, with the lower estimates dependent on aggressive emission reductions.[3] Based on current mitigation policies, plus pledges made since the Copenhagen Climate Conference in 2009, scientists estimate that the world is currently on track to well over 3°C of warming by 2100, with a 20% chance of exceeding 4°C.[4,5] Figure 1 below illustrates a selection of possible temperature pathways.

[1] Australian Climate Commission. The Critical Decade. http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf. Accessed 5 June 2013.

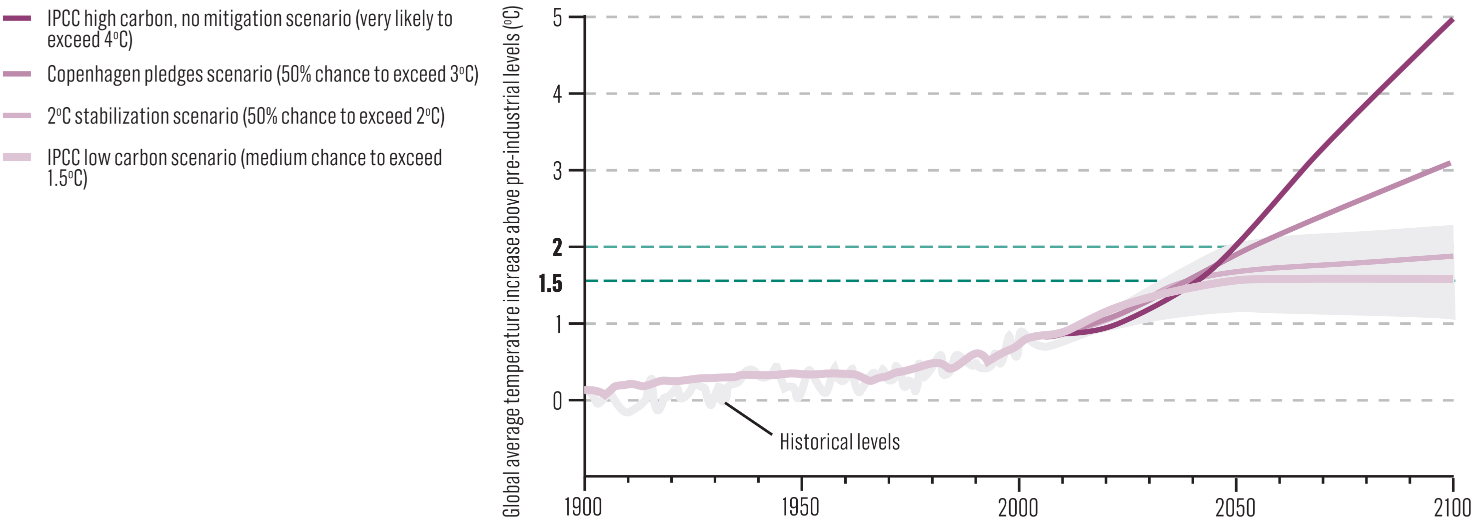
[2] IPCC Fourth Assessment Report. Synthesis Report. http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains3-2-1.html

[3] Australian Climate Commission. The Critical Decade. http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf. Accessed 5 June 2013.

[4] Some scientists consider that even this trajectory might be optimistic, especially if it fails to take account of new emissions sources in the short to medium term such as fugitive shale gas emissions or the exploitation of other new fossil fuel reserves. (Personal communication, K. Anderson, Tyndall Centre)

[5] Potsdam Institute for Climate Impact Research and Climate Analytics. 'Turn down the Heat' http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf. Accessed 11 July 2013.

