MCC

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EXPERT ADVISORY BOARD

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DEVELOPMENTS AT MCC FROM 2020 TO 2022

Imprint

Developments from 2020 to 2022 (as of mid-2022)

Submitted to MCC's Expert Advisory Board by the institute's directorate

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MCC was founded jointly by

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Zusammenfassung: Höhepunkte und Erfolge 2020-2022

Das MCC wurde vor zehn Jahren mit dem Ziel gegründet, lösungsorientierte Politikpfade aufzuzeigen für Klimaschutz sowie generell für das Bewirtschaften der globalen Gemeinschaftsgüter – und damit für die Stärkung einer nachhaltigen Entwicklung und der vielen Aspekte des menschlichen Wohlergehens. Auf Basis unserer wirtschafts- und sozialwissenschaftlichen Expertise, die sich in einer hohen Publikationsrate in renommierten Fachzeitschriften äußert, informieren wir in einem iterativen gesellschaftlichen Lernprozess die politischen Entscheiderinnen und Entscheider.

An der Schnittstelle zwischen Wissenschaft und Politik haben wir in den vergangenen beiden Jahren den Konzeptnachweis erbracht. Wir haben gezeigt, dass unsere wissenschaftliche Forschung und unsere Aktivitäten an der Schnittstelle zwischen Wissenschaft und Politik nun vollständig integriert sind. Und wir sind in der Lage, überzeugende Impact-Stories zu produzieren, also unseren hochrangigen wissenschaftlichen Analysen politische Wirkung zu verschaffen.

In diesem Bericht stellen wir die wichtigsten Impact-Stories vor und beleuchten dabei, wie Forschung und Politik-Dialog interagieren und sich gegenseitig bereichern. So hat das MCC mit seinem spezifischen Know-how als klimapolitischer Thinktank zeitnah und fundiert auf die aktuelle Energiepreiskrise reagiert, die durch Russlands Angriffskrieg in der Ukraine ausgelöst wurde. Es hat Expertisen zu entsprechenden Politik-Optionen erstellt und auf hoher Ebene Diskussionen mit Entscheidungsträgerinnen und Entscheidungsträgern geführt.

Andere Impact-Stories betreffen etwa den Kohleausstieg und nachhaltige Entwicklung im globalen Süden, eine adäquate Governance-Architektur für CO_2-Entnahmen aus der Atmosphäre, das Adressieren der Zentralbanken beim vieldiskutierten Thema klimaorientierte Geldpolitik sowie die Stärkung neuer deliberativer Erkenntnisprozesse in Bürgerdialoge zur Klimapolitik.

Auch im Bereich der Assessment-Prozesse und Beratungsgremien gibt es eine wichtige Erfolgsgeschichte. Die MCC-Gruppenleiter Jan Minx und Felix Creutzig waren Koordinierende Leitautoren wichtiger Kapitel im Sechsten Sachstandsbericht (AR6) des Weltklimarats IPCC, der im April 2022 veröffentlicht wurde – dem wichtigsten klimapolitischen Bericht seit acht Jahren. Diese Beteiligung führte zu einer Welle von hochkarätigen Aktivitäten an der Schnittstelle zwischen Wissenschaft und Politik.

MCC-Generalsekretärin Brigitte Knopf berät die Bundesregierung seit 2020 als stellvertretende Vorsitzende des Expertenrats für Klimafragen. Auf EU-Ebene ist MCC-Direktor Ottmar Edenhofer seit März 2022 Vorsitzender des European Scientific Advisory Board on Climate Change.

Die Publikationsstatistik des MCC verzeichnet für 2021 einen neuen Höchststand. Neben einer großen Anzahl von Veröffentlichungen in hochrangigen interdisziplinären Zeitschriften wie *Nature*, *Science* und *PNAS* hatte das MCC auch Beiträge in hochrangigen Wirtschaftsjournals wie dem *American Economic Journal: Economic Policy*.

Was die Kommunikation und die Öffentlichkeitsarbeit betrifft, so hat sich gezeigt, dass der Rückgang infolge der Covid-19-Pandemie nur vorübergehend war. Die Zahl der Medienberichte ist 2021 stark angestiegen und lag im ersten Halbjahr 2022 mit 4.106 erneut um 50 % höher als im gleichen Zeitraum des vergangenen Jahres. Das liegt nicht zuletzt an den sehr aktiven Gruppenleitungen, die die Institutsleitung als „Gesichter des MCC" ergänzen. Unsere Forscherinnen und Forscher nutzen zudem zunehmend die sozialen Medien als direkte Form der Wissenschaftskommunikation. Auf Twitter und LinkedIn hat das MCC als Institut derzeit über 8.100 Follower, Anfang 2019 waren es noch 1.800.

Trotz der Pandemie wurden die Forschungsaktivitäten und -ergebnisse des MCC kontinuierlich in diversen Formaten des wissenschaftlichen und politischen Dialogs vorgestellt und diskutiert. Die Zahl der MCC-Präsentationen nimmt zu, ebenso die Zahl der MCC-Veranstaltungen. Zu den jüngsten Event-Höhepunkten

gehören das über mehrere Standorte verteilte Climate Neutrality Forum im September 2021, verschiedene Side-Events auf der Weltklimakonferenz COP 26 im November 2021 in Glasgow sowie ein hybrides Event in Berlin mit Live-Übertragung auf unserer Website im April 2022, bei der über den jüngsten Weltklimarat-Bericht zur Klimapolitik berichtet wurde. Zudem organisierte das MCC bedeutsame Veranstaltungen im Rahmen des vom Bundesministerium für Bildung und Forschung (BMBF) geförderten Kopernikus-Projekts Ariadne zur Energiewende.

In Bezug auf die Organisationsstruktur und den Personalbestand hat es zuletzt eine gewisse Konsolidierung gegeben. Angesichts der Partnerschaft mit dem PIK im Rahmen des dort neu eingerichteten Future Labs „Political Economy for inclusive wealth and sustainability (CERES)" besteht keine Notwendigkeit mehr, am MCC die offene Stelle in der Governance-Gruppe zu besetzen, da sich diese Themenbereiche weitgehend überschneiden. Nach einer Aufstockung des Personals im Jahr 2021, die vor allem mit dem Ariadne-Projekt zusammenhing, ist die Zahl der Mitarbeiter am MCC in diesem Jahr wieder leicht rückläufig; sie liegt derzeit bei gut 45 Vollzeitäquivalenten (VZÄ).

Unsere künftige Arbeit wird sicherlich von der aktuellen geopolitischen Krise und der Energiepreiskrise beeinflusst werden. Wir wollen unser spezifisches Fachwissen einbringen, damit die Bekämpfung des Klimawandels weiterhin ganz oben auf der Tagesordnung steht. Dies beinhaltet: 1) Beratung zu konkreten Antworten auf die Verteilungskonflikte der Klimapolitik, die durch die aktuelle Energiepreiskrise besonders in den Fokus gerückt sind; 2) Schärfung unseres Verständnisses für das Design und die Wirkung von Politikinstrumenten durch Anwenden und Weiterentwickeln stringenter Forschungsmethoden; und 3) Intensivierung und Vertiefung unserer Kompetenzen auf jenen Feldern, auf denen wir bereits stark sind (z. B. Optionen und Instrumente zur CO_2-Entnahme, CDR) und Fortsetzung und weiterer Ausbau unserer Aktivitäten zu neuartigen Entwicklungen und innovativen Themen (z. B. Gesundheit oder künstliche Intelligenz (KI) jeweils im Kontext des Klimawandels).

Executive summary: Highlights and achievements 2020–2022

MCC started ten years ago with the mission to provide solution-oriented policy pathways for climate mitigation, for governing the global commons in general, and for enhancing sustainable development and the many aspects of human wellbeing. Based on our economic and social science expertise, which results in a high rate of publication in renowned journals, we inform policymaking in an iterative societal learning process.

Within the last two years, we have provided a proof of concept with our work at the science–policy interface. We have shown that our scientific research and activities at the science–policy interface are now fully integrated, and we are in a position to generate powerful policy impact stories, combining our high-level analyses with policy impact.

In the report, we provide the most important impact stories, including how research and policy dialogue interact and mutually benefit each other. For example, with our specific know-how as a climate policy think tank, MCC has reacted promptly and profoundly to the current energy price crisis triggered by Russia's war of aggression in Ukraine, preparing expert reports on related policy options and conducting high-level discussions with decision makers.

Other impact stories include coal phase-out and sustainable development in the Global South, adequate governance of atmospheric carbon removal, addressing central banks on the much-debated issue of a climate-oriented monetary policy, and enhancing further climate deliberation processes through the implementation of citizens' dialogues.

There is also an important success story to tell in the area of assessment processes and advisory bodies. MCC group leaders Jan Minx and Felix Creutzig were coordinating lead authors of important chapters in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), published in April 2022 – the most important climate policy report in eight years. This involvement resulted in a wave of high-level activity at the science–policy interface.

MCC secretary general Brigitte Knopf has been advising Germany's Federal Government as deputy chair of the Council of Experts on Climate Change since 2020. At EU level, MCC Director Ottmar Edenhofer has served as Chair of the European Scientific Advisory Board on Climate Change since March 2022.

MCC's publication statistics showed a new peak in 2021. In addition to a huge number of publications in high-impact interdisciplinary journals such as *Nature, Science* and *PNAS*, MCC also has contributions in high-ranking economics journals, such as the *American Economic Journal: Economic Policy*.

When it comes to communication and outreach, the Covid-19 pandemic dip has proven to be temporary. We experienced a steep increase in media reports for 2021, and their number in the first half of 2022 (at 4,106) was once again 50% higher than in the same period last year. This is not least due to very active group leaders, who complement the directorate as the "faces of MCC". Our researchers are also increasingly discovering social media as a direct form of science communication. MCC as an institute currently has 8,100 followers on Twitter and LinkedIn, up from 1,800 in early 2019.

Despite the pandemic, MCC research activities and results have been continuously presented and discussed in various scientific and policy dialogue formats. The number of MCC presentations is growing, as is the number of MCC events. Recent event highlights include a Climate Neutrality Forum spread over several locations in September 2021; various contributions to the COP 26 climate conference side programme in November 2021 in Glasgow; and a hybrid event in Berlin which was broadcast live on our website in April 2022, telling the story of the recent IPCC report on climate policy. Also, MCC has organised influential events within the Ariadne energy transition project funded by the German Federal Ministry of Education and Research (BMBF).

In terms of organisational structure and staffing levels, there has been some consolidation recently. Since partnering with PIK on their new Future Lab "Political Economy for inclusive wealth and sustainability", we no longer feel the need to fill the open position in the Governance group at MCC, as these topics largely overlap. Following an increase in staffing in 2021, mainly related to the Ariadne project, the number of staff at the MCC is declining again this year; it currently stands at a good 45 full-time equivalents (FTEs).

Our future work will certainly be influenced by the current geopolitical crisis. We want to contribute our specific expertise to keep climate change mitigation high on the agenda. This includes: 1) providing guidance on tangible responses to the distributional conflicts of climate policy, which have come into particular focus due to the current energy price crisis; 2) sharpening our understanding of the design and impact of policy instruments by applying and advancing rigorous research methods; and 3) intensifying and deepening our competences in fields where we are already strong (e.g. options and instruments for carbon dioxide removal (CDR)) and continuing and further strengthening our activities on new developments and innovative topics (e.g. health or artificial intelligence (AI) in the context of climate change).

1   Research highlights and policy impact stories

In the past two years, MCC's most powerful achievement has been to interlink the two central areas of our work: scientific excellence and policy relevance. Our high-level economic and social science analyses on climate solutions are regularly published in high-ranking peer-reviewed journals and released as ad hoc MCC working papers. Building on this, our policy dialogue on a broad scale across the institute has had considerable impact on a variety of topics, by a wide range of staff members. MCC researchers are present in various assessment processes and advisory boards, and we have further structured and strengthened our work at the science–policy interface. We delivered a proof of concept for the idea of the Policy Unit that was set up in 2018. We have also provided major contributions to climate-related deliberation processes and have been active in agenda-setting for a number of topics. These include the distributional effects of climate policies, the political economy of coal, and demand-side solutions and carbon dioxide removal (CDR) for reaching net-zero goals. As scientific research and activities at the science–policy interface become more and more integrated, we provide the combined stories of our research highlights and policy impact in the following.

1.1   Cushioning the energy crisis

Since 24 February 2022, the world has changed fundamentally. The war in Ukraine has brought terrible suffering to countless people and has shaken the international order. It also affects substantially energy and climate policy. Prices for fossil fuels have risen to a record high and critical issues arising from this include the distributional impacts on private households, and energy-saving potentials to avoid a supply emergency. Our specific know-how as a climate think tank is in particular demand in these circumstances. Immediately after Russia's invasion of Ukraine, MCC contributed to the preparation of an appropriate response of Germany on several levels: MCC director Ottmar Edenhofer has discussed the oil and gas embargo in the leading national media, like *FAZ or Handelsblatt*. He also was part of an author team of Germany's National Academy of Science Leopoldina, emphasising the necessity to respond effectively to a potential gas and oil embargo. Researchers at MCC provided essential scientific reports:

Distributional effects of the energy price hike and policy options for compensation. By March, Matthias Kalkuhl and his team had proposed specific packages to cushion the effects of rising energy prices for Germany. Later, an analysis of the distributional effects of the government relief packages was provided. Our work was taken up in the media (newspaper and TV) and we have provided specific briefings for ministries, parliamentarians and bilateral meetings, and have presented results at several events. The study has shown how the rising costs of fossil fuels should be distributed among households, and how can politics ensure social compensation? MCC has been working on this topic for several years; in the context of researching solution-oriented policy portfolios for climate mitigation, carbon pricing is considered to be a core instrument. With specially designed and promptly produced expertise, we are in communication with policymakers at various levels.

Like climate policy, the geopolitical position of the EU against Russia depends on the ability to distribute costs of specific measures (e.g. import bans) within and between member states. In this context, Jan Steckel and colleagues have provided an EU-wide analysis of who is affected most and how this can be socially balanced. The results emphasise that higher energy prices can be cushioned by well-designed transfers, which can further increase the space for geopolitical as well as climate policy measures (see Figure 1).

Key publications:

- Kalkuhl et al., 2022. Effects of the energy price crisis on households in Germany. Socio-political challenges and policy options, <u>MCC working paper</u>.
- Kellner et al., 2022. *Entlastungspakete für Energiepreisanstiege: Auswirkungen und Nachbesserungsbedarf* (Relief packages for energy price increases: effects and need for improvement), <u>MCC working paper</u> (in German).
- Steckel et al., 2022. Effects of the energy price crisis on European households. Socio-political challenges and policy options, <u>MCC working paper.</u>
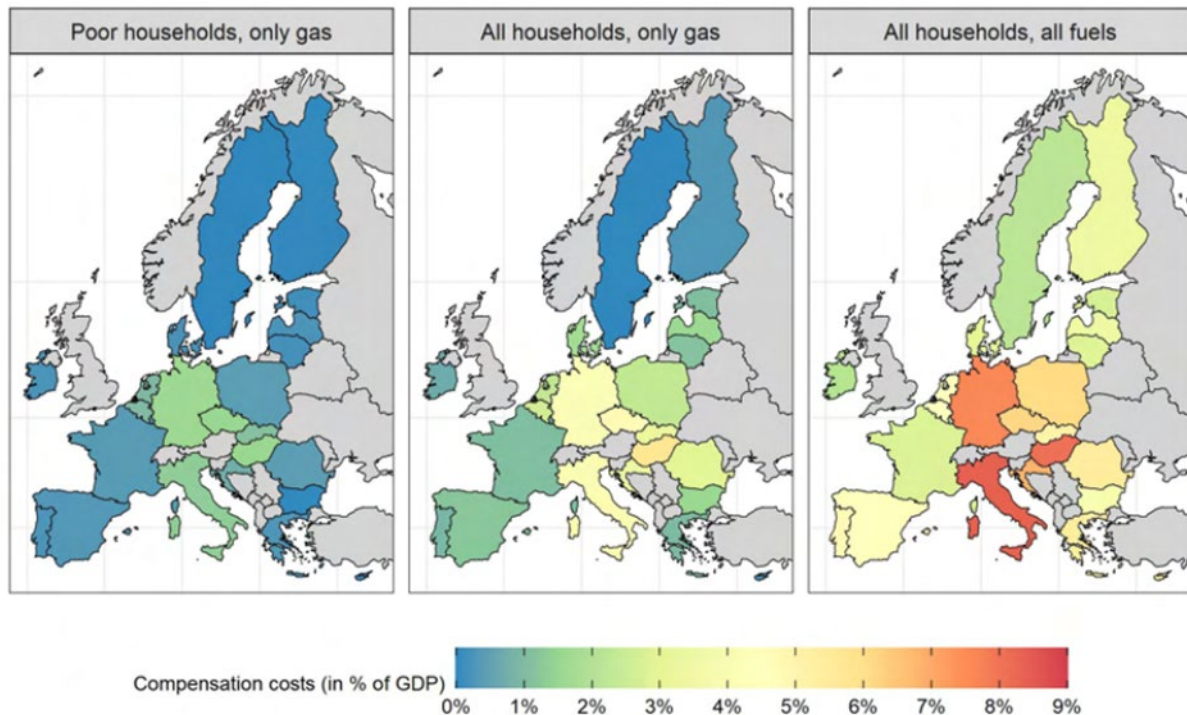
Figure 1: Fiscal costs in percentage of GDP for three stylised compensation schemes to cushion energy price shocks for vulnerable households. Steckel et. Al. (2022)

Short-term energy-saving potentials to ensure supply security. The idea of large-scale behavioural changes in energy use in transport or housing, or changes in diet has always been rather a sleeping giant in the context of the climate debate – much, as-yet untapped potential. Given the economic and energy policy consequences of the Ukraine war, this might now change. Based on previous work, especially in the context of the MCC-led chapter on demand-side solutions for the IPCC, we have provided input for the public debate in Germany. As early as three weeks after the beginning of the war, MCC researchers Jan Minx and Tarun Khanna outlined the path to far-reaching energy savings in private households in the influential Berlin-based decision-maker newsletter *Tagesspiegel Background*, drawing on a ground-breaking meta-study on energy-saving options they had just published in *Nature Energy* (Khanna et al. 2021). And a few weeks later, based on his IPCC expertise (see below), Felix Creutzig provided further input for the debate through a nationally and internationally widely acclaimed article in *Nature*. In this paper, he quantified the impact of policy-provoked behaviour changes in the context of the current energy crisis.

