COMMENTARY:

Delays in US mitigation could rule out Paris targets

Benjamin M. Sanderson and Reto Knutti

Political upsets could stall coordinated international mitigation action, but emissions and investments over the next few years will have long-term consequences. Any delays to mitigation or cuts to renewable energy research by the US will likely render the 2 °C target unachievable if a global precedent is set.

On 4 November 2016 the Paris Agreement entered into force: the first global plan to limit climate change, a milestone after more than twenty years of difficult international negotiations. Days later the Republican candidate Donald Trump, who has stated that he would pull out of the Paris Agreement, was elected as the next US president. Much has been speculated about the future of the Paris Agreement since then, but quantitative analyses of the consequences of plausible scenarios in light of the election are worth considering. A naive assessment of a brief delay in US climate mitigation could conclude that the world would just reach its climate targets a few years later. This idea that 'if we don't fix it today, we'll fix it next year' works for many problems, like rebuilding infrastructure, but not for climate change: CO_2 continues to accumulate, and warming is essentially proportional to the total accumulated emissions over time, rather than those in a given year (see ref. 1 for a review). Achieving a temperature target of below 2 °C or 1.5 °C as agreed in Paris therefore implies a fixed total amount of CO_2 that can be emitted, often called the carbon budget. The sum of all future emissions depends on three factors: the timescale of carbon policy implementation, the aggressiveness of emissions reduction, and whether large scale removal of CO_2 from the atmosphere can be deployed to compensate for emissions (or to pull us back if the budget is overspent). As we argue here, decisions by the new US administration may affect all of these.

It is too early to speculate about what will actually happen, and we caution against overinterpreting the numbers of this analysis because of the large uncertainty in how the economic and ideological shift in US governance will affect greenhouse gas emissions. But based on climate models we can explore a range of bounding scenarios that could plausibly happen. An optimistic assumption, for the Paris Agreement, is that the new administration would maintain current policy, and implement the US Nationally Determined Contributions to reduce CO_2 together with other parties. That would not be sufficient for the temperature targets in the Paris Agreement[2], but would keep all options open. The information available suggests a very different path to this for future US climate policy, although the new administration has not outlined the details of its intended energy and environmental policies. Early indications suggest a fossil fuel centric energy policy, with a relaxation of environmental regulation and reduction in clean energy research; the possibility of the US withdrawing from the Paris Agreement entirely has also been suggested. The exit of the US from the Paris Agreement, or the failure of the US to meet its targets, would likely present severe challenges for the international community to meet its emissions goals. Legally US inaction does not affect other countries' obligations, but the fear that others would free-ride was one of the main hurdles in over twenty years of climate negotiations. In their initial response, China indicated that US plans would not affect their mitigation efforts, but India said they could. So it is at least plausible that other countries would also reduce their efforts, and it is worth exploring the consequences.

A plausible but still optimistic pathway would thus be a simple delay by eight years (the possible term of any US president), keeping emissions at today's levels. The US currently accounts for about 18% of global emissions and in isolation would only have a small effect. However, if all other countries were to follow a similar path of delay, about 350 billion tonnes of additional CO_2 would be emitted (about 0.25 °C of additional warming). But there are other plausible outcomes to consider. First, policies supporting a higher reliance on coal might cause emissions to increase in the near term as they did until recently, rather than remain constant. First studies for the US hint in that direction[3]. Even if emissions were to decrease again after eight years, it could take an additional 15–25 years for emissions to get back to current levels, assuming mitigation rates typical for strong mitigation scenarios.

Second, the new administration has suggested a cut in renewable energy research, which could reduce the maximum emissions reduction rate achievable, because technology will be lacking even if a future administration wanted to reduce emissions. And third, lack of research might also hit the development of technologies to remove carbon from the atmosphere. This would reduce the amount of negative emissions possible at a given cost, and the ability to globally implement net negative emissions if there is an overshoot of the carbon budget). Such carbon sequestration and storage methods are contentious[4] but are part of most scenarios that stay below 2 °C.

