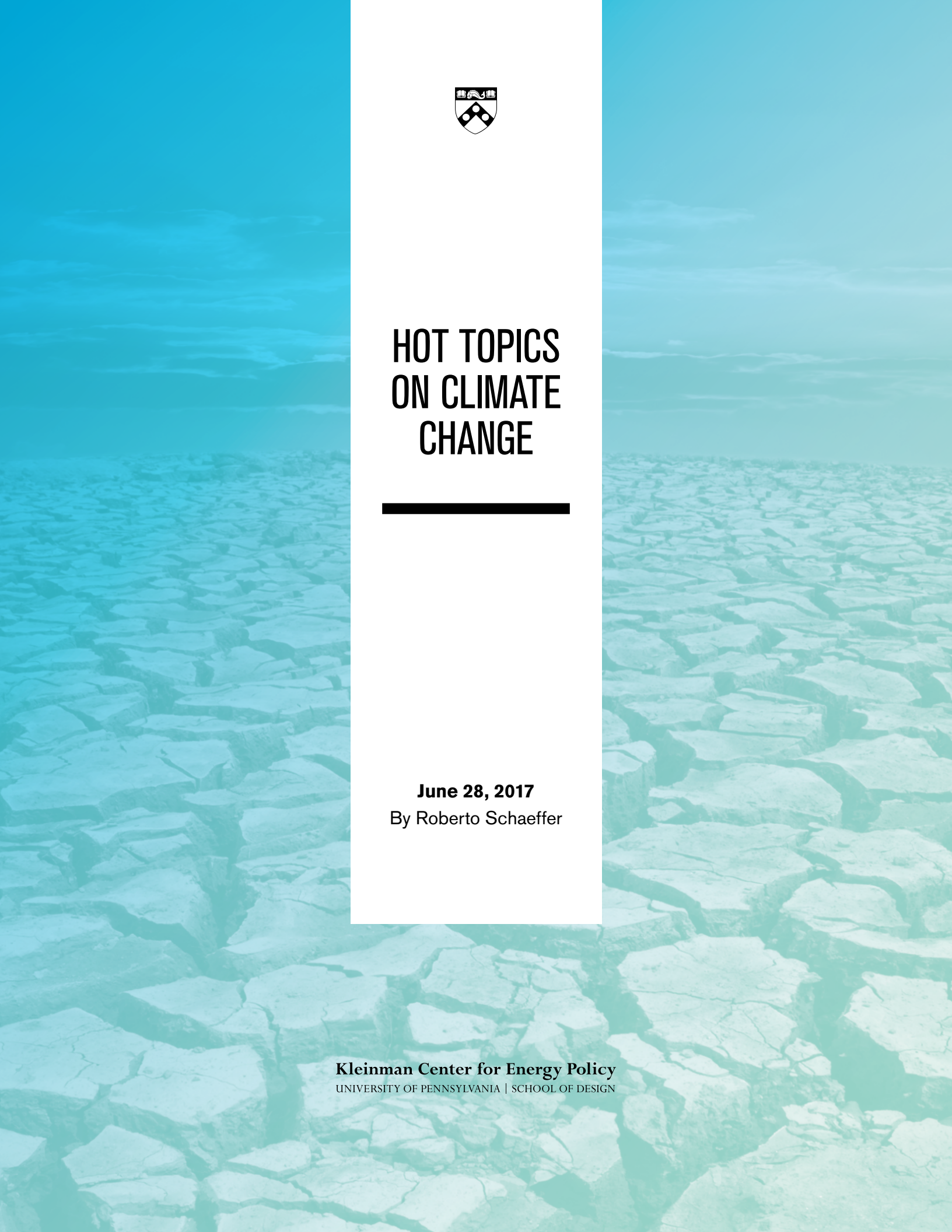

HOT TOPICS ON CLIMATE CHANGE

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Roberto Schaeffer, June 28, 2017 kleinmanenergy.upenn.edu

ON JUNE 1, 2017, U.S. PRESIDENT DONALD TRUMP ANNOUNCED HE WILL WITHDRAW THE UNITED STATES FROM THE PARIS CLIMATE AGREEMENT. IN SPITE OF THIS ANNOUNCEMENT, THE FACT REMAINS THAT A GLOBAL CLIMATE CHANGE AGREEMENT UNDER THE UNITED NATIONS WAS ADOPTED IN DECEMBER 2015 IN PARIS.