Key publications:

- Khanna et al., 2021. A multi-country meta-analysis on the role of behavioral change in reducing energy consumption and CO_2 emissions in residential buildings, <u>Nature Energy</u>
- Creutzig 2022. Fuel crisis: slash demand in three sectors to protect economies and climate, <u>Nature</u>

1.2   Political economy of climate policy

Climate targets are set, and policymakers have reiterated their commitment to the Paris Agreement and to limiting global warming to 1.5 degrees on several occasions. However, adequate climate action and implementation of policy measures is often lacking. Whether the urgently needed rapid progress can be achieved depends to a large extent on the possible objections and resistance to climate change mitigation being recognised in advance – such as political economy or distributional issues – addressed appropriately and thus overcome. Here, too, the integration of research and policy dialogue at MCC proves to be effective.

Designing and advocating socially balanced carbon pricing in Germany and Europe. Should Germany be ambitious and expand carbon pricing in the transport and building sectors, as launched at the beginning of 2021? Should Germany use carbon pricing as a guiding instrument of climate policy, and support such a policy at the EU level, as laid out in the European Commission's Fit for 55 package? And how should the revenues of carbon pricing be distributed in Germany? The latter was a major topic in the 2021 Bundestag election campaign and in the subsequent coalition negotiations of the new government coalition. MCC was strongly involved in this, focussing on the distribution and efficiency advantages of carbon pricing with per capita reimbursement of revenues – the so-called "*Klimageld*" that was taken up in the coalition treaty. Currently, questions arise around administrative implementation issues, taking behavioural and socioeconomic factors into account. In this context, Matthias Kalkuhl and team provided impulse papers, and launched a much-noticed carbon pricing calculation online tool (see Figure 2) that was adopted by *ZEIT Online*; results were taken up by Germany's weekly "*Die WirtschaftsWoche*". In addition, our research on carbon pricing, its distributional effects and the implementation of the "*Klimageld*" is being discussed in a regular dialogue forum where we bring together different ministries at one table. This format is very much appreciated, and trust has grown over the years. MCC researchers and members of the Policy Unit have also gave key note speeches and organised several discussions with representatives of business, civil society and parliamentarians. In addition, MCC staff members such as Matthias Kalkuhl and Brigitte Knopf have often been interviewed in the media, and MCC's work has been prominently incorporated in various podcasts (*Lage der Nation, Tagesspiegel Gradmesser*).

Key publications:

- Kalkuhl et al., 2021. *CO_2-Bepreisung: Mehr Klimaschutz mit mehr Gerechtigkeit* (Carbon pricing: greater climate protection with greater justice), MCC working paper.
- MCC carbon price calculator (in German): CO_2-Preis-Rechner des MCC.
- Kellner et al., 2022. *Entlastung der Haushalte von der CO_2-Bepreisung: Klimageld vs. Absenkung der EEG-Umlage* (Relief for households from carbon pricing: climate money vs. lowering the EEG levy), MCC working paper.
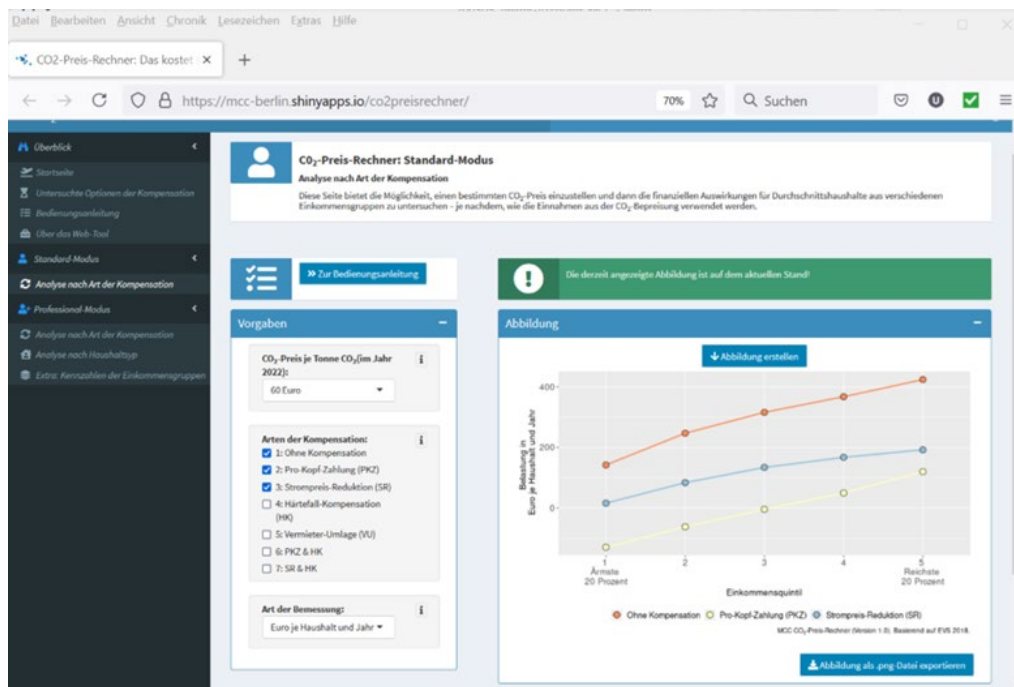
Figure 2: MCC's carbon pricing calculator (online tool)

Addressing the ongoing coal boom in the Global South. To limit global warming to 1.5 degrees Celsius, the world must do one thing above all – exit coal. According to the IPCC, carbon emissions from global coal use must be reduced by around 70% by 2030 compared to 2020. While there were some promising announcements before and during COP26 in Glasgow, coal-fired power generation is still being promoted by strong political and economic forces. MCC has led various key publications on the economics of coal in poor countries (e.g. Montrone et al. 2022), the political economy of coal (Jakob and Steckel 2021) and the global finance flows of coal (e.g. Manych et al. 2021). MCC researchers have also carried the coal question into public debates (e.g. through op-eds in *Süddeutsche Zeitung* and *Handelsblatt* in the German context and the *East Asia Forum* at the international level). At a side-event at COP26, Jan Steckel presented and discussed his team's ongoing extensive research on the political economy of coal, focussing on key players in the Global South, where he continues to be strongly engaged in research and policy dialogue. Policy briefs for phasing out coal for four key countries (India, Indonesia, Philippines and Vietnam) are also available.

Key publications:

- Jakob and Steckel (Editors), 2021. The Political Economy of Coal: Obstacles to Clean Energy Transitions, London, Routledge.
- Montrone, Steckel, and Kalkuhl, 2022. The type of power capacity matters for economic development-Evidence from a global panel. Resource and Energy Economics, 101313.
- Manych, Steckel, and Jakob, 2021. Finance-based accounting of coal emissions. Environmental Research Letters, 16(4), 044028.

Advising foreign governments on the implementation of carbon pricing. MCC is at the forefront of conducting and communicating research on carbon pricing in low- and middle-income countries. Jan Steckel was invited to discuss carbon pricing issues in the influential "Tell me how" podcast, hosted by World Bank's Roumeen Islam, and Ira Dorband and Jan Steckel have co-authored a chapter on the role of carbon taxes in Africa in the Brookings Foresight Africa report 2021. Jan Steckel has frequently discussed issues of carbon pricing with policymakers and stakeholders in Latin America (facilitated through UN CEPAL), with policymakers in the Arab League (facilitated through the German service provider for international cooperation – GIZ) and delegations to MCC from Vietnam, UAE and Mexico. MCC has also

been advising the Indonesian Ministry of Finance on efficient and socially acceptable carbon pricing in a three-year project in cooperation with GIZ, BMZ and Indonesian partners. A report on the social consequences of carbon pricing in Israel and how to alleviate them has been introduced at a high-level forum of Israeli ministries.

Key publications:

- Steckel and Missbach, 2021. Leaving No One Behind – Carbon Pricing in Israel: Distributional Consequences across Households, Policy Paper Series: Shaping the Transition to a Low-Carbon Economy – Perspectives from Israel and Germany. Israel Public Policy Institute and Heinrich Böll Foundation Tel Aviv.
- Steckel et al., 2021. Distributional impacts of carbon pricing in developing Asia. Nature Sustainability, 4(11), 1005–1014.
- Steckel, Renner and Missbach, 2021. Distributional Impacts of Carbon Pricing in Low-and Middle-Income Countries. In CESifo Forum (Vol. 22, No. 05, pp. 26–32). München: ifo Institut-Leibniz-Institut für Wirtschaftsforschung an der Universität München.

1.3   Contributions to assessments and leading positions in advisory boards

In addition to participating in informal science–policy processes via interactions with high-level stakeholders and institutions, MCC is directly and actively involved in large-scale, international and formalised assessment processes. This aspect is strengthened by some recent outstanding personal appointments to official government-appointed independent advisory boards.

Substantial contribution to the latest IPCC report. As coordinating lead authors (CLA), two working group leaders of our institute have been overseeing important chapters of the 6th Assessment Report (AR6) of Working Group (WG) III "Mitigating Climate Change". Jan Minx coordinated the chapter on trends and drivers of greenhouse gas emissions. In this context, an MCC-led research team compiled the most comprehensive stocktake of the various climate gases. The associated dataset has already been downloaded many thousands of times, setting a new standard for data accessibility in IPCC assessments. The development work on this highly valuable research infrastructure is now being continued by MCC researcher William Lamb in the context of the next UN Emissions Gap Report, in which he will serve as a lead author, coordinating the chapter on GHG emissions trends.

In the AR6 report, Felix Creutzig was in charge of the chapter on demand, services and social aspects of climate mitigation which formed part of the IPCC report for the first time. It highlights how the supply of renewable energy and energy-efficient production should not be viewed in isolation; climate mitigation policy must also address energy demand (i.e. energy use behaviour in transport, housing and diet). MCC-led scientific research prepared for this purpose was the basis for one of the figures in the IPCC Summary for Policymakers on the mitigation potential of demand-side options (see Figure 3).

In the Summary for Policymakers, which was co-authored by four MCC researchers, half of the eight figures were taken from the two chapters coordinated by the two MCC convening CLAs, indicating their importance to the overall report.

MCC used this report as an opportunity for extensive activities at the interface with politics. There were presentations to members of the Bundestag, the Chancellors office, the Foreign Office, the Federation of German Industries (BDI), the state development bank KfW, the German Labour Unions, *Deutscher Wasserstoffrat*, the heads of delegation of the G7, together with international appearances at the University of Oxford and the University of Leeds. In addition, MCC organised a public event with panellists from different ministries and stakeholders on the IPCC report and the impact on German climate policy,

in Berlin and online. There was much media and press attention with TV appearances in ARD, ZDF, NTV, NBC, CNC as well as appearances on radio/podcast such as the Economist podcast "Babbage".

Key publications:

- Minx et al., 2021. A comprehensive and synthetic dataset for global, regional and national greenhouse gas emissions by sector 1970–2018 with an extension to 2019, Earth System Science Data.
- Lamb et al., 2021. A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018, Environmental Research Letters.
- Creutzig et al., 2021. Demand-side solutions to climate change mitigation consistent with high levels of wellbeing, Nature Climate Change.

Demand-side mitigation can be achieved through changes in socio-cultural factors, infrastructure design and use, and end-use technology adoption by 2050.

Figure 3: Indicative potential of demand-side mitigation options by 2050. Figure SPM.6 from IPCC WG III Report (2022)

Policy dialogue through independent official advisory bodies. MCC, especially in the person of its Director and Secretary General, is established in highly respected independent advisory boards and advises the German government and the European Commission via the reports prepared by these bodies. MCC director Ottmar Edenhofer chairs the steering committee of the *"Wissenschaftsplattform Klimaschutz"* (Science Platform Climate Protection) set up by of the Ministry of Education and Research (BMBF) and Ministry of Environment (BMU), as well as the European Scientific Advisory Board on Climate Change of the EU, which is based on the European Climate Law. At the German level, MCC Secretary General Brigitte Knopf is Vice Chair of the *"Expertenrat für Klimafragen"* (Council of Experts on Climate Change), which has a statutory mandate based on the Federal Climate Change Act, which came into force in December 2019, amended in May 2021. The Council of Experts helps to ensure that yearly sectoral emission reduction targets are achieved in Germany. Participation in these high-level advisory bodies not only strengthens MCC's impact on the science–policy interface through their direct activities, but also indirectly through the networking that this facilitates (see Section 4).

1.4   Further impact stories

CDR as an important part of the mitigation portfolio. Backed by our large number of peer-reviewed publications in this field, we are now very involved in the policy debate. The fact that the world, Europe, and Germany need large-scale carbon removals as part of climate mitigation is evident from the latest IPCC reports. Contributing to the German political discourse, led by Sabine Fuss, MCC develops policy design options for efficient and targeted governance that might facilitate the imminent rollout of policies. In this context, the land requirements of CDR should be balanced with those of the food sector and biodiversity. Discussion forums for such debate include the Science Platform Climate Protection set up by the German Federal Government and intensive talks with the ministry of environment. MCC, in collaboration with *Stiftung Wissenschaft und Politik* (SWP), has just launched a new ministerial roundtable on CDR with broad participation across ministries including the Chancellery, the Ministry for Economic Affairs and Climate Action, the Foreign Office, the Ministry of Finance, Ministry of Education and Research, and the Ministry of Food and Agriculture. With regard to land use and CDR in particular, MCC will increase the focus of the institute's activities also with a focus on Europe (see Outlook in Section 7).

At the European level, one of MCC's working group leaders, Jan Minx, is a project leader in the GENIE project ("GeoEngineering and Negative Emission Pathways in Europe"). To facilitate this project, the European Research Council has granted 9-million-euro funding for six years. The task is to critically assess the potential role of CDR and solar radiation management (SRM) in climate policy in Europe.

Key publications:

- Edenhofer et al., 2021. *Wissensstand zu CO_2-Entnahmen: Bedarf & Potenziale, Technologien & Politikinstrumente, weltweit & in Deutschland* (State of knowledge on carbon removals: demand & potentials, technologies & policy instruments, worldwide & in Germany), MCC working paper.
- Fuss et al., 2021. *CO_2-Entnahmen: Notwendigkeit und Regulierungsoptionen* (Carbon removals: necessity and regulatory options). Study commissioned by the Science Platform Climate Protection (Wissenschaftsplattform Klimaschutz), Berlin (in German).
- Madhu et al., 2021. Understanding environmental trade-offs and resource demand of direct air capture technologies through comparative life-cycle assessment, Nature Energy.

Exploring the role of central banks in backing the climate transition. As pressing as the fight against global heating is, it must be carefully managed regarding the financial markets. If fossil-fuel-related assets are abruptly reassessed, bank capital could deteriorate, leading to a credit crunch and economic decline.

An MCC-led model study has illuminated more comprehensively than ever before the key role of central banks in this context, including the interplay between monetary policy and climate policy. It was published in *Journal of Environmental Economics and Management*, the top journal in its field. With this research in a field that is still little explored, MCC has received attention and impacted the community of central bank officials, such as the Bundesbank to whom the work was presented and discussed at several workshops. Additionally, MCC's econometric work on climate impacts has been adopted for climate risk modelling by central banks within the Network of Central Banks and Supervisors for Greening the Financial System (NGFS).

Key publication:

- Diluiso et al., 2021. Climate Actions and Macro-Financial Stability: The Role of Central Banks, Journal of Environmental Economics and Management
- Kalkuhl and Wenz, 2020. The Impact of Climate Conditions on Economic Production. Evidence from a Global Panel of Regions. Journal of Environmental Economics and Management 103, 102360.

Co-production of policy pathways with citizens. Although MCC's main focus group are decision-makers, in the past two years we have also initiated dedicated citizen dialogues within the BMBF-funded Ariadne project and with a local focus in Brandenburg, funded by *Deutsche Bundesstiftung Umwelt* (DBU). In Ariadne's three major rounds of citizen engagement, based on their scientific findings and modelling, more than 100 randomly selected citizens deliberated over the pros and cons of different national-level transport policy options and options for increased renewables deployment. Analogously, and again supported by innovative science visualisation, the citizens involved in the local-level DBU project co-developed future forest management pathways in an iterative learning process with scientific experts, policymakers and various stakeholders. Building on MCC's pragmatic-enlightened science–policy model (Edenhofer & Kowarsch, 2015), our special approach links mini-public deliberations with scientific assessment to openly explore and compare policy alternatives in light of their effects. The accompanying social science research reveals that such a highly integrated approach can help to increase societal legitimacy of policy options and facilitate learning among all actors involved. Moreover, integrating diverse values, ethics and viewpoints from the outset in an iterative learning process contributes to a more comprehensive map of policy alternatives and their diverse implications for society. This way they can better inform political decision-making processes.

Key publications:

- Blum et al., 2021. *Was ist uns wichtig bei Verkehrs- und Stromwende? Bürgerinnen und Bürger sprechen über Herausforderungen und Ziele* (What is important for the transformation in the transport and electricity sector?). Ariadne Report.
- Lenzi and Kowarsch, 2021. Integrating Justice in Climate Policy Assessments: Towards a Deliberative Transformation of Feasibility. In: S. Kenehan/C. Katz (eds.): Principles of Justice and Real-World Climate Politics. Lanham: Rowman & Littlefield.
- Blum, Treichel, and Kowarsch, 2022. *Bürgersichten auf zukünftige Energiewelten. Ergebnisse der Ariadne-Bürgerkonferenz* (Citizens' views on future energy worlds. Results of the Ariadne Citizens' Conference). Ariadne Report.

Policy impact through communication. To make its voice heard in the political discourse, MCC is increasingly using social platforms and communication channels.

An example of such success involves the MCC study "Discourses of climate delay" published in *Environmental Research Letters* in July 2020. In this research work, an MCC-led group of social scientists studying climate change observed recent debates and created a typology of climate delay discourses, thus shedding light on the excuses for doing nothing that circulate in the public debate on global warming. A few months later, MCC co-produced a web-based learning game that helps people quickly familiarise themselves with this topic by learning through gaming. The study has also led to comic adaptations by the illustration artists Léonard Chemineau (here) and Céline Keller (here), which, in turn, were widely circulated on Twitter (see Figure 4). The lead author, MCC researcher William Lamb, regularly reports on this study in presentations to various stakeholder groups.

Secretary general Brigitte Knopf, for example, has had considerable response from Twitter threads explaining the climate-political relevance of new MCC studies or highlighting evidence produced by the MCC for a current climate policy debate. Some of these threads have been retweeted around 400 times on Twitter, achieving about 270,000 impressions.

On our MCC Common Economics Blog, a broad range of MCC staff have contributed with op-eds to public discourse. All articles have been originally published in renowned German and international media outlets including *Frankfurter Allgemeine Zeitung, Süddeutsche Zeitung, Handelsblatt, Tageszeitung, Carbon Brief* or *The Conversation*. In addition, MCC director Ottmar Edenhofer wrote a series of full-page commentaries in the influential German business newspaper *Handelsblatt*. High-level feedback on these contributions included reactions from European Commission President Ursula von der Leyen.