FIGURE 1 Global temperature scenarios



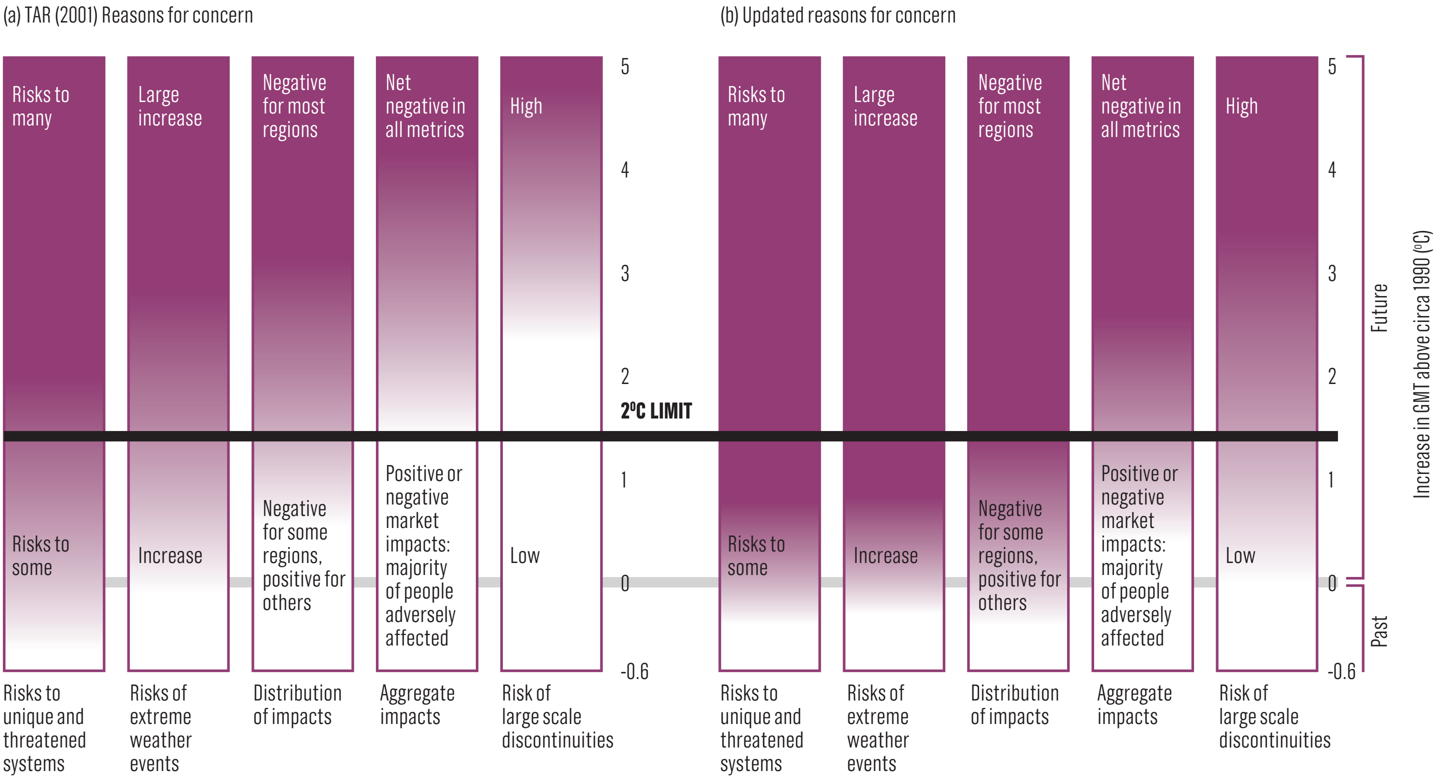
Source: http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf.

NB: gray shaded area indicates possible temperature range for the 1.5-2°C scenarios.

WHY KEEPING BELOW 2°C MATTERS

While it is self-evident that the greater the degree of warming the more serious the likely climatic impacts will be, the precise temperature at which 'dangerous climate change' will occur is uncertain. The oft-quoted 2°C benchmark for maximum 'safe warming' owes more to politics and value judgements about what constitutes dangerous climate change, than it does to science. Research in recent years points to important thresholds, across a variety of natural systems, being crossed below the 2°C mark. The 'burning embers' diagram below, originally published in the IPCC's 2001 Assessment Report and updated in 2009, highlights how the assessment of risk has changed over the last ten years. This shift suggests a need to re-evaluate the appropriateness of the 2°C target as a key reference point for policymaking and business decisions.

FIGURE 2 Risks from climate change in a 2°C world



Source: http://www.pnas.org/content/early/2009/02/25/0812355106

NB: increased intensity of shading indicates greater reason for concern.

POSSIBLE IMPACTS BASED ON CURRENT TRAJECTORY OF 4ºC

A review of climate modeling predictions conducted for the World Bank in 2012 identified a range of possible impacts arising from 4ºC of warming by 2100.[6] It is important to emphasize that while this level of warming is not inevitable, it is still possible based on current policy settings and mitigation targets. Table 1 on the next page highlights some of the projected impacts covered in the World Bank report.

