METHODOLOGY

EXTRACTING RELEVANT SCENARIO RANGES CONSISTENT WITH THE PARIS AGREEMENT GOALS

REVIEW OF EXISTING METHODOLOGIES

Scenarios are used by the private sector, international organisations and academia alike to explore how the future could evolve under an internally consistent set of assumptions. Over the past decades, many thousands of scenarios have been published exploring questions of how the energy system and society as a whole could transform in line with varying levels of climate policy stringency. At regular time intervals these scenarios have been compiled in public databases, often as part of multi-model intercomparison exercises[3,4] or the assessment work carried out by the Intergovernmental Panel on Climate Change[5-7] (IPCC). This provides a valuable resource to further explore the range and space of future evolutions of the energy system as projected by a multitude of models, for example, consistent with the Paris Agreement.

To assess general features of scenarios consistent with a specific climate goal, scenarios are often re-analysed and grouped in terms of a specific climate-related scenario characteristic, for example, the projected level of greenhouse gas concentrations in the atmosphere and its related climate forcing[6], or the amount of global-average temperature increase that would be caused by the scenario over the course of the 21st century[7,9]. Such reviews of large sets of scenarios can help identify robust features compatible with a specific climate goal.

Very often, these studies provide minimum-maximum ranges across all available scenarios[6,7], or alternatively the percentile distribution across all available scenarios[6-8]. However, several limitations and potential pitfalls exist when assessing characteristics of scenarios, in particular because the combined set of scenarios available in public databases represent what is referred to as an ensemble of opportunity. That means, a "serendipitous collection of scenario data from a variety of sources and studies"[10]. Good practice recommendations for assessing such scenario sets have recently been published[10]. These include recommendations to:

- not interpret the distribution of scenarios in an ensemble of opportunity as a statistical sample or as an indicator of likelihood or agreement in the literature;
- not only focus on medians;
- infer additional insights from an informed selection of scenarios; and
- not to conclude that the absence of a particular scenario indicates that it would be not be possible to be created.

RECOMMENDATION OF SELECTION CRITERIA FOR PARIS AGREEMENT CONSISTENT SCENARIOS

The Paris Agreement[11] aims to hold warming well-below 2°C and to pursue limiting it to 1.5°C relative to preindustrial levels[1]. This combined statement is referred to as the Paris Agreement Long Term Temperature Goal (LTTG)[12]. Several interpretations can be consistent with this wording and a scientific

[1] The exact wording reads: „Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change"

exploration of potential future developments in line with the Paris Agreement hence needs to take into account this diversity in possible interpretations[12].

Scenario data compiled for the IPCC Special Report on Global Warming of 1.5°C[7] (SR15) is made available through an online portal hosted at the International Institute for Applied Systems Analysis[10,13] (IIASA). This resource has been used as a basis for selecting scenarios that are consistent with meeting the Paris Agreement LTTG.[2]

The IPCC SR15 groups available scenarios based on their projected climate outcome in terms of global-average temperature increase over the 21st century relative to preindustrial levels. For the BP Energy Outlook, scenarios are considered consistent with the Paris LTTG if they at least keep global average temperature rise below 2°C with 66% probability. Within that group of "Paris-consistent" scenarios we can identify two subsets. The first subset, referred to as *Lower 2°C,* is compatible with the aim of holding warming well below 2°C but falls short of the 1.5°C goal. The second subset, referred to as *1.5°C with no or low overshoot,* is, compatible with limiting warming to 1.5°C.

These two subsets are further refined by excluding:

a) scenarios in which historical year 2010 CO_2 emissions from energy and industrial sources deviate more than 5% from the mean of the scenario sample;
b) scenarios with implied pre-2020 carbon prices higher than $30 per ton CO_2 ($2010).

[2] Guidance on scenario selection was provided by Dr Joeri Rogelj, Imperial College and IPCC lead author. We gratefully acknowledge Dr Rogelj's assistance, while noting that his contribution to this exercise does not imply his endorsement of any of the views expressed in the BP Energy Outlook.

REFERENCES

3 Riahi, K. *et al.* The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change* **42**, 153-168, doi:10.1016/j.gloenvcha.2016.05.009 (2017).

4 Kriegler, E. *et al.* Making or breaking climate targets: The AMPERE study on staged accession scenarios for climate policy. *Technological Forecasting and Social Change* **90, Part A**, 24-44, doi:10.1016/j.techfore.2013.09.021 (2015).

5 Nakicenovic, N. & Swart, R. *IPCC Special Report on Emissions Scenarios*. 570 (Cambridge University Press, 2000).

6 Clarke, L. *et al.* in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds O. Edenhofer *et al.*) Ch. 6, 413-510 (Cambridge University Press, 2014).

7 Rogelj, J. *et al.* in *Global Warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (eds Greg Flato, Jan Fuglestvedt, Rachid Mrabet, & Roberto Schaeffer) Ch. 2, 93-174 (IPCC/WMO, 2018).

8 UNEP. The Emissions Gap Report 2018. 1-113 (UNEP, Nairobi, Kenya, 2018).

9 Rogelj, J. *et al.* Emission pathways consistent with a 2°C global temperature limit. *Nature Clim. Change* **1**, 413-418, doi:10.1038/nclimate1258 (2011).

10 Huppmann, D., Rogelj, J., Kriegler, E., Krey, V. & Riahi, K. A new scenario resource for integrated 1.5 °C research. *Nature Climate Change* **8**, 1027-1030, doi:10.1038/s41558-018-0317-4 (2018).

11 UNFCCC. Paris Agreement. 1-25 (UNFCCC, Paris, France, 2015).

12 Schleussner, C.-F. *et al.* Science and policy characteristics of the Paris Agreement temperature goal. *Nature Climate Change* **6**, 827-835, doi:10.1038/nclimate3096 (2016).

13 Huppmann, D. *et al.* in *IAMC 1.5°C Scenario Explorer and Data hosted by IIASA* (Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018).