Expert Report – Joeri Rogelj
4 March 2024

Background

1. My name is Joeri ROGELJ. I am a Professor of Climate Science & Policy at the Centre for Environmental Policy at Imperial College London, and also Director of Research at the Grantham Institute for Climate Change and Environment at Imperial College London.

2. I have published over 125 peer-reviewed scientific studies on the topic of climate change, greenhouse gas emissions reductions, climate change scenarios, low-carbon transformations and climate justice.

3. As an independent scientific expert, I am a long-serving contributor to international climate science assessments. I was one of the coordinating lead authors on the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C (SR1.5) for which I coordinated the chapter tasked with assessing mitigation scenarios compatible with limiting global warming to 1.5°C in the context of sustainable development[1]. I also served as a lead author on the IPCC's latest, sixth assessment (AR6), both on the chapter assessing the remaining carbon budget[2] and the annex on *Scenarios and Modelling Methods* dedicated to improving the transparency of modelling assumptions and enhance the communication of scenario results[3].

---

[1] Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, S., Kriegler, E., Mundaca, L., Séférian, R., Vilariño, M.V., 2018. Mitigation pathways compatible with 1.5°C in the context of sustainable development, in: Flato, G., Fuglestvedt, J., Mrabet, R., Schaeffer, R. (Eds.), *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*. IPCC/WMO, Geneva, Switzerland, pp. 93–174. https://www.ipcc.ch/sr15/chapter/chapter-2/

[2] Canadell, J.G., Monteiro, P.M.S., Costa, M.H., Cotrim da Cunha, L., Cox, P.M., Eliseev, A.V., Henson, S., Ishii, M., Jaccard, S., Koven, C., Lohila, A., Patra, P.K., Piao, S., Rogelj, J., Syampungani, S., Zaehle, S., Zickfeld, K., 2021. Global Carbon and other Biogeochemical Cycles and Feedbacks, in: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-5/

[3] Guivarch, C., Kriegler, E., Portugal-Pereira, J., Bosetti, V., Edmonds, J., Fischedick, M., Havlik, P., Jaramillo, P., Krey, V., Lecocq, F., Lucena, A.F.P., Meinshausen, M., Mirasgedis, S., O'Neill, B., Peters, G.P., Rogelj, J., Rose, S.,

4. The studies and reports I co-authored have been cited over 55,000 times globally[4].

5. I serve on the editorial boards of *Science* magazine, published by the American Association for the Advancement of Science (AAAS), and the journal *Environmental Research Letters*, published by publishing arm of the UK Institute of Physics.

6. I serve as one of the fifteen independent members of the European Scientific Advisory Board on Climate Change (ESABCC), established by the 2021 European Climate Law to provide independent scientific advice on climate policy in the European Union.

Code of Conduct

7. I deliver this report in my capacity as independent expert. Statements represent my expert assessment and not those of the institutions I serve or am affiliated with.

8. I confirm that the matters on which I have been asked to provide evidence are within my area of professional expertise.

My instructions

9. I have been asked by Milieudefensie c.s. to deliver an expert report on the topic of emission reduction scenarios as generated by integrated assessment models (IAMs), in response to evidence presented by Shell dated 15 December 2023.

10. The specific questions I have been asked are the following:

    a. What are the conceptual assumptions underlying scenarios and the models used to create them (called Integrated Assessment Models)?
    b. What does the IPCC scenario assessment do and how can we understand the IPCC vetting process?
    c. How can the changes between the IPCC Special Report on Global Warming of 1.5°C and the latest IPCC Sixth Assessment be understood, specifically in relation to the reported emissions reductions by 2030 for 1.5°C-compatible scenarios?
    d. How can the regional distribution of emissions reductions in 1.5°C-compatible scenarios be understood in the context of equity and fairness?
    e. What are the implications of assumed contributions from carbon dioxide removal in stringent mitigation scenarios?
    f. Could you verify the emissions reductions calculated by Shell's expert, Prof. Hawkes?

Saheb, Y., Strbac, G., Hammer Stromman, A., Van Vuuren, D.P., Zhou, N., 2022. IPCC, 2022: Annex III: Scenarios and modelling methods, in: *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Annex-III.pdf

[4] Based on total numbers reported here: Joeri Rogelj - Google Scholar

My expert assessment

A. Conceptual assumptions underlying scenarios generated by Integrated Assessment Models

11. To understand the strengths and limitations of the climate change mitigation scenario literature and mitigation objectives derived from it, it is useful to start by establishing a common understanding of the concept of scenarios, and of the core characteristics of the models that scientists use to create these scenarios. Here, I will draw from key descriptions and definitions from the latest assessment report of the Intergovernmental Panel on Climate Change (IPCC).

12. Scenarios are *"plausible description[s] of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships."* [5] The IPCC notes that *"scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions."*[6]

13. Researchers create mitigation scenarios[7] by running computer models, known in the climate research community as process-based Integrated Assessment Models (or IAMs for short). These models cover *"multiple sectors of the economy, such as energy, land use and land-use change; interactions between sectors; the economy as a whole; associated greenhouse gas (GHG) emissions and sinks; and reduced representations of the climate system"*[8]. They are used to understand how economic, social and technological development are linked, and what their impact is on global greenhouse gas emissions and the climate.

14. Scenarios serve the scientific community as tools for the quantitative exploration of the implications of policy choices, but the insights that can be derived from these scenarios depend on the validity, desirability and appropriateness of scenario assumptions.

15. Mitigation scenarios calculated with process-based IAMs are the outcome of a cost-effectiveness analysis, representing globally the cheapest way to stay within a carbon

---

[5] IPCC, 2022. Annex I: Glossary [van Diemen, R., J.B.R. Matthews, V. Möller, J.S. Fuglestvedt, V. Masson-Delmotte, C. Méndez, A. Reisinger, S. Semenov (eds)]., in: Shukla, P.R., Skea, J., Slade, R., Khourdajie, A.A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.020, pages 1812-1813

[6] See reference footnote 5

[7] Byers, E., Krey, V., Kriegler, E., Riahi, K., Schaeffer, R., Kikstra, J., Lamboll, R., Nicholls, Z., Sandstad, M., Smith, C., van der Wijst, K., Lecocq, F., Portugal-Pereira, J., Saheb, Y., Stromann, A., Winkler, H., Auer, C., Brutschin, E., Lepault, C., Müller-Casseres, E., Gidden, M., Huppmann, D., Kolp, P., Marangoni, G., Werning, M., Calvin, K., Guivarch, C., Hasegawa, T., Peters, G., Steinberger, J., Tavoni, M., van Vuuren, D., Al -Khourdajie, A., Forster, P., Lewis, J., Meinshausen, M., Rogelj, J., Samset, B., Skeie, R., 2022. AR6 Scenarios Database. https://doi.org/10.5281/zenodo.5886912

[8] See reference footnote 5, page 1805

budget or limit warming to a specified limit.[9] This fundamental assumption underlying the creation of mitigation scenarios has implications for their interpretation.[10]

16. In concrete terms, this underlying assumption of global cost-effectiveness means that emissions reductions are prescribed to happen where they are cheapest, both across countries and across sectors, starting from a specified start year onward (e.g. 2010, or 2020).[11]

17. The scientific literature describes how this approach results in low-income economies reducing a relatively larger share of emissions and carrying a relatively larger associated mitigation cost than developed economies.[12]

18. The distribution of mitigation effort in scenarios created based on this underlying cost-effectiveness assumption therefore disregards considerations of equity and fairness that are central to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.

19. The scientific literature highlights that *"without transfers, cost-efficient international climate policies tend to cause regressive income effects that deepen economic inequality."*[13] This shortcoming is often countered by the suggestion that IAMs do not prescribe who ultimately is expected to pay for emissions reductions. However, finance flows from developed to developing countries have been shown to be far below promised levels[14,15,16], which in themselves are only a fraction of the levels of international climate finance that would be required to balance out regional mitigation effort differences.[17]

---

[9] The IPCC Glossary (see footnote 5, page 1799) defines cost-effectiveness analysis as "a type of economic evaluation that compares the costs of different courses of action reaching the same outcome". It further goes to clarify that in the context of mitigation scenarios, "cost-effectiveness analysis focuses on comparing the costs of mitigation strategies designed to meet a prespecified climate change mitigation goal (e.g., an emission-reduction target or a temperature stabilisation target)".

[10] Riahi, K., Schaeffer, R., Arango, J., Calvin, K., Guivarch, C., Hasegawa, T., Jiang, K., Kriegler, E., Matthews, R., Peters, G.P., Rao, A., Robertson, S., Sebbit, A.M., Steinberger, J., Tavoni, M., Van Vuuren, D.P., 2022. Mitigation pathways compatible with long-term goals., in: Shukla, P.R., Skea, J., Slade, R., Khourdajie, A.A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.005

[11] See reference footnote 3, page 1875

[12] Bauer, N., Bertram, C., Schultes, A., Klein, D., Luderer, G., Kriegler, E., Popp, A., Edenhofer, O., 2020. Quantification of an efficiency–sovereignty trade-off in climate policy. *Nature* 588, 261–266. https://doi.org/10.1038/s41586-020-2982-5

[13] See reference footnote 12, page 262.

[14] United Nations Framework Convention on Climate Change. Biennial Assessment and Overview of Climate Finance Flows. Available on: https://unfccc.int/topics/climate-finance/resources/biennial-assessment-and-overview-of-climate-finance-flows [accessed: 20 February 2024]

[15] OECD (2022), *Aggregate Trends of Climate Finance Provided and Mobilised by Developed Countries in 2013-2020*, OECD Publishing, Paris, https://doi.org/10.1787/d28f963c-en

[16] USD 100 billion by 2020 was promised in the outcome of the 15th Conference of the Parties (COP15) that was held in 2009 in Copenhagen.

[17] Pachauri, S., Pelz, S., Bertram, C., Kreibiehl, S., Rao, N.D., Sokona, Y., Riahi, K., 2022. Fairness considerations in global mitigation investments. *Science* 378, 1057–1059. https://doi.org/10.1126/science.adf0067

20. The suggestion that a cost-effective yet inequitable distribution of regional emissions reductions would be fully resolved by finance flows also disregards several of the provisions that exist under the UNFCCC and the Paris Agreement. In particular, the UNFCCC and the Paris Agreement require developed countries to adopt national mitigation policies that demonstrate that developed countries – not developing countries – are taking the lead in reducing global greenhouse gas emissions.[18] Under the Paris Agreement countries have also decided that their successive national pledges[19] should represent a country's highest possible ambition – not their minimum contribution to a globally cheapest solution.[20]

21. What is considered a cost-effective level of mitigation for a given year in the future (e.g., the year 2030) changes as the assumed starting point for mitigation action is delayed. For example, if researchers create a scenario that starts a mitigation trajectory in 2020 compared to starting it in 2015, the inferred cost-effective emissions reductions by 2030 will differ. There are at least two reasons for this.

   a. First, the technological and economic context in the two start years will differ. For example, weak climate measures and policies implemented between 2015 and 2020 will affect which and how much carbon-intensive and polluting infrastructure was built up over this period (or alternatively, how much of that infrastructure was not retired in a timely manner). Starting emissions reductions from a world with a higher build-up of carbon intensive infrastructure in 2020 than was assumed in a cost-effective pathway starting from 2015 will result in IAMs suggesting higher costs to emissions reductions in the next decade. As a consequence, cost-effective pathways that start from later dates than 2015 preferentially suggest less near-term emissions by 2030.

   b. Second, simply having less time available to achieve emissions reductions by 2030 (e.g., 10 years starting from 2020 compared to 15 years starting from 2015) will mean that less emissions reductions can be achieved. In extremis, if starting from the year 2029, the suggested cost-effective emissions reductions by 2030 will be very minor. This dynamic is also one of the reasons why emissions reductions by 2030 in line with limiting warming to 1.5°C with no or limited overshoot are smaller in the most recent report of the IPCC published in 2022, compared to those suggested in the IPCC SR1.5 published in 2018. See also paragraph 34.b below.

22. The IPCC highlights that cost-effective pathways can provide a useful benchmark but may not reflect all real-world developments as IAMs represent social, political, and institutional factors in a rudimentary way only.[21]

23. One aspect in which the assumptions of IAMs are not reflective of the diversity of real-world contexts is the way in which the costs of finance vary across countries. The cost of capital is typically higher in developing countries where higher investment risks exist.[22]

---

[18] For example, see UNFCCC (1992) Article 4.2, and Paris Agreement (2015) Article 4.4.

[19] Known as 'nationally determined contributions' or NDCs.

[20] See Paris Agreement (2015), Article 4.3

[21] See reference footnote 10, pages 304–305

[22] International Energy Agency (2023), Cost of Capital Observatory. Available from: https://www.iea.org/reports/cost-of-capital-observatory [Accessed: 28 February 2024]

Representing these risks in an IAM results in cost-effective pathways suggesting deeper mitigation should take place in the developed world.[23]

24. When models carry out a cost-effectiveness analysis of mitigation measures over the entire 21st century, assumptions need to be made about how costs are aggregated over time. Typically, models will calculate the net present value of costs, by summing up the costs in any given year adjusted by a discount rate. The IPCC reports a range of assumed discount rates in IAMs of 3–5%[24], but a closer look at the IAMs with which the scenarios are created shows that predominantly a 5% discount rate was assumed in the creation of the stringent mitigation scenarios presented in the latest IPCC report[25]. Meanwhile, a dedicated study on this topic reported a range of 5–6% based on published IAM model documentation[26]. The choice of this discount rate affects the suggested cost-effective trajectory of mitigation, with high discount rates favouring reductions later in the century to the detriment of deep emissions reductions in the near term (e.g., until 2030).

25. The scientific literature identifies several reasons why lower discount rates in the range of 2–3% should be considered when modelling mitigation scenarios in line with limiting warming to 1.5°C. These reasons include considerations of intergenerational equity because assuming high discount rates will decrease the mitigation effort of current generations at the expense of future ones.[27] The high discount rates assumed by the IAMs represent an implicit value judgement about intergenerational equity that is infused in all scenarios assessed by IPCC. Although the effect on a specific pathway varies, assuming a lower discount rate will consistently lead to stronger emissions reductions being suggested for the near term.

26. An important limitation of the cost-effectiveness analysis that underlies mitigation scenarios as assessed by the IPCC is that the IAMs that are used to create these scenarios ignore the costs associated with projected or avoided climate impacts[28]. This structural shortcoming has two important implications:

---

[23] Iyer, G.C., Clarke, L.E., Edmonds, J.A., Flannery, B.P., Hultman, N.E., McJeon, H.C., Victor, D.G., 2015. Improved representation of investment decisions in assessments of CO2 mitigation. *Nature Climate Change* 5, 436–440. https://doi.org/10.1038/nclimate2553

[24] See reference footnote 3, page 1875

[25] See references footnotes 3, 7, and 10. This group of scenarios that are labelled as C1 are explained in the Summary for Policymakers (SPM) of the Working Group 3 Contribution to the Sixth Assessment of the IPCC. The SPM clarifies that *"Category C1 comprises modelled scenarios that limit warming to 1.5°C in 2100 with a likelihood of greater than 50%, and reach or exceed warming of 1.5°C during the 21st century with a likelihood of 67% or less. In this report, these scenarios are referred to as scenarios that limit warming to 1.5°C (>50%) with no or limited overshoot. Limited overshoot refers to exceeding 1.5°C global warming by up to about 0.1°C and for up to several decades"* and that *"scenarios in this category are found to have simultaneous likelihood to limit peak global warming to 2°C throughout the 21st century of close to and more than 90%"*.

[26] Emmerling, J., Drouet, L., Wijst, K.-I. van der, Vuuren, D. van, Bosetti, V., Tavoni, M., 2019. The role of the discount rate for emission pathways and negative emissions. *Environmental Research Letters* 14, 104008. https://doi.org/10.1088/1748-9326/ab3cc9

[27] See reference footnote 26

[28] See reference footnote 3, page 1875

a. The costs of mitigation are systematically overestimated because benefits of avoided climate impacts are disregarded, providing a skewed picture of the societal burden of climate action.[29]

b. Meanwhile, the cost-effective near-term emission reductions (for 2030 and 2040) are systematically underestimated. If benefits of avoided impacts are adequately accounted for, research suggests a strengthening of near-term action in cost-effective mitigation pathways.[30]

B. IPCC assessment and vetting of mitigation scenarios

27. The task of the IPCC is to *"assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation"*[31]. As part of that mandate, they also assess the mitigation scenario literature.

28. The mitigation scenario assessment by the IPCC presents a clear recognition and discussion of its strengths and limitations, as well as a quantitative analysis of the mitigation scenarios available in the literature.[32]

29. As part of the quantitative analysis of mitigation scenarios, the IPCC also carries out a vetting procedure[33]. This vetting procedure is a purely technical step that checks if key indicators related to global emissions and energy are within reasonable ranges over the recent historical period.[34] This step also means, however, that scenarios that describe worlds in which stringent mitigation action in line with limiting warming to 1.5°C was assumed to start before 2020 (e.g., in 2015) are removed from the scenario set because of a lack of 1.5°C-compatible mitigation action in the real world up to the year 2020.[35]

30. While checking the technical quality of scenario data submitted to the IPCC, the IPCC vetting process does not address any issues of conceptual bias or limitations in the

---

[29] Köberle, A.C., Vandyck, T., Guivarch, C., Macaluso, N., Bosetti, V., Gambhir, A., Tavoni, M., Rogelj, J., 2021. The cost of mitigation revisited. *Nature Climate Change* 11, 1035–1045. https://doi.org/10.1038/s41558-021-01203-6

[30] Schultes, A., Piontek, F., Soergel, B., Rogelj, J., Baumstark, L., Kriegler, E., Edenhofer, O., Luderer, G., 2021. Economic damages from on-going climate change imply deeper near-term emission cuts. *Environmental Research Letters* 16, 104053. https://doi.org/10.1088/1748-9326/ac27ce

[31] Principles Governing IPCC Work, Paragraph 2, https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-principles.pdf [accessed: 20 February 2024]

[32] See the broader evidence and discussion in the references in footnotes 3, 7, and 10, as well as Lecocq, F., Winkler, H., Daka, J.P., Fu, S., Gerber, J.S., Kartha, S., Krey, V., Lofgren, H., Masui, T., Mathur, R., Portugal-Pereira, J., Sovacool, B.K., Vilariño, M.V., Zho, N., 2022. Mitigation and development pathways in the near- to mid-term., in: Shukla, P.R., Skea, J., Slade, R., Khourdajie, A.A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.006

[33] As documented in section A.III.II.3.1 of the reference in footnote 3.

[34] Table 11 in the reference in footnote 3 provides an overview of the vetting criteria.

[35] See reference footnote 3, page 1884

scenarios. For example, the structurally embedded model assumptions related to cost-effectiveness and choice of discount rate that result in specific scenario characteristics are not checked, let alone reviewed or corrected for. As the IPCC vetting process is impartial to these aspects of IAMs, scenarios that have passed the IPCC vetting are therefore conceptually equally vulnerable to the pitfalls and limitations related to international and intergenerational equity introduced above.

31. Similarly, these embedded limitations are not resolved by relying on a larger set of scenarios derived with the same models or based on similar fundamental assumptions.

C. Changes in emissions reductions by 2030 between 1.5°C scenarios in IPCC SR1.5 and IPCC AR6

32. The IPCC Special Report on Global Warming of 1.5°C (SR1.5), published in 2018, reported the emission characteristics of a category of scenarios that limits warming to 1.5°C with no or limited overshoot.[36] All scenarios in this category are characterised by keeping global warming close to 1.5°C, with a maximum exceedance of about 0.1°C tolerated (as per the 'limited overshoot' of the scenario category name). The Mitigation Report of IPCC Sixth Assessment (AR6), published in 2022, updated these emission reduction characteristics based on an updated set of scenarios.[37]

33. Given that almost 5 years have passed between the publication of the SR1.5 and the AR6 during which global CO_2 emissions have continued to deplete the very small remaining carbon budget in line with keeping warming below 1.5°C[38], one would expect that the required 1.5°C-aligned emissions reductions by 2030 would be deeper in the AR6 report compared to the SR1.5. However, surprisingly maybe, the AR6 often suggests weaker emissions reductions by 2030 than earlier estimates by the IPCC.

