Tyndall°Centre
for Climate Change Research

University of East Anglia

Briefing Note

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The implications of global warming of 1.5°C and 2°C

This Briefing Note summarises research examining the implications of global warming of 1.5°C and 2°C funded by (i) the UK department for Business, Energy and Industrial Strategy (BEIS) undertaken by researchers at the Tyndall Centre, and (ii) the Natural Environment Research Council (NERC) and conducted by researchers at other universities.

Context

Global carbon emissions from fossil fuel burning, which reached an all-time high in 2017 after being nearly constant during 2014-2016, need to peak imminently and decline rapidly to have any possibility of achieving the Paris commitment of limiting warming to well below 2°C;

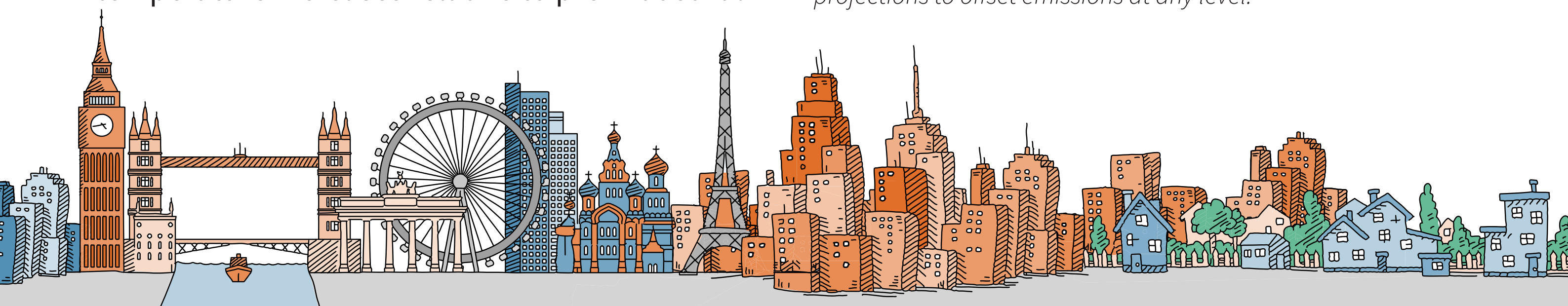
The current pledges under the Paris agreement are insufficient to limit global mean temperature increases relative to pre-industrial levels to well below 2°C. Instead global mean surface temperatures will probably increase by around 3°C, or more, and 1.5°C will likely be exceeded in the decade of the 2030s and 2°C in the 2060s;

Global emissions from CO_2 and other GHGs need to decrease to approximately zero to stop warming at any level. Zero emissions from energy use can be achieved in principle, but because of expected residual emissions of CO_2 from some sectors (e.g. aviation, some industry), from non-energy use, from other GHGs related to agricultural processes, removal of CO_2 from the atmosphere (here called 'negative emissions'[1]), e.g. through reforestation or Biomass Energy with Carbon Capture and Storage (BECCS), will be necessary to stabilize any temperature rise.

Cumulative Carbon Emissions

The cumulative CO_2 emissions allowed post 2017 to achieve the 1.5°C and 2°C goals,

1 Negative emission technologies are also used in model projections to offset emissions at any level.



because these temperature goals are so near in the future, are dominated by uncertainties, ranging from about 100 to 800 $GtCO_2$, and about 800 to 1700 $GtCO_2$, respectively. These results are mostly higher than those reported in 5th Assessment report of the IPCC[2] , but they include a limited number of studies only. The IPCC special report on 1.5°C published in October 2018 has provided an updated assessment.

Estimates of the allowable amounts of cumulative carbon to achieve climate goals are dependent upon: the probability (e.g., 50% versus 66%) of limiting climate change below a specified temperature; the future evolution of non-CO_2 emissions (especially methane and aerosols); the magnitude of the carbon feedbacks through carbon released from natural wetlands and permafrost thaw; the uptake of CO_2 by the oceans; and the details of the calculations regarding the level of present-day warming.

Peak emissions and rates of emissions reductions

Rates of CO_2 emissions reductions needed to meet the Paris climate commitments are stringent in all reported publications, but the exact amplitude varies because the rate is highly dependent on: (i) the cumulative CO_2 emissions allowed; (ii) whether the model assumes an overshoot of the temperature goal followed by negative emissions to bring temperatures back down; and (iii) whether the model assumes emissions reductions start immediately or whether the emissions follow the NDCs[3] until 2030.

Similarly, it is urgent that global emissions peak soon to meet any scenarios consistent with the Paris temperature goals. The vast majority of published scenarios that meet the 1.5°C goal have peak emissions in the coming decade, even when considering overshoot followed by large-scale negative emissions. All scenarios have a trade-off between the time of peak emissions and the amount of BECCS deployed, whereby an earlier peak reduces the need for BECCS and other negative emissions technologies and vice versa.

