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Energy, Climate, and Environment (ECE) Program
Self Assessment Report 2021-2024

Contents

ECE Program Activities and Goals

The objective of the ECE Program is to understand the nature, dynamics and pace of feasible systems transformations that can address environmental problems in a socially and economically sustainable manner. Addressing climate change while assuring human health and wellbeing, and the reduction of social inequalities, implies rapid and unprecedented structural changes to reach, e.g., net-zero GHG emissions over the next decades. Our focus is on exploring regional, national and local policy decisions and actions required in the short term to put the world on track for achieving long-term targets. We study how to accelerate technology diffusion and substitution dynamics, while also exploring the governance needs and social innovations that are required for this. The Program's niche builds upon the systematic and holistic analysis of energy policy objectives and their interactions to identify possible synergies and trade-offs. This includes the identification of salient co-benefits from meeting a range of environmental, economic, and social objectives that at the same time are robust against multiple uncertainties that the future entails.

ECE comprises four closely integrated **Research Groups**. Research on global, regional and national transformation pathways in the *Integrated Assessment and Climate Change Research* Group (IACC) is complemented by bottom-up and more local studies in the *Pollution Management* Group (PM). The *Sustainable Service Systems* Group (S^3) focuses on demand-side transitions and disruptive end-use innovation, lifestyles & behavior – thus going beyond the traditional supply-side bias of climate mitigation studies. Finally, the *Transformative Institutional and Social Solutions* (TISS) Group is critical since it permits the integration of social science perspectives into quantitative transformation pathways, with specific focus on governance and institutional change as well as poverty eradication, equity, and justice. A fifth Group on *Integrated Climate Impacts* has just been established to further help integrate climate mitigation, adaptation, and impacts across ECE (and the rest of IIASA). Most ECE staff have affiliations across multiple ECE Research Groups (and Programs) to assure integration of research across the domains. In addition, ECE has established **six Cross-cutting Research Themes** each led by Senior Researchers that further facilitate integration and collaboration across the Groups, helping co-create the research agenda. Multiple internally and externally funded research activities coordinated by ECE also involve other IIASA Programs and help leverage synergies particularly in the areas of just transition and decent living (POPJUS/EF/SI), climate modelling (ASA), integrated assessment (BNR), biodiversity assessments (BNR); energy, water, land nexus (BNR), impacts and adaptation (ASA/BNR/POPJUS), SSPs (BNR/POPJUS/ASA), and carbon dioxide removal (ASA).

From a **methodological perspective,** ECE work aims to both enhance and extend the presently available tools (e.g., the MESSAGEix IAM framework and GAINS) and to develop novel operational methodologies. In the period 2021-2024, a framework of tools has been developed, which is interlinked and can be flexibly adapted to address various research objectives and their integration, rather than focusing on many independent and dispersed tools for which a critical mass of research capacity is difficult to maintain. Extensions of the modeling framework have focused specifically on 1) novel tools to better understand lifestyle and behavioral changes and the barriers of the sharing economy (LIFE in collaboration with Oxford University), demand-side tools of the build environment (CHILLED and STURM); 2) granular agent based models to understand city transitions (BENCH), 3) new material supply and demand modules, including circularity, which is critical for understanding industrial transformation away from the currently energy intensive economy to a more material intensive one, 4) integration of biophysical climate impacts into the IAM framework through novel emulator approaches (RIME, CHILLED), and 5) continued systems integration of air pollution, short-term forcers and climate change through coupled modeling (GAINS-MESSAGEix).

Research on **climate transformation pathways** has played an important role in the period 2021-24 due to the coalescence of major international assessments and ECE's leadership in IAM model comparisons feeding into those assessments. An overarching strategic objective of the research was

to support international policy through the identification of critical regional and global systems milestones for limiting global warming to 1.5C as stated by the Paris Agreement. Specific focus has been on exploring the remaining carbon budget (Riahi et al., 2021; Rogelj et al., 2023; Gidden et al., 2023) as well as how to manage the increasing risk of overshooting the agreed targets (Drouet et al., 2021, Rogelj et al., 2023). Our work has further contributed to a better understanding of net-zero emissions systems (Riahi et al., 2021), the required investments and finance (Bertram et al., 2021), as well as sectoral transition needs (Hasegawa et al., 2021; Guo et al., 2022). The Program assumed a leadership role in the community by coordinating the major modeling comparisons feeding into the IPCC (more than half of all Paris-compatible mitigation scenarios assessed in the IPCC Sixth Assessment Report (AR6) were developed in projects led by ECE-IIASA, Riahi et al., 2021); co-leading the key chapter on "Transformation Pathways" (WGIII: Riahi et al., 2022) and contributing as Lead Authors to several other chapters in the AR6.

Gaining a better understanding of the **demand-side of the system is critically important** since demand "sizes" the overall challenge, and since changes in demand can occur more rapidly through the reliance on granular and distributed technologies - as compared to the supply-side, which is characterized by relatively slow technology diffusion and policy inertia (Wilson et al., 2020). Building upon pioneering work in the past on low energy demand scenarios (LED: Grubler et al., 2018), ECE focused in 2021-2024 on a blend of activities to design the so-called "High with Low (HwL)" pathway (Wilson et al., 2023). HwL aims at a set of measures and policy packages (combining sharing economy elements with circularity) that can achieve high well-being with low resource inputs. Several recent studies have focused on the role of behavioral change, e.g., assessing the role of peer influence in adoption of clean technology (Niamir et al., 2024), as well as exploring benefits of behavioral options in a post-COVID environment (Kikstra et al., 2021). An important insight of the studies is stressing the large cost-effective near-term mitigation potential of demand-side "Avoid-Shift-Improve" measures, e.g. with a potential of reducing >60% of emissions in the buildings sector (Mastrucci et al., in review). A major achievement in this area is the establishment of a global research community (EDITS) focusing on demand-side solutions to mitigation. EDITS is co-convened by IIASA and Japan-RITE. It has led to dozens of community research activities enhancing our understanding of demand-side changes and pushing the frontiers of modeling for quantitative low demand scenario applications in different sectors (e.g., Mastrucci et al., 2023, Wiedenhofer et al., in review, Thomas et al., in review).

Mitigation of non-CO_2 GHG is an essential and ever more urgent element of strategies to address climate change and to limit the overshoot of stringent global warming goals. ECE contributed to the UNEP methane assessments (UNEP, 2021; 2022), and focused on several key, often poorly understood, aspects of non-CO_2 sources and their mitigation, including novel options to mitigate farmland N_2O emissions through bacterial sources (Hiis et al., 2024). A first global SSP assessment of GHG emissions and mitigation potential from circular waste management systems was conducted (Gomez-Sanabria et al., 2022), and then further developed considering also the leakage to aquatic environments (Gomez-Sanabria and Lindl, 2024). From a policy perspective, we showed the need to go beyond the Kigali Amendment to the Montreal Protocol in order to make F-gases and HFC emissions compatible with the Paris Agreement goals (Purohit et al., 2022), contributed to the **International Nitrogen Assessment** - a major compendium of the global advancements of nitrogen research scheduled for publication in 2025, also providing insights about the role of nitrogen in climate and pollution, of which one highly policy-relevant aspect is how actions addressing nitrogen pollution can reduce premature mortality (Gu et al., 2021).

Policy analysis on the **health and ecosystem benefits** of mitigation and pollution strategies across varied spatial and temporal scales were conducted in support the European Commission, UNECE Air Convention, UNEP, Climate and Clean Air Coalition, and the World Bank. Several *Lancet* studies were conducted in collaboration with the health community (Watts et al., 2021; Romanello et al., 2021, 2023; Hamilton et al., 2021; Zhang et al., 2023; van Daalen et al., 2024), including the most recent *Lancet Countdown*, which builds upon a new ECE indicator, that permits splitting mortality from

ambient air pollution by economic sector. Novel decomposition approaches permitted a further study of the impacts of population dynamics for the resulting health co-benefits (Rafaj et al., 2021). Exploring the severe **pollution inequalities** in India, we show that while the burden is generated by the wealthy, the poor suffer most of the associated health impacts (Rao et al., 2021). In a new area of research, ECE scenarios for **mercury** (Hg) assessed the complementary role of targeted Hg control policies in addition to stringent climate and air pollution controls (Brocza et al., 2024). Finally, considering the important role of aerosols in climate forcing, ECE supported the Arctic Monitoring and Assessment Program (AMAP, 2021), highlighting the important role of air quality policies in order to **slow down Arctic warming** (von Salzen et al., 2022).

Several ECE research activities in 2021-2024 aimed to **increase policy realism** through a better integration of social sciences into systems-engineering and economic modelling. This comprised specifically pioneering work on 1) the role of **governance** and institutional changes (Andrijevic et al., 2020; Gidden et al., 2023), as well as 2) a systematic exploration of the different dimensions of **feasibility** (Brutschin et al., 2021). In the latter area, ECE established a novel conceptual framework that underpins the IPCC assessment of feasibility of mitigation pathways, and which illustrates that the main feasibility concerns are not technological or economic, but rather connected to the lack of effective governance and institutions in many developing countries. In the latter area, empirical assessments of the determinants of governance were conducted as a basis for future projections of governance and institutional change (Andrijevic et al., 2020). This, together with empirical work on the relationship between environmental effectiveness and governance capacity, has laid the foundation for a first modelling study with endogenous representation of governance as a mitigation barrier in the global south (Gidden et al., 2023). Impact of the research was amplified through the uptake of the methodology by the IAM community in its recent modelling intercomparison project on the role of governance/institutional capacity in mitigation (Bertram et al., accepted in NCC – policy brief). Insights that have emerged from this study, suggest that the challenges to reach some climate goals might be larger than anticipated earlier (e.g., by the IPCC), but also that there are important enabling conditions that can help to address the governance challenges.

In 2021-24 ECE made significant methodological and conceptual strides in incorporating **poverty eradication, equity, fairness and justice** concerns into transformation pathway analysis. At the heart of this is a comprehensive bottom-up framework for defining "Decent Living Standards" (DLS: Rao et al., 2018), which forms the backbone of new advanced modeling tools from industrial ecology, including input-output and lifecycle analyses. These methodological advances have provided the foundation for exploring the poverty dimension of sustainable energy demand pathways. In a first-of-its kind analysis we have quantified *decent living gaps* and energy needs around the world (Kikstra et al., 2021), illustrating the critical role of embodied energy and material requirements of infrastructure in the developing world. ECE has also developed, together with colleagues from the POPJUS Program, a new conceptual framework for how to systematically include justice and fairness considerations in climate mitigation and scenario analysis (Zimm et al., 2024). The framework underpins the current community effort led by IIASA-ECE to conduct a justice model intercomparison (JustMIP) employing integrated assessment models (IAMs). The work is supported by both the Earth Commission and was endorsed recently also by the UN group of high-level representative advisors at the 2024 UN Science, Technology and Innovation Forum. For the communication of the research ECE developed a series of innovative web-based tools, including the *Fair Mitigation Finance Explorer*, which allows users to explore 'fair' regional contributions to mitigation investments (Pachauri et al., 2022), as well as the *Carbon Debt Tool* offering stakeholders insights into carbon debt and credit projections, fostering the understanding of regional 'fair' shares in managing the transition to net-zero and related responsibilities for overshooting climate targets (Pelz et al., submitted).

Research on **technology innovation** has aimed to provide a better understanding of the patterns, drivers, constraints, and impacts of technological change, particularly in areas that are key for framing global sustainability conditions. Specific focus has been on exploring the role of ***granular technologies***

and their potential in acerating technology transition through more rapid diffusion and innovation potential (Wilson et al., 2020; Wilson et al., 2023), as well as the role of ***digitalization*** as a major driver of innovation with a high potential for decarbonization, but also as a source of additional resource use with the potential to negatively impact planetary stability (Wilson et al., 2020 and Creutzig et al., 2022). Empirical analysis on the diffusion dynamics of granular technologies and their potential for economics of scales were translated into a novel modelling formulation of technological learning (Pratama et al., forthcoming).

The work on technology patterns was complemented by research on promising new individual technologies or technology clusters. The technologies are selected from areas where critical innovation gaps exist in order to reach, e.g., a net-zero emissions system. Two main technology clusters studied in 2021-24 include 1) **carbon dioxide removal** technologies (CDR) and 2) unconventional **energy storage technologies**. Research on CDR is supported by a "synergy grant" of the European Research Council (ERC), and combines empirical work, surveys, structured reviews and modelling. We explore new technological options (such as Direct Air Capture and Storage) as well as the portfolio of nature-based solutions (ranging from afforestation and biochar to sustainable bioenergy supply with CCS). In the area of energy storage, ECE is pioneering new storage technology designs, ranging from gravity-based storage systems (e.g., in lifts, mines, trucks), to buoyancy and deep ocean hydrogen and compressed air storage technologies. Global potentials and costs of these technologies have been assessed in a series of papers (Hunt et al., 2021a, 2021b, 2022a, 2022b, 2023a, 2023b, 2023c, 2023d, 2024) The work received widespread attention by the media as well as the industrial sector with multiple start-ups (Green Gravity, Economical Energy), commercial implementation on the ground (China lift energy storage buildings), and government programs (e.g., deep coal mine storage initiative in Romania).

ECE has established itself as a **community data hub**. Following IIASA's role as the host of the RCP and SSP data sets for the scientific community, ECE has invested in the development of a more versatile and user-friendly Scenario Explorer infrastructure that is currently being used in more than 40 international multi-model applications. Building upon ECE's role as a hub for scenario data within the broader scientific community, a formal "Agreement of Collaboration" was established between IIASA, IPCC, and the IAMC, giving responsibility to IIASA to host the IPCC AR6 scenario data sets (Byers et al., 2022). The ECE scenario databases serve multiple purposes, helping with quality control and comparability of data sets from different modeling groups, as well as for data dissemination, transparency and communication. The databases have developed into a central service for scenario users and the integrated assessment modeling community itself, with demand being substantial: over the course of 2023, the scenario datasets were downloaded more than 15,000 times by 90.000 users.

From 2021 to 2024, the ECE's in-house research effort averaged 65.5 scientific person-months per year, supported by an annual budget of €4,850 million, approximately 71.4% of which was externally funded. During this period, ECE researchers produced a significant body of work, including 569 peer-reviewed journal articles, 46 book chapters/books, 24 research/policy reports, and 56 other publications. Notably, 98 of these publications appeared in prestigious journals such as Science, Nature, and the Nature cluster of journals accounting for more than 60% of all IIASA publications in these top-tier journals during this timeframe.

In 2023, six ECE staff members were recognized as highly cited researchers globally and were included in Reuters' list of the top 1000 most influential climate scientists. Among them, ECE Program Director Keywan Riahi was ranked first on this prestigious list.

ECE Policy Impact

The ECE Program has been highly successful in engaging a range of key stakeholders from government, civil society, and the energy industry through one-on-one consultations with key decision makers and presentations at international conferences. In this section, some selected Program contributions to international policy reports and activities are summarized; it aims primarily at highlighting some of the main activities while not attempting to be fully comprehensive.

At the international level, ECE provided critical inputs to several high-level initiatives, including the United Nations High-level Political Forum (HLPF 2021 and 2022), where ECE organized and participated in multiple inter-ministerial sessions on the implementation of the 2030 Agenda. The Program Director of ECE, Keywan Riahi, has been appointed to the **UN Secretary-General's Group of Ten High-level Representatives** for two successive terms (2022-2023 as well as 2024-2025). The UN "10-Member-Group" of High-level Representatives of Civil Society, the Private Sector, and Scientific Community support the UN Technology Facilitation Mechanism and the UN interagency task team on science technology and innovation (STI). ECE scientist, Shonali Pachauri, also serves on the **SDG7 Technical Advisory Group**, feeding the Programs work directly into efforts to achieve the energy related sustainability goals. Through these activities, ECE helps the UN to identify frontier technologies and innovations critical for science and evidence-based implementation of the Sustainable Development Goals (SDGs).

A milestone in the period 2021-2024, was the contribution of ECE to the **IPCC AR6**. With no less than 17 Authors (Coordinating Lead Authors, Lead Authors, or Contributing Authors), ECE contributed to all major AR6 outputs of Working Groups I and III. This involved coordination of major scientific community efforts as input to the IPCC AR6 (e.g., the community model comparison on overshoot, ENGAGE), leadership of key chapters and sections in the Summary for Policy Makers, facilitating the collection of the scenarios for the IPCC, and hosting and curating the AR6 WGIII scenario data (Byers et al., 2022). These contributions offered comprehensive, policy-relevant insights that underpin the AR6's evaluation of climate mitigation and adaptation, including the AR6 Summary for Urban Policymakers, launched at the COP27 (Revi et al., 2022). From a scientific community perspective, it is important to emphasize that these assessments were made possible only through the coordination of major scientific community organizations, such as the Integrated Assessment Modelling Consortium (IAMC), and the ICONICS where ECE staff Bas van Ruijven, Volker Krey and Keywan Riahi serve as members of the Steering Committees.

Beyond the IPCC, ECE scientists (Matt Gidden, Shonali Pachauri, and Joeri Rogelj) were involved as Lead Authors and Steering Group members on the **UNEP GAP reports**. The reports provide a regular update on the progress of climate policy for the UNFCCC negotiations and identify critical policy gaps across sectors and regions. Furthermore, ECE staff, Lena Höglund-Isaksson, serves on the Scientific Oversight Committee of the **International Methane Emissions Observatory** (IMEO), and has co-authored the Global Methane Assessment (GMA) which informs the *Methane Pledge* of over 155 countries. Several ECE scientists have participated in related IPCC, UNEP, and other side-events at COP26, COP27, and COP28 explaining key insights of these reports to decision makers.

Through the **Network of Greening the Financial Sector (NGFS)**, ECE has been instrumental in developing climate and macroeconomic scenarios used by central banks and financial regulators to assess climate-related risks. By providing robust, science-based scenarios, ECE aids financial institutions integrate climate risks into their financial models, leading to better informed decision-making and robust risk management strategies. Specifically, ECE's work supports the NGFS in creating guidelines for climate stress testing. These tests are crucial for evaluating the resilience of financial institutions under various climate scenarios, promoting a more proactive approach to managing climate risks.

Policy impact at the European level comprised several influential reports by the European Advisory Board on Climate Change (EUABCC). ECE scholars Joeri Rogelj and Keywan Riahi are members of the EUABCC and coordinated the Board's advice to reduce greenhouse gas emissions by 90-95% in 2040. Subsequently, the European Commission followed the advice of the EUABCC in its proposal to the EU Parliament to adopt the "heroic" **2040 EU target of >90%.** ECE has also been part of the scientific backbone underlying the strategies that were laid out by the European Commission aiming to deliver the climate objectives of the European Green Deal, i.e., the so called **'Fit for 55' package**. Together with colleagues from IIASA-BNR, ECE provided the scientific foundation for assessing the non-CO_2 greenhouse gas emissions and mitigation options in the EU. ECE modelling tools were used to provide the 'Fit for 55' package with country-specific mitigation pathways for all the 27 EU countries.

Examples of EU high-level policy impact in the area of air pollution include the recent European Commission proposal for the revision of the Ambient Air Quality Directive**,** which is directly based on the modelling work done by the ECE GAINS team. ECE has further led the work on Clean Air Outlooks assessing whether the objectives of the National Emission reduction Commitments Directive (NECD) and the Zero Pollution Action Plan of the Green Deal can be achieved. This will be instrumental in the forthcoming review of the Directive in 2025. Finally, the EMEP Center for Integrated Assessment Modelling (CIAM) of the UNECE **Convention on Long-range Transboundary Air Pollution** was hosted by ECE in 2021-24, assessing the feasibility of the UNECE region to achieve further significant reductions of health impacts and biodiversity loss by 2040. This analysis supported the Executive Body decision to initiate the revision of the Convention's Gothenburg Protocol scheduled for 2024-26; CIAM is charged with providing scientific input to the process working closely with other scientific bodies of Convention, national experts and eventually negotiators of the revised Protocol.

On the national scale, ECE provided policy advice to many countries around the world, supporting government agencies as well as multilateral initiatives (e.g., the GAINS health impact assessments organized through the World Bank). Systematic co-design and capacity development on **national integrated assessment tools** were provided in 2021-24 in India, China, Pakistan, Lebanon, Egypt, Israel, Uzbekistan, Canada, and Australia. Important success factors for the national policy support are 1) the organization of regular training workshops; and 2) strategic collaborations where national government agencies (e.g., NITI Aayog in India) are brought together with local knowledge institutions, with IIASA-ECE serving as the external methodology and knowledge provider. Long-term ECE collaborators have been using the tools in various national decision-making processes, such as, Brazil (COPPE) where the MESSAGE modelling framework is now used for the quantification of Brazil's Nationally Determined Contributions (NDC) in the UNFCCC negotiations. ECE also provided dedicated support and established the **infrastructure for national modeling comparisons** in India and China. In Austria, the host country of IIASA, ECE researchers are co-chairing the **Austrian Assessment Report on Climate Change (AAR2).** The AAR2 is established after the IPCC model with support of the Ministry of Environment and brings together all important climate research institutions in Austria to provide the scientific basis for climate actions in Austria.

Supported by the **World Bank Pollution Management and Environmental Health (PMEH) Program**, ECE has developed holistic road maps for action in China, Vietnam, India and South Africa, which enables local authorities in these countries to develop comprehensive air quality management plans. This work has been recently extended to address regions in other countries within the Indo-Gangetic Plane airshed including Pakistan, Nepal, Bhutan, and Bangladesh. Through 2021-24, ECE has 1) continued to support the **International Energy Agency (IEA)** providing the air quality impact assessment of the IEA World Energy Outlook, and 2) collaborated with **UNEP** and policymakers and scientists in Cambodia, Thailand, and Indonesia in order to assess the costs of inaction on air pollution. The latter project identified, jointly with the respective countries' Ministries of Environment, national investment cases for action, and supported the development of better integrated, science-based policy measures in these countries.

Several activities provided **policy support at the city scale** informing urban air pollution strategies as well as broader urban development agendas. Successful examples include Keywan Riahi's role in the Scientific Advisory Board of the City Council of Vienna where he is supporting the city in the design of the "Vienna Climate Law" and the implementation of its climate action plan. ECE is a key contributor also to the initiative between the German and Chinese authorities to design digital transformation strategies for four cities in China and Europe (Beijing, Ordos, Vienna and Helsinki). The project has been established directly upon the initiative of the President of the Environment Protection Agency in Germany (Dirk Messner), which will host its next meeting in July 2024 at IIASA.

The activities described above are only some examples of the policy impact of the Program. Further elaboration of policy relevant work is also summarized in the following sections that present the achievements and impacts of each of the individual ECE Research Groups.

ECE Budget, Staff, and External Projects

From 2021 to 2024, the ECE's in-house research effort averaged 65.5 scientific person-months per year, supported by an annual budget of €4,850 million, approximately 71.4% of which was externally funded.

	2021	2022	2023
Total income	**4,383,333**	**4,734,442**	**5,432,260**
External Projects and Grants	2,904,638	3,499,781	3,984,168
Internal allocation	1,478,695	1,234,662	1,448,093
Total expenses	**4,010,491**	**4,308,714**	**5,326,431**
Program surplus	372,841	425,729	105,829
Total FTEs	**61.25**	**70.40**	**84.24**
FTEs scientific	54.39	62.52	76.01
FTEs non-scientific	6.86	7.86	8.21

Table 1: Overall program budget (2021-2023) including external/internal, personnel/non-personnel costs. The budget for 2024 is pending per final allocations. Internal allocations for 2024 are in the order of 1,160 million Euro.