34. Several reasons for this have been identified, including by the IPCC:

a. Although referred to by the IPCC by the same name, the scenarios in IPCC AR6 category C1 (limiting warming to 1.5°C with no or limited overshoot) are less ambitious than the scenarios in the category with the same name of the IPCC SR1.5. The reason for this is simple. The scenarios informing the IPCC SR1.5 assessment were centred

---

[36] Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, S., Kriegler, E., Mundaca, L., Séférian, R., Vilariño, M.V., 2018. Mitigation pathways compatible with 1.5°C in the context of sustainable development, in: Flato, G., Fuglestvedt, J., Mrabet, R., Schaeffer, R. (Eds.), *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*. IPCC/WMO, Geneva, Switzerland, pp. 93–174. https://www.ipcc.ch/sr15/chapter/chapter-2/

[37] See reference footnote 36, Table 2.1 on page 100, and reference footnote 10, Table 3.1 on page 305. See also footnote 25 for more details about these scenarios.

[38] Forster, P.M., Smith, C.J., Walsh, T., Lamb, W.F., Lamboll, R., Hauser, M., Ribes, A., Rosen, D., Gillett, N., Palmer, M.D., Rogelj, J., von Schuckmann, K., Seneviratne, S.I., Trewin, B., Zhang, X., Allen, M., Andrew, R., Birt, A., Borger, A., Boyer, T., Broersma, J.A., Cheng, L., Dentener, F., Friedlingstein, P., Gutiérrez, J.M., Gütschow, J., Hall, B., Ishii, M., Jenkins, S., Lan, X., Lee, J.-Y., Morice, C., Kadow, C., Kennedy, J., Killick, R., Minx, J.C., Naik, V., Peters, G.P., Pirani, A., Pongratz, J., Schleussner, C.-F., Szopa, S., Thorne, P., Rohde, R., Rojas Corradi, M., Schumacher, D., Vose, R., Zickfeld, K., Masson-Delmotte, V., Zhai, P., 2023. Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence. *Earth System Science Data* 15, 2295–2327. https://doi.org/10.5194/essd-15-2295-2023

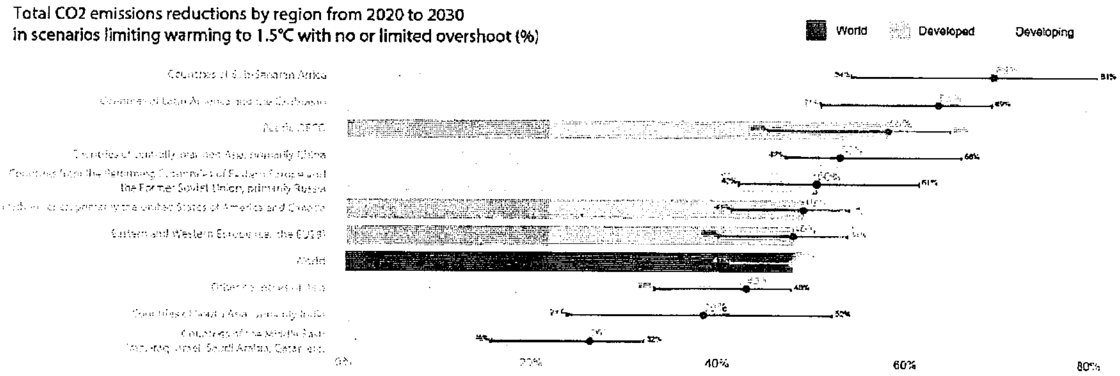
around 1.5°C of maximum warming, but most of the scenarios informing the AR6 assessment exceed 1.5°C and have a maximum warming closer to 1.6°C, which is the cut-off value for still being considered having 'limited overshoot'.[39] The emissions reductions for the lowest scenario category reported in the most recent IPCC AR6 are therefore for scenarios that have a larger likelihood of failing to keep maximum warming to 1.5°C.

b. In addition, IPCC also ascribes the difference in part to the change in starting year of the scenarios (2020 in AR6 versus 2015 in SR1.5) and the fact that historical emissions have increased from 2015 to 2020. This increase in the starting level of emissions means that less stringent emissions reductions are suggested in the near term (i.e., by 2030) in the cost-effective scenarios in AR6.[40]

D. Regional distribution of emissions reductions in 1.5°C-compatible scenarios

35. To clarify the global and regional evolution of emissions in line with limiting warming to 1.5°C with no or limited overshoot (also referred to as category C1 scenarios), I use the scenario data contained in the public database accompanying the IPCC AR6 assessment[41]. Figure 1 below shows how reductions in total CO_2 emissions are distributed across 9 world regions in the scenarios from the IPCC category C1 that limit warming to 1.5°C with no or limited overshoot.

Figure 1 | Illustration of regional total CO_2 emission reduction contributions in scenarios that limit warming to 1.5°C with no or limited overshoot (IPCC category C1).



36. From 2020 to 2030, cost-effective pathways in the C1 category suggest that several key developing regions lead the world in their reduction of total CO_2 emissions. In particular, the visual shows how Sub-Saharan Africa as well as South America and the Caribbean are

---

[39] Specifically, IPCC highlights in Annex III to the Working Group 3 Report of the Sixth Assessment (see reference footnote 3), Section A.III.II.3.2.1, that the median warming across all scenarios in the C1 category of scenarios with no or limited overshoot of 1.5°C in AR6 is estimated at 1.58°C, while in SR1.5 it was 1.52°C.

[40] See reference footnote 3, Section A.III.II.3.2.1, page 1889, and reference footnote 10, Executive Summary on page 298 and Section 3.3.2.3 on page 329.

[41] See footnote 25 for a detailed explanation of the scenarios.

assumed to lead all developed regions in their regional total CO_2 reductions. China is also assumed to reduce emissions by a larger percentage between 2020 and 2030 than North America and Europa.

37. The ways in which these near-term emissions reductions are achieved differs across regions, but there are a few key drivers that can be identified. In particular:

a. Both in developed and developing regions the highest relative reductions in fossil fuel use between 2020 and 2030 are because coal use is reduced. Across all 9 regions coal use is assumed to be reduced in cost-effective C1 pathways by at least 50% and up to about 90%. These relative coal reduction percentages show a clear trend but are best understood when considering how the starting points of different regions vary. In particular, the share of primary energy supply that is currently covered by coal varies strongly across regions.[42] For example, in 2022, the economies of China, India, Indonesia, Vietnam, and South Africa relied for 55%, 55%, 45%, 45%, and 69%, respectively, on coal for covering their primary energy demand. This contrasts to the share of coal in the primary energy mix of developed countries and regions such as the US or Europe with 10% and 13%, respectively. In key developing regions, the CO_2 reductions assumed under a cost-effective 1.5°C-compatible scenario are therefore to a large extent driven by assumed reductions in coal, whereas in developed country regions they represent a much smaller part of the regional emissions reductions.

b. In addition, the CO_2 reductions in developing regions assume in many cases (i.c., in Sub-Saharan Africa, Latin America, and Asia) a very sizeable contribution from reductions in CO_2 emissions from agriculture, forestry and land use (AFOLU), mainly through the halting of deforestation, as well as through restauration, reforestation or afforestation.[43]

38. The suggested deep reductions in coal use and AFOLU emissions are the logical result of the cost-effectiveness approach followed by IAMs. Indeed, coal is the most carbon-intensive of all fossil fuels and there are lower-carbon technologies available for its substitution. Based on cost and emissions considerations only, the suggestion to move away from coal is a logical one. Also, AFOLU emissions are typically assumed to be able to be reduced at low cost and at a high pace as the halting of deforestation is not governed by infrastructural lock-in or inertia that is present in, for example, the energy system.

39. The challenges and institutional capacities for transitioning away from coal are very distinct in some of the developing countries compared to in developed countries. The International Energy Agency developed a 'Coal Transition Exposure Index' that illustrates through the combination of several indicators how challenging a coal transition would be for a country.[44] China, India, Indonesia, Vietnam, and South Africa rank among the top six

---

[42] Energy Institute (2023) Statistical Review of World Energy 2023. Available from https://www.energyinst.org/statistical-review/resources-and-data-downloads [Accessed: 23 Feb 2024]. Primary energy shares for non-fossil-based energy are calculated based on the equivalent amount of fossil fuel input to required to generate that amount of electricity in a standard thermal power plant.

[43] Restauration refers to reversing forest degradation, reforestation to the planting of forest in areas that have been deforested in the (recent) past, and afforestation to the planting of forest in areas where there was previously none.

[44] International Energy Agency (2022) *Coal in Net Zero Transitions.* Paris, France. Available from: https://www.iea.org/reports/coal-in-net-zero-transitions [Accessed: 23 February 2024]

countries with challenges regarding a coal transition according to this indicator. Cost-effectiveness analysis by IAMs suggests strong contributions of reductions in coal and AFOLU emissions in developing countries but these calculations do not account for some of the institutional challenges illustrated by the Coal Transition Exposure Index.

40. The regional emissions reductions that are suggested by IAMs as the globally cost-effective distribution for meeting a climate goal therefore come with important caveats. In particular, in absence of further consideration of the real-world context that is currently not modelled by IAMs, this globally cost-effective approach distributes efforts in a way that appears to be counter to the decisions and agreement of countries under the UNFCCC and the Paris Agreement (see also paragraph 20). In particular, the decisions that developed countries should take the lead in emissions reductions contrasts strongly with the deepest near-term emissions reductions until 2030 being assumed in the poorest regions such as Sub-Saharan Africa.

E. Impact of carbon dioxide removal assumptions on scenarios

41. Mitigation scenarios can use all the mitigation measures that are represented in the IAMs with which they are created. Some of these measures are speculative or can have important sustainability trade-offs when deployed at large scale.[45,46] A special class of these measures is carbon dioxide removal (CDR). CDR refers here to any measure that results in an active removal of carbon dioxide (CO_2) from the atmosphere followed by durable storage of this CO_2 so that it remains out of the atmosphere. Some CDR measures are technology based, such as the use of chemical filters to extract CO_2 from ambient air, while others are nature-based, such as afforestation.

42. Many if not all technology-based CDR methods are still speculative, currently not deployed at large scale and associated with high costs[47]. Combined with the high discount rate assumed in IAMs, their main contribution in mitigation scenarios is therefore projected to be in the second half of the century and beyond.

43. CDR is deployed for at least two reasons: first, to achieve net zero CO_2 emissions by balancing any remaining emissions from other sectors that cannot be avoided, and second, to achieve net negative CO_2 emissions and try to reverse global warming.

---

[45] Summary for Policymakers, in: Shukla, P.R., Skea, J., Slade, R., Khourdajie, A.A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.001

[46] The term, sustainability trade-offs, refers to cases where the achievement of sustainability goals such as the UN Sustainable Development Goals (SDGs) for 2030 are potentially undermined by the deployment of a specific mitigation measure. For example, see Section D1 and Figure SPM.8 in reference footnote 45.

[47] Smith, S.M., Geden, O., Nemet, G.F., Gidden, M.J., Lamb, W.F., Powis, C., Bellamy, R., Callaghan, M.W., Cowie, A., Cox, E., Fuss, S., Gasser, T., Grassi, G., Greene, J., Lück, S., Mohan, A., Müller-Hansen, F., Peters, G.P., Pratama, Y., Repke, T., Riahi, K., Schenuit, F., Steinhauser, J., Strefler, J., Valenzuela, J.M., Minx, J.C., 2023. *The State of Carbon Dioxide Removal - 1st Edition. The State of Carbon Dioxide Removal.* https://doi.org/10.17605/OSF.IO/W3B4Z, pages 10, 16, and Table 1.1 on pages 18–19

44. Global warming could be gradually reduced again by achieving and sustaining net negative global CO_2 emissions through the large-scale deployment of CDR but this leads to greater feasibility and sustainability concerns compared to pathways without overshoot.[48] While the evidence supports that global temperatures can be brought down again if CO_2 is removed from the atmosphere at a global scale,[49] a temporary exceedance of a temperature limit (referred to as overshoot) comes with a set of fundamental risks, all of which increase significantly with the magnitude and duration by which the intended level of warming (i.c., 1.5°C) is exceeded.[50] These risks include:

a. While global temperatures can be reversed by removing CO_2 from the atmosphere, several climate impacts such as ecosystem and biodiversity loss are irreversible and other impacts such as sea level rise are irreversible for centuries to millennia. Moreover, the long-term severity of sea-level rise increases both as a function of the magnitude and the duration of overshoot.[51,52] During the period of overshoot, society is also exposed to higher risks of so-called climate tipping points occurring.[53]

b. Other risks relate to the technical achievability and sustainability of assumed anthropogenic CO_2 removals. As a central estimate[54], 220 billion tons of CO_2 ($GtCO_2$) have to be removed from the atmosphere and permanently stored in geological storage by CDR to reverse 0.1°C of global warming. Comparing this to sustainable levels of CDR[55], this already shows that it will be difficult to achieve this amount of net removal over the course of this century while not infringing on sustainability limits. Higher levels of overshoot not only make the scale of CDR more challenging, but also

---

[48] See reference footnote 45

[49] IPCC, 2021. Summary for Policymakers. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/9781009157896.001

[50] See IPCC, 2023: Summary for Policymakers. In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, doi: 10.59327/IPCC/AR6-9789291691647.001, Section B.7, page 23

[51] See reference footnote 49, page 21, and footnote 50, page 23, which says *"Overshooting 1.5°C will result in irreversible adverse impacts on certain ecosystems with low resilience, such as polar, mountain, and coastal ecosystems, impacted by ice-sheet melt, glacier melt, or by accelerating and higher committed sea level rise."*

[52] For example, one study showed how delayed action in the near term, leading to a higher overshoot, results to higher committed sea-level rise. See Mengel, M., Nauels, A., Rogelj, J., Schleussner, C.-F., 2018. Committed sea-level rise under the Paris Agreement and the legacy of delayed mitigation action. *Nature Communications* 9, 601. https://doi.org/10.1038/s41467-018-02985-8

[53] See reference footnote 50, key message B.3.2: "**B.3.2** The likelihood and impacts of abrupt and/or irreversible changes in the climate system, including changes triggered when tipping points are reached, increase with further global warming *(high confidence)*. As warming levels increase, so do the risks of species extinction or irreversible loss of biodiversity in ecosystems including forests *(medium confidence)*, coral reefs *(very high confidence)* and in Arctic regions *(high confidence)*. At sustained warming levels between 2°C and 3°C, the Greenland and West Antarctic ice sheets will be lost almost completely and irreversibly over multiple millennia, causing several metres of sea level rise *(limited evidence)*. The probability and rate of ice mass loss increase with higher global surface temperatures *(high confidence)*."

[54] This estimate takes the central IPCC estimate of the amount of warming expected per ton of CO_2 emitted by human activities, which is 0.45°C per 1000 $GtCO_2$, see reference footnote 2.

[55] Deprez, A., Leadley, P., Dooley, K., Williamson, P., Cramer, W., Gattuso, J.-P., Rankovic, A., Carlson, E.L., Creutzig, F., 2024. Sustainability limits needed for CO2 removal. *Science* 383, 484–486. https://doi.org/10.1126/science.adj6171, assuming maximum levels of CDR through bioenergy and carbon capture and storage (BECCS) and nature-based removals that stay within low sustainability risk levels.

undermine the effectiveness and permanence of removals that rely on ecosystems to capture and store carbon.[56]

c. Finally, overshoot risks are often underestimated as they are typically discussed for central estimates of warming. For example, the overshoot considered in IPCC C1 scenarios that limit warming to 1.5°C with no or limited overshoot applies to the central (median or 50%) estimate of future global warming. A scenario with a 50% chance of limiting warming to 1.5–1.6°C has simultaneously a 1-in-10 chance that warming ends up above 2°C.[57] This in itself can already be considered a risky bet. Every additional 0.1°C of overshoot of 1.5°C will result in an increase in the chances that even 2°C of warming is exceeded. For example, scenarios that lead to a central warming estimate over the course of this century of about 1.7°C simultaneously imply about a 1-in-5 to 1-in-4 chance that 2°C of warming is exceeded.[58]

45. Assumptions about the scale of contributions of CDR can have important implications on the shape and characteristics of mitigation scenarios, and their associated risk profile.

a. For example, assuming that large-scale CDR will become available in the second half of the century can lead to mitigation deterrence in scenarios, where near-term emissions reductions are postponed in the hope to make up for them through CDR at a later point in the century.[59]

b. The assumed availability of CDR in the near term also leads to strong mitigation deterrence of gross emission reductions in scenarios. Indeed, if CDR is assumed to be available in the near term at low costs (for example, through deep reductions in AFOLU emissions) fewer reductions in the sources of greenhouse gas emissions are required to reach net zero emissions. Such deep reductions in AFOLU emissions are assumed, for example, in scenarios that limit warming to 1.5°C with no or limited overshoot (IPCC category C1). These C1 scenarios assume a global elimination of all agriculture, forestry and other land-use (AFOLU) related CO_2 emissions between 2019 and 2030, and project that sector to remove about half of its current magnitude of emissions by 2050.[60] A similar risk exists when assuming large-scale availability of carbon capture and storage combined with continued fossil fuel use.

---

[56] Babiker, M., Berndes, G., Blok, K., Cohen, B., Cowie, A., Geden, O., Ginzburg, V., Leip, A., Smith, P., Sugiyama, M., F Yamba, 2022. Cross-sectoral perspectives, in: Shukla, P.R., Skea, J., Slade, R., Khourdajie, A.A., van Diemen, R., McCollum, D., Pathak, M., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.005, Section 12.3.2
[57] See footnote 25.
[58] See Table SPM.2 in reference footnote 45, with data for scenario category C2 (return warming to 1.5°C (>50%) after a high overshoot) and scenario category C3 (limit warming to 2°C (>67%)) showing that the central estimate of peak warming in these scenario categories is 1.7°C in both cases and the probability that 2°C is exceeded 18% and 24%, respectively.
[59] Note that because the IPCC 1.5°C scenarios that limit warming to 1.5°C with no or limited overshoot are selected based on the maximum level of warming they reach at any point over the course of the century, the impact of this risk is limited across the set of C1 scenarios.
[60] See Table 3.6 in reference footnote 10, with AFOLU CO_2 emissions in C1 scenarios changing by -100% between 2019 and 2030 (interquartile range -105% to -95%) and by -150% between 2019 and 2050 (interquartile range -200% to -100%).

46. The scientific literature has explored these risks and highlights the *"major concerns around the scale of CDR deployment in many low-carbon scenarios, and the risk that anticipated future CDR could dilute incentives to reduce emissions now"* [61], and shows how *"the pathway for the 2020s is highly sensitive to assumptions around CDR availability"*[62]. One study[63] found that if the uncertainty in the delivery of CDR is included in the cost-effective analysis of 1.5°C scenarios, the resulting calculations would suggest global cost-effective CO_2 emissions in 2030 that are about 10 $GtCO_2$ lower than if no uncertainty around CDR would be assumed[64]. In other words, when accounting for the uncertainty in CDR, a 1.5°C-aligned global emissions reduction target for 2030 relative to 2020 would have to be about 25 percentage points lower[65] compared to what IAMs otherwise suggest.

47. The deployment of CDR measures also comes with risks for sustainability, as the land required for bioenergy production or afforestation can compete with other uses, including food production and biodiversity protection. A recent study assessed the sustainability risks for different levels of CDR deployment[66], expanding on the technical assessment of the latest IPCC assessment with greater attention to the ecological, biological and societal impact of land-based CDR. For a set of land-based CDR methods that are referred to as 'nature-based' measures – and which include afforestation, reforestation and agroforestry – the study identified a transition from low to medium sustainability risk at 2.6 $GtCO_2$/year of removal by these measures, and from medium to high sustainability risk at 5.1 $GtCO_2$/year. IAMs very often only cover afforestation and reforestation in their nature-based CDR portfolio, and for this subset of CDR measures the border from low to medium and medium to high sustainability risks is set at 1.3 $GtCO_2$/year and 3.8 $GtCO_2$/year, respectively. The upper bounds of medium risk are considered the limit between acceptable and unacceptable impacts and risks to biodiversity, water availability, biogeochemical cycles, and competition for food production.[67]

48. Given all these challenges and risks with the assumption of CDR in mitigation scenarios, scholars have argued that pursuing strategies that rely heavily on large amounts of CDR may contravene norms and principles of international law[68], adding further evidence in support of prudent and cautious consideration of CDR in mitigation strategies.

---

[61] Grant, N., Hawkes, A., Mittal, S., Gambhir, A., 2021. Confronting mitigation deterrence in low-carbon scenarios. *Environmental Research Letters* 16, 064099. https://doi.org/10.1088/1748-9326/ac0749

[62] See reference footnote 61

[63] Grant, N., Hawkes, A., Mittal, S., Gambhir, A., 2021. The policy implications of an uncertain carbon dioxide removal potential. *Joule* 5, 2593–2605. https://doi.org/10.1016/j.joule.2021.09.004

[64] With global CO2 emissions in 2010 of the order of 40 GtCO2, this represents a strengthening of the cost-effective 1.5°C-compatible emissions reduction target for 2030 with about 25 percentage points.