Prior to Trump's presidency, countries—including the United States— had submitted their "intended nationally determined contributions" (INDCs) for the next one-and-a-half decades. These INDCs lower global greenhouse gas emissions compared to existing policies. However, when projected further into the future, the INDCs still suggest a median warming of roughly 2.5 to 3.0°C by 2100. This exceeds the "well-below 2°C" aim of the Paris Agreement, and year-2030 emissions are higher than what energy-economic analyses indicate would minimize overall costs in view of the necessary long-term reductions. Should the United States really depart the Paris Agreement, which can only technically happen on November 4, 2020 (at the earliest), the situation will only get worst.

Many hot topics have marked the year when it comes to climate change. And it is very likely —more than 90 percent probability—using Intergovernmental Panel on Climate Change (IPCC) technical language, that these topics, and many others, will continue to be increasingly hot in the United States and elsewhere during 2017 and beyond.

THE CLIMATE IN 2016

Climate conditions were not that great in 2016. Last year the National Oceanic and Atmospheric Administration (NOAA) reported that the global surface temperature was record warm in 2015. This presses the record set the year before by 0.16°C, the largest margin ever by which one year has beaten another on the records (NOAA 2016). And climate trends continued to break marks in 2016, according to NASA (2016).

Only in the course of this year will we know for certain, but a preliminary November 2016 WMO report assessed that 2016 will likely be the hottest year on record, with global temperatures reaching even higher marks than the record-breaking temperatures of 2015 (WMO 2016). Global average temperature by the end of 2016 was already running 1.2°C above pre-industrial levels, a number perilously close to the 1.5°C target aim of the Paris climate agreement of December 2015.

On other fronts, while global temperatures warmed, here in the United States the political climate also began to heat up. Exactly a month and a half after the landmark Paris Agreement officially took effect on November 4, 2016—when one hundred nations, accounting for 69 percent of global greenhouse-gas (GHG) emissions, had formally joined the treaty (UNFCCC 2016)—Mr. Donald John Trump was formally elected by the United States Electoral College on December 19, 2016 as the country´s 45th President.

The hot topic here is that, on various recent occasions, President Trump expressed his skepticism about human-induced climate change. This included a tweet expressing a view that "the concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive," and various other public manifestations. Trump stated that with his "America First Energy Plan" he would revert all of President Obama´s policies on climate change, which would include cancelling the country's participation in the Paris Agreement, ending U.S. funding of the United Nations climate change programs, and abandoning the Clean Power Plan—in order to bring back the coal industry.

Mr. Trump's leadership choices for the Department of Energy, the Department of Interior and the Environmental Protection Agency—the three most important, energy-policy-related Federal State institutions—have either denied or strongly challenged the science of climate change. In fact, at the same time that many world leaders are creating dedicated policies to support climate change mitigation and supporting renewable energy sources in order to open new economic sectors, some world leaders perceive this movement as a threat to existing, more conservative, economic forces, like the ones associated with the fossil-fuel industry (Nature 2016b). And indeed, on June 1, 2017, when President Trump proclaimed that the United States was quitting the Paris Climate Agreement, he very much pleased some of the forces within his administration that goaded him to do so.

THE PARIS AGREEMENT: THE STARTING POINT OF A THREE-YEAR PROCESS

Under the December 2015 United Nations Framework Convention on Climate Change Paris Agreement, more than 190 nations committed to take ambitious action 1) to hold the increase in global average temperature to well below 2°C above pre-industrial levels, 2) to pursue efforts to limit the increase to 1.5°C, and 3) to achieve net zero emissions in the second half of this century (UNFCCC 2016a). This means that, from emissions of roughly 50 $GtCO_2eq/yr$ today, in the second half this century these emissions will not only need to be zeroed completely, but turned negative.

This will only be possible with massive carbon sequestration, which is the process of removing carbon from the atmosphere and depositing it in a reservoir. The candidate sectors for this process are the land use sector, with the afforestation and reforestation of large areas of the globe, and the power sector, with the use of carbon dioxide removal technologies, such as fossil-fuel-based and biomass-based power plants with carbon capture and sequestration facilities.

Already earlier, in preparation of the agreement, countries had submitted their "intended nationally determined contributions" (INDCs) for the agreed 2025 to 2030 period, promising to lower global GHG emissions compared to already existing policies. These INDCs outline national plans to address climate change after 2020. They address a range of issues of which targets and actions for mitigating GHG emissions are a core component.

