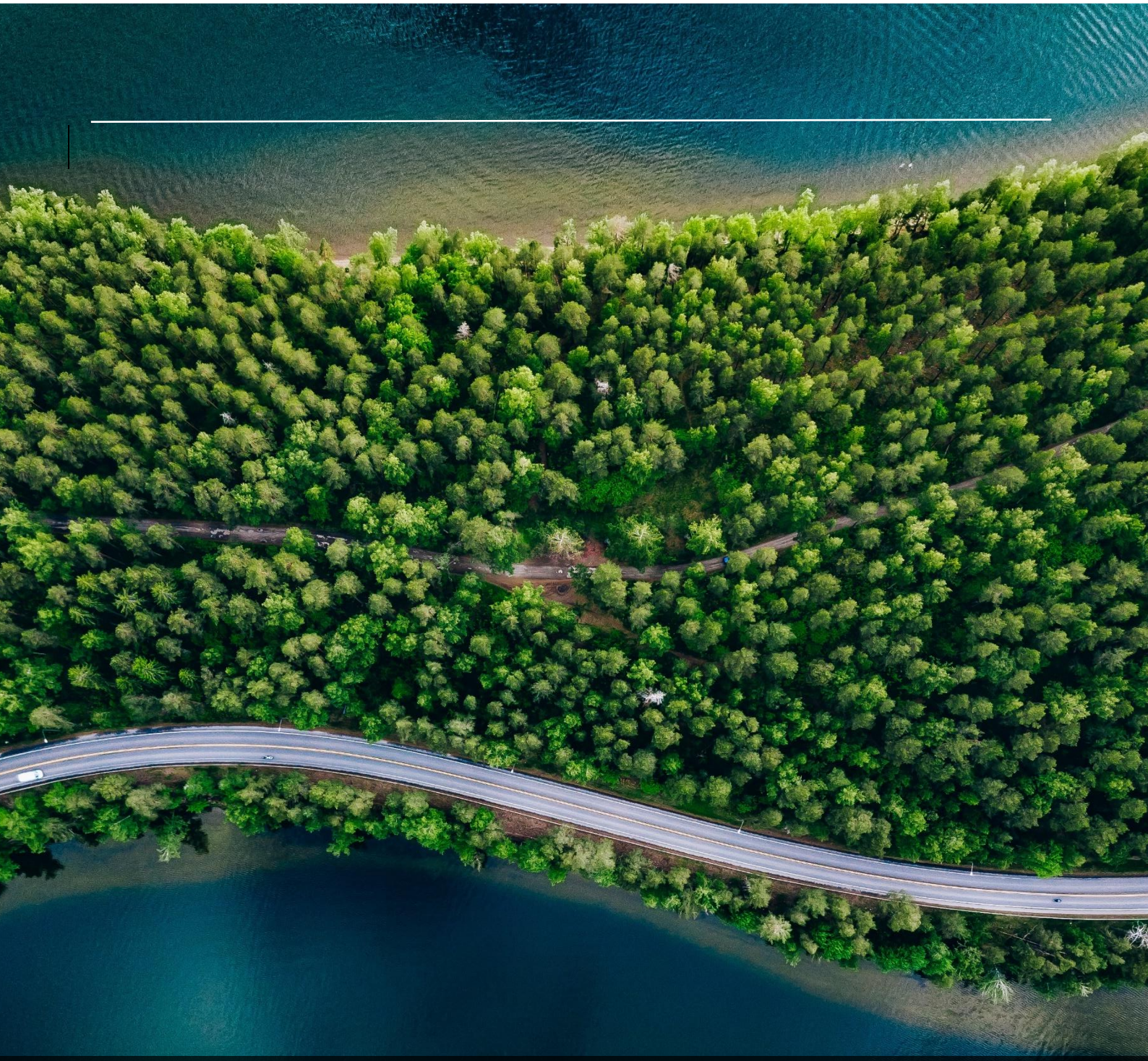


# CLIMATE CHANGE MODELLING INFORMATION

**Quarterly report – Q2 2021 report**

# CLIMATE CHANGE MODELLING INFORMATION

## Quarterly report – Q2 2021 report

A report submitted by ICF S.A.
Date: 13 May 2021

Jerome Kisielewicz
4th Floor
Avenue Marnix 17
1000 Brussels
T +32 (0) 2 275 01 00
F +32 (0) 2 275 01 09
jerome.kisielewicz@icf.com
www.icf.com

# Contents

# High-level executive summary

This report under the "**Climate change modelling information**" series presents recent developments reported by key international climate modelling institutions. This issue sets an emphasis on the **transport sector**, in addition to the regular sections on the implementation of **Nationally Determined Contributions** and **mid-century strategies**.