The different cases in a simple climate model ensemble[5] are shown in Fig. 1, starting from a typical scenario that likely (>66% probability) remains below 2 °C from pre-industrial, with net negative emissions by 2100 as in SSP1-RCP2.6 (ref. 6). The eight years of delay could be much more important than one might expect at the first glance. Delay, reduced mitigation, and initial near term fossil use each could contribute

350–450 billion tonnes of CO_2 in cumulative emissions if the US sets a precedent and the rest of the world behaves similarly. In the extreme case shown here, that almost doubles cumulative future emissions over the next century. Even if temperatures are very similar over the next decade or two, the probability of staying below 2 °C drops from about two thirds to about 10% towards the end of the century, the most likely warming increases from about 1.7 °C to 2.5 °C. The detailed carbon budgets, reduction rates and exceedance probabilities depend on various factors, including assumptions on non-CO_2 forcing[7], but the qualitative conclusions here are robust.

The argument that society could reduce faster after the delay period is optimistic: to remain within a carbon budget for 2 °C in the baseline scenario considered, peak reduction rates of CO_2 emissions around 2.4% per year are needed starting mitigation now. A global delay of mitigation action of eight years increases that to 4.2% per year (black dashed in Fig. 1a) — extremely challenging both economically and technically. The only alternative would be an overshoot in temperature and negative emissions thereafter. Research in negative emissions should therefore be a priority, but near term policy should work under the assumption that such technology would not be available at large scale and low cost soon.

Scientists have long pointed out the long-term climate change commitment from CO_2 emissions: it takes thousands of years for the ocean to warm up and take up CO_2, and part of the emitted CO_2 remains in the atmosphere forever. As a consequence, emissions today and tomorrow have impacts over centuries to millennia[8]. But just as important, there is a critical commitment in society and infrastructure[9]. Decisions on spatial planning or investments in infrastructure and energy systems affect the future for half a century or more. The implication is obvious: only immediate, global concerted and effective action can achieve the temperature targets discussed in Paris. Delay is the worst enemy for any climate target[8,10], and can only be made worse by cutting research on energy technologies that would be crucial to get back on track again for the target.

It is not up to us as climate scientists to speculate, judge or decide on climate policy. And it is not easy to remain dispassionate watching an uncertain future unfold. Yet science can and needs to inform policy objectively. Based on well-understood physics and dynamics of the coupled climate-carbon cycle system, we can put some first numbers on different scenarios,