The Paris Agreement is a general document, with a framework and overarching goals for global climate action. It is the beginning of a longer process. Some of its loose ends were tied up during the 22nd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 22) in Marrakech in November of 2016 (UNFCCC 2016b)—which served as the first meeting of the governing body of the Agreement. But ironing out Paris Agreement details will take some time. Countries participating in COP 22 aim to have the process established by 2018, with a review of progress planned for this same year. But the only concrete outcomes of COP 22 were procedural in nature, with parties to the Convention adopting work plans for further discussions.

However, the real result of the Paris Agreement and of COP 22 (and their long-term success) will depend on assessments of whether or not the already committed pledges, and the ones to come, will have the expected effect on reducing aggregate GHG emissions. Success will mean that the world achieved the temperature objective of holding global warming to well below 2°C and is continuing to "pursue efforts" to limit it to 1.5°C.

TEMPERATURE INCREASE AS A CONSEQUENCE OF THE INDCs

It should come as no surprise that limiting global warming to any level implies that the total amount of GHG emissions that can ever be emitted into the atmosphere is finite, given the technical and economic limitations of carbon sequestration possibilities to compensate for that. For example, for a higher than 66 percent chance (meaning "likely") of limiting global warming to below the internationally agreed temperature limit of 2°C, carbon budget estimates range around 590 to1,240 Gt CO_2 from 2015 onward (Rogelj et al 2016b).

According to IPCC language, a statement that an outcome is "likely" means that the probability of this outcome can range from ≥66 percent (fuzzy boundaries implied) to 100 percent probability. This implies that all alternative outcomes are "unlikely" (0 to 33 percent probability). To put this carbon-budged range in perspective, given current annual emissions of about 40 Gt CO_2 globally, this means that the world has a budget of no more than 15 to 60 years of

CO_2 emissions left at the level of today's emissions to limiting global warming to 2°C. Only the successful deployment of carbon sequestration practices and technologies could extend this time frame.

More specifically, for keeping warming to below 2°C, some two thirds of the total CO_2 budget have already been emitted, with an urgent need for global CO_2 emissions to start to decline, so as not to foreclose the possibility of holding warming to below 2°C. The Paris Agreement acknowledges both of these insights and aims, on the one hand, to reach global peaking of GHG emissions as soon as possible and, on the other hand, to achieve "a balance" between anthropogenic emissions and removals of GHGs in the second half of this century (UNFCCC 2016a).

The purpose of this digest is to assess the extent to which the proposed INDCs impact global GHG emissions by 2030, and explore the consistency of these reductions with the "well below 2°C" objective of the Paris Agreement. This analysis draws heavily on a previous published work (Rogelj et al 2016a), in which I was one of the authors, and where we updated and expanded INDC modeling results that were collected in the framework of the 2015 UNEP Emissions Gap Report (UNEP 2015), in which I was also one of the authors.

The number of INDCs considered by the studies we assessed ranged from the initial 118 INDCs submitted by October 1, 2015 to the final 160 INDCs from the different parties submitted by December 12, 2015 (Rogelj et al 2016a). These INDCs cover emissions from Parties to the Convention responsible for roughly 85 to 88 percent to more than 96 percent of global emissions in 2012. Furthermore, we look at projections of global-mean temperature increase over the twenty-first century that would be consistent with the INDCs, and at post-2030 implications of the INDCs for limiting warming to no more than 2°C.

We used four scenario groups to frame the implications of the INDCs for global GHGs in 2030: 1) no-policy baseline scenarios, 2) current-policy scenarios, 3) INDC scenarios, and 3) least-cost 2°C scenarios. Their definitions and descriptions can be found in the box to the right.

Scenerio Definitions

No-policy baseline scenarios are emissions projections that assume that no new climate policies have been put into place from 2005 onwards. In this analysis, the no-policy baseline scenarios are selected from the scenario database that accompanied the Fifth Assessment Report (AR5) (available at: https://tntcat.iiasa.ac.at/AR5DB/) of the Intergovernmental Panel on Climate Change (IPCC) By design, these no-policy baseline scenarios exclude climate policies, but may include other policies that can influence emissions and are implemented for other reasons, like some energy efficiency or energy security policies.