[65] Based on historical global CO_2 emissions data for the year 2020 of 39.3 $GtCO_2$ from the Global Carbon Project. Friedlingstein, *et al*, 2023. Global Carbon Budget 2023. *Earth System Science Data* 15, 5301–5369. https://doi.org/10.5194/essd-15-5301-2023

[66] See reference in footnote 55.

[67] For bioenergy with carbon capture and storage (BECCS), the study set the border between low and medium sustainability risks at 0.7 or 1.2 $GtCO_2$/year[67] of BECCS deployment, depending on how efficiently biomass is converted into energy and how efficiently the CO_2 is captured. The border between medium and high sustainability risks was set at 1.3 to 2.8 $GtCO_2$/year of BECCS removals.

[68] Stuart-Smith, R.F., Rajamani, L., Rogelj, J., Wetzer, T., 2023. Legal limits to the use of CO2 removal. *Science* 382, 772–774. https://doi.org/10.1126/science.adi9332

F. Verification of emissions reductions calculated by Shell's expert

49. I have been asked to verify the emissions reductions presented in the second Expert Report of Professor Adam Hawkes that was submitted by Shell and dated 15 December 2023. In what follows this report will be referred to with the acronym ER-AH2.

50. This verification focusses on the calculation of numerical values in ER-AH2 that are derived from scenarios available in the database accompanying the IPCC Sixth Assessment Report[69], and as presented most prominently in ER-AH2 Tables 1 and A.1. The absence of additional comments on other statements by Prof. Hawkes in ER-AH2 does neither imply my agreement with them nor my confirmation of their accuracy.

51. To verify the accuracy of the values reported in ER-AH2, I systematically follow the steps laid out in Appendix A, paragraph 6, of ER-AH2 to select scenarios aligned with certain characteristics. For ease of reference, these steps are reproduced in full in Annex I to this report. I have verified the ER-AH2 values for scenarios based on the filtering by Prof. Hawkes and one additional set[70]. Following good scientific practice, I have ensured all calculations were peer-reviewed thanks to the support of two colleagues, Jarmo Kikstra[71] and Dr Elina Brutschin[72], who assisted in the coding, reviewing and execution of the verification calculations. It is because of this internal peer-review process that I have good confidence in the correctness of these verification calculations.

52. Diligently following the steps laid out in ER-AH2 does not allow the values presented in the expert report submitted by Shell to be reproduced.

53. Table AI.1 in Annex I to this report shows the discrepancies between Shell's ER-AH2 numbers and those calculated by me. For example, this independent verification shows that ER-AH2 underreports reductions in oil and gas between 2020 and 2030 in scenarios that limit warming to 1.5°C with no or limited overshoot. Discrepancies between ER-AH2 and the verification calculations are large, with some of the oil and gas reductions reported by ER-AH2 being 10 to 20 percentage points too weak.

54. Before looking deeper into the corrected reduction values, some further reflections can be made regarding the ER-AH2 analysis presented by Shell.

a. First, ER-AH2 presents emission reduction values for specific groups of scenarios in its Table 1. These include:

i. **IPCC C1 scenarios:** limiting warming to 1.5°C with no or limited overshoot at 50% probability, which simultaneously have close to and more than 90% likelihood to limit peak global warming to 2°C throughout the 21st century[73].

---

[69] See reference footnote 7.
[70] See paragraph 54.a.iii
[71] Contributing Author: IPCC AR6 WG3 Summary for Policymakers (2022); IPCC AR6 WG3 Chapter 3 (2022) – Mitigation Pathways Compatible with Long-term Goals; and IPCC AR6 WG3 Annex III (2022) – Scenarios and Modelling Methods
[72] Contributing Author: IPCC AR6 WG3 Chapter 3 (2022) – Mitigation Pathways Compatible with Long-term Goals
[73] See full explanation in footnote 25

ii. **IPCC C1a scenarios**: limiting warming to 1.5°C with no or limited overshoot at 50% probability while achieving net zero greenhouse gas emissions in the second half of the century.
iii. **A subset of IPCC C1a scenarios**: limiting warming to 1.5°C with no or limited overshoot at 50% probability and to 2°C with greater than 90% probability over whole century, while achieving net zero greenhouse gas emissions in the second half of the century (subset based on reference in footnote *74*).

Based on my scenario and modelling expertise, the category of IPCC C1 scenarios would be the most recommendable and least biased choice as a starting point for further filtering (see paragraph 54.b below) and to inform near-term emissions reductions in line with limiting warming to 1.5°C with no or limited overshoot. This recommendation is based on considerations of both the strengths and limitations of the cost-effective scenarios available in the literature. Scenarios available in the literature show archetypical behaviour due to the way in which they are created by IAMs[75]. For example, an IAM pursues the cheapest, cost-effective path of action and will therefore never opt to implement emissions reductions that would not be necessary to meet the minimum design specifications defined by a modeller (e.g., this design specification can be: keep warming to precisely 1.5°C by 2100 by staying within a specified carbon budget). In case of a scenario with ambitious near-term emissions reductions (of which there are several examples in the IPCC C1 category[76]), this can imply that emissions reductions beyond net zero greenhouse gas emissions are not required for the IAM. The early action in the scenario resulted in a low warming peak during the 21st century and as a result the IAM does not need to try to reverse warming very rapidly to still stay within 1.5°C of warming by 2100. Achieving net zero greenhouse gas emissions was in that case not a requirement for the IAM [77]. This is a clear example of structural design bias in scenarios. In reality, ambitious near-term emissions reductions show technically possible reductions that are not precluding the achievement of even lower emissions multiple decades into the future. Importantly, exclusion of scenarios that do not achieve net zero greenhouse gas emissions over the course of the 21st century from the IPCC C1 scenario category, will typically result in

---

[74] Schleussner, C.-F., Ganti, G., Rogelj, J., Gidden, M.J., 2022. An emission pathway classification reflecting the Paris Agreement climate objectives. *Communications Earth & Environment* 3, 1–11. https://doi.org/10.1038/s43247-022-00467-w

[75] For example, see: Rogelj, J., Huppmann, D., Krey, V., Riahi, K., Clarke, L., Gidden, M., Nicholls, Z., Meinshausen, M., 2019. A new scenario logic for the Paris Agreement long-term temperature goal. *Nature* 573, 357–363. https://doi.org/10.1038/s41586-019-1541-4; and Riahi, K., Bertram, C., Huppmann, D., Rogelj, J., Bosetti, V., Cabardos, A.-M., Deppermann, A., Drouet, L., Frank, S., Fricko, O., Fujimori, S., Harmsen, M., Hasegawa, T., Krey, V., Luderer, G., Paroussos, L., Schaeffer, R., Weitzel, M., van der Zwaan, B., Vrontisi, Z., Longa, F.D., Després, J., Fosse, F., Fragkiadakis, K., Gusti, M., Humpenöder, F., Keramidas, K., Kishimoto, P., Kriegler, E., Meinshausen, M., Nogueira, L.P., Oshiro, K., Popp, A., Rochedo, P.R.R., Ünlü, G., van Ruijven, B., Takakura, J., Tavoni, M., van Vuuren, D., Zakeri, B., 2021. Cost and attainability of meeting stringent climate targets without overshoot. *Nature Climate Change* 11, 1063–1069. https://doi.org/10.1038/s41558-021-01215-2

[76] For example, see reference footnote 45, Table SPM.2, where a subset of scenarios from C1 (called C1b) achieves deep emissions reductions by 2030, but no net zero greenhouse gas emissions over the course of the century. This contrasts with the C1a subset of scenarios which sees less pronounced reductions by 2030 but reaches net zero greenhouse gas emissions in the second half of the century.

[77] Note: reaching net zero greenhouse gas emissions as defined under the UNFCCC and in IAMs results in a peak and gradual decline of global warming. See reference footnote 49.

the exclusion of scenarios with ambitious near-term emissions reductions. It is thus recommended to use the IPCC C1 scenarios as a guide or starting point to avoid biasing reduction percentages by 2030 towards weak near-term action.

b. Second, Shell's ER-AH2 calculations use several filters to narrow down the analysis to scenarios that are considered more sustainable or feasible (see Annex I of this report for details). The narrowing down of a scenario set in this way is a reasonable and well-established approach. While ER-AH2 assumes feasibility or sustainability filters for afforestation and bioenergy use in 2050 and on carbon sequestration via carbon capture and storage (CCS) in 2030, it does not consider limits to the scale of CCS in 2050 despite the IPCC reporting on them in their latest assessment[78]. It is recommended to consider the scale of CCS up to mid-century when selecting scenarios for the determination of reduction benchmarks, because the use of scenarios that rely on unrealistic amounts of CCS throughout the century would bias calculations towards weaker reductions for fossil fuels than would otherwise be required.

c. Third, in some cases very few remaining scenarios remain after filtering, and estimating statistical values such as the median becomes less meaningful in that case.

55. Corrected values for fossil fuel reductions between 2020 and 2030 are shown in Table AI.1 in Annex I for the world, and Table AI.2 for developed countries. A selection based on IPCC C1 scenarios is shown in Table 1 below. Despite efforts to understand the differences with the ER-AH2 report, we were unable to identify a single reason as to why the values reported in ER-AH2 turn out to be different and inaccurate.

Table 1 | Corrected values for the fossil fuel reductions between 2020 and 2030 in scenarios that limit warming to 1.5°C with no or limited overshoot. The "range of percent change" refers to the range of median estimates across several cases with either a 100 or 135 EJ/yr cut-off for biomass energy, not the full range across all scenarios in the IPCC C1 set. Data are shown for calculations starting from the IPCC C1 scenario set, which is recommended for near-term emissions reductions as it avoids some of the selection bias towards weaker near-term reduction percentages (see paragraph 54.a for an explanation). Scenarios that exceed specified feasibility or sustainability limits have been removed as per the method of ER-AH2, reproduced in Annex I to this report. Tables AI.1 and AI.2 in Annex I show values for each sensitivity case individually, for the world and developed country regions, respectively.

Scenarios that limit warming to 1.5°C with no or low overshoot this century (starting from IPCC C1 scenarios)	Verified calculations of: **Range of percent change 2020 – 2030, by fuel type**		
	Coal	Oil	Gas
Global	-78%	-13% to -26%	-28% to -31%
Developed countries	-78% to -83%	-30% to -31%	-42%

[78] See Table 8 in reference footnote 3.

G. Concluding reflections

56. Based on the overview of strengths and limitations of cost-effective mitigation scenarios created by IAMs we can draw a set of concluding insights and implications.

a. Scenarios are most useful if the assumptions and value judgments that were made during their creation align with the scenarios' intended use or the questions they intend to inform. If these aspects do not align, their results have to be interpreted based on an understanding of their limitations.

b. Mitigation scenarios included in IPCC scenario assessment describe the cheapest way to achieve emission reductions compatible with limiting warming to 1.5°C with no or limited overshoot, and this from a global perspective and from the perspective of a person living today.

i. The focus on achieving the cheapest reductions possible irrespective of development and institutional context and the challenges to mobilizing international financial transfers means the emission reduction burden suggested to be carried by developing countries can be considered inequitable or unfair from an international fairness perspective as embedded in the UNFCCC and the Paris Agreement.

ii. The use of discount rates that are higher than recommended from a social point of view and that are used to assess costs over the entire century in present terms puts a stronger burden on future generations and can be considered unfair from an intergenerational fairness perspective.

c. Taking a more equitable approach regarding intergenerational fairness would result in stronger near-term reductions globally. Taking a more equitable approach regarding international fairness would result in stronger near-term reductions in developed countries with a shift in the contributions of different energy sources and fossil fuel types. The following paragraphs 57 to 59 show how this is likely to imply larger reductions in oil and gas.

57. Taking a more equitable approach regarding international fairness could be pursued by more explicitly reflecting the provisions and principles of the UNFCCC and Paris Agreement in the design of mitigation scenarios. Such approach would reasonably assume less stringent absolute reductions in the near term in developing country regions and more stringent absolute reductions in the near term in developed country regions. For example, the most recent, updated Net Zero Emissions by 2050 scenario by the International Energy Agency (IEA NZE) incorporates such an equity-informed adjustment.[79]

58. In particular, the updated NZE scenario from the International Energy Agency that explicitly integrates considerations of equity in its modelling shows a less abrupt transition for emerging markets and developing economies. The consideration of equity in the scenario design leads to a relatively slower decline in coal emissions in emerging markets and developing economies, while firm and ambitious action in advanced economies leads

[79] International Energy Agency (IEA), 2023. *Net Zero Roadmap - A Global Pathway to Keep the 1.5 °C Goal in Reach - 2023 Update*. International Energy Agency, Paris. Available at: https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach [Accessed: 28 February 2024]

to greenhouse gas emissions from oil and gas to fall faster in the IEA NZE scenario than would otherwise be the case for scenarios aiming for the same temperature goal. The IEA highlights that under these more equitable assumptions, emissions in advanced economies are reported to fall nearly 2 times faster in the current decade compared to emissions in emerging market and developing economies.[80]

59. While the specific interpretation and implementation of international equity in stringent mitigation scenarios can vary, the implications of a more equitable perspective are in my opinion firmly illustrated by the updated IEA NZE scenario: a stronger emphasis on emissions reductions in developed country regions and a stronger emphasis on absolute reductions in oil and gas – to provide a more equitable proposition to developing country region contributions. Given the status and world-renowned energy modelling expertise of the International Energy Agency, the IEA NZE scenario can serve as a technically sound and authoritative illustration of what it means if a more equitable approach to scenario design would be taken, showing that it is technically feasible to implement more equity-aligned deviations of cost-effective 1.5°C scenarios.

60. The IEA explores the implications of considering equity in the distribution of efforts in the energy sector, already indicating a markedly faster absolute emission reduction in advanced economies compared to emerging market and developing economies. Considering equity related to the distribution and scale of AFOLU emissions reductions would further point towards a sharpening of emissions reductions in developed countries and other sectors compared to the regional and sectoral distribution in IPCC C1 scenarios compatible with limiting warming to 1.5°C with no or limited overshoot.

Name: Joeri Rogelj
Title: Professor of Climate Science and Policy

[redacted]

Date: 4 March 2024

[80] See reference footnote 79, Box 2.1 – Integrating equity into the NZE Scenario design, page 59

Annex I – verification of calculations: details

This list restates the steps that were laid out in Appendix A of ER-AH2 and which were followed for the verification and attempted reproduction of the ER-AH2 analysis. References have been updated in square brackets to fit their new context:

"

a) Scenarios are sourced from AR6 Scenario Explorer hosted by IIASA (version 1.1), which is the full set of modelled climate change mitigation scenarios submitted to the IPCC to support its 6th Assessment Report.

b) [ER-AH2] then refine[s] this overall scenario set to three subsets; (1) C1a, (2) all of C1, and (3) the scenario set identified by Schleussner et al. (2022)[[81]] which is a subset of C1a and C2 scenarios.[[82]]

c) Select the relevant variables from the scenarios; these are the variables labelled "Primary Energy|Coal (EJ/yr) (TOTAL)", "Primary Energy|Oil (EJ/yr) (TOTAL)", "Primary Energy|Gas (EJ/yr) (TOTAL)", "Primary Energy|Biomass (EJ/yr) (TOTAL)", "Carbon Sequestration|Land Use|Afforestation (MtCO2/yr)", "Carbon Sequestration|Land Use (MtCO2/yr)" and "Carbon Sequestration|CCS (MtCO2/yr) (TOTAL)".

d) Eliminate scenarios that exceed 3.6 $GtCO_2$/year removals via afforestation (or using land use CO_2 sequestration as a proxy where afforestation is not reported[[83]]) in 2050. Eliminate scenarios that exceed 100 EJ/year or 135 EJ/year primary bioenergy use in 2050. Eliminate scenarios that exceed 1.25 $GtCO_2$ sequestration via CCS in 2030.

"

Scenarios that do not report a minimum set of relevant variables are excluded from the calculation. This means that reported values are required for all variables listed under item c) of the list above, except for the variables "Carbon Sequestration|Land Use|Afforestation (MtCO2/yr)" and "Carbon Sequestration|Land Use (MtCO2/yr)" of which at least one of the two has to be reported.

---

[81] Schleussner, C.-F., Ganti, G., Rogelj, J., Gidden, M.J., 2022. An emission pathway classification reflecting the Paris Agreement climate objectives. *Communications Earth & Environment* 3, 1–11. https://doi.org/10.1038/s43247-022-00467-w

[82] Note that the scenario set identified by Schleussner et al (2022; see reference footnote 81) consists of a subset of C1a scenarios. As per Table 2 and Figure 1a in Schleussner et al (2022), and does not contain and C2 scenarios (which return warming to 1.5°C after a high overshoot).

[83] In this analysis, "Carbon Sequestration|Land Use (MtCO2/yr)" was used instead of "Carbon Sequestration|Land Use|Afforestation (MtCO2/yr)" in case the latter was not available, although ER-AH2 does not specify how this "proxy" was implemented.

Table AI.1 | Comparison of global reductions in coal, gas, and oil between 2020 and 2030 as calculated by ER-AH2 and as independently verified by this report. Cells containing ER-AH2's values are coloured orange. Independently verified values are reported in light blue cells. ER-AH2's reported reduction percentages are inaccurate. Particularly for estimates starting from the C1 subset of scenarios from the IPCC Sixth Assessment Report (scenarios that limit global warming to 1.5°C with no or limited overshoot), numbers reported by ER-AH2 show a drastic underreporting of the magnitude of global reductions required in oil and gas. Rows with clear discrepancies in the ER-AH2 estimates are highlighted in red and bold. n/a refers to values that were not reported in ER-AH2 but were deemed of interest to be included in the verification set for completeness. Calculations based on Achakuwisut et al. (2023)[84], reported in ER-AH2, were not verified and are therefore not included in this comparison.

World					
Starting scenario subset	**Fuel**	**Bioenergy limit in 2050 (EJ/yr)**	**Median percent change 2020-2030 (%)**		**Number of scenarios**
			As reported in ER-AH2	**Independent verification**	
Set as described in Schleussner et al. (2022) study (subset C1a)	**Coal**	135	-76	-72	12
		no limit	-69	-70	29
	Gas	135	-5	-11	12
		no limit	-8	-10	29
	Oil	135	-2	-11	12
		no limit	-3	-6	29
Starting from C1a	**Coal**	100	-75	-75	4
		135	-75	-75	10
	Gas	100	-20	-20	4
		135	-11	-11	10
	Oil	100	-8	-8	4
		135	-3	-3	10
Starting from C1	**Coal**	100	-76	-78	14
		135	-76	-78	28
	Gas	100	-26	-31	14
		135	-15	-28	28
	Oil	100	-4	-26	14
		135	-3	-13	28

[84] Achakulwisut, P., Erickson, P., Guivarch, C., Schaeffer, R., Brutschin, E., Pye, S., 2023. Global fossil fuel reduction pathways under different climate mitigation strategies and ambitions. *Nature Communications* 14, 5425. https://doi.org/10.1038/s41467-023-41105-z

Table AI.2 | Reductions in coal, gas, and oil between 2020 and 2030 for developed countries for all cases shown in Table AI.1. Developed country data is based on the R5OECD90+EU region as defined in the model registration for the IPCC AR6 scenario database and which covers the OECD, the EU, and EU candidate countries. The ER-AH2's column is greyed out as the report did not cover reductions at the regional level and therefore no comparison data is available for this table.