Key publication:

- Lamb et al., 2020. Discourses of climate delay, Global Sustainability
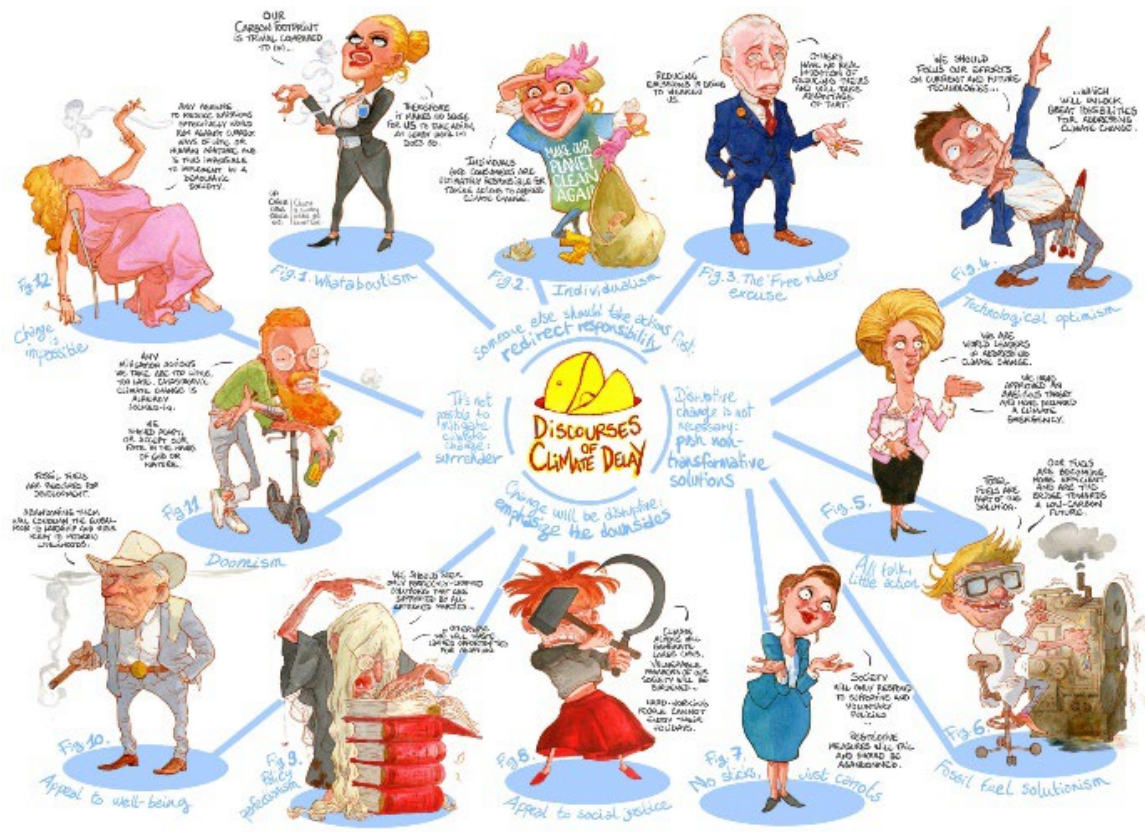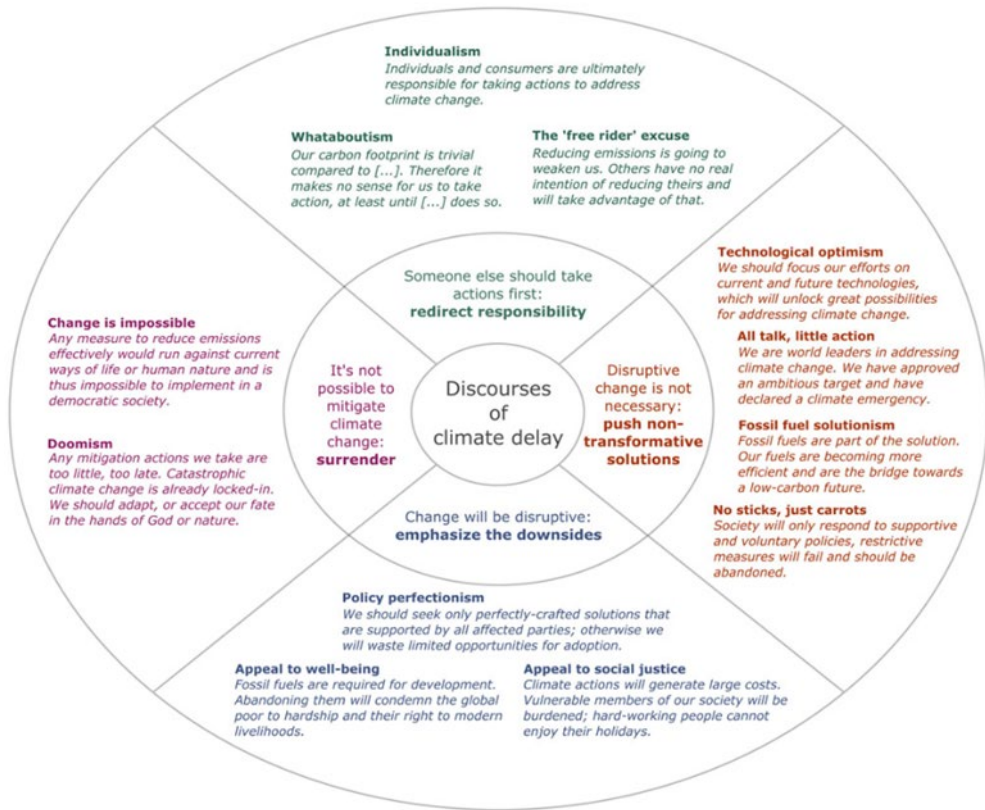
Figure 4: A typology of climate delay discourses. Original figure in the paper by Lamb et. al. (2020) (upper panel) and the illustration produced based on the publication by artist Léonard Chemineau (lower panel).

2   Publications

2.1   Publications highlights

MCC's basis are peer-reviewed publications in high-ranking journals. We have published in **high-ranking economics journals** including: *American Economic Journal: Economic Policy*; *European Economic Review*; and *Journal of Environmental Economics and Management* (e.g. Klauber et al. 2022, Martinet et al. 2022, Roolfs et al. 2021, Diluiso et al. 2021). In addition, between June 2020 and June 2022, about 25 of our publications were published in the following **high-impact interdisciplinary journals:** *Nature*; *Nature Energy*; *Nature Climate Change*; *Nature Sustainability*; *Science*; *PNAS*; and *ERL* (these were (co-)authored by a range of MCC researchers such as Felix Creutzig, Jan Steckel, Anjali Ramakrishnan, Francesca Diluiso, Sebastian Kraus, Max Callaghan, Niccolò Manych and others). Other MCC manuscripts have been published in **top field journals** such as *World Development, Resource and Energy Economics*, and *Energy Economics* (e.g. Dorband et al, 2022, Steckel et al., 2021, Montrone et al., 2022, Feindt et al. 2021). We also increasingly publish in **high-ranking social science journals**, especially related to questions of the energy transition, such as: *Global Environmental Politics*; *Energy Research & Social Science*; *Global Environmental Change*; and *Environmental Science and Policy* (e.g. Jakob et al. 2020 and 2021, Leipprand et al., 2020, Ordonez et al., 2021).

In addition, MCC's systematic reviews and meta-analysis have gained a lot of momentum in the last two years. MCC has advanced systematic reviews as an intermediate tool for scientific assessments of climate change mitigation, adaptation and planetary health. The work features prominently in the IPCC AR6 as well as upcoming assessments such as the *Lancet Countdown on Health and Climate Change 2022*, its European and Chinese regional variants as well as the *Climate Vulnerability Monitor*. Methodologically, this was driven and facilitated by the MCC's working group "Applied Sustainability Science" and included state-of-the art methods for search queries, machine learning-assisted screening and critical appraisal. As a further highlight, the MCC commissioned two focus collections of systematic reviews in *Environmental Research Letters*. Finally, Jan Minx is Co-Chair and William Lamb Editor of the "Campbell Climate Solutions Coordinating Group", which aims to catalyse and coordinate high-quality systematic review work in the field.

Below we provide an annotated overview of all publications with a Top-10 list of peer-reviewed publications and a Top-10 list of systematic reviews, with MCC contributors' names in bold.

Box: Top-10 peer-reviewed publications
Callaghan, M., Schleussner, C., Nath, S., Lejeune, Q., Knutson, T., Reichstein, M., Hansen, G., Theokritoff, E., Andrijevic, M., Brecha, R., Hegarty, M., Jones, C., Lee, K., Lucas, A., van Maanen, N., Menke, I., Pfleiderer, P., Yesil, B., **Minx, J.**, 2021. **Machine learning-based evidence and attribution mapping of 100,000 climate impact studies**, Nature Climate Change *This paper provides a new AI-based methodology for comprehensively assessing vast amounts of evidence on attributable climate impacts; it was cited by Barack Obama during COP26 and provides the first figure in the IPCC WG II Report.*
Creutzig, F., **Niamir, L.**, Bai, X., Callaghan, M., Cullen, J., Díaz-José, J., Figueroa, M., Grübler, A., **Lamb, W.**, Leip, A., Masanet, E., Mata, É, **Mattauch, L.**, **Minx, J.**, Mirasgedis, S., Mulugetta, Y., Nugroho, S., Pathak, M., Perkins, P., Roy, J., de la Rue du Can, S., Saheb, Y., Some, S., Steg, L., Steinberger, J., Ürge-Vorsatz, D., 2021. **Demand-side solutions to climate change mitigation consistent with high levels of wellbeing**, Nature Climate Change *This paper was one of the cornerstones for the IPCC AR6 WGIII chapter on demand-side solutions.*
Jakob, M., **Steckel, J.** (Editors), 2022. **The Political Economy of Coal: Obstacles to Clean Energy Transitions**, London, Routledge *This book demonstrates that MCC can develop theory in social science and lead community-wide efforts.*
Kraus, S., **Koch, N.**, 2021. **Provisional Covid-19 infrastructure induces large, rapid increases in cycling**, Proceedings of the National Academy of Sciences *This is a prominent example of MCC's ex post policy analysis. It achieved high media impact and was cited by policymakers.*
Khanna T M, Baiocchi G, **Callaghan M, Creutzig F**, Guias H, Haddaway N R, Hirth L, **Javaid A, Koch N, Laukemper S**, Löschel A, **Zamora Dominguez M del M** and **Minx J C**, 2021. **A multi-country meta-analysis on the role of behavioural change in reducing energy consumption and CO_2 emissions in residential buildings**, Nature Energy *The first comparative systematic review of ex post evaluations of behavioural interventions, highlighting the effectiveness of pricing tools and the potential for packages of interventions; key input to Chapter 5 of IPCC WG III.*
Kornek, U., Klenert, D., **Edenhofer, E.**, Fleurbaey, M., 2021. **The social cost of carbon and inequality: When local redistribution shapes global carbon prices**, Journal of Environmental Economics and Management *High-level economic publication on the social costs of carbon.*
Diluiso, F., Annicchiarico, B., **Kalkuhl, M., Minx, J.**, 2021 **Climate actions and macro-financial stability: The role of central banks**, Journal of Environmental Economics and Management *High-level economic publication and an important contribution to the debate on the role of central banks.*
Klauber, H., Holub, F., **Koch, N.**, Pestel, N., **Ritter, N., Rohlf, A.**, 2021. **Killing Prescriptions Softly: Low Emission Zones and Child Health from Birth to School**, American Economic Journal: Economic Policy (accepted) *Based on a thorough empirical analysis, this paper shows how powerful ex post policy analysis can be for measuring the impact of policy instruments.*
Kraus, S., Liu, J., **Koch, N.**, **Fuss, S.**, 2021. **No aggregate deforestation reductions from rollout of community land titles in Indonesia yet**, Proceedings of the National Academy of Sciences *High-level economic analysis evaluating the Indonesian Ostrom-inspired land titling policy in an empirically rigorous way; this was taken up by peers and European media, as well as in Asian media outlets.*
Steckel, J., Dorband, I., Montrone, L., Ward, H., Missbach, L., Hafner, F., Jakob, M., Renner, S., 2021. **Distributional impacts of carbon pricing in developing Asia**, Nature Sustainability *Example of MCC's work in the field of development economics, including an outline of MCC's methodological foundation on distributional questions.*

Box: Top-10 peer-reviewed publications of systematic reviews and meta-analysis
Lamb, W. et. al., 2021. **A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018**, Environmental Research Letters *Data-driven review of emissions trends and drivers; this provided the backbone for consistent treatment in IPCC AR5.*
Creutzig, F., Callaghan, M., Ramakrishnan, A., Javaid, A., Niamir, L., Minx, J., Müller-Hansen, F. et al., 2021. **Reviewing the scope and thematic focus of 100,000 publications on energy consumption, services and social aspects of climate change: a big data approach to demand-side mitigation.** Environmental Research Letters *Complete map of the literature underpinning the assessment of demand-side climate solutions in IPCC AR6.*
Ivanova, D., Barrett, J., Wiedenhofer, D., Macura, B., **Callaghan, M., Creutzig, F.,** 2020. **Quantifying the potential for climate change mitigation of consumption options.** Environmental Research Letters *Quantitative systematic review of 60 consumption options to reduce GHG emissions, cited 137 times in the first 24 months.*
Sietsma A J, Ford J D, **Callaghan M. W. and Minx J. C.**, 2021. **Progress in climate change adaptation research.** Environmental Research Letters *First combination of survey-based expert elicitation with machine learning-enhanced mapping methodologies for analysing issues brought up in the survey.*
Berrang-Ford L, Sietsma A J, **Callaghan M, Minx J C,** Scheelbeek P F D, **Haddaway N R,** Haines A and Dangour A D, 2021. **Systematic mapping of global research on climate and health: a machine learning review,** Lancet Planetary Health *MCC provides machine learning pipeline for first fully automated living-map methodology for tracking progress on climate and health research. The study methodology is now the basis for a new indicator for the Lancet Countdown.*
Berrang-Ford L, **Callaghan, M., Minx, J., [...]**, et al., 2021a. **A systematic global stocktake of evidence on human adaptation to climate change,** Nature Climate Change *MCC provides a machine learning methodology for the largest effort (to date) on tracking adaptation research in peer-reviewed literature. Keystone paper for IPCC AR6 in WG II.*
Ohlendorf, N., Jakob, M., Minx, J. C., Schröder, C., **& Steckel, J. C.,** 2021. **Distributional impacts of carbon pricing: A meta-analysis.** Environmental and Resource Economics *This has become the go-to reference on distributional impacts, widely referred to in the literature; ~100 citations in the first 18 months.*
Schulte, I., Eggers, J., Nielsen, J.Ø., **Fuss, S.**, 2021. **What influences the implementation of natural climate solutions? A systematic map and review of the evidence.** Environmental Research Letters *This paper moves from reviewing the work on the potentials and costs of natural climate solutions to answering the question of how to implement such solutions.*
Javaid, A., Creutzig, F. and Bamberg, S., 2020. **Determinants of low-carbon transport mode adoption: systematic review of reviews.** Environmental Research Letters *First-ever systematic review of behavioural, social and infrastructural underpinnings of transport mode choice (simultaneously).*
Ramakrishnan, A., Creutzig, F., 2021. **Status consciousness in energy consumption: a systematic review.** Environmental Research Letters *A PhD-led systematic review.*

2.2   Publication statistics

Publications are a cornerstone of MCC's work (see Figure 5 and Table 1) and most of our publications appear in peer-reviewed journals. In 2020, these totalled 100, with almost 3.5 publications per scientific full-time-equivalent (FTE), of which 74 (2.5 per scientific FTE) were peer-reviewed (see Figure 5 and Table 1). In 2021, the total number of papers increased to 131 (i.e. 4.3 publications per scientific FTE) of which 91 (3.0 per FTE) were peer-reviewed. Extrapolating from the first half of the year, the number of publications in 2022 might be lower than in the past. There may be several reasons for this, for example a delayed effect of the pandemic, the heavy involvement of MCC researchers in finalising the IPCC AR6 report in 2021, or an increasing number of policy-relevant publications crowded out papers for peer-review. We will carefully evaluate this development in early 2023 when all publications for 2022 are available.
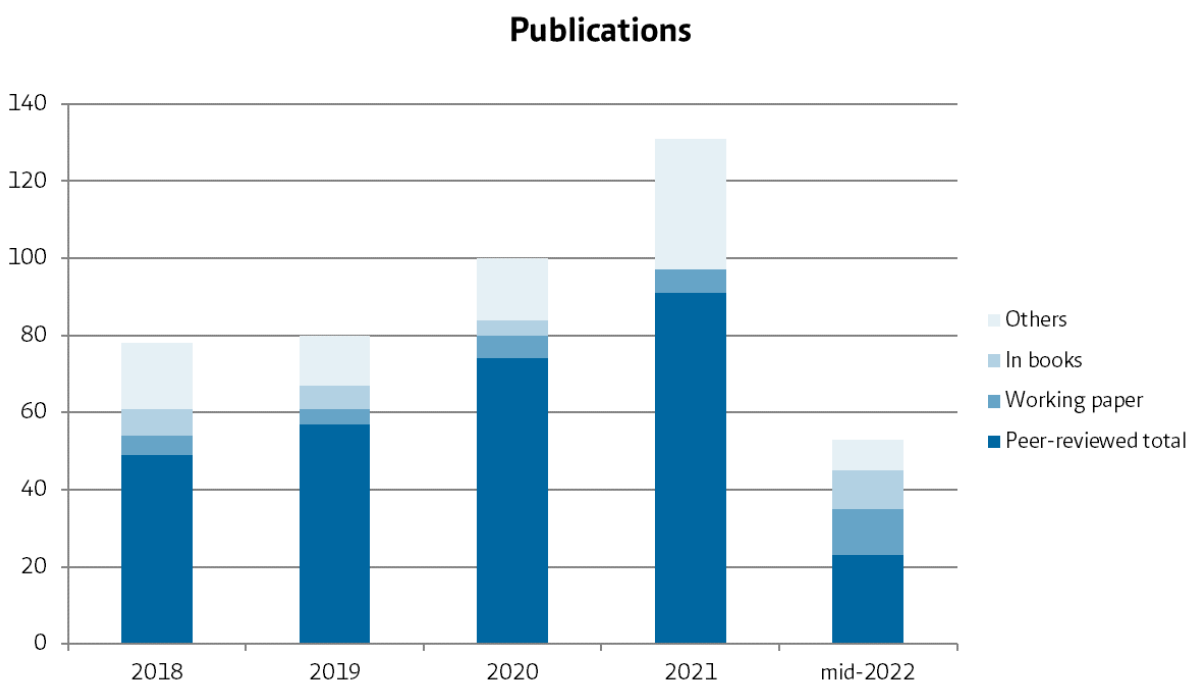
Publications

Figure 5: Total number of publications 2018–2022. For 2022, numbers are given until July 2022.

|	**2018**	**2019**	**2020**	**2021**	**mid-2022**
Publications per FTE	3.0	3.6	3.4	4.3	1.9
Peer-reviewed publication per FTE	1.9	2.5	2.5	3.0	0.8
Web of Science publications per FTE	1.7	2.1	1.6	2.0	0.7

Table 1: Publications per scientific FTE.

