PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC SCIENCE BRIEF: SHOULD THE RCP 8.5 EMISSIONS SCENARIO REPRESENT "BUSINESS AS USUAL"?

The state of the future climate depends on human actions, primarily the emission of greenhouse gases and other industrial pollutants. This raises the questions: "What path are recent historical emissions following?" "What path would we be on, if we continue with business-as-usual, in the absence of further mitigation action?" And, "Are these paths reliable guides to future emissions?" One scenario that is commonly used in the scientific literature, RCP 8.5, is often referred to as "business-as-usual." Recently, some scientists have taken issue with this description, saying it is unrealistic and may hinder the goal of emissions reductions policy. Others argue that, in fact, RCP 8.5 is the scenario that most closely tracks cumulative emissions to date, that it is thus of the most use for planning out to the middle of the century. In this Science Brief, we unpack each of these arguments and evaluate what these differing perspectives can tell us about the ultimate objective of emissions scenarios as tools for exploring future climate change.

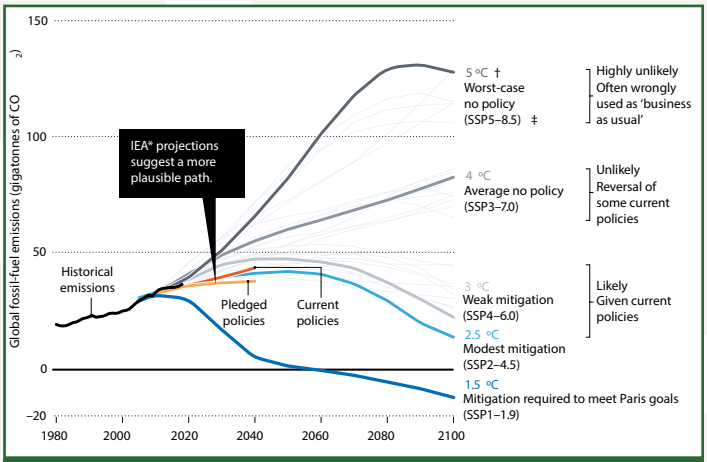

Figure 1: Global Fossil Fuel Emissions (from Hausfather and Peters, 2020a).
This figure shows historical and projected-future global fossil-fuel emissions. The scenarios used are projections from the International Energy Agency and selected scenarios from the Shared Socioeconomic Pathways (SSPs), as labelled. The resulting average projected temperature from each SSP (as determined by a simple climate model) is presented along the right, along with the authors' assessed likelihood of each outcome. In particular, here SSP5-8.5 stands in for Representative Concentration Pathway 8.5 (RCP 8.5) as a point of comparison.

Introduction

In a broad range of areas, planning for the future requires some knowledge of the future climate. However, we cannot make a forecast of the climate of 30, 50 or 80 years in the future. The state of the future climate depends crucially on human emissions of greenhouse gases and aerosols[1], which in turn depend on a number of factors, including the makeup of the future global energy system. The makeup of the future energy system itself depends on global population growth, energy needs and future technologies. Technological change is difficult to predict and can quickly alter the energy landscape. For example, the advent of profitable hydraulic fracturing[2] and the rapidly falling price of energy from solar photovoltaics have affected the mix of global energy sources, while the carbon footprint of cryptocurrencies has grown rapidly and now rivals that of many countries[3].

While we cannot predict the state of the global climate by the middle or end of the century, we can use our understanding of the Earth system and the fundamental physical laws that govern it to develop a range of plausible future scenarios that can be used to inform planning. There is particular interest in determining which scenario best represents the path we are on, or the path that we would be on if we were to continue with "business as usual." That is, what would the future climate look like, given current policies and in the absence of significant further mitigation action? There has been an ongoing debate about what future scenario constitutes business-as-usual that spans the scientific and popular literature. This Science Brief examines an illustrative portion of this exchange that captures some of the key points of interest.

1. The future climate may also depend on various types of geoengineering or technologies that have yet to be imagined. For an overview of some of the main proposed methods of geoengineering, see Royal Society (2009).
2. Hydraulic fracturing, or, "fracking," involves injecting water, sand, and sometimes other chemicals into a well at high pressure in order to cause fracturing in underground bedrock to increase the flow of oil or gas reserves in the well.
3. For more on the energy consumption of cryptocurrency, see: https://www.bbc.com/news/technology-56012952.