Scenarios using the IMAGE integrated assessment model project annual rates of change in global CO_2 emissions in the 2020s of around -4.0%, and -2.5%, to achieve the 1.5°C and 2°C goals with a 66% probability respectively, assuming CCS is deployed at scale from 2020 and BECCS from 2030. Excluding BECCS and other negative emissions technologies, the emission reduction rate for the 2°C goal was found to be slightly above 3% in the 2020s. Faster required rates of -5.4% and -2.7% to achieve the 1.5°C and 2°C goals, respectively, were found using a simpler model with no CCS. As these rates are global, faster rates need to occur in industrial countries to offset some growth associated with development elsewhere.

In the past decade, eighteen countries including the UK have decreased their emissions but the average rates of -2.6% per year still fall short of the rapid rates needed to achieve the Paris temperature goals.

The date to reach net zero emissions[4]

The factors that influence the rates of emissions reductions also influence the date to reach net zero emissions.

Net zero global CO_2 emissions were reached around 2050 and 2075 respectively, in the IMAGE scenarios that achieve the 1.5°C and 2°C goals with a 66% probability, allowing for overshoot and use of BECCS. A separate analysis with emissions following the NDCs until 2030 found comparable results, with requirements to reach net zero around 2045 and in the 2080s for the 1.5°C and 2°C goals, respectively. Note that the date to reach net zero for all greenhouse gases was not analysed here.

If BECCS and other negative emissions technologies prove not to be technically, environmentally, socially or economically viable at the scales assumed in the models, with only reforestation and afforestation removing carbon from the atmosphere, emissions need to decrease to levels near zero more rapidly,

2 IPCC 5th Assessment Synthesis Report http://www.ipcc.ch/report/ar5/syr/

3 The Nationally Determined Contributions (NDCs) are the pledges submitted to the UNFCCC under the Paris Agreement. Their mitigation goals mostly refer to year 2030.

4 The term 'net' zero emissions refers to the sum of positive emissions plus removals. It can thus be achieved by reducing positive emissions to zero, or offsetting positive emissions by the active removal of GHG from the atmosphere.

although small levels of above-zero emissions can remain during the full century.

The date for the UK to reach net zero CO_2 emissions was examined in one study using a simple model initialised from current emissions. When assuming the global cumulative emissions are shared based on equal per-capita emissions and BECCS is deployed at scale in the UK, but not including equity measures for past responsibility, the year of net zero in the UK was similar to or slightly earlier than that for the world. This result is particularly sensitive to a range of choices, including to various measures of equity, and needs to be examined further.

Biomass energy with carbon capture and storage (BECCS)

Most projections that keep warming well below 2°C rely heavily on the use of BECCS at large-scale to produce negative emissions.

However, there are critical uncertainties associated with the technical, economic and environmental feasibility of BECCS. For example:

- ▹ this technique has not been demonstrated at the scale required and has received to date little financial and political support;
- ▹ the required rate of deployment is extremely ambitious in many scenarios, exceeding in places the historical rates for market uptake of fossil, renewable and nuclear technologies, and is entirely dependent on incentives;
- ▹ its environmental and ecological sustainability, and therefore effectiveness, is questioned, in part because two-thirds of the bioenergy crops are projected to be grown in regions with weaker sustainability governance; and
- ▹ if BECCS involves replacing high-carbon content systems (e.g. boreal forests) with crops, then afforestation and avoided deforestation are often more efficient for atmospheric CO_2 removal than BECCS.

The significant issues raised on the plausibility of large-scale deployment of BECCS need to be urgently addressed through a combination of finance, deployment, and research. Governments should be very cautious on relying on this technology to meet the Paris commitments until large scale deployment is set in motion. In the meantime, increased emphasis on an immediate and rapid transition to a low-carbon economy is needed, in both the production and use of energy, as well as aggressive mitigation of all sources of CO_2 and other GHG emissions from all sectors.

Mitigation technologies and options

Within most models, energy demand is poorly characterized compared with energy supply. Consequently, highly ambitious decarbonisation of energy supply is considered in detail, whilst opportunities for more aggressive reductions in energy demand are seldom included in future projections therefore providing additional mitigation opportunities beyond those that are currently captured.

While the energy transformations to achieve zero emissions are possible in some sectors (e.g. buildings), zero emissions are currently thought to be unobtainable with foreseeable technologies in a small number of critical sectors, including shipping, aviation and some industrial activities (e.g. production of chemicals). Potential for emission reductions from energy demand could be explored further.