3   Communication and outreach

3.1   Media

MCC's press and public relations activities over the past two years, from mid-2020 to mid-2022, have been dominated by four major work streams: 1) socially balanced climate policy against the backdrop of the "Fit for 55" action plan, adopted by the European Commission in July 2021, and the German parliamentary elections two months later, 2) strategies for an integrated climate and development policy for countries in the Global South, with the global coal phase-out as a key issue, 3) a series of fundamental research papers in the context of the IPCC AR6, which was co-led by MCC experts, and 4) the energy, climate and social policy challenges in the EU and Germany as a result of the Russian invasion of Ukraine and the resulting turbulence in global energy markets.

During this two-year period, MCC Communications has published about 80 press releases and news items, which is a similar level to previous years – we intend to be visible and well-known to the media, but not to overload them. Remarkably, there has been a strong increase in the media response to our content compared to the past. For the first half of 2022, our media monitoring service provider reported 4,106 media articles related to the MCC staff – almost 50% more than in the same period in 2019 – our previous record year (see Figure 6). This shows the relevance of our four major work streams, and also reflects well on our media work.
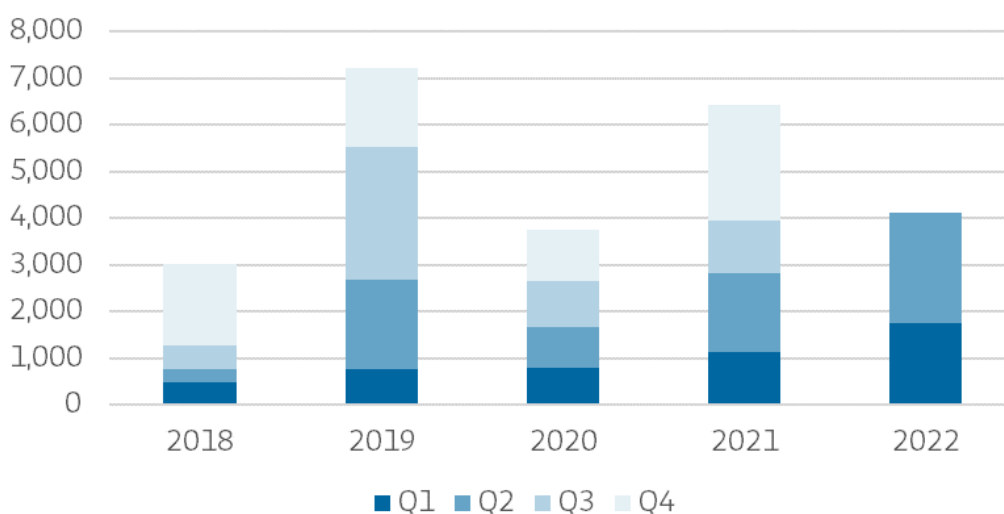
Figure 6: MCC media contributions in total numbers by quarter.

The dip in the Covid-19 year of 2020 has obviously not been permanent. In the first half of 2020, the so-called "advertisement equivalence value" of MCC media contributions reached more than 36 million euros, compared to 21.5 million euros in the first half of 2019. Contributions include agency reports, print articles, online publications, TV and radio broadcasts, and increasingly new formats such as Instagram posts, podcasts and multimedia stories. We also see progress against our strategic goal of presenting a diversity of MCC faces to the media, in addition to our director, Ottmar Edenhofer. The share of MCC staff in media articles is now one-third; in 2019, it was only one-fifth.

For example, MCC Secretary General Brigitte Knopf now has significantly higher visibility, boosted by her role as Vice Chair of the Council of Experts on Climate Change. At the group-leader level, Sabine Fuss, Jan Minx, and Felix Creutzig undertook successful outreach activities related to their roles as lead authors of the special report "Global Warming of 1.5°C" (2018) and of IPCC AR6 (2022). Jan Steckel was visible with

his research and advisory projects dealing with the global coal phase-out, and Matthias Kalkuhl focussed on the incidence of higher energy costs for private households and policy options for social compensation. About two dozen other MCC scientists provided additional resonance with research papers, some of which were very high-profile.

MCC's various communication channels continue to see increasing traffic and growing audiences. A March 2022 tweet about an MCC working paper on the energy price crisis has since garnered 34,000 impressions. MCC now has 6,100 followers on Twitter (up from 1,800 in early 2019), 2,000 on our recently set up LinkedIn profile, and around 2,500 people have subscribed to the monthly newsletter. The monthly number of website visits is currently around 14,000, which is more than twice as high as in 2018. A good half of the visits come from users outside of Germany.

MCC has innovated by publishing research insights as interactive web graphics; notable among these are a learning game on climate excuses, a carbon pricing calculator and an interactive map on heat stress of elderly people. In April 2022, a hybrid MCC event on the new IPCC AR6 report was available as a livestream on our website, where it is also available for retrospective viewing. MCC also established the new format of web-based press briefings, which are easy to access and therefore particularly attractive for journalists.

The media are increasingly making proactive requests for MCC's assessments of German and international climate policies, with queries coming in virtually every day. In this context, a dialogue format with public broadcasters ARD and ZDF is noteworthy: in September and November 2021, MCC director Ottmar Edenhofer and secretary general Brigitte Knopf had two opportunities to brief the makers and presenters of leading news programmes on climate policy topics, specifically along the lines of "What should we have in mind when we ask studio guests about climate policy?"

3.2   Talks and presentations

MCC researchers were less able to present their research activities in person in 2020 due to the Covid-19 pandemic. At the same time, MCC quickly adapted to modern technology and software, allowing researchers to participate in and contribute to a large number of virtual events. Despite the Covid-19 pandemic, MCC staff were able to make a total of 226 presentations in 2021, following up on the successful year of 227 talks and presentations in 2019 (see Figure 7). We have already delivered 150 talks and presentations in the first half of 2022, matching the total for all of 2020. This highlights the high demand for MCC's research and expertise. Despite the Covid-19 pandemic, every scientist (FTE) gave more than seven presentations on average in 2020–2022 (compared to more than ten presentations per scientist FTE in 2018–2020) to national and international audiences (see also Figure 8).

While we focus is on lectures and scientific talks, we are also increasingly participating in policy dialogues. During the Bundestag election campaign in particular, we were involved in policy discussions about the implementation of carbon pricing in Germany (*Klimageld*). More recently, we have been active in debates about the impacts of the energy crisis, and MCC's science-based policy advice has been sought by ministries and various parliamentary groups in the Bundestag.
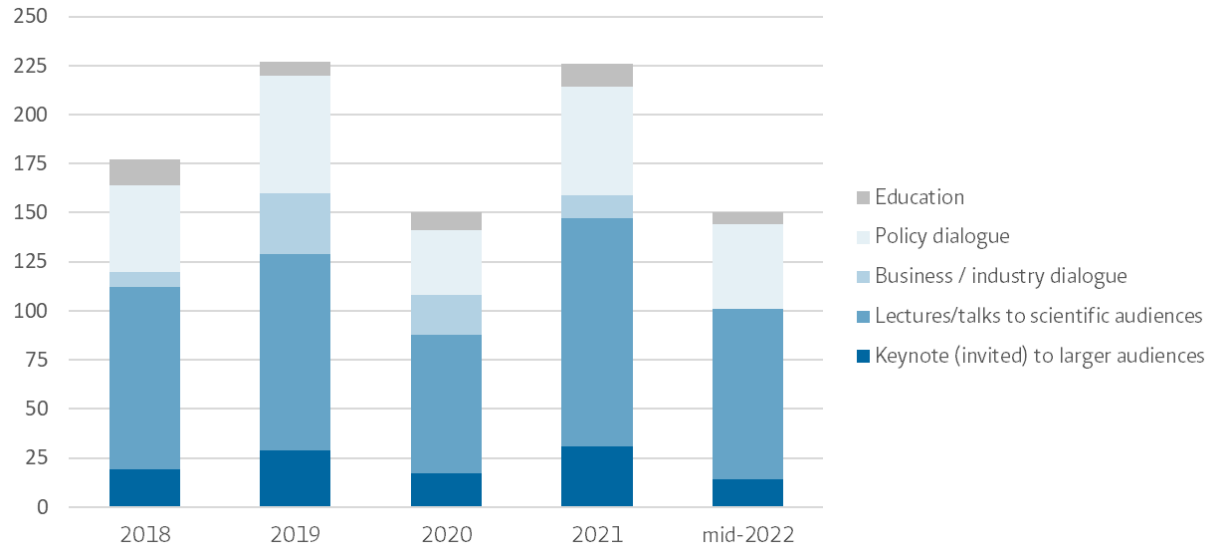
Figure 7: Total number of presentations by MCC researchers per year. Numbers for 2022 are for the first half of the year.
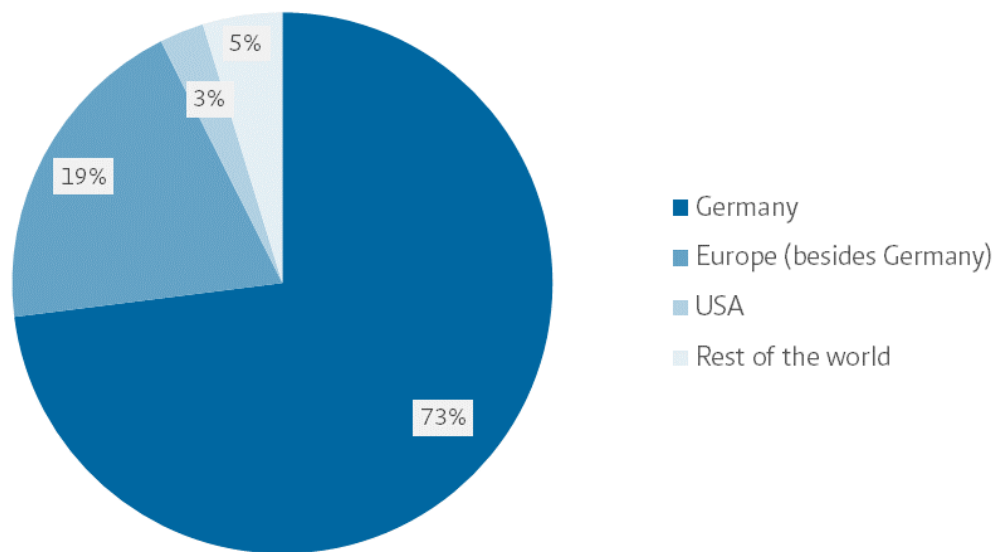
Figure 8: Share of the nationally and internationally held presentations by MCC researchers from 2020 to mid-2022.

3.3   Events

With the announcement of the first Covid-19 lockdown, MCC made a commitment to continue providing as many events as possible. From mid-2020 to mid-2022, MCC (co-)organised 73 events (see Figure 9). In the first half of 2022, we have already held 24 events – as many as in the whole of 2020. This shows that the Covid-19 pandemic has not affected MCC's ambition to organise events.
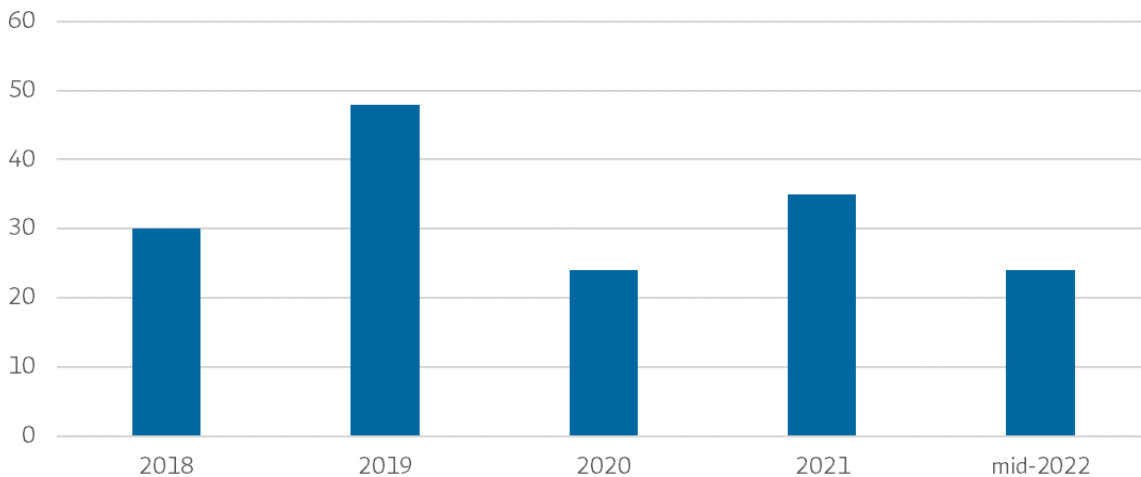
Figure 9: Total number of events organised by/at MCC from 2018 to mid-2022.

MCC events are targeted at academic audiences as well as stakeholders from politics, industry and civil society. Some of these events are highlighted below.

Together with the European Institute on Economics and the Environment (Milan) and Oxford Net Zero at the University of Oxford, MCC organised the Climate Neutrality Forum in September 2021. The hybrid event brought together academics and policymakers to discuss the challenges and opportunities for climate policy to achieve climate neutrality in Europe and globally. The findings were further specified in subsequent webinars and presented at COP26.

In June 2021, MCC co-organised the two-day Kopernikus Symposium[1] together with PIK, in the context of the Ariadne project. The virtual event consisted of expert talks, panel discussions and breakout sessions on specific topics. The four Kopernikus projects were discussed with experts from practice and research, focussing on innovations and measures that can help to realise a climate-neutral energy system, as well as how Germany can advance the European Green Deal together with the other EU member states. Around 800 people from politics, business and civil society took part in the event.

In a high-level stakeholder event with 22 representatives from politics, industry and civil society in August 2021, Nicolas Koch and Ottmar Edenhofer talked about the impact of a ban on new combustion vehicles as a policy instrument. The group discussed the opportunities and challenges presented by the ban as proposed in the European Commission's "Fit for 55" action plan.

Accompanying the Ariadne project's publication of a comprehensive "scenario report on climate neutrality in Germany in 2045" in November 2021, MCC and PIK co-organised a series of webinars on the results of the Ariadne model comparison and the transformation in the industry sector, building sector and transport sector. In total, more than 700 participants from science, politics, industry and civil society attended at least one webinar.

With the publication of the IPCC AR6 WG III, MCC organised a series of outreach events with German lead authors. In addition to a parliamentary breakfast and an inter-ministerial dialogue event, the "MCC Policy Dialogue on the New Intergovernmental Panel on Climate Change Report: Global Emission Trends and Demand-Side Climate Solutions" took place in April 2022. At this hybrid event, Sven Giegold, state secretary of the Federal Ministry for Economy and Climate Protection, gave a keynote speech and

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[1] The German Federal Ministry of Education and Research (BMBF) funds four so-called Kopernikus projects to research, develop and demonstrate solutions and technologies that enable climate neutrality in Germany by 2050. The Ariadne project is one of the four Kopernikus projects.

subsequently discussed the political options for German and European climate policy with Ottmar Edenhofer. Jan Minx and Felix Creutzig gave brief inputs on the key scientific results and participated in two high-level panel discussions with representatives from politics, business and civil society (e.g. Federal Ministry for Economy and Climate Protection, Federal Ministry for Digital and Transport, WWF Germany, Federation of German Industry, Federation of German Consumer Organisations). Fifty participants were on site in Berlin and around 80 people followed the event via livestream.

MCC undertook stakeholder analysis to improve the targeting of relevant decision-makers. The evaluation of the above-mentioned policy dialogues (the November 2021 Ariadne webinars and the April 2022 hybrid event) revealed that 745 stakeholders participated in total. Of these, 40% came from science and academia, while 25% were from the federal ministries, governmental agencies and semi-governmental institutions (e.g. Federal Environment Agency, dena – German Energy Agency) or the Bundestag (members of parliament and parliamentary employees) (see Figure 10). In a next step, we will analyse whether all required stakeholder groups were addressed, or whether specific groups should be targeted in upcoming event invitations.
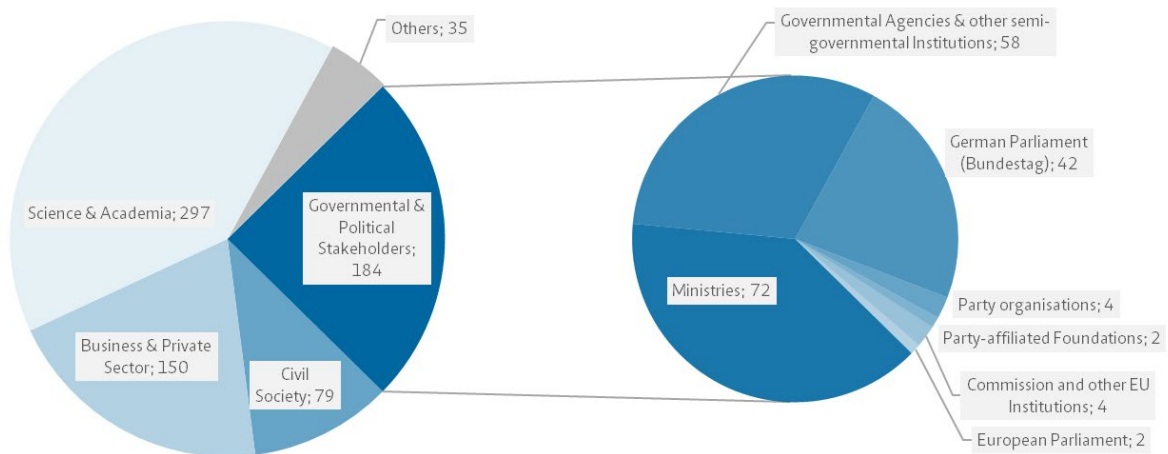
Figure 10: Attendance of MCC outreach, by stakeholder group (specifically, Ariadne webinars on sectoral transformation pathways in October/November 2021 and MCC's policy dialogue in April 2022).

4   Networks

We enhance our impact at the science–policy interface through various networks: memberships on editorial boards and institutional bodies, collaboration with other institutes and our broad alumni network.