ECE Staff (2021-2024)

Over the past three years, our team had more than 200 members, comprising full-time staff, research exchange scientists, guest scientists, and post-docs (see Annex A).

Externally Funded Projects (2021-2024)

The budget from the externally funded projects and grants increased from about 2,9 million in 2021 to almost 4 million in 2023. The funding sources are diverse, ranging from grant from the European Research Council to World Bank and Industry partners (e.g., Toyota). A high fraction from the budget comes from community projects funded by the European Union Horizon Program. The portfolio of projects are listed in Annex B.

Integrated Assessment and Climate Change (IACC) Research Group

Traditionally, integrated assessment research has focused on climate change mitigation, but addressing mitigation in isolation without considering the many linkages that a transformation toward a low-carbon economy has for essentially all aspects of society and the environment. IACC's main goal is therefore to push the research frontier toward the development of pathways that cover many more aspects of sustainable development to ultimately increase their policy relevance.

To reach this objective, research in IACC focused on five broader research areas that have been identified in the 2021-24 Research Plan: (i) energy system and carbon management solutions, (ii) integration of climate change impacts and mitigation strategies, (iii) integration of circular economy strategies into mitigation research, (iv) integration of analysis across scales including national transformation and analysis, and (v) climate change scenario services and good open science practices. Improving the representation of social-science research has emerged as a cross-cutting topic across most of these research areas.

Energy system and carbon management solutions

The global energy system is in a transitional phase with fast-paced changes meaning that new knowledge gaps and challenges are being identified in short succession. IACC has tackled three of these novel challenges in our understanding of supply-side transitions leading to a more sophisticated understanding of the potential contribution of carbon dioxide removal, a better integration of novel energy storage technologies allowing for a more faithful representation of the potential role of variable renewable energy, and a trailblazing integration of institutional, governance and socio-cultural dimensions in the modeling of energy system futures.

Traditionally bioenergy with carbon capture and storage (BECCS) has been the key energy system-based carbon dioxide removal (CDR) option considered in transformation pathways. This has been extensively criticized in the literature. Broadening the portfolio of CDR options, most notably under ERC synergy grant GENIE (Co-PI: Keywan Riahi) has thus been a focus of IACC research. To date, different variants of Direct Air Carbon Capture and Storage (DACCS) and options in chemicals production in the industry sector have been added to the IAM framework and analyzed in terms of their potential contributions to carbon removal (Gidden et al.,2023; Unlu et al.,2024). Further options that allow storing carbon in the built environment, including carbon-negative cement, wood-based construction, and the usage of bio-based materials are currently being explored. In addition, improving the comparability between land-based carbon fluxes of IAM projections on the one hand and national greenhouse gas inventories and stated emission targets based upon them on the other hand has also been in focus (Gidden et al.,2023b). This work reveals that achieving the benchmarks of IAM-based pathways as assessed by the IPCC is more challenging than suggested by a naïve comparison with the stated pledges of countries under UNFCCC. These improvements allow exploring alternative configurations of the undisputed need for CDR to achieve the Paris goals, taking into account local deployment constraints and societal acceptance of the different options.

With variable renewable energy sources such as solar photovoltaics and wind turbines having successfully scaled up over the past decades, system integration constraints have become a major concern for a successful transformation. Identifying and analyzing **novel energy storage technologies** as an alternative to well-known storage options to enable renewable energy futures has been another focus area of IACC. This is complemented by assessments of renewable resource potentials and detailed power systems modeling (Hunt et al.,2021, 2022, 2023, 2023, 2024, Weber et al.,2024) to address systems integration questions (see section on integration across scales below).

Global transformation pathways are most directly useful to policymaking if they adequately **represent the institutional, governance and socio-cultural dimensions** of the energy systems transformation.

To this end, social science insights about the feasibility of specific transformations (developed by TISS researchers (Brutschin et al.,2021)) have been incorporated in global scenarios based on MESSAGEix-GLOBIOM and other IAMs (Bertram et al., accepted, Brutschin et al., in preparation). As a result, pathways not only become more realistic but also more equitable as institutional capacity in countries of the global south limits the speed at which the transformation can happen, which is traditionally not represented in IAMs.

Integration of climate change impacts and mitigation strategies

Integration of climate change impacts into the integrated assessment of climate change remains essential to appropriately reflect the main benefits of mitigation (through avoided climate change impacts) and design strategies that are resilient in a changing climate. To better understand how climate impacts will affect different parts of the population, specifically taking into account the aspects of vulnerability and equity and the degree to which affected population segments are able to adapt, research has focused on quantifying the benefits of mitigation. Such a quantification requires an understanding of both the risks of climate change impacts and extremes through a range of suitable impact indicators (Werning et al., 2024) and the vulnerability and adaptive capacity (based on social science research) of those exposed to the physical impacts (Andrijevic et al., 2023). Risk emulation to rapidly assess the former is key for its integration into IAMs. The Rapid Impact Model Emulator (RIME, Byers et al., in preparation) delivers this. Important applications in this area that combine **risk emulation and risk assessment** include the implications of climate change for cooling energy needs in the buildings sector (Byers et al., in review), and the interaction of climate change impacts and mitigation action related to a broader set of sustainable development objectives related to water, energy, food, and land resources (Awais et al., 2024, Falchetta et al., 2023, Vinca et al., in review). Ongoing research also includes integrating the latest insights of econometric studies on economic climate change impacts (Kotz et al., 2024, Waidelich et al., Burke et al.) into IIASA's MESSAGEix-GLOBIOM framework to overcome the current limitation of most mitigation studies that macro-economic GDP and consumption estimates show higher losses under stringent mitigation compared to pathways without significant mitigation efforts (Vinca et al., in preparation). IACC is expanding the research in this area, also in collaboration with other research groups at IIASA (IBF, MDM, SYRR, and the newly established ICI group within ECE), and leads the SPARCCLE project.

Integration of circular economy strategies into mitigation research

The production of energy-intensive materials is responsible for about 25% of global GHG emissions. A new research area that was started with the establishment of the IACC group is the integration of energy and material flows in the IAM framework to broaden the strategy space beyond classic energy- and land-based climate mitigation strategies to include **circular economy approaches**. Initially, the research focused on bulk materials such as steel, cement, aluminum (Pedneault et al., 2021) and base chemicals including ethylene, propylene, methanol and ammonia for which production and recycling options have been integrated into a new industry sector module called MESSAGEix-Materials (Unlu et al., 2024). Looking at circular economy options beyond recycling, e.g. by utilizing material stocks more efficiently via sharing and service-based approaches and lifetime extension is a key objective of the research in IACC. Therefore, linking the demand for materials to key energy services such as shelter (Wang et al., 2022, Streeck 2022) and mobility (Virag et al., 2022) is work in progress together with the S^3 and TISS groups, exploiting synergies with the EDITS network (Sugiyama et al., 2024, Wiedehofer et al., 2023). Including acceptance of circular economy approaches both on consumer and producer side based on social-science research conducted under the CircEUlar project led by IACC is currently under way. Another ongoing stream of research is to include important critical metals for key low-carbon technologies, such as batteries, solar PV cells or wind turbines.

National transformation and methodological advancements to integrate analysis across scales

To help decision-makers at regional, national and subnational levels to understand requirements to align with global climate goals, the **integration of analysis across different spatial scales** has been a

research focus relevant to all the previously described activities of the IACC Group, requiring further methodological development. Key aspects of this challenge are on the one hand, increasing the spatial and temporal granularity of relevant parts of the IAM framework, and on the other, explicitly representing policy options at those levels, e.g. at the national or subnational scale. With respect to spatial resolution, a national model prototyping approach has been developed, which allows creating national or regional standalone models. This approach has been successfully demonstrated or is in development for Australia (Li et al., 2023, Kikstra et al., 2024), Canada (Awais et al., 2021), the central Asia region (Zakeri et al., 2022), China (Liu et al., 2022), Egypt, the Indus basin (Awais et al., 2022), Israel (Palatnik et al., 2021,2023), India, Lebanon, Pakistan (Mansoor 2024), the UNECE region (UNECE 2022), Uzbekistan, and Zambia (Awais et al., 2024).

Where finer scale information is critical for decision making as, for example, in the case of managing water resources, which at least requires hydrological basin representation in the decision-making process, the MESSAGEix-Nexus model (Awais et al., 2024) has been developed. The approach is scalable and has been applied at country and basin-level (e.g., Zambia, Indus basin) as well as at a global scale (Awais et al., 2022, 2024).

Another key example where bridging scales in decision-making is critical is air quality with a strong dependence on the energy system configuration but requiring high spatial resolution to understand exposure of humans and the environment to concentration of air pollutants. This is addressed by **linking MESSAGEix to the GAINS model** (see PM section). Applications of this include cases stretching from city (Beijing, Liu et al., 2022) to global scale (Rafaj et al., 2021).

High resolution assessments of geospatial data form the basis for modeling approaches that can be applied at different regional scales. Machine-learning based approaches to generate such datasets are actively being developed in IACC, for example to assess renewable energy potentials (Joshi et al., 2021, 2024).

Beyond spatial resolution, increased temporal resolution has also become vital to assess the viability of increasing the share of variable renewable energy sources and utilize load management options in IAMs. Linking MESSAGEix-GLOBIOM to power systems models (Brinkerink et al., 2022, Gotske et al., in preparation) has generated further insights on the level at which renewable energy sources can be utilized in the transformation to a net-zero GHG emission energy system.

Climate change scenario services and good open science practices

Finally, IACC is committed to **a full-fledged open science approach** with the MESSAGEix model, and its components being made available under open source and open data licenses (Fricko et al., 2023, Kishimoto et al., 2024). The different components of the IAM framework are developed in a modular way to allow for flexibility in adoption for different use cases but also reduces maintenance and potential lock-in. Sharing of the modeling tools is accompanied by community and **capacity building activities** to broaden the user base, in particular in IIASA member countries, and ultimately the decision-making impact of research. Since 2022, IACC annually organizes a MESSAGEix community meeting in hybrid format to engage with users of the modeling tools outside of IIASA, sharing use cases, latest developments and experience with the modeling framework. The meeting is attended by some 25 participants in person and a further 40-60 participants remotely. In addition, IACC is conducting regular training workshops on MESSAGEix for YSSP participants, external collaborators and other interested. A recent example includes a workshop held in Addis Ababa in October 2023 with 30 participants from 14 Sub-Saharan African countries.

Also, other software tools that are primarily developed in IACC and allow efficient use and handling of IAM-related data, such as the Python package pyam (Huppmann et al., 2021), are open source tools and have been adopted by a wide user community with in some cases tens of thousands of installations. Beyond making its own software tools and data openly available, ECE/IACC has positioned itself as a **community data hub for global climate change mitigation and transformation**

pathways, for example, by hosting datasets for the IPCC's AR6 (Byers et al., 2022), the IAM community, such as related to the Shared Socioeconomic Pathways, or for the finance community (Richters et al., 2023). These community data services are complemented by the development and maintenance of tools that disseminate and such as the IIASA Scenario Explorer as an expert tool and the Climate Solutions Explorer, a tool aimed at the scenario user community.

IACC Highlights of scientific output and policy impact

IACC research has systematically explored **the role of temperature overshoot and negative emissions** (Riahi et al., 2021), thereby informing IPCC reports and the UNFCCC climate negotiations. Up until then, most studies have focused on the distant future, requiring only that the temperature goals of the Paris agreement are achieved by the end of the 21st century. Consequently, almost all the resulting scenarios allow global temperature to overshoot around mid-century, only later turning the dial back down again by sequestering carbon from the atmosphere. The scenario design pioneered in Rogelj et al., (2019) has been rolled out to a larger set of IAMs, generating robust insights on the costs of temperature overshoot (Riahi et al., 2021) that has shaped key insights of the IPCC AR6 (Skea et al., 2022). In the meantime, this scenario design has become a de facto standard in the IAM community, used by dozens of studies.

The **climate scenario services** developed and provided to the research and policy communities by IACC have set new transparency standards, highly improving reproducibility of scenario analysis and enabling dozens of follow-up studies. The AR6 Scenario Explorer (Byers et al., 2022) that provides access to more than 3000 global, regional, national and sectoral scenarios, underpinning key insights of the IPCC AR6, and the NGFS Scenario Explorer (Richters et al., 2023) that is highly utilized by financial sector analysts to evaluate the transition risk of financial assets (cf. S^3 highlights) are key examples of IACC's policy impact, in addition to hosting dozens of other open scenario datasets. To complement the publication and hosting of key community datasets, the MESSAGEix-GLOBIOM IAM has been made available as an open-source tool (Fricko et al., 2023, Kishimoto et al., 2024), along with the newly developed Materials (Unlu et al., 2023) and Nexus modules (Awais et al., 2023).

With variable renewable energy sources such as solar PV and wind turbines having successfully scaled up over the past decades, system integration constraints have become a major concern for a successful transformation. IACC has focused thus on identifying and analyzing **novel energy storage technologies,** such as gravity storage systems (in lifts, mines and on mountains), buoyance storage systems, or deep ocean storage based on compressed air and/or hydrogen (Hunt et al., 2021, 2022, 2023, 2023, 2024, Weber et al., 2024). Many of these technologies can provide an alternative to currently available storage options, thus enabling renewable energy futures. Beyond the impact in the academic literature, these solutions also get implemented by companies as a new business model that facilitates the transformation towards a renewable-based energy system.

By **combining geospatial information with machine learning approaches** (Joshi et al., 2021, 2024), new high-quality datasets create novel analysis opportunities, increasing their relevance and timeliness. As a first application, the method is applied to roof-top solar PV potential. Mitigation scenarios to contain global warming to below 1.5ºC envisage a significant role for solar PV, but they are often very limited in evaluating the role of decentralised rooftop solar PV within the solution space. This gap has been addressed with the MESSAGEix model and scenario analysis, showing that by 2050 rooftop PV can account for >50% of total solar PV generation, thereby significantly reducing the land footprint of PV deployment. An assessment for Europe (Göke et al., 2023) using the methodology and data showed that available rooftop area would suffice for generating the annual demand of the EU27 by 2030.

Taking **adaptive capacity** as a key concept into account in studies that assess climate change impacts and opportunities to adapt to it has been an important contribution of Andrijevic et al., (2023). Global models that assess the impacts of climate change and policy options to reduce them most often do

not elaborately represent adaptation. When they do, they rarely account for heterogeneity in societies' adaptive capacities and their temporal dynamics. The study proposes ways to quantify adaptive capacity within the framework of the SSPs that are widely used by climate impact and integrated assessment models. A related ECE community service in this area is the SSP Extensions Explorer, which gathers adaptative capacity and numerous other quantitative extensions of the SSPs in a central database for easy use by the research community.

IACC specific SWOT Analysis

Strengths: The scientific staff is the biggest asset of IACC. The strategy has been to have a balanced mix of senior researchers with the experience to position the group in promising new and impactful research areas, and a generally young interdisciplinary team, bringing in new ideas and cutting edge methods. Combining knowledge across different disciplines, in particular integrating social science research into integrated assessment both through in-house expertise and external collaborations is a major asset of IACC. The broad set of cultural backgrounds of IACC staff is also an advantage when integrating national, regional and global analysis.

The development of new research proposals is handled in an inclusive way, offering young and mid-career researchers the opportunity to shape the future research direction of the IACC group and develop skills related to proposal writing and grant acquisition. This environment allows mid-careers researchers to develop experience and a scientific track record, creating career opportunities within and outside of IIASA. The latter ultimately leads to broadening the group's scientific network and opening new opportunities for collaboration. IACC has been very successful in raising external funding in support of its research activities with a proposal success rate well above 50%. Currently IACC is part of an ERC synergy grant (GENIE), and is leading two large collaborative EC funded Horizon projects (CircEUlar, SPARCCLE), and is participating in many other externally-funded high-impact activities, such as the new Earth Fund Project to establish a new climate scenario compass facility (CSCI).

IACC has become the place to go for open science services, hosting key datasets on behalf of the IAM community and by making its own IAM framework available as an open-source tool. The Scenario Services and Scientific Software team as part of IACC enables the adoption of high quality standards in tool development and open data. IACC is thus well positioned and prepared for an environment where funders and users of the research demand full transparency, reproducibility and enabling reuse of the research along all dimensions.

Weaknesses: Resources required to maintain and develop data-intensive large-scale models and tools (e.g., MESSAGEix IAM framework, Scenario Explorer infrastructure) could lead to lock-in and reduced agility when it comes to the adoption and development of new methods. The modular structure of IAM framework and other tools is an attempt to allow easier and more targeted maintenance to reduce the risk. Also, the wide-spread diffusion of artificial intelligence-based methods and big data applications could become a threat if the opportunities offered by the adoption of these methods are not adequately integrated into IACC's research portfolio. Currently, machine learning methods are used for processing large spatially and temporally resolved datasets as input for the IAM framework, an activity that is planned to be scaled up and expanded.

Opportunities: High resolution data on energy, climate, and environment is increasingly becoming available and has the potential to significantly improve the foundations of integrated assessment modeling by adopting data-driven modeling approaches. An example in this direction are the machine learning methods used by IACC researchers to estimate renewable energy potentials. Close collaborations with other research groups and programs at IIASA, including S^3, TISS, and POPJUS, have helped to bring social sciences into a new generation of integrated assessment modeling. The resulting policy advice and mechanisms (e.g., incentives) can be tailored to the needs of different socio-economic groups, thereby increasing policy effectiveness and resource efficiency to achieve overarching societal goals.

Threats: The large fraction of external funding makes strategic development of research activities challenging. While the acquisition of external funding is the responsibility of the research programs and groups, IIASA lacks a mechanism of reliable "banking and borrowing" of internal budget to buffer fluctuations in the success rates of external funding proposals. With the increase of societal relevance of IACC research topics over the past decade, also external funding opportunities from different funders (public, private, foundations) have increased significantly which has led to steady but sustained growth of IACC. As a result of no reliable reserves at the group level, temporarily declining external funding sources would translate into a loss of staff members which, combined with the need for maintaining large-scale datasets and models would reduce competitiveness. With the mainstreaming of energy and climate related research, commercial entities have increased and continue to increase activity in applied systems analysis, particularly for highly visible activities such as the hosting and dissemination of community datasets and compete for external funding sources.

Pollution Management (PM) Research Group

Solving immediate and near-term environmental problems (ecosystems collapse, health impacts from pollution) and social problems (widening inequality gaps) in a cost-effective manner is an important step in enabling challenging, but indisputably needed, long-term transformations toward a sustainable world. Understanding such multiple benefits and their distribution across different groups in society could also enhance public support for these transformations.

While in the past the work of PM group had a strong air pollution and non-CO_2 GHGs focus, this is not sufficient to adequately address the current and emerging needs of society and policymakers. To address that, the PM group defined goals for the 2021-24 period, aiming to expand its focus toward the development of new approaches for multi-sectoral policy interventions to manage pollution across different media (air, water, soil) at various scales (global, regional, urban/rural), and further develop understanding of mitigation potential for non-CO_2 GHGs. The key achievements supporting meeting the goals and objectives of PM group in 2021-24 include:

Supporting evaluation and development of air quality and climate policies

Two major contributions supporting review and development of **EU air quality policies** included (i) 2nd, 3rd, and ongoing 4th Clean Air Outlook that assess the prospects for achieving the objectives of the National Emission reduction Commitments Directive (NECD), Zero Pollution Action Plan, and provide input for the review of the NECD scheduled for 2025, and (ii) modelling work underpinning the proposal for revision of the Ambient Air Quality Directives that align more closely with the latest recommendations of the World Health Organization and required further development of the GAINS model to enable fine scale analysis for NO_2 and $PM_{2.5}$ (Denby et al., 2024). Preparing for harmonization of legislation with the EU, PM team held national consultations and employed GAINS model to calculate preliminary emission reduction commitments for Republic of Moldova and West Balkan countries, within the EU funded project EU4Green. For the **EU climate policy**, GAINS model provided analytical input, i.e., assessment of mitigation potential and costs for non-CO_2 GHG underpinning the European Green Deal – see also next section (Highlights).

In December 2023, the Executive Body of the UNECE Convention on **Long-range Transboundary Air Pollution (LRTAP)** initiated the revision of the Gothenburg Protocol, setting new and more ambitious targets addressing health impacts and loss of biodiversity due to air pollution. PM group (hosting the Convention's EMEP Center for Integrated Assessment Modelling (CIAM)) provided essential assessments during the review of the Protocol, evaluating feasibility of the new ambition, and will support preparations and eventual negotiations of the new Protocol in the period 2024-26. Addressing objectives of the Protocol, has required development of new methods for simultaneous analysis and optimization for mitigation of impacts on health, crops, ecosystems (including loss of biodiversity) as

well as addressing equity considerations. The newly extended and updated GAINS capacity to address mercury emissions (Brocza et al., 2024) has been already supporting discussion within the Minamata Convention.

PM group has continued providing air quality impact assessment for the **World Energy Outlook** reports of the International Energy Agency. Supporting **Arctic Council** in development of the Arctic Monitoring and Assessment Program report (AMAP, 2021), analysis with the GAINS model underpinned results of the studies showing that well-designed air quality policy could help slowing Arctic warming (von Salzen et al., 2022; Whaley et al., 2022) and that managing forest fire risks in the Arctic will become increasingly important (McCarthy et al., 2021). PM scientists co-developed the Summary for Policy Makers that was presented at the 12 Ministerial meeting.

Air pollution and public health in Asia

Air pollution has been a major issue in Asia, contributing to severe health impacts and economic costs. The World Bank **Pollution Management and Environmental Health** (PMEH) program has developed jointly with PM researchers a systematic road map for action that should enable local authorities to develop comprehensive air quality management (AQM) plans for their respective regions. The GAINS model has been extended, evaluated and applied to specific regions in China, jointly with the Chinese Research Academy of Environmental Sciences (Shu et al., 2022, 2023), and Vietnam (Hanoi) and supported development and validation of inventories and policy scenarios to achieve compliance with national air quality legislation. In 2023, the World Bank, in collaboration with PM researchers published the South Asia Flagship study **Striving for Clean Air,** highlighting the critical role of interjurisdictional cooperation within airsheds in achieving clean air targets in a cost-effective manner. Building on the PMEH and the flagship study, PM group, jointly with the scientists from Indian institutions (including IIT Delhi, IIT Kanpur, State Pollution Control Boards), supports the World Bank and the Central Pollution Control Board, to further **develop and evaluate the AQM plans in the Indo-Gangetic Plane** states/regions. This work has been recently extended to address regions in other countries within the same airshed including Pakistan, Nepal, Bhutan, and Bangladesh.

Air pollution in often perceived as an urban issue, because the largest pollution levels are typically measured within cities. However, it is found that **in most cities a large share of $PM_{2.5}$ originates from sources outside of the cities**. Coordination and cooperation among authorities beyond city boundaries is indispensable. PM group, supported by Ministry of Environment Japan (MOEJ), have been working to identify and assesses interdependencies between urban and rural air pollution and highlight the air quality benefits from regionally and internationally coordinated response action. This work required significant further development of the GAINS model, involving scientists from the Norwegian Met Office and Kyoto University; the results were presented at the 2023 Better Air Quality Conference, and papers are in preparation.

The joint work with collaborators in North East Asia focused on development of decarbonization scenarios and assessment of their impacts at different scales, from local and national to regional (e.g., Liu et al., 2022; Cai et al., 2021; Qin et al., 2021), understanding role and trends of key pollution sources (e.g., Kanaya et al., 2021), and addressing secondary organic aerosols by applying an innovative approach to provide first such assessment at the global level (Huang et al., 2023).