The first section of the report is dedicated to modelling developments linked to the **transport sector**. As the transport sector is one of the big contributors to greenhouse gas emissions, transforming it is also key to achieving a climate-neutral economy. The research featured in this section assesses different technological pathways to a more sustainable transport sector, including reducing transport demand, promoting electrification, and the use of biofuels. Researchers in Switzerland examine different policy pathways to achieving a net zero $CO_2$ Swiss mobility system. Researchers from Germany compare different options for electrifying heavy-duty vehicles. Researchers in the UK have developed a transport model to simulate various scenarios for demand for freight transport, associated energy consumption and emissions by 2050. Another research team in Germany has integrated various existing models to calculate current day traffic emission inventories in Germany and develop consistent future scenarios for 2040. A study from the UK analyses instruments and technologies which can decarbonise the UK's inland freight sector.

Various research developments linked to the implementation of **the Nationally Determined Contributions (NDCs)** are reported in the second section. Research teams across the world are fine-tuning the models used to estimate the economic and climate impacts of NDCs, including comparing various technological pathways and carbon tax designs. Research institutes in Switzerland present an analysis of the long-term energy transformation pathways in Switzerland. The LEEEP modelling team at Peking University has a working paper comparing eight economy-wide CGE models for China with different characteristics to examine f carbon tax scenarios. China and the USA researches have published an article examining the environmental co-benefits and economic impact of China's deep decarbonisation pathways (DDPs).

In the third section, the report features research linked to **mid-century strategies**. The articles critically examine long-standing assumptions (e.g., net negative emissions), the implications of incorporating new technologies (e.g., carbon dioxide removal) and climate risks into mid-century strategies. Researchers from Austria have developed a new set of global emissions scenarios that exclude net negative $CO_2$ emissions (NNCE). A working paper from a research team in Australia examines the global economic impacts of climate shocks, climate policy and changes in climate risk assessment. A research team across Switzerland, France and Qatar assesses the impact of long-term climate strategies for oil- and gas-producing countries in the Gulf Cooperation Council (GCC).

# Introduction

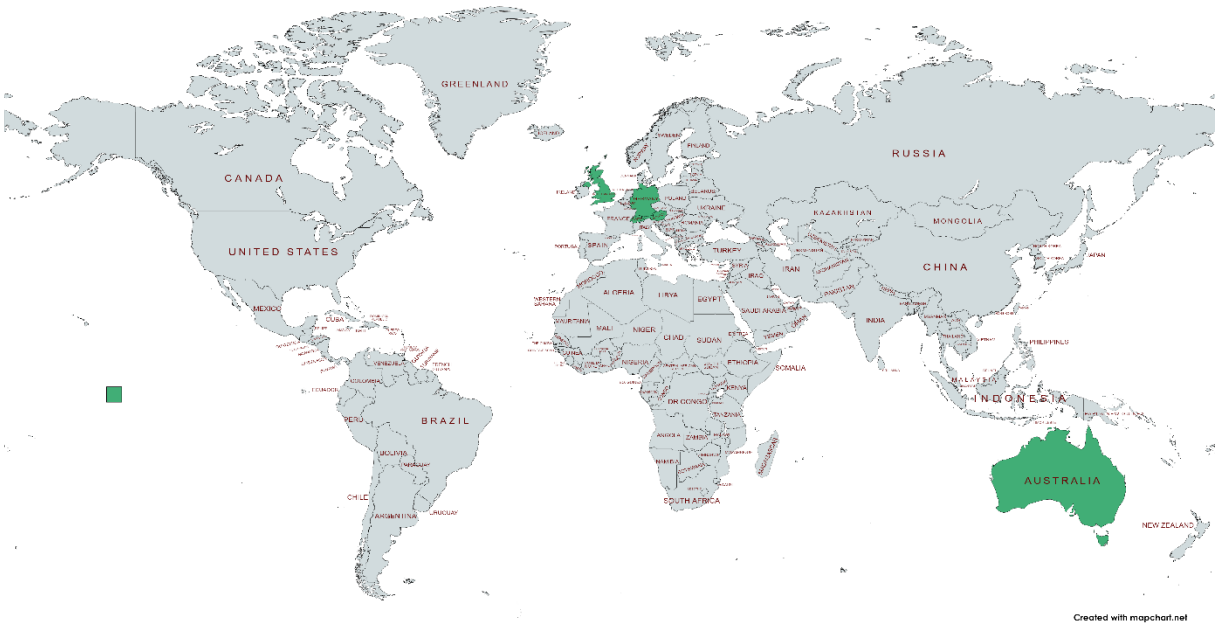
This report is the second quarterly report of 2021 under the series 'Climate Change Modelling Information' financed by the European Commission. This project aims to provide the EU and global climate change modelling community and interested policy makers with up-to-date information about ongoing modelling developments and projected results. The project focusses in particular on economic assessments of policies to mitigate climate change, ways to combine climate action with other global priorities, and assessments of the impacts of climate change and how to adapt to it. The data presented in this report were collected through an open survey sent to more than 200 modelling teams worldwide and open from 1-16 April 2021.