4.1   Participation on boards of both public and private institutions

Ottmar Edenhofer co-chairs the *"Wissenschaftsplattform Klimaschutz"* of the German Federal Ministry of Education and Research (BMBF) and the Federal Ministry for Economic Affairs and Climate Action (BMWK) and is member of the VW Sustainability Council. He is also Chairman of the European Scientific Advisory Board on Climate Change, which gives scientific advice on EU policies and supports the achievement of EU climate neutrality by 2050. Furthermore, Ottmar Edenhofer is a member of the Sustainability Advisory Board of the State of Brandenburg and a member of the High-Level Commission on Carbon Prices. He also is a member of the Advisory Board of the DemoUpCARMA project at the ETH Zurich and a member of the External Advisory Panel in the OECD project "Building Climate and Economic Resilience in the Transition to a Low-carbon Economy".

Brigitte Knopf is a member of the "Expert Council on Climate Issues" (*Expertenrat für Klimafragen*), advising the German government on the implementation of the Climate Action Law. Sabine Fuss is a board member of the Steering Committee in the Austrian Panel on Climate Change. Jan Minx is Co-Chair of the Campbell Collaborating Group on Climate Solutions. He also is a Commissioner of the Global Commission on Evidence to Address Societal Challenges. Jan Steckel is a member of the Steering Committee in the RENEWT Network as well as a member of the Advisory Board in the "Just Transitions" project of the Friedrich-Ebert-Foundation (China Office). He also is a Lead of the Emissions Pricing for Development programme in the Environment for Development Initiative. Martin Kowarsch is a member of the Scientific Board of Trustees in the Climate Civil Council (*Bürgerrat Klima*). Felix Creutzig is a member of the Advisory Board in the network "Climate Change AI". Nikola Milojevic-Dupont is a member of Board of Directors in the network "Climate Change AI".

4.2   Membership of scientific journal editorial boards

Ottmar Edenhofer is editor of the journal *Review on Environmental Economies and Policies* (REEP). Sabine Fuss is a member of the editorial board of the *Environmental Research Communications* (ERC) journal. She also is an editorial board member at the journal *Climate Policy* and associate editor for the "Negative Emission Technologies" section of *Frontiers in Climate*. Jan Minx is a guest editor for *Environmental Research Letters*.

4.3   Collaboration with other institutions

MCC is an institutional member of the European Association of Environmental and Resource Economists (EAERE), the Green Growth Knowledge Platform (GGKP) initiated by the World Bank and the OECD, and the Green Fiscal Policy Network (GFPN), a partnership between the UN Environment Programme (UNEP), the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) and the IMF. Furthermore, MCC is a partner in the Environment for Development (EfD) network and the Energy Transition Hub – an Australian–German research and innovation partnership. Moreover, MCC is and is supporting the Lancet Pathfinder Commission and contributing to the Lancet Countdown and its regional sub-initiatives for Europe, South America and China. MCC is also a founding member of the Campbell Collaborating Group on Climate Solutions.

4.4   Alumni network

About one-third of MCC's alumni are still in academia and some have obtained professorships, for example at the Hertie School of Governance in Berlin and at the Universities of Leiden, Oxford and Kiel. Furthermore, MCC's former employees are currently working in policy roles, such as at the German Federal Ministries for Economy and Climate Protection, Finance and Economic Development and Cooperation and in the German Bundestag. Others have taken up policy roles in international organisations such as the World Bank, IMF and EU, international NGOs (e.g. WWF) or in industry/consulting. This underscores MCC's approach as a scientific think tank, with opportunities for both academic and policy career pathways.

5   Funding structure and financial developments

MCC is primarily funded by Stiftung Mercator, with 16.4 million euros granted for the first six-year funding phase (2012–2017) (i.e. approximately 2.3 million euros per year), while the financing for the second phase (2019–2024) is slightly lower with 12.5 million euros (i.e. 2.1 million euros per year). Against this background, and given Stiftung Mercator's clearly communicated "exit strategy" from all projects, third-party funding becomes an increasingly important issue at MCC. Figure 11 below shows the increase in third-party funding from 2018 to 2022 (expected), and Figure 12 shows how it is distributed. In 2021, MCC received 3.1 million euros of third-party funding. With the BMBF-funded Ariadne project, MCC acquired over 1.5 million euros in 2021, which amounts to more than 50% of that year's total third-party funding. Also in 2021, together with two further principal investigators, Jan Minx obtained a European Research Council grant for the GENIE project worth 870,000 euros. Taken together, third parties contributed more than 50% of MCC's funding from 2020 to 2022.

Third-party funds come from a range of sources, with the majority provided by the German Ministry of Education and Research (BMBF). EU project funding increased from 3% (2016–2020) to 16% (2020–2022). Furthermore, several researchers receive individual grants; for example, PhDs have received funding via different foundations and postdocs have accessed funding through fellowships. These are not reflected in Figure 12.
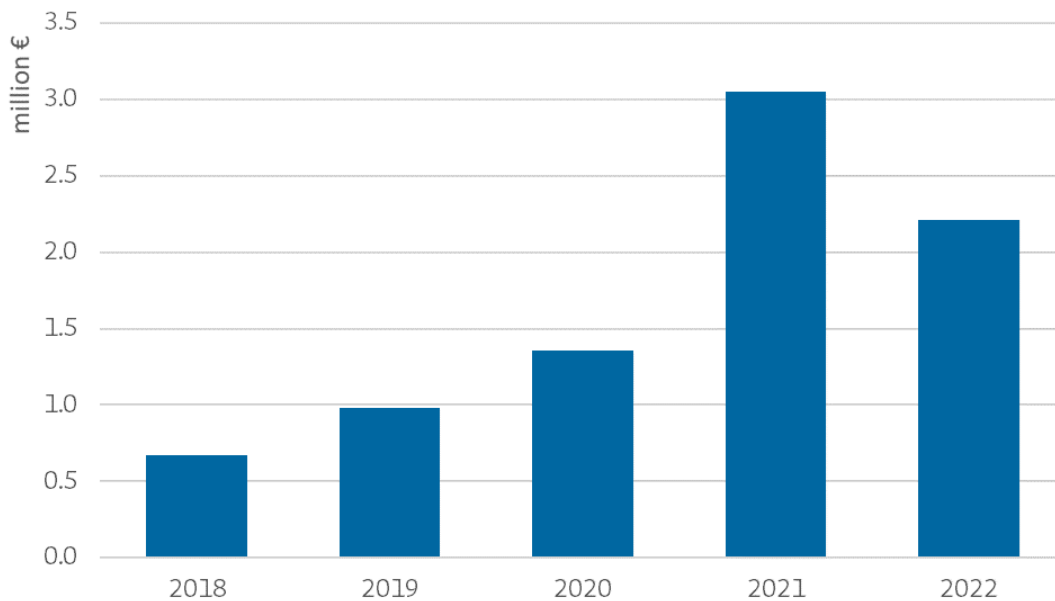
Figure 11: Development of third-party funding (excluding individual grants) from 2018 to 2022. For 2022 it is the expected value.
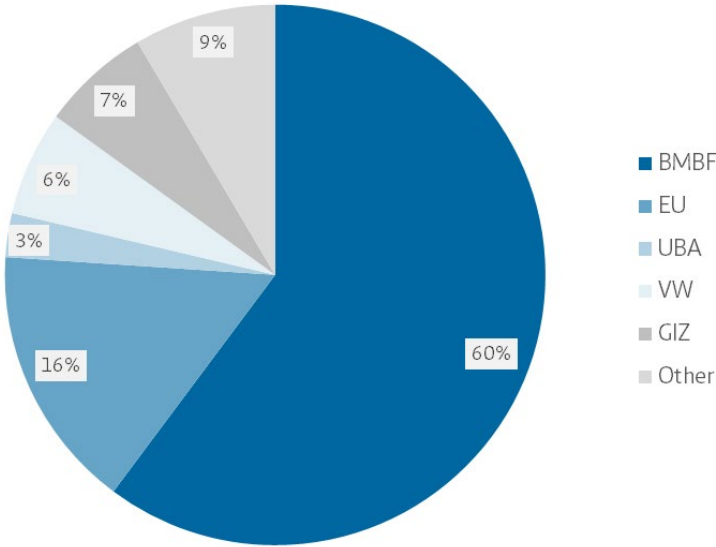
Figure 12: Sources of third-party funding: shares contributed by the German Ministry of Education and Research (BMBF), European Union (EU), the German Federal Environmental Agency (UBA), VW Sustainability Council (VW), German Society for International Cooperation (GIZ) and others, 2018 to 2022. For 2022 it is the expected value. Individual grants are not reflected in this figure.

6   Organisational structure and staff development

6.1   Organisational structure

MCC is led by director Ottmar Edenhofer and secretary general Brigitte Knopf, and organised around seven working groups and two cross-cutting units – the Policy Evaluation Lab and the Policy Unit (see Figure 13). The organisational structure reflects the MCC's ambition of "governing the global commons" and providing "scientific policy advice". Five working groups focus on the analysis of socioeconomic drivers and the institutional design and political economy of governing the global commons. Two working groups, together with the Policy Evaluation Lab, provide a methodological approach to research synthesis, empirical *ex post* analysis, and reflection of scientific assessment making. In addition, the Policy Unit was instigated to respond to the enhanced profile of the policy dialogue and provide a systematic approach to the science–policy interface. To strengthen collaboration with PIK, two of PIK's seven "Future Labs" are run jointly with MCC. The working groups and cross-cutting units are presented in detail in Section 8.
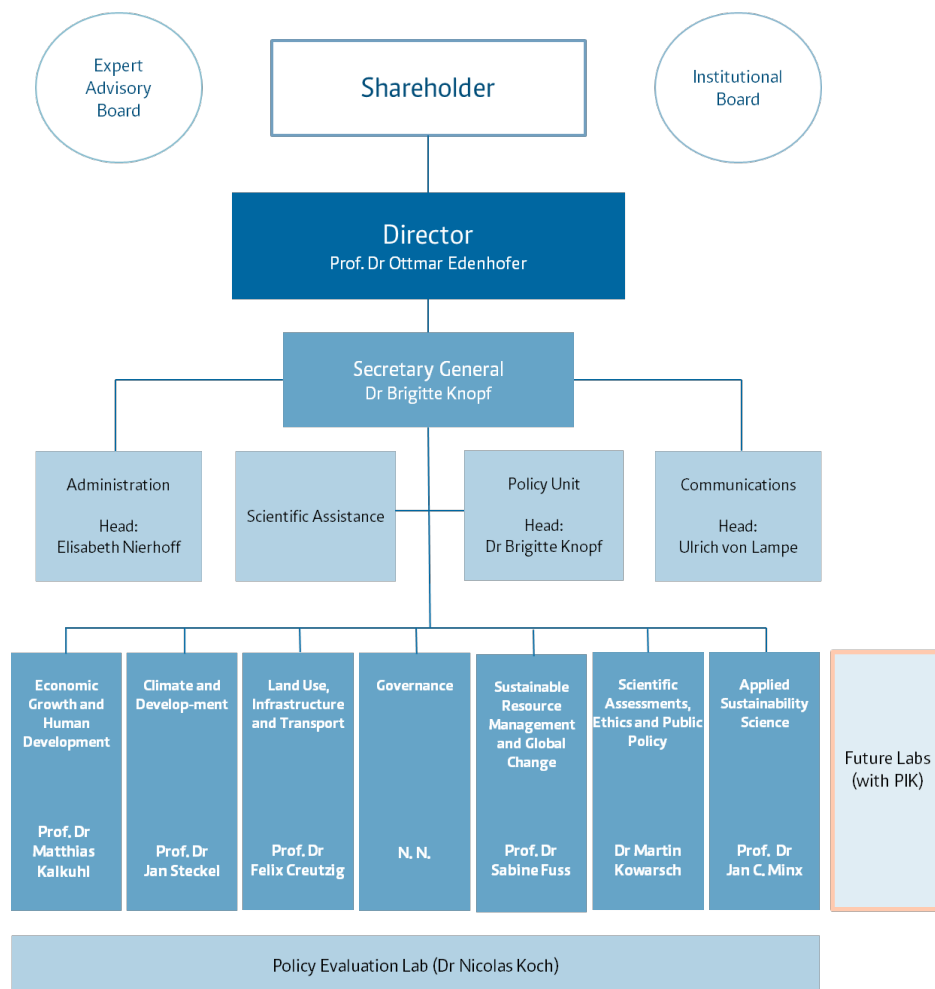
Figure 13: Organisational chart of MCC.

While the original plan was to proactively search for a successor to Ulrike Kornek as head of the Governance group, the final decision was not to fill the position because governance aspects are already covered by PIK's new Future Lab "Political economy for inclusive wealth and sustainability" (see Outlook in Section 7), of which MCC is a strong project partner.

6.2   Staff development

The number of MCC staff has grown since the last report to the Expert Advisory Board (see Figure 14). This is especially due to the increase in third-party projects (e.g. Ariadne). In 2022, we experienced a slight decline in staff. This is because MCC student researchers submitted successful master theses and promising new career developments for some of our other researchers. Unfortunately for MCC's gender balance, many female postdoctoral researchers have left the institute. This counteracts MCC's successful efforts to hire new female postdocs.
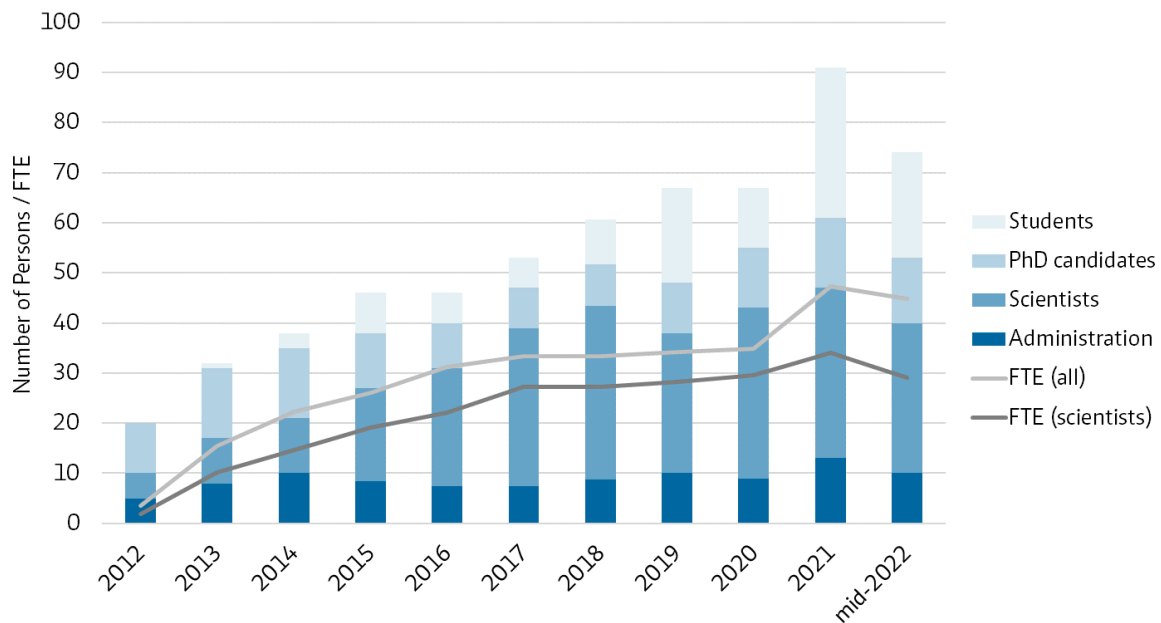
Figure 14: Staff development.

Equal opportunity strategy: In 2020, MCC implemented its equal opportunity strategy, with the long-term goal of having an equal share of women and men on our scientific staff. To strengthen this strategy, MCC staff elected three Equal Opportunity Representatives (EORs) who have, for example, a mandate to attend job interviews. In addition, MCC adopted a diversity guideline. The voluntary Equal Opportunity Team (EOT) is still active. The team set up a "safe space box" for all MCC employees to communicate (anonymously) any gender concerns to the three EORs. Furthermore, the EOT held a women's assembly and currently plans a women's breakfast with MCC masters students to talk about career prospects in research and academia.

Nonetheless, about 40% of the current MCC staff is female (see Figure 15). While the proportion of female PhD candidates remains stable, MCC experienced a decrease in female employees among the junior researchers.
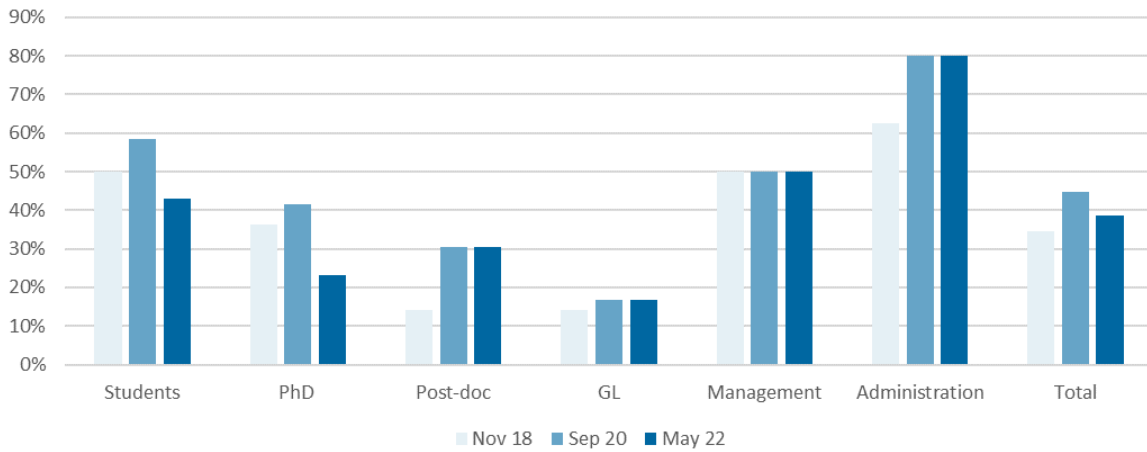
Figure 15: Proportion of female employees at MCC from November 2018 to May 2022, by level; GL: Group Leader

Academic career development pathways: Currently, five of the group leaders have a joint professorship with a university in Berlin, Potsdam, Leeds, and with Jan Steckel's recent professorship, Cottbus.

Other staff members have followed career pathways within academia, with national and international organisations, German ministries and industry/consulting (see details of our alumni network in Section 4.4).

7   Outlook

In the context of the current geopolitical crisis, we want to contribute our specific expertise to keep climate change mitigation high on the agenda. This includes: 1) providing competent responses to the distributional conflicts of climate policy, which have come into particular focus due to the current energy price crisis; 2) sharpening our understanding of the design and impact of policy instruments by applying and advancing rigorous research methods; and 3) intensifying and deepening our competences in fields where we are already strong (e.g. options and instruments for CDR), and continuing and further strengthening our activities on new developments and innovative topics (e.g. health or AI in the context of climate change).