TABLE 1 Potential project impacts in a 4ºC world

	EXAMPLES OF POTENTIAL IMPACTS IN A 4ºC WORLD[7]
EXTREME TEMPERATURES	– Once-in-several hundred year temperatures expected to become the norm by 2100 over most continental areas – Every second European summer expected to be as hot as record breaking 2003 summer (which killed over 70,000)[8] – In the tropics, unusually cold months in 2100 expected to be warmer than record warm months experienced today
SEA-LEVEL RISE	– 0.47-0.96 meters on average but possibly up to 1.2 meters with several more meters committed to in following century
OCEAN ACIDIFICATION	– Up to 150% more acidic at an atmospheric CO_2 concentration of 800 parts per million (ppm) (equivalent to 4ºC) NB: Coral reefs begin to dissolve above 550 ppm
PRECIPITATION	– Intensification of the water cycle: drier regions become drier (Australia, Sahel, Mediterranean); wetter regions become wetter (large parts of Northern Hemisphere, South and South East Asia, Antarctic) – Most extreme droughts predicted over the Amazon, western US, the Mediterranean, southern Africa and southern Australia
TROPICAL CYCLONES	– Increased intensity of storms likely, but uncertainty remains over increase in frequency
AGRICULTURE	– Potential reduction in yields of wheat, corn and soybean of 25%, 34% and 30% respectively at 3.2ºC of warming (and with no adaptation e.g. cultivar changes) – Total drought disaster affected area predicted to increase from 15.4% to 44% +/- 6% (i.e. amount of global crop area affected by drought at any one time)
WATER RESOURCES	– Danube, Mississippi, Amazon rivers predicted to see mean annual runoff decrease by 60%, 40% and 80% respectively above 4ºC
ECOSYSTEMS AND BIODIVERSITY	– Risk of tipping point for tropical rainforests above 3.5ºC, changing to biologically less diverse savannah – 75% reduction in rainforest possible – Poleward shifts of ecosystems of up to 400 kilometers (and extinction for those that can't) – Loss of species currently identified as 'critically endangered' would lead to mass extinction on a scale that has only happened five times in the past 540 million years
HUMAN HEALTH	– 60-165,000 extra heat related deaths in Europe (without adaptation) but also 60-250,000 fewer cold-related deaths – 5.2 billion people at risk of malaria in 2050 (assuming no adaptation) as habitat of malaria-bearing mosquito increases

[6] Ibid

[7] NB: Some of these impacts are taken from individual modeling studies, rather than a range of studies which would provide a greater level of confidence.

[8] Robine et al. Death toll exceeded 70,000 in Europe during the summer of 2003. http://www.sciencedirect.com/science/article/pii/S1631069107003770. Accessed 19 July 2013.

