Pathways for Achieving the Paris Agreement's Articles 2 and 4 Goals

Presented by: Joeri Rogelj
Energy Program – International Institute for Applied Systems Analysis

General context

The Paris Agreement defines a set of global climate and mitigation objectives. Here we try to understand the implications for future mitigation pathways of the Paris Agreement's Articles 2 and 4. We focus on the objectives that define *(i)* a global limit to the increase in global average temperatures relative to pre-industrial levels (as defined in Article 2), and *(ii)* the aim to embark on a stringent greenhouse gas mitigation pathway as soon as possible and to achieve a balance between sinks and sources of anthropogenic greenhouse gases (Article 4). We explore two questions in this regard with an analysis of the scenario literature and dedicated integrated assessment modelling experiments:

1. **Are the temperature objectives of Article 2 consistent with the emissions pathways implied by the objectives of Article 4?**
2. **What are key characteristics, as well as potential differences, of pathways which stay within the global temperature limits introduced in Article 2?**

"Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels"

Paris Agreement Article 2

"In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible […], and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"

Paris Agreement Article 4

Internal consistency of Article 2 & 4

We re-analyze the emissions scenarios available in the database that accompanied the Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5 WGIII) together with more recent studies (see references), and group them based on their temperature outcomes in 2100 (Figure 1a). This is a weak interpretation of the Paris Agreements Article 2 objectives as it does not avoid the 1.5°C and 2°C limits to be exceeded temporarily prior to 2100. We find that:

- Achieving a balance between anthropogenic sinks and sources of greenhouse gases in the second half of the century is **consistent** with returning warming to below 1.5°C relative to pre-industrial levels by 2100 (Figure 1b).
- **Global net zero CO_2** emissions are a requirement to achieve the Article 4 balance, and these are **achieved before the Article 4 balance is achieved**.
- **Net negative CO_2** emissions are further needed to **compensate for residual emissions** from sectors like agriculture.
- Achieving a **balance as described in Article 4 is an insufficient condition** in itself. In many scenarios, median warming still exceeds 2°C of warming, even if a balance is achieved in the second half of the century (Figure 1c).
- **Additional, intermediate benchmarks are therefore necessary** to guarantee achievement of the Article 2 temperature objectives.

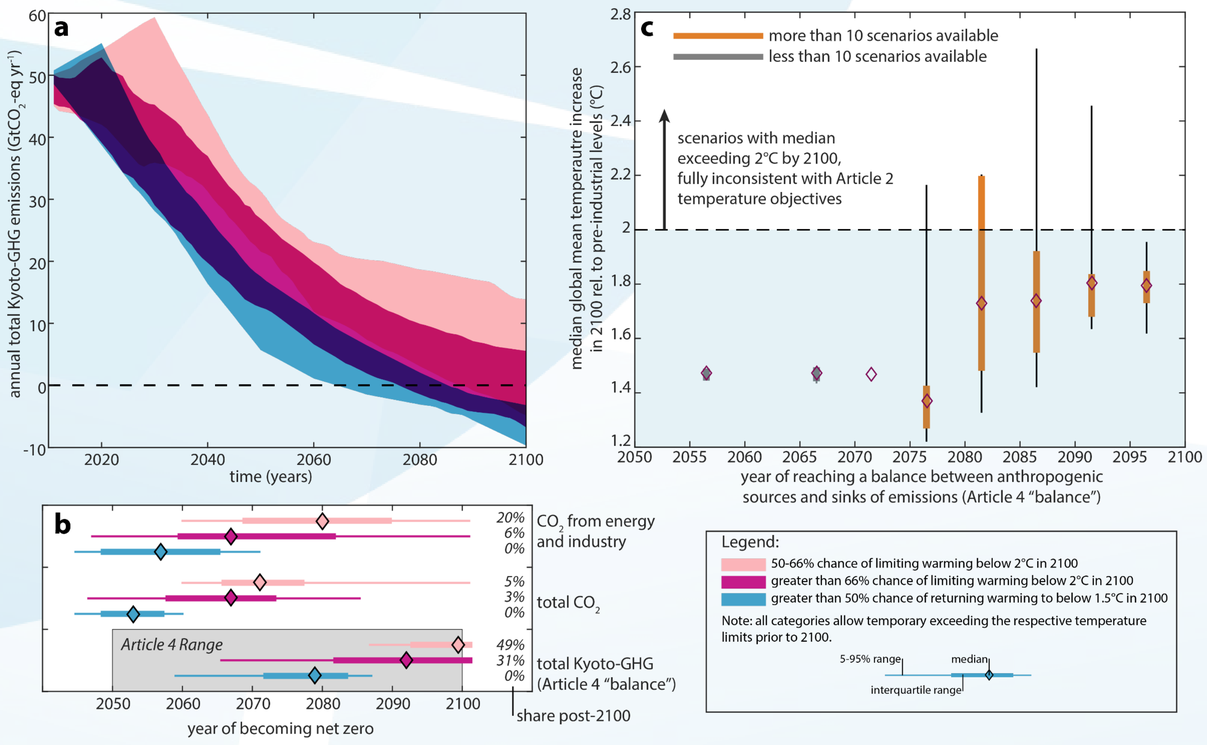

Figure 1: Comparison of emissions pathways with varying probabilities of keeping warming to below 2°C and further to below 1.5°C, and the timing of achieving the emission balance objective of Article 4.