1) **Providing competent responses to the distributional conflicts of climate policy:**

    - Due to the Russian invasion of Ukraine, we have increased our focus on analysing climate and social policy in the context of energy price shocks and business cycles using incidence analyses, optimal tax models and macroeconomic models (New Keynesian and Dynamic Stochastic General Equilibrium models). We will conduct new **research on the role of debts** – particularly from political economy and acceptance perspectives.

    - In cooperation with GIZ, we will develop the **Carbon Pricing Incidence Map**, an online tool allowing us to assess first-order distributional effects of carbon pricing on particular societal groups, as well as the effects of targeted and untargeted revenue schemes.

    - **Inclusive tax policy for a decarbonising world:** Modern tax policy needs to raise public revenues in an economically efficient, socially fair and financially sustainable way. As fossil energy (which has been a source of revenue for many countries) is phased out, and with the increasing role of price instruments to reduce emissions, pollution and non-environmental externalities, we aim to identify new tax bases and reforms to existing fiscal systems. We will explore the introduction of taxes in other domains (e.g. agriculture, nutrition, plastic pollution or even land rent taxation) including a fair use of revenues from carbon pricing that could provide a model for broader environmental taxation. In this context, we will also engage with stakeholders and citizen deliberation groups to engender ownership of this process. This builds on the expertise we have gained through our involvement in the Ariadne project, which we will continue to develop over the second phase of the project.

2) **Sharpening our understanding of the design and impact of policy instruments:**

    - One important milestone in the coming year will be **the "What Works Climate Solutions Summit" in 2023:** With a range of international partners (IPCC, Evidence Synthesis International, Cochrane, Campbell Collaboration, Collaboration for Environmental Evidence, Global Commission on Evidence, 3ie, Wellcome Trust) MCC will organise a major conference in Berlin (June 2023) with 300 participants to promote and catalyse synthetic evidence on climate solutions for upcoming climate change assessments – particularly the IPCC's 7th Assessment Report — as well as other forms of scientific policy advice. The key idea is to kick-start systematic review ecosystems in peer-reviewed literature to comprehensively inform decision-making with robust scientific knowledge about which solutions work under what conditions and why. MCC is already part of a network of international partners working on review ecosystems on carbon pricing, CDR technologies and behavioural interventions for households.

    - Another future focus is the development of **machine learning-assisted approaches to identify effective policy mixes**. Policymakers almost always introduce policies in bundles, but current policy evaluation tools can only quantify the effect of a single policy intervention in isolation.

- We will continue to analyse specific policies and policy designs. One future focus will be **analysing policy instruments for land-use management & CDR.** We will undertake substantial work in the field of policy design to incentivise carbon removal, focussing on incentives, information, and distributional and environmental aspects.

- **Political economy and inclusive wealth (together with PIK):** MCC will reflect on the normative foundations of planetary boundaries and on the governance of global commons. This work will also include empirical studies on the state-level capacity of democratic and autocratic systems to manage crucial natural resources. Additionally, we will develop welfare indicators for inclusive wealth as well as models of economic growth with finite resources. Finally, we will assess the impact of the distribution of resource rents on the structure of governments.

3) **Intensifying and deepening our competences in fields where we are already strong, and continuing and further strengthening our activities on new developments and innovative topics.**

- **Launch of a bi-annual report on CDR in October 2022:** In collaboration with the University of Oxford, SWP and the University of Wisconsin, MCC leads a global community effort to publish a (bi-)annual scientific assessment titled "The State of Carbon Removal"; the aim is to fill a critical evidence gap in this fast-developing policy space. The first edition will be launched in October 2022. The subsequent edition will provide an interactive, open-access data platform that will bring together the currently widely dispersed evidence on carbon removal for scientists and policymakers.

- **Climate and health:** MCC has already contributed important research on the attribution of climate change impacts to health outcomes at the global and the local levels. Future research will expand this work along two lines: We seek first to advance our understanding of the inequality implications of climate change-related health impacts (e.g. on labour market), and second to advance the literature on the health co-benefits of climate policy by providing tangible evidence for the causal chains at play. MCC will further engage and advance future versions of the Lancet Countdown – an authoritative scientific assessment in the field.

- **Artificial intelligence (AI) for climate change mitigation:** MCC, together with a network of international partners, is currently developing a living systematic review ecosystem that aims to understand which policy interventions (including policy packages) in the building sector work, under what conditions and why. We use innovative new approaches that combine machine learning with traditional econometrics in quasi-experimental research designs for *ex post* policy evaluation (Koch et al., 2022) in example applications. AI methods can also significantly improve urban planning. We will map every street and every building in Europe, adapt state-of-the-art machine learning algorithms, and establish new routines that connect big geolocated data with energy use. We aim to use these data to provide mayors with what they need to advance climate action goals in their cities, contributing to policy-relevant output.

8 Working group factsheets

The following factsheets provide an overview of each of MCC's seven working groups, as well as the Policy Evaluation Lab and the Policy Unit. This covers each ones' major achievements, outlook, top 10 publications and team members.

Economic Growth and Human Development
Head of working group: Prof. Dr Matthias Kalkuhl

Aim: Analyse the macroeconomic and public economics aspects of climate policy

The group focuses on the role of climate and fiscal policies for economic growth and human development. Specific research topics are: (i) tax and transfer policies to account for vertical and horizontal equity effects of climate policy, (ii) debt, monetary and fiscal policy to facilitate the energy transition, and (iii) policy designs for broader environmental issues (e.g. CDR, planetary boundaries). Methodological focus is on analytical and calibrated numerical equilibrium models (e.g. growth models, optimal taxation models) but also empirical and conceptual analyses.

Major achievements

Scientifically, a key achievement was the publication of new climate damage estimates and the implied **social cost of carbon** (Kalkuhl & Wenz 2020). The estimates have been used for further quantitative analyses on climate risks and damages by central banks and the US EPA. Another highlight is the development of a macroeconomic New Keynesian model for assessing **transition risks and the role of central banks** in the decarbonisation process (Diluiso et al. 2021). This provides a novel multi-sectoral modelling framework and allows us to study both conventional and unconventional monetary policies (quantitative easing) together with financial and climate policy measures. A third scientific highlight relates to the development of a novel **optimal taxation model that distinguishes the vertical and horizontal equity effects** of climate policy (Hänsel et al. 2022). The model allows us to study several climate policies in the context of broader income tax reforms with different informational requirements. It determines optimal policy mixes (for example, using carbon price revenues for cash transfers or subsidies), depending on the social inequality aversion (see figure) which is very well suited to MCC's science–policy approach.
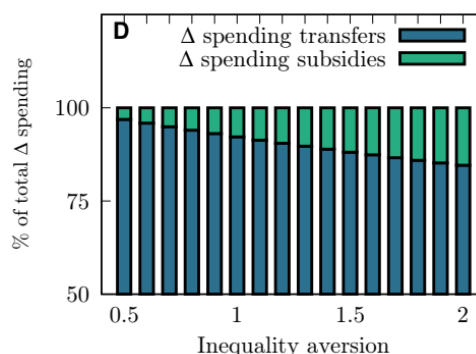
On the **science–policy interface**, the group has been assessing the potential for various **environmental tax reforms** in Germany and was very active in analysing the **distributional effects of carbon and energy price changes**. A key highlight is the carbon price calculator website, which allows users to set carbon price levels and different revenue recycling options to assess the costs and benefits for different population segments (see figure). The website has been used by NGOs, ministries, journalists and researchers, among others, to provide objective information on distributional effects. The analyses have been part of several **dialogue processes with members of parliament, ministries and NGOs**. Finally, the group has contributed to a report on the field of **policy instruments to incentivise CDR**, which contributed to a report for the science platform on climate protection (WPKS).

www.mcc-berlin.net/co2preisrechner
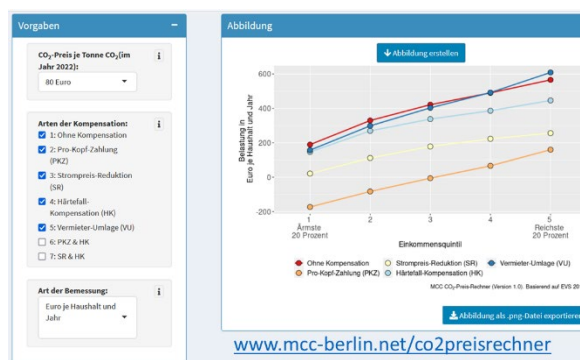
The group won a research grant from the German Research Foundation (DFG) on the Public Economics of Carbon Dioxide Removal.

Outlook

Due to the war in Ukraine, the group has focussed on analysing climate and social policy in the context of energy price shocks and business cycles, using incidence analyses and macroeconomic models (New Keynesian and DSGE models). We will conduct new research on the role of debts – particularly from political economy and acceptance perspectives. With the DFG research grant, we will undertake substantial work in the field of policy design to incentivise carbon removal, focussing on incentive, information, and distributional and environmental aspects. In a joint project with PIK, we will conduct further conceptual and basic research on policies to maintain global commons and planetary boundaries. This work also includes welfare measurement, growth with finite resources, and distributional and political economy aspects.

Top 10 publications

- **Blanz, A.,** Eydam, U., Heinemann, M., **Kalkuhl, M.,** 2022. *Energiepreiskrise und Klimapolitik: Sind antizyklische CO$_2$-Preise sinnvoll?* ifo Schnelldienst, 75(05), 34–38.
- Budolfson, M., Dennig, F., Errickson, F., **Feindt, S.,** Ferranna, M., Fleurbaey, M., […] Zuber, S., 2021. Climate action with revenue recycling has benefits for poverty, inequality and well-being. Nature Climate Change, 11(12), 1111–1116.
- **Diluiso, F.**, Annicchiarico, B., **Kalkuhl, M.**, Minx, J. C., 2021. Climate actions and macro-financial stability: The role of central banks. Journal of Environmental Economics and Management 110, 102548.
- Edenhofer, O., M. Franks, **M. Kalkuhl**, 2021. Pigou in the 21st Century. A tribute on the occasion of the 100th anniversary of the publication of The Economics of Welfare. International Tax and Public Finance 28, 1090–1121.
- **Feindt, S.,** Kornek, U., Labeaga, J. M., Sterner, T., Ward, H., 2021. Understanding regressivity: Challenges and opportunities of European carbon pricing. Energy Economics 103, 105550.
- Hänsel, M. C., Franks, M., **Kalkuhl, M.,** Edenhofer, O., 2022. Optimal carbon taxation and horizontal equity: A welfare-theoretic approach with application to German household data. Conditionally accepted at Journal of Environmental Economics and Management.
- **Kalkuhl, M.,** Wenz, L., 2020. The Impact of Climate Conditions on Economic Production. Evidence from a Global Panel of Regions. Journal of Environmental Economics and Management 103, 102360.
- Kotz, M., L. Wenz, A. Stechemesser, **M. Kalkuhl**, A. Levermann, 2021. Day-to-Day Temperature Variability Reduces Economic Growth. Nature Climate Change 11, 319–325.
- Martinet, V., **Del Campo, S.,** Cairns, R. D., 2022. Intragenerational inequality aversion and intergenerational equity. European Economic Review, 144, 104075.
- **Roolfs, C.,** Gaitan, B., Edenhofer, O., 2021. Make or brake—rich states in voluntary federal emission pricing. Journal of Environmental Economics and Management 109, 102463.

Team

Group leader: Prof. Dr Matthias Kalkuhl. Postdocs: Stellio Del Campo, Francesca Diluiso, Maximilian Kellner, Christina Roolfs. PhD students: Maximilian Amberg, Tobias Bergmann, Alkis Blanz, Simon Feindt, Friedemann Gruner, Nikolaj Moretti, Michael Sureth.

Climate and Development
Head of working group: Prof. Dr Jan Christoph Steckel

Aim: To understand which and how climate change mitigation policies work in the context of low- and middle-income countries and how they impact economic development.

To achieve international climate targets, low- and middle-income countries will need to leapfrog the emissions-intensive development pathways of today's developed countries. We investigate three main components of how this can be achieved: First, we conduct research on the political economy of fossil energy transitions. Second, we explore the distributional effects of climate- and energy policies. Third, we conduct research on structural change and energy- and emissions patterns. We use modern econometric methods, such as quasi-experimental designs, multi-regional input–output models combined with microsimulations on household survey data and demand systems, qualitative methods such as interviews, and computational methods applying machine learning such as topic models.

Major achievements

We have contributed to a strong understanding of international coal transitions, particularly taking political economy aspects into account. Based on a framework that we had developed within our group (Jakob et al. 2020), we coordinated and conducted interview-based case studies in 15 countries, leading to multiple publications in peer-reviewed journals (e.g. on the political economy of coal in India, Indonesia, Vietnam and the Philippines), a book publication with Routledge, a *Nature* comment as well as various op-eds (e.g. in *Handelsblatt, Süddeutsche Zeitung* and *East Asia Forum*) and (country-specific) policy briefs. This work also featured prominently at a COP26 side-event. An expert elicitation study on the political economy of coal could further shed light on tactics and objectives of coal proponents in key coal investing countries (Ohlendorf et al. 2022). Our work was rounded off with publications on international coal finance (Manych et al. 2021) and a quasi-experimental study on the effects of power investment on regional growth and economic growth, using global panel data from 1960–2015 (Montrone et al. 2022).

We have intensified our research on the distributional effects of carbon pricing in low- and middle-income countries. We have worked on building a comprehensive database of harmonised household survey data (now covering >60 countries) to foster primary cross-country research. A first study covering the vertical and horizontal effects of carbon pricing (as well as compensation schemes) in eight Asian countries has been published in *Nature Sustainability* (Steckel et al. 2021). We have additionally published a detailed meta-analysis on the existing literature (Ohlendorf et al. 2021). We constantly engage with various stakeholders in multiple countries, including Indonesia where we are part of a multi-year advisory project of the country's Ministry of Finance on the distributional effects of carbon pricing in Israel. We have also published on this topic in non-technical journals (*CESifo Forum*) and *Brookings Foresight Africa*. Our research has been picked up by prominent media outlets such as *Deutschlandfunk* and the World Bank podcast "Tell me how". Building on our model and data infrastructure we were able to publish a comprehensive analysis of the distributional effects of expected fossil fuel price increases for EU countries due to the war in Ukraine.

On career development, Jan Steckel got promoted to professor of Climate and Development Economics at BTU Cottbus. PhD students have found positions at the World Bank (Ira Dorband), the Joint Research Centre of the EU in Seville (Jose Ordonez) and the Federal Ministry of Economic Affairs and Climate Action (Nils Ohlendorf). Niccolò Manych will start a postdoc at Boston University in 2023.

Outlook

While we will continue our work on the distributional effects of carbon pricing, we will increasingly focus on the development impacts of carbon pricing (e.g. using demand systems). We will further intensify econometric and numerical modelling work on the political economy of climate policy, increasingly investing in research on social and political acceptability of particular climate policy packages in low- and middle-income countries.

Together with colleagues from the Indian Statistical Institute and the University of Gothenburg, we have founded the Emissions Pricing for Development Initiative which allows the group's work to be closely linked to the EfD network, hence broadening our academic and policy outreach in Low- and Middle-Income Countries (LMICs).

In cooperation with the Policy Unit, we have started regular roundtables on the role of climate clubs for climate change mitigation in LMICs. In cooperation with GIZ, we will develop the Carbon Pricing Incidence Map, an online tool that will allow us to assess the first-order distributional effects of carbon pricing on particular societal groups as well as the effects of targeted and untargeted revenue schemes. The group aims to increase the number of postdocs; funding for four new positions has been secured by two incoming Horizon EU projects.

Top 10 publications

- **Dorband, I. I., Jakob, M., Steckel, J. C., Ward, H.**, 2022. Double progressivity of infrastructure financing through carbon pricing—Insights from Nigeria. World Development Sustainability, 1, 100011.
- **Jakob, M.,** Flachsland, C., **Steckel, J. C.**, Urpelainen, J., 2020. Actors, objectives, context: A framework of the political economy of energy and climate policy applied to India, Indonesia, and Vietnam. Energy Research & Social Science, 70, 101775.
- **Jakob, M., Steckel, J. C.**, 2022, Eds. The Political Economy of Coal: Obstacles to Clean Energy Transitions. London, UK & New York, NY: Routledge.
- **Jakob, M., Steckel, J. C.**, Jotzo, F., Sovacool, B. K., Cornelsen, L., Chandra, R., [...], Urpelainen, J. (2020). The future of coal in a carbon-constrained climate. Nature Climate Change, 10(8), 704–707.
- **Jakob, M., Ward, H., Steckel, J. C.**, 2021. Sharing responsibility for trade-related emissions based on economic benefits. Global Environmental Change, 66, 102207.
- **Manych, N., Steckel, J. C., Jakob, M.**, 2021. Finance-based accounting of coal emissions. Environmental Research Letters, 16(4), 044028.
- **Montrone, L., Steckel, J. C.**, Kalkuhl, M., 2022. The type of power capacity matters for economic development-Evidence from a global panel. Resource and Energy Economics, 101313.
- **Ohlendorf, N., Jakob, M.**, Minx, J. C., Schröder, C., **Steckel, J. C.**, 2021. Distributional impacts of carbon pricing: A meta-analysis. Environmental and Resource Economics, 78(1), 1–42.
- **Ohlendorf, N., Jakob, M., Steckel, J. C.**, 2022. The political economy of coal phase-out: Exploring the actors, objectives, and contextual factors shaping policies in eight major coal countries. Energy Research & Social Science, 90, 102590.
- **Steckel, J. C., Dorband, I. I., Montrone, L., Ward, H., Missbach, L., Hafner, F.,..., Renner, S.**, 2021. Distributional impacts of carbon pricing in developing Asia. Nature Sustainability, 4(11), 1,005–1,014.
- **Steckel, J. C., Jakob, M.** (2022). To end coal, adapt to regional realities. Nature, 607, 29–31.

Team

Group leader: Jan Steckel. Postdocs: Sebastian Renner. PhD students: Raavi Aggarwal, Ira Dorband, Niccolò Manych, Leonard Missbach, Farah Mohammadzadeh Valencia, Lorenzo Montrone, Nils Ohlendorf, Jose Antonio Ordonez. Research fellows: Paula Blechschmidt, Marlene Merchert, Michael Jakob, Marie Zeller.

Transport, Infrastructure and Land Use
Head of working group: Prof. Dr Felix Creutzig

Aim: Advancing urban climate solutions based on high resolution data of buildings and streets, AI for low-carbon urban planning prediction, and urban data governance.

Our main focus is building up a new big data-based and AI-supported platform for identifying climate solutions for municipal policymakers at a resolution of individual buildings and streets. For this purpose we have collected terabytes of data on European building stocks and street networks, and are computing missing values with sophisticated deep learning methods. In related research, we investigate the urban economics of urban transport and seek to build a comprehensive framework of urban data governance that supports mayors to make use of the above-mentioned big data and machine learning-based predictive modelling for low-carbon urban planning.