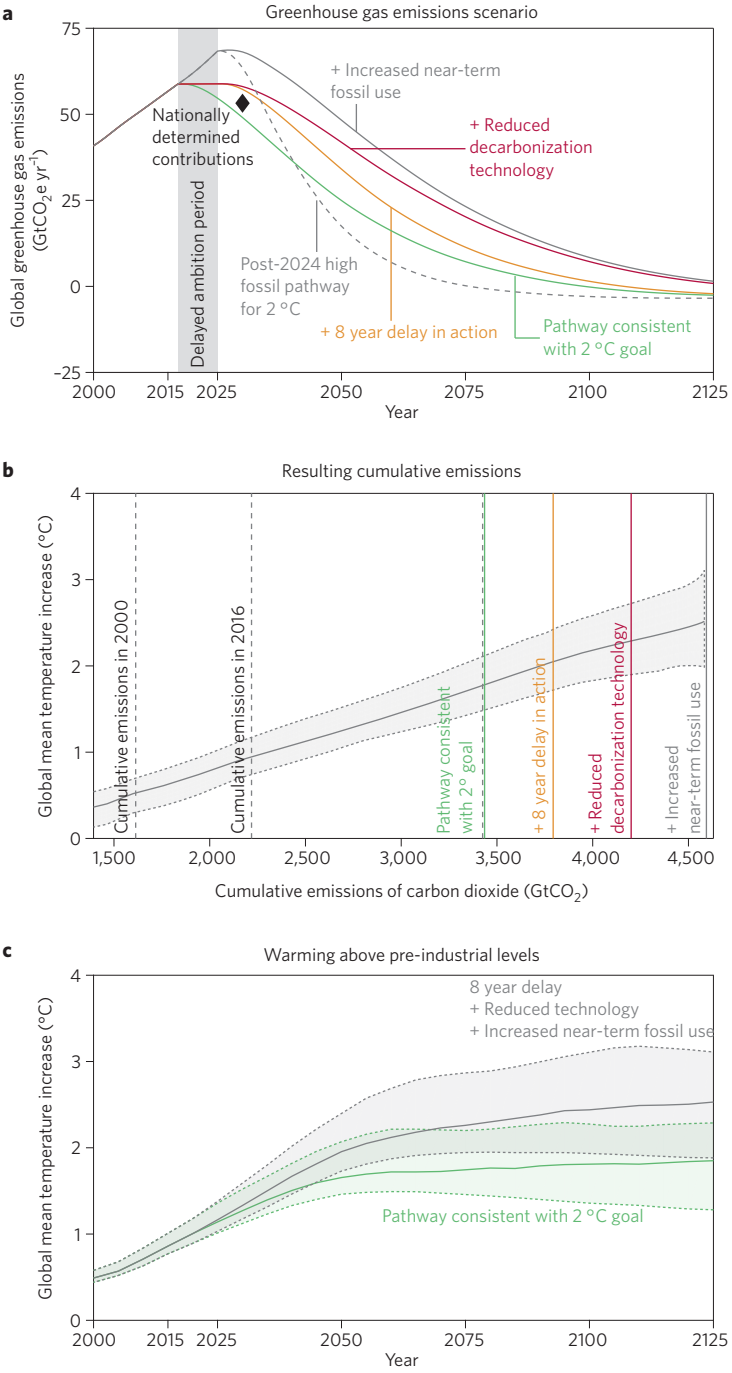

Figure 1 | Delayed-action emissions pathways and their consequences for global temperatures. **a**, Greenhouse gas emission pathways and implications for climate targets' global equivalent CO_2 emissions for all climate forcings for number of idealized emissions scenarios designed using the protocol of ref. 3. A likely 2 °C baseline scenario (green) departs from RCP8.5 in 2016 and decays to a long-term negative emissions floor of –3.2 $GtCO_2$ equivalent per year; a delay scenario (yellow) introduces an 8 year delay at present day emissions rates before decaying at the same rate as the base case; a reduced decarbonization pathway (red) also reduces the peak decay rate from 2.4% per year to 2.0% per year; and a near term fossil fuel increase pathway (black) follows RCP8.5 until 2024 before beginning mitigation. The dashed black line shows a 2 °C pathway necessary after following RCP8.5 until 2024. **b**, Global mean temperature above pre-industrial levels as a function of cumulative CO_2 emissions. The black line indicates the central estimate while grey shading indicates 10–90% probabilities. Vertical lines indicate the peak cumulative emissions associated with each scenario in (**a**). **c**, Global mean temperature above pre-industrial levels for the baseline scenario (green) and the near term increased fossil fuel pathway (black). Shading indicates 10–90% probability range.

and the conclusions are obvious: society is at a crossroad, and the decisions made in the US and elsewhere over the next 4–8 years may well determine if it is possible to limit climate change to levels agreed in Paris. ❐

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References

1. Kutti, R. & Rogelj, J. *Climatic Change* **133,** 361–373 (2015).
2. *The Emissions Gap Report 2016* (UNEP, 2016).
3. Jacques, C. *A Trump Presidency Could Mean 3.4 Billion Tons More US Carbon Emissions than a Clinton One* (luxresearch, 2016).
4. Fuss, S. *et al. Nat. Clim. Change* **4,** 850–853 (2014).
5. Sanderson, B. M., O'Neill, B. C. & Tebaldi, C. *Geophys. Res. Lett.* **43,** GL069563 (2016).
6. *Shared Socioeconomic Pathways* Version 1.1 (Science for Global Insight, accessed 15 November 2016); http://go.nature.com/2iepr2x
7. Rogelj, J. *et al. Nat. Clim. Change* **6,** 245–252 (2016).
8. Solomon, S., Plattner, G.-K., Knutti, R. & Friedlingstein, P. *Proc. Natl Acad. Sci. USA* **106,** 1704–1709 (2009).
9. Matthews, H. D. & Solomon, S. *Science* **340,** 438–439 (2013).
10. Rogelj, J., McCollum, D. L., Reisinger, A., Meinshausen, M. & Riahi, K. *Nature* **493,** 79–83 (2013).

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