Advancing understanding of sources and mitigation opportunities for non-CO_2 GHGs

The PM group has contributed to strengthening the knowledge about **methane** and its mitigation along several avenues: by contributing bottom-up emission estimates as prior to inverse modelling analysis (Naveen et al.,2024; Petrescu et al.,2023, 2024; Zhang et al.,2021), by co-authoring the Global Methane Assessments (UNEP, 2021; 2022), which provided the scientific basis for the Global Methane Pledge, and by providing non-CO_2 GHGs scenarios and mitigation potential underpinning Green European Deal (Höglund-Isaksson et al., 2023). Other achievements include contribution to the UNEP Gap Report (UNEP, 2021), the IPCC WGIII (Babiker et.al., 2022), and a perspective on the urgency of

methane mitigation (Shindell et al., 2024; *accepted*). Among key resources supporting the methane Pledge is the International Methane Emissions Observatory (IMEO) with PM staff, Lena Höglund-Isaksson, on the IMEO Scientific Oversight Committee.

GAINS includes now an integrated representation of the waste and resources sector enabling consideration of the **interlinkages between greenhouse gas emissions, air pollution, water contamination, and material circularity** (Gómez-Sanabria et al., 2022; Gómez-Sanabria and Lindl, 2024; *accepted*) and will be extended to address plastic pollution (e.g., Brahney et al., 2021). The updated model has been used supporting EU climate policy work ('Fit for 55' package), sustainable waste management policy in South Africa (Gómez-Sanabria and Hoglund-Isaksson, 2023), and is currently assisting the government of Uganda to develop the strategy to reduce short-lived climate pollutants from the organic waste sector, which will be included in the next update of the Nationally Determined Contributions (NDCs).

The GAINS model enables a **comprehensive assessment of F-gas emissions** at high source, region, and species (HCFCs/HFCs, PFCs, SF_6, and NF_3) resolution and identify cost-effective management strategies, a unique approach not widely used by other modeling teams. The model now incorporates recently implemented regulations (regionally and globally) and approved commercialized alternative low-GWP refrigerants and abatement technologies for various applications and has served as scientific basis supporting revision of the EU climate policy ('Fit for 55' package) and contribution to the forthcoming report on Life Cycle Refrigerant Management. The recent contribution to discussion of global mitigation potential for F-gases is included in the 'Highlight' section below.

Integration of multiple nitrogen sources, compounds (NOx, NH_3, and N_2O), and diverse impacts in GAINS allows to adopt a "**nitrogen lens**" and **capture co-benefits of measures** across several pollution domains/dimensions. GAINS work contributed to the revision of global N_2O budget for the Global Carbon Project (Tian et al., 2024, *in press*) and improvements in bottom-up modelling (Del Grosso et al., 2022; Cui et al., 2024). Focusing on primary N_2O mitigation, soil inoculation with N_2O consuming bacteria was investigated (Hiis et al., 2024) offering an entirely new and innovative mitigation opportunities, and low-cost options in chemical industry were revealed (Davidson and Winiwarter, 2023). On the air pollution side, detailed studies on NH_3 emissions (Adalibieke et al., 2021) led to quantification of the effect of different abatement strategies on adverse health impacts of particulate matter, specifically considering the role of NH_3 and NOx (Gu et al., 2021). A shift in the chemical regimes of PM formation over time and space also needs to be considered as it affects efficacy of respective nitrogen strategies (Liu et al., 2023). Innovative work analyzing reactive nitrogen flows in urban areas (Kaltenegger et al., 2023) combined with GAINS mitigation scenarios, will form a core contribution to the International Nitrogen Assessment (see www.inms.international), a major compendium of the global advancements of nitrogen research scheduled for publication in 2025.

Sizable cuts in anthropogenic methane emissions within the next decades is one of few options available for constraining near-term warming and avoiding the profound risks of temperature overshoot in the next few decades. ECE program research groups work closely together to **maximize synergies between the modelling tools in the ECE program** and operationalize dynamic and flexible links between the models, especially GAINS and MESSAGEix. These joint efforts lead to more robust projections of non-CO_2 GHG in global assessments but also enables analysis and comparison of several health and ecosystem impact indicators for MESSAGEix (and in the future other global IAMs) produced scenarios, including forthcoming new SSPs, where GAINS provides for appropriate source, spatial, and temporal resolution. This works includes also parameterization of air pollutant emissions and has been initiated under the Horizon project CD-LINKS and continues, supported by OPEN-Entrance, ENGAGE as well as funding from Korea (AQNEA, GUIDE) and China's power grid company (GEIDCO).

Linking health impacts, equity, and climate change

Applying innovative decomposition methods, Rafaj et al., (2021) found that **population dynamics**, especially aging and urbanization, counteract in many regions the mortality reductions due to

declining emissions; also Conibear et al. (2021), using GAINS model scenarios, have shown similar results for China. In another study focusing on India, Rao et al., (2021) showed that **pollution burden is generated by the wealthy**, while the poor suffer most of the health impact. PM researchers have critically contributed to the *Lancet Countdown* **introducing an indicator for mortality from ambient air pollution by economic sector**. The changing climate has already affected and worsened several indicators of ecosystem and human health, disproportionately affecting populations who have contributed least to the problem (Watts et al., 2021). A third of the premature deaths attributed to anthropogenic sources of ambient air pollution in 2019 was directly related to fossil fuels exposing the **costs of the delayed decarbonization and air quality regulation** (Romanello et al., 2021). In another contribution, Hamilton et al., (2021) conclude that a greater consideration of health in the NDCs and climate change mitigation policies (addressing air pollution, diets, physical activity) has the potential to yield considerable health gains as well as bring additional climate benefits – these are further analyzed for the EU under the Horizon Europe project CATALYSE where GAINS model is employed to develop scenarios reflecting on impacts of active mobility and dietary change.

Quantifying the **cost of inaction on air pollution** could help building stronger investment cases for action and support the development of more integrated, science-based policy providing benefits for health, climate, and sustainable development. Through 2021-23, PM researchers have engaged with UNEP and policymakers and scientists in Cambodia, Thailand, and Indonesia to assess cost of inaction on air pollution evaluating respective evidence and assessing feasible mitigation strategies building on the 'Clean Air and Climate Solutions for ASEAN ' study, where modelling was led by PM group (CCAC/UNEP, 2024; *in press*). Providing this analysis required adaptation and further development of the GAINS model expanding its capacity to include for the first time morbidity (Ru et al., 2023).

PM Highlights of scientific output and policy impact

PM research has contributed to the scientific backbone underlying the impact assessments of the European Commission aim to deliver the climate objectives of the **European Green Deal**. Phase-out of fossil fuel use is key to achieving climate neutrality, but it will not be enough unless a net zero balance in non-CO_2 greenhouse gas emissions and land-based CO_2 emissions and sinks is also achieved. As part of a long-standing collaboration with other European modeling groups, PM's GAINS model has provided non-CO_2 greenhouse gas mitigation pathways at the country and sector level for EU's 27 countries, which along with land-use CO_2 pathways from BNR's GLOBIOM model, are used to ensure the scientific rigorousness of EU's climate policy strategies.

Using a novel decomposition approach, an PM led study on the **pollution-demography-climate nexus** highlighted impacts of population dynamics for the resulting health co-benefits of mitigation (Rafaj et al., 2021). The study finds that demographic processes, particularly aging population, but also urbanization, counteract in many regions the mortality reductions realized through lower emissions and consequently declining pollutant concentrations. Building on this work, the *Lancet Countdown* studies use now an indicator for mortality from ambient air pollution by economic sector, introduced by PM researchers who regularly contribute to *Lancet* (Watts et al., 2021; Romanello et al., 2021, 2023; Hamilton et al., 2021; Zhang et al., 2023; van Daalen et al., 2024). PM research shows that contrary to common beliefs and often implemented policies, in most cities a large share of $PM_{2.5}$ originates from sources outside of the cities.

Some of the climate and air quality co-benefits offered by **circular waste management** systems are poorly understood. We developed the first global assessment of emissions and mitigation potential from such systems for SSP-consistent scenarios, considering urban and rural distinctions (Gomez-Sanabria et al., 2022). Recently, spatial analysis was integrated to the analysis to quantify waste leakage into aquatic environments (Gomez-Sanabria and Lindl, 2024; a*ccepted).* Insights from this work and in-house expertise contributed to the Global Waste Management Outlook (UNEP, 2024).

These advances expand the analytical capacity and application scope of the GAINS model, enabling better representation of this sector in the global integrated assessment models.

Limiting growth of F-gases emissions has been a priority, underscored by the Kigali Amendment to the Montreal Protocol. However, stronger international action to reduce HFCs are necessary to align F-gases emission trajectory compatible with Paris Agreement goals and increase the chances of limiting global warming to 1.5°C (Purohit et al., 2022) while further mitigation can be achieved by switching to low-GWP refrigerants, such as propane (Purohit et al., 2022). Furthermore, understanding the ecological and human health implications of some HFC alternatives has important implications on policy and industry towards development and application of safe and reliable low-GWP alternatives (David et al., 2021).

PM group, hosting the EMEP Center for Integrated Assessment Modelling (CIAM), supported **review of the Gothenburg Protocol** to the UNECE Air Convention (the first multipollutant-multieffect international agreement) playing a key role in providing evaluation of progress in achievement of its objectives and exploiting potential for future steps. New GAINS model analysis, performed in collaboration with other scientific bodies, national and international stakeholders within the Convention, assessed implications of introducing collective risk-based targets for the UNECE region (including Europe, Central Asia, and North America) to address air pollution impacts on health and ecosystems, including risk of biodiversity loss. In December 2023, drawing on this analysis, the Executive Body of the Convention decided to start the revision of the Protocol - work scheduled for 2024-2026.

PM specific SWOT Analysis

In our view, one of the main **strengths** of the PM group is its international and interdisciplinary team of scientists that continue providing insights and guidance to policymakers working at local, national, regional and global scale addressing human and societal wellbeing and emerging environmental challenges. The innovative perspectives developed by the team are now shaping scientific thinking and regional and global policy processes on multi-pollutant/multi-effect approaches to the management of air pollutants and non-CO_2 greenhouse gases, including focus on short-lived climate forces (e.g., black carbon, CH_4) and co-benefits of measures for different policy objectives. Building on the trust and credibility (also because of open access model tools) established within the EC and UNECE policy community, PM group expanded its scope interacting and supporting World Bank, UNEP, CCAC in Asia, Africa, and globally making PM a reliable and attractive collaboration partner for other scientific organizations and policy outlets. Over time, the group has been very successful in strategically using IIASA's institutional contributions, also capitalizing on the interactions and capacity within the ECE program, to leverage additional financial resources and enhance its scientific capacity through a large network of collaborators around the world.

There are challenges to overcome some of our perceived **weaknesses**, including increasing resource need to maintain and keep up-to-date large-sale datasets and modelling infrastructure of the GAINS model. Not addressing this challenge might lead to delays or lack of capacity to develop and implement new methods and extend tools to address emerging issues. We also perceive the simplified representation of systems dynamics in the current GAINS framework as another (theoretical) weakness, although it has arguably facilitated the understanding and acceptance of GAINS results by decision makers. However, a proper representation of the dynamics (e.g., from long-lived infrastructure) while maintaining transparency and manageability of the entire system is at the core of our current research agenda. Finally, employment of machine learning tools, for example to improve spatial distribution of emissions, downscaling of activity projections, and error detection needs further attention.

While the new program/group structure and retirement of few critical PM staff members brought some threats, we have seen those also as an **opportunity,** bringing in new expertise into PM and

explore the benefits of closer collaboration across the groups within the ECE program, especially with respect to better addressing the interactions across temporal and spatial scales, building links between GAINS and the MESSAGEix models, and analysis of links between wellbeing and pollution. This experience has been opening up further potential for work closer with the global integrated assessment community extending analysis capacity at both ends. The global implementation of GAINS with rich source and spatial detail offers the chance to contribute information on spatial heterogeneities to the science communities that address the evolution of emissions, atmospheric chemistry and climate at the global scale. Furthermore, there is wide scope for knowledge transfer on potential co-benefits and methods to harness synergies in a systematic way to scientists and decision makers in many world regions. In particular, the new feature of linking pollution levels at street level to the sources at different scales could provide a powerful instrument for local planners to reveal local benefits of larger scale interventions.

Finally, there are a number of potential **threats**. The vitality of different strands of work in the PM depends critically on the level of policy interest. Strong interests from the policy community helps to activate financial support and motivate international scientific networks to participate in the development of new tools and insights. Since preferences differ across the world regions, diversification of research lines, and in particular the inclusion of other types of co-benefits and policy priorities, could substantially reduce such threats. PM has been addressing these by extending the expertise in the team and further developing the model increasing its analytical capacity to address emerging issues. Increasing share of external funding and lack of internal 'banking and borrowing' of internal budget might lead to difficulties to buffer natural fluctuations in successful acquisition of such funding. This could result in challenges to retain scientific staff and maintain the modelling infrastructure that is already under 'funding pressure'. A rather important potential threat to the vitality of the research group relates to the ability to attract qualified young scientists. The competitiveness of IIASA's employment terms seems to decline, especially for early career scientists with family commitments.

Sustainable Service Systems (S^3) Research Group

Traditionally, climate mitigation scenarios have often focused on supply-side mitigation measures, in which large-scale technologies provide a clean supply of energy. Such scenarios had little representation of energy-using behaviors and showed a limited need for changes in energy demand. The emergence of strong demand-focused scenarios (Grubler et al., 2018), initiated a renewed focus on the role of behavior and lifestyles and their potential in reducing environmental pressures.

To drive scientific progress in this area, the stated goals of the S^3 group for 2021-2024 included two main research objectives. First, to explore the evolution of people's behaviors and lifestyles in using services and goods that require energy and assessing their environmental impacts, and second, to identify and analyze policy interventions that can change behaviors and lifestyles to minimize environmental impacts. The research in S^3 focused on three domains that are critical for the sustainable transformation challenge: buildings, mobility, and consumer goods. Across these three domains, research in S^3 focused on two cross-cutting connections: infrastructures and lifestyles. Infrastructure developments in one domain influence the other domains, and the slowly evolving infrastructures provide the boundaries for individual behavioral choices. "Lifestyle" is the aggregate of behaviors that emerge across individual behaviors in different domains.

Beyond this focus, the research in S^3 also contains ECE's efforts to provide scenarios for the financial sector and to improve the representation of the financial sector in climate scenarios. Hence, major achievements to meeting the goals described above can be clustered in five key research areas:

Identification of policy interventions that capture the benefits of behavioral change.

Upon the outbreak of the COVID-19 pandemic, S^3 researchers developed global scenarios for behavioral change during the recovery from the pandemic (see highlight 1 below) and found that low-demand lifestyle changes would enable faster climate mitigation at lower costs (Kikstra et al., 2021). Policy insights from this study have percolated to the European Commission, and in IPCC AR6. S^3 researchers pioneered the development of detailed demand-side policy scenarios and implementing policies that represent avoiding, shifting, or improving the way households use energy in the buildings sector (Mastrucci, et al., in review) and found a mitigation potential for global residential space heating and cooling of up to 60% of CO_2 emissions in 2050 relative to 2015, enabling net-zero emissions when combined with supply-side measures. These scenarios have subsequently been taken up by the research community in multi-model studies (Kriegler et al., 2023) that confirm the novel insights.

S^3 researchers have also broadened the scope of policy options by expanding the types of scenarios to be analyzed. For example, the innovative Low Energy Demand scenario (Grubler et al., 2018) has been further deepened and detailed into concrete policy interventions in the High-with-Low scenario, showing how high wellbeing can be achieved with low energy and material resource consumption (Wilson et al., 2023, Niamir et al., 2024). Another example is the development of a local sustainability narrative with strong focus on wellbeing in collaboration with Japanese colleagues (Kamei et al., 2021). More recently, researchers from the S^3 group have been at the forefront of developing and implementing the first post-growth and degrowth scenarios in global and national integrated assessment models (Min et al., in review Kikstra et al., 2024).

New granular, sector-level, modeling frameworks that represent heterogeneity and behavior.

A major focus of S^3 researchers during the first years of the research group has been on developing new modeling frameworks that enable to analyze the pace, potential, and costs of demand-side climate policy measures and the climate and energy consequences of providing basic needs to all. These new frameworks include descriptions of access to services, physical activity and infrastructures, efficiency and technology choice in the buildings and transport sectors with high socioeconomic and geographic granularity (Mastrucci et al., 2021, Poblete Cazenave et al., 2021). A fundamental review of the modeling needs to properly represent demand-side measures also highlighted the innovativeness of the S^3 modeling frameworks (Mastrucci et al., 2023).

The new modeling frameworks have allowed to us explore topics that could not be studied in the context of Integrated Assessment modeling before. For example, we showed that lifetime extension of buildings, switch to wood-based construction, reduction of per-capita floorspace, could reduce the demand for building materials in China by 60% compared to reference in 2060 (Mastrucci et al., accepted, Zhang et al., 2022). Novel datasets that expand global coverage of materials intensity further enable this research (Fishman et al., 2024). Finally, closing the cooling gap without strongly increasing energy use (Mastrucci et al., 2022, Andrijevic et al., 2021) and using cool roofs as adaptation measure (Nutkiewicz et al., 2022) could now be studied as well.

Methodological advancements and empirical analyses to understand and represent the role of social interactions and behavioral changes in future scenarios.

Researchers in S^3 have developed new methods to empirically identify the differences in energy and resource use between different lifestyle groups and, in collaboration with behavioral scientists, explored diversity in response to policy interventions (such as nudges or price-signals). These new empirical insights were turned into modeling frameworks and will help in the future to formulate effective and realistic demand-side policies. Jointly with Oxford University, S^3 researchers quantified behaviors of different lifestyle groups diverge with climate policies and found that this can lead to bifurcation in society between 'engaged' and 'disengaged' groups, and that these groups apply different measures to avoid, shift, or improve their energy use, depending on their available means

(Pettifor et al., 2023). In another example, coupling an agent-based model with building stock modeling showed how information and peer influence helps to diffuse energy efficient behaviours (Niamir et al., 2024).

To meet the highly granular data requirements for this type of research, S^3 is also leading the explorative use of social media data as complementary data source to characterize heterogeneous behaviour in societal groups (Eker et al., 2021, Eker et al., 2023, Gaup and Eker, 2024)

Establishment of a global research community focusing on demand-side solutions to mitigation

Beyond IIASA, the S^3 group is also leading the establishment of a global research community on Energy Demand changes Induced by Technological and Social innovations (EDITS) . EDITS aims to strengthen the understanding of behavior, wellbeing, and resource use, to increase the evidence base for low energy demand scenarios and to better inform policy makers. Highlights of EDITS community research activities with strong ECE/S^3 involvement include a deep assessment of the state of science, as well as the modeling needs for quantifying low demand scenarios (Mastrucci et al., 2023, Wiedenhofer et al., 2024, Thomas et al., in review), laying out a research agenda to increase the evidence base for demand-focused scenarios in climate assessments (Sugiyama et al., 2024) and a study finding that demand-side measures are more beneficial for energy security than supply-side measures (Bento et al., 2024)

Pioneering the climate scenarios for financial risk assessment and the role of finance in IAMs.

Researchers in S^3 pioneered a novel avenue for policy impacts by working with the financial sector and developing new climate scenarios for financial risk assessment. This started with activities to visualize and explain insights from climate scenarios for financial analysts and collaborating with the UNEP Finance Initiative to guide commercial banks into the use of climate scenarios (van Ruijven and Min, 2020). Subsequent development of bespoke MESSAGEix-GLOBIOM scenarios for the Network for Greening the Financial System (NGFS), a group of 138 central banks and financial supervisors that use these scenarios for financial stress testing in their jurisdictions, including annual updates and releases, and the provision of downscaled IAM scenario outputs at the country level (Bertram et al., 2020, Bertram et al., 2021, Richters et al., 2022, Richters et al., 2023) represents a major and direct impact of ECE research on financial decision making in the climate transition.

Complementary to these activities, researchers in S^3 worked to improve the representation of the financial sector in climate scenarios. By laying out a framework for including financial sector attitudes (Battiston et al., 2022) as well as providing a pioneering example (Al Khourdajie, et al., in prep.) we provide a constructive contribution to improving integrated assessment scenarios.

S^3 Highlights of scientific output and policy impact

1. The publication by Kikstra et al., (2021) introduced a set of global COVID-19 shock-and-recovery scenarios, systematically exploring the lasting effects of demand changes. This paper in Nature Energy exemplifies a swift and impactful scientific response to the COVID-19 crisis, significantly enhancing the policy relevance of demand-side research. It compellingly demonstrated that integrating energy-efficient practices into new travel, work, consumption, and production patterns post-pandemic would alleviate climate mitigation challenges. This influential work has been discussed with policymakers and business leaders across the USA, Europe, Asia, and with the OECD, and was prominently cited in the IPCC AR6 to emphasize the potential impact of behavioral change on mitigation.
2. Significant scientific progress has been made through the development of a holistic, interdisciplinary framework for buildings-related energy demand. This framework integrates stock turnover modeling (Mastrucci et al., 2021), detailed microsimulation of household choices on cooking energy and appliance ownership and use (Poblete-Casenave, 2021), and behavioral

modeling on renovation decisions (Niamir et al., 2024). This comprehensive approach enables the analysis of a wider array of policy options in climate scenarios and marks a major advancement in providing critical information to policymakers.

3. The innovative lifestyle simulation model by Pettifor et al., (2023) combines extensive empirical research from Oxford University with advanced model development at IIASA. This groundbreaking approach simulates low-carbon lifestyle heterogeneity and changes, enabling dynamic analysis of distinct lifestyle contributions to targeted mitigation strategies. The model reveals a significant gap between 'engaged' types, who achieve faster and greater reductions in final energy demand, and 'disengaged' types. Furthermore, drivers of lifestyle change vary across different actions, with 'disengaged' types responding more strongly to energy-saving behaviors.
4. The scenarios developed by S^3 and IACC for the Network for Greening the Financial System (NGFS) significantly influence global financial decision-making. These scenarios are mandated for climate stress testing by 138 central banks and financial supervisors worldwide. In addition to the MESSAGEix-GLOBIOM scenarios, IIASA has pioneered an advanced method for downscaling IAM outputs to the country level and maintains the essential database backbone for this complex project and public outreach. The annually updated, bespoke scenarios for the finance sector have a rapidly expanding user base among financial consultancies, commercial banks, and financial supervisors.
5. In June 2022, S^3 spearheaded the organization of the second Forum on Scenarios for Climate and Societal Futures at IIASA. Stepping up the leadership of ICONICS to create a global scenarios research community. This event united over 500 researchers from 33 countries, spanning climate science, impacts, adaptation, and mitigation research. They discussed ongoing scenario developments and applications, identified successes, and outlined necessary modifications and next steps for the community scenario process. By spearheading research community leadership, organizing webinars, meetings, and projects, IIASA decisively supports this emerging research community, driving progress and innovation in the field.

S^3 specific SWOT Analysis

The main **strength** of the S^3 research group are its highly motivated, experienced, and exceptionally qualified staff, whose expertise and dedication drive its success. This excellence is further enhanced by the group's robust interconnectedness with other research initiatives at IIASA and on the global scale. In recent years, the younger generation of S^3 research scholars has built a formidable reputation through groundbreaking research and community leadership. This rising cohort has significantly contributed to the group's achievements, with many currently moving into senior positions, spearheading the acquisition of funding, and mentoring early career researchers.