Developed countries					
Starting scenario subset	Fuel	Bioenergy limit in 2050 (EJ/yr)	Median percent change 2020-2030 (%)		Number of scenarios
			As reported in ER-AH2	Independent verification	
Set as described in Schleussner et al. (2022) study (subset C1a)	Coal	135	n/a	-79	12
		no limit	n/a	-82	29
	Gas	135	n/a	-39	12
		no limit	n/a	-28	29
	Oil	135	n/a	-22	12
		no limit	n/a	-21	29
Starting from C1a	Coal	100	n/a	-85	4
		135	n/a	-91	10
	Gas	100	n/a	-42	4
		135	n/a	-42	10
	Oil	100	n/a	-29	4
		135	n/a	-26	10
Starting from C1	Coal	100	n/a	-78	14
		135	n/a	-83	28
	Gas	100	n/a	-42	14
		135	n/a	-42	28
	Oil	100	n/a	-31	14
		135	n/a	-30	28

Joeri ROGELJ

CONTACT j.rogelj@imperial.ac.uk

EDUCATION

PH.D., **Doktor der Wissenschaften (Dr. Sc. ETH)** — ETH Zurich (CH) 2010—2013
- Department of Environmental System Science
- Title: Uncertainties of low greenhouse gas emission scenarios

MASTERS, **Master in Cultures and Development Studies**, KULeuven (B) 2003—2005
- Complementary Masters Studies at Department of Social and Cultural Anthropology
- Title: Sustainable development and university education (Ibagué, Colombia)

MASTERS, **Burg. Werktuigk.-Elektrotech. Ingenieur (Ir.)**, KULeuven (B) 1998—2003
- MSc Mechanical Engineering - Biomedical Engineering Technology

HIGH SCHOOL, **ASO Latin-Math.**, O.-L.-V. van Lourdesinst., Ekeren (B) 1992—1998

PAST & PRESENT APPOINTMENTS

2022—present ***Professor in Climate Science & Policy*** — Centre for Environmental Policy, Imperial College London (UK)

2020—present ***Director of Research*** — Grantham Institute – Climate Change & Environment, Imperial College London (UK)

2021—2022 ***Reader in Climate Science & Policy*** — Centre for Environmental Policy, Imperial College London (UK)

2018—2021 ***Lecturer in Climate Change & Environment*** — Grantham Institute, Imperial College London (UK)

2017—2018 ***Visiting Fellow*** — Oxford Martin School
School of Geography and the Environment, University of Oxford (UK)

2018—present ***Senior Research Scholar*** — Energy, Climate and Environment Program (formerly Energy Program)
International Institute for Applied Systems Analysis — IIASA (A)
- Energy transitions, scenario analysis & integrated assessment
- Climate change & sustainable development

2014—2018 ***Research Scholar*** — Energy Program, IIASA (A)

2013—2014 ***Postdoctoral Researcher*** — Climate Physics Groups, ETH Zurich (CH)

2013—2014 ***Part-time Research Scholar*** — Energy Program, IIASA (A)

2009—2010 ***Researcher*** — PRIMAP Research Group
Potsdam Institute for Climate Impact Research — PIK (D)
- Policy analysis & scenario design, co-developer PRIMAP model

2009—2010 ***Expert Consultant*** — Danish Ministry of Climate and Energy (DK)
- Scientific advisor to the UNFCCC COP15 Presidency
- Quantitative analysis of UNFCCC emission reduction proposals

2007—2008 ***Project Engineer*** — SHER Ingénieurs-Conseils, Kigali (RWA)

2006 ***Cooperation Assistant*** — Belgian Embassy, Kigali (RWA)

2005 ***Research Engineer***, Custom8 N.V. — K.U.Leuven (B)

ADVISORY ROLES AND ASSESSMENT	*Member* — European Scientific Advisory Board on Climate Change	2022—present
	Member — Scientific Steering Committee, Global Carbon Project	2020—present
	Member — UN Secretary General Climate Summit Science Advisory Group	2019—2020
	Scientific Advisor — International Cryosphere Climate Initiative	2019—present
	Scientific expert — Children vs Climate Crisis: United Nations Committee on the Rights of the Child (UNCRC)	2019—2021
	Lead Author — Intergovernmental Panel on Climate Change (IPCC) • Working Group I Contribution: The Physical Science Basis • IPCC Sixth Assessment Report	2018—2022
	Lead Author — United Nations Environment Program (UNEP) • UNEP Emissions Gap Report • Lead author annually since inception of report series in 2010	2010—present
	Coordinating Lead Author — IPCC • Special Report on Global Warming of 1.5 °C	2016—2018
	Extended Writing Team — IPCC • Synthesis Report of the IPCC Fifth Assessment Report	2012—2014
HONOURS & AWARDS	*Early Career Scientist Award (Europe)* — International Science Council • For exceptional contribution to science and international scientific collaboration by an early career researcher	2021
	Ranked 31 on Reuters Hot List, World's top climate scientists — Reuters • Ranking the world's top climate scientists based on how influential they are.	2021
	Highly Cited Researcher, Environment & ecology — Web of Science • Recognizing the world's most influential researchers of the past decade, with multiple highly-cited papers that rank in the top 1% by citations for field and year	2019—2023
	Invited member — Science, Board of Reviewing Editors (AAAS)	2019—present
	Visiting Fellowship — Oxford Martin School, University of Oxford (UoO)	2017—2018
	Honorary Research Associate — School of Geography & Environment (UoO)	2017—2018
	Inaugural Piers Sellers Award • Received for World Leading Contributions to Solution-Focused Climate Research • Priestley International Centre for Climate, Leeds University (UK)	2016
	ETH Medal — ETH Zurich (CH) • Received for outstanding PhD research	2014
	ETH Delegation — Global Young Scientist Summit (GYSS@one-north, Singapore)	2014
	Peccei Award and Scholarship — IIASA • Received for outstanding research project	2011
	Cum laude, M CADES — K.U.Leuven (B)	2005
	Award for Outstanding MSc Research — Flanders' Biomedical Society (B)	2003
	Magna cum laude, MSc Eng. (Ir.) — K.U.Leuven (B)	2003

LANGUAGES

	Speaking	**Reading**	**Writing**
Dutch (mother tongue)	Fluent	Fluent	Fluent
English	Fluent	Fluent	Fluent
Spanish/French/German	Intermediate	Fluent	Intermediate
Slovenian/Ukrainian	Elementary	Elementary	Elementary

PROFESSIONAL ACTIVITIES & SERVICE

EDITORIAL ROLES & SERVICE

2019—present	***Science*** (AAAS) — *Board of Reviewing Editors*
2019—present	***ONE Earth*** (Cell Press) — *Editorial Board Member*
2016—present	***Environmental Research Letters*** (IOP) — *Editorial Board Member*
2018—2020	***SN Applied Science*** (Springer-Nature) — *Editorial Board Member*
2019—2021	***Journal of Business Ethics*** (Springer) — *Guest Editor*: Special Issue on 'Corporate GHG Emissions' Estimation, Reporting, Accountability and Integrity'
2018—2020	***Applied Energy*** (Elsevier) — *Guest Editor*: Special Issue on 'Robust energy & climate policies for deep decarbonization'
2016	***Proceedings of the National Academy of Sciences of the USA*** (National Academy of Sciences) — *Guest Editor*
2014—present	***Ad-hoc Peer-reviewer*** (selection) — Nature, Science, Nature Climate Change, Nature Geoscience, Nature Energy, Nature Communication, PLOS ONE, Climatic Change, Climatic Change Letters, Environmental Research Letters, Scientific Reports, Review of Environmental Economics and Policy, Applied Energy, Environmental Science & Technology, Technological Forecasting & Social Change, Geoscientific Model Development, Geophysical Research Letters, Journal of Climate, Earth System Dynamics, Climate Policy, Earth's Future, Global and Planetary Change, Current Opinion in Environmental Sustainability, Journal of the American Statistical Association

Publication list

A – OVERVIEW & INDICATORS

	h-index	*# documents*	*# citations*
Scopus	61	149	21300
Web of Science	62	155	22700
Google Scholar	87	300+	58500 (includes reports)

Web Of Knowledge Highly Cited Researcher 2019—2023 – Environment & Ecology
Recognizing the world's most influential researchers of the past decade with multiple highly-cited papers that rank in the top 1% by citations for field and year

B – HIGHLIGHTS

J. **Rogelj**, T. Fransen, M. G. J. den Elzen, R. D. Lamboll, C. Schumer, T. Kuramochi, F. Hans, S. Mooldijk, and J. Portugal-Pereira, "Credibility gap in net-zero climate targets leaves world at high risk," *Science*, vol. 380, no. 6649, 1014–1016, Jun. 2023. DOI: 10.1126/science.adg6248

J. **Rogelj**, D. L. McCollum, A. Reisinger, M. Meinshausen, and K. Riahi, "Probabilistic cost estimates for climate change mitigation," *Nature*, vol. 493, no. 7430, 79–83, 2013. DOI: 10.1038/nature11787

J. **Rogelj**, G. Luderer, R. C. Pietzcker, E. Kriegler, M. Schaeffer, V. Krey, and K. Riahi, "Energy system transformations for limiting end-of-century warming to below 1.5°C," *Nature Clim. Change*, vol. 5, no. 6, 519–527, 2015. DOI: 10.1038/nclimate2572

J. **Rogelj**, M. den Elzen, N. Höhne, T. Fransen, H. Fekete, H. Winkler, R. Schaeffer, F. Sha, K. Riahi, and M. Meinshausen, "Paris Agreement climate proposals need a boost to keep warming well below 2°C," *Nature*, vol. 534, no. 7609, 631–639, 2016. DOI: 10.1038/nature18307

J. **Rogelj**, P. M. Forster, E. Kriegler, C. J. Smith, and R. Séférian, "Estimating and tracking the remaining carbon budget for stringent climate targets," *Nature*, vol. 571, no. 7765, 335–342, 2019. DOI: 10.1038/s41586-019-1368-z

J. **Rogelj**, D. Huppmann, V. Krey, K. Riahi, L. Clarke, M. Gidden, Z. Nicholls, and M. Meinshausen, "A new scenario logic for the Paris Agreement long-term temperature goal," *Nature*, vol. 573, no. 7774, 357–363, 2019. DOI: 10.1038/s41586-019-1541-4

J. **Rogelj**, O. Geden, A. Cowie, and A. Reisinger, "Three ways to improve net-zero emissions targets," *Nature*, vol. 591, no. 78507850, 365–368, 2021. DOI: 10.1038/d41586-021-00662-3

C – REFEREED PAPERS

2010

[1] J. **Rogelj**, J. Nabel, C. Chen, W. Hare, K. Markmann, M. Meinshausen, M. Schaeffer, K. Macey, and N. Höhne, "Copenhagen accord pledges are paltry," *Nature*, vol. 464, no. 7292, 1126–1128, 2010. DOI: 10.1038/4641126a

[2] J. **Rogelj**, C. Chen, J. Nabel, K. Macey, W. Hare, M. Schaeffer, K. Markmann, N. Höhne, K. Krogh Andersen, and M. Meinshausen, "Analysis of the copenhagen accord pledges and its global climatic impacts—a snapshot of dissonant ambitions," *Environmental Research Letters*, vol. 5, no. 3, p. 034013, 2010. DOI: 10.1088/1748-9326/5/3/034013

2011

[3] J. E. M. S. Nabel, J. **Rogelj**, C. M. Chen, K. Markmann, D. J. H. Gutzmann, and M. Meinshausen, "Decision support for international climate policy – the primap emission module," *Environmental Modelling & Software*, vol. 26, no. 12, 1419–1433, 2011. DOI: 10.1016/j.envsoft.2011.08.004

[4] J. **Rogelj**, W. Hare, C. Chen, and M. Meinshausen, "Discrepancies in historical emissions point to a wider 2020 gap between 2°C benchmarks and aggregated national mitigation pledges.," *Environmental Research Letters*, vol. 6, no. 2, p. 9, 2011. DOI: 10.1088/1748-9326/6/2/024002

[5] J. **Rogelj**, W. Hare, J. Lowe, D. P. van Vuuren, K. Riahi, B. Matthews, T. Hanaoka, K. Jiang, and M. Meinshausen, "Emission pathways consistent with a 2°C global temperature limit," *Nature Clim. Change*, vol. 1, no. 8, 413–418, 2011. DOI: 10.1038/nclimate1258

2012

[6] N. Höhne, C. Taylor, R. Elias, M. D. Elzen, K. Riahi, C. Chen, J. **Rogelj**, G. Grassi, F. Wagner, K. Levin, E. Massetti, and Z. Xiusheng, "National ghg emissions reduction pledges and 2°C: Comparison of studies," *Climate Policy*, vol. 12, no. 3, 356–377, 2012. DOI: 10.1080/14693062.2011.637818

[7] J. **Rogelj**, M. Meinshausen, and R. Knutti, "Global warming under old and new scenarios using ipcc climate sensitivity range estimates," *Nature Clim. Change*, vol. 2, no. 4, 248–253, 2012. DOI: 10.1038/nclimate1385

2013

[8] J. **Rogelj**, D. L. McCollum, B. C. O'Neill, and K. Riahi, "2020 emissions levels required to limit warming to below 2°C," *Nature Clim. Change*, vol. 3, no. 4, 405–412, 2013. DOI: 10.1038/nclimate1758

[9] J. **Rogelj**, D. L. McCollum, A. Reisinger, M. Meinshausen, and K. Riahi, "Probabilistic cost estimates for climate change mitigation," *Nature*, vol. 493, no. 7430, 79–83, 2013. DOI: 10.1038/nature11787

[10] J. **Rogelj**, D. L. McCollum, and K. Riahi, "The UN's "sustainable energy for all" initiative is compatible with a warming limit of 2°C," *Nature Clim. Change*, vol. 3, no. 6, 545–551, 2013. DOI: 10.1038/nclimate1806

2014

[11] P. Friedlingstein, R. M. Andrew, J. **Rogelj**, G. P. Peters, J. G. Canadell, R. Knutti, G. Luderer, M. R. Raupach, M. Schaeffer, and D. P. van Vuuren, "Persistent growth of CO2 emissions and implications for reaching climate targets," *Nature Geoscience*, vol. 7, no. 10, 709–715, 2014. DOI: 10.1038/ngeo2248

[12] J. **Rogelj**, M. Schaeffer, M. Meinshausen, D. T. Shindell, W. Hare, Z. Klimont, G. J. Velders, M. Amann, and H. J. Schellnhuber, "Disentangling the effects of CO2 and short-lived climate forcer mitigation," *Proc Natl Acad Sci U S A*, vol. 111, no. 46, 16325–30, 2014. DOI: 10.1073/pnas.1415631111

[13] J. **Rogelj**, M. Meinshausen, J. Sedláček, and R. Knutti, "Implications of potentially lower climate sensitivity on climate projections and policy," *Environmental Research Letters*, vol. 9, no. 3, p. 031 003, 2014. DOI: 10.1088/1748-9326/9/3/031003

[14] J. **Rogelj**, S. Rao, D. L. McCollum, S. Pachauri, Z. Klimont, V. Krey, and K. Riahi, "Air-pollution emission ranges consistent with the representative concentration pathways," *Nature Clim. Change*, vol. 4, no. 6, 446–450, 2014. DOI: 10.1038/nclimate2178

[15] S. J. Smith, T. M. L. Wigley, M. Meinshausen, and J. **Rogelj**, "Questions of bias in climate models," *Nature Clim. Change*, vol. 4, no. 9, 741–742, 2014. DOI: 10.1038/nclimate2345

2015

[16] A. A. Fawcett, G. C. Iyer, L. E. Clarke, J. A. Edmonds, N. E. Hultman, H. C. McJeon, J. **Rogelj**, R. Schuler, J. Alsalam, G. R. Asrar, J. Creason, M. Jeong, J. McFarland, A. Mundra, and W. Shi, "Can paris pledges avert severe climate change?" *Science*, vol. 350, no. 6265, 1168–1169, 2015. DOI: 10.1126/science.aad5761

[17] N. Johnson, V. Krey, D. L. McCollum, S. Rao, K. Riahi, and J. **Rogelj**, "Stranded on a low-carbon planet: Implications of climate policy for the phase-out of coal-based power plants," *Technological Forecasting and Social Change*, vol. 90, Part A, no. 0, 89–102, 2015. DOI: 10.1016/j.techfore.2014.02.028

[18] R. Knutti and J. **Rogelj**, "The legacy of our co2 emissions: A clash of scientific facts, politics and ethics," *Climatic Change*, vol. 133, no. 3, 361–373, 2015. DOI: 10.1007/s10584-015-1340-3

[19] M. Meinshausen, L. Jeffery, J. Guetschow, Y. Robiou du Pont, J. **Rogelj**, M. Schaeffer, N. Höhne, M. den Elzen, S. Oberthur, and N. Meinshausen, "National post-2020 greenhouse gas targets and diversity-aware leadership," *Nature Clim. Change*, vol. 5, no. 12, 1098–1106, 2015. DOI: 10.1038/nclimate2826

[20] J. **Rogelj**, G. Luderer, R. C. Pietzcker, E. Kriegler, M. Schaeffer, V. Krey, and K. Riahi, "Energy system transformations for limiting end-of-century warming to below 1.5°C," *Nature Clim. Change*, vol. 5, no. 6, 519–527, 2015. DOI: 10.1038/nclimate2572

[21] J. **Rogelj**, M. Meinshausen, M. Schaeffer, R. Knutti, and K. Riahi, "Impact of short-lived non-co2 mitigation on carbon budgets for stabilizing global warming," *Environmental Research Letters*, vol. 10, no. 7, p. 075 001, 2015. DOI: https://doi.org/10.1088/1748-9326/10/7/075001

[22] J. **Rogelj**, A. Reisinger, D. L. McCollum, R. Knutti, K. Riahi, and M. Meinshausen, "Mitigation choices impact carbon budget size compatible with low temperature goals," *Environmental Research Letters*, vol. 10, no. 7, p. 075 003, 2015. DOI: 10.1088/1748-9326/10/7/075003

2016

[23] C.-F. Schleussner, T. K. Lissner, E. M. Fischer, J. Wohland, M. Perrette, A. Golly, J. **Rogelj**, K. Childers, J. Schewe, K. Frieler, M. Mengel, W. Hare, and M. Schaeffer, "Differential climate impacts for policy-relevant limits to global warming: The case of 1.5°C and 2°C," *Earth System Dynamics*, vol. 7, no. 2, 327–351, 2016. DOI: https://doi.org/10.5194/esd-7-327-2016

[24] C. Cameron, S. Pachauri, N. D. Rao, D. McCollum, J. **Rogelj**, and K. Riahi, "Policy trade-offs between climate mitigation and clean cook-stove access in south asia," *Nature Energy*, vol. 1, p. 15 010, 2016. DOI: 10.1038/nenergy.2015.10

[25] S. Hallegatte, J. **Rogelj**, M. Allen, L. Clarke, O. Edenhofer, C. B. Field, P. Friedlingstein, L. van Kesteren, R. Knutti, K. J. Mach, M. Mastrandrea, A. Michel, J. Minx, M. Oppenheimer, G.-K. Plattner, K. Riahi, M. Schaeffer, T. F. Stocker, and D. P. van Vuuren, "Mapping the climate change challenge," *Nature Clim. Change*, vol. 6, no. 7, 663–668, 2016. DOI: 10.1038/nclimate3057

[26] C. D. Jones, P. Ciais, S. J. Davis, P. Friedlingstein, T. Gasser, G. P. Peters, J. **Rogelj**, D. P. v. Vuuren, J. G. Canadell, A. Cowie, R. B. Jackson, M. Jonas, E. Kriegler, E. Littleton, J. A. Lowe, J. Milne, G. Shrestha, P. Smith, A. Torvanger, and A. Wiltshire, "Simulating the earth system response to negative emissions," *Environmental Research Letters*, vol. 11, no. 9, p. 095 012, 2016

[27] R. Knutti, J. **Rogelj**, J. Sedlacek, and E. M. Fischer, "A scientific critique of the two-degree climate change target," *Nature Geosci*, vol. 9, no. 1, 13–18, 2016. DOI: 10.1038/ngeo2595

[28] R. Millar, M. Allen, J. **Rogelj**, and P. Friedlingstein, "The cumulative carbon budget and its implications," *Oxford Review of Economic Policy*, vol. 32, no. 2, 323–342, 2016. DOI: 10.1093/oxrep/grw009

[29] Y. Robiou du Pont, M. L. Jeffery, J. Gütschow, J. **Rogelj**, P. Christoff, and M. Meinshausen, "Equitable mitigation to achieve the paris agreement goals," *Nature Climate Change*, vol. 7, p. 38, 2016. DOI: 10.1038/nclimate3186

[30] J. Rockström, H. J. Schellnhuber, B. Hoskins, V. Ramanathan, P. Schlosser, G. P. Brasseur, O. Gaffney, C. Nobre, M. Meinshausen, J. **Rogelj**, and W. Lucht, "The world's biggest gamble," *Earth's Future*, n/a–n/a, 2016. DOI: 10.1002/2016EF000392

[31] J. **Rogelj**, M. den Elzen, N. Höhne, T. Fransen, H. Fekete, H. Winkler, R. Schaeffer, F. Sha, K. Riahi, and M. Meinshausen, "Paris Agreement climate proposals need a boost to keep warming well below 2°C," *Nature*, vol. 534, no. 7609, 631–639, 2016. DOI: 10.1038/nature18307