The survey asked modellers to report relevant developments with a focus on the transport sector, the implementation of Nationally Determined Contributions (NDCs), and mid-century strategies.

Although the objective of this report is to present an extensive list of recent developments, it cannot be considered as exhaustive. For this quarterly report, responses came from eight countries (see Figure 2.1), nine organisations and covered ten different modelling developments and projects.

Additional research was undertaken to complement the survey results.

**1 Geographical coverage of climate change modelling developments reported through the online survey (n = 9)**




*Source*: ICF, 2021. Climate change modelling information Q2 2021 survey.

The modelling developments discussed in this report are summarised below and further described in the coming chapters.

**Modelling developments linked to the transport sector:**

- Pathways to a net zero $CO_2$ Swiss mobility system (Switzerland)
- Comparing options to electrify heavy-duty vehicles (Germany)
- Climate policies for freight transport: Energy and emissions projections through 2050 (Germany)
- Decarbonising the UK's freight sector by 2050 (UK)

**Modelling developments linked to nationally determined contributions:**

- Long-term energy transformation pathways (Switzerland)
- General equilibrium impacts of carbon tax policy in China (China)
- Environmental co-benefits and economic impact of China's low-carbon pathways (China)

**Modelling developments linked to mid-century strategies:**

- Long-term economic benefits of stabilising warming without temperature overshoot (Austria)
- Global economic impacts of climate shocks, climate policy and changes in climate risk assessment (Australia)

- Economic assessment of the development of $CO_2$ direct reduction technologies in long-term climate strategies of the Gulf countries (Switzerland)
- Regional coverage expansion of the E3ME model (UK)

## Modelling developments linked to the transport sector

- In March 2021, the Swiss Competence Centre for Energy Research Efficient Technologies and the Systems for Mobility (SCCER Mobility) published a white paper titled "**Pathways to a net zero $CO_2$ Swiss mobility system**." In order for Switzerland to achieve its net-zero ambition by 2050, a massive acceleration of $CO_2$ reduction efforts must be initiated and maintained over the next decades. The paper is underpinned by analysis combining Life Cycle Assessment (LCA) methodology with internal and external cost assessment, risk assessment, multi-criteria decision analysis (MCDA) and energy economic systems modelling. Integrated model-based scenario results are derived from the Swiss TIMES Energy system Model (STEM). STEM employs a cost optimization approach and generates possible future trajectories of the entire Swiss energy system under specific assumptions about the developments of technologies, socioeconomics and policies.

  **Results of the study**: The white paper assesses a variety of pathways to a more sustainable mobility system in Switzerland and identifies **the following policy steps as most promising**: Avoid excessive transport demand; Shift to more efficient and environmentally compatible modes of transportation; Improve energy conversion efficiency along the full conversion chain from primary to useful energy; Replace fossil energy carriers with new ones exhibiting net zero $CO_2$ emissions through direct or indirect electrification. The paper is available online.