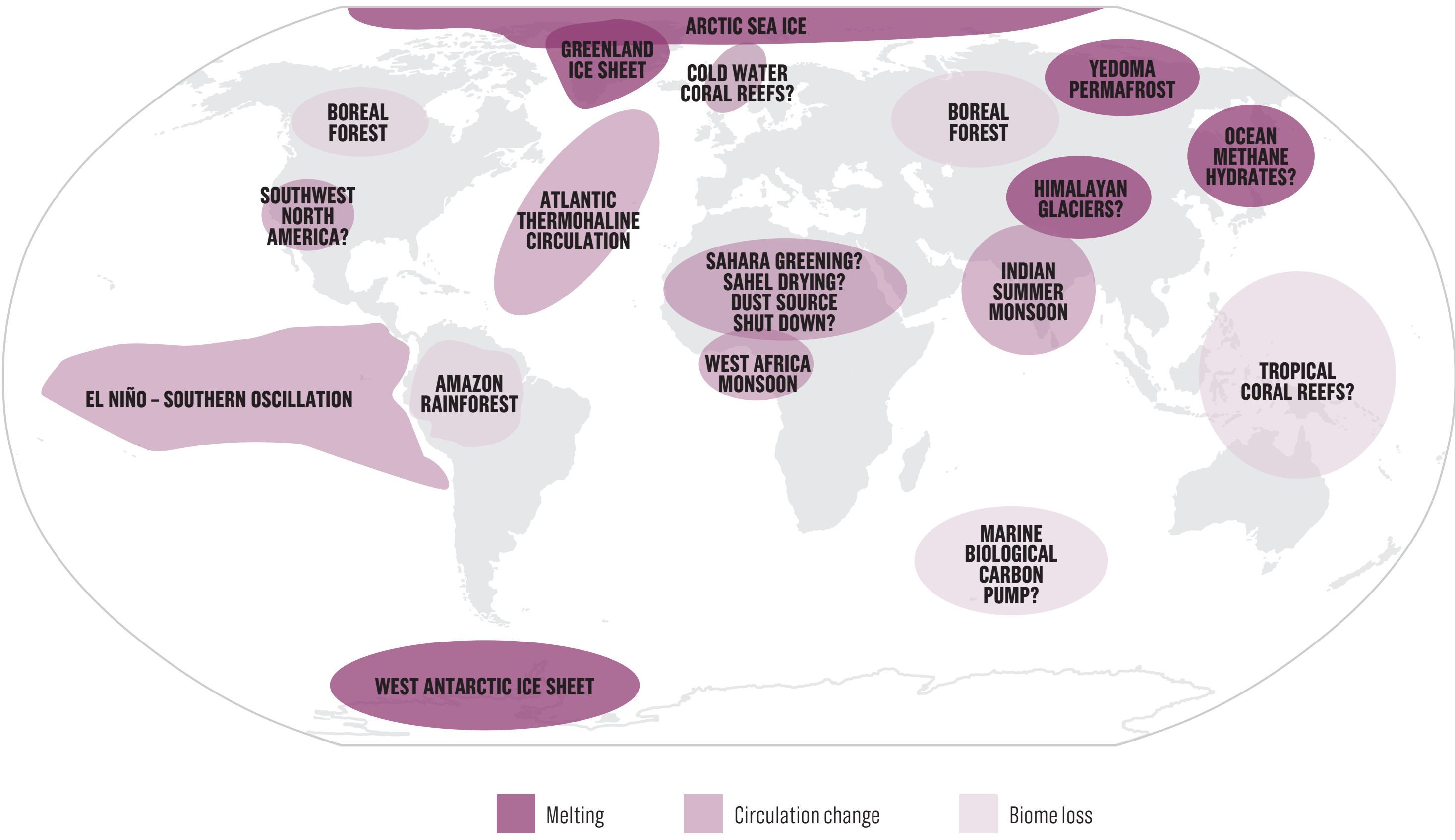
TIPPING-POINTS

A key uncertainty surrounding future climate impacts is the effect of tipping points in the climate system. These potentially abrupt changes are known to occur in natural systems and can create both positive and negative feedback mechanisms that amplify the direction of change. In a warming world, most feedbacks are positive, accelerating the warming trend. Worryingly, according to research undertaken for the World Bank, few climate models take account of tipping-points in their projections.[9]

Examples of known potential tipping-points include the melting of Arctic permafrost, which could release large amounts of additional climate-warming methane. A slowdown in the Atlantic Thermohaline Circulation due to changes in ocean temperature is another example. Somewhat counter-intuitively, this tipping point could lead to lower temperatures in Europe as less warm water is brought up from the tropics by this ocean heat conveyor. Although this cooling could offset temperature rises, it would also bring its own complications, such as disrupting agricultural production.

Tipping-points are often irreversible once triggered. It is estimated for example, that once the loss of ice lowers the height of the Greenland ice sheet to a certain level, complete melting is virtually certain. This is because at lower altitudes, less freezing takes place and precipitation begins to fall as rain rather than snow, thereby inexorably accelerating the melting process.[10] Complete ice loss would occur over centuries. Figure 3 below indicates some of the potential tipping-points around the world, identified by scientists.

FIGURE 3 Potential climate and natural system tipping-points in a warming world



NB: Question marks indicate systems whose status as policy-relevant tipping elements is particularly uncertain.

Source: http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf

[9]Potsdam Institute for Climate Impact Research and Climate Analytics. 'Turn down the Heat' http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf. Accessed 11 July 2013.

[10]Australian Climate Commission. The Critical Decade. http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf. Accessed 5 June 2013.