[32] J. **Rogelj**, M. Schaeffer, P. Friedlingstein, N. P. Gillett, D. P. van Vuuren, K. Riahi, M. Allen, and R. Knutti, "Differences between carbon budget estimates unravelled," *Nature Clim. Change*, vol. 6, no. 3, 245–252, 2016. DOI: 10.1038/nclimate2868

[33] C.-F. Schleussner, J. **Rogelj**, M. Schaeffer, T. Lissner, R. Licker, E. M. Fischer, R. Knutti, A. Levermann, K. Frieler, and W. Hare, "Science and policy characteristics of the Paris Agreement temperature goal," *Nature Climate Change*, vol. 6, no. 9, 827–835, 2016. DOI: 10.1038/nclimate3096

[34] P. Smith, S. J. Davis, F. Creutzig, S. Fuss, J. Minx, B. Gabrielle, E. Kato, R. B. Jackson, A. Cowie, E. Kriegler, D. P. van Vuuren, J. **Rogelj**, P. Ciais, J. Milne, J. G. Canadell, D. McCollum, G. Peters, R. Andrew, V. Krey, G. Shrestha, P. Friedlingstein, T. Gasser, A. Grubler, W. K. Heidug, M. Jonas, C. D. Jones, F. Kraxner, E. Littleton, J. Lowe, J. R. Moreira, N. Nakicenovic, M. Obersteiner, A. Patwardhan, M. Rogner, E. Rubin, A. Sharifi, A. Torvanger, Y. Yamagata, J. Edmonds, and C. Yongsung, "Biophysical and economic limits to negative co2 emissions," *Nature Clim. Change*, vol. 6, no. 1, 42–50, 2016. DOI: 10.1038/nclimate2870

[35] D. P. van Vuuren, H. van Soest, K. Riahi, L. Clarke, V. Krey, E. Kriegler, J. **Rogelj**, M. Schaeffer, and M. Tavoni, "Carbon budgets and energy transition pathways," *Environmental Research Letters*, vol. 11, no. 7, p. 075 002, 2016

2017

[36] O. Fricko, P. Havlik, J. **Rogelj**, Z. Klimont, M. Gusti, N. Johnson, P. Kolp, M. Strubegger, H. Valin, M. Amann, T. Ermolieva, N. Forsell, M. Herrero, C. Heyes, G. Kindermann, V. Krey, D. L. McCollum, M. Obersteiner, S. Pachauri, S. Rao, E. Schmid, W. Schoepp, and K. Riahi, "The marker quantification of the shared socioeconomic pathway 2: A middle-of-the-road scenario for the 21st century," *Global Environmental Change*, vol. 42, 251–267, 2017. DOI: 10.1016/j.gloenvcha.2016.06.004

[37] R. James, R. Washington, C. F. Schleussner, J. **Rogelj**, and D. Conway, "Characterizing half-a-degree difference: A review of methods for identifying regional climate responses to global warming targets," *Wiley Interdisciplinary Reviews: Climate Change*, vol. 8, no. 2, e457–n/a, 2017. DOI: 10.1002/wcc.457

[38] R. J. Millar, J. S. Fuglestvedt, P. Friedlingstein, J. **Rogelj**, M. J. Grubb, H. D. Matthews, R. B. Skeie, P. M. Forster, D. J. Frame, and M. R. Allen, "Emission budgets and pathways consistent with limiting warming to 1.5 °C," *Nature Geoscience*, vol. 10, p. 741, 2017. DOI: 10.1038/ngeo3031

[39] A. Nauels, J. **Rogelj**, C.-F. Schleussner, M. Meinshausen, and M. Mengel, "Linking sea level rise and socioeconomic indicators under the shared socioeconomic pathways," *Environmental Research Letters*, vol. 12, no. 11, p. 114 002, 2017. DOI: 10.1088/1748-9326/aa92b6

[40] K. Riahi, D. P. van Vuuren, E. Kriegler, J. Edmonds, B. C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J. C. Cuaresma, S. Kc, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling, K. Ebi, T. Hasegawa, P. Havlik, F. Humpenöder, L. A. Da Silva, S. Smith, E. Stehfest, V. Bosetti, J. Eom, D. Gernaat, T. Masui, J. **Rogelj**, J. Strefler, L. Drouet, V. Krey, G. Luderer, M. Harmsen, K. Takahashi, L. Baumstark, J. C. Doelman, M. Kainuma, Z. Klimont, G. Marangoni, H. Lotze-Campen, M. Obersteiner, A. Tabeau, and M. Tavoni, "The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview," *Global Environmental Change*, vol. 42, 153–168, 2017. DOI: 10.1016/j.gloenvcha.2016.05.009

[41] J. Rockström, O. Gaffney, J. **Rogelj**, M. Meinshausen, N. Nakicenovic, and H. J. Schellnhuber, "A roadmap for rapid decarbonization," *Science*, vol. 355, no. 6331, 1269–1271, 2017. DOI: 10.1126/science.aah3443

[42] J. **Rogelj**, O. Fricko, M. Meinshausen, V. Krey, J. J. J. Zilliacus, and K. Riahi, "Understanding the origin of Paris Agreement emission uncertainties," *Nature Communications*, vol. 8, p. 15 748, 2017. DOI: 10.1038/ncomms15748

[43] J. **Rogelj**, C.-F. Schleussner, and W. Hare, "Getting it right matters: Temperature goal interpretations in geoscience research," *Geophysical Research Letters*, vol. 44, no. 20, pp. 10,662–10,665, 2017. DOI: 10.1002/2017gl075612

2018

[44] C. Bataille, C. Guivarch, S. Hallegatte, J. **Rogelj**, and H. Waisman, "Carbon prices across countries," *Nature Climate Change*, vol. 8, no. 8, 648–650, 2018. DOI: 10.1038/s41558-018-0239-1

[45] E. Byers, M. Gidden, D. Leclère, J. Balkovic, P. Burek, K. Ebi, P. Greve, D. Grey, P. Havlík, A. Hillers, N. Johnson, T. Kahil, V. Krey, S. Langan, N. Nakicenovic, R. Novak, M. Obersteiner, S. Pachauri, A. Palazzo, S. Parkinson, N. Rao, J. **Rogelj**, Y. Satoh, Y. Wada, B. Willaarts, and K. Riahi, "Global exposure and vulnerability to multi-sector development and climate change hotspots," *Environmental Research Letters*, vol. 13, no. 5, p. 055 012, 2018. DOI: 10.1088/1748-9326/aabf45

[46] P. U. Clark, A. C. Mix, M. Eby, A. Levermann, J. **Rogelj**, A. Nauels, and D. J. Wrathall, "Sea-level commitment as a gauge for climate policy," *Nature Climate Change*, vol. 8, no. 8, 653–655, 2018. DOI: 10.1038/s41558-018-0226-6

[47] J. Fuglestvedt, J. **Rogelj**, R. J. Millar, M. Allen, O. Boucher, M. Cain, P. M. Forster, E. Kriegler, and D. Shindell, "Implications of possible interpretations of 'greenhouse

gas balance' in the Paris Agreement," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 376, no. 2119, 2018. DOI: 10.1098/rsta.2016.0445

[48] S. Fujimori, T. Hasegawa, J. **Rogelj**, X. Su, P. Havlik, V. Krey, K. Takahashi, and K. Riahi, "Inclusive climate change mitigation and food security policy under 1.5 °C climate goal," *Environmental Research Letters*, vol. 13, no. 7, p. 074033, 2018. DOI: 10.1088/1748-9326/aad0f7

[49] J. C. Minx, W. F. Lamb, M. W. Callaghan, S. Fuss, J. Hilaire, F. Creutzig, T. Amann, T. Beringer, W. de Oliveira Garcia, J. Hartmann, T. Khanna, D. Lenzi, G. Luderer, G. F. Nemet, J. **Rogelj**, P. Smith, J. L. Vicente, J. Wilcox, and M. d. M. Zamora Dominguez, "Negative emissions—part 1: Research landscape and synthesis," *Environmental Research Letters*, vol. 13, no. 6, p. 063001, 2018. DOI: 10.1088/1748-9326/aabf9b

[50] S. Fuss, W. Lamb, M. W. Callaghan, J. Hilaire, F. Creutzig, T. Amann, T. Beringer, W. de Oliveira Garcia, J. Hartmann, T. Khanna, G. Luderer, G. F. Nemet, J. **Rogelj**, P. Smith, J. L. Vicente, J. Wilcox, M. d. M. Zamora Dominguez, and J. C. Minx, "Negative emissions—part 2: Costs, potentials and side effects," *Environmental Research Letters*, vol. 13, no. 6, p. 063002, 2018. DOI: 10.1088/1748-9326/aabf9f

[51] A. Grubler, C. Wilson, N. Bento, B. Boza-Kiss, V. Krey, D. L. McCollum, N. D. Rao, K. Riahi, J. **Rogelj**, S. De Stercke, J. Cullen, S. Frank, O. Fricko, F. Guo, M. Gidden, P. Havlík, D. Huppmann, G. Kiesewetter, P. Rafaj, W. Schoepp, and H. Valin, "A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies," *Nature Energy*, vol. 3, no. 6, 515–527, 2018. DOI: 10.1038/s41560-018-0172-6

[52] D. Huppmann, J. **Rogelj**, E. Kriegler, V. Krey, and K. Riahi, "A new scenario resource for integrated 1.5 °C research," *Nature Climate Change*, vol. 8, no. 12, 1027–1030, 2018. DOI: 10.1038/s41558-018-0317-4

[53] E. Kriegler, G. Luderer, N. Bauer, L. Baumstark, S. Fujimori, A. Popp, J. **Rogelj**, J. Strefler, and D. P. van Vuuren, "Pathways limiting warming to 1.5°C: A tale of turning around in no time?" *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 376, no. 2119, 2018. DOI: 10.1098/rsta.2016.0457

[54] G. Luderer, Z. Vrontisi, C. Bertram, O. Y. Edelenbosch, R. C. Pietzcker, J. **Rogelj**, H. S. De Boer, L. Drouet, J. Emmerling, O. Fricko, S. Fujimori, P. Havlík, G. Iyer, K. Keramidas, A. Kitous, M. Pehl, V. Krey, K. Riahi, B. Saveyn, M. Tavoni, D. P. Van Vuuren, and E. Kriegler, "Residual fossil co2 emissions in 1.5–2 °C pathways," *Nature Climate Change*, vol. 8, no. 7, 626–633, 2018. DOI: 10.1038/s41558-018-0198-6

[55] D. L. McCollum, L. G. Echeverri, S. Busch, S. Pachauri, S. Parkinson, J. **Rogelj**, V. Krey, J. C. Minx, M. Nilsson, A. S. Stevance, and K. Riahi, "Connecting the sustainable development goals by their energy inter-linkages," *Environmental Research Letters*, vol. 13, no. 3, 2018. DOI: 10.1088/1748-9326/aaafe3

[56] M. Mengel, A. Nauels, J. **Rogelj**, and C.-F. Schleussner, "Committed sea-level rise under the Paris Agreement and the legacy of delayed mitigation action," *Nature Communications*, vol. 9, no. 1, p. 601, 2018. DOI: 10.1038/s41467-018-02985-8

[57] R. J. Millar, J. S. Fuglestvedt, P. Friedlingstein, J. **Rogelj**, M. J. Grubb, H. D. Matthews, R. B. Skeie, P. M. Forster, D. J. Frame, and M. R. Allen, "Reply to 'interpretations of the Paris climate target'," *Nature Geoscience*, vol. 11, no. 4, 222–222, 2018. DOI: 10.1038/s41561-018-0087-7

[58] P. Pfleiderer, C. F. Schleussner, M. Mengel, and J. **Rogelj**, "Global mean temperature indicators linked to warming levels avoiding climate risks," *Environmental Research Letters*, vol. 13, no. 6, p. 064 015, 2018. DOI: 10.1088/1748-9326/aac319

[59] J. **Rogelj**, A. Popp, K. V. Calvin, G. Luderer, J. Emmerling, D. Gernaat, S. Fujimori, J. Strefler, T. Hasegawa, G. Marangoni, V. Krey, E. Kriegler, K. Riahi, D. P. van Vuuren, J. Doelman, L. Drouet, J. Edmonds, O. Fricko, M. Harmsen, P. Havlík, F. Humpenöder, E. Stehfest, and M. Tavoni, "Scenarios towards limiting global mean temperature increase below 1.5 °C," *Nature Climate Change*, vol. 8, no. 4, 325–332, 2018. DOI: 10.1038/s41558-018-0091-3

[60] C.-F. Schleussner, D. Deryng, C. Müller, J. Elliott, F. Saeed, C. Folberth, W. Liu, X. Wang, T. A. M. Pugh, W. Thiery, S. I. Seneviratne, and J. **Rogelj**, "Crop productivity changes in 1.5 °C and 2 °C worlds under climate sensitivity uncertainty," *Environmental Research Letters*, vol. 13, no. 6, p. 064 007, 2018. DOI: 10.1088/1748-9326/aab63b

[61] S. I. Seneviratne, J. **Rogelj**, R. Séférian, R. Wartenburger, M. R. Allen, M. Cain, R. J. Millar, K. L. Ebi, N. Ellis, O. Hoegh-Guldberg, A. J. Payne, C.-F. Schleussner, P. Tschakert, and R. F. Warren, "The many possible climates from the Paris Agreement's aim of 1.5 °C warming," *Nature*, vol. 558, no. 7708, 41–49, 2018. DOI: 10.1038/s41586-018-0181-4

[62] S. I. Seneviratne, R. Wartenburger, B. P. Guillod, A. L. Hirsch, M. M. Vogel, V. Brovkin, D. P. van Vuuren, N. Schaller, L. Boysen, K. V. Calvin, J. Doelman, P. Greve, P. Havlik, F. Humpenöder, T. Krisztin, D. Mitchell, A. Popp, K. Riahi, J. **Rogelj**, C.-F. Schleussner, J. Sillmann, and E. Stehfest, "Climate extremes, land–climate feedbacks and land-use forcing at 1.5°C," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 376, no. 2119, 2018. DOI: 10.1098/rsta.2016.0450

[63] C. Weber, D. L. McCollum, J. Edmonds, P. Faria, A. Pyanet, J. **Rogelj**, M. Tavoni, J. Thoma, and E. Kriegler, "Mitigation scenarios must cater to new users," *Nature Climate Change*, vol. 8, no. 10, 845–848, 2018. DOI: 10.1038/s41558-018-0293-8

2019

[64] S. Fujimori, J. **Rogelj**, V. Krey, and K. Riahi, "A new generation of emissions scenarios should cover blind spots in the carbon budget space," *Nature Climate Change*, vol. 9, no. 11, 798–800, 2019. DOI: 10.1038/s41558-019-0611-9

[65] A. Gambhir, J. **Rogelj**, G. Luderer, S. Few, and T. Napp, "Energy system changes in 1.5 °C, well below 2 °C and 2 °C scenarios," *Energy Strategy Reviews*, vol. 23, 69–80, 2019. DOI: 10.1016/j.esr.2018.12.006

[66] J. Hilaire, J. C. Minx, M. W. Callaghan, J. Edmonds, G. Luderer, G. F. Nemet, J. **Rogelj**, and M. del Mar Zamora, "Negative emissions and international climate goals—learning from and about mitigation scenarios," *Climatic Change*, 2019. DOI: 10.1007/s10584-019-02516-4

[67] C. D. Jones, T. L. Frölicher, C. Koven, A. H. MacDougall, H. D. Matthews, K. Zickfeld, J. **Rogelj**, K. B. Tokarska, N. P. Gillett, T. Ilyina, M. Meinshausen, N. Mengis, R. Séférian, M. Eby, and F. A. Burger, "The zero emissions commitment model intercomparison project (ZECMIP) contribution to C4MIP: Quantifying committed climate changes following zero carbon emissions," *Geosci. Model Dev.*, vol. 12, no. 10, 4375–4385, 2019. DOI: 10.5194/gmd-12-4375-2019

[68] J. **Rogelj**, P. M. Forster, E. Kriegler, C. J. Smith, and R. Séférian, "Estimating and tracking the remaining carbon budget for stringent climate targets," *Nature*, vol. 571, no. 7765, 335–342, 2019. DOI: 10.1038/s41586-019-1368-z

[69] J. **Rogelj**, D. Huppmann, V. Krey, K. Riahi, L. Clarke, M. Gidden, Z. Nicholls, and M. Meinshausen, "A new scenario logic for the Paris Agreement long-term temperature goal," *Nature*, vol. 573, no. 7774, 357–363, 2019. DOI: 10.1038/s41586-019-1541-4

[70] J. **Rogelj** and C.-F. Schleussner, "Unintentional unfairness when applying new greenhouse gas emissions metrics at country level," *Environmental Research Letters*, vol. 14, no. 11, p. 114 039, 2019. DOI: 10.1088/1748-9326/ab4928

[71] C.-F. Schleussner, A. Nauels, M. Schaeffer, W. Hare, and J. **Rogelj**, "Inconsistencies when applying novel metrics for emissions accounting to the paris agreement," *Environmental Research Letters*, vol. 14, no. 12, p. 124 055, 2019. DOI: 10.1088/1748-9326/ab56e7

[72] M. Siegert, A. Atkinson, A. Banwell, M. Brandon, P. Convey, B. Davies, R. Downie, T. Edwards, B. Hubbard, G. Marshall, J. **Rogelj**, J. Rumble, J. Stroeve, and D. Vaughan, "The antarctic peninsula under a 1.5°C global warming scenario," *Frontiers in Environmental Science*, vol. 7, no. 102, 2019. DOI: 10.3389/fenvs.2019.00102

[73] C. J. Smith, P. M. Forster, M. Allen, J. Fuglestvedt, R. J. Millar, J. **Rogelj**, and K. Zickfeld, "Current fossil fuel infrastructure does not yet commit us to 1.5 °C warming," *Nature Communications*, vol. 10, no. 1, p. 101, 2019. DOI: 10.1038/s41467-018-07999-w

[74] K. B. Tokarska, C.-F. Schleussner, J. **Rogelj**, M. B. Stolpe, H. D. Matthews, P. Pfleiderer, and N. P. Gillett, "Recommended temperature metrics for carbon budget estimates, model evaluation and climate policy," *Nature Geoscience*, vol. 12, no. 12, 964–971, 2019. DOI: 10.1038/s41561-019-0493-5

[75] K. B. Tokarska, K. Zickfeld, and J. **Rogelj**, "Path independence of carbon budgets when meeting a stringent global mean temperature target after an overshoot," *Earth's Future*, vol. n/a, no. n/a, 2019. DOI: 10.1029/2019ef001312

[76] M. Wildemeersch, O. Franklin, R. Seidl, J. **Rogelj**, I. Moorthy, and S. Thurner, "Modelling the multi-scaled nature of pest outbreaks," *Ecological Modelling*, vol. 409, p. 108 745, 2019. DOI: 10.1016/j.ecolmodel.2019.108745

[77] H. Waisman, H. D. Coninck, and J. **Rogelj**, "Key technological enablers for ambitious climate goals: Insights from the IPCC special report on global warming of 1.5 °C," *Environmental Research Letters*, vol. 14, no. 11, p. 111 001, 2019. DOI: 10.1088/1748-9326/ab4c0b

2020

[78] N. Höhne, M. d. Elzen, J. **Rogelj**, B. Metz, T. Fransen, T. Kuramochi, A. Olhoff, J. Alcamo, H. Winkler, S. Fu, M. Schaeffer, R. Schaeffer, G. P. Peters, S. Maxwell, and N. K. Dubash, "Emissions: World has four times the work or one-third of the time," *Nature*, vol. 579, no. 77977797, 25–28, 2020. DOI: 10.1038/d41586-020-00571-x

[79] H. Duan, J. **Rogelj**, J. Veysey, and S. Wang, "Modeling deep decarbonization: Robust energy policy and climate action," *Applied Energy*, vol. 262, p. 114 517, 2020. DOI: 10.1016/j.apenergy.2020.114517

[80] R. A. Fofrich, D. Tong, K. V. Calvin, H. S. d. Boer, J. Emmerling, O. Fricko, S. Fujimori, G. Luderer, J. **Rogelj**, and S. J. Davis, "Early retirement of power plants in climate mitigation scenarios," *Environmental Research Letters*, 2020. DOI: 10.1088/1748-9326/ab96d3

[81] A. H. MacDougall, T. L. Frölicher, C. D. Jones, J. **Rogelj**, H. D. Matthews, K. Zickfeld, V. K. Arora, N. J. Barrett, V. Brovkin, F. A. Burger, M. Eby, A. V. Eliseev, T. Hajima, P. B. Holden, A. Jeltsch-Thömmes, C. Koven, N. Mengis, L. Menviel, M. Michou, I. I. Mokhov, A. Oka, J. Schwinger, R. Séférian, G. Shaffer, A. Sokolov, K. Tachiiri, J. Tjiputra, A. Wiltshire, and T. Ziehn, "Is there warming in the pipeline? a multi-model analysis of the zero emissions commitment from co2," *Biogeosciences*, vol. 17, no. 11, 2987–3016, 2020. DOI: 10.5194/bg-17-2987-2020