  **Policy Implications**: To achieve the rapid decarbonization of the mobility system (representing 48% of the $CO_2$ emissions in Switzerland), a range of policy measures including pricing (e.g., $CO_2$ taxes and vehicle registration taxes seeking to internalize externalities), consideration of behavioural aspects (e.g., labels) and appropriate use of digitalization will be required. This needs to be combined with support of public and low-speed passenger transportation modes, spatial planning and addressing potential rebound effects.

- A recent article in the *World Electric Vehicle Journal* from researchers at the Fraunhofer Institute for Systems and Innovation Research ISI compares **options for electrifying heavy-duty vehicles**. While the electrification of passenger vehicles is in full swing, various challenges still exist for the decarbonization of heavy-duty trucks. Especially the high energy consumption in combination with high daily driving ranges makes battery electric operation much more difficult for heavy-duty vehicles than for passenger cars. The authors analyse a broad set of different drivetrains, inter alia hydrogen trucks, catenary hybrid trucks and synthetic fuels. One main advantage of the direct use of electricity in trucks is the high energy efficiency. Still, for heavy duty trucks different concepts for electrification do exist. The authors compare battery electric trucks with a fast-charging option, full electric catenary trucks and battery swap trucks.

  **The results show that** while battery electric trucks or battery swap are advantageous since they can be operated in niche operations and thus allow a demand driven rollout of charging infrastructure, catenary infrastructure needs high investments upfront which entails financial risks, but allows for lowest cost if utilized to capacity. Climate modellers can use the empirical results derived from pilot projects to fine-tune and calibrate model assumptions about electric vehicles technology, costs and use. The article is available online.

**Policy implications:** Electrification of the transport sector is one of the key pathways to achieving carbon emissions reductions. The article compares different technological options for the electrification of heavy-duty vehicles and their respective implications on costs, use and investment needs.

- Researchers from the Economic and Social Research Institute and Trinity College Dublin developed a **transport model** to simulate various scenarios for **demand for freight transport** and associated energy consumption and emissions by 2050. The model incorporates detailed freight transport profiles and behavioural parameters to assess the effectiveness of different climate policies including $CO_2$ emission performance standards and carbon taxes.

  **The study shows that**, in a context of strong projected growth of freight transport despite increasing carbon taxes, new EU emission performance standards on light and heavy-duty vehicles will be realised in the longer term as the vehicle stock is replaced with new technology vehicles. Notably, adoption of biofuel and alternative freight vehicles are expected to bring additional reductions in future energy consumption and emissions. The study is available online.

  **Policy Implications**: The study shows the need to develop a comprehensive climate policy agenda for transport including technology specific standards and pricing mechanisms and to promote low or zero emission vehicles technologies, especially for heavy goods vehicles.

- A research team from the Helmholtz-Zentrum Geesthach and the German Aerospace Center developed an **advanced model chain** integrating various existing models to **calculate current day traffic emission inventories in Germany** and develop consistent **future scenarios for 2040**. These include the national transport model DEMO, the vehicle stock model VECTOR 21, the emission profile model HBEFA and an upstream modelling of the energy supply. The work presented in this paper is a first attempt to combine spatially and temporally resolved transport and emission models that enable the calculation of future transport and air quality scenarios. The new model system also allows to build emission scenarios that include modifications of the traffic flows, changes of the fleet including new technologies, and the share of engine sizes.

  **Results of the study:** The study develops three traffic emission scenarios for the year 2040 which reflect certain policies and consistent possible societal developments with regard to street traffic. In all three scenarios, it is expected that nitrogen oxides (NOx) emissions from traffic decrease by approximately 80% while particulate matter (PM) emissions show a lower reduction. The stricter environmental regulations scenario, however, presents lower NOx and PM emissions compared to the scenario based on a free market economics logic. With the necessary adjustments and the specific input data this new approach could be applied to model traffic emissions for other countries as well. This study is part of the German project Traffic Development and the Environment and is available online.

  **Policy implications:** The share of transport emissions for greenhouse gases as well as for NOx has been constantly increasing in Europe since 1990, partly because emission have been reduced faster in other sectors and their relative share has gone down, partly because of increasing road transport demand. In 2016, they represented 27% to the total European $CO_2$ emissions according to the EEA. The study shows that more stringent regulations, combined with investments in infrastructure for public transport and financial instruments to foster the development of certain clean technologies, are

more effective to reduce emissions than measures based on the liberal market-economic logic. The difference in emission can be attributed to behaviour changes (mode shift, less car travel) and technologies (more plug-in hybrid vehicles and battery electric vehicles).