The central, leading role of S^3 within the EDITS network has provided substantial opportunities for colleagues to refine their research and leadership skills. This prominent position has enabled them to implement ambitious research agendas in collaboration with renowned scholars, influence policy-making, and attract talented new staff. S^3 has secured a diverse array of research funding from a variety of sources, including international research funders, foundations, and businesses. This diverse funding portfolio underscores the group's broad appeal and capability to sustain and expand its innovative research endeavors.

A third strength is the multidisciplinary, multi-faceted demand-side modeling framework that the group developed. The combination of models from engineering, economic, and social science traditions with high levels of granularity has the ability to respond to information needs from a variety of policy makers at the world, country and city levels.

The **weaknesses** of S^3 relate to the strong interconnectedness of demand-side research with many other research topics, such as energy supply, climate, social sustainability, equity and justice. This

diversity of demands requires a careful harmonization of plans to respond adequately to the evolving needs of NMOs, stakeholders, or funders. While this flexibility to respond to new opportunities and research questions is fundamentally a strength of IIASA, it also places a significant burden on staff to adapt quickly and manage the risk of overcommitment.

Additionally, the early stages of establishing the research group and modeling tools present another challenge. As the group transitions from the innovative and original model development phase to a focus on maintaining and updating more mature modeling tools, it faces the need for a stable and continuous funding environment. Model and data maintenance, while less rewarding to both researchers and funders, is essential for sustaining the ability to perform world-class research.

The primary **opportunities** for S^3 lie in its capability to meet the growing information needs on demand side solutions from policy makers, science funders, and scenario users. There is a rising demand for more granular, sectoral information in climate scenarios, which the S^3 group is well positioned to provide. Moreover, policy makers are increasingly interested in the evaluation of broader and more concrete policy measures in cities and for different sectors, and S^3 is well equipped to respond to these requests. Financial actors have a special interest in detailed sectoral information, even though this has yet led to translate to concrete funding for the S^3 research, catering effectively to these users would be an opportunity for the group.

The emergence of new datasets on behavioral aspects of society provides another opportunity to structurally enhance the underpinning of demand-side research. To fully leverage this opportunity, however, investments in methodological development, data consistency, and data processing will be essential. These investments will enable S^3 to harness the full potential of these datasets, thereby strengthening the foundation of their research.

Another opportunity is that S^3 has been spearheading the creation of a global demand-side research community in EDITS. Due to its strong ties and central leading role in this community, S^3 and has the opportunity to leverage benefits through well-designed collaborative studies with globally leading scientists to feed information needs related to its own research.

Threats for the S^3 research emerge from the strong dependence on external funding and the workload for staff. While the funding portfolio has a diversity in sources, the recent trends of high inflation and volatile exchange rates, combined with the lack of a banking and borrowing system for research programs at IIASA portrays a threat for the continuity of employment and development of the research group. These financial risks and the reduced employment benefits at IIASA also complicate an adequate response to the increased competition in attracting highly qualified researchers. Finally, many highly interesting opportunities for S^3 staff to contribute their impactful research to policy processes come without additional funding or capacity expansion. Consequently, the workload of staff is high and increasing, which is not sustainable for IIASA in the longer term and risks limiting its capacity to flexibly respond to future opportunities.

Transformative Institutional and Social Solutions (TISS) Research Group

Efforts to address the environmental impacts of climate change have typically relied on centralized, large-scale technical solutions, drawing primarily from engineering, economics, and the natural sciences. Assessed using economic cost and efficiency-based criteria, such solutions often neglect social, institutional, and distributional aspects that are key for implementation. This calls for a more comprehensive and integrated approach to simultaneously meet developmental, planetary and public health, and wellbeing related goals.

In line with this call, the TISS Group's stated goals for the 2021-2024 period are to explore innovative solutions to environmental issues that integrate social, institutional and governance drivers with technological, and economic considerations, with an emphasis on improving conditions for the most deprived and marginalized in society.

Thus, the TISS RG emphasizes two focal areas in its research:

- A systemic analysis of technological, social, and institutional innovations (including inter alia new business models, social entrepreneurship, and novel public policy designs) with a focus on end-use services for human wellbeing that minimize negative environmental impacts.
- Integration of heterogeneity, governance, and diverse justice considerations in policy analysis and implementation under a broader framing of transformations towards more resilient and sustainable futures.

Major advancements across four key research areas are described below that have been fundamental to achieving the stated goals of the TISS RG over the last four years.

Global and regional analyses of multidimensional deprivations, pathways to ensure a decent life for all and improve wellbeing while respecting critical planetary processes.

Over the past four years, the TISS RG has made significant strides in conducting original global and regional analyses aimed at measuring multidimensional poverty and deprivations, and devising pathways that ensure a decent living standard for all while simultaneously minimizing environmental impacts. Through a multidisciplinary approach integrating methods from economics, industrial ecology, environmental and social sciences, and engineering, the TISS RG in close collaboration with the S^3 and IACC RGs have explored decent living gaps globally, as well as access to specific energy services such as cooking, cooling and other essential household end-uses that relate to fundamental human needs (Kikstra et al., 2021; Poblete-Cazenave et al., 2021; Pachauri et al., 2021; Zimm et al., 2022; Mastrucci et al., 2022; Virag et al., 2022; Ummel et al., 2024; Hoffman et al., 2024 under review).

Our work has contributed to the identification of key regions of the world and population groups facing multidimensional deprivations and insights on innovative interventions needed to enable the achievement of a decent life by all. In this effort, we have also undertaken processing, cleaning, and standardizing of household survey microdata from a series of developing countries to enable sub-national detailed analysis of access to decent living standards, energy consumption, and energy poverty. We are now also exploring how these factors intersect with sub-national climate vulnerability, to inform climate resilient development futures. Additional research has critically assessed the multidimensional benefits of improving access to fundamental energy services and decent living standards by leveraging advanced quantitative methods and data analytics (Falchetta et al., 2023; Pelz et al., 2023; Rao et al., 2021; Belmin et al., 2021).

Novel theoretical frameworks and practical tools to assess and incorporate equity, fairness and justice concerns in transition scenarios and analyses.

To weave equity and fairness into climate scenarios, the TISS RG has developed a series of innovative tools and analytical frameworks grounded in philosophical principles and the effort sharing literature. The Fair Mitigation Finance Explorer, accompanying the paper 'Fairness considerations in global mitigation investments' (Pachauri, et al., 2022), is a web application that allows users to explore 'fair' regional contributions to mitigation investment needs by selecting from various indicators linked to emerging fairness principles. This foundational work informed the European Scientific Advisory Board on Climate Change's advice to the EU on what a fair and feasible 2040 target for the EU could be (Pelz et al., 2023).

An award winning YSSP project led by PhD student Gaurav Ganti (Humbold University, Berlin) in 2023, outlines a framework to enhance the integration of equity in climate change mitigation strategies, addressing a gap noted by the IPCC. The work highlights the need for additional diagnostic scenarios

to broaden the solution space enabling the consideration of a wider range of trade-offs across mandatory and optional normative fairness considerations in mitigation pathways linked closely to the textual elements of the Paris Agreement (Ganti 2023).

The development of the Carbon Debt Tool within the ELEVATE project offers stakeholders insights into carbon debt and credit projections, encouraging an intuitive understanding of 'fair' shares in carbon accounting post net-zero (Pelz et al., 2024 submitted). Our work on integrating carbon debt into the model protocol of a justice model intercomparison project (JustMIP), which we are co-developing, is a significant step towards embedding diverse justice considerations in climate modeling. Finally, a recent publication introduces a new justice framework aimed at influencing the next cycle of the IPCC scenario generation and related climate policy discussions and research more broadly (Zimm et al., 2024). Ongoing work also analyzes the distributive patterns implied in IPCC scenarios and is working with stakeholders via a tool to enlarge the scenario space capturing more diverse accounts of justice.

Research on the co-production of mitigation and sustainability scenarios with several stakeholders and policy actors, applying methods from systems dynamic modeling, is part of ongoing research in projects like WorldTrans. Methodological developments are also underway to improve the diversity and inclusivity of scenario generation processes by also incorporating voices of marginalized and indigenous communities.

These contributions are crucial to inform global discussions on equitable climate action and support stakeholders in navigating the complexities of climate mitigation strategies. We have also initiated efforts to actively engage with policymakers, negotiators, and other stakeholders to test our tools and ensure that our research is effectively translated into actionable recommendations and policies.

Methodological advancements and empirical analyses to evaluate the significance of governance and institutional factors in shaping the feasibility of transitions.

To support a better understanding of feasibility from a multidimensional perspective, TISS scholars have developed a new framework for ex-post scenario evaluation of outputs from Integrated Assessment Models (IAMs), which include, among other factors, considerations of institutional feasibility regarding the implied speed and scale of emissions reductions (Brutschin et al., 2021). The core of the framework uses insights from qualitative and quantitative studies of past transitions to deduce either the rates of change observed under the best-case scenario or the enablers of major advances in line with more ambitious transformations. This framework has been used by other scholars (Achakulwisut et al., 2023; Gidden et al., 2023; van de Ven et al., 2023) and discussed in Nature Climate Change (Pianta & Brutschin, 2023). It has also been modified and applied in the context of the EU advisory board (Byers et al., 2023).

Further developments of the framework have explored in more detail the drivers of a more ambitious coal phase-out (Brutschin et al., 2022), technology diffusion (Zimm, 2021), scaling up nuclear energy (Brutschin, 2021), and carbon dioxide removal (Gidden et al., 2023; Schenuit et al., forthcoming), with a strong focus on the role of governance and institutions in enabling or constraining these transitions. There have also been major efforts to advance the framework on how insights from the social sciences can be linked to global integrated assessment models in close collaboration with colleagues from the IACC RG (Brutschin & Andrijevic, 2022; Pianta & Brutschin, 2022, Andrijevic et al., under review).

Key contributions to improve our understanding of tipping points and safe and just earth system boundaries.

Scholars in the TISS RG have been supporting the Earth Commission (EC) of the Global Commons Alliance since its inception, contributing also to its scientific foundations (Nakicenovic et al., 2016; Rockström et al., 2024). Over the past few years, TISS scholars have been co-hosting the scientific secretariat of Working Group 1 on the Earth and Human System Modelling Inter-comparison Project, with a special focus on a bridging role between different working groups and disciplines. To this end, TISS scholars have contributed to research by the EC on the delineation of safe and just boundaries

(Rockström et al., 2023; Gupta et al., (accepted). This work has included foremost setting safe climate and aerosol boundaries that account for harm to people (Lenton et al., 2023), committed impacts (Winkelmann et al., in review) and tipping dynamics (Abrams et al., 2023; GTPR 2023). Additional work has focused on quantifying a minimum access to resources for those deprived (Rammelt et al., 2022), a water boundary (Stewart-Koster et al., 2023), and biodiversity targets (Obura et al., 2022). Translating these boundaries to different actors and science-based targets is a key challenge where TISS staff have supported the development of a protocol (Bai et al., 2024; Ishii et al., 2021). The next phase will focus on pathways within a safe and just corridor (Rockström et al., 2021; van Vuuren et al., 2022).

The TISS RG has been leading the virtual interdisciplinary Tipping Points Discussion Series, a joint endeavor of the EC, WCRP's Safe Landing Lighthouse, AIMES, and Future Earth. Since September 2021, 25 webinars on Earth and human system tipping have featured ~90 experts discussing the state of knowledge on irreversibility and abrupt change.

TISS Highlights of scientific output and policy impact

1. A pathbreaking paper by Brutschin et al., 2021, that introduces **a multidimensional framework to assess scenario feasibility**, has served as a foundation for a new stream of studies that now also incorporate governance and institutional indicators to assess the feasibility of required scale and speed of transformations under ambitious climate mitigation scenarios. This work also fed into the IPCC assessment of feasibility of mitigation pathways in its AR6 WGIII report and has underpinned the governance model intercomparison study within the ENGAGE project.

2. A timely publication by Pachauri et al., 2021, explores how **access to clean cooking services** could improve under alternative baseline and climate mitigation scenarios, as well as a specially designed COVID-19 recovery scenario. The work highlights that the already slow progress on expanding clean cooking access might further stall and exacerbate global inequities if there were a protracted recession after the pandemic or ambitious climate mitigation action is implemented without additional support policies to expand energy access and protect the poor. It concludes that utilizing pandemic recovery and climate funds to specifically target the poorest people and regions to make clean cooking services accessible and affordable is urgently needed. The results of this research have been highlighted in policy briefs (e.g., Leveraging energy action for advancing SDGs UNHLPF 2021).

3. A groundbreaking study, for which Jarmo Kikstra received an Early Career Research Award from the Integrated Assessment Modeling Consortium, focused on quantifying the additional **energy required to provide decent living standards to everyone**, including infrastructure needs (Kikstra et al., 2021). It concluded that this is less than half of the projected future energy demand under climate goals, implying that the two goals are compatible, an important insight that was also highlighted in the latest IPCC AR6 reports. The study attracted broad coverage both in media (e.g., World Economic Forum, Carbon Brief, and Grist) and policy (e.g., a policy brief for UN DESA6). Multiple projects and studies are now built on this work, including studies under JustTrans4All, ELEVATE, and EDITS

4. A recent research report on **equity in emissions pathways at the EU level** provides a systematic consideration of fairness, building on international and European law principles, to suggest fair allocation approaches of mitigation effort within the EU (Pelz et al., 2023). This work informed the European Scientific Advisory Board on Climate Change and has underpinned the setting of the EU's 2040 targets.

5. **Support to Working Group 1 of the Earth Commission (EC) of the Global Commons Alliance** has resulted in several high-level publications already mentioned above (Rockström et al., 2021; van Vuuren et al., 2022; Rockström et al., 2024; Bai et al., 2024) and a highly attended and impactful

virtual webinar series to advance knowledge about tipping points, irreversibility, and abrupt changes in the Earth system. The series has been attended by around 4,000 participants and recordings of the events have collected several thousand views.

TISS specific SWOT Analysis

The **strengths** of the TISS research group begin with its exceptionally talented and highly skilled research staff, who bring expertise and innovative thinking to their research efforts. The small but agile group can adapt swiftly to emerging challenges and opportunities. The interdisciplinarity of the team allows for leveraging diverse methodological approaches to tackle complex issues from multiple angles. The ability to integrate traditionally qualitative research domains with quantitative scenario analysis has become a distinguishing feature of the TISS RG, providing a significant advantage. The mix of senior emeritus level scholars with mid-career and early career scholars, as well as visiting scholars, provides a broad and diverse mix of experience and expertise within the group. The group's extensive international networks facilitate global collaborations and knowledge exchange, enhancing their research impact. Furthermore, the group benefits from robust collaborations both within the ECE program and across the broader IIASA community to drive forward cutting-edge research initiatives.

The group faces some **weaknesses** that have an impact on its effectiveness and sustainability. Fluctuating and uncertain budgets create significant resource constraints and make long-term planning and staff retention challenging. A reduced inflow of internal funding to ECE and greater reliance on external funding limits the flexibility to pursue blue sky research, limiting the capacity to undertake innovative high-risk projects that could lead to methodological advancements and groundbreaking new insights. This also brings with it an additional risk of diluting the group’s efforts across scattered projects, leading potentially to challenges with maintaining a cohesive research focus.

The TISS research group is well positioned to capitalize on several promising **opportunities**. The increasing realization and demand for addressing equity and justice considerations in policies and actions to transform energy systems provides fertile ground for the group to engage in and expand its research in ways that can have positive real-world impact on policy and decision-making. Furthermore, the availability of new datasets, including from satellite observations, provides opportunities for more granular analysis, enabling the group to generate more precise and actionable insights. The expertise of the group in leading stakeholder engagement processes and addressing critical political economy dimensions of transitions allows for informing the design of policy and action that has the potential to be both more feasible and acceptable. Leveraging in-house collaborations can help the TISS research group to foster interdisciplinary research that integrates diverse expertise. For instance, the formation of the new ICI research group opens new avenues for exploring how climate vulnerabilities and impacts intersect with socioeconomics and demographics and a lack of access to decent living standards. Finally, the emergence of new funding streams offers the potential to secure more stable financial support that can enable the TISS RG to pursue its long-term research goals and enhance its contributions.

The TISS research group also faces some **threats** that could hinder its work and future progress. Maintaining a delicate balance between research, capacity building, and networking activities is challenging, potentially stretching resources thin and impacting the quality of outcomes in each area. Additionally, striking a balance between retaining in-house talent and attracting new talent is crucial but difficult, as both are essential for maintaining a dynamic and innovative team. The increased effort and time required for internal administrative processes further strain the group's limited resources, diverting attention from core research activities. Compounding these issues, shrinking internal funding threatens the group's ability to support its projects and staff adequately, jeopardizing its long-term stability and success.

Annex A: ECE Staff

List of staff working in ECE and the respective Research Groups over the period 2021-2024.

Name	Research Groups	Staff category
Riahi, Keywan *	IACC, ICI, PM, S3, TISS	Scientific, Program Director, Principal Research Scholar
Klimont, Zbigniew *	PM	Scientific, Research Group Leader, Principal Research Scholar
Krey, Volker *	IACC; S3	Scientific, Research Group Leader, Principal Research Scholar
Pachauri, Shonali *	TISS; IACC; S3	Scientific, Research Group Leader, Principal Research Scholar
Schleussner, Carl	ICI	Scientific, Research Group Leader, Senior Research Scholar
van Ruijven, Bas *	S3; TISS; IACC	Scientific, Research Group Leader, Principal Research Scholar
Marcos, Carmen	PM	Professional, Operational
Wagner, Pat	IACC, S3, TISS	Professional, Operational
Abera, Yared	PM	Scientific, Research Assistant, Guest
Agarwal, Prerita	PM; YSSP	Scientific, Research Assistant, YSSP
Akugre, Francis	TISS; YSSP	Scientific, Research Assistant, YSSP
Al Khourdajie , Alaa	IACC; S3	Scientific, Research Scholar, Guest
Amann, Markus	PM	Scientific, Senior Research Scholar
Andrijevic, Marina	IACC; TISS	Scientific, Research Scholar
Angeli, Jakob	S3	General Service, Operational
Appelgren, Katherina	PM	General Service, Operational
Artuso, Silvia	S3	General Service, Operational
Awais, Muhammad	IACC; S3	Scientific, Researcher
Bagheri, Marzieh	PM; YSSP	Scientific, Research Assistant, YSSP
Baloloy, Marko Niko	PM	Scientific, Research Intern
Bankert, Emily	IACC	Scientific, Research Intern
Ben-Nissan, Roee	IACC; YSSP	Scientific, Research Assistant, YSSP, Guest
Bhattacharya, Anindya	IACC	Scientific, Research Scholar, Guest
Blass, Vered	IACC; NMOD; S3	Scientific, Research Scholar, Guest
Borken-Kleefeld, Jens	PM; S3	Scientific, Research Scholar
Bossy, Thomas	EM; IACC; YSSP	Scientific, Research Assistant, YSSP
Boza-Kiss, Benigna	S3; TISS	Scientific, Research Scholar
Brito, Thiago	PM	Scientific, Researcher
Brocza, Flora	PM; YSSP	Scientific, Research Assistant, YSSP, Researcher
Brutschin, Elina	TISS	Scientific, Research Scholar
Byers, Edward	IACC; S3	Scientific, Senior Research Scholar, Theme Leader
Cabardos, Anique-Marie	S3	Professional, Operational
Cao, Yuheng	IACC; TISS; YSSP	Scientific, Research Assistant, YSSP
Castella, Lucie	IACC	Scientific, Research Intern
Chen, Shi	PM	Scientific, Research Assistant, Guest
Chowdhary, Sandeep	S3	Scientific, Research Scholar
Chowdhury, Swaptik	ASA; EM; TISS; YSSP	Scientific, Research Assistant, YSSP
Clar, Cathrin	S3	Scientific, Research Intern
Coldrey, Olivia	S3; TISS	Scientific, Research Scholar, Guest
Davis, Charlotte	S3	General Service, Intern
De Assis Brasil Weber, Natália	IACC; YSSP	Scientific, Research Assistant, YSSP
De Stercke, Simon	IACC	Scientific, Research Scholar, Guest
Deepshikha, Deepshikha	PM	Scientific, Research Intern
Di Natale, Anna	S3	Scientific, Research Scholar
Diaz, Juan	TISS	General Service, Intern
Ding, Bingqing	IACC	Scientific, Research Assistant, Guest
Donovan, Anna	TISS	General Service, Intern
During, Daniel	PM; YSSP	Scientific, Research Assistant, YSSP, Guest
Dutta, Jayshree	TISS	Scientific, Research Assistant, Guest
Eker, Sibel	S3	Scientific, Senior Research Scholar
Falchetta, Giacomo	IACC	Scientific, Research Scholar
Fishman, Tomer	IACC; NMOD; S3	Scientific, Research Scholar, Guest
Franz, Sebastian	S3; YSSP	Scientific, Research Assistant, YSSP
Fricko, Oliver	IACC; S3	Scientific, Research Scholar
Fujimori, Shinichiro	IACC; S3; TISS	Scientific, Research Scholar, Guest
Ganji, Roja	PM	Scientific, Research Assistant
Ganti, Gaurav	IACC; TISS; YSSP	Scientific, Research Assistant, YSSP, Guest
Gasser, Thomas	EM; IACC	Scientific, Senior Research Scholar, Theme Leader
Gaur, Ankita	IACC; S3; YSSP	Scientific, Research Assistant, YSSP