[82] D. L. McCollum, A. Gambhir, J. **Rogelj**, and C. Wilson, "Energy modellers should explore extremes more systematically in scenarios," *Nature Energy*, 2020. DOI: 10.1038/s41560-020-0555-3

[83] S. J. Smith, J. Chateau, K. Dorheim, L. Drouet, O. Durand-Lasserve, O. Fricko, S. Fujimori, T. Hanaoka, M. Harmsen, J. Hilaire, K. Keramidas, Z. Klimont, G. Luderer, M. C. P. Moura, K. Riahi, J. **Rogelj**, F. Sano, D. P. van Vuuren, and K. Wada, "Impact of methane and black carbon mitigation on forcing and temperature: A multi-model scenario analysis," *Climatic Change*, 2020. DOI: 10.1007/s10584-020-02794-3. [Online]. Available: https://doi.org/10.1007/s10584-020-02794-3

[84] M. F. Gibson, N. D. Rao, R. B. Slade, J. P. Pereira, and J. **Rogelj**, "The role of energy in mitigating grain storage losses in india and the impact for nutrition," *Resources, Conservation and Recycling*, vol. 163, p. 105 100, 2020, ISSN: 0921-3449. DOI: 10.1016/j.resconrec.2020.105100

[85] M. Andrijevic, C.-F. Schleussner, M. J. Gidden, D. L. McCollum, and J. **Rogelj**, "COVID-19 recovery funds dwarf clean energy investment needs," *Science*, vol. 370, no. 6514, 298–300, 2020. DOI: 10.1126/science.abc9697

[86] P. M. Forster, H. I. Forster, M. J. Evans, M. J. Gidden, C. D. Jones, C. A. Keller, R. D. Lamboll, C. L. Quéré, J. **Rogelj**, D. Rosen, C.-F. Schleussner, T. B. Richardson, C. J. Smith, and S. T. Turnock, "Current and future global climate impacts resulting from covid-19," *Nature Climate Change*, 1–7, 2020. DOI: 10.1038/s41558-020-0883-0

[87] K. B. Tokarska, V. K. Arora, N. P. Gillett, F. Lehner, J. **Rogelj**, C.-F. Schleussner, R. Séférian, and R. Knutti, "Uncertainty in carbon budget estimates due to internal climate variability," *Environmental Research Letters*, 2020. DOI: 10.1088/1748-9326/abaf1b

[88] H. Graven, R. F. Keeling, and J. **Rogelj**, "Changes to carbon isotopes in atmospheric co2 over the industrial era and into the future," *Global Biogeochemical Cycles*, vol. n/a, e2019GB006170, 2020. DOI: 10.1029/2019GB006170

[89] R. D. Lamboll, Z. R. J. Nicholls, J. S. Kikstra, M. Meinshausen, and J. **Rogelj**, "Silicone v1.0.0: An open-source python package for inferring missing emissions data for climate change research," *Geoscientific Model Development*, vol. 13, no. 11, 5259–5275, 2020, ISSN: 1991-959X. DOI: https://doi.org/10.5194/gmd-13-5259-2020

[90] H. D. Matthews, K. B. Tokarska, Z. R. J. Nicholls, J. **Rogelj**, J. G. Canadell, P. Friedlingstein, T. L. Frölicher, P. M. Forster, N. P. Gillett, T. Ilyina, R. B. Jackson, C. D. Jones, C. Koven, R. Knutti, A. H. MacDougall, M. Meinshausen, N. Mengis, R. Séférian, and K. Zickfeld, "Opportunities and challenges in using remaining carbon budgets to guide climate policy," *Nature Geoscience*, vol. 13, no. 1212, 769–779, 2020, ISSN: 1752-0908. DOI: 10.1038/s41561-020-00663-3

[91] Z. R. J. Nicholls, M. Meinshausen, J. Lewis, R. Gieseke, D. Dommenget, K. Dorheim, C.-S. Fan, J. S. Fuglestvedt, T. Gasser, U. Golüke, P. Goodwin, C. Hartin, A. P. Hope, E. Kriegler, N. J. Leach, D. Marchegiani, L. A. McBride, Y. Quilcaille, J. **Rogelj**, R. J.

Salawitch, B. H. Samset, M. Sandstad, A. N. Shiklomanov, R. B. Skeie, C. J. Smith, S. Smith, K. Tanaka, J. Tsutsui, and Z. Xie, "Reduced complexity model intercomparison project phase 1: Introduction and evaluation of global-mean temperature response," *Geoscientific Model Development*, vol. 13, no. 11, 5175–5190, 2020, ISSN: 1991-959X. DOI: https://doi.org/10.5194/gmd-13-5175-2020

[92] S. J. Smith, J. Chateau, K. Dorheim, L. Drouet, O. Durand-Lasserve, O. Fricko, S. Fujimori, T. Hanaoka, M. Harmsen, J. Hilaire, K. Keramidas, Z. Klimont, G. Luderer, M. C. P. Moura, K. Riahi, **J. Rogelj**, F. Sano, D. P. van Vuuren, and K. Wada, "Impact of methane and black carbon mitigation on forcing and temperature: A multi-model scenario analysis," 2020, ISSN: 1573-1480. DOI: 10.1007/s10584-020-02794-3. [Online]. Available: https://doi.org/10.1007/s10584-020-02794-3

2021

[93] S. Fiedler, K. Wyser, J. **Rogelj**, and T. van Noije, "Radiative effects of reduced aerosol emissions during the covid-19 pandemic and the future recovery," *Atmospheric Research*, vol. 264, p. 105 866, 2021, ISSN: 0169-8095. DOI: 10.1016/j.atmosres.2021.105866

[94] G. Grassi, E. Stehfest, J. **Rogelj**, D. van Vuuren, A. Cescatti, J. House, G.-J. Nabuurs, S. Rossi, R. Alkama, R. A. Viñas, K. Calvin, G. Ceccherini, S. Federici, S. Fujimori, M. Gusti, T. Hasegawa, P. Havlik, F. Humpenöder, A. Korosuo, L. Perugini, F. N. Tubiello, and A. Popp, "Critical adjustment of land mitigation pathways for assessing countries' climate progress," *Nature Climate Change*, 1–10, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01033-6

[95] A. G. F. Hoepner and **J. Rogelj**, "Emissions estimations should embed a precautionary principle," 1–3, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01109-3

[96] N. Höhne, M. J. Gidden, M. den Elzen, F. Hans, C. Fyson, A. Geiges, M. L. Jeffery, S. Gonzales-Zuñiga, S. Mooldijk, W. Hare, and J. **Rogelj**, "Wave of net zero emission targets opens window to meeting the paris agreement," 1–3, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01142-2

[97] C. D. Jones, J. E. Hickman, S. T. Rumbold, J. Walton, R. D. Lamboll, R. B. Skeie, S. Fiedler, P. M. Forster, **J. Rogelj**, M. Abe, M. Botzet, K. Calvin, C. Cassou, J. N. S. Cole, P. Davini, M. Deushi, M. Dix, J. C. Fyfe, N. P. Gillett, T. Ilyina, M. Kawamiya, M. Kelley, S. Kharin, T. Koshiro, H. Li, C. Mackallah, W. A. Müller, P. Nabat, T. v. Noije, P. Nolan, R. Ohgaito, D. Olivié, N. Oshima, J. Parodi, T. J. Reerink, L. Ren, A. Romanou, R. Séférian, Y. Tang, C. Timmreck, J. Tjiputra, E. Tourigny, K. Tsigaridis, H. Wang, M. Wu, K. Wyser, S. Yang, Y. Yang, and T. Ziehn, "The climate response to emissions reductions due to covid-19: Initial results from covidmip," *Geophysical Research Letters*, vol. 48, no. 8, e2020GL091883, 2021, ISSN: 1944-8007. DOI: https://doi.org/10.1029/2020GL091883

[98] D. H. Matthews, K. B. Tokarska, **J. Rogelj**, C. J. Smith, A. H. MacDougall, K. Haustein, N. Mengis, S. Sippel, P. M. Forster, and R. Knutti, "An integrated approach to quantifying uncertainties in the remaining carbon budget," *Communications Earth & Environment*, vol. 2, no. 11, 1–11, 2021, ISSN: 2662-4435. DOI: 10.1038/s43247-020-00064-9

[99] Z. Nicholls, M. Meinshausen, J. Lewis, M. R. Corradi, K. Dorheim, T. Gasser, R. Gieseke, A. P. Hope, N. J. Leach, L. A. McBride, Y. Quilcaille, **J. Rogelj**, R. J. Salawitch, B. H. Samset, M. Sandstad, A. Shiklomanov, R. B. Skeie, C. J. Smith, S. J. Smith, X. Su, J. Tsutsui, B. Vega-Westhoff, and D. L. Woodard, "Reduced complexity model intercomparison project phase 2: Synthesising earth system knowledge for probabilistic

climate projections," *Earth's Future*, vol. n/a, no. n/a, e2020EF001900, 2021, ISSN: 2328-4277. DOI: https://doi.org/10.1029/2020EF001900

[100] J. **Rogelj**, O. Geden, A. Cowie, and A. Reisinger, "Three ways to improve net-zero emissions targets," *Nature*, vol. 591, no. 78507850, 365–368, 2021. DOI: 10.1038/d41586-021-00662-3

[101] J. **Rogelj** and C.-F. Schleussner, "Reply to comment on 'unintentional unfairness when applying new greenhouse gas emissions metrics at country level'," *Environmental Research Letters*, vol. 16, no. 6, p. 068 002, 2021, ISSN: 1748-9326. DOI: 10.1088/1748-9326/ac02ec

[102] W. Thiery, S. Lange, J. **Rogelj**, C.-F. Schleussner, L. Gudmundsson, S. I. Seneviratne, M. Andrijevic, K. Frieler, K. Emanuel, T. Geiger, D. N. Bresch, F. Zhao, S. N. Willner, M. Büchner, J. Volkholz, N. Bauer, J. Chang, P. Ciais, M. Dury, L. François, M. Grillakis, S. N. Gosling, N. Hanasaki, T. Hickler, V. Huber, A. Ito, J. Jägermeyr, N. Khabarov, A. Koutroulis, W. Liu, W. Lutz, M. Mengel, C. Müller, S. Ostberg, C. P. O. Reyer, T. Stacke, and Y. Wada, "Intergenerational inequities in exposure to climate extremes," *Science*, vol. 374, no. 6564, 158–160, 2021. DOI: 10.1126/science.abi7339

[103] J. S. Kikstra, A. Vinca, F. Lovat, B. Boza-Kiss, B. van Ruijven, C. Wilson, J. **Rogelj**, B. Zakeri, O. Fricko, and K. Riahi, "Climate mitigation scenarios with persistent covid-19-related energy demand changes," *Nature Energy*, 1–10, 2021, ISSN: 2058-7546. DOI: 10.1038/s41560-021-00904-8

[104] A. Gambhir, M. George, H. McJeon, N. W. Arnell, D. Bernie, S. Mittal, A. C. Köberle, J. Lowe, J. **Rogelj**, and S. Monteith, "Near-term transition and longer-term physical climate risks of greenhouse gas emissions pathways," *Nature Climate Change*, 1–9, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01236-x

[105] I. Sognnaes, A. Gambhir, D.-J. van de Ven, A. Nikas, A. Anger-Kraavi, H. Bui, L. Campagnolo, E. Delpiazzo, H. Doukas, S. Giarola, N. Grant, A. Hawkes, A. C. Köberle, A. Kolpakov, S. Mittal, J. Moreno, S. Perdana, J. **Rogelj**, M. Vielle, and G. P. Peters, "A multi-model analysis of long-term emissions and warming implications of current mitigation efforts," *Nature Climate Change*, 1–8, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01206-3

[106] A. C. Koberle, T. Vandyck, C. Guivarch, N. Macaluso, V. Bosetti, A. Gambhir, M. Tavoni, and J. **Rogelj**, "The cost of mitigation revisited," *Nature Climate Change*, 1–11, 2021, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01203-6

[107] M. A. Martin, O. A. Sendra, A. Bastos, N. Bauer, C. Bertram, T. Blenckner, K. Bowen, P. M. Brando, T. B. Rudolph, M. Büchs, M. Bustamante, D. Chen, H. Cleugh, P. Dasgupta, F. Denton, J. F. Donges, F. K. Donkor, H. Duan, C. M. Duarte, K. L. Ebi, C. M. Edwards, A. Engel, E. Fisher, S. Fuss, J. Gaertner, A. Gettelman, C. A. J. Girardin, N. R. Golledge, J. F. Green, M. R. Grose, M. Hashizume, S. Hebden, H. Hepach, M. Hirota, H.-H. Hsu, S. Kojima, S. Lele, S. Lorek, H. K. Lotze, H. D. Matthews, D. McCauley, D. Mebratu, N. Mengis, R. H. Nolan, E. Pihl, S. Rahmstorf, A. Redman, C. E. Reid, J. Rockström, J. **Rogelj**, M. Saunois, L. Sayer, P. Schlosser, G. B. Sioen, J. H. Spangenberg, D. Stammer, T. N. S. Sterner, N. Stevens, K. Thonicke, H. Tian, R. Winkelmann, and J. Woodcock, "Ten new insights in climate science 2021: A horizon scan," *Global Sustainability*, vol. 4, 2021, ISSN: 2059-4798. DOI: 10.1017/sus.2021.25. [Online]. Available: https://www.cambridge.org/core/journals/global-sustainability/article/ten-new-insights-in-climate-science-2021-a-horizon-scan/F8154615FCDB3453D7C6E198B9AFD114

[108] A. Nikas, A. Elia, B. Boitier, K. Koasidis, H. Doukas, G. Cassetti, A. Anger-Kraavi, H. Bui, L. Campagnolo, R. De Miglio, E. Delpiazzo, A. Fougeyrollas, A. Gambhir, M. Gargiulo, S. Giarola, N. Grant, A. Hawkes, A. Herbst, A. C. Koberle, A. Kolpakov, P. Le Mouël, B. McWilliams, S. Mittal, J. Moreno, F. Neuner, S. Perdana, G. P. Peters, P. Plötz, J. **Rogelj**, I. Sognnaes, D.-J. Van de Ven, M. Vielle, G. Zachmann, P. Zagamé, and A. Chiodi, "Where is the eu headed given its current climate policy? a stakeholder-driven model inter-comparison," *Science of The Total Environment*, vol. 793, p. 148 549, 2021, ISSN: 0048-9697. DOI: 10.1016/j.scitotenv.2021.148549

[109] Y. Ou, G. Iyer, L. Clarke, J. Edmonds, A. A. Fawcett, N. Hultman, J. R. McFarland, M. Binsted, R. Cui, C. Fyson, A. Geiges, S. Gonzales-Zuñiga, M. J. Gidden, N. Höhne, L. Jeffery, T. Kuramochi, J. Lewis, M. Meinshausen, Z. Nicholls, P. Patel, S. Ragnauth, J. **Rogelj**, S. Waldhoff, S. Yu, and H. McJeon, "Can updated climate pledges limit warming well below 2°c?" *Science*, vol. 374, no. 6568, 693–695, 2021. DOI: 10.1126/science.abl8976

[110] J. **Rogelj** and M. Willers QC, "Youth activists are forcing governments to take account of the intergenerational impact of climate change," *Energy Law Review*, no. 3, 6–11, 2021, ISSN: 2632-0258

[111] A. Schultes, F. Piontek, B. Soergel, J. **Rogelj**, L. Baumstark, E. Kriegler, O. Edenhofer, and G. Luderer, "Economic damages from on-going climate change imply deeper near-term emission cuts," *Environmental Research Letters*, vol. 16, no. 10, p. 104 053, 2021, ISSN: 1748-9326. DOI: 10.1088/1748-9326/ac27ce

[112] A. H. MacDougall, J. **Rogelj**, and P. Withey, "Estimated climate impact of replacing agriculture as the primary food production system," *Environmental Research Letters*, 2021, ISSN: 1748-9326. DOI: 10.1088/1748-9326/ac3aa5. [Online]. Available: http://iopscience.iop.org/article/10.1088/1748-9326/ac3aa5

[113] R. D. Lamboll, C. D. Jones, R. B. Skeie, S. Fiedler, B. H. Samset, N. P. Gillett, J. **Rogelj**, and P. M. Forster, "Modifying emissions scenario projections to account for the effects of covid-19: Protocol for covidmip," English, *Geoscientific Model Development*, vol. 14, no. 6, 3683–3695, 2021, ISSN: 1991-959X. DOI: 10.5194/gmd-14-3683-2021

[114] Z. Nicholls, M. Meinshausen, J. Lewis, M. R. Corradi, K. Dorheim, T. Gasser, R. Gieseke, A. P. Hope, N. J. Leach, L. A. McBride, Y. Quilcaille, J. **Rogelj**, R. J. Salawitch, B. H. Samset, M. Sandstad, A. Shiklomanov, R. B. Skeie, C. J. Smith, S. J. Smith, X. Su, J. Tsutsui, B. Vega-Westhoff, and D. L. Woodard, "Reduced complexity model intercomparison project phase 2: Synthesising earth system knowledge for probabilistic climate projections," en, *Earth's Future*, vol. n/a, no. n/a, e2020EF001900, 2021, ISSN: 2328-4277. DOI: https://doi.org/10.1029/2020EF001900

2022

[115] M. R. Allen, G. P. Peters, K. P. Shine, C. Azar, P. Balcombe, O. Boucher, M. Cain, P. Ciais, W. Collins, P. M. Forster, D. J. Frame, P. Friedlingstein, C. Fyson, T. Gasser, B. Hare, S. Jenkins, S. P. Hamburg, D. J. A. Johansson, J. Lynch, A. Macey, J. Morfeldt, A. Nauels, I. Ocko, M. Oppenheimer, S. W. Pacala, R. Pierrehumbert, J. **Rogelj**, M. Schaeffer, C. F. Schleussner, D. Shindell, R. B. Skeie, S. M. Smith, and K. Tanaka, "Indicate separate contributions of long-lived and short-lived greenhouse gases in emission targets," en, *npj Climate and Atmospheric Science*, vol. 5, no. 11, 1–4, Jan. 2022, ISSN: 2397-3722. DOI: 10.1038/s41612-021-00226-2

[116] C.-F. Schleussner, G. Ganti, J. **Rogelj**, and M. J. Gidden, "An emission pathway classification reflecting the paris agreement climate objectives," en, *Communications Earth*

and Environment, vol. 3, no. 11, 1–11, 2022, ISSN: 2662-4435. DOI: 10.1038/s43247-022-00467-w

[117] A. Gambhir, M. George, H. McJeon, N. W. Arnell, D. Bernie, S. Mittal, A. C. Köberle, J. Lowe, J. **Rogelj**, and S. Monteith, "Near-term transition and longer-term physical climate risks of greenhouse gas emissions pathways," en, *Nature Climate Change*, vol. 12, no. 11, 88–96, 2022, ISSN: 1758-6798. DOI: 10.1038/s41558-021-01236-x

[118] M. Gibson, J. Portugal Pereira, R. Slade, and J. **Rogelj**, "Agent-based modelling of future dairy and plant-based milk consumption for uk climate targets," *Journal of Artificial Societies and Social Simulation*, vol. 25, no. 2, p. 3, 2022, ISSN: 1460-7425

[119] J. S. Kikstra, Z. R. J. Nicholls, C. J. Smith, J. Lewis, R. D. Lamboll, E. Byers, M. Sandstad, M. Meinshausen, M. J. Gidden, J. **Rogelj**, E. Kriegler, G. P. Peters, J. S. Fuglestvedt, R. B. Skeie, B. H. Samset, L. Wienpahl, D. P. van Vuuren, K.-I. van der Wijst, A. Al Khourdajie, P. M. Forster, A. Reisinger, R. Schaeffer, and K. Riahi, "The ipcc sixth assessment report wgiii climate assessment of mitigation pathways: From emissions to global temperatures," English, *Geoscientific Model Development*, vol. 15, no. 24, 9075–9109, Dec. 2022, ISSN: 1991-959X. DOI: 10.5194/gmd-15-9075-2022