- Transport & Environment recently released a paper analysing instruments and technologies which can significantly contribute to completely **decarbonise the UK's inland freight sector**. It is shown that efficiency gains and modal shift will need to be accompanied by a rapid shift away from fossil fuels to zero-emission or GHG-neutral technology to decarbonise road freight. Liquid and gaseous biofuels are not considered as a viable pathway due to limitations of sustainable feedstock. Instead, heavy-goods vehicles (HGVs) will need to run on clean electricity, whether directly or indirectly in the form of electricity-based fuels. The available technologies require different amounts of electricity and vary in their system and user costs. The options which are identified as capable to fully decarbonise road freight need to be based on renewable electricity from additional installed capacity, whether domestically generated or imported. The paper is available online.

  **Policy implications**: The rapid decarbonisation of all urban, regional delivery and long-haul freight is essential to meet the climate targets at the least societal cost. In the UK, transport represents the country's biggest emitting sector with 33% of total GHG emissions in 2018. To achieve this, new regulations will be needed and complemented by investment in infrastructure and taxation reform to deliver the transformation.

## Modelling developments linked to Nationally Determined Contributions (NDCs)

- Researchers at the Paul Scherrer Institute have published an **integrated scenario analysis of the long-term energy transformation pathways in Switzerland**. The analysis was performed within the Swiss Competence Centre for Energy Research (SCCER) Joint Activity Scenarios and Modelling (JASM) by using the Swiss TIMES energy systems model (STEM). STEM is based on the IEA TIMES modelling framework and represents more than 90 energy end uses and hundreds of technologies in 17 energy demand sectors. The JASM framework consists of energy-system and sectoral models using a consistent set of drivers and scenarios definitions. STEM was extended in the representation detail of the Swiss energy system and technologies.

  **The report finds that** the transition in Switzerland to net-zero emissions is technologically feasible, but radical action is needed across all sectors of the energy system. Electrification is a key pathway to net-zero emissions, but it cannot alone decarbonize the energy system. Hydrogen, bioenergy and CCS are essential elements of reaching Switzerland's net-zero emissions goals.

  **Policy Implications**: The findings contribute to the current policy and societal debate on the long-term Swiss climate and energy strategy. In particular, the study contributes to the new $CO_2$ Act which aims to reduce the GHG emissions by 50% by 2030 from the 1990 levels. In June 2021, the approval of the new $CO_2$ Act will be subject to a public referendum. The Act is considered by the Federal Council as the first step of the implementation of the long-term climate strategy, within the framework of the energy strategy. It is available here.

- A working paper from the Laboratory of Energy and Environmental Economics and Policy (LEEEP) at Peking University, compares eight **economy-wide computable general equilibrium (CGE) models for China**. It has different characteristics to examine how they estimate the effects of a plausible range of **carbon tax scenarios** – low, medium and high carbon taxes – in the near-term 2020, medium-term 2030, and distant future 2050. The eight models used in the analysis are IMED| CGE, C-GEM, CHEER|CGE Model, CHINAGEM, DRC CGE, DREAM, HTCGE and SICGE. To make them comparable the authors impose the same population growth, the same GDP growth path and world energy price shocks.

  **They find that** the 2030 NDC target for China are easily met in all models, but the 2060 carbon neutrality goal cannot be achieved even with the highest carbon tax rates modelled. Through this carbon tax comparison, the authors find that all eight CGE models differ substantially in terms of impacts on the macroeconomy, aggregate prices, energy use and carbon reductions, as well as industry level output and price effects. The study discusses the reasons for the divergent simulation results including differences in model structure, substitution parameters, baseline renewable penetration and methods of revenue recycling. The paper is available upon request from the authors.

  **Policy Implications**: Carbon pricing is one of the main policy instruments to achieve $CO_2$ emissions reduction goals. This paper offers an improved understanding of the intrinsic CGE model characteristics that that may affect predictions for the effects of carbon pricing, and therefore provides policymakers with a better understanding of the impacts of carbon pricing instruments.

- Another research team from China and the USA, has published an article examining the **environmental co-benefits and economic impact of China's deep decarbonisation pathways** (DDPs). The study uses the novel approach of soft-linking the bottom-up model MAPLE with a top-down CGE model to assess the comprehensive impact of DDPs.