George, Mel	TISS; YSSP	Scientific, Research Assistant, YSSP
Gidden, Matthew	IACC; S3	Scientific, Senior Research Scholar
Glatter, Fridolin	IACC	Professional, Software Development
Goedeking, Nicholas	IACC; YSSP	Scientific, Research Assistant, YSSP
Gomez Sanabria, Adriana	PM; TISS	Scientific, Research Scholar
Gøtske, Ebbe	IACC; S3; YSSP	Scientific, Research Assistant, YSSP
Greene, Jenna	IACC; TISS; YSSP	Scientific, Research Assistant, YSSP
Grubler, Arnulf	IACC; S3; TISS	Scientific, Emeritus Research Scholar
Guéret, Samuel	PM	Scientific, Researcher
Guo, Fei	IACC; S3	Scientific, Research Scholar
Guo, Yixin	CDAT; NMOD; PM	Scientific, Research Scholar, Guest
Hackstock, Philip	IACC	Professional, Software Development
Han, Xiao	TISS	Scientific, Research Assistant, Guest
Hara, Takuya	IACC; S3	Scientific, Research Scholar, Guest
He, Wei	S3	Scientific, Research Assistant, Guest
He, Yue	IACC; EM	Scientific, Researcher
Hertwich, Edgar	IACC	Scientific, Senior Research Scholar, Guest
Heyes, Chris	PM	Scientific, Emeritus Research Scholar
Higashitani, Takuya	IACC; S3; YSSP	Scientific, Research Assistant, YSSP
Höglund Isaksson, Lena	PM	Scientific, Senior Research Scholar, Theme Leader
Holzinger, Maria	IACC	Scientific, Researcher
Hooke, Daniel	IACC	Scientific, Research Intern
Huang, Chen	PM	Scientific, Research Scholar, Guest
Hunt, Julian	IACC; S3	Scientific, Research Scholar
Huppmann, Daniel	IACC	Scientific, Senior Research Scholar, Theme Leader
Hwong, Yi Ling	IACC	Scientific, Research Scholar, Guest
Hyun, Jung Hee	IACC; NMOD; PDOC; SYRR	Scientific, Research Scholar, Guest
Jang, Youjung	PM	Scientific, Research Assistant, Guest
Javaid, Aneeque	IACC; S3	Scientific, Research Scholar
Joshi, Siddharth	IACC; YSSP	Scientific, Research Assistant, YSSP, Research Scholar, Theme Leader
Jovanovic, Marina	IACC	Professional, Operational
Ju, Yiyi	S3	Scientific, Research Scholar
Kaltenegger, Katrin	PM	Scientific, Researcher
Kang, Minsung	TISS	Scientific, Research Scholar, Guest
Kiesewetter, Gregor	PM	Scientific, Research Scholar
Kikstra, Jarmo	IACC; S3; TISS	Scientific, Researcher, Research Scholar
Kim, Jintea	IACC; S3	Scientific, Research Assistant, Guest
Kim, Younha	PM	Scientific, Research Scholar
Kishimoto, Paul	IACC; S3	Scientific, Research Scholar
Kolp, Peter	IACC, TISS	Professional, Software Development
Koutsandreas, Diamantis	IACC	Scientific, Research Scholar
Kraschitzer-Grant, Marianne	IACC	Professional, Operational
Krenmayr, Nora	PM; YSSP	Scientific, Research Assistant, YSSP
Kuehnle-Nelson, Lovisa	PM	Scientific, Research Intern
Lee, Hanbit	S3	Scientific, Research Intern
Lei, Mingyu	TISS	Scientific, Research Assistant, Guest
Lei, Tianyang	PM; YSSP	Scientific, Research Assistant, YSSP
Lewis, Jared	IACC	Scientific, Research Scholar
Li, Jin	PM; YSSP	Scientific, Research Assistant, YSSP
Lichtenberger, Andreas	EF; PM; YSSP	Scientific, Research Assistant, YSSP
Lindl, Florian	PM	Scientific, Researcher
Liu, Xiaorui	PM; YSSP	Scientific, Research Assistant, YSSP
Liu, Zehui	PM	Scientific, Research Assistant, Guest
Lovat, Francesco	IACC; S3	Scientific, Researcher
Lu, Chaoqun	PM	Scientific, Research Scholar, Guest
Ma, Tieju	S3; TISS	Scientific, Research Scholar, Guest
MacDonald, Jennifer Faa	S3, IACC	Professional, Operational
Maczek, Florian	IACC	Scientific, Researcher
Makowski, Marek	IACC; S3	Scientific, Senior Research Scholar, Guest
Mastrucci, Alessio	S3; TISS	Scientific, Research Scholar
McCollum, David	IACC; S3	Scientific, Research Scholar, Guest
Meng, Measrainsey	IACC; S3	Scientific, Research Scholar
Meng, Wenjun	PM; YSSP	Scientific, Research Assistant, YSSP
Merschroth, Simon	TISS	Scientific, Research Intern
Min, Jihoon	S3; TISS	Scientific, Research Scholar
Mitterrutzner, Benjamin	IACC	Scientific, Researcher

Möller, Tessa	ICI	Scientific, Research Intern
Molloy, Aubrey	IACC; S3; TISS	General Service, Intern
Monasterolo, Irene	S3	Scientific, Research Scholar, Guest
Mussak, Pino	IACC	Professional, Software Development
Nakicenovic, Nebojsa	IACC; TISS	Scientific, Emeritus Research Scholar
Nguyen Khanh , Chi	PM	Scientific, Research Intern
Nguyen, Binh	PM	Scientific, Research Scholar, Theme Leader
Nguyen, Khanh	TISS	Scientific, Research Intern
Niamir, Leila	S3; TISS	Scientific, Research Scholar
Nicholls, Zeb	IACC	Scientific, Research Scholar
Nishiura, Osamu	IACC; S3; YSSP	Scientific, Research Assistant, YSSP
Palatnik, Ruslana	IACC; S3	Scientific, Research Scholar, Guest
Park, Minwoo	PM; YSSP	Scientific, Research Assistant, YSSP
Parkinson, Simon	IACC; TISS	Scientific, Research Scholar
Patange, Omkar	EF; PM; S3; TISS	Scientific, Research Scholar
Pauls, Anna	PM	Scientific, Research Scholar
Pelz, Setu	TISS; YSSP	Scientific, Research Assistant, YSSP, Research Scholar
Pimmer, Michael	IACC	Professional, Software Development
Poblete Cazenave, Miguel	TISS	Scientific, Research Scholar
Posch, Maximilian	PM	Scientific, Senior Research Scholar, Guest
Pratama, Yoga	IACC	Scientific, Research Scholar
Purohit, Pallav	PM	Scientific, Research Scholar
Puteani-Holl, Akos	PM	Scientific, Research Intern
Quade, Merle	S3	Scientific, Researcher
Quilcaille, Yann	EM; IACC	Scientific, Research Scholar
Radin, Mark	TISS; YSSP	Scientific, Research Assistant, YSSP
Rafaj, Peter	IACC; PM	Scientific, Senior Research Scholar
Ramamurthi, Pooja	TISS; YSSP	Scientific, Research Assistant, YSSP
Rao, Narasimha	TISS	Scientific, Senior Research Scholar
Rathod, Sagar	PM; YSSP	Scientific, Research Assistant, YSSP
Rauchenwald, Verena	IACC	Scientific, Researcher
Ren, Hongtao	IACC	Scientific, Research Scholar, Guest
Rogelj, Joeri	IACC; TISS	Scientific, Senior Research Scholar
Rogner, Holger	IACC	Scientific, Emeritus Research Scholar
Sander, Robert	PM	Professional, Software Development
Scheifinger, Karl	IACC	Scientific, Researcher
Schenuit, Felix	TISS; YSSP	Scientific, Research Assistant, YSSP
Schöpp, Wolfgang	PM	Scientific, Research Scholar, Guest
Schowalter, Gretchen	IACC	Scientific, Research Intern
Semeria, Francesco	IACC; TISS; YSSP	Scientific, Research Assistant, YSSP
Sengupta, Sreyam	IACC	Scientific, Researcher
Séra, Carmen	IACC; TISS; YSSP	Scientific, Research Assistant, YSSP
Sferra, Fabio	IACC; S3	Scientific, Researcher
Shah, Deepak	IACC	Professional, Software Development
Shrivastav, Gaurav	EM; IACC	Professional, Software Development
Shu, Yun	PM	Scientific, Research Scholar, Guest
Slater, Jessica	PM	Scientific, Research Scholar
Smith, Chris	IACC	Scientific, Research Scholar, Guest
Soh, Jin Young	S3	Scientific, Research Scholar, Guest
Srivastava, Parul	PM	Scientific, Research Scholar
Stegmann, Paul	IACC; YSSP	Scientific, Research Assistant, YSSP
Steinhauser, Jan	IACC; NODES	Scientific, Researcher
Streeck, Jan	IACC; YSSP	Scientific, Research Assistant, YSSP
Sun, Yisheng	PM; YSSP	Scientific, Research Assistant, YSSP
Swamy, Deepthi	S3	Scientific, Research Scholar
Tan, Jinxiao	IACC; S3	Scientific, Research Assistant, Guest
Toth, Ferenc	IACC; S3	Scientific, Senior Research Scholar, Guest
Trimmel, Heidelinde	S3	Scientific, Research Scholar
Tshuva, Moshe	IACC	Scientific, Senior Research Scholar, Guest
Ünlü , Gamze	IACC; TISS	Scientific, Researcher
Van Laere, Jonas	S3	Scientific, Research Intern
Vinca, Adriano	IACC; TISS	Scientific, Researcher, Research Scholar
Virág, Doris	TISS; YSSP	Scientific, Research Assistant, YSSP
Vivier, Lucas	S3; TISS; YSSP	Scientific, Research Assistant, YSSP
Wagner, Fabian	CDAT; PDOC; PM; TISS; YSSP	Scientific, Senior Research Scholar
Wang, Jason	S3	General Service, Intern

Wang, Manyu	TISS	Scientific, Research Assistant, Guest
Warnecke, Laura	PM	Scientific, Researcher
Werning, Mia	IACC	Scientific, Researcher
Wienpahl, Laura	IACC	Professional, Software Development
Wilson, Charlie	S3; TISS	Scientific, Senior Research Scholar
Winiwarter, Wilfried	PM	Scientific, Senior Research Scholar, Theme Leader
Wolschlager, Maximilian	IACC	Professional, Software Development
Woo, Jung Hun	PM	Scientific, Research Scholar, Guest
Xiang, Pianpian	IACC, S3	Scientific, Research Assistant, Guest
Xie, Judy	S3; TISS; YSSP	Scientific, Research Assistant, YSSP, Guest
Xu, Minghao	IACC	Scientific, Research Assistant, Guest
Yang, Hui	PM; YSSP	Scientific, Research Assistant, YSSP
Yang, Li	PM	Scientific, Research Scholar
Yang, Lei	PM	Scientific, Research Scholar, Guest
Yangji, Gesang	IACC; S3; YSSP	Scientific, Research Assistant, YSSP
Zakeri, Behnam	IACC; S3	Scientific, Senior Research Scholar
Zhang, Shaohui	PM	Scientific, Research Scholar
Zhang, Shu	IACC; S3	Scientific, Research Assistant, Guest
Zhang, Zixuan	IACC; S3; YSSP	Scientific, Research Assistant, YSSP
Zhao, Jinyang	TISS; IACC; YSSP	Scientific, Research Assistant, YSSP
Zhao, Shiya	S3; TISS; YSSP	Scientific, Research Assistant, YSSP
Zhong, Xiaoyang	IACC; S3	Scientific, Research Scholar
Zhu, Bing	IACC; S3; TISS	Scientific, Senior Research Scholar, Guest
Zhu, Biqing	EM; IACC	Scientific, Research Scholar
Zimm, Caroline	EQU; TISS	Scientific, Research Scholar
Zwickl-Bernhard, Sebastian	IACC; YSSP	Scientific, Research Assistant, YSSP

Annex B: Externally Funded ECE Projects

List of externally funded projects during the period 2021-2024 and with a budget of >50k Euro per year

AAQD IA Study to support the impact assessment for the revision of the EU Ambient Air Quality Directives **Duration:** 2021-2023 **Funder:** European Commission, DG Env **Website:** **Policy Briefs or other material links:** https://data.europa.eu/doi/10.2779/327850	Impact assessment for the revision of the EU Ambient Air Quality Directives. The project focuses on 1) Develop and assess policy options for alignment of the EU air quality standards with the (updated) recommendations of WHO; 2) improvement of the air quality legislative framework, including provisions on penalties and public information, to enhance effectiveness, efficiency, and coherence, and 3) ways to strengthen air quality monitoring, modelling and air quality plans. **Contracted (IIASA) amount:** EUR 97,265 **Groups:** PM
AAR2 Austrian Assessment Report **Duration:** 2023–2026 **Funder:** Austrian Climate Research Program (ACRP) **Website:** https://ccca.ac.at/wissenstransfer/apcc/aar2 **Policy Briefs or other material links:**	The Second Austrian Assessment Report on Climate Change (AAR2) is a comprehensive community activity which lays out past, present and potential future impacts of climate change in Austria and defines opportunities and limits of mitigation and adaptation. The stakeholder engagement process assures the reports' policy relevance and facilitates the joint identification of key policy questions to provide necessary evidence-base for effective policy decisions and contribute to increased awareness about climate change mitigation and adaptation. Further, AAR2's companion project for science communication and dissemination ensures that the report's insights and findings are also accessible to the wider public. **Contracted (IIASA) amount I.:** EUR 144,920 **Contracted (IIASA) amount II.:** EUR 73,000 **Contracted (IIASA) amount III.:** EUR 71,920 **Contracted (IIASA) amount III.:** EUR 94,000
ALPS (multi-year) ALternative Pathways toward Sustainable development and climate stabilization (ALPS) **Duration:** 2010–2024 **Funder:** Research Institute of Innovative Technology for the earth (RITE) **Website:** https://www.rite.or.jp/system/en/research/alps/ **Policy Briefs or other material links:** Scenarios on global population and global GDP until 2100; Scenario analysis of halving global CO2 emission by 2050; Global CO2 and GHG scenarios until 2050	The ALPS project aims at providing alternative plausible future scenarios and through quantification of multiple aspects of society on the assumptions that the real-world society intrinsically consists of a wide range of values. This approach allows us to inform decision makers of more appropriate strategies toward sustainable development and climate stabilization from longer and wider perspectives. Another focus is to gain a clearer understanding of CO2 emissions structure on a national, sectoral and technological basis in order to deal with short and mid-term climate challenges. The scenarios on combinations of macro and micro views would generate further insights into climate change mitigation and sustainable development. **Contracted (IIASA) amount:** EUR 204,512 **Contracted (IIASA) amount:** EUR 241,763 **Contracted (IIASA) amount:** EUR 235,520 **Contracted (IIASA) amount:** EUR 241,763 **Groups:** IACC, S3, TISS
AQNEA	The AQNEA project's objective is to develop and establish a systematic approach for the integrated management of air

Development of a collaborative, integrated management framework to improve future air quality in Northeast Asia **Duration:** 2021–2025 **Funder:** National Research Foundation of Korea (NRF) **Website:** https://iiasa.ac.at/projects/aqnea **Policy Briefs or other material links:** https://pmcenter.kist.re.kr/_common/new_download_file.php?menu=boardfile&file_no=1601	quality across Northeast Asia. This objective will be achieved in a collaborative effort involving researcher groups from Korea, China, Japan, and IIASA jointly developing consistent regional database with principal data and scenarios necessary to model current and future evolution of air pollution, specifically ambient fine particulate matter, in the region. Several alternative scenarios will be developed and analyzed with respect to compliance with the national standards, health impacts, and their cost-effectiveness to achieve given limits. The Stage 1 research efforts have relied on national database and Integrated Assessment Models (IAMs), such as GUIDE, METER, and ABaCAS. The assumptions, data, and results in Sate 2, however, will be documented and made available via publicly accessible tools, e.g., the GAINS model and IIASA Scenario Explorer. **Contracted (IIASA) amount: EUR** 385,700 **Groups:** PM, IACC
ARIADNE (multi-phase) Evidence-based assessment for the design of the German energy transition **Duration:** 2020-2026 **Funder:** Deutsches Bundesministerium für Bildung und Forschung **Website:** https://ariadneprojekt.de/ https://ariadneprojekt.de/en/aspirations-of-ariadne/ **Policy Briefs or other material links:** Scenario Explorer	This project investigates energy transition strategies and their systemic effects as well as sectoral interactions in Germany. Ariadne investigates policy instruments to achieve climate goals efficiently and in a socially balanced manner. And Ariadne evaluates what governance and institutions are needed to create effective climate protection. **Contracted (IIASA) amount:** EUR 176,450 **Contracted (IIASA) amount:** EUR 176,300 **Groups:** IACC
ARTIC-BC EC-Black Carbon in the Arctic **Duration:** 2018 - 2021 **Funder:** European Commission, Service for Foreign Policy Instruments (FPI) **Website:** **https://eua-bca.amap.no/** **Policy Briefs or other material links:** **https://www.amap.no/work-area/document/3544**	The main objective of the action, was “to contribute to the development of collective responses to reduce black carbon emissions in the Arctic and to the reinforcement of international cooperation to protect the Arctic environment.” The man tasks were: develop modelled scenarios for different policy options to reduce BC emissions and establish publicly available datasets for international inventories and projected emissions that affect the Arctic; assess and synthesize BC information and data to identify knowledge gaps, improve source; quantification, and evaluate the climate impacts in the Arctic; develop outreach materials and communicate findings to key stakeholders including policy-makers, with a special focus on efforts to facilitate coordination with the Arctic Council and UN ECE CLRTAP; and outline an indicative roadmap for enhanced international cooperation under a number of key national, regional and global initiatives. **Contracted (IIASA) amount: EUR** 396,589 **Groups:** PM

ASEAN CCAC Strengthening the Case for Action to Address the 1.5°C Challenge **Duration:** 2020 -2021 **Funder:** United Nations Environment Programme (UNEP) **Website:** **Policy Briefs or other material links:** **https://asean.org/wp-content/uploads/2021/10/ASCCR-e-publication-Correction_8-June.pdf**	The activities carried out in this project were: 1) to provide identify priority measures from the 25 Science-based Solutions report on a national basis for the countries in the Association of Southeast Asian Nations (ASEAN); 2) to build a strong technical information base that will support policy and regulatory and investment actions; and 3) to provide reference scenarios and mitigation data and analyses to support CCAC 2030 strategic planning process. **Contracted (IIASA) amount:** EUR 57,522 **Groups:** PM
ASEAN ENV HEALTH Strengthening ASEAN Member State Policies with Environmental Health Data on Costs of Inaction and Co-Benefits **Duration:** 2022 - 2023 **Funder:** United Nations Environment Programme (UNEP) **Website:** https://iiasa.ac.at/policy-briefs/oct-2023/cost-of-inaction-tackling-air-pollution-in-asean-region **Policy Briefs or other material links:** https://pure.iiasa.ac.at/18852	The 2021-2023 Strengthening ASEAN Member State Policies with Environmental Health Data project developed national capacities and facilitate South-South cooperation around the use of data and tools to assess co-benefits and costs of inaction on environmental health issues, with a strong focus on air pollution. These actions supported science-based policy planning and more integrated and inclusive policy interventions in Cambodia, Indonesia and Thailand, and across the ASEAN region, in line with the aims of the Manila Declaration and as an activity under Action Line 3.2.1 of the Plan of Action to Implement the Joint Declaration on Comprehensive Partnership between ASEAN and the United Nations (2021-2025). **Contracted (IIASA) amount:** EUR 76,114 **Groups:** PM
CAO3 Support to the development of the Third Clean Air Outlook **Duration:** 2021-2022 **Funder:** European Commission, DG Environment **Website:** https://environment.ec.europa.eu/publications/third-clean-air-outlook_en **Policy Briefs or other material links:** https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0673R(01)	This contract's objective was mainly to provide analysis supporting the Commission's third Clean Air Outlook report. The analysis performed for this Outlook was also used for the Zero Pollution Monitoring and Outlook Report planned for 2022 and for the preparation of the review of the NEC Directive, due by 2025. Involvement of the Member States experts to jointly review and validate key assumptions and parameters used in modelling was of utmost importance and was achieved through individual consultations with Member States expert teams. **Contracted (IIASA) amount:** EUR 399,895 **Groups:** PM
CAO4 Support to the development of the Fourth Clean Air Outlook **Duration:** 2023-2024 **Funder:** European Commission, DG Environment **Webs** https://environment.ec.europa.eu/topics/air/clean-air-outlook_en **Policy Briefs or other material links:**	The overall objective for this service request is to provide the underlying analysis to support the preparation of the Commission's fourth Clean Air Outlook report. Alongside this, the outputs will also help to inform the Commission's review of the NEC Directive due in 2025. The project covers the following activities: • Up-to-date modelling framework for the analysis. • Updated baseline reflecting the latest policy developments and sectoral changes. • Direct engagement with the Member States on the baseline assumptions. • Development and modelling of a series of policy scenarios and further analysis of the outputs.

	• Assessment of the costs and benefits associated with each scenario. The geographical scope of the analysis will be each EU Member State as well as the EU as a whole. Consideration will need to be made of transboundary pollution within the EU and to and from non-EU neighboring countries. The temporal scope of the analysis will include 2005 as the base year (as set out in the NEC Directive) and modelling for the years 2025, 2030, 2040, and 2050 **Contracted (IIASA) amount:** EUR 235,310 **Groups:** PM
CARES City Air Remote Emission Sensing **Duration:** 2019-2022 **Funder:** EU, Innovation and Networks Executive Agency (INEA) **Website:** https://cares-project.eu/ **Policy Briefs or other material links:**	The overarching objective of CARES was, in line with the 2018-2020 Mobility for Growth Call, to offer cities and regional and national authorities "improved tools and mechanisms for monitoring and detection of emissions from road vehicles" and provide "evidence of long term impacts of the current developments" of road transport combustion engine technologies. **Contracted (IIASA) amount:** EUR 122,275 **Groups:** PM
CATALYSE Climate Action to Advance HeaLthY Societies in Europe **Duration:** 2022-2027 **Funder:** EC, Horizon Europe **Website:** https://catalysehorizon.eu/ **Policy Briefs or other material links:** https://catalysehorizon.eu/publications/	The overall objective of CATALYSE is to provide new knowledge, data, and innovative tools on: i) the relationships between changes in environmental hazards caused by climate change, ecosystems, and human health; ii) the health co-benefits of climate action; iii) the role of health evidence in decision making; and iv) the societal implications of climate change for health systems**.** ECE/PM will develop policy-relevant scenarios through 2050 of mitigation actions outside of the health sector and their corresponding emissions (GHGs, air pollutants) and impacts on ecosystems (acidification, eutrophication damage to vegetation evaluated in terms of exceedance of critical loads) and the economy. The EUCLIMIT modelling suite used by the EC will be used to generate coherent projections. **Contracted (IIASA) amount:** EUR 721,180 **Groups:** PM
CIAM Centre for Integrated Assessment Modelling – for negotiations under the Convention on long-range Transboundary Air Pollution (LRTAP) **Duration:** since 1999 to 2024 (ongoing) **Funder:** United Nations Economic Commission for Europe (UNECE) and Norwegian Meteorological Institute **Website:** https://iiasa.ac.at/projects/integrated-assessment-modelling-for-negotiations-under-convention-on-long-range **Policy Briefs or other material links:**	Since 1999 IIASA has been hosting the Centre for Integrated Assessment Modelling (CIAM), one of the four centres assigned for the European Monitoring and Evaluation Programme (EMEP) of the Convention on Long-range Transboundary Air Pollution. CIAM prepares technical background material for the annual meetings of the Task Force on Integrated Assessment Modelling (TFIAM). The Task Force brings together information gathered from the Parties and from other Convention bodies on cost-effective emission control strategies. Its regular reports to the negotiating bodies of the Convention assist - through computer models - in the development of legal instruments (protocols). **Contracted amount (2021-2024):** EUR 750,000 **Groups:** PM

https://unece.org/sites/default/files/2024-05/TFIAM-CIAM%20GP%20review%20item-3_new.pdf	
CircEUlar Developing circular pathways for a EU low-carbon transition **Duration:** 2022-2026 **Funder:** EC, Horizon Europe, Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation UKRI **Website:** https://circeular.org/ **Policy Briefs or other material links:** Publications, Datasets, and Softwares	The goal of the CircEUlar Project is to understand the potential of circular economy strategies for reducing greenhouse gas emissions and achieving the EU's net zero emissions target by 2050. The project will address circularity and related impacts on emissions from a systems perspective, taking into account different levers for change, such as dematerialization and the transition to a service-based economy to limit material stock growth, extending the lifetimes of products via repair, maintenance, and reuse, and reducing waste while increasing recycling. **Contracted (IIASA) amount:** EUR 918,495 *ECE Consortium Lead 4,495,434 Total grant **Groups:** IACC, S3, PM, TISS
COMMITTED Enhanced sharing of good practices on greenhouse gas emissions modelling between EU and Asian countries **Duration:** 2023-2026 **Funder:** EC DG Clima **Website:** **https://iiasa.ac.at/projects/committed** **Policy Briefs or other material links:** https://www.elevate-climate.org/committed	**C**OMMITTED is an international project funded by the European Commission's Directorate on Climate (DG CLIMA). The project aims to enhance sharing of good practices on greenhouse gas emissions modelling between EU and Asian countries. The Consortium comprises major global integrated assessment modelling teams as well as institutions from major Asian economies. **Contracted (IIASA) amount:** EUR 163,861 **Groups:** IACC
CSCI Climate Scenario Compass Initiative **Duration**: 2024-2026 **Funder**: Bezos Earth Fund	Led by the International Institute of Applied Systems Analysis (IIASA) and Utrecht University (UU), this project will bring together leading organizations from the global scenarios community to make the thousands of scenarios now in circulation more usable and accessible. The project will create a database with a user-friendly interface and dashboard that will allow users to input and compare scenarios. The project will rely on the best researchers to come up with scientifically grounded criteria for categorizing scenarios. And the project will bring these researchers together with influential scenario users (e.g., Systems Change Lab [SCL], Climate Action Tracker [CAT], Science Based Targets Initiative [SBTI]) to collaboratively design the interface and assessment criteria. **Contracted (IIASA) amount:** 800,000 *ECE Consortium Lead: 2,284,666 **Groups**: IACC, S3, TISS
CUSSH Complex Urban Systems for Sustainability and Health **Duration:** 2018–2023 **Funder:** Welcome Trust **Website:** https://projectcussh.org/	Key global research on the systems that connect urban development and population health. Since 2018, CUSSH has worked with thirteen partner organizations across four continents to help cities develop in ways which improve population health and environmental sustainability. In each of six cities London (UK), Rennes (France), Kisumu and Nairobi (Kenya), and Beijing and Ningbo (China) its work