Major achievements

- Organising an epistemic community around demand-side climate mitigation to deliver a chapter for the IPCC AR6.
- Two team members are co-authors of the Summary for Policymakers in the IPCC AR6, WG III.
- Organising a special issue on demand-side solutions for transitioning to low-carbon societies in *Environmental Research Letters*, successfully commissioning 21 systematic reviews.
- Recognised as global leading expert/team on the global and urban governance of big data and AI for climate change, with invitations to contribute to UNEP and UNDP panels, and corresponding publications.
- Obtained start-up funding to create a new Einstein Center Climate Change and Public Policy of Human Settlements.
- Organised a conference on the Public Policy of Human Settlements, bringing together climate solution researchers, architects, building planners, transport engineers, psychologists, design artists, administration researchers and political scientists with the aim of shaping an epistemic community.

Outlook

- Build up a model platform, based on big geographic data and machine learning, that delivers customised climate solutions for mayors in Europe, but that is scalable worldwide.
- Establish a framework for urban data governance that is data-saving, delivers climate solutions and helps to address social inequity in cities, both procedurally and outcome-wise.
- Get the Einstein Center Climate Change up and running, compute climate solutions for Berlin and Brandenburg that work now, and establish processes that translate ideas into reality.

Top 10 publications

- **Creutzig, F.**, 2020. Fuel crisis: slash demand in three sectors to protect economies and climate, Nature 606, 460–462.
- **Creutzig, F., Niamir, L.**, Bai, X., Cullen, J., Díaz-José, J., Figueroa, M., Grübler, A., Lamb, W., Leip, A., Masanet, E., Mata, E., Mattauch, L., Minx, J., Mirasgedis, S., Mulugetta, Y., Nugroho, S., Pathak, M., Perkins, P., Roy, J., Saheb, Y., Steg, L., Steinberger, J., Ürge-Vorsatz, D., 2022. Demand-side solutions to climate change mitigation consistent with high levels of wellbeing, Nature Climate Change 12, 36–46.
- **Javaid, A., Creutzig, F.**, Bamberg, S., 2020. Determinants of low-carbon transport mode adoption: systematic review of reviews, Environmental Research Letters 15, no. 10 (2020): 103002.
- Madhu, K., Pauliuk, S., Dhathri, S., **Creutzig, F.**, 2021. Understanding environmental trade-offs and resource demand of direct air capture technologies through comparative life-cycle assessment, Nature Energy 6, 1035–1044.
- **Milojevic-Dupont, N., Creutzig, F.**, 2020. Machine learning for geographically differentiated climate change mitigation in urban areas, Sustainable Cities and Society 64, 102526.
- **Milojevic-Dupont, N., Hans**, N., Kaack, L. H., **Zumwald**, M., Andrieux, F., de Barros Soares, D., **Lohrey, S.**, Pichler, P.-P., **Creutzig, F.**, 2020. Learning from urban form to predict building heights, PLoS ONE 15, e0242010.
- Nielsen, K.S., Nicholas, K.A., **Creutzig, F.**, Dietz, T., Stern, P.C., 2021. The role of high-socioeconomic-status people in locking in or rapidly reducing energy-driven greenhouse gas emissions, Nature Energy 6, 1011–1016.
- **Creutzig, F.**, 2021. From smart city to digital urban commons: Institutional considerations for governing shared mobility data, Environmental Research: Infrastructure and Sustainability 1, 025004.
- **Ramakrishnan, A., Creutzig, F.**, 2021. Infrastructure and Sustainability. Status consciousness in energy consumption decisions: A systematic review, Environmental Research Letters 16, 053010.
- Rockstrom, J., Beringer, T., Hole, D., Griscom, B., Mascia, M. B., Folke, C., **Creutzig, F.**, 2021. Opinion: We need biosphere stewardship that protects carbon sinks and builds resilience, Proceedings of the National Academy of Sciences 118 (38).

Team:

Group leader: Felix Creutzig. Postdocs: Peter Berrill, Aneeque Javaid. PhD students: Eva Ayaragarnchanakul, Nikola Milojevic-Dupont, Josefine Hintz, Jiawei Hu, Charlotte Liotta, Florian Nachtigall, Zakia Soomauroo, Felix Wagner.

Sustainable Resource Management and Global Change
Head of working group: Prof. Dr Sabine Fuss

Aim: Showing empirically what works and what does not work in terms of climate policy and resource management, and exploring the decision-space with anticipatory and uncertainty analysis.

We explore the design and functioning of policy instruments and solutions for sustainable resource management and the provision of public goods using empirical methods and big data, research synthesis, meta-analysis and review, economic modelling, uncertainty analysis and scenario assessment.

Major achievements

Under Nicolas Koch's leadership, road CO_2 emissions reductions can, for the first time, be attributed to specific policy mixes (see figure), resulting in a high-level publication in *Nature Energy*.

Our past work on techno-economic assessments of CDR was a major input to the IPCC's AR6 (WG I, WG III) in 2021 and 2022. In a new study for the WPKS in collaboration with other groups at MCC and PIK under Sabine Fuss' leadership, first analysis is provided on implementation with a focus on Europe and Germany. This has been the basis for many consultations and discussions at the science–policy interface with NGOs, media and practitioners; see WPKS study (Edenhofer et al. 2022).

Without dedicated efforts to prevent it, tropical deforestation will contribute in the order of 200 billion tons of CO_2 to the atmosphere by 2100. Our new modelling work shows that protecting tropical forests at scale offers an outsized – and indispensable – economic return on climate investment (see Fuss et al. 2021). At the same time, high-level empirical publications shed more light on the performance of specific forest protection policies in the tropics (see e.g. Kraus et al. 2021) for the first time. Both strands of work have been prominently taken up in the media.

Outlook

- Move from techno-economic assessment of **CDR** to **implementation** with stylised modelling, policy analysis, new conceptual work and systematic review: How to integrate CDR into EU and German climate policy architecture?
- Put more emphasis on the role of **land** in net-zero strategies: What are the distributional impacts of land-based climate policy? Furthermore, what are the governance requirements and uncertainties?
- Policymakers almost exclusively introduce mixes of interacting policies, but current policy evaluation tools can only analyse the outcomes of individual policies in isolation. We aim to **advance methods for causal evaluation of climate policy mixes** using machine learning.
- Move from narrative and back-of-envelope calculations to **hard evidence for the health co-benefits of climate policy.**
- Put more emphasis on **nexus between finance and climate policy**: How does climate policy affect access to credit? Do climate policy impacts hinge upon financial constraints? How important are stranded assets for households?

Top 10 publications

- Andrijevic, M., Byers, E., Mastrucci, A., Smits, J., **Fuss, S.**, 2021. Future cooling gap in shared socioeconomic pathways. Environment and Development Economics 1–24.
- **Fuss, S.,** Golub, A., & Lubowski, R., 2021. The economic value of tropical forests in meeting global climate stabilization goals. Global Sustainability, 4, E1.
- **Fuss, S.,** Johnsson, F., 2021. The BECCS Implementation Gap–A Swedish Case Study. Frontiers in Energy Research, 8:553400.
- Jackson, R.B., Abernethy, S., Canadell, J.G., Cargnello, M., Davis, S.J., Féron, S., **Fuss, S.,** Heyer, A.J., Hong, C., Jones, C.D., Damon, Matthews, H., O'Connor, F.M., Pisciotta, M., Rhoda, H.M., de Richter, R., Solomon, E.I., Wilcox, J.I., Zickfeld, K., 2021. Atmospheric methane removal: a research agenda. Philosophical Transactions of the Royal Society A.
- **Koch, N.,** Naumann, L., Pretis, F., **Ritter, N.**, Schwarz, M., 2022. Attributing agnostically-detected large reductions in road CO_2 emissions to policy mixes, Nature Energy, forthcoming.
- **Kraus, S., Koch, N.**, 2021. Provisional Covid-19 infrastructure induces large, rapid increases in cycling, Proceedings of the National Academy of Sciences, 118 (15).
- **Kraus, S**., Liu, J., **Koch, N., Fuss, S**., 2021. No aggregate deforestation reductions from rollout of community land titles in Indonesia yet. Proceedings of the National Academy of Sciences 118(43).
- **Rohlf, A.,** Holub, F., **Koch, N., Ritter, N.**, 2020. The effect of clean air on pharmaceutical expenditures, Economics Letters, 192, 109–221.
- **Schulte, I.,** Eggers, J., Østergaard Nielsen, J., **Fuss, S.**, 2021. What influences the implementation of natural climate solutions? A systematic map and review of the evidence. Environmental Research Letters.
- **Fuss, S.,** 2021. What influences the implementation of natural climate solutions? A systematic map and review of the evidence. Environmental Research Letters.

Team

Group leader: Sabine Fuss. Postdocs: Nicolas Koch, Nolan Ritter, Luke Haywood, Ingrid Schulte. PhD students: Hannah Klauber, Johanna Arlinghaus, Valentin Guye. Research fellows: Alexander Rohlfs, Marion Bachelet, Constantino Dockendorff, Francesco Scarazzato.

Scientific Assessments, Ethics and Public Policy
Head of working group: Dr Martin Kowarsch

Aim: Research the science–policy interface, participatory deliberation and ethical issues.

The group carries out (1) interdisciplinary research on the design and evaluation of participatory, environment-related policy assessments, as well as (2) philosophical research on ethics, justice and deliberative democracy for sustainability governance. We focus on how to facilitate deliberation and learning about policy options and how to integrate ethics and citizens' values appropriately into integrated assessment processes. The group employs various methods, including philosophical argumentation and empirical methods, as well as applications of deliberative democracy theory, the Values–Beliefs–Norms theory and social learning theory.

Major achievements

Putting our philosophical science–policy model into practice. Together with colleagues, the group implemented science-informed citizen dialogues within the BMBF-funded Ariadne project (on transport policy options and renewables deployment, 2020–23) and with a local focus in Brandenburg (sustainable forest management, 2021–22, funded by DBU). In three major rounds of engagement, randomly selected citizens deliberated on the pros and cons of different policy options in an iterative learning process, based on scientific findings. Our innovative approach links deliberative mini-publics with integrated policy assessment and builds on the pragmatic-enlightened science–policy model (PEM) (Edenhofer & Kowarsch, 2015.
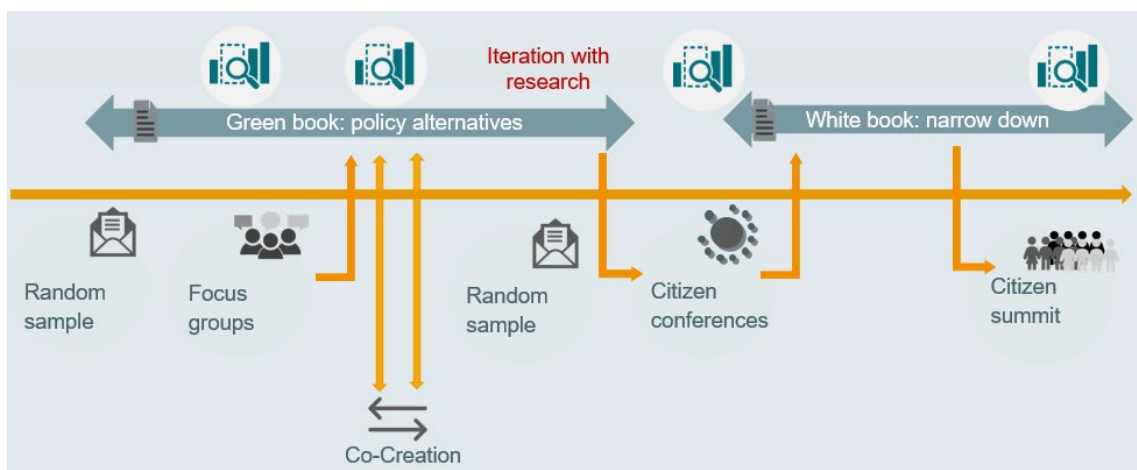
Overview of Ariadne's citizen engagement process – integrating Ariadne's scientific assessment of energy transition pathways with citizen deliberation processes.

Within the Formas-funded RIVET project (2020–24) on "Risk, values, and decision-making in the economics of climate change" with the University of Lund, the group refined and specified its approach to diverse values in (economic) assessments. Several publications are in the making. We organised a workshop in March 2022 together with international experts from different disciplines to *inter alia* discuss the appropriate treatment of values and deliberation in climate economics.

Outlook

- The final round of the deliberative citizen engagement in Ariadne will take place in early 2023.
- The group will continue to empirically analyse and evaluate the outcomes of the citizen engagement within the Ariadne and DBU "*Wald-Brandenburg*" projects, and publish several papers in this regard. This will also inform possible future participatory processes at the local or national levels.
- The group will deepen its philosophical and interdisciplinary research on the relationship between the economic modelling of climate policy options, diverse ethical viewpoints and deliberative, participatory learning processes within the RIVET research project.

Top 10 publications

- **Beck, L.**, 2022. forthcoming. The Econ within or the Econ above? On the plausibility of preference purification. Economics and Philosophy.
- **Blum, M.,** 2020. Whose Climate? Whose forest? Power struggles in a contested carbon forestry project in Uganda. Forest Policy and Economics, vol. 115, issue C.
- **Blum, M.**, Treichel, K., **Kowarsch, M.**, 2022. *Sichten von Bürgerinnen und Bürgern auf vier Zukunftspfade der Verkehrswende — Ergebnisse der Ariadne-Bürgerkonferenz.* Kopernikus-Projekt Ariadne, Potsdam.
- **Blum, M.**, Colell, A., Hoffmann, J., Karohs, K., **Kowarsch, M.**, **Krude, M.**, Saur, M., Thiel, H., 2021. *Was ist uns wichtig bei Verkehrs- und Stromwende? Bürgerinnen und Bürger sprechen über Herausforderungen und Ziele.* Ariadne Report.
- **Kowarsch, M.**, 2021. *Beratung für Corona- und Klimapolitik: Fakten, Handlungsvorschläge oder gar Ziele?* In: Forschung – Politik, Strategie, Management 3+4/2020, 97-100
- **Lenzi, D.**, 2021. On the Permissibility (Or Otherwise) of Negative Emissions. Climatic Change 169, 20.
- Heyward, C., **Lenzi, D.**, 2021. Special Claims from Improvement: A Comment on Armstrong. Global Justice : Theory Practice Rhetoric 13/1, 17-32.
- **Lenzi, D.**, Jakob, M., Honegger, M., Droege, S., Heyward, J.C., Kruger, T., 2021. Equity implications of net zero visions. Climatic Change, 169(3-4): 20.
- **Lenzi, D.**, **Kowarsch, M.**, 2021. Integrating Justice in Climate Policy Assessments: Towards a Deliberative Transformation of Feasibility. In: S. Kenehan/C. Katz (eds.): Principles of Justice and Real-World Climate Politics. Lanham: Rowman & Littlefield.
- Maas, T. Y.; Montana, J., van der Hel, S., **Kowarsch, M.**, Tuinstra, W., Schoolenberg, M., Mahony, M., Lucas, P. L.., Kok, M., Bakkes, J., Turnhout, E., 2021. Effectively empowering: A different look at bolstering the effectiveness of global environmental assessments. Environmental Science & Policy 123, 210–219.

Team

Group leader: Dr Martin Kowarsch. Postdocs: Dr Mareike Blum, Dr Dominic Lenzi (until Dec 2021), Lukas Beck (since May 2022). Research Assistant: Katharina Hagemann.

Applied Sustainability Science (APSIS)
Head of working group: Jan C. Minx, PhD (Guest Professor University of Leeds)

Aim: *The working group aims to foster learning on climate solutions at the science–policy interface by delivering robust scientific evidence.*

The working group aims to foster learning on climate solutions by delivering robust evidence. The core methodology across the group is systematic evidence synthesis: rigorous qualitative and quantitative methods for mapping out the literature, appraising its quality and synthesising the resulting evidence base. We advance and mainstream these methods for applications on climate solutions using machine learning to work towards "living evidence ecosystems" that deliver robust scientific evidence in near-real-time and can deal with vast and rapidly growing bodies of scientific literature. We apply similar data science approaches to exploit vast digital archives of text to measure public perception and preferences, polarisation in discourses and political influence. Topical focus areas are: (1) analysing greenhouse gas emissions trends and drivers; (2) CDR technologies; (3) tracking and evaluating (*ex post*) climate policies; (4) political economy of climate policies; (5) climate change discourses and public perception.

Major achievements

Prominently advanced evidence synthesis methods using machine learning to provide the first comprehensive assessment of climate impact evidence, highlighting that attributable anthropogenic impacts may be occurring across 80% of the world's land area, where 85% of the population resides (Callaghan et al., 2021). We developed a new method for inquisitive evidence mapping (Sietsma et al., 2021), provided the machine learning pipeline for the largest evidence mapping on adaptation to date (Berrang Ford et al., 2021a) and comprehensively mapped the climate and health space (Berrang-Ford et al., 2021b), which now features as a new indicator for the Lancet Countdown (Romanello et al., forthcoming; van Daalen et al., forthcoming).

Secured prestigious long-term funding on CDR. The group attracted large-scale funding (six years, ~€9 million, four partners) from the European Research Council for the Synergy project GENIE (GeoEngineering and Negative Emissions Pathways In Europe) as well as funding from the Ministry of Education and Research as part of the new funding priority on carbon removal.

Expanded activities in key areas by unlocking new, innovative research fields. The group exploits vast digital archives to better understand the political economy of climate policy. We have studied coal in parliamentary debates (Müller-Hansen, 2021) and have developed new methods for studying discourses and public perception using social media data (forthcoming).

Substantial contributions to scientific assessment. The group led the IPCC AR6 chapter on "Emissions Trends and Drivers" in WG3, supplying a synthesised, peer-reviewed dataset on historic emissions while coordinating its consistent use across the report (Minx et al., 2021; Lamb et al., 2021a; Lamb et al.; 2021b). An MCC-led community effort to fill evidence gaps ahead of IPCC AR6 yielded two systematic review special issues in *Environmental Research Letters* with about 40 contributions. In 2022, the group also had leading roles in the forthcoming UNEP Emissions Gap report, the Lancet Countdown and the European Lancet Countdown.

Outlook

- **A new, regular science assessment on CDR**: In collaboration with the University of Oxford, SWP and the University of Wisconsin, we lead a global community effort to publish a (bi-)annual scientific assessment "The State of Carbon Removal" to fill a critical evidence gap in this fast-developing policy space. The first edition will be launched in October 2022.
- **Preparing for AR7 – What Works Climate Solutions Summit**: With a range of international partners (IPCC, Evidence Synthesis International, Cochrane, Campbell Collaboration etc.) we will organise a major conference in Berlin (June 2023) to promote and catalyse synthetic evidence on climate solutions for upcoming climate change assessments – particularly the IPCC's AR7 — as well as other forms of scientific policy advice.
- **Systematic review ecosystems for rigorous policy advice**: We lead four community efforts to catalyse interrelated sets of systematic reviews to comprehensively inform decision-making with the best available scientific evidence on the following topics: 1) CDR; 2) behavioural interventions; 3) carbon pricing; (4) public attitudes on climate policies.
- **Towards systems of living evidence**: We work to build systems of living evidence using data science approaches that provide robust information when it is needed by decision-makers. First living maps are prototyped and will be made publicly available as a resource in 2023.