  **The results for China show** that DDPs can lead to a peak in or before 2030, and that the share of non-fossil energy consumption in 2030 is higher than China's NDC target. The key finding of the study is that if the environmental co-benefits of DDPs are taken in account, the estimated GDP loss from DDP reduces from 0.45% to 0.15%.

  **Policy Implications**: The article provides evidence that countries can achieve more ambitious NDC targets through DDPs, which have clear environmental co-benefits that offset the economic losses. The article is available here.

## Modelling developments linked to Mid-century strategies

- Researchers from the International Institute for Applied Systems Analysis (IIASA) are leading a team across 19 research institutes in a project examining the **long-term economic benefits of stabilising global warming without temperature overshoot**. One of the key criticisms of current global emissions scenarios is their heavy reliance on net negative $CO_2$ emissions (NNCE) resulting from allowing temperature limits to be temporarily exceeded (hoping to recover from the overshoot later). The research team has developed a new set of global emissions scenarios that exclude NNCE; the scenarios were developed for nine integrated assessment models (AIM-Hub, COFFEE, GEM-E3, IMAGE, MESSAGEix-GLOBIOM, TIAM-ECN, POLES, REMIND-MAgPIE and WITCH-GLOBIOM). The scenarios are set up to keep the warming below peak temperature

throughout the modelling horizon; this means that there is no temperature overshoot at the cost of deep negative emissions in the second half of the century.

**The results of the study show** that such scenarios require a more rapid near-term transformation with significant long-term economic gains. The study also identifies possible alternative configurations of net-zero $CO_2$ emissions systems and distinct roles for different sectors and regions in order to balance emissions sources and sinks. The article is currently under review at a Nature Portfolio Journal, but a pre-print is available online at Research Square.

**Policy Implications:** NNCE assumptions are at the heart of many climate models, and therefore, also at the heart of many policy scenarios. The article helps policymakers better understand the economic and distributional implications of this assumption, and provides predictions for policy scenarios without temperature overshoot.

- A research team from the Australian National University has published a working paper on the **global economic impacts of climate shocks, climate policy and changes in climate risk assessment**. The paper assesses the global economic consequences of climate-related risks in three broad areas: (1) the macroeconomic impacts of physical climate risk due to chronic climate change; (2) the macroeconomic effects of climate policies designed to transition to net zero emissions by 2050; and (3) the potential macroeconomic consequences of changes in risk premia in financial markets. The authors consider four widely used climate scenarios (Representative Concentration Pathways, or RCP), and identify the physical damage functions due to chronic climate risks. The chronic climate risks include sea-level rise, crop yield changes, heat-induced impacts on labour, and increased incidence of diseases. They also estimate the future incidence of climate-related extreme events, such as droughts, floods and wildfires. After translating physical climate shocks into economic shocks to labour force and sectoral productivity, the authors investigate the macroeconomic consequences under the climate scenarios using the G-Cubed Model.

  **The results demonstrate that** physical climate risk is likely to cause large economic losses in all RCP scenarios, both through chronic climate change and extreme climate shocks. The paper is available online from the CAMA working paper series.

  **Policy Implications:** The article helps policymakers better understand the impacts of climate risks and different transition pathways (e.g., different carbon tax policies), including the impacts on different sectors.

- A recent article in *Climatic Change* assesses the impacts of long-term climate strategies for **oil- and gas-producing countries** in the Gulf Cooperation Council (GCC) in relation to the Paris Agreement. The study evaluates the possible role of carbon dioxide removal (CDR) technologies under an international emissions trading market as a way to mitigate welfare losses. To model the strategic context, the authors assume that a global cumulative emissions budget will have been allocated among different coalitions of countries—the GCC being one of them—and the existence of an international emissions trading market. They propose a meta-game model in which deployment of CDR technologies as well as supply of emission rights are strategic variables, and the payoffs are obtained from simulations of a general equilibrium model.

  **The results of the simulations indicate** that oil and gas producing countries and especially the GCC countries face a significant welfare loss risk, due to “unburnable oil”. The development of CDR technologies, in particular direct air capture (DAC) alleviates

somewhat this risk and offers these countries a new opportunity for exploiting their gas reserves and the carbon storage capacity offered by depleted oil and gas reservoirs. The article was written under the PARIS REINFORCE project and is available online.