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Emissions Scenarios

We begin by looking at the two most recent sets of emissions and concentration scenarios developed for the Intergovernmental Panel on Climate Change's (IPCC) assessment reports, with a focus on the Representative Concentration Pathways[4] (RCPs) developed for the Fifth Assessment Report (AR5). The RCPs are comprised of four paths that future atmospheric greenhouse gas emissions may follow: RCP 2.6, which projects low greenhouse gas emissions, RCP 4.5 projects moderate emissions, RCP 6.0 projects moderate-to-high emissions and RCP 8.5, which projects high emissions. They are named for the net change in the balance of incoming solar and outgoing longwave radiation at the top of the troposphere[5] at the end of the 21st century, measured in watts per square metre.

In place of the RCPs, the upcoming report IPCC Sixth Assessment Report uses the Shared Socioeconomic Pathways[6] (SSPs), a set of five trajectories (SSP1 through SSP5) that illustrate different ways that global societies may develop. The SSPs are broadly comparable to the RCPs (see Aside).

RCP 8.5: Business As Usual?

Although RCP 8.5 was developed as a high-emissions scenario, it has widely been described in the scientific and popular literature as a business-as-usual scenario. This raises a number of questions, among them: does RCP 8.5 actually represent business-as-usual? In which contexts and to whom is RCP 8.5 useful?

In their *Nature* comment article titled, *Emissions — the 'business as usual' story is misleading*, Hausfather and Peters (2020a) argue that the business-as-usual designation sometimes given to RCP 8.5 is misleading. Their arguments are largely centered around emissions projections and the

ASIDE: COMPARING THE RCPs AND THE SSPs

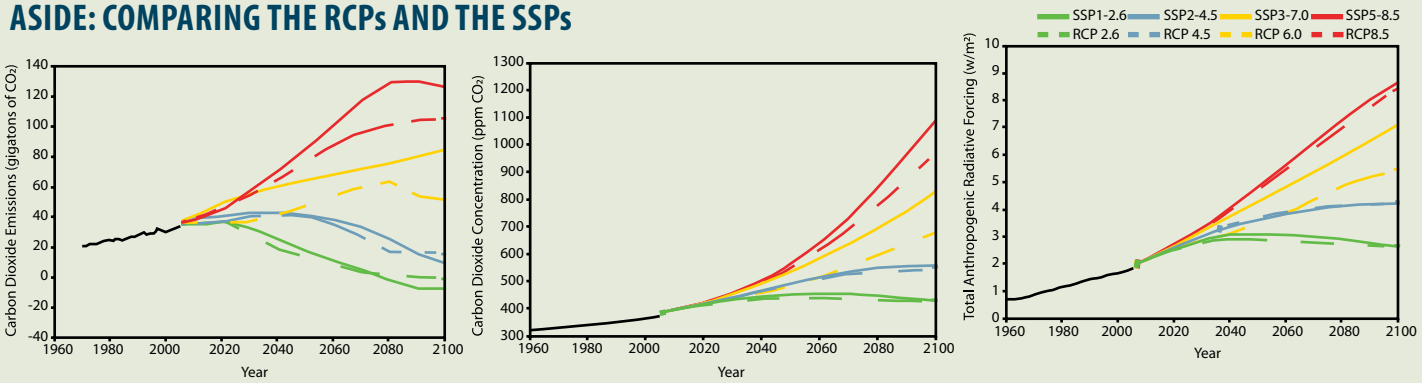

Figure 2: Anthropogenic CO_2 Emissions, Concentrations and Resulting Radiative Forcing (modified from O'Neill et al. (2016)).

This figure shows anthropogenic carbon dioxide (CO_2) emissions (left panel), global mean concentrations (centre panel), and resulting net radiative forcings (right panel). The Representative Concentration Pathways used in CMIP5 are represented by solid lines and selected Shared Socioeconomic Pathways used in CMIP6 are represented by dashed lines, all colours as indicated in the legend.