[120] Z. Nicholls, M. Meinshausen, J. Lewis, C. J. Smith, P. M. Forster, J. S. Fuglestvedt, J. **Rogelj**, J. S. Kikstra, K. Riahi, and E. Byers, "Changes in ipcc scenario assessment emulators between sr1.5 and ar6 unraveled," en, *Geophysical Research Letters*, vol. 49, no. 20, e2022GL099788, 2022, ISSN: 1944-8007. DOI: 10.1029/2022GL099788

[121] B. Zakeri, K. Paulavets, L. Barreto-Gomez, L. G. Echeverri, S. Pachauri, B. Boza-Kiss, C. Zimm, J. **Rogelj**, F. Creutzig, D. Ürge Vorsatz, D. G. Victor, M. D. Bazilian, S. Fritz, D. Gielen, D. L. McCollum, L. Srivastava, J. D. Hunt, and S. Pouya, "Pandemic, war, and global energy transitions," *Energies*, vol. 15, no. 17, 2022, ISSN: 1996-1073. DOI: 10.3390/en15176114. [Online]. Available: https://www.mdpi.com/1996-1073/15/17/6114

2023

[122] J. **Rogelj**, T. Fransen, M. G. J. den Elzen, R. D. Lamboll, C. Schumer, T. Kuramochi, F. Hans, S. Mooldijk, and J. Portugal-Pereira, "Credibility gap in net-zero climate targets leaves world at high risk," *Science*, vol. 380, no. 6649, 1014–1016, Jun. 2023. DOI: 10.1126/science.adg6248

[123] P. M. Forster, C. J. Smith, T. Walsh, W. F. Lamb, R. Lamboll, M. Hauser, A. Ribes, D. Rosen, N. Gillett, M. D. Palmer, J. **Rogelj**, K. von Schuckmann, S. I. Seneviratne, B. Trewin, X. Zhang, M. Allen, R. Andrew, A. Birt, A. Borger, T. Boyer, J. A. Broersma, L. Cheng, F. Dentener, P. Friedlingstein, J. M. Gutiérrez, J. Gütschow, B. Hall, M. Ishii, S. Jenkins, X. Lan, J.-Y. Lee, C. Morice, C. Kadow, J. Kennedy, R. Killick, J. C. Minx, V. Naik, G. P. Peters, A. Pirani, J. Pongratz, C.-F. Schleussner, S. Szopa, P. Thorne, R. Rohde, M. Rojas Corradi, D. Schumacher, R. Vose, K. Zickfeld, V. Masson-Delmotte, and P. Zhai, "Indicators of global climate change 2022: Annual update of large-scale indicators of the state of the climate system and human influence," English, *Earth System Science Data*, vol. 15, no. 6, 2295–2327, Jun. 2023, ISSN: 1866-3508. DOI: 10.5194/essd-15-2295-2023

[124] R. F. Stuart-Smith, L. Rajamani, J. **Rogelj**, and T. Wetzer, "Legal limits to the use of co2 removal," *Science*, vol. 382, no. 6672, 772–774, Nov. 2023. DOI: 10.1126/science.adi9332

[125] J. J. Xie, M. Martin, J. **Rogelj**, and I. Staffell, "Distributional labour challenges and opportunities for decarbonizing the us power system," en, *Nature Climate Change*, 1–10, Nov. 2023, ISSN: 1758-6798. DOI: 10.1038/s41558-023-01802-5

[126] S. Palazzo Corner, M. Siegert, P. Ceppi, B. Fox-Kemper, T. L. Frölicher, A. Gallego-Sala, J. Haigh, G. C. Hegerl, C. D. Jones, R. Knutti, C. D. Koven, A. H. MacDougall, M. Meinshausen, Z. Nicholls, J. B. Sallée, B. M. Sanderson, R. Séférian, M. Turetsky, R. G. Williams, S. Zaehle, and J. **Rogelj**, "The zero emissions commitment and climate stabilisation," English, *Frontiers in Science*, vol. 0, 2023, ISSN: 2813-6330. DOI: 10.3389/fsci.2023.1170744. [Online]. Available: https://www.frontiersin.org/journals/science/articles/10.3389/fsci.2023.1170744/full

[127] U. Kloenne, A. Nauels, P. Pearson, R. M. DeConto, H. S. Findlay, G. Hugelius, A. Robinson, J. **Rogelj**, E. A. G. Schuur, J. Stroeve, and C.-F. Schleussner, "Only halving emissions by 2030 can minimize risks of crossing cryosphere thresholds," en, *Nature Climate Change*, vol. 13, no. 11, 9–11, Jan. 2023, ISSN: 1758-6798. DOI: 10.1038/s41558-022-01566-4

[128] P. Forster, A. Pirani, D. Rosen, J. **Rogelj**, and J. Cook, "Climate science as foundation for global climate negotiations," en, *Environmental Research: Climate*, 2023, ISSN: 2752-5295. DOI: 10.1088/2752-5295/acc67f. [Online]. Available: http://iopscience.iop.org/article/10.1088/2752-5295/acc67f

[129] M. G. J. den Elzen, I. Dafnomilis, A. F. Hof, M. Olsson, A. Beusen, W. J. W. Botzen, T. Kuramochi, L. Nascimento, and J. **Rogelj**, "The impact of policy and model uncertainties on emissions projections of the paris agreement pledges," en, *Environmental Research Letters*, vol. 18, no. 5, p. 054 026, May 2023, ISSN: 1748-9326. DOI: 10.1088/1748-9326/acceb7

[130] R. D. Lamboll, Z. R. J. Nicholls, C. J. Smith, J. S. Kikstra, E. Byers, and J. **Rogelj**, "Assessing the size and uncertainty of remaining carbon budgets," en, *Nature Climate Change*, 1–8, Oct. 2023, ISSN: 1758-6798. DOI: 10.1038/s41558-023-01848-5

[131] R. Prütz, J. Strefler, J. **Rogelj**, and S. Fuss, "Understanding the carbon dioxide removal range in 1.5 °c compatible and high overshoot pathways," en, *Environmental Research Communications*, vol. 5, no. 4, p. 041 005, Apr. 2023, ISSN: 2515-7620. DOI: 10.1088/2515-7620/accdba

[132] J. **Rogelj**, "Net zero targets in science and policy," en, *Environmental Research Letters*, vol. 18, no. 2, p. 021 003, Jan. 2023, ISSN: 1748-9326. DOI: 10.1088/1748-9326/acb4ae

[133] D.-J. van de Ven, S. Mittal, A. Gambhir, R. D. Lamboll, H. Doukas, S. Giarola, A. Hawkes, K. Koasidis, A. C. Köberle, H. McJeon, S. Perdana, G. P. Peters, J. **Rogelj**, I. Sognnaes, M. Vielle, and A. Nikas, "A multimodel analysis of post-glasgow climate targets and feasibility challenges," en, *Nature Climate Change*, vol. 13, no. 66, 570–578, Jun. 2023, ISSN: 1758-6798. DOI: 10.1038/s41558-023-01661-0

[134] K. Zickfeld, A. J. MacIsaac, J. G. Canadell, S. Fuss, R. B. Jackson, C. D. Jones, A. Lohila, H. D. Matthews, G. P. Peters, J. **Rogelj**, and S. Zaehle, "Net-zero approaches must consider earth system impacts to achieve climate goals," en, *Nature Climate Change*, vol. 13, no. 1212, 1298–1305, Dec. 2023, ISSN: 1758-6798. DOI: 10.1038/s41558-023-01862-7

[135] A. Gambhir, S. Mittal, R. D. Lamboll, N. Grant, D. Bernie, L. Gohar, A. Hawkes, A. Köberle, J. **Rogelj**, and J. A. Lowe, "Adjusting 1.5 degree c climate change mitigation pathways in light of adverse new information," en, *Nature Communications*, vol. 14, no. 11, p. 5117, Aug. 2023, ISSN: 2041-1723. DOI: 10.1038/s41467-023-40673-4

2024

[136] J. **Rogelj** and R. D. Lamboll, "Substantial reductions in non-co2 greenhouse gas emissions reductions implied by ipcc estimates of the remaining carbon budget," en, *Communications Earth & Environment*, vol. 5, no. 1, p. 35, Jan. 2024, ISSN: 2662-4435. DOI: 10.1038/s43247-023-01168-8

[137] P. M. Cox, M. S. Williamson, P. Friedlingstein, C. D. Jones, N. Raoult, J. **Rogelj**, and R. M. Varney, "Emergent constraints on carbon budgets as a function of global warming," en, *Nature Communications*, vol. 15, no. 11, p. 1885, Feb. 2024, ISSN: 2041-1723. DOI: 10.1038/s41467-024-46137-7

D – SOFTWARE, TOOLS & CODE

[138] D. Huppmann, E. Kriegler, V. Krey, K. Riahi, J. **Rogelj**, S. K. Rose, J. Weyant, N. Bauer, C. Bertram, V. Bosetti, K. Calvin, J. Doelman, L. Drouet, J. Emmerling, S. Frank, S. Fujimori, D. Gernaat, A. Grubler, C. Guivarch, M. Haigh, C. Holz, G. Iyer, E. Kato, K. Keramidas, A. Kitous, F. Leblanc, J.-Y. Liu, K. Löffler, G. Luderer, A. Marcucci, D. McCollum, S. Mima, A. Popp, R. D. Sands, F. Sano, J. Strefler, J. Tsutsui, D. Van Vuuren, Z. Vrontisi, M. Wise, and R. Zhang, *IAMC 1.5°C Scenario Explorer and Data hosted by IIASA*. Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018. DOI: 10.22022/SR15/08-2018.15429. [Online]. Available: https://data.ene.iiasa.ac.at/iamc-sr15-explorer

[139] D. Huppmann, J. **Rogelj**, E. Kriegler, L. Mundaca, P. Forster, S. Kobayashi, R. Séferian, and M. V. Vilariño, "Scenario analysis notebooks for the IPCC Special Report on Global Warming of 1.5°C," 2018. DOI: 10.22022/SR15/08-2018.15428. [Online]. Available: https://github.com/iiasa/ipcc_sr15_scenario_analysis

[140] V. Krey, P. Havlik, O. Fricko, J. Zilliacus, M. Gidden, M. Strubegger, G. Kartasasmita, T. Ermolieva, N. Forsell, M. Gusti, and et al., *MESSAGE-GLOBIOM 1.0 Documentation*. 2016. [Online]. Available: http://data.ene.iiasa.ac.at/message-globiom/

[141] E. Byers, V. Krey, E. Kriegler, K. Riahi, R. Schaeffer, J. Kikstra, R. Lamboll, Z. Nicholls, M. Sandstad, C. Smith, K. van der Wijst, F. Lecocq, J. Portugal-Pereira, Y. Saheb, A. Stromann, H. Winkler, C. Auer, E. Brutschin, C. Lepault, E. Müller-Casseres, M. Gidden, D. Huppmann, P. Kolp, G. Marangoni, M. Werning, K. Calvin, C. Guivarch, T. Hasegawa, G. Peters, J. Steinberger, M. Tavoni, D. van Vuuren, A. Al Khourdajie, P. Forster, J. Lewis, M. Meinshausen, J. **Rogelj**, B. Samset, and R. Skeie, *Ar6 scenarios database*, eng, 2022. DOI: 10.5281/zenodo.5886912. [Online]. Available: https://zenodo.org/record/5886912

[142] R. D. Lamboll and J. **Rogelj**, "Code for estimation of remaining carbon budget in ipcc ar6 wgi," en, 2022. DOI: 10.5281/zenodo.6373365. [Online]. Available: https://www.zenodo.org/record/6373365

E – OTHER CONTRIBUTIONS

[143] J. **Rogelj**, B. Hare, J. Nabel, K. Macey, M. Schaeffer, K. Markmann, and M. Meinshausen, "Halfway to copenhagen, no way to 2°C," *Nature Reports Climate Change*, no. 0907, 81–83, 2009. DOI: 10.1038/climate.2009.57

[144] J. **Rogelj**, "Earth science: A holistic approach to climate targets," *Nature*, vol. 499, no. 7457, 160–161, 2013. DOI: 10.1038/nature12406

[145] J. **Rogelj** and R. Knutti, "Geosciences after paris," *Nature Geosci*, vol. 9, no. 3, 187–189, 2016. DOI: 10.1038/ngeo2668

[146] J. **Rogelj**, "A path awaiting decisive steps in the pathway toward a net-zero-emissions future," *One Earth*, vol. 1, no. 1, 18–20, 2019. DOI: 10.1016/j.oneear.2019.07.001

[147] J. **Rogelj**, "The uk's rollback of climate policies will cost its citizens and the world," en, *Nature*, vol. 622, no. 7981, 9–9, Sep. 2023. DOI: 10.1038/d41586-023-03057-8

[148] T. Busch, C. H. Cho, A. G. F. Hoepner, G. Michelon, and J. **Rogelj**, "Corporate greenhouse gas emissions' data and the urgent need for a science-led just transition: Introduction to a thematic symposium," en, *Journal of Business Ethics*, Jan. 2023, ISSN: 1573-0697. DOI: 10.1007/s10551-022-05288-7. [Online]. Available: https://doi.org/10.1007/s10551-022-05288-7

[149] S. Palazzo Corner and J. **Rogelj**, *Taking earth's temperature: Will zero carbon mean zero change?* en, 2023. [Online]. Available: https://kids.frontiersin.org/articles/10.3389/frym.2023.1248929

F – REPORTS

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE — IPCC

IPCC Fifth Assessment Report (2013-2014)

IPCC (2013) *Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis.* Cambridge University Press, Cambridge, UK and New York, NY, USA. — **contributing author**
- Summary for Policymakers
- Technical Summary
- Chapter 10: *Detection and Attribution of Climate Change: from Global to Regional*
- Chapter 12: *Long-term Climate Change: Projections, Commitments and Irreversibility*

IPCC (2014) *Working Group III Contribution to the IPCC Fifth Assessment Report Climate Change 2014: Mitigation.* Cambridge University Press, Cambridge, UK and New York, NY, USA. — **contributing author**
- Summary for Policymakers
- Chapter 6: *Assessing Transformation Pathways*

IPCC (2014) *Synthesis Report of the IPCC Fifth Assessment Report.* Cambridge University Press,, Cambridge, UK and New York, NY, USA. — **extended writing team member**

[150] IPCC, "Summary for policymakers," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. Midgley, Eds. Cambridge University Press, 2013, 1–29, ISBN: ISBN 978-1-107-66182-0

[151] T. Stocker, D. Qin, G.-K. Plattner, L. Alexander, S. Allen, N. Bindoff, F.-M. Bréon, J. Church, U. Cubasch, S. Emori, P. Forster, P. Friedlingstein, N. Gillett, J. Gregory, D. Hartmann, E. Jansen, B. Kirtman, R. Knutti, K. K. Kumar, P. Lemke, J. Marotzke, V. Masson-Delmotte, G. Meehl, I. Mokhov, S. Piao, V. Ramaswamy, D. Randall, M. Rhein, M. Rojas, C. Sabine, D. Shindell, L. Talley, D. Vaughan, and S.-P. Xie, "Technical summary," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. Midgley, Eds. Cambridge University Press, 2013, 33–115, ISBN: ISBN 978-1-107-66182-0

[152] N. Bindoff, P. Stott, K. AchutaRao, M. Allen, N. Gillett, D. Gutzler, K. Hansingo, G. Hegerl, Y. Hu, S. Jain, I. Mokhov, J. Overland, J. Perlwitz, R. Sebbari, and X. Zhang, "Detection and attribution of climate change: From global to regional," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T.

Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. Midgley, Eds. Cambridge University Press, 2013, 867–952, ISBN: ISBN 978-1-107-66182-0

[153] M. Collins, R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W. J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A. Weaver, and M. Wehner, "Long-term climate change: Projections, commitments and irreversibility," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. Midgley, Eds. Cambridge University Press, 2013, 1029–1136, ISBN: ISBN 978-1-107-66182-0

[154] IPCC, "Summary for policymakers," 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*, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. v. Stechow, T. Zwickel, and J. Minx, Eds. Cambridge University Press, 2014, 1–33

[155] L. Clarke, K. Jiang, K. Akimoto, M. Babiker, G. Blanford, K. Fisher-Vanden, J.-C. Hourcade, V. Krey, E. Kriegler, A. Löschel, D. McCollum, S. Paltsev, S. Rose, P. Shukla, M. Tavoni, B. v. d. Zwaan, and D. v. Vuuren, "Assessing transformation pathways," 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*, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. v. Stechow, T. Zwickel, and J. Minx, Eds. Cambridge University Press, 2014, 413–510

[156] IPCC, "Summary for policymakers," in *Climate Change 2014: Synthesis Report of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 2014, 1–32

IPCC Special Report on Global Warming of 1.5 °C (2018)

IPCC (2018) *Special Report on Global Warming of 1.5 degrees.*
– Summary for Policymakers: **core writing team**
– Chapter 2: *Mitigation Pathways Compatible with 1.5 °C in the Context of Sustainable Development*: **coordinating lead author**
– Chapter 3: *Impacts of 1.5 °C of Global Warming on Natural and Human Systems*: **contributing author**
– Chapter 4: *Strengthening and Implementing the Global Response*: **contributing author**
– Supplementary Material: *Mitigation Pathways Compatible with 1.5 °C in the Context of Sustainable Development*: **lead author**
– Annex I: *Glossary*: **lead author**

[157] IPCC, "Summary for policymakers," 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*, V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. Matthews, Y. Chen, X. Zhou, M. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T.

Waterfield, Eds. World Meteorological Organization, 2018, p. 32. [Online]. Available: http://www.ipcc.ch/report/sr15/

[158] J. **Rogelj**, D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M. V. Vilariño, "Mitigation pathways compatible with 1.5°C in the context of sustainable development," 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*, G. Flato, J. Fuglestvedt, R. Mrabet, and R. Schaeffer, Eds. IPCC/WMO, 2018, 93–174. [Online]. Available: http://www.ipcc.ch/report/sr15/

[159] O. Hoegh-Guldberg, D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K. L. Ebi, F. Engelbrecht, Z. Guangsheng, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S. I. Seneviratne, A. Thomas, and R. Warren, "Impacts of 1.5°C of global warming on natural and human systems," 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*, J. A. Marengo, J. Pereira, and B. Sherstyukov, Eds. World Meteorological Organisation, 2018. [Online]. Available: http://www.ipcc.ch/report/sr15/

[160] H. de Coninck, A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, J.-C. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, and T. Sugiyama, "Strengthening and implementing the global response," 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*, A. Abdulla, R. Boer, M. Howden, and D. Ürge Vorsatz, Eds. World Meteorological Organisation, 2018. [Online]. Available: http://www.ipcc.ch/report/sr15/

[161] P. Forster, D. Huppmann, E. Kriegler, L. Mundaca, C. Smith, J. **Rogelj**, and R. Séférian, "Mitigation pathways compatible with 1.5°C in the context of sustainable development supplementary material.," 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.* World Meteorological Organisation, 2018. [Online]. Available: http://www.ipcc.ch/report/sr15/

[162] J. R. Matthews, M. Babiker, H. de Coninck, S. Connors, R. van Diemen, R. Djalante, K. L. Ebi, N. Ellis, A. Fischlin, T. Guillén Bolaños, K. de Kleijne, V. Masson-Delmotte, R. Millar, E. S. Poloczanska, H.-O. Pörtner, A. Reisinger, J. **Rogelj**, S. I. Seneviratne, C. Singh, P. Tschakert, and N. M. Weyer, "Annex I: Glossary," 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*, J. R. Matthews, M. Babiker, H. de Coninck, S. Connors, R. van Diemen, R. Djalante, K. L. Ebi, N. Ellis, A. Fischlin, T. Guillén Bolaños, K. de Kleijne, V. Masson-Delmotte, R. Millar, E. S. Poloczanska, H.-O. Pörtner, A. Reisinger, J. **Rogelj**, S. I. Seneviratne, C. Singh, P. Tschakert, and N. M. Weyer, Eds. IPCC/WMO, 2018, 541–562

IPCC Sixth Assessment Report (2021–2023)

IPCC (2021)*Working Group I Contribution to the IPCC Sixth Assessment Report Climate Change 2021: The Physical Science Basis.*

- Summary for Policymakers: **core writing team**
- Technical Summary: **lead author**
- Chapter 5: *Global Carbon and other Biogeochemical Cycles and Feedbacks*: **lead author**
- Chapter 1: *Framing, Context, and Methods*: **contributing author**
- Chapter 2: *Changing State of the Climate System*: **contributing author**
- Chapter 6: *Short-Lived Climate Forcers*: **contributing author**
- Chapter 7: *The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity*: **contributing author**
- Chapter 12: *Weather and Climate Extreme Events in a Changing Climate*: **contributing author**
- Annex VII: *Glossary*: **editorial team**