**Policy Implications:** The article offers a possible solution to oil- and gas-producing countries to employ CDR technologies to offset the economic losses implied in the global carbon regime.

- Cambridge Econometrics has expanded the regional coverage of the **E3ME model** to cover ten additional regions in **Africa.** The regions are part of an ongoing analysis of global climate targets with special focus on transition impacts on these regions. In a forthcoming publication for **IRENA**, Cambridge Econometrics will examine just transition issues, climate finance and technology deployment in these ten regions.

# Events

| Event | Location, Date | Objectives | Topics covered / relevance to climate change modelling | Deadlines | Comment / Action |
|---|---|---|---|---|---|
| 24th Annual Conference on Global Economic Analysis | 23-25 June, 2021, online | The conference is coordinated by the Global Trade Analysis Project (GTAP), Purdue University, with the support of national and international agencies. The purpose of the conference is to promote the exchange of ideas between economists conducting quantitative analysis of global economic issues. Emphasis will be placed on applied general equilibrium methods, data and application. | The theme of the conference is 'Global Food System: opportunities and Challenges':<br>• Agricultural innovation and resource constraints<br>• International trade and supply chain links<br>• Inclusive economic growth<br>• Climate change and environmental sustainability<br>• Food-energy linkages<br>• Food and agricultural policies | Registration not open. | There are a number of papers on modelling techniques. The conference has been shifted to an entirely online format. |
| European Association of Environmental and Resource Economists (EAERE) 26th Annual Conference | 23-26 June 2021, online | The conference is organised by TU Berlin and Humboldt-Universitaet zu Berlin. The conference is supported by the German Institute for Economic Research (DIW Berlin) and Mercator Research Institute on Global Commons and Climate Change (MCC). | | Registration closes June 21, 2021 | To be held online |
| Fourteenth IAMC Annual Meeting 2021 | 29 November – 3 December 2021, online | The IAMC annual meeting is a scientific meeting intended for peer sharing and vetting. | Topics can be found online: https://www.iamconsortium.org/event/fourteenth-iamc-annual-meeting-2021/#purpose | Registrations will open in September 2021 and will close on November 26th, 2021. | |
| The International Society for Ecological Modelling Global Conference | 3-7 May 2022, University of Toronto, Canada | ISEM 2022 aims to provide insights into the current state of the field of ecological modelling, and highlight the major challenges in supporting adaptive management implementation. | • Dynamic ecosystem models<br>• Uncertainty analysis<br>• Ensemble modelling<br>• Data assimilation and optimization techniques<br>• Machine learning and (big) data<br>• Model integration, metamodels<br>• Individual-based modelling | Call for symposium proposals | Programme not yet available |

| | | | | | |
|---|---|---|---|---|---|
| 2022: Ecological Models for Tomorrow's Solutions | | | • Software and tools<br>• Bioenergetics: Dynamic energy budget models<br>• Network modelling<br>• Models of socio-ecological systems<br>• Models of global, climate and land-use change<br>• Sustainability and resilience<br>• Ecosystem services<br>• Biodiversity and conservation<br>• Community models<br>• Marine ecology and fisheries<br>• Forests<br>• Freshwaters (lakes and rivers)<br>• Models of epidemics | | |
| 2nd International Conference on Negative CO2 emissions | 14-17 June 2022, Chalmers University of Technology, Gothenburg, Sweden | The purpose of this conference series is to bring together a wide range of scientists, experts and stakeholders, in order to engage in various aspects of research relating to negative CO2 emissions | Various negative emission technologies, climate modelling, climate policies and incentives will be discussed. The main topics of the conference, around which the sessions will be built, include:<br>• BECCS<br>• Biopheric storage<br>• Cross-cutting sessions<br>• Direct air capture<br>• Enhanced weathering<br>• Modeling<br>Ocean alkalisation | Call for abstracts<br>TBD | Postponed to 2022 |
| Energy Modelling Forum Snowmass Workshop | Date not announced, Snowmass, CO | A two-week annual workshop that brings together climate change experts to discuss the state of the art in climate policy analysis. The workshop has been organised in Snowmass, Colorado since 1995. | The workshop covers the latest developments in energy and environment modelling, with specific topics changing annually. | | |