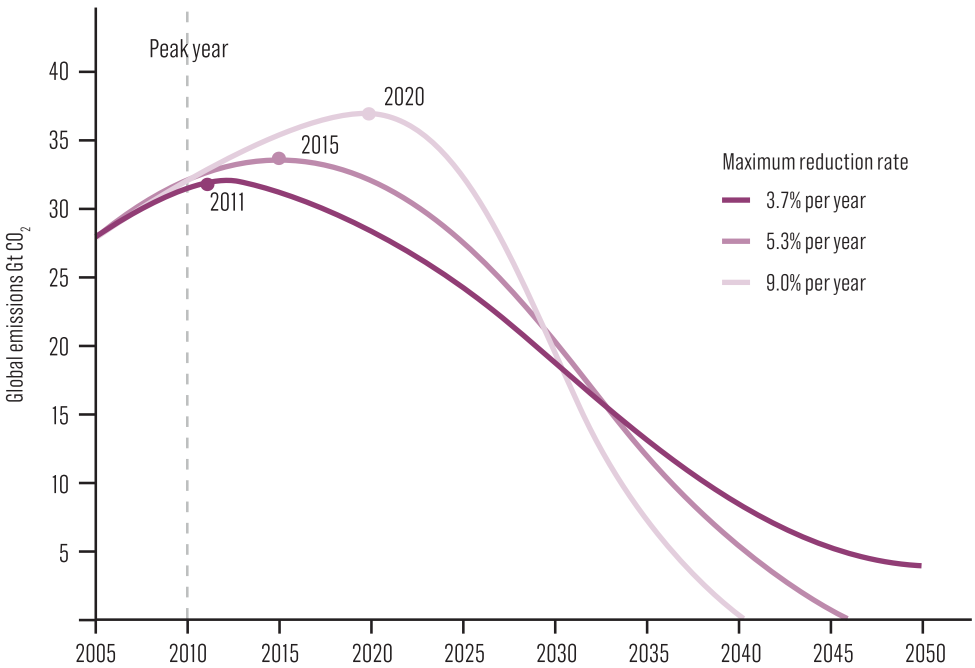
WHAT AVOIDING 2ºC WARMING MEANS IN PRACTICE

Given the observed changes seen already in the climate system with just 0.8ºC of warming above the pre-industrial average, and with models suggesting major impacts before a 2ºC increase is reached, it is clear that ambitious emission reductions are required in the coming decades. But what exactly does this mean in practice?

Based on climate modeling, scientists calculate that for a 75% chance of limiting warming to 2ºC no more than 1,000 billion tons of CO_2 can be released between 2000 and 2050.[11] Annual global CO_2 emissions in 2012 were approximately 35 billion tons and since 2000, the cumulative total is around 391 billion tons.[12] This means that in 13 years the world has burned through around 39% of its carbon budget to 2050.

Keeping within the budget over the next 35 years will be easier if global emissions peak before 2020, but even then the annual rate of reduction will be very challenging. Peaking in 2020 or later will require 9% or greater annual rate of emission reduction, which may be impossible to achieve from a political and even technological perspective.[13] Also, the later emissions peak, the more ambitious and earlier the final reduction needs to be. Figure 4 below summarizes potential reduction pathways for limiting warming to 2ºC.

FIGURE 4 Emission trajectory reduction pathways for a 2ºC world



Source: http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf

[11]Maltehausen M, et al. 'Greenhouse gas emission targets for limiting global warming to 2ºC'. http://www.nature.com/nature/journal/v458/n7242/full/nature08017.html. Accessed July 12 2013.

[12]Australian Climate Commission. 'The Critical Decade'. http://climatecommission.gov.au/wp-content/uploads/The-Critical-Decade-2013_Website.pdf. Accessed June 5 2013

[13]Anderson K., Bows, A. 'Beyond dangerous climate change: emission scenarios for a new world'. http://rsta.royalsocietypublishing.org/content/369/1934/20.full.pdf+html . Accessed July 16 2013.

CONCLUSION

The results from today's climate models provide us with a clear choice. Even if these predictions come with a degree of uncertainty, the magnitude of potential change, even at the lower range of temperature increase, demands prudent action. Were these potential impacts caused instead by health or security threats, global political and business action would almost certainly be swift; a damning indictment of the low priority decision-makers still give to climate change. As negotiators work towards a new global climate treaty by 2015, and as governments and businesses implement new climate policies and clean energy technologies, the evidence from climate science research needs to form the basis of smart, future-proofing decision making.

FURTHER READING

IN THIS SERIES OF CLIMATE SCIENCE BRIEFINGS:

Part I: The fundamentals

Part II: Observed climatic impacts

Part IV: The IPCC and its work

Part V: Short-lived climate pollutants (available from September 2013)

(Freely available to The Climate Group partners and otherwise on request – see contact details below.)

USEFUL AND AUTHORITATIVE SOURCES ON THE WEB INCLUDE:

Skeptical Science http://skepticalscience.com

A very accessible source of information and explanations on climate science issues for non-experts

Real Climate http://www.realclimate.org

In-depth, technical information and discussion on climate science from climate scientists

Met Office (UK) http://www.metoffice.gov.uk/climate-change

The UK's leading public institution engaged in climate change research and communication

NOAA http://www.noaa.gov/climate.html

One of the key US government agencies engaged in climate science research, especially with respect to the ocean

NASA http://climate.nasa.gov

One of the key US government agencies engaged in climate science research, especially with respect to satellite observation

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