Current-policy scenarios consider the most recent estimates of global emissions and take into account implemented policies. These scenarios were drawn from three global INDC analyses (see Rogelj et al 2016a for more details). Not all countries and sectors are covered by these official and independent country-specific data sources. If this is the case, the median estimate of the three global studies for the 'current-policy baseline' for that country or sector is assumed.

INDC scenarios are at the core of this analysis. They project how global GHG emissions would evolve under the INDCs. These projections are based on the eight global INDC analyses (see Rogelj et al 2016a for more details), which in their calculations use official estimates from the countries themselves.

2°C scenarios are idealized global scenarios which are consistent with limiting warming to well below 2°C, keeping open the option of strengthening the global temperature target to 1.5°C. These scenarios are based on a subset of scenarios from the IPCC AR5 Scenario Database that meet the following criteria: they have a greater than 66 per cent chance of keeping warming to below 2°C by 2100; until 2020, they assume that the actions countries pledged earlier under the UNFCCC Cancun Accord are fully implemented; and after 2020, they distribute emission reductions across regions, gases and sectors in such a way that the total discounted costs of the necessary global reductions are minimised, often referred to as least-cost or cost-optimal trajectories.

All scenarios are here expressed in terms of billion tons of global annual CO_2 equivalent emissions (Gt CO_2e/yr), with. CO_2 equivalence of other GHGs calculated by means of 100-year global warming potentials (GWP-100) (Rogelj et al 2016a).

INDC AGGREGATE EMISSIONS IMPACT

Different countries report their INDCs differently. Some provide ranges instead of a single number of emissions reductions. Many INDCs lack necessary details, including clarity on sectors and gases covered, on the base year or a reference from which reductions would be measured, or accounting practices related to land use and the use of specific market mechanisms. Also, some of the actions listed in INDCs are, implicitly or explicitly, conditional on other factors, like the availability of financial or technological support. The interpretation of all these factors influences the range of possible outcomes. So, conditional and unconditional INDC scenarios have to be distinguished from each other, although some argue that, implicitly, all INDCs are conditional, with "some being more conditional than others." This is because, even if a country submits an unconditional INDC, later in time facts out of a country's control may change its future priorities. Even so, we will keep here a distinction between conditional and unconditional INDCs.

Unconditionally, the INDCs are expected to result in global GHG emissions of about 55 (52 to 57; 10 to 90 percent range) billion tons of annual CO_2 equivalent emissions (Gt CO_2e/yr; see *Scenerio Definitions* and *Figure 1*) in 2030. This is a reduction of around 9 (7 to 13) Gt CO_2e/yr by 2030 relative to the median no-policy baseline scenario estimate and around 4 (2 to 8) Gt CO_2e/yr relative to the median current-policy scenario estimate. To have these numbers in context, global GHG emissions in 2010 are estimated at about 48 (46 to 50) Gt CO_2e/yr (UNEP 2015), and our median no-policy baseline estimate reaches about 65 Gt CO_2e/yr by 2030.

A number of countries place conditions on all or part of their INDC. Some included a range of reduction targets in their INDC and attached conditions to the implementation of the more ambitious end. Others indicate that their entire INDC is conditional. Of the INDCs submitted, roughly half came with both conditional and unconditional components, a third was conditional only, and the rest did not make any distinction.

For a number of countries, the targets included in their INDC submission suggest achieving emission levels above the estimated no-policy baseline or their current-policy scenario. These countries are thus expected to overachieve their INDC climate targets by default.