The emission of greenhouse gases such as CO_2 (Figure 2, left panel), alters their global mean atmospheric concentrations (centre panel) which results in a net radiative forcing (right panel), which in turn causes in an increase in mean global surface temperatures. The upcoming IPCC Sixth Assessment Report uses the Shared Socioeconomic Pathways[5] (SSPs), a set of five trajectories (SSP1 through SSP5) that illustrate different ways that global societies may develop, each of which has several associated emissions and concentration scenarios. These are used to create climate projections for the report. The RCPs and the SSPs are named for the radiative forcings that result from a given pathway by the end of the century, for example, RCP 4.5 and SSP2-4.5 both results in a radiative forcing of 4.5 watts per square metre (Wm^{-2}) by 2100. Unlike the RCPs, SSPs allow more than a single radiative forcing target to be achieved within a given SSP. The SSPs were developed by considering a number of factors, such as plausible future population growth, human development, economic growth, changes to lifestyles, policies and institutions, developments in technology, and management of the global environment and natural resources. A knowledge of these factors permits estimates of country-level quantities such as Gross Domestic Product and the degree of urbanization that are known to strongly control greenhouse gas and aerosol emissions. Generally speaking, the SSPs are designed to capture a range of possible ways in which societies may develop and, because of this, they do not follow a simple linear ordering in terms of emissions, from SSP1 to SSP5. However, for a given radiative forcing target, RCPs and SSPs are quite comparable (Figure 2, right panel).

4. For more information on the RCPs, see van Vuuren et al., (2011).
5. The Earth's atmosphere can be divided up into successive layers by height: the troposphere, stratosphere, mesosphere, thermosphere and exosphere. The troposphere is the layer closest to Earth's surface.

hazards of normalizing overly pessimistic projections as "business-as-usual." They begin by pointing out that, despite the fact that RCP 8.5 was meant to capture an unlikely and high-risk future, it has since been used by policymakers as a business-as-usual scenario. The authors argue that end-of-century emissions projections under RCP 8.5 now appear implausible, given recent historical emissions trends. For example, while global coal use appears to have peaked in recent years, RCP8.5 reflects a fivefold increase in emissions from this energy source by 2100. Hausfather and Peters also suggest that current policies would lead to a world that is about 3°C warmer by the end of this century, short of the approximately 5°C of warming projected under RCP 8.5.

The authors contend that describing RCP 8.5 as "business-as-usual," and therefore as probable, may lead to defeatism and overestimating the costs of climate action. Scenarios issued without guidance for their use (in the form of at least qualitative probabilities) effectively invite users to assign such likelihoods themselves, Hausfather and Peters say. And a focus on the extremes, in the form of best- and worst-case scenarios, ignores the space of more likely outcomes that lies in between. As examples of more likely outcomes, the authors point to the IEA's scenarios up to 2040, which are based upon countries' current emissions policies and targets (Figure 1).

Responding in the *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, Schwalm, Glendon and Duffy (2020a) counter that future emissions scenarios should not be viewed as predictions, with associated likelihoods—which we have no way of quantifying—but rather as planning tools with multiple outcomes by design. In other words, RCP 8.5 cannot be viewed as "misleading," because it can't be validated against (unknown) future emissions. With respect to the cumulative emissions of carbon dioxide up to the present, RCP 8.5 actually holds up well, argue the authors, being within 1% of observational estimates, and they further note that this is unaffected by the COVID-19 pandemic.

Looking to the 2030s and 2050s, Schwalm, Glendon and Duffy make use of two near-term IEA-based projections mentioned by Hausfather and Peters as being more "realistic." The authors develop projections by combining historical emissions with the IEA projections, emissions from land use change and industrial emissions. They then compared these scenarios, representing nations' "current policies" and "stated policies," with the RCPs for these future periods (Figure 3). The authors find that RCP 8.5 most closely matches cumulative emissions for 2030, for both IEA scenarios. By 2050, the IEA-projected emissions fall between RCP 8.5 and RCP 4.5. So why choose RCP 8.5 over

