Carbon budget science

Dr Frank McGovern

21st October 2019

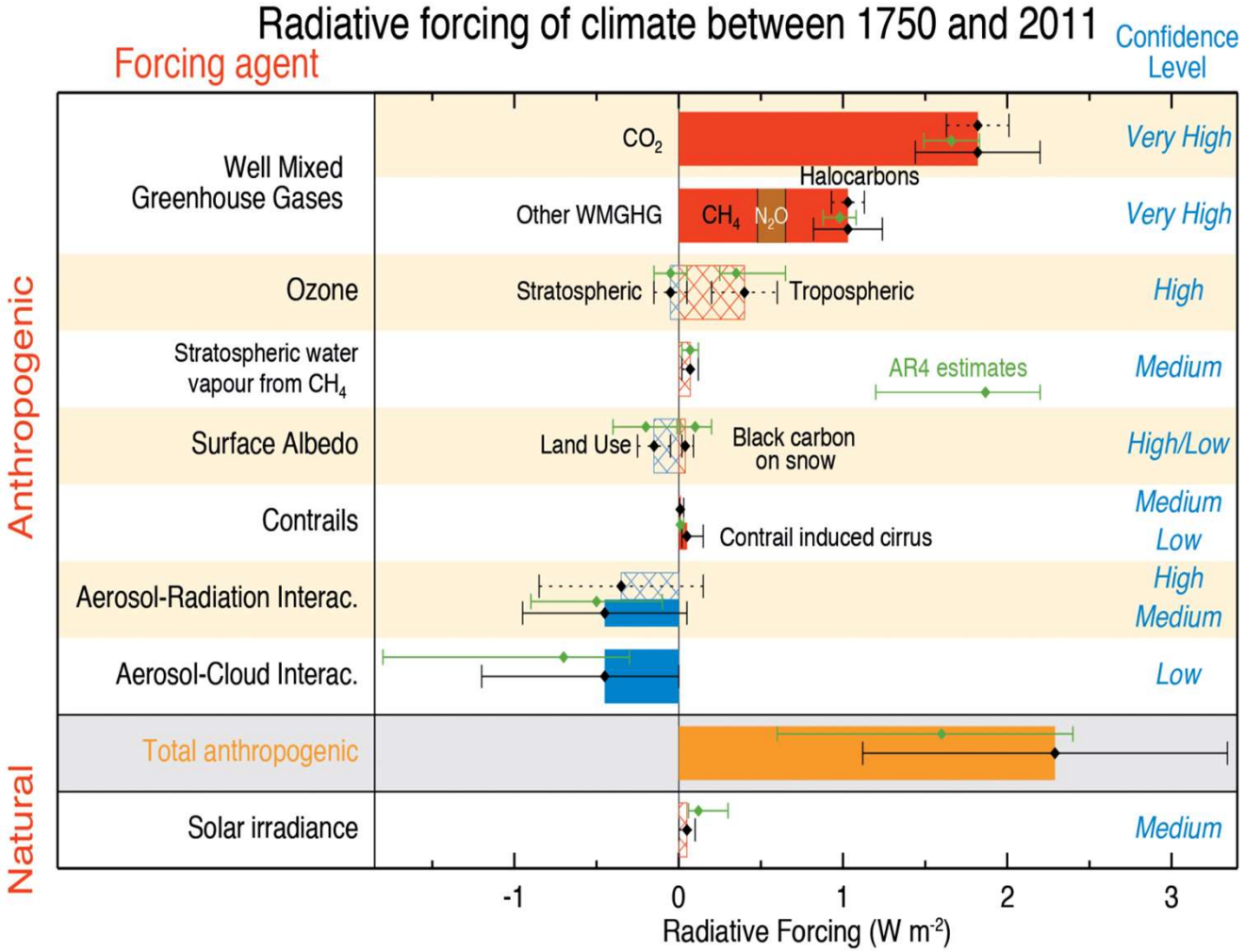
Contents

1. Introduction
2. Energy imbalance
3. Carbon budgets and their implications
4. Concluding points

Introduction

- The Earth's energy balance has remained relatively stable for millennia
- This balance is regulated by the atmosphere; the basic science of this has been understood for more than a century and a half
- Greenhouse Gases (GHGs) play a key role in determining the Earth's energy balance
- Since the industrial revolution this balance has been increasingly altered due to the build up of additional GHGs in the atmosphere

Energy imbalance – radiative forcing



The energy imbalance is **2.29 W m^{-2}** which adds up to more than **6.0 Zeta Joules** annually
Zeta = 10^{21} the oceans are taking up more than 90% of this energy.