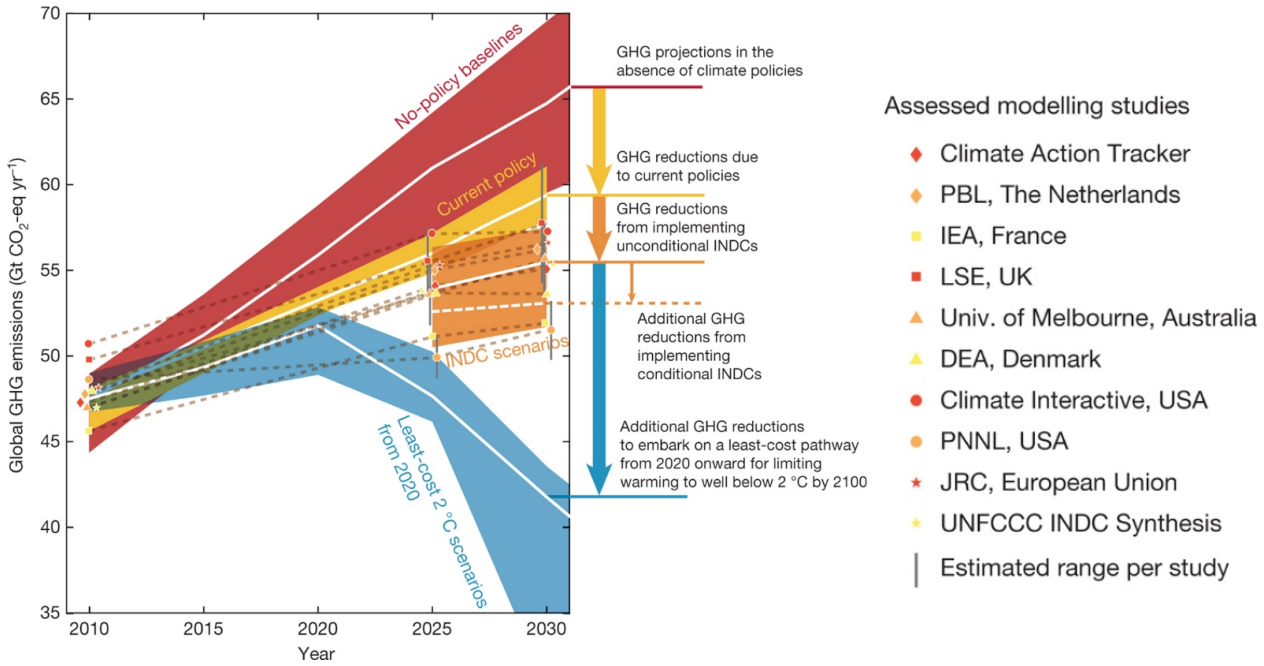

***Figure 1**: Global greenhouse gas emissions as implied by submitted INDCs compared to no-policy baseline, current-policy, and 2 °C scenarios. White lines show the median of each respective range. The white dashed line shows the median estimate of what the INDCs would deliver if all conditionalities are met. To avoid clutter, the 20th and 80th percentile ranges are shown for the no-policy baseline and 2 °C scenarios. For current-policy and the INDC scenarios, the minimum-maximum and central 80th percentile range across all assessed studies are given. Each different symbol-colour combination represents one study. Dashed brown lines connect data points for each study (Rogelj et at 2016a).*

UNCERTAINTIES IN THE ESTIMATES AND OPTIMAL 2°C PATHWAYS

There is a wide range of possible estimates of future emissions under nominally similar scenarios. These differences are a result of a number of factors, including modelling methods, input data, and assumptions regarding country intent. In fact, four confounding factors in this respect can be identified: 1) global and national sectors coverage, 2) uncertainties in projections, 3) land-use emissions, and 4) historical emissions and metrics.

Once the GHG implications of the INDCs by 2030 are quantified, the question that remains is whether these levels are consistent with the Paris Agreement's aim of holding warming to well below 2°C. The Paris Agreement's aim of reaching net-zero GHG emissions in the second half of the century goes even further. For some non-CO_2 emissions, only limited mitigation options have been identified. Therefore, net-zero CO_2 emissions are always achieved before achieving net-zero GHG emissions. The Scenario Database that accompanied the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Chang (IPCC) is used to explore cost-optimal 2°C pathways from 2020 onward (see *Scenerio Definitions*).

The comparison of these cost-optimal 2°C scenarios to the INDC projections shows a large discrepancy (*Fig. 1*). The median cost-optimal path towards keeping warming to below 2°C (starting reductions in 2020) and the emissions currently implied by the unconditional INDCs differ by about 14 (10–16) Gt CO_2e/yr in 2030. Even if the conditions that are linked to some INDCs are met, this difference remains of the order of 11 Gt CO_2e/yr. As they stand now, the INDCs clearly do not lead the world to a pathway towards limiting warming to well below 2°C.

IMPLICATIONS OF INDCS POST 2030

A large share of the potential warming until 2100 is determined not just by the INDCs until 2025 or 2030, but also by what happens afterwards. Different approaches can be followed to extend INDCs into the future, which basically assume that climate action stops, continues, or accelerates. Stopping action is often modelled by assuming that emissions return to a no-climate-policy trajectory after 2030; continuing action by assuming that the level of post-2030 action is similar to pre-2030 action on the basis of a metric of choice; and accelerating action by post-2030 action that goes beyond such a level. Because of the path-dependence and inertia of the global energy system, the INDCs have a critical role in preparing what can come afterwards.