Policy Briefs or other material links: https://www.ucl.ac.uk/complex-urban-systems/cussh	focuses both on local priorities and city-scale actions aligned with planetary health. **Contracted (IIASA) amount:** EUR 404,906 **Groups:** PM
DATNEA Data input for study on benefits of air quality improvements in North East Asia **Duration:** 2020–2021 **Funder:** Organization for Economic Co-operation and Development (OECD) **Website:** **Policy Briefs or other material links:**	Providing data and information on emission projections for scenarios with different technological developments, including data on projected activity levels and policy costs as well as detailed pollutant concentration maps, based on the GAINS model. Which contributed to the quantitative analysis of benefits of air quality improvements in North East Asia, based on the ENV-Linkages model. The detailed information was also fed into the OECD report on integrated benefits of policy action in North East Asia. **Contracted (IIASA) amount:** EUR 50,000 **Groups:** PM
DG-GROW Analysis of Life-cycle Greenhouse Gas Emissions and Removals of EU Buildings and Construction **Duration:** 2023-2025 **Funder:** European Commission, DG for Internal Market, Industry, Entrepreneurship and SMEs **Website:** https://c.ramboll.com/life-cycle-emissions-of-eu-building-and-construction **Policy Briefs or other material links:**	This project models the whole life carbon impact of the EU building stock and the associated construction, renovation and demolition activity on emissions and carbon removals. We assess and compare strategies for whole life carbon emissions reduction and removal, within the perspective of reaching climate neutrality and resilience in 2050. This study further contributes to improving the availability of data to assess the whole life carbon impact of the EU building stock. **Contracted (IIASA) amount:** EUR 64,000 **Groups:** S3
ECEMF European Climate and Energy Modelling Forum **Duration:** 2021–2025 **Funder:** EC, Horizon 2020, Research and Innovation (RIA) **Website:** https://www.ecemf.eu/ **Policy Briefs or other material links:** ECEMF Policy Brief: Insights on EU2040 targets; Publications; Insights – engagement focused analysis: here & here; ECEMP Platform; Scenario database; Future-Sight – the ECEMF data visualization tool	The ECEMF will create a closer, stronger, European modelling community. The forum will improve collaboration beyond Europe, which will lead to a greater influence on global energy and climate policy. The aim is to inform future energy and climate policies at national and European level, especially the European Green Deal and the transformation to a climate-neutral society, and present a more coherent, unified evidence base that will, in turn, form a concrete basis for action by policy makers. **Contracted (IIASA) amount:** EUR 584,812 **Groups:** IACC, S3, TISS
ECMG Earth Commission Modeling Working Group **Duration:** 2020–2024 **Funder:** Rockefeller Philanthropy Advisors **Website:** **https://earthcommission.org/earth-and-human-systems-modelling/** **Policy Briefs or other material links:**	The work of the Earth Commission provides a unified and integrated agenda for transformation toward a safe and just future for the people and the planet including the translation into local action by cities and the private sector. Working Group 1 identifies, assesses and models key interactions that regulate the state of the planetary (i.e., the physical climate system, the cryosphere, oceans, terrestrial biosphere systems, cycles of water, nutrients and carbon), and human systems. This informs setting targets for a stable and safe planet and helps us in developing and understanding pathways that are compatible with these targets.

	Contracted (IIASA) amount: EUR 187,794 **Contracted (IIASA) amount:** EUR 178,645 **Contracted (IIASA) amount:** EUR 121,243 **Groups:** TISS, IACC
EDITS (multi-year) Energy Demand changes Induced by Technological and Social innovations **Duration:** 2010–2024 **Funder:** Research Institute of Innovative Technology for the earth (RITE) and Ministry of Economy, Trade, and Industry (METI), Japan **Website:** https://iiasa.ac.at/projects/edits **Policy Briefs or other material links:**	IIASA coordinates the EDITS project together with RITE (Japan). EDITS focuses on increasing the evidence base for Low Energy Demand (LED) scenarios, based on IIASA's published 2018 example in Nature Energy (Grubler et al. 2018). EDITS aims to create, improve and assess Low Energy Demand scenarios across all sectors and geographic levels. **Contracted (IIASA) amount V:** EUR 250,000 **Contracted (IIASA) amount IV:** EUR 240,941 **Contracted (IIASA) amount III:** EUR 275,848 **Contracted (IIASA) amount II:** EUR 298,520 **Contracted (IIASA) amount I:** EUR 263,399 **Groups:** IACC, S3, TISS
EFC (multi-phase) China's carbon neutrality pathways **Duration:** 2021–2022 and 2023-2024 **Funder:** Energy Foundation China, The China Sustainable Energy Program **Website:** N/A **Policy Briefs or other material links:** https://www.efchina.org/Reports-en/report-snp-20221104-en, https://iiasa.ac.at/events/nov-2022/iiasa-ece-scientists-at-ecf-cop27-side-event-on-electrification-in-chinas-carbon	A series of multi-institution synthesis reports that assess China's carbon neutrality transition provides an overview of China's new policies and energy and emissions trends since 2020 and an updated understanding of the country's pathways toward carbon neutrality. IIASA's main activates include: 1) develop two 2060 net-zero scenarios for China with different carbon emission peak time with MESSAGEix-GLOBIOM; 2) provide and maintain the online CMIN (Chinese Model Intercomparison) scenario database to host the scenario data from all involved modeling teams in this project; 3) contribute to the writing of this year's Synthesis Report on electrification, mainly for the Chapter of electrification roadmap of building sector; 4) conduct the deep-dive analysis on sectoral links of building and industry sectors based on certain newly developed features of the MESSAGEix-GLOBIOM IAM model. **Contracted (IIASA) amount (2021-22):** EUR 94,698 **Contracted (IIASA) amount (2023-24):** EUR 102,635 **Groups:** IACC, S3
EHSMIP Earth and Human Systems Modelling Intercomparison Project **Duration**: 2023-2024 **Funder**: Future Earth Sweden **Website:** https://iiasa.ac.at/projects/earth-commission https://earthcommission.org/earth-and-human-systems-modelling/ **Policy Briefs or other material links:** https://tippingpointsseries.confetti.events/	Ongoing contributions and general support to the overall goals of the Earth Commission (EC) of the Global Commons Alliance since its inception. This includes co-hosting the scientific secretariat of Working Group 1 on the Earth and Human System Modelling Inter-comparison Project, organizing the Tipping Points Webinar series, writing and reviewing of scientific publications and reports initiated under EC 1.0, and engaging with the EC community and wider scientific network to develop EC 2.0 The scope of work under this collaboration will contribute to providing scientific and administrative support to the Earth Commission and the specific objectives. **Contracted (IIASA) amount:** EUR 138,515 **Groups:** TISS, IACC

ELEVATE Enabling and Leveraging Climate Action Towards Netzero Emissions **Duration:** 2022–2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://iiasa.ac.at/projects/elevate **Policy Briefs or other material links:** https://www.elevate-climate.org/	Current policies are still insufficient to reach the Paris Agreement targets. ELEVATE aims to create a robust scientific understanding required to strengthen NDCs and current national climate policies focused on achieving net-zero emissions mid-century in line with the Paris Agreement. As part of the ELEVATE project, the ECE program leads the work on Justice, Equity and Just Transition scenarios. ECE also studies national climate policies through a feasibility lens, assesses national climate policy impacts on IAM scenarios, and develops scenarios for the trade of emission allowances. **Contracted (IIASA) amount:** EUR 588,750 **Groups:** IACC, S3, TISS
EMERGE Evaluation, control and Mitigation of the EnviRonmental impacts of shipping **Duration:** 2020–2024 **Funder:** European Commission, DG Executive Agency for Small and Medium-sized Enterprises (EASME) **Website:** https://emerge-h2020.eu/ **Policy Briefs or other material links:** https://emerge-h2020.eu/publications/	EMERGE systematically analyzes the complex interactions between technological options, pollutant emissions and dispersion, and environment. It carries out measurements and modelling on actual vessels, along main shipping routes and in sensitive European marine regions. Measurements focus on abatement techniques and include emissions to, and concentrations in water, air and marine biota. **Contracted (IIASA) amount:** EUR 399,750 **Groups:** PM
ENGAGE Exploring National and Global Actions to reduce Greenhouse gas Emissions **Duration**: 2019–2023 **Funder**: EC, Horizon 2020 **Website**: http://www.engage-climate.org/ **Policy Briefs or other material links:** *Policy briefs* ENGAGE Summary for Policymakers (Chinese; Indonesian; Portuguese; Korean); Stakeholder engagement in climate change solutions; Feasible futures; Promising climate progress; A fair climate; Finding a feasible path; Avoiding overshoot: why and how; United scenarios; Scenario ensembles and database resources; Download ENGAGE Publications	IIASA coordinated this 30-partner global project to develop a new generation of co-produced global and national decarbonization pathways and new methods to assess feasibility of mitigation scenarios. The pathways were designed on characteristics of the Paris agreement, included multidimensional feasibility limitations and had a special emphasis on avoided impacts of climate change and the co-benefits and trade-offs of climate policy **Contracted (IIASA) amount:** EUR 1,267,418 *ECE Consortium Lead EUR 7,089,831 total grant **Groups:** IACC, PM, S3, TISS, IBF

ESM2025 Earth System Models for the Future **Duration:** 2021–2025 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://www.esm2025.eu/ **Policy Briefs or other material links:** Publications; Tools & Data; Research Highlights; *Policy Briefings & Reports:* Science-to-Policy Briefing #1 & Science-to-Policy Briefing #2; Climate Research Network; Educational Resources; Climate Education Summer Universities (CESU) workshops	ESM2025 aims to develop the next generation of Earth System Models (ESMs), providing relevant climate simulations for the development of ambitious and realistic mitigation and adaptation strategies in line with the Paris Agreement. The project will also improve the consistency between ESMs and Integrated Assessment Models (IAMs) and thus better represent the full Earth system response to anthropogenic emissions and treatment of human land use change in the ESMs. **Contracted (IIASA) amount:** EUR 438,750 **Groups:** IACC
EU4Green-WB Support the implementation of the Green Agenda for the Western Balkans **Duration:** 2023 – 2024 **Funder:** EU, DG for Neighborhood and Enlargement Negotiations (NEAR) **Website:** https://eu4green.eu/ **Policy Briefs or other material links:** https://www.umweltbundesamt.at/en/news220617en	The Project EU4Green aims to support the Western Balkan economies in implementing the Green Agenda, the EU's regional strategic roadmap against the climate crisis, and to initiate the corresponding reforms. Within the EU4Green project, concrete plans for the implementation of the Green Agenda, the authorities in the partner countries and national representatives from industry and civil society will be developed. **Contracted (IIASA) amount:** EUR 60,000 **Groups:** PM
EUCDs EU Climate Dialogues (India) **Duration:** 2023-2024 **Funder:** Deutsche Gesellschaft für International Zusammenarbeit (GIZ) GmbH	The EU Climate Dialogues (EUCDs) project funded by EU's Foreign Policy Instruments (FPI) and led by DG CLIMA of the European Commission (i) facilitates exchanges on climate policy options, expertise, success stories and good practices between the EU and non-EU major economies, (ii) advances bilateral trade, investment and innovation in pursuit of the goals of the Paris Agreement, and (iii) contribute to improving public awareness of challenges and opportunities associated with the implementation of the Paris Agreement. As part of this activity, IIASA jointly with the JRC supports low carbon modeling and a series of four technical exchanges, outreach and training sessions with Indian modeling teams. **Contracted (IIASA) amount:** EUR 101,358 **Groups:** IACC, IBF
EUCLIMIT VI Model based Assessment of EU Climate Policies **Duration:** 2021 – 2023 **Funder:** EU - DG CLIMA **Website:** https://iiasa.ac.at/news/aug-2021/iiasa-science-supports-european-green-deal **Policy Briefs or other material links:**	The EUCLIMIT modelling suite is operated by E3-Modelling, IIASA and EuroCARE and is used extensively over the years to support the preparation of Impact Assessments underpinning key EU energy and climate legislation. Full expansion of the EU established modelling suite in the Energy Community will help institutionalize the national modelling capacity of Contracting Parties, increase harmonization, promote regional coordination, and ultimately facilitate alignment with EU climate and energy goals towards 2030 and beyond.

https://www.researchgate.net/figure/The-integrated-modelling-network-in-EUCLIMIT-source-euclimiteu_fig1_312626206	**Contracted (IIASA) amount:** EUR 176,500 **Groups:** PM
EUCLIMIT VII EU GHG modelling for beyond 2030 **Duration:** 2024 – 2025 **Funder:** EU - DG CLIMA **Website:** https://iiasa.ac.at/news/aug-2021/iiasa-science-supports-european-green-deal **Policy Briefs or other material links:**	The general objective of this project is to make state-of-the-art, quantitative modelling tools available to the Commission and to apply these in the context of EU climate policy, to analyze scenarios and policy options to assess economic, environmental and social implications for the EU at economy-wide level. IIASA's Pollution Management (PM) group will contribute by developing baseline emission scenarios for non-CO2 GHGs (CH4, N2O, HFCs, PFCs, SF6, and NF3) and air pollutants (NOx, SO2, PM2.5-10, NH3, BC/OC, VOC) using a consistent methodological approach across all member states. Under this approach, activity data is coupled with country-, source-, and technology- specific emission factors collected from various published sources, as well as with application rates for different control technologies, to arrive at source-specific annual emission estimates for each country. **Contracted (IIASA ECE/PM) amount:** EUR 176,500 Groups: PM
EUCLIMIT-9EAST Extension of the EU Energy and Climate Modelling Capacity to include the Energy Community and its Nine Contracting Parties **Duration:** 2021–2022 **Funder:** European Commission, DG Energy **Website:** **Policy Briefs or other material links**	To make available modelling capacity to produce long-term quantitative projections for the energy system, its greenhouse gas emissions, and non-energy GHG emissions for the Energy Community countries. And to Use the modelling capacity to develop consistently a baseline and a series of alternative scenarios to examine different methodologies and set-ups for possibly 2030 energy efficiency, renewables and GHG emissions reduction targets for the CPs (non-EU contracting Parties) individually and as a group. The scenarios should further be used in the governance process for the NECPs of the nine CPs. **Contracted (IIASA) amount:** EUR 79,500 **Groups:** PM
EYE-CLIMA Verifying Emissions of Climate Forcers **Duration:** 2023–2026 **Funder:** EC, Horizon Europe **Website:** https://eyeclima.eu/ **Policy Briefs or other material links:** First EYE-CLIMA Outlook; Publications; Datasets	EYE-CLIMA will address the need for independent verification of NGHGIs by developing top-down methods based on atmospheric inversion (using both satellite remote sensing and ground-based observations) to a level of readiness where they can be used to determine emissions at national and sub-national scales and be incorporated into NGHGIs. In addition, EYE-CLIMA will work closely together with NGHGI compilers. **Contracted (IIASA) amount:** EUR 230,000 **Groups:** PM, IACC
FORCeS Constrained aerosol forcing for improved climate projections **Duration:**2019 - 2024 **Funder:** EC, Research & Innovation (RIA) **Website: https://forces-project.eu/** **Policy Briefs or other material links:**	The overall objective of FORCeS is to understand and reduce the long-standing uncertainty in anthropogenic aerosol radiative forcing, which is crucial in order to increase confidence in climate projections. The process analysis within FORCeS will be conducted with the overall aim of improving a set of leading European climate models, which all provide essential information to climate assessments such as the IPCC report.

https://forces-project.eu/publications/	**Contracted (IIASA) amount:** EUR 50,757
GAINS-China GAINS-China: Service Contract for Greenhouse Gas Air Pollution Interactions and Synergies China on a BUAA server **Duration:** 2019–2025 **Funder:** Beihang University (BUAA) **Website:** **Policy Briefs or other material links:**	Developing and maintaining the GAINS-China interface software based on the existing source code of GAINS-China. The software and related database will be implemented on the Beihang University (BUAA), allowing BUAA to define groups of users. **Contracted (IIASA) amount:** EUR 100,000 **Groups:** PM
GAINS-IGP Technical Assistance to the Air Quality Management Modelling project in the Indo-Gangetic Plain **Duration:** 2020–2022 **Funder:** The World Bank **Website:** **Policy Briefs or other material links:** https://www.worldbank.org/en/region/sar/publication/striving-for-clean-air	To support the creation of the AQMmod (Air Quality Management modelling) project, by providing internationally proven scientific methods and relevant modelling tools that enable the development of cost-effective policy response strategies, and to tailor them to the specific needs in the IGP states (Punjab, Chandigarh Union territory (UT), Haryana, Uttar Pradesh, Bihar, Jharkhand and West Bengal). The AQMmod project brought together results from ambient air quality monitoring (AAQM) and source apportionment studies, emission inventories, receptor modeling and dispersion modeling performed under other contracts in the states/UT in the IGP region. **Contracted (IIASA) amount:** EUR 172,762 **Groups:** PM
GCF-CRR Climate-related risks and mitigation measures **Duration:** 2019–2021 **Funder:** Green Climate Fund **Website:** https://climateanalytics.org/projects/gcf-country-programme **Policy Briefs or other material links:** https://iiasa.ac.at/options-magazine/summer-2021/understanding-impacts-of-climate-change	To address the identified shortcomings of the Green Climate Fund's Country Programme processes and to maximise the robustness and usefulness of Country Programmes for the Fund and the various stakeholders, the partners of the consortium supported developing countries during the entire spectrum of activities required to develop and improve their country programme. IIASA and its partners Climate Analytics and CCAP worked with Chile, Mexico, Nicaragua, Uzbekistan, The Solomon Islands, Kiribati, Ghana, Lebanon and Malaysia. Each country chose their priorities out of a list of suggested services ranging from Climate Change Data Management, Vulnerability Analysis, Development of Economic Risk Profiles to Emission Pathway scenarios and Finance Mapping. **Contracted (IIASA) amount:** EUR 163,631 **Groups:** IACC
GEIDCO Typical Mode and Quantitative Study of Carbon-based Resource Cycle under Global Energy Interconnection 1.5°C (GEI1.5C) Scenario **Duration:** 2019-2024 **Funder:** Global Energy Interconnection Development Company (GEIDCO) **Website:** https://en.geidco.org.cn/ **Policy Briefs or other material links:** https://pure.iiasa.ac.at/id/eprint/17487/, Guo et al. (2022)	In this series of projects, IIASA works with the Global Energy Interconnection Development Company (GEIDCO), a subsidiary of China State Grid, to analyze the role of Ultra-High-Voltage, long-distance, transmission lines in the global energy system. **Contracted (IIASA) amount:** EUR 159,525 **Groups:** S3, IACC, PM

GENIE GeoEngineering and NegatIve Emissions pathways in Europe **Duration:** 2021–2027 **Funder:** European Commission, DG European Research Council Executive Agency (ERCEA) **Website:** https://genie.ece.iiasa.ac.at/ **Policy Briefs or other material links:** Publications; Media mentions and press releases; Leaflet – project summary	The path to climate neutrality needs to explicitly consider the roles of solar geoengineering and negative emissions technologies. A meta-analytical framework where social science, engineering, and physical science disciplines merge is necessary for a comprehensive mapping of this transition. The EU-funded GENIE project will explore the environmental, technical, social, legal, ethical and policy dimensions of greenhouse gas removal and solar radiation management. GENIE aims to produce a comprehensive scientific assessment for evidence-based policymaking to address climate change, and to expand our toolkit for a zero-emissions future. Geoengineering technologies, such as solar radiation management (SRM), and negative emissions technologies, such as greenhouse gas removal (GGR), are emerging options to address climate change. This project will investigate the environmental, technical, social, legal, and policy dimensions of GGR and SRM. We provide an urgently needed interdisciplinary and holistic perspective of these technologies in order to understand conditions under which they might be deployed at scale. Our meta-analytical framework integrates insights from social science, engineering and physical science disciplines to provide a comprehensive view of GGR and SRM in the transition to climate neutrality in Europe and the world. The project will conduct excellent research and generate a robust, scientific assessment for evidence-based policymaking. **Contracted (IIASA) amount:** EUR 2,846,494 **Groups:** IACC, S3, TISS, ICI
GUIDE (multi-year) Development of a global integrated assessment modeling system for climate-air pollutants management focused on Northeast Asia (II) **Duration:** 2022 – 2024 **Funder:** Industry-Academic Cooperation Foundation of Konkuk University **Website:** https://iiasa.ac.at/projects/guide **Policy Briefs or other material links:** https://iiasa.ac.at/events/nov-2022/guide-global-project-international-workshop	The GUIDE project will develop a global MESSAGEix-GAINS model for climate-air pollutant assessment and management, with a focus on Northeast Asia. Joint work between Konkuk University and IIASA will be conducted on harmonizing common elements of IAM design to enable a comparison of scenario results between the GUIDE-Global/Local and MESSAGEix-GAINS modeling framework and, by extension, to similar analysis conducted by other researchers. The multiple-scale development and implementation of the updated and newly developed tools in the project, will allow to work with regionalized SSPs reflecting better the local situation and providing results and insights more directly related to local and regional policy actors. The results will help future air quality policy implementation. **Contracted (IIASA) amount:** EUR 195,000 (yearly) **Groups:** PM, IACC, S3

iDesignRES Integrated Design of the Components of the Energy System to Plan the Uptake of Renewable Energy Sources: An Open Source Toolbox **Duration:** 2021-2027 **Funder: E**uropean Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://iiasa.ac.at/projects/idesignres **Policy Briefs or other material links:**	The project develops optimised open-source tools for comprehensive energy system modelling (representing long term planning and short-term operations), and on creating dynamic multi-physics models. These models will be applied to empower network operators and public authorities with user-friendly visualisation tools for long-term multi-carrier grid planning. These state-of-the-art models are validated through diverse European use cases together with local industrial partners to develop scenarios for a sustainable and efficient energy future. **Contracted (IIASA) amount:** EUR 339,687 **Groups:** IACC
Imp_DroP I*mpact of longer Drought Periods on Climate in Greater Vienna: appropriate Mitigation measures* **Duration:** 2023-2024 **Funder:** Austrian Climate Research Program (ACRP) **Website:** **Policy Briefs or other material links:**	In this project, IIASA is a partner of BOKU, Vienna, to provide local climate analysis and advice to the city of Vienna and explore the potential effects of greening and irrigation on the city climate. **Contracted (IIASA) amount:** EUR 53,068 **Groups:** S3
INMS CWI-UefcNEP Global Nitrogen Cycle Towards INMS **Duration:** 2017 - 2023 **Funder:** United Nations Environment Programme (UNEP) **Website:** https://www.inms.international/ **Policy Briefs or other material links:** https://www.inms.international/reports	To improve the global/region N cycle understanding and investigate/test practices and management policies at the regional, national and local levels to reduce negative impacts of reactive nitrogen on the ecosystems. The PM Group contributed by developing indicators for assessing full N budgets, use, levels and impacts, including N use efficiency and benchmarking; approach to using existing N flux/pathway models for regional assessments and visualization for potential scenarios to assist with development and reduction strategies; and definition of programmes and policy options for improved Nr management at local/regional/global levels, supported by cost-benefit analysis to underpin options for the Green Economy **Contracted (IIASA) amount:** EUR 178,214 **Groups:** PM
KIS- Graz Klimainformationssystem der Stadt Graz **Duration:** 2023-2025 **Funder:** Climate Innovation City Graz **Website:** KIS **Policy Briefs or other material links:**	The KIS records climatic factors in order to create a sound planning basis and support sustainable planning. KIS provides comprehensive, current and high-quality basic data on temperature, precipitation and wind provides a dense network of measuring stations develops new methods for modeling and simulation creates climate scenarios for Graz and the surrounding area covers large parts of the Styrian central area draws attention to the health aspects of climate change. **Contracted (IIASA) amount:** EUR 114,500 **Groups:** S3
LEAP-RE Long-Term Joint European Union – African Union Research and Innovation Partnership on Renewable Energy	LEAP-RE is a joint initiative of the European Union and African Union to advance the cooperation in research and innovation actions on renewable energy with the RE4AFAGRI project. LEAP-RE - RE4AFAGRI aims at