Top 10 publications

- Berrang-Ford, L., **Callaghan, M., Minx, J., [...]**, 2021. A systematic global stocktake of evidence on human adaptation to climate change. Nat. Clim. Chang. 11, 989–1000.
- Berrang-Ford, L., **Sietsma, A. J., Callaghan, M., Minx, J. C.**, [...], 2021. Systematic mapping of global research on climate and health: a machine learning review. The Lancet Planetary Health 5, e514–e525.
- **Callaghan, M. W.**, [...], **Minx, J. C.**, 2021. Machine learning-based evidence and attribution mapping of 100,000 climate impact studies, Nat. Clim. Chang. 11, 966–972.
- **Diluiso, F.**, [...], **Minx, J.**, 2021. Climate actions and macro-financial stability: The role of central banks. Journal of Environmental Economics and Management 110, 102548.
- Elliott, J., **Minx, J**, [...], 2021. Decision makers need constantly updated evidence synthesis, Nature 600, 383–385.
- **Khanna, T. M.**, [...], **Callaghan, M. W., Laukemper, S., Zamora Dominguez, M del M., Minx, J. C.**, 2020. A multi-country meta-analysis on the role of behavioural change in reducing energy consumption and CO_2 emissions in residential buildings, Nature Energy 6, 925–932.
- **Lamb, W. F.**, [...], **Minx, J.**, 2021. A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. Environ. Res. Lett. 16, 073005.
- **Minx, J., Lamb, W. F., Döbbeling, N.**, [...], 2021. A comprehensive and synthetic dataset for global, regional and national greenhouse gas emissions by sector 1970–2018 with an extension to 2019, Earth Syst. Sci. Data 13, 5213–5252.
- **Müller-Hansen, F., Callaghan, M. W.**, [...], **Minx, J. C.**, 2021. Who cares about coal? Analyzing 70 years of German parliamentary debates on coal with dynamic topic modeling. Energy Research & Social Science 72, 101869 (2021).
- **Sietsma, A. J.**, [...], **Callaghan, M. W., Minx, J. C.**, 2021. Progress in climate change adaptation research Environ. Res. Lett. 16, 054038.

Team

Group leader: Prof. Dr Jan C. Minx. Postdocs: Dr Max Callaghan, Dr Nicola Cerutti, Dr Francesca Diluiso, Tarun Khanna, Dr Sarah Lück, Dr William F. Lamb, Dr Finn Müller-Hansen, Dr Tim Repke. PhD students: Niklas Döbbeling, Anne Sietsma (external), Farah Mohammadzadeh Valencia. Research fellows: Klaas Miersch.

Policy Evaluation Lab
Head of unit: Dr Nicolas Koch

Aim: We provide rigorous causal impact evaluations of climate and environmental policies to strengthen data-driven policy assessments and a culture of persistent policy experimentation and evaluation in public policymaking.

We combine advanced methods for causal impact and welfare analysis from modern empirical economics with the power of big data and machine learning to improve public policymaking on pressing environmental policy challenges. Specific research areas include carbon pricing, command-and-control policy (e.g. vehicle bans or coal exit), subsidies on green technology and infrastructure (e.g. for electric vehicles), clean air policy and road pricing. We provide both *ex post* evidence on the real-world impacts of already implemented policies, and *ex ante* evidence on more efficient policy alternatives. As a cross-sectional unit, we provide methodological support to other MCC researchers doing empirical work.

Major achievements

Four key papers, with relevance to major policy questions, highlight our approach to learning from data generated by policies. This has established the Policy Evaluation Lab among academics & policymakers.

How can we change people's mobility behaviour? Conventional wisdom is that people are stuck in the status quo of their mobility choices and that modal shifts take decades. Our research has refuted the generality of this belief. We used the rollout of pop-up bike lanes during the Covid-19 pandemic in 106 European cities to estimate the pull effect of new cycling infrastructure. The large, immediate increases in cycling that we find imply that new climate-friendly infrastructure can have a significant steering effect when people are willing or forced to rethink their habits [published in *PNAS*].

What reduced CO_2 emissions? There is significant pressure to strengthen climate policy in the transport sector, but policymakers face substantial uncertainty around which policy mixes are effective. We have introduced a novel approach to identify effective policies in the EU road transport sector by first detecting substantial emission changes using machine learning and subsequently attributing them to policy interventions. We show that the most successful policy mixes combine carbon or fuel taxes with green vehicle incentives. We further highlight that emissions reductions on a magnitude that matches the EU zero emissions targets are possible [forthcoming in *Nature Energy*].

How can we make healthy cities? Public health concerns motivate ever more cities to ban cars, but the health effects of such policies are contested. We have shown that Low Emission Zones, which ban emission-intensive cars from cities, have long-lasting health benefits for children. These benefits remain undetected in the most widely used health measures, but alone recover about a quarter of the policy costs. To show this, we blend a novel quasi-experimental research design with big health data from a major public health insurer, which allows us to track the complete medical history of one-third of all children in Germany over a decade [Accepted at *American Economic Journal: Economic Policy*].

Jobs versus the climate? Job loss is the main argument against a coal exit. We have analysed exhaustive social security data on the employment biographies of workers in the German lignite coal industry to quantify the welfare costs of the German coal exit. We show that the problem is not unemployment, but insecure, low-paid job alternatives. Because workers aged 31–49 (and not those who are 50+) are most affected, we show that a wage insurance scheme (rather than early retirement) may greatly reduce welfare costs while maintaining employment [Revise & Resubmit at *JAERE*].

Outlook

- Policymakers almost exclusively legislate mixes of interacting policies (e.g. a carbon price with green subsidies and standards) but current policy evaluation tools can only quantify the effect of single policy interventions in isolation. We will develop a new approach to **identify effective policy mixes** by detecting treatment effects in a machine learning-assisted search for structural breaks in emissions. Our vision is a global, cross-sectoral evaluation that can inform the next IPCC assessment cycle.

- We seek to advance the literature on the **health co-benefits of climate policy**, which is still largely based on back-of-the-envelope calculations, by providing tangible evidence for the causal chains at play (e.g. carbon pricing → more active travel → better health). Such evidence is crucial because behavioural responses and regulatory details are likely to drive a significant wedge between expected health impacts and actual health outcomes.

- We will put more emphasis on the **nexus between finance and climate policy**: How does climate policy affect access to credit? Do climate policy impacts hinge upon financial constraints? How important are stranded assets for households?

Top 10 publications

- **Klauber, H.**, Holub, F., **Koch, N.**, Pestel, N., **Ritter, N.**, **Rohlf, A.**, 2022. Killing Prescriptions Softly: Low Emission Zones and Child Health from Birth to School, American Economic Journal: Economic Policy, accepted.

- **Koch, N.**, Naumann, L., Pretis, F., **Ritter, N.**, Schwarz, M., 2022. Attributing agnostically-detected large reductions in road CO_2 emissions to policy mixes, Nature Energy, forthcoming.

- **Koch, N.**, **Ritter, N.**, **Rohlf, A.**, **Scarazzato, F.**, 2022. When is the electric vehicle market self-sustaining? Evidence from Norway, Energy Economics, 110, 105991.

- **Koch, N.**, Themann, M., 2022. Catching up and falling behind: Cross-country evidence on the impact of the EU ETS on firm productivity, Resource and Energy Economics, 69, 101315.

- Kraus, S., **Koch, N.**, 2021. Provisional Covid-19 infrastructure induces large, rapid increases in cycling, Proceedings of the National Academy of Sciences, 118 (15).

- Kraus, S., Liu, J., **Koch, N.**, Fuss, S., 2021. No aggregate deforestation reductions from rollout of community land titles in Indonesia yet, Proceedings of the National Academy of Sciences 118 (43).

- **Haywood, L.**, Neumann, M., 2021. Equilibrium effects of tax exemptions for low pay, Labour Economics, 69, 101976.

- **Haywood, L.**, Janser, M., **Koch, N.**, 2021. *Sozialer Kohleausstieg oder zusätzliche Entschädigung der Industrie? Das Anpassungsgeld für Kohlebeschäftigte*, Perspektiven der Wirtschaftspolitik, 22(2), 130–141.

- **Klauber, H.**, **Koch, N.**, 2021. *Individuelle und regionale Risikofaktoren für hitzebedingte Hospitalisierungen der über 65-Jährigen in Deutschland*. In Versorgungs-Report: Klima und Gesundheit. Medizinisch Wissenschaftliche Verlagsgesellschaft.

- **Rohlf, A.**, Holub, F., **Koch, N.**, **Ritter, N.**, 2020. The effect of clean air on pharmaceutical expenditures, Economics Letters, 192, 109–221.

Team

Lead: Dr Nicolas Koch. Postdocs: Dr Luke Haywood, Dr Nolan Ritter. PhD students: Maximilian Amberg, Hannah Klauber, Patrick Klösel. Research fellows: Marion Bachelet, Dr Alexander Rohlf, Francesco Scarazzato.

Policy Unit
Head of unit: Dr Brigitte Knopf

Aim: As a cross-cutting unit, the Policy Unit aims to contribute to a societal learning process based on dialogue-oriented scientific policy advice. The unit's main task is to strategically orient the interface between the institute, politics and society.

We believe that evidence-based and dialogue-informed policy advice produces long-term and socially viable policy decisions when it brings together different types of knowledge, and processes it in such a way that it contributes to societal learning and feeds into policymaking. The Policy Unit supports this endeavour by communicating MCC's research results in a comprehensible way, by building networks with various stakeholders and drawing on their perspectives, feeding these back into the MCC research process. We contribute to this social learning process with a variety of dialogue formats and publications.

Major achievements

The Policy Unit enables learning between science, politics, business and civil society through structured dialogues in various formats, many of which were implemented in the Ariadne project:

- Dialogue forum: a constant group of industry, policy and NGO stakeholders meets regularly with researchers to discuss research results in the context of current political events (e.g. for the building sector and industry sector).
- Inter-ministerial dialogue forum: regular dialogue where representatives from different ministries are invited to facilitate an exchange around a specific cross-cutting research topic (e.g. carbon pricing) presented by MCC.
- Stakeholder dialogue: ad hoc events addressing a specific topic drawn, for example, from the Ariadne project's citizen deliberation or from research findings in the context of current political events (e.g. photovoltaic rooftop obligations and large solar parks).
- Parliamentary events: parliamentary breakfasts or dinners where policy-relevant research results are discussed with members of the German Bundestag (e.g. competitiveness of German industry and carbon leakage protection).
- Citizens' dialogue and deliberation: in addition to exchange formats with organised stakeholder groups, the Policy Unit pursues dialogue with citizens through the Ariadne project regarding the challenges, opportunities and policy options associated with the expansion of renewable energy and the transformation of the transport sector.

The Policy Unit is cross-linked with all MCC working groups and communicates both internally and externally. Recent activities include:

- Organisation of a briefing event to Members of the German Bundestag about the energy crisis and its consequences for German climate policy
- Organisation of several outreach events with MCC researchers on the new IPCC AR6 report
- Organisation of roundtable events with German ministries about CDR and carbon pricing
- Contribution to the Council of Experts on Climate Change reports
- Organisation of a roundtable on "Climate Clubs" in the context of Germany's G7 presidency

The Policy Unit has taken a professional stakeholder management process to target the MCC's scientific policy advice to German and EU policymakers.

Outlook

- The Policy Unit will continue its work on systematic stakeholder mapping to strategically improve the MCC's outreach and dialogue activities.
- The unit will further work on the implementation of a per-capita-dividend ("*Klimageld*") in Germany.
- We will organise side-events on facilitating the global coal phase-out for the COP27 in Egypt.
- For 2023, a citizens' summit will be prepared within the Ariadne project.

Publications

As a non-scientific group, the Policy Unit contributes to MCC working papers, publications in the Ariadne project and engages in public debate through op-eds:

- Blum, M., **Colell, A.**, Hoffmann, J., Karohs, K., Kowarsch, M., Krude, M., Saur, M., Thiel, H., 2021. *Was ist uns wichtig bei Verkehrs- und Stromwende*, Ariadne Report.
- Blum, M., **Treichel, K.**, Kowarsch, M., 2022. *Sichten von Bürgerinnen und Bürgern auf vier Zukunftspfade der Verkehrswende – Ergebnisse der Ariadne-Bürgerkonferenz*. Kopernikus-Projekt Ariadne, Potsdam.
- **Colell, A.**, **Knopf, B.**, 2022. *Teilhabe ist mehr – Energiewende gesellschaftlich tragen*, Tagesspiegel Background**.**
- Flachsland, C., aus dem Moore, N., Müller, T., Kemmerzell, J., Edmondson, D., Görlach, B., Kalkuhl, M., Knodt, M., **Knopf, B.**, Levi, S., Luderer, G., Pahle, M., 2021. *Wie die Governance der deutschen Klimapolitik gestärkt werden kann*. Ariadne-Kurzdossier.
- Kalkuhl, M., Flachsland, C., **Knopf, B.**, Amberg, M., Bergmann, T., Kellner, M., Stüber, S., **Haywood, L.**, Roolfs, C., Edenhofer, O., 2022. *Auswirkungen der Energiepreiskrise auf Haushalte in Deutschland: sozialpolitische Herausforderungen und Handlungsoptionen*, MCC-Arbeitspapier.
- Knodt, M., Rodi, M., Flath, L., Kalis, M., Kemmerzell, J., **Leukhardt, F.**, Flachsland, C., 2022. *Mehr Kooperation wagen: Wasserstoff-Governance im deutschen Föderalismus*. Interterritoriale Koordination, Planung und Regulierung. Ariadne-Analyse.
- **Knopf, B.**, Geden, O., 2022. *Ist Deutschland auf dem 1,5-Grad-Pfad? Eine Einordnung der Diskussion über ein nationales CO_2-Budget*, MCC-Arbeitspapier.
- **Knopf, B.**, 2021. *Ein sozialverträglicher ausgestalteter CO_2-Preis als Wegbegleiter für Klimaneutralität*, Blog Politische Ökonomie.
- Pietzcker, R., **Feuerhahn, J.**, **Haywood, L.**, **Knopf, B.**, **Leukhardt, F.**, Luderer, G., Osorio, S., Pahle, M., Rodrigues, R., Edenhofer, O., 2021. *Notwendige CO_2-Preise zum Erreichen des europäischen Klimaziels 2030*, Ariadne-Hintergrund.
- **Treichel, K.**, Blum, M., Kowarsch, M., 2022. *Bürgersichten auf zukünftige Energiewelten, Ergebnisse der Ariadne-Bürgerkonferenz*, Ariadne Report.

Team

Lead: Dr Brigitte Knopf. Policy analysts: Janik Feuerhahn, Luke Haywood, Falko Leukhardt, Katja Treichel, Marie Zeller. Press relations & communications (Ariadne): Maria Bader. Team support & event management: Ellen Lindner-Rhinow. Student assistant: Julian Kilchling.

Annex

A.1. Board members

Expert Advisory Board		
Name	Function	Affiliation
Jotzo, Frank (Chair)	Professor Crawford School of Public Policy Director Centre for Climate and Energy	Australian National University
Bals, Christoph	Policy Director	Germanwatch
Barrett, Scott	Lenfest Earth Institute Professor of Natural Resource Economics	Columbia University, School of International and Public Affairs
Berrang Ford, Lea	Research Chair in Climate & Health	Priestley International Centre for Climate, University of Leeds
Carraro, Carlo	President Emeritus and Professor of Environmental Economics	University Ca' Foscari of Venice
Dubash, Navroz	Senior Fellow	Centre for Policy Research
Faber, Joachim	Chairman	Harald Quandt Holding
Fischer, Carolyn	Research Manager, Sustainability and Infrastructure, Development Economics	World Bank
Hackmann, Heide	Inaugural Chief Executive Officer	International Council for Science (ICSU)
Hallegatte, Stéphane	Senior Economist, Climate Change Group	The World Bank
Harvey, Hal	CEO	Energy Innovation: Policy and Technology LLC
Reisch, Lucia	Professor for Consumer Behaviour and Consumer Policy; Editor in Chief of the Journal of Consumer Policy	Copenhagen Business School
Runge-Metzger, Artur	Former Director "Climate strategy, governance and emissions from non-trading sectors", DG Climate Action, European Commission. Fellow at MCC	

Runkel, Marco	Professor for Economics; Chair of Public Sector Economics and Health Economics, School of Economics and Management	Technische Universität Berlin
Sach, Karsten	Former Director General "Climate Policy, European and international Policy" at Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).	
Schlacke, Sabine	Professor of Public Law with a focus on administrative and environmental law at the University of Greifswald. Executive Director of the Institute for Energy, Environmental and Maritime Law (IfEUS)	University of Greifswald
Schöb, Ronnie	Professor of International Public Economics	Freie Universität Berlin
Schreurs, Miranda	Professor of Environment and Climate Policy	Technical University of Munich, Bavarian School of Public Policy
Seto, Karen C.	Frederick C. Hixon Professor of Geography and Urbanization Science; Senior Associate Dean of Research; Director of Doctoral Studies	Yale University, School of Forestry & Environmental Studies
Sterner, Thomas	Professor of Environmental Economics	University of Gothenburg
Tubiana, Laurence	CEO	European Climate Foundation
Wilsdon, James	Professor of Research Policy, Department of Politics; Director of Research and Innovation, Faculty of Social Sciences	University of Sheffield

Institutional board

Name	Function	Affiliation
Braig, Marianne	Vice President	Freie Universität Berlin
Frensch, Peter A.	Vice President for Research	Humboldt-Universität zu Berlin
Hallerberg, Mark	Dean Faculty & Research	Hertie School of Governance
Hipp, Christiane	President	Brandenburg University of Technology Cottbus-Senftenberg
Prof. Dr Barbara Höhle	Vice President for Research, Young Scientists and Equal Opportunity	University of Potsdam
Hostert, Patrick	Chair of Geomatics Lab, Director of IRI THESys	Humboldt-Universität zu Berlin
Rauch, Geraldine	President	Technische Universität Berlin
Wellner, Kristin	Dean of the Faculty VI – Planning, Building and Environment	Technische Universität Berlin
Guests		
Klaus Hoffmann-Holland	First Vice President	Freie Universität Berlin

A.2. List of publications (07/2020 – 07/2022)

MCC authors are highlighted in bold letters.

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