[163] IPCC, *Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. 2021

[164] P. A. Arias, N Bellouin, E Coppola, R. G. Jones, G Krinner, J Marotzke, V Naik, M. D. Palmer, G.-K. Plattner, J **Rogelj**, M Rojas, J Sillmann, T Storelvmo, P. W. Thorne, B Trewin, K Achuta Rao, B Adhikary, R. P. Allan, K Armour, G Bala, R Barimalala, S Berger, J. G. Canadell, C Cassou, A Cherchi, W Collins, W. D. Collins, S. L. Connors, S Corti, F Cruz, F. J. Dentener, C Dereczynski, A Di Luca, A Diongue Niang, F. J. Doblas-Reyes, A Dosio, H Douville, F Engelbrecht, V Eyring, E Fischer, P Forster, B Fox-Kemper, J. S. Fuglestvedt, J. C. Fyfe, N. P. Gillett, L Goldfarb, I Gorodetskaya, J. M. Gutierrez, R Hamdi, E Hawkins, H. T. Hewitt, P Hope, A. S. Islam, C Jones, D. S. Kaufman, R. E. Kopp, Y Kosaka, J Kossin, S Krakovska, J.-Y. Lee, J Li, T Mauritsen, T. K. Maycock, M Meinshausen, S.-K. Min, P. M. S. Monteiro, T Ngo-Duc, F Otto, I Pinto, A Pirani, K Raghavan, R Ranasinghe, A. C. Ruane, L Ruiz, J.-B. Sallée, B. H. Samset, S Sathyendranath, S. I. Seneviratne, A. A. Sörensson, S Szopa, I Takayabu, A.-M. Treguier, B van den Hurk, R Vautard, K von Schuckmann, S Zaehle, X Zhang, and K Zickfeld, "Technical summary," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[165] J. G. Canadell, P. M. S. Monteiro, M. H. Costa, L Cotrim da Cunha, P. M. Cox, A. V. Eliseev, S Henson, M Ishii, S Jaccard, C Koven, A Lohila, P. K. Patra, S Piao, J **Rogelj**, S Syampungani, S Zaehle, and K Zickfeld, "Global carbon and other biogeochemical cycles and feedbacks," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[166] D Chen, M Rojas, B. H. Samset, K Cobb, A Diongue Niang, P Edwards, S Emori, S. H. Faria, E Hawkins, P Hope, P Huybrechts, M Meinshausen, S. K. Mustafa, G. K. Plattner, and A. M. Tréguier, "Framing, context, and methods," in *Climate Change 2021:*

The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[167] S. K. Gulev, P. W. Thorne, J Ahn, F. J. Dentener, C. M. Domingues, S Gerland, D Gong, D. S. Kaufman, H. C. Nnamchi, J Quaas, J. A. Rivera, S Sathyendranath, S. L. Smith, B Trewin, K von Shuckmann, and R. S. Vose, "Changing state of the climate system," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[168] V Naik, S Szopa, B Adhikary, P Artaxo, T Berntsen, W. D. Collins, S Fuzzi, L Gallardo, A Kiendler Scharr, Z Klimont, H Liao, N Unger, and P Zanis, "Short-lived climate forcers," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[169] P Forster, T Storelvmo, K Armour, W Collins, J. L. Dufresne, D Frame, D. J. Lunt, T Mauritsen, M. D. Palmer, M Watanabe, M Wild, and H Zhang, "The earth's energy budget, climate feedbacks, and climate sensitivity," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[170] S. I. Seneviratne, X Zhang, M Adnan, W Badi, C Dereczynski, A Di Luca, S Ghosh, I Iskandar, J Kossin, S Lewis, F Otto, I Pinto, M Satoh, S. M. Vicente-Serrano, M Wehner, and B Zhou, "Weather and climate extreme events in a changing climate," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, V Masson-Delmotte, P Zhai, A Pirani, S. L. Connors, C Péan, S Berger, N Caud, Y Chen, L Goldfarb, M. I. Gomis, M Huang, K Leitzell, E Lonnoy, J. B. R. Matthews, T. K. Maycock, T Waterfield, O Yelekçi, R Yu, and B Zhou, Eds. Cambridge University Press, 2021

[171] IPCC, *Annex vii: Glossary*, V. Masson-Delmotte, P. Zhai, A. Pirani, S. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. Matthews, T. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, Eds., Cambridge, United Kingdom and New York, NY, USA, 2021. DOI: 10.1017/9781009157896.022

IPCC (2022)*Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*

– Cross-Working Group Box: *Attribution in the IPCC Sixth Assessment Report* in Chapter 1 *Point of Departure and Key Concepts*: **author**
– Cross-Chapter Box: *Nature-Based Solutions for Climate Change Mitigation and Adaptation* in Chapter 2 *Terrestrial and Freshwater Ecosystems and Their Services*: **author**

[172] R. Rawshan Ara Begum, R. Lempert, T. B. E. Ali, T. Bernauer, W. Cramer, X. Cui, K. Mach, G. Nagy, N. Stenseth, R. Sukumar, and P. Wester, "Point of departure and key concepts," in *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge, UK and New York, USA: Cambridge University Press, 2022, pp. 121–196, ISBN: 9781009325844. DOI: 10.1017/9781009325844.003

[173] C. Parmesan, M. Morecroft, Y. Trisurat, R. Adrian, G. Anshari, A. Arneth, Q. Gao, P. Gonzalez, R. Harris, J. Price, N. Stevens, and G. Talukdarr, "Terrestrial and freshwater ecosystems and their services," in *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge, UK and New York, USA: Cambridge University Press, 2022, pp. 197–378, ISBN: 9781009325844. DOI: 10.1017/9781009325844.004.198

IPCC (2022)*Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*

– Annex III: *Scenarios and modelling methods*: **lead author**
– Chapter 3: *Mitigation pathways compatible with long-term goals*: **contributing author**

[174] C. Guivarch, E. Kriegler, J. Portugal-Pereira, V. Bosetti, J. Edmonds, M. Fischedick, P. Havlik, P. Jaramillo, V. Krey, F. Lecocq, A. F. P. Lucena, M. Meinshausen, S. Mirasgedis, B. O'Neill, G. P. Peters, **J. Rogelj**, S. Rose, Y. Saheb, G Strbac, A. Hammer Stromman, D. P. Van Vuuren, and N. Zhou, "Ipcc, 2022: Annex iii: Scenarios and modelling methods," in *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 2022

[175] K. Riahi, R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G. Peters, A. Rao, S. Robertson, A. Sebbit, J. Steinberger, M. Tavoni, and D. Van Vuuren, "Mitigation pathways compatible with long-term goals.," in *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, P. Shukla, J. Skea, R. Slade, A. A. Khourdajic, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, and J. Malley, Eds. Cambridge, UK and New York, NY, USA: Cambridge University Press, 2022. DOI: 10.1017/9781009157926.005

UNITED NATIONS ENVIRONMENT PROGRAMME — UNEP

UNEP Emissions Gap Reports – UNEP Synthesis Reports:

- UNEP (2010) *The Emissions Gap Report — Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2 °C or 1.5 °C?* – Chapter 2 and 5: **Lead author**
- UNEP (2011) *Bridging the Emissions Gap* – Chapter 2: **Lead author**
- UNEP (2012) *The Emissions Gap Report 2012* – Chapter 3: **Lead author**
- UNEP (2013) *The Emissions Gap Report 2013* – Chapter 3: **Lead author**
- UNEP (2014) *The Emissions Gap Report 2014* – Chapter 1 and 2: **Lead author**
- UNEP (2015) *The Emissions Gap Report 2015* – Chapter 2.2: **Lead author**; Chapter 3: **Contributing author**
- UNEP (2016) *The Emissions Gap Report 2016* – Chapter 3: **Lead author**
- UNEP (2017) *The Emissions Gap Report 2017* – Chapter 3: **Contributing author**
- UNEP (2018) *The Emissions Gap Report 2018* – Chapter 3: **Lead author**
- UNEP (2019) *The Emissions Gap Report 2019* – Chapter 3: **Lead author**
- UNEP (2020) *The Emissions Gap Report 2020* – Chapter 3: **Lead author**
- UNEP (2021) *The Emissions Gap Report 2021* – Chapter 3 and 4: **Lead author**
- UNEP (2022) *The Emissions Gap Report 2022* – Chapter 4: **Lead author**
- UNEP (2023) *The Emissions Gap Report 2023* – Chapter 3: **Contributing author**; Chapter 4: **Lead Author**

[176] W. Hare, J. Lowe, J. **Rogelj**, E. Sawin, and D. van Vuuren, "Chapter 2: Which emission pathways are consistent with a 2°C or 1.5°C temperature limit?" In *The Emissions Gap Report — Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2°C or 1.5°C?*. UNEP, 2010, 23–30, ISBN: 978-92-807-3134-7. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2010

[177] W. Hare, J. Lowe, J. **Rogelj**, E. Sawin, and D. van Vuuren, "Chapter 5: Twenty-first century temperature projections associated with the pledges.," in *The Emissions Gap Report — Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2°C or 1.5°C?*. UNEP, 2010, 45–48, ISBN: 978-92-807-3134-7. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2010

[178] N. Höhne, **J. Rogelj**, and K. Jiang, "Chapter 2: The emissions gap - an update," in *Bridging the Emissions Gap — A UNEP Synthesis Report*. UNEP, 2011, 15–27, ISBN: 978-92-807-3229-0. [Online]. Available: https://www.unenvironment.org/resources/bridging-emissions-gap

[179] J. **Rogelj** and P. R. Shukla, "Chapter 3: The emissions gap - an update," in *The Emissions Gap Report 2012 — A UNEP Synthesis Report*. UNEP, 2012, 21–29, ISBN: 978-92-807-3303-7. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2012

[180] G. Luderer, J. **Rogelj**, and R. Schaeffer, "Chapter 3: The emissions gap and its implications," in *The Emissions Gap Report 2013 — A UNEP Synthesis Report*. UNEP, 2013, 13–22, ISBN: 978-92-807-3353-2. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2013

[181] J. Alcamo, D. Puig, and J. **Rogelj**, "Chapter 1: Introduction," in *The Emissions Gap Report 2014 — A UNEP Synthesis Report*. UNEP, 2014, 1–2, ISBN: 978-92-807-3413-3. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2014

[182] J. **Rogelj**, D. McCollum, and S. Smith, "Chapter 2: What emission levels will comply with temperature limits?" In *The Emissions Gap Report 2014 — A UNEP Synthesis Report*. UNEP, 2014, 3–20, ISBN: 978-92-807-3413-3. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2014

[183] J. **Rogelj**, "Chapter 2: The importance of pre-2020 action – global emission pathways and the importance of enhanced action," in *The Emissions Gap Report 2015 — A UNEP Synthesis Report*. UNEP, 2015, 3–7, ISBN: 978-92-807-3491-1. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2015

[184] M. G. J. Den Elzen, T. Fransen, N. Hohne, H. Winkler, R. Schaeffer, F. Sha, and A. Garg, "Chapter 3: The emissions gap in 2025 and 2030," in *The Emissions Gap Report 2015 — A UNEP Synthesis Report*. UNEP, 2015, 12–27, ISBN: 978-92-807-3491-1. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2015

[185] M. G. J. Den Elzen, N. Hohne, and J. **Rogelj**, "Chapter 3: 2030 trends and ambition," in *The Emissions Gap Report 2016 — A UNEP Synthesis Report*. UNEP, 2016, 10–22, ISBN: 978-92-807-3617-5. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2016

[186] M. G. J. Den Elzen, N. Hohne, and K. Jiang, "Chapter 3: The emissions gap and its implications," in *The Emissions Gap Report 2017 — A UNEP Synthesis Report*. UNEP, 2017, 11–26, ISBN: 978-92-807-3673-1. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2017

[187] G. Luderer, J. **Rogelj**, M. G. J. Den Elzen, and K. Jiang, "Chapter 3: The emissions gap," in *The Emissions Gap Report 2018*. UNEP, 2018, 16–22, ISBN: 978-92-807-3726-4. [Online]. Available: https://www.unenvironment.org/interactive/emissions-gap-report/2018

[188] J. **Rogelj** and M. G. J. Den Elzen, "Chapter 3: The emissions gap," in *The Emissions Gap Report 2019*. UNEP, 2019, 21–27, ISBN: 978-92-807-3766-0. [Online]. Available: https://www.unenvironment.org/resources/emissions-gap-report-2019

[189] J. **Rogelj**, J. Portugal, and M. G. J. Den Elzen, "Chapter 3: The emissions gap," in *The Emissions Gap Report 2020*. UNEP, 2020, p. 132, ISBN: DEW/2310/NA. [Online]. Available: https://www.unep.org/emissions-gap-report-2020

[190] J. **Rogelj**, S. Smith, and S. Yu, "Chapter 3: Net zero emissions targets," in *The UNEP Emissions Gap Report 2021*. UNEP, 2021, 18–28, ISBN: 978-92-807-3890-2. [Online]. Available: https://www.unep.org/resources/emissions-gap-report-2021

[191] M. G. J. Den Elzen, J. Portugal Pereira, and J. **Rogelj**, "Chapter 4: The emissions gap," in *The UNEP Emissions Gap Report 2021*. UNEP, 2021, 29–37, ISBN: 978-92-807-3890-2. [Online]. Available: https://www.unep.org/resources/emissions-gap-report-2021

[192] T. Kuramochi, M. G. J. Den Elzen, and T. Fransen, "Chapter 3: Nationally determined contributions and long-term pledges: The global landscape and g20 member progress," in *The UNEP Emissions Gap Report 2022: The Closing Window, Climate crisis calls for rapid transformation of societies*. Nairobi, Kenya: UNEP, 2022, 11–25, ISBN: 978-92-807-3979-4

[193] J. **Rogelj**, M. G. J. Den Elzen, and J. Portugal-Pereira, "Chapter 4: The emissions gap," in *The UNEP Emissions Gap Report 2022: The Closing Window, Climate crisis calls for rapid transformation of societies*. Nairobi, Kenya: UNEP, 2022, 26–37, ISBN: 978-92-807-3979-4. [Online]. Available: https://www.unep.org/resources/emissions-gap-report-2022

[194] T. Kuramochi, M. G. J. Den Elzen, and T. Fransen, "Chapter 3: Nationally determined contributions and long-term pledges: The global landscape and g20 member progress," in *The UNEP Emissions Gap Report 2023: Broken Record - Temperatures hit new highs, yet world fails to cut emissions (again).* Nairobi, Kenya: UNEP, 2023, 11–22, ISBN: 978-92-807-4098-1

[195] J. **Rogelj**, M. G. J. Den Elzen, and J. Portugal Pereira, "Chapter 4: The emissions gap in 2030 and beyond," in *The UNEP Emissions Gap Report 2023: Broken Record - Temperatures hit new highs, yet world fails to cut emissions (again).* Nairobi, Kenya: UNEP, 2023, 23–33, ISBN: 978-92-807-4098-1

EUROPEAN SCIENTIFIC ADVISORY BOARD ON CLIMATE CHANGE — ESABCC

[196] O. Edenhofer, J. B. Jacobsen, L. Díaz Anadón, M. van Aalst, C. Cartalis, S. Dessai, V. Eory, E. Hertwich, L. Kitzing, E. López-Gunn, L. J. Nilsson, K. Riahi, J. **Rogelj**, N. Schrijver, and J.-F. Soussana, "Setting climate targets based on scientific evidence and eu values: Initial advice to the european commission on an eu-wide 2040 climate target and a greenhouse gas budget for the 2030–2050 period," eng, Jan. 2023. DOI: 10.2800/609405. [Online]. Available: https://climate-advisory-board.europa.eu/reports-and-publications/setting-climate-targets-based-on-scientific-evidence-and-eu-values-initial-recommendations-to-the-european-commission

[197] O. Edenhofer, J. B. Jacobsen, L. Díaz Anadón, M. van Aalst, C. Cartalis, S. Dessai, V. Eory, E. Hertwich, L. Kitzing, E. López-Gunn, L. J. Nilsson, K. Riahi, J. **Rogelj**, N. Schrijver, and J.-F. Soussana, "Scientific advice for the determination of an eu-wide 2040 climate target and a greenhouse gas budget for 2030–2050," eng, Jun. 2023. DOI: 10.2800/609405. [Online]. Available: https://data.europa.eu/doi/10.2800/609405

[198] O. Edenhofer, J. B. Jacobsen, L. Díaz Anadón, M. van Aalst, C. Cartalis, S. Dessai, V. Eory, E. Hertwich, L. Kitzing, E. López-Gunn, L. J. Nilsson, K. Riahi, J. **Rogelj**, N. Schrijver, and J.-F. Soussana, "Towards eu climate neutrality: Progress, policy gaps and opportunities," eng, Jan. 2024. DOI: 10.2800/73564. [Online]. Available: https://climate-advisory-board.europa.eu/reports-and-publications/towards-eu-climate-neutrality-progress-policy-gaps-and-opportunities

OTHER REPORTS (SELECTION)

[199] L. Seburikoko, M. Schaeffer, L. De Marez, B. Hare, K. Macey, C. C., and J. **Rogelj**, *Adequacy of Copenhagen mitigation pledges: The case for low carbon development strategies.* 2010

[200] J. Füssler, M. Herren, M. Guyer, J. **Rogelj**, and R. Knutti, *Emission Pathways to Reach 2°C Target. Model Results and Analysis.* 2012

[201] T. W. Bank, *Turn Down the Heat: Why a 4°C Warmer World Must be Avoided.* 2012, ISBN: 978-1-4648-0056-6. [Online]. Available: http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf

[202] M. Schaeffer, B. Hare, M. Rocha, and J. **Rogelj**, *Adequacy and feasibility of the 1.5°C long-term global limit.* Climate Action Network Europe, 2013. [Online]. Available: http://www.climateanalytics.org/sites/default/files/attachments/publications/Adequacy%20%26%20feasibility%20of%201.5c%20long-term%20global%20limit%20-%20July%202013-v2.pdf

[203] CONSTRAIN, *ZERO IN ON the remaining carbon budget and decadal warming rates* (The CONSTRAIN Project Annual Report), A. Nauels, D. Rosen, T. Mauritsen, A. Maycock, C. McKenna, J. **Rogelj**, C.-F. Schleussner, E. Smith, C. Smith, and P. Forster, Eds. CONSTRAIN Consortium, 2019. [Online]. Available: https://doi.org/10.5518/100/20

[204] S. Connors, M. Dionne, G. Hanák, R. Musulin, N. Aellen, M. Amjad, S. Bowen, D. Ruiz Carrascal, E. Coppola, E. Dal Moro, A. Dosio, S. H. Faria, T. Y. Gan, M. Gomis, J. M. Gutiérrez, P. Hope, R. Kopp, S. Krakovska, K Leitzell, D. Maraun, V. Masson-Delmotte, R. Matthews, T. Maycock, S. Paddam, G.-K. Plattner, A. Pui, M. Rahimi, R Ranasinghe, J. **Rogelj**, A. C. Ruane, S. Szopa, A Turner, R. Vautard, Y. Velichkova, A. P. Weigel, and X. Zhang, *Climate Science: A Summary for Actuaries. What the IPCC Climate Change Report 2021 Means for the Actuarial Profession.* Ottawa, Canada, 2022, p. 61. [Online]. Available: https://www.actuaries.org/IAA/Documents/Publications/Papers/Climate_Science_Summary_Actuaries.pdf

[205] O. Richters, C. Bertram, E. Kriegler, J. Anz, T. Beck, D. N. Bresch, M. Charles, L. Clarke, R. Cui, J. Edmonds, P. Hackstock, J. Hilaire, D. Holland, I. Hurst, A. Al Khourdajie, J. Kikstra, C. Kropf, Q. Lejeune, J. Lewis, I. Liadze, M. Meinshausen, J. Min, Z. Nicholls, P. Pfleiderer, F. Piontek, J. **Rogelj**, I. Sauer, C.-F. Schleussner, J. R. Schleypen, N. Schwind, F. Sferra, B. van Ruijven, P. Weigmann, S. Yu, A. Zhao, A. Zimmer, and M. Zwerling, "Ngfs climate scenarios database: Technical documentation v3.1," eng, Nov. 2022. [Online]. Available: https://www.ngfs.net/en/ngfs-climate-scenarios-central-banks-and-supervisors-september-2022

[206] S. Pelz, J. **Rogelj**, and K. Riahi, *Evaluating equity in european climate change mitigation pathways*, en, Monograph, Laxenburg, Austria, Jun. 2023. [Online]. Available: https://iiasa.dev.local/