Duration: 2021–2025 **Funder:** EC, Horizon 2020 **Website:** **https://iiasa.ac.at/projects/leap-re** https://www.leap-re.eu/ **RE4AFAGRI:** https://www.re4afagri.africa/ **Policy Briefs or other material links:** Reports; Publications; Communication materials (press releases, newsletters, media mentions); Data, Code, Documentation, Online Training Videos and Materials	developing the state of the art of climate-water-energy – land-food-environment nexus modeling in rural areas of developing countries to bridge the current gap between large-scale and local-scale analysis approaches. The project aims to provide a set of open-source validated tools developed through analytical and empirical approaches that can be exploited by stakeholders in future applications. In addition, LEAP-RE - RE4AFAGRI aims to design business models that allow the implementation of integrated technological solutions in rural areas, based on identified best practices, regulatory obstacles and opportunities through the participation of African companies, public authorities and consortia of small owners. The ultimate goal is to support policy makers in defining policy frameworks that ensure that the identified business models can be successfully implemented by local entrepreneurs, while also meeting the technical and environmental requirements to achieve development goals in rural areas. **Contracted (IIASA) amount:** EUR 204,781 **Groups:** IACC
LOW-AI Data-driven understanding of low-carbon lifestyles **Duration:** 2023-2025 **Funder:** Office of Naval Research Global **Website:** **https://iiasa.ac.at/projects/low-ai** **Policy Briefs or other material links:**	The project Data-driven understanding of low-carbon lifestyles (LOW-AI) aims at using social media data to understand behavior change with respect to low-carbon lifestyles. In order to limit global warming to a safe level of 1.5℃, individual action is required. LOW-AI deploys social media data to monitor lifestyle changes and attitudes towards lifestyle changes in the global population, developing tools that can be implemented with a higher geographical reach and are less costly than traditional approaches. **Contracted (IIASA) amount: EUR** 317,840 **Groups:** S3
MAPEHP Modelling Air Pollution Control and Environmental Health Perspectives under the Green and Low Carbon Transition of Global Energy System **Duration:** 2021–2021 **Funder:** Global Energy Interconnection Development and Cooperation Organization **Website:** **Policy Briefs or other material links:**	Analyzed the relationships between energy, environmental pollution and public health (including the related co-benefits and trade-offs), based on the literature review and assessed the co-benefits between energy transition, air pollution and environment health effects across globe, under different scenarios developed in this project. **Contracted (IIASA) amount:** EUR 155,699 **Groups:** PM
MICAT Multiple Impacts CAlculations Tooll **Duration:** 2020 – 2023 **Funder:** European Commission, DG Executive Agency for Small and Medium-sized Enterprises (EASME) **Website:** **https://iiasa.ac.at/projects/micat** **Policy Briefs or other material links:** **https://app.micatool.eu/**	The project developed a comprehensive approach to estimate Multiple Impacts of Energy Efficiency (MI-EE) by co-creating a free, easy-to-use, scientifically sound online tool (MICATool). The MICATool enable holistic analyses of MI-EE at the European, national and local levels to strengthen the climate strategy of the Energy Union and accelerate an affordable and just sustainable energy transition. **Contracted (IIASA) amount:** EUR 145,588 **Groups:** PM

MOLDOVA Advisory services to the Republic of Moldova on developing emission projections and emission reduction. **Duration:** 2023 – 2024 **Funder:** United Nations Economic Commission for Europe (UNECE) **Website:** **https://iiasa.ac.at/events/nov-2023/gains-workshop-for-eecca-countries** https://unece.org/environmental-policy/events/subregional-workshop-gains-model-eecca-countries **Policy Briefs or other material links:** http://gains.iiasa.ac.at/EECCA/	Assisting EECCA countries in developing emission projections, estimating base year emissions and emission reduction targets for 2020 and beyond. For which EECCA countries received in-depth training on the GAINS model, worked with their country data and thus improved capacity at national level to work with the model. This will help them in developing emission projections and setting their emission reduction targets for 2020 and beyond, which is a necessary step in the ratification process for the Gothenburg Protocol. **Contracted (IIASA) amount:** EUR 66,400 **Groups**: PM
NAVIGATE Next generation of AdVanced InteGrated Assessment modeling to support climaTE policy making **Duration:** 2019-2023 **Funder:** European Commission, DG Executive Agency for Small and Medium-sized Enterprises (EASME) **Website:** https://iiasa.ac.at/projects/navigate https://www.navigate-h2020.eu/navigator/use/ **Publications:** IIASA Pure	NAVIGATE will critically improve the capability of Integrated Assessment Models (IAMs) to inform the design and evaluation of climate policies by targeting major advancements in two areas: describing transformative change in the economy, in technology and in consumer goods and services, and describing distributional impacts of climate change and climate policy. By tackling existing weaknesses and lack of capabilities of the current generation of IAMs, NAVIGATE will provide new insight into how long-term climate goals can translate into short-term policy action, and how countries and sectors can work in concert to implement the Paris Agreement. IIASA leads the work on energy demand in the NAVIGATE project and works on improving the representation of energy demand modeling for the buildings and transport sectors in the MESSAGEix-GLOBIOM framework. We also work to improve the modeling frameworks for energy-water-land nexus research and the tools to explore synergies and trade-offs between mitigation and the Sustainable Development Goals. **Contracted (IIASA) amount:** EUR 611,354 **Groups:** S3, IACC, TISS, PM, IBF
NetZero2040 NetZero2040 **Duration:** 2021–2023 **Funder:** Austrian Climate Research Program (ACRP) **Website:** **https://iiasa.ac.at/projects/netzero2040** **https://www.netzero2040.at/** **Policy Briefs or other material links:** **https://www.netzero2040.at/publikationen**	The NetZero2040 project developed a set of comprehensive and consistent alternative emission pathways that can ensure reaching the Austrian 2040 climate target. These scenarios integrate the development of the energy system, energy imports and the energy demand sectors, such as buildings, mobility, food, etc. **Contracted (IIASA) amount:** EUR 59,009 **Groups:** IACC, TISS
NGFS (multiyear) Modeling work to support the NGFS **Duration:** 2020–2024 **Funder:** ClimateWorks Foundation	In April 2019, the Network for Greening the Financial System (NGFS) has outlined a scenario framework for central banks and supervisors, combining climate change transition risks and physical risks. Through these subsequent projects a

Website: https://www.ngfs.net/ngfs-scenarios-portal/ **Policy Briefs or other material links:**	scientific consortium including IIASA developed bespoke climate scenarios for financial risk analysis, including downscaling to the country level and macro-economic assessment, and annual updates and releases. **Contracted (IIASA) amount:** EUR 55,981.20 (24-138) **Contracted (IIASA) amount:** EUR 432,916 (21-176 contract) **Contracted (IIASA) amount:** EUR 186,000 (20-137 contract) **Groups:** S3, IACC, TISS
Non-CO2 JRC Non-CO2 Greenhouse Gas emissions and emission reduction potentials associated. **Duration:** 2021–2022 **Funder:** Commission of the European Communities, Directorate General Joint Research Centre (JRC) **Website:** **Policy Briefs or other material links:**	The comprehensive modelling of climate change mitigation scenarios in POTEnCIA required additional information as regards non-CO2 greenhouse gas emissions, their technical mitigation potential and associated costs. This project provided: • Projection over time of baseline non-CO2 GHG emissions that is consistent with the baseline energy scenario of POTEnCIA. • Assessment of additional technical non-CO2 GHG emission reduction potential beyond those achieved under baseline assumptions, • Development of marginal abatement cost curves for non-CO2 GHG emission abatement from a baseline POTEnCIA scenario. These tasks were fulfilled by employing the analytical framework for non-CO2 greenhouse gases included in the Greenhouse gas and Air pollution Interactions and Synergies (GAINS) model. **Contracted (IIASA) amount: EUR** 81,445 **Groups:** PM
OpenEntrance Open ENergy TRANsition ANalyses for a low-Carbon Economy **Duration:** 2019–2023 **Funder:** European Commission, DG Climate Action **Website:** https://iiasa.ac.at/projects/openentrance https://openentrance.eu/about-openentrance/ **Policy Briefs or other material links:**	OpenENTRANCE aimed at developing, using and disseminating an open, transparent and integrated modelling platform for assessing low-carbon transition pathways in Europe. The scenarios and case studies quantify and support the EU's efforts to reduce greenhouse gas emissions to the point of becoming climate neutral by 2050 and prevent the negative and irreversible effects of climate change. This goal includes shifting the energy system to renewable and clean system, as well as technological, behavioural and organisational changes in the economy and society. For doing so, the coordination of relevant technologic solutions, policies, funding and actors, with well-defined targets based on scientific analyses will be required. **Contracted (IIASA) amount:** EUR 368,940 **Groups:** IACC, PM

OpenMod4Africa A global collaboration to empower Africa's energy future **Duration:** 2023–2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://openmod4africa.eu/ **Policy Briefs or other material links:**	The OpenMod4Africa toolbox will provide science-based results to policymakers and local actors, to assist them in achieving a clean energy transition. • Develop an open energy system modelling toolbox tailored for African needs: the OM4A Toolbox • Design and demonstrate capacity building and skills enhancing processes related to energy system modelling and the OM4A Toolbox for African experts • Provide new insights into the possible pathways for the development of the African energy system • Engage African decision-makers and planners to increase their knowledge on how to develop a sustainable, secure and competitive energy system in Africa **Contracted (IIASA) amount:** EUR 121,875 **Groups:** IACC
PRISMA net zero Pathway Research through Integrated aSsessment Model Advancements **Duration:** 1 January 2023 - 31 December 2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://iiasa.ac.at/projects/prisma https://www.net0prisma.eu/ **Policy Briefs or other material links:** Publication	Integrated Assessment Models with their ability to consider complex relationships and provide calibrated numerical results have become ever more important in the last decade. The PRISMA project aims to bring these models to the next level by focusing on four key areas of improvement, namely the representation of distributional justice and efficiency, innovation and finance, climate impacts and land-use implications, and lifestyle change and circularity. In these four key areas we will improve existing large-scale IAMs and sectorial models, and consider the linking of different models where applicable. Two cross-cutting shared themes across these areas are the improvement of the temporal and spatial resolution of the analysis, and the representation of disruptive and structural change in the economy. Notably we will increase the spatial granularity with a focus on Europe, and look at the yearly and in particular near term detailed modeling of rapid decarbonization pathways. **Contracted (IIASA) amount:** EUR 679,375 **Groups:** IACC, S3
PROVIDE Calibration of the OSCAR emulator, simulations and evaluation of the results of overshoot scenarios **Duration:** 2023-2024 **Funder:** French Alternative Energies and Atomic Energy Commission (CEA) **Website:** https://www.cea.fr **Policy Briefs or other material links:**	Subcontract to EU H2020 PROVIDE project (grant #101003687) with CEA (France) as contractor This subcontract's mission is to deliver two new modules for the reduced-complexity Earth system model OSCAR. These modules focus on two key biogeochemical feedbacks: permafrost thaw and wildfires. They are developed following state-of-the-art procedures, to emulate the behavior of complex models whose data is provided by the contractor. They are to be used within the OSCAR model to investigate overshoot scenarios provide by the contractor (and developed within the wider project). **Contracted (IIASA) amount:** EUR 60,006 **Groups:** IACC, EM
PSP	The project conducted a model-based analysis for the UNECE region and explores various pathways for

Pathways to Sustainable Energy - Enhancing understanding of the implications and opportunities of moving to carbon neutrality in the UNECE region across the power and energy intensive industries by 2050 **Duration:** 2021–2022 **Funder:** United Nations Office at Geneva **Website:** **Policy Briefs or other material links:** https://digitallibrary.un.org/record/4025290/files/1386960_EN.pdf	policymakers to attain carbon neutrality by 2050 through technology interplay and to implement the 2030 SDG Agenda. **Contracted (IIASA) amount:** EUR 79,314 **Groups:** IACC
RE-CONNECT Modelling, projecting and tracking emissions reduction pathways **Duration:** 2023–2026 **Funder:** European Commission, DG Climate Action **Website:** https://www.ricardo.com/en/case-studies/re-connect-modelling-projecting-and-tracking-emissions **Policy Briefs or other material links:** N/A	RE-CONNECT brings together leading international experts in modeling and transparency and in-country participants from developed, emerging and developing countries aiming to provide high-quality, scientific analytical support to selected countries needed to design their nationally determined contributions (NDCs) and long-term low-emission development strategies (LT-LEDS) and report on progress towards their commitment under the Paris Agreement. **Contracted (IIASA) amount:** EUR 200,000 **Groups:** IACC
RESCUE Response of the Earth System to overshoot, Climate neUtrality and negative Emissions **Duration:** 2022–2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://www.rescue-climate.eu/ **Policy Briefs or other material links:** Scientific publications; RESCUE Leaflet; Leaflet – Modellers' Workshop 2024; Leaflet – Collaboration Workshop 2023; RESCUE Poster; Climate Classroom: Introduction to Carbon Dioxide Removal (CDR)	The RESCUE (Response of the Earth System to overshoot, Climate neUtrality and negative Emissions) project responds to the urgent necessity of reliable science-based recommendations to inform climate policies for the coming decades. It aims to expand on our understanding of the potential role of both land- and ocean-based carbon dioxide removal (CDR) techniques in future mitigation scenarios. The project will build on previous research and knowledge, including the results of the H2020 projects LANDMARC and OceanNETs. **Contracted (IIASA) amount:** EUR 98,875 Groups: IACC, EM
Scenario Forum **Duration:** 2022 **Funder:** ClimateWorks Foundation **Website:** https://scenariosforum.org/ https://scenariosforum.org/partners-and-sponsors/	By taking stock of recent progress, reflecting on the use of scenarios in environmental assessments and policy-making, and facilitating further scenario-related research, this meeting will inform the use of scenarios in the preparation for the next cycle of IPCC Assessment Reports (AR7) and help ensure a research base sufficient to inform future national and international assessments as well as policy initiatives, including the Sustainable Development Goals (SDGs). **Contracted (IIASA) amount:** USD 100,000 Groups: All of IIASA

SCIL Scoping the Climate Impacts Landscape **Duration:** 2023-2024 **Funder:** ClimateWorks Foundation **Website:** **Policy Briefs or other material links:**	This is a scoping project to map the science landscape on climate impacts and adaptation for the Climate Works foundation with the prospect of developing into a long-term collaboration. It includes an overview report on the current state of impacts research field identifying organization, tools, individuals and events/convenings, and the co-development of a conceptual framework/taxonomy for impacts and adaptation for internal use by Climate Works. **Contracted (IIASA) amount:** EUR 91,768 **Groups:** ICI, IACC
SEED MICAT Support Energy Efficiency Deployment with the Multiple Impacts CAlculation Tool **Duration:** 2023 – 2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://micatool.eu/seed-micat-project-en/ **Policy Briefs or other material links:** **https://micatool.eu/seed-micat-project-en/publications.php**	Based on the MICAT tool, SEED MICAT is "sowing the seeds" for a broad application of the principle. The project extends its MI framework to include renewable energy sources, advocates integrating policy modules, and showcases how it applies at different levels. SEED MICAT also includes replication analysis, capacity building, and a strong dissemination approach to promote knowledge on implementing the EE1 principle. ECE/PM will carry out specific analyses on selected current and upcoming topics of Multiple Impacts of energy efficiency and climate neutrality pathways. **Contracted (IIASA) amount:** EUR 133,637 **Groups:** PM
SHAPE Sustainable development pathways achieving Human well-being while safeguarding the climate And Planet Earth **Duration:** 2019-2023 **Funder:** Austrian Research Promotion Agency (FFG) **Website**: https://iiasa.ac.at/projects/shape https://shape-project.org/ **Policy Briefs or other Materials:**	SHAPE aims to contribute an in-depth analysis of sustainable development pathways (SDPs) that achieve the SDGs in 2030 and maintain sustainable development to reach the Paris climate goals until 2100. It will investigate measures to overcome trade-offs to enable simultaneous achievement of a broad range of sustainable development objectives. The SDPs will be developed using world-leading state-of-the-art integrated assessment models taking climate change as the entry point. They will be combined with regional and global scale analysis of governance challenges, where business and civil society actors now play as significant a role as national governments. Through engagement with diverse SDG action processes, stakeholders will steer the identification of regionally and sector-relevant sustainable development indicators for 2030 and beyond, and refine the usefulness of the SDPs for informing policy processes on multiple scales. **Contracted (IIASA) amount:** EUR 205,172 **Groups:** S3, IACC, TISS
SPARCCLE Socioeconomic Pathways, Adaptation, and Resilience to a Changing CLimate in Europe **Duration:** 2023-2027 **Funder:** EC, Horizon Europe, Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation UKRI **Website:** https://sparccle.eu/	SPARCCLE is a research project that is co-developing modelling tools with policymakers, scientists and civil society to support us all in making better decisions to reduce the risks and build resilience within the society and economy of Europe in the face of climate change. By engaging policymakers, public and private sector stakeholders, and scientific experts throughout the project, SPARCCLE aims to deliver actionable insights and recommendations for policy makers at all levels, businesses, and the civil society based on state-of-the-art science. This involves iterative activities throughout the project lifetime such as co-design of scenarios, validation of results, and

Policy Briefs or other material links: Publications	capacity building. SPARCCLE will co-design Stress Test Scenarios with key stakeholders, to explore high impact components of the socioeconomic risks of climate change in Europe. We will demonstrate and accelerate the application of this established method from the finance community across other sectors. (Stress test scenarios explore the implications of exceptional, yet plausible, changes in risk factors). **Contracted (IIASA) amount:** EUR 875,811 **Groups:** IACC, TISS, S3, SYRR, IBF, MDM *ECE Consortium lead 4,610,787 total grant
SPIPA China Support for the China's long-term low greenhouse gas emission development strategy in the AFOLU sector **Duration:** 2019-2021 **Funder**: European Commission, DG CLIMA **Website**: N/A **Policy Briefs or other materials:**	The project aims to develop and improve modeling tools and develop a "harmonious and beautiful" long-term climate neutral transition pathway for China, which is able to be informative to the development and implementation of long-term low greenhouse gas (GHG) emission strategies under the Paris Agreement. Pathways developed will consider socioeconomic development, energy, climate change, environment, and other important development dimensions, combined with the domestic development needs of the construction of an ecological civilization, green low-carbon sustainable development, and building "a beautiful China" in conjunction with the international requirements for limiting global warming to well below 2°C above pre-industrial levels, while pursuing efforts to stay under 1.5°C, led by the development strategy put forward at the 19th national congress, and in line with Chinese characteristics of the new era of development. **Contracted (IIASA) amount:** EUR 113,584 **Groups:** IACC, S3, TISS, PM, IBF
SPIPA India Joint Modelling Initiative for Preparing Low Carbon Development Scenarios for India up to 2050 **Duration:** 2020–2022 **Funder:** Deutsche Gesellschaft fuer International Zusammenarbeit (GIZ) GmbH **Website:** https://www.cecp-eu.in/resource-center/post/spipa/home **Policy Briefs or other material links:** Report	The overall objective of the project was to support EU-India collaboration on the development of modelling capacities to improve the quality of modelling tools, and integrated modelling analysis frameworks developed by modelling teams in India, thereby improving the knowledge of how action in India relates to global and sub-national low carbon development pathways, as well as to selected co-benefits of trade-offs of climate policy. To strengthen the India-EU cooperation on climate change the "Strategic Partnership for the Implementation of Paris Agreement (SPIPA)" project was funded by the European Union and German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMUV). The project contributed to the European Union (EU)'s climate diplomacy efforts and cooperation between the EU and India to implement the EU-India Clean Energy and Climate Partnership and to support the implementation of the Paris Agreement. The SPIPA project's nodal partner ministry in India was the Ministry of Environment, Forest and Climate Change (MoEFCC). **Contracted (IIASA) amount:** EUR 214,616 **Groups:** IACC, S3, PM, IBF

SR3-AQ Analysis of air pollutant emission trends towards 2050 for EU energy intensive industry sectors **Duration:** 2022 – 2023 **Funder:** European Commission, DG Environment **Website:** **Policy Briefs or other material links:**	Development and analysis of the trends towards 2050 of air pollutant emissions from energy intensive industry sectors in the EU under a baseline and maximum technically feasible mitigation scenario. Assessment of the reasons driving these trends, both methodological (including assumptions taken) and economic (drivers, activities at stake, costs etc.); Assessment, for each scenario, pollutant, and activity under the sectors at stake, of the pollution control measures, how they relate with the expected evolution of BAT, their uptake level and emission reduction effectiveness. **Contracted (IIASA) amount:** EUR 73,300 **Groups:** PM
Syn-CAN Synergies of Reducing Greenhouse Gases and Nitrogen Pollution in Europe **Duration:** 2024 – 2026 **Funder:** European Commission, DG Research Executive Agency (REA) **Website:** **Policy Briefs or other material links:**	To enable synergistic and cost-effective mitigation policies, SynCAN will: (1) analyze interactions and drivers of GHG-Nr emissions in Europe; (2) identify feasible sectoral mitigation options and cost-effective pathways of coordinated GHG-Nr emissions, targeting efficiency gains and cost savings; and (3) Assess the systemic changes and national gaps associated with coordinated GHG-Nr mitigation efforts in Europe. To achieve this, SynCAN will employ interdisciplinary and intersectoral approaches that bridge natural science, environmental science, economics, and management. **Contracted (IIASA) amount:** EUR 199,449 **Groups:** PM
TMC (multiyear) Utilization of IAMs in the automotive industry **Duration:** 2022-2025 **Funder:** Toyota Motor Corporation **Website:** N/A **Policy Briefs or other material links:**	Toyota Motor Company has sent a visitor to IIASA for the period 2022-2024 to learn working with the MESSAGEix-Transport model and improve understanding of climate scenarios and integrated assessment modeling. This funding allows the support of IIASA staff for these collaborations. **Contracted (IIASA) amount:** EUR 125,755 **Groups:** S3, IACC
UNCNET Urban nitrogen cycles: new economy thinking (UNCNET) to master the challenges of climate chang. **Duration:** 2019 - 2022 **Funder:** Austrian Research Promotion Agency (FFG) **Website:** https://www.uncnet.org/ **Policy Briefs or other material links:** https://www.uncnet.org/public-project-repository/	UNCNET is a three-year project funded under the Joint Programming Initiative Urban Europe in collaboration with the Chinese National Science Foundation. It tackles existing and future challenges of urban sustainability that are closely connected to the fate of reactive nitrogen compounds**.** The project developed “urban nitrogen budgets” to understand the reasons, pathways and possible intervention points of the release of nitrogen compounds. Nitrogen budgets and their impacts in European and Chinese cities. **Contracted (IIASA) amount:** EUR 295,546 **Groups:** PM