Carbon budgets

Carbon dioxide is the main driver of current and future climate change

The German Advisory Council 2009 promoted a carbon budget approach

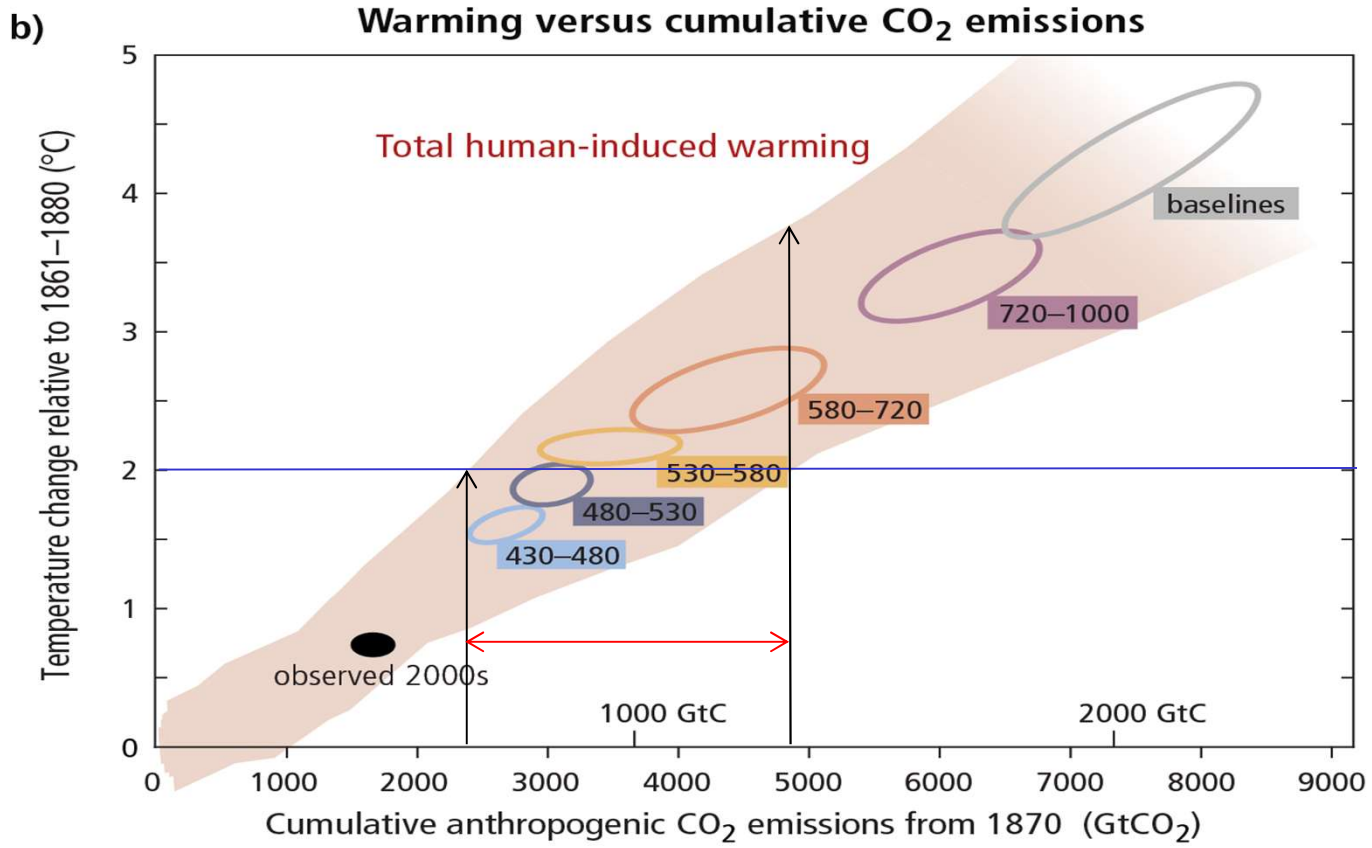
change. CO_2 from anthropogenic sources must, however, play a key role in all considerations regarding climate protection due to the large amounts released and the extensive length of time it is retained in the environment (up to thousands of years). Conse-

IPCC Report, 2013

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond (see Figure SPM.10). Most aspects of climate change will persist for many centuries even if emissions of CO_2 are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO_2. {12.5}

- A large fraction of anthropogenic climate change resulting from CO_2 emissions is irreversible on a multi-century to millennial time scale, except in the case of a large net removal of CO_2 from the atmosphere over a sustained period. Surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of net anthropogenic CO_2 emissions. Due to the long time scales of heat transfer from the ocean surface to depth, ocean warming will continue for centuries. Depending on the scenario, about 15 to 40% of emitted CO_2 will remain in the atmosphere longer than 1,000 years. {Box 6.1, 12.4, 12.5}