Each approach may lead to different global temperature outcomes, even when starting from the same INDC assessment for 2025 to 2030. As a conservative interpretation of the Paris Agreement, the assumption made here is that climate action continues after 2030 at a level of ambition that is similar to that of the INDCs. The assumption that climate action will continue or accelerate over time is supported by the Agreement's requirement that the successive nationally determined contribution (NDC) of each country must represent a progression beyond the earlier contributions, and reflect the highest possible ambition of that country.

Under these assumptions of continued climate action, the 2030 unconditional-INDC emission range is roughly consistent with a median warming relative to pre-industrial levels of 2.6 to 3.1°C (median, 2.9°C; full scenario projection uncertainty, 2.2 to 3.5°C; Table 1), with warming continuing its increase afterwards. This is an improvement on the current-policy and no-policy baseline scenarios, whose median projections suggest about 3.2°C and more than 4°C of temperature rise by 2100, respectively.

The successful implementation of all conditional INDCs would decrease the median estimate by an additional 0.2°C, but keeps the outcome far from the targets the Paris Agreement is aiming for, with well-below 2°C and 1.5°C of warming. Moreover, all above-mentioned values represent median projections coming out of emission scenarios, which in themselves are a function of uncertain assumptions with respect to population growth (more growth, more emissions), economic growth (here too, more growth, more emissions) and even rates of technological improvements (more improvements, less emissions).

Because the climate response to GHG emissions remains uncertain, it is also possible that substantially higher temperatures will materialize with compelling likelihoods (*Table 1*). For example, at the 66th percentile level, warming under the unconditional INDCs is projected to be about 0.3°C higher (3.2°C, with a range of 2.9 to 3.4°C). Finally, the INDC cases that are discussed here will exceed the available carbon budget for keeping warming to below 2°C by 2030 with 66 percent probability (that is, roughly 750

Global-mean temperature rise by 2100 (in °C) that is not exceeded with the given probability			
Scenerio	**50%**	**66%**	**90%**
No-Policy Baseline	4.1 (3.5–4.5) [3.1–4.8]	4.5 (3.9–5.1) [3.4–5.4]	5.6 (4.8–6.3) [4.2–6.8]
Current Policy	3.2 (3.1–3.4) [2.7–3.8]	3.6 (3.4–3.7) [2.9–4.1]	4.4 (4.2–4.6) [3.6–5.2]
INDC (Unconditional)	2.9 (2.6–3.1) [2.2–3.5]	3.2 (2.9–3.4) [2.4–3.8]	3.9 (3.5–4.2) [2.8–4.7]
INDC (Conditional)	2.7 (2.5–2.9) [2.1–3.2]	3.0 (2.7–3.1) [2.2–3.6]	3.7 (3.3–3.9) [2.6–4.4]

***Table 1**: Estimates of global temperature rise for INDC and other scenarios categories. For each scenario, temperature values at the 50 percent, 66 percent and 90 percent probability levels are provided for the median emission estimates, as well as the 10th–90th-percentile range of emissions estimates (in parentheses) and the same estimates when also including scenario projection uncertainty (in brackets). Temperature increases are relative to pre-industrial levels (1850–1900), and are derived from simulations with a probabilistic set-up with the simple model MAGICC (see Rogelj et al 2016a for more details).*

to 800 Gt CO_2e implied emissions under the INDCs during the 2011 to 2030 period compared to the 750 to 1,400 Gt CO_2e available).

The question thus arises whether global temperature rise can be kept to well below 2°C with accelerated action after 2030. Global scenarios that aim to keep warming to below 2°C and that achieve this objective from 2030 GHG emissions similar to those from the INDC range have been assessed in detail by recent large-scale model-comparison projects (Clarke et al 2014 and Riahi et al 2015), but show that even with accelerated action after 2030 options to keep warming to well below 2°C from current INDCs are severely limited, particularly if some key mitigation technologies, such as Carbon Capture and Storage (CCS) or CCS with biomass energy (BECCS), for example, do not scale up as anticipated.