UNEP-Sector Explorer Sectoral pathway comparison tool **Duration:** 2023–2023 **Funder:** UNEP-FI **Website:** **Policy Briefs or other material links:** https://iiasa.ac.at/events/mar-2024/navigating-sector-scenarios-for-net-zero-target-setting	The UNEP Finance Initiatives funds IIASA in this project to unlock climate scenario information for users in the financial sector by providing detailed information on the content of scenarios from different producers (NGFS, IEA, OneEarth) and developing a tailored scenario dashboard for financial analysts. **Contracted (IIASA) amount: EUR** 138,255 **Groups:** S3
UPTAKE Bridging current knowledge gaps to enable the UPTAKE of carbon dioxide removal methods **Duration:** 2023-2027 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://iiasa.ac.at/projects/uptake https://www.cdr-uptake.eu/ **Policy Briefs or other material links:**	UPTAKE aims to carry out a systemic and integrated appraisal of a large portfolio of CDR methods and their interactions with decarbonization and sustainability strategies. Ultimately, UPTAKE will propose resilient and implementable strategies for CDR at the European and global levels by taking policy, governance, financial constraints, and distributional (socioeconomic, demographic, geographical, sectoral, and temporal) impacts into account. UPTAKE will achieve this by pursuing three objectives: • Comprehensive assessment of *individual* CDR methods, • *Systemic* integration of CDR into leading modelling frameworks, and • Facilitation and acceleration of CDR uptake considering real-world implementability constraints. **Contracted (IIASA) amount:** EUR 659,387 **Groups:** IACC, IBF, AFE
WB-Flagship II Ambient Air Quality and Public Health in South Asia - Phase II **Duration:** 2020–2021 **Funder:** The World Bank **Website:** **Policy Briefs or other material links:**	This assignment provided input to the World Bank regional flagship study on 'Ambient Air Quality and Public Health in South Asia'. The flagship study aimed to fill in three key knowledge gaps to help South Asian governments design and implement more effective policies to reduce the public health threats of address ambient air pollution. The research in this study provided new insights for air quality policy makers in order to better assess environmental effectiveness of policy measures and the circumstances in which cross-jurisdictional cooperation is particularly necessary. **Contracted (IIASA) amount:** EUR 91,112 **Groups:** PM
WB-South Africa Cost Effectiveness/Air Quality Management Planning for South Africa **Duration:** 2020–2021 **Funder:** The World Bank **Website:** **Policy Briefs or other material links:**	The project evaluated and improved emission inventories, health data and source apportionment results, translated that into regional-scale photochemical and dispersion modeling and incorporated each of these into a GAINS cost-effectiveness analysis to provide recommendations on the most effective control strategies to address air pollution in GJA, which included the cities of Johannesburg, Tshwane and Ekurhuleni. **Contracted (IIASA) amount:** EUR 84,156 **Groups:** PM

WEO 2021-2024 (multiyear) World Energy Outlook - Air Pollution and Emissions Analysis & Modelling **Duration:** 2021–2024 **Funder:** International Energy Agency **Website:** **Policy Briefs or other material links:** World Energy Outlook 2021 (iea.blob.core.windows.net) https://www.iea.org/reports/world-energy-outlook-2022 https://www.iea.org/reports/world-energy-outlook-2023	To provide support to the IEA's WEO team by providing the Pollutants-related Results for three given scenarios, including analysis regarding the extent of air pollutant emissions in the energy sector in different countries and regions, the implications for air quality in these countries/regions and the associated impact on human health. The contributions are required for the yearly editions of the IEA's World Energy Outlook (WEO) publication and potentially other ad hoc special reports in the WEO series. **Contracted (IIASA) amount:** EUR 160,000 **Groups:** PM
WorldTrans Transparent Assessment for Real People **Duration:** 2022–2026 **Funder:** European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) **Website:** https://iiasa.ac.at/projects/worldtrans-transparent-assessments-for-real-people **Policy Briefs or other material links:**	For Europe to deliver on its Green Deal ambition, citizen stakeholder engagement may be as important as dry facts and figures. People (not economies) react to climate change, people make decisions to act or not to act. Such is the nature of a democratic process. Only by understanding their part in the bigger picture - the system - can individuals realize the incentives to behave differently. A more comprehensive understanding of how the climate is affected requires being able to connect the various knowledge systems, and the connection between human behavior and climate change must be quantified and built into the models. However, due to the multiscale and multidiscipline range of climate change issues, it is extremely difficult to develop a common modelling framework. WorldTrans will address systemic, structural weaknesses and limitations of current IAMs. By using simpler models that focus on feedbacks, cross-sector connections and linkages, WorldTrans aims to overcome transparency issues, incorporate human behavior and actor heterogeneity more explicitly, explore a wider range of uncertainties, and assess the implications of feedback loops and engage citizens and stakeholders in inspiring environments of co-production and learning. **Contracted (IIASA) amount:** EUR 346,062 **Groups:** S3

External Projects with contracted (IIASA) amount of under Eur 50,000.

- ABC-iCAP: Arctic Black Carbon – impacting Climate and Air Pollution - European Commission, Service for Foreign Policy Instruments (FPI) (EUR 22,500)
- CAEP: IIASA-CAEP cooperation on modelling Chinese Clean Air Pathway up to 2035 - Climate Imperative Foundation (EUR 41,175)
- CAP-1 India: Clean Air Project in India - Phase 1 - Swiss confederation, The Federal Department of Foreign Affairs (EUR 49,400)
- CIAM 2022 Norway City - Norway's support to CIAM Work - Norwegian Ministry of Climate and Environment (EUR 19,300)
- CDR: State of the CDR Report - Quadrature Climate Foundation (EUR 24,490)
- City: Research Project on City Transformation – IGES (EUR 30,000)
- CS N0W - Analysis to model the health and economic co-impact of climate mitigation actions across sectors and regions - University College of London (EUR 12,000)

- EUCLDB - Steady-State Critical Loads for eutrophication and acidification for European terrestrial ecosystems - Umwelt Bundesamt Germany (EUR 10,000)
- Emission Clock: World Emissions data model - World Data Lab (EUR 32,000)
- GCF-CRR: Climate-related risks and mitigation measures – Green Climate Fund (EUR 25,370)
- GEOHealth-Peru **-** Regional Geohealth Hub centered in Peru-US- National Institute of Health (NIH) (EUR 40,000)
- Foell Fund for IIASA-University of Wisconsin Partnership (EUR 4,630)
- GAINS Italy-4-Maintenance Contract for GAINS ITALY - Italian Agency for New Technology Energy and the Environment (ENEA) (EUR 40,000)
- GAINS-Korea VII - Development of Climate Pollutants Emission Inventory for East Asia (V) - Konkuk University (EUR 22,300)
- GAINS-JJJ2CRAES - Air Quality Management - Capacity Building using GAINS - The World Bank (EUR 43,797)
- IRP: International Resource Panel (IRP) Scenario Explorer and material scenarios – United Nations Environment Programme (EUR 20,611)
- IPCC WGI Lead- IPCC 6th Assessment Report Review - European Environment Agency (EUR 20,180)
- IPCC Chapters - IPCC 6th Assessment Report Review - Chapters review - European Environment Agency (EUR 20,517)
- MESSAGE-Korea**:** Development of a MESSAGE-Korea in support of JustTrans4All - Konkuk University (EUR 12,896; EUR 13,561; EUR 13,830)
- NaturaConnect**:** Designing a resilient and coherent Trans-European Network for Nature and People – European Commission (EUR 37,000) (with BNR)
- NCM-cPM: Revising historical PM2.5 emissions from residential combustion to consistently include condensable organics and asses the implication for the review of Gothenburg Protocol – Nordic Working Group for Climate and Air (NKL) (EUR 8,607)
- NRCP: Developing an integrated model for analyzing linkages between India's water, land and energy policies and the Sustainable Development Goals - Ministry of Environment Forests, and Climate Change of India (EUR 14,684)
- POLES - Linking POLES and GAINS data flows -French National Institute for Industrial Environment and Risks (INERIS) (EUR 9,998)
- S3&SDGs&ENVI: Smart Specialisation, Sustainable Development Goals and Environmental Commons - Commission of the European Communities, Directorate General Joint Research Centre (JRC) (EUR 14,684)
- RECREATE - Resource nexus for transformation to circular, resilient, and livable cities in the context of climate change - Austrian Research Promotion Agency (FFG) (EUR46,521)
- Rutgers: Multi-scale modelling of interactions between climate change, air quality, and inequalities - National Science Foundation (NSF) (EUR 18,221)
- Rutgers2Texas: Multi-scale modelling of interactions between climate change, air quality, and inequalities (Phase 2) - National Science Foundation (NSF) (EUR 35,617)
- SR15: Systematic assessment of monitoring air pollutants not covered under Directives 2004/107/EC an 2008/50/EC - European Commission, DG Environment (EUR 49,800)
- SR1-AQ: Service request on increasing policy coherence between bioenergy and clean air policies and measures - European Commission, DG Environment (EUR 5,000)
- SwissRE Chile: Health and economic costs of air pollution in South America, in the context of climate change - Swiss Re Management Ltd (EUR 44,219)
- TCE-IHISET: Integrated High Impact Innovation in Sustainable Energy Technology - Energy System Analysis; Asian Development Bank (EUR 44219)

- WASTE-SA - A comprehensive waste management model for promoting effective decision-making and sustained climate change stabilization for South Africa - Council for Scientific and Industrial Research (CSIR) (EUR 23,673)
- WB-PMEH Vietnam - Training, capacity building and GAINS model linkages for the air emission sectoral data verification – The World Bank (EUR 43,816)

Annex C: ECE Publications List

Complete list of publications per program and groups using IIASA Publications Repository (PURE)

- ECE | IACC | PM | S3 | TISS
- ECE publications all – generated by PURE

Journal articles

1. Oshiro, K. & Fujimori, S. (2024). Mid-century net-zero emissions pathways for Japan: Potential roles of global mitigation scenarios in informing national decarbonization strategies. *Energy and Climate Change* 5 e100128. 10.1016/j.egycc.2024.100128.
2. de Assis Brasil Weber, N., Hunt, J. , Zakeri, B. , Smith Schneider, P., Asfor Parente, F.S., Delavald Marques, A., & Olímpio Pereira Junior, A. (2024). Seasonal pumped hydropower storage role in responding to climate change impacts on the Brazilian electrical sector. *Journal of Energy Storage* 87 e111249. 10.1016/j.est.2024.111249.
3. Alkemade, F., de Bruin, B., El-Feiaz, A., Pasimeni, F., Niamir, L. , & Wade, R. (2024). Social tipping dynamics in the energy system. *Earth System Dynamics* 15 (2) 485-500. 10.5194/esd-2023-25.
4. Kim, E., Kim, B.-U., Kim, H.C., Liu, Y., Kang, Y.H., Jacob, D.J., Kim, Y.P., Woo, J.-H., Kim, J., Wang, S., Yoo, C., Bae, C., Kim, Y. , & Kim, S. (2024). North Korean CO emissions reconstruction using DMZ ground observations, TROPOMI space-borne data, and the CMAQ air quality model. *Science of the Total Environment* 921 e171059. 10.1016/j.scitotenv.2024.171059.
5. Bhar, S., Lele, S., Min, J. , & Rao, N. (2024). Water, air pollution and carbon footprints of conspicuous/luxury consumption in India. *Ecological Economics* 218 e108104. 10.1016/j.ecolecon.2024.108104.
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8. Husein, M., Moner-Girona, M., Falchetta, G. , Stevanato, N., Fahl, F., & Szabó, S. (2024). The impacts of incentive policies on improving private investment for rural electrification in Nigeria – A geospatial study. *Heliyon* 10 (5) e27440. 10.1016/j.heliyon.2024.e27440.
9. Suchowska-Kisielewicz, M., Greinert, A., Winiwarter, W. , Kaltenegger, K. , Jędrczak, A., Myszograj, S., Płuciennik-Koropczuk, E., Skiba, M., & Bazan-Krzywoszańska, A. (2024). The fate of nitrogen in the urban area – The case of Zielona Góra, Poland. *Science of the Total Environment* 915 e169930. 10.1016/j.scitotenv.2024.169930.
10. Man, J., Ma, T., Yu, Y., & Ren, H. (2024). Levelized costs and potential production of green hydrogen with wind and solar power in different provinces of mainland China. *Journal of Renewable and Sustainable Energy* 16 (2) 10.1063/5.0183511.
11. Carr, D., Falchetta, G. , & Wing, I.S. (2024). Population Aging and Heat Exposure in the 21 st Century: Which U.S. Regions Are at Greatest Risk and Why? *The Gerontologist* 64 (3) gnad050. 10.1093/geront/gnad050.
12. Jurasz, J., Guezgouz, M., Campana, P.E., Kaźmierczak, B., Kuriqi, A., Bloomfield, H., Hingray, B., Canales, F.A., Hunt, J. , Sterl, S., & Elkadeem, M.R. (2024). Complementarity of wind and solar power in North Africa: Potential for alleviating energy droughts and impacts of the North Atlantic Oscillation. *Renewable and Sustainable Energy Reviews* 191 e114181.
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Annex D: Selected Talks, Lectures, and Capacity Building Efforts

Selected talks and presentations

- Guo Fei and Krey Volker: Flagship Report Launch: Electrification in China's Carbon Neutrality Pathways, COP27 Side-event, Energy Foundation China, Sharm El-Sheikh, Egypt, November 2022
- Grubler Arnulf: Side event on Energy Demand changes Induced by Technological and Social innovations at the 26th Conference of the Parties (CoP) of the signatories of The United Nations Framework Convention on Climate, November 2021
- Höglund-Isaksson Lena: Invited speaker COP27, organized by Arctic Council-AMAP Pathways to Reducing Black Carbon and Methane Emissions Impacting Arctic Climate and Air Quality: My talk title was: "Reducing methane emissions from human activities globally and in Artic Council member and observer countries), Sharm El-Sheikh, Egypt, November 2022.
- Höglund-Isaksson Lena: Invited speaker, Harvard Kennedy School COP-27 Side Event on Measuring Methane Emissions to Advance Global Climate Policy, my talk was entitled: "The use of bottom-up emission inventories in methane policy processes", Sharm El-Sheikh, Egypt, November 2022.
- Höglund-Isaksson Lena: Invited speaker, COP27, Food4Climate Pavillion side event Closing the Global Methane Pledge Gap: How the Global North can step up as champions of food system change "Controlling methane emissions in EU's Agricultural sector Sharm El-Sheikh, Egypt, November 2022.
- Klimont and Höglund-Isaksson Lena, keynote speeches on 'Air pollution in a global perspective' and 'Global Methane Pledge: future projections of methane' Saltsjöbaden VII – International science-policy workshop on ways forward for improved air quality, Gothenburg, Sweden, March 2023
- Klimont Zbigniew: Keynote speech on Clean air & climate solutions and costs of inaction in the ASEAN region, at the 5th Indian Clean Air Summit 2023 (ICAS), Bangalore, India, August 2023
- Klimont Zbigniew: Keynote speech on "Low carbon scenarios: Air quality benefits and challenges" at the International Symposium on Low-carbon Transition Pathway for Global Energy. Infrastructure: Challenges and Opportunities. Tsinghua University, China (virtual), August 2021
- Krey Voker and Keywan Riahi, Publication of the IPCC's Sixth Assessment Report on Mitigation of Climate Change , Press conference, Climate Change Center Austria (CCCA), Vienna, Austria, April 2022.
- Niamir Leila: Demand-side measures in the IPCC report: What's the role of lifestyle changes and sufficiency in the transition? ISI-Fraunhofer (virtual event), May 2022
- Nakicenovic Nebojsa: EU policies to be the first carbon-neutral continent in the transforming world, ALPS Symposium, Research Institute of Innovative Technology for the Earth (RITE), Tokyo, Japan, March 2024.
- Nakicenovic Nebojsa: High-Level Summit on Fundamental Life Science meets Climate, Environment and Sustainability, Keynote Speaker, June 2023
- Pachauri Shonali: Driving Climate Action through Clean Cooking, keynote speech at the CCA WHO and CCAC webinar, Oct 20, 2021

- Pachauri Shonali: Decarbonization in the Global South: Embedding efforts to mitigate climate change with those to achieve decent standards of living for all, Plenary talk at the 40th International Energy Workshop (IEW), 26 May 2022)
- Pachauri Shonali: Presentation to launch the IIASA Flagship report – Systems Analysis for Sustainable Wellbeing: 50 years of IIASA research, 40 years after the Brundtland Commission, contributing to the post-2030 Global Agenda, at the official UN event during the HLPF in September 2023.
- Riahi Keywan: COP27 IPCC Side-event and COP27 side-event on demand-side solutions to climate change
- Riahi Keywan: invited speaker and moderator at multiple interministerial sessions at the UN High-level Political Forum and the UN STI Forum 2022, 2023, and 2024 on climate solutions, digitalization, and distributional impacts of climate policies.
- Riahi Keywan: invited keynote speech at the SDEWES 2023 Dubrovnik - 18th Conference on Sustainable Development of Energy, Water and Environment Systems
- Riahi Keywan: invited keynote speech at the ISIMIP 2023 Conference in Prague
- Riahi Keywan: invited panelist at the World Leaders Forum, Korea, Seoul, June 15, 2022
- Riahi Keywan: keynote speaker at IAMC Annual Meetings 2022, College Park, MD, USA and 2023, Venice, Italy.
- Riahi Keywan: keynote speech at the Forum on Promotion and Demonstration of Digital Technologies for Sustainable Development, CBAS, Beijing, September 2023.
- van Ruijven Bas: Feasible scenarios to increase climate ambition, ECEMP conference keynote presentation, October 2023
- van Ruijven Bas: Towards continuous evaluation of plausible ranges for the RCPs, Scenarios Forum 2022 plenary presentation, Laxenburg, Austria, June 2022
- Winiwarter Wilfried: Invited speaker at the Int. Conference on Zero Greenhouse Gas Emission in High Productive Agriculture. "Maximum ambition GHG abatement scenarios in agriculture: opportunities and limitations of integrated modelling approaches", Copenhagen, May 2022.

Selected lectures

- Brutschin Elina: Advanced Research Methods to Master's students in the International Relations Department at Webster Vienna Private University (since 2020)
- Brutschin Elina: Introduction to Quantitative Research Methods course at the Central European University (Fall term 2020/21)
- Boza-Kiss Beni and van Ruijven Bas: organized the EDITS webinar series, 2022-2024
- Eker Sibel: Assistant Professor in System Dynamics, Radboud University, Nijmegen, Netherlands
- Interdisciplinary Tipping Points Discussion Series, a joint endeavor of the EC, WCRP's Safe Landing Lighthouse, AIMES, and Future Earth (since 2021).
- Höglund-Isaksson Lena: Environmental Economics course as part of a larger Master program in Environmental Science and Policy at the Central European University, Vienna, Austria (2020-2022)
- Huppmann Daniel: Open Source Energy System Modeling, course at Technical University Vienna, Austria (2021, 2023, 2024)
- Ju Yiji: adjunct affiliation with Waseda University and visiting affiliation with University of Tokyo.
- Klimont Zbigniew and several ECE staff: GAINS Community Meeting, IIASA (and online), November 2022.

- Krey Volker: Integrated Assessment Modelling, PhD course at Norwegian University of Science and Technology (NTNU), Norway, Spring 2022
- Krey Volker: Standardization of scenario data collection via the IAMC data template: past developments and future challenges, IAMC webinar on the occasion of receiving the 2022 edition of the IAMC Award for Extraordinary Contributions to the field of IAM, June 2023
- Krey Volker: IPCC scenarios, integrated assessment models and key concepts for integrating climate change research across research domains, Indian Climate and Energy Modeling Forum (ICEMF) Webinar, August 2023, Niti Aayog.
- Nguyen Binh: Senior lecturer in the Information Technology Department of Hue University, Vietnam
- Nguyen Binh: Course on Data and Knowledge Discovery (Master students- hybrid on-off line) and online PhD course on Advanced Software Engineering and System Integration, University of Sopron.
- Purohit Pallav: Academic Seminar on Co-benefits of global HFC phase-down under the Kigali (Virtual) - at Tsinghua University, China, May 2022
- Riahi Keywan: Guest Professor in the field of Energy Systems Analysis, Graz University of Technology, Austria
- Riahi Keywan: Organized a seminar series and lectures at the Forum Alpbach 2023
- Riahi Keywan: Seminar series of the Austrian Academy of Sciences, 2023 (together with Georg Brasseur)
- Several ECE scholars: Lecture Series on Just Transitions at The University of Applied Arts Vienna, (Fall 2022/23)
- Van Ruijven Bas: organized the ICONICS webinar series, 2021-2024
- Van Ruijven Bas: Faculty member of the European University Institute / Florence School of Banking and Finance, Climate Risks Academy, 2019-2022
- Winiwarter Wilfried: Research Professor at the University of Zielona Góra Doctoral school of science and technology, Poland
- Zakeri Behnam: Global Energy Transitions and Climate Policy, master course at Technical University Vienna, Austria

Selected Capacity Building

- EECCA workshop on the GAINS model (UNECE funded), November 2023, participants from Republic of Moldova, Ukraine, Georgia, Armenia, and Kazakhstan
- GAINS training for GEIDCO (Online) July 2021
- GAINS Workshop for the Chinese Academy of Environmental Planning (CAEP) (online) April, 2023
- Hosting and training two scientists from the Chinese Research Academy of Environmental Sciences (CRAES) in application of GAINS for China and JJJ (Beijing, Tianjin and Hebei) region
- IOP Environmental Research 2023
- IPCC Scenario Explorer workshop series (additional material), jointly organized with IPCC TG Data, Europe, Oceania, Latin America and Asia, January – April 2023.
- Joint Workshop on tools for planning, scenarios and policy analysis of the water-energy-land nexus for equitable development in rural Africa, joint workshop organized by IIASA, WRI and UN ESMAP, Addis Ababa, Ethiopia, October 2023.
- MESSAGEix capacity building workshops (2021, 2022, 2023, 2024), IIASA and online
- MESSAGEix community meeting (2022, 2023, 2024), IIASA and online
- NAVIGATE-ENGAGE Summer School, 2023

- NGFS CEROC lectures “Climate change scenarios for financial risk analysis” (2022, 2023, 2024)
- NGFS Scenarios Webinars (2021, 2022, 2023)
- Open Energy Modelling (openmod) workshop, IIASA, March 2023.
- Quaker United Nations Summer School (2022)
- SPIPA India – GAINS Workshop, April 2021
- South-Africa (World Bank); virtual workshop for experts and local-city decision makers, and hosting two scientists from CSIRO
- The European Forum Alpbach (EFA) (2021, 2023).
- Training courses on GAINS for IGP - Evaluation, implementation, and further development of air quality policies in the Indo-Gangetic Plain (IGP) region. (World Bank funded), March and November 2022.
- West Balkan (EU4Green) - Consultations with national technical experts and policy makers on development of emission inventories, projections, and application of GAINS model to develop cost-effective mitigation strategies.