A Carbon budget for warming of 2˚C



Scientific uncertainty means we have a budget range rather than one number

Implications of a carbon budget

UNFCCC review of the adequacy of the long term global goal (2015).

limited. There is an approximately linear relationship between cumulative total anthropogenic CO_2 emissions and the global average temperature rise. Therefore, limiting global warming implies a maximum amount of cumulative CO_2 emissions. This means that **halting the global average temperature rise at any level will require net zero global CO_2 emissions** at some point in the future.[28] Furthermore, because of the cumulative budget constraint, higher global emissions in the near term would require lower global emissions in the long term, and, in case of overshooting, the use of CO_2 removal technologies.[29]

decline in the near future for a range of scenarios and warming limits. **CO_2 removal technologies** are needed to compensate for past GHG emissions overshooting the target and, more importantly in the second half of the century, also for emissions that cannot be reduced to zero (e.g. non-CO_2 emissions from agriculture). Although reducing non-CO_2 emissions can be an important element of mitigation strategies, the temperature change is mainly determined by the cumulative budget of CO_2 emissions, and CO_2 emissions drive long-term warming.[36]

temporary concentration overshoot. They warned that simple calculations of the remaining number of years of emitting at current levels while limiting warming to below 2 °C or 1.5 °C based on the cumulative budget, without considering the possibility of achieving negative emissions, may make achievement of the temperature limit appear too challenging.[37] While noting the difficulty of quantifying changes in land and ocean sinks

IPCC Special Report on warming of 1.5°C, 2018

- Confirmed that limiting global warming requires staying within a total carbon budget

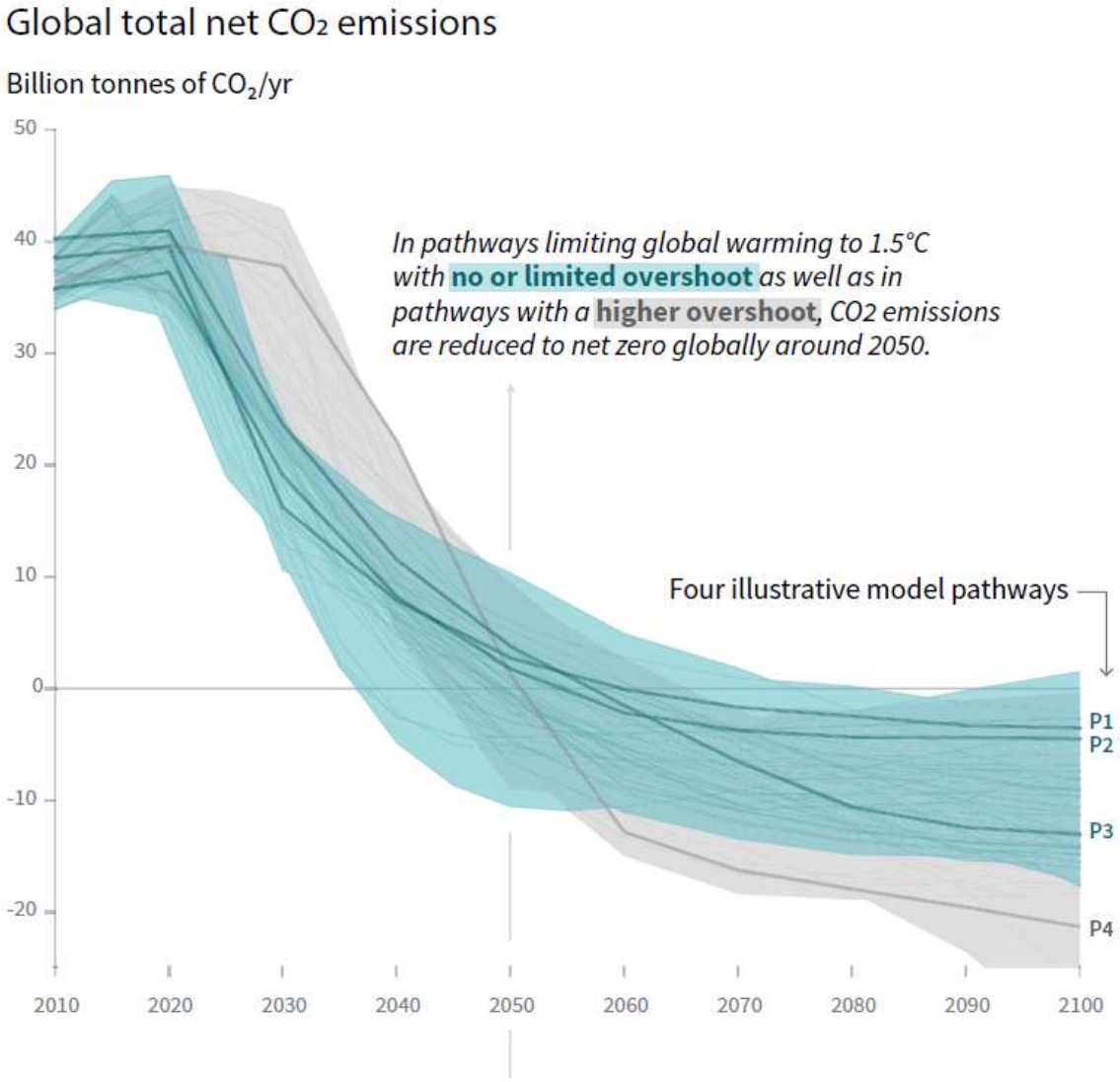
- To limit warming to below 2°C, global CO_2 emissions are reduced by about 20% from 2010 levels by 2030, **reaching net-zero around 2075 (2065–2080)**