Key characteristics of 1.5°C pathways and differences with 2°C pathways

Detailed energy-economy-environment scenarios, created by two state-of-the-art integrated assessment models (IAMs: the MESSAGE model from IIASA, and the REMIND model from the Potsdam Institute for Climate Impact Research), were used to determine the characteristics of pathways that limit warming to below 1.5°C by 2100, and to compare those to scenarios which keep warming to below 2°C with a 66% chance, but do not reduce warming further to below 1.5°C in 2100 (Figure 2).

Key characteristics of 1.5°C pathways:

- Additional greenhouse gas reductions come mainly from CO_2
- Global CO_2 reductions beyond net zero are required (net zero shortly after mid-century)
- A rapid near-term decarbonisation of energy supply (about 70% low-carbon share in 2030, and >95% in 2050)
- Greater demand side mitigation efforts (particularly in the building and the transport sector)
- Energy efficiency improvements are crucial (at a sustained global rate of 2.5%/year until 2050)
- Particularly in the near term, mitigation costs are higher (between double and triple from a 66% 2°C pathway)
- Comprehensive reductions achieved in coming decade (all pathways peak global emissions around 2020 or earlier)

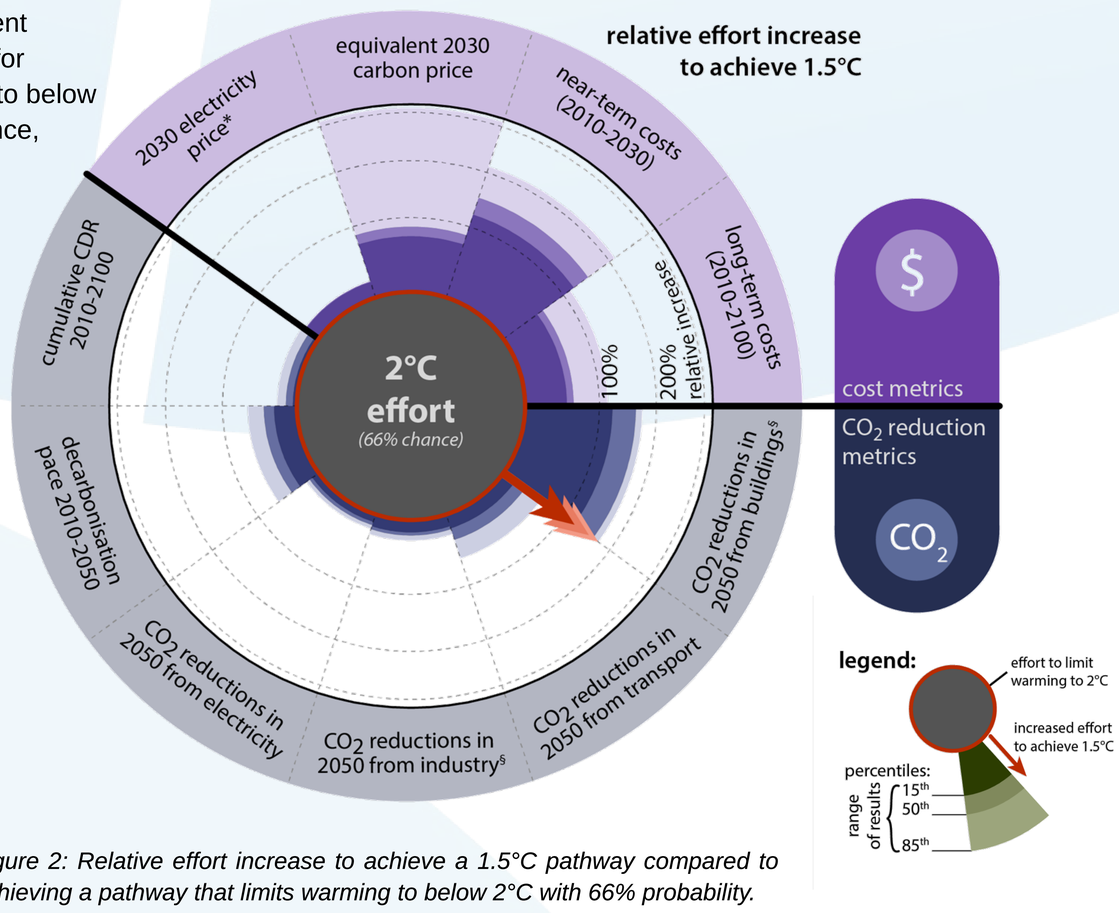

Figure 2: Relative effort increase to achieve a 1.5°C pathway compared to achieving a pathway that limits warming to below 2°C with 66% probability.

References

The IPCC AR5 WGIII Scenario Database is hosted at IIASA and available at: http://tntcat.iiasa.ac.at/AR5DB/
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Rogelj, J., G. Luderer, R. C. Pietzcker, E. Kriegler, M. Schaeffer, V. Krey & K. Riahi (2015). "Energy system transformations for limiting end-of-century warming to below 1.5°C." Nature Climate Change 5(6): 519-527.