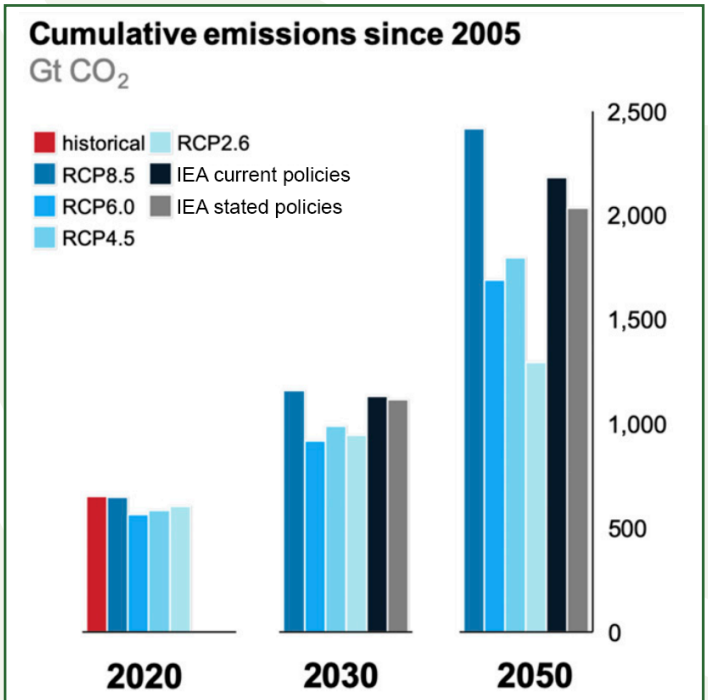

Figure 3: Cumulative Emissions Since 2005 (modified from Schwalm, Glendon and Duffy, 2020a).
This figure shows historical and projected-future cumulative global carbon dioxide emissions for years 2020, 2030 and 2050. The scenarios used are projections from the International Energy Agency (combined with emissions from land use change and industrial emissions) and the RCPs, as labelled, with historical data from the Global Carbon Project.

RCP 4.5 on this longer time horizon? Schwalm and coauthors contend that it would be prudent to do so, given that the IEA estimates do not account for additional carbon dioxide released from positive climate feedback mechanisms. They also point to recent research that finds there is a 35% chance that carbon dioxide emissions will exceed the emissions assumed by RCP 8.5 by the end of this century (see Christensen, Gillingham and Nordhaus, 2018). This illustrates one of the key differences between the two sets of commentators: while Hausfather and Peters believe that scenarios should be "realistic," Schwalm et al. feel it is more important for the to be "useful," in the sense of bracketing possible outcomes in an uncertain future.

Two further responses in *PNAS* flesh out the arguments at play, largely focused on the issue of emissions from land use change. Hausfather and Peters (2020b) argue that, in terms of cumulative emissions, both current policies and stated policy intentions result in emissions that are closer to RCP 4.5 and RCP 6.0 than they are to RCP 8.5 for 2030

6. For more on the SSPs, see O'Neill et al. (2014) and O'Neill et al (2017).

and 2050. They argue that Schwalm et al.'s response relies heavily on highly uncertain estimates of land use change and assume an increase in emissions from this source, whereas the RCPs and SSPs assume a decline. Whereas Schwalm et al. (2020b) note that the most important thing is the amount of carbon dioxide in the atmosphere. They reiterate that RCP 8.5 is the closest match to observed atmospheric carbon dioxide concentrations, remains the best choice for risk assessment through to the middle of the century, and point out that land use change emissions have consistently failed to peak, despite projections.

Outlook: Scenarios, Not Forecasts

With the advent of CMIP6 and the IPCC's Sixth Assessment Report, RCP8.5 will likely cede its place to one of the SSPs. Differing views such as those highlighted above may continue to be heard between those arguing for the "realism" of scenarios on one side and for their overall utility on the other. But is the adoption of one viewpoint or the other helpful to users of climate projections?

Much of this dialogue can be seen as complementary. Given that RCP 8.5 is not the most "likely" outcome of emissions following business-as-usual or stated policy intentions, it's reasonable to refer to it as a high-emissions scenario instead of business-as-usual. And cumulative emissions thus far do follow RCP 8.5 quite closely, so it remains useful for planning through to the middle of the century. However, in terms of projected global climate change, significant differences between the scenarios do not emerge until near the middle of the century. Thus, projected climate impacts over the next two decades are similar across scenarios. Also, given the substantial uncertainty involved in making projections of future emissions, it is unclear how much recent changes and trends in emissions tell us about what emissions will be decades from now.

The economic forecasters, who originally pioneered scenario development in partnership with the IPCC, did not intend for them to be understood as either value-based or probabilistic. Rather, they were tasked with the "formulation of [...] narrative scenario 'storylines' to describe alternative futures," and the "quantification of each storyline using a variety of modeling approaches." (IPCC, 2000). Specifically, they formulated high-emissions scenarios such as RCP 8.5 with the expressed intent of generating strong climate forcings, which provide better tests for climate models than more moderate forcings. But the intent was not merely academic. Emergency management planners, for example, are also likely to value RCP 8.5, since they are concerned with how society can respond to low-likelihood, high-risk disasters. Other users, such as government planners and industry, who may be more interested in examining "likely" scenarios, may steer away from high-emissions scenarios. In any event, we would do well to note that the very exercise of scenario development involves aiming at a moving target, as the global energy landscape continues to shift beneath our feet.

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