- To limit warming to 1.5°C, global CO_2 emissions are reduced by about 45% from 2010 levels by 2030, **reaching net-zero around 2050 (2045–2055)**

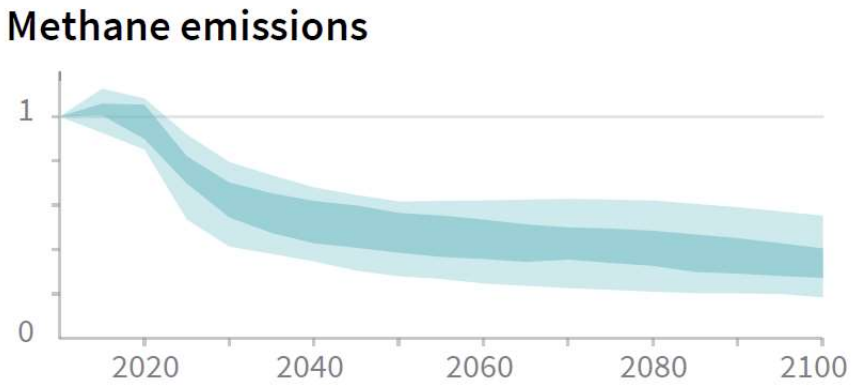
- Emissions of non-CO_2 GHGs are also reduced but do not reach zero, the reductions are similar for 1.5°C and 2°C pathways

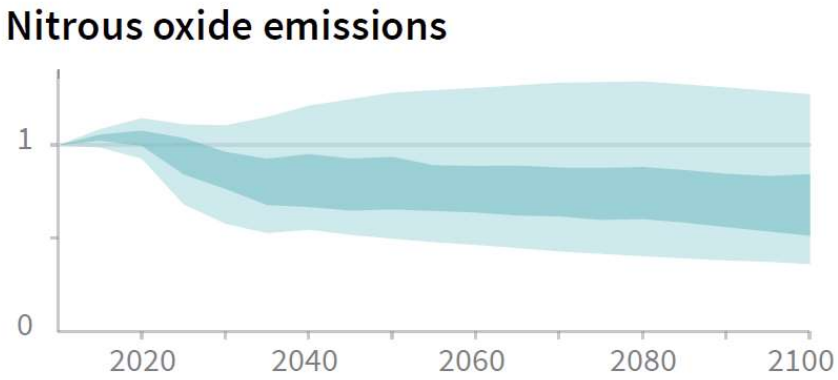
- Carbon dioxide removal technologies (CDR) are needed to offset any overshoot in CO_2 emissions and to offset the emissions of non-CO_2 GHGs

Carbon dioxide pathways relative to 2010 to limit warming to 1.5°C



Global pathways; non-CO_2 emissions relative to 2010





.

These are similar for 1.5 and 2°C pathways

Concluding points

- Accumulated carbon dioxide emissions will largely determine the long term global temperature increase
- Carbon budgets should inform planning for effective actions on climate change, including framing; short, medium, and longer term emissions pathways to reach net-zero CO_2 emissions
- Planned and timely deployment of decarbonisation technologies can reduce future reliance on carbon dioxide removals
- However planning for large scale and sustained removals of atmospheric carbon dioxide should be initiated

A carbon budget?

- How much would the Earth warm by if the atmospheric concentration of carbon dioxide was doubled? "Climate sensitivity"
- A fundamental calculation in climate science and central to estimations of the global "carbon budget".
- The IPCC considers that the "climate sensitivity" is likely to be between 1.5° and 4.5°C i.e. doubling of the CO_2 concentration could warm the world by at least 1.5° and possibly by 4.5°C.
- **Scientific uncertainty means we have a budget range rather than one number**.