Scenarios in which global warming is successfully contained show rapidly declining emissions after 2030, with global CO_2 emissions from energy- and industry-related sources reaching net-zero levels between 2060 and 2080. The global economy is thus assumed to fully decarbonize in the time span of three to five decades and from 2030 levels that are higher than today's. Furthermore, about two-thirds of these scenarios achieve a balance of global GHG emissions between 2080 and 2100. Because some non-CO_2 emissions are virtually impossible to eliminate entirely (for example those from specific agricultural or animal agricultural sources), reaching such a balance will involve net-negative CO_2 emissions at a global scale to compensate for any residual non-CO_2 emissions, limiting global-average temperatures increase over time.

Exploring futures in which a global balance of GHG emissions can be achieved in the second half of this century with technically feasible and societally acceptable technologies represents a major research challenge emerging from the Paris Agreement. This challenge is particularly relevant to policy, because limiting emissions in 2030 does not only increase the chances of attaining the 2°C target, but also reduces the need to rely on unproven, potentially risky or controversial technologies in the future (Clark et al 2014 and Riahi et al 2015).

FINAL CONSIDERATIONS

The world has made its decision on Climate Change, despite some recent setbacks here and there. As a recent Editorial of the New York Times put it very clearly, "It´s hard to know how Mr. Trump will change climate policy, but it is almost certain that he won´t advance it" (The New York Times 2016). And indeed, if it is true that the United States will leave the Paris Agreement, for sure it will lose the ability to pressure other countries, including the large emerging economies like Brazil, China and India, to do more.

On the global front, as discussed here, actions may still be too slow and/or too weak, but we can be optimistic and say that, in spite of some hurdles on the way, momentum is building. Covering more than 90 percent of the world's GHG emissions with climate plans in the form of INDCs was a historic achievement. Now that the Paris Agreement came into force, and that the original INDCs are not simply "Intended" anymore (so, they are no longer INDCs but now Nationally Determined Contributions, or NDCs), it will continue with NDCs, subject to strong transparency of individual contributions and a global stock-take, in the light of equity and science, every five years.

However, the optimism accompanying this process has to be carefully balanced against the important challenges that current INDCs imply for post-2030 emissions reductions. Even starting now limiting warming to no more than 2°C relative to preindustrial levels constitutes an enormous societal challenge. While the contributions open a new era for climate policy under the Paris agreement, they also represent both an invitation and call, if not a need, for further action. Furthering deeper reductions in the coming decade, as well as preparing for a global transformation until mid-century are critical. In absence of incrementally stronger policy signals over the coming five years to a decade, the likelihood that our society will be able to meet the challenge of limiting warming to below 2°C with less than even odds will become extremely small.

Therefore, let us put this clear: Should the United States' new administration, indeed step back from the previous administration commitment, two possibilities could arise. First, other major emitting nations could also follow suit, turning the Paris Agreement an absolutely irrelevant effort of international negotiation, driving the planet towards unknown climate consequences. Second, because the United States is the second largest GHG emitter, with some 15 percent of world´s total emissions, any climate-change global agreement to succeed would probably also require to have the United States on board, something that is now under a question mark. Therefore, the latter in itself is already a problem even if the former does not materialize. Interestingly enough, the very structure of the Paris Agreement, like the Kyoto Protocol, was designed largely to United States specifications, and also an answer to United States' prayers.

The problem is that, in fact, political upsets could stall coordinated international mitigation action, with long-term consequences, eventually even rendering the 2°C target unachievable (Sanderson et at 2016). Interesting enough, although the governments of the world have requested the IPCC to assess, through a Special Report due in 2018 (IPCC 2016), the impacts of 1.5°C of warming, as well as ways to prevent temperatures from rising higher, many scientists have practically already written off the chances of limiting warming to 1.5°C (Rogelj et al 2016b and Luderer et al 2016).

As discussed before, the Paris Agreement commits governments to keeping average global surface temperatures to between 1.5°C and 2°C above the preindustrial level, but warming has already passed the 1°C mark (WMO 2016). If the 2°C goal is already seen implausible by some, given a lack of more effective actions and current politics, let alone the even more ambitions 1.5°C target (Nature 2016a), let us hope that the economies of the world will be able to do their homework on time. We cannot travel the last mile with quick fixes, which would be too dependent on extremely risky and uncertain technologies, such as geoengineering, as some have begun to consider (Hubert et al 2016). Unfortunately, the recent move of the current United States Administration with respect to the Paris Agreement is not going to be of much help in that respect.

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