Achieving transformations in energy systems will require societal and behavioural changes, with the following overarching issues and opportunities being identified globally:

- ▹ Given public opposition to certain low-carbon strategies (e.g. reduced indoor heating), it is critical to increase public participation (e.g. via deliberative focus groups) in mitigation policy-making and implementation, capitalizing upon public support for sustainable energy sources and efficiency measures;
- ▹ Renewables are preferred as sources of energy, with nuclear and fossil fuels garnering the least support. Opposition to large-scale energy infrastructure often stems from perceived risks and poor community engagement. Householder adoption of solar PVs is driven primarily by financial considerations as well as a desire to be environmentally-friendly. Biomass energy is comparatively under-researched, with most

concerns related to sustainability. There is low public awareness of Carbon Capture and Storage (CCS), with mixed views about its benefits and risks amongst those who do know about it.

▹ In principle the public are positive about energy efficiency measures, but barriers exist to the adoption of measures (e.g. initial cost, habit). Demand-side reduction through restrictions on energy services are often resisted by individuals. Overall, there is more public support for 'pull measures', e.g., public transport, than 'push measures', e.g., increased taxes/tolls which may restrict individual freedom. Behaviour change interventions have achieved energy savings of 5-10%.

▹ There is potential to reduce emissions through disruptive innovations offering goods and services with novel attributes to consumers, e.g., car-sharing, mobility-as-a-service, electric vehicle integration with electricity grids, internet-enabled appliances, digitally-enabled food waste reduction schemes, modular urban farming and smart infrastructure. These reductions are not typically included in model projections. Scaling up evidence from early-adopter groups to the UK population as a whole suggests additional emission reduction potentials of up to 10% across food, mobility and buildings.

Policies

According to results based on the E3ME macro-economic model, policy measures needed to limit warming to 1.5°C are largely based on scaling-up existing and proposed measures, bringing forward time scales of implementation and coordinated global actions, and tackling all sectors of the economy. This includes ambitious levels of action through taxes, subsidies, efficiency incentives and direct regulations. While substantial near-term green growth GDP and total employment gains are possible in fossil fuel importing countries, in exporting countries there are generally negative impacts on GDP and employment. Non-action and delayed action by individual countries and groups of countries have a negative economic effect in the near-term on the country avoiding action, because of increased dependence on energy imports, stranding of fossil-fuel assets and missing the benefits of investment in low-carbon technologies.

Impacts and risks on human-related and ecological systems

For most sectors and ecological systems, the impacts of climate change are reduced significantly by reducing warming from 3.7°C[5] to 2°C, and the impacts are statistically lower at 1.5°C than at 2°C.

Losses in 2100 relative to the observed 1961-1990 climate for temperature changes of 3.7°C, 2°C and 1.5°C are projected to be (i) 13%, 5.1% and 3.7%, for crop yields; (ii) 550, 69, and 54 trillion $ for net present value (NPV); (iii) 146.0, 40.6, and 22 millions of people affected by 100-year fluvial flooding events; and (iv) 2870.7, 1316.3, and 969.5 millions of people at risk from drought in any given month;

Considering climate change alone, limiting global warming to 1.5°C above pre-industrial levels avoids half the risks associated with warming of 2°C for plants, animals, and two thirds of the risks to insects in terms of climate change induced range loss, and areas which benefit the most in terms of avoiding declines in species richness are Southern Africa, Southern Europe and Australia.

Temperature overshoot can have significant negative effects on ecosystems if they persist long enough that rapidly-dispersing species can over-adapt to new conditions, and then need to retreat. Temperature changes are projected to lead to extreme risks to population health affecting the ability to perform essential activities of daily living such as physical work, across many tropical and sub-tropical regions in response to future global warming of 1.5°C, and become widespread in these regions around global warming of 2.5°C to 3°C. The exact population exposed depends on the specific choice of thresholds, but conservative estimates are in the tens of millions, while top-end estimates are in the billions of people.

Projected changes in sea level in the 1.5°C and 2°C scenarios are lower in 2100 by 20-30 cm, and

5 A reference scenario with no climate policy beyond the Cancun pledges.

substantially lower in 2300 by 2-3m compared to a scenario that exceeds 4°C. Even under climate stabilization, sea level rise continues over multiple centuries. Millions of people are projected to be displaced under all scenarios without additional adaptation measures.

Projected levels of ocean acidification for the 1.5°C and 2°C scenarios in 2100 are of about 10% and 30% higher acidity respectively, compared to the average level between 1986 and 2005. These levels mean waters become increasingly corrosive to carbonate shells, with the worst effects to occur in winter at high latitudes of both poles. Global mean ocean acidification stabilizes within a century under both scenarios.

Full report available at:

Robert T. Watson and Corinne Le Quéré (2018) ***The Implications of global warming of 1.5ºC and 2ºC Summary Report,*** Tyndall Centre Working Paper 164, Tyndall Centre for Climate Change Research, University of East Anglia

This report contains research material that is not yet published and may be under embargo. Therefore please do not share the report, and direct any requests to **Asher Minns** at the Tyndall Centre at a.minns@uea.ac.uk.

www.tyndall.ac.uk/afterparis/summaryreport

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