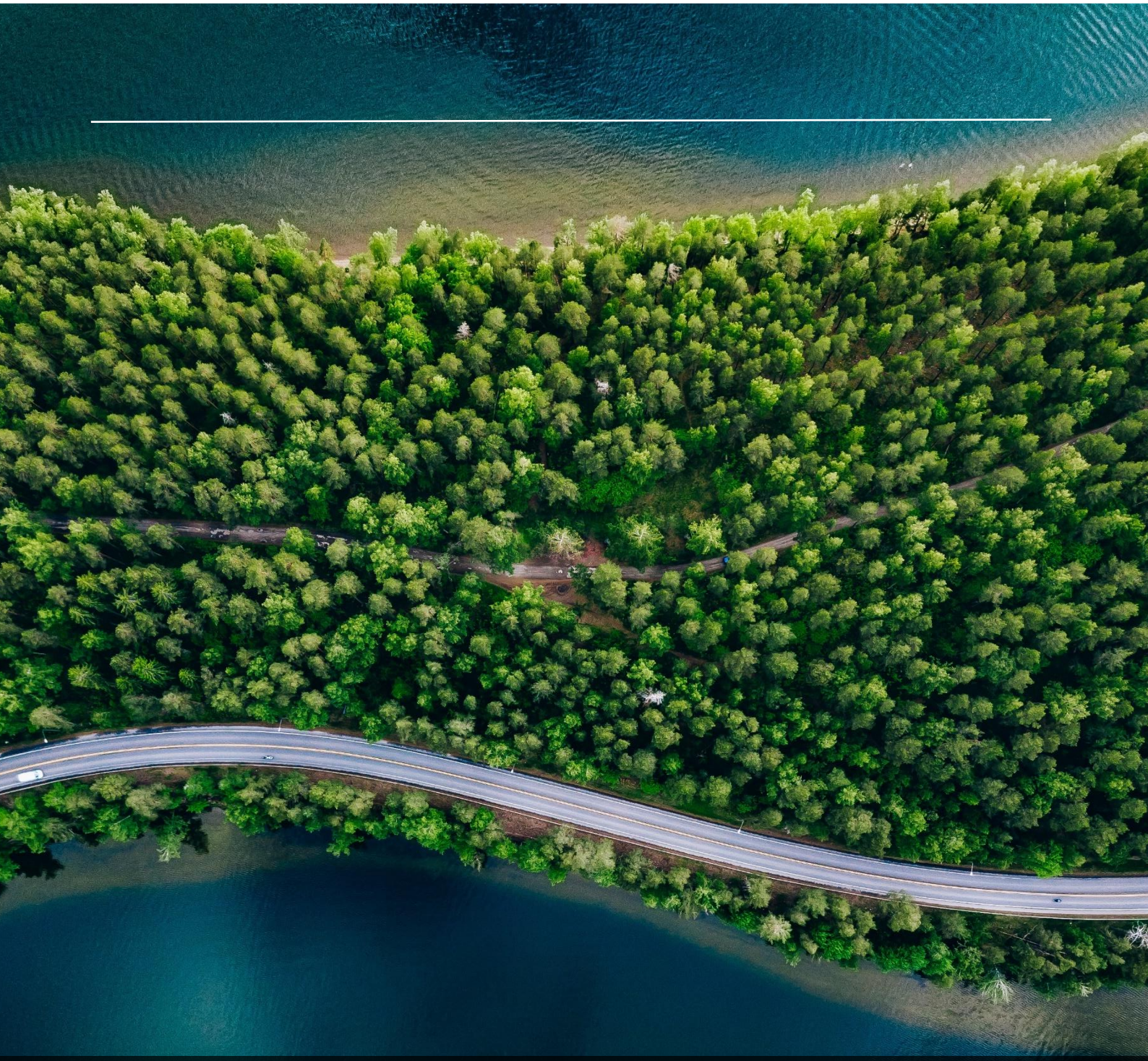

CLIMATE CHANGE MODELLING INFORMATION

Quarterly report – Q2 2022 report

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A report submitted by ICF S.A.
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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

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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 particular emphasis on the **employment impacts of climate mitigation policies**, in addition to the regular sections on Nationally Determined Contributions, Mid-century strategies and Sustainable Development Goals.

The first section of the report features modelling studies analysing the **employment impacts of climate mitigation policies**. Researchers from the University of Cambridge, **UK**, investigate the effects that climate change mitigation policies and, in particular, the introduction of a carbon tax have on workers within and across countries; the paper shows that sectors like oil, coal, and natural gas will suffer the largest drop in wages, and labour outflow. Another study from researchers from the **Barbados** analyses the labour market effects of a shift to more environmentally sustainable production, showing that workers in green industries appear to earn about 7% more than those working in non-green industries. Another study conducted by researchers from **Italy** assesses the extent to which a national green growth strategy can promote social equity, showing that a combination of policies that address both the social and ecological crisis together can lead to social prosperity and sustainability outcomes, including positive impact on employment levels.

Research developments linked to the implementation of the **Nationally Determined Contributions (NDCs)** are reported in the second section. Researchers from the **USA and Canada** have used a newly developed dynamic macro-econometric regional simulation model, E3-India, to explore the socio-economic impacts of decarbonisation pathways aligned with NDCs for India, finding that more ambitious NDCs will have unequal distributional impacts across states and sectors. Researchers led by **PBL Netherlands Environmental Assessment Agency** have used the IMAGE integrated assessment model and the TIMER energy system model to analyse the macroeconomic impact of the NDCs, suggesting that countries should strongly increase the ambition level of their NDCs to keep the Paris Agreement's climate goals within reach. Another study published by the **World Resources Institute of China** uses the Low Emissions Analysis Platform (LEAP) model, an integrated assessment model to assess road transport's emission, to evaluate transport decarbonisation policies and finds that radical structural changes in addition to the stated policies would help China meet its 2060 carbon neutrality commitment.

The third section features research linked to **mid-century strategies**, presenting a study conducted in **the Netherlands** on the mitigation of greenhouse gas emissions in hard-to-abate sectors using the IMAGE model; it finds that both technological innovation and structural changes are needed to achieve net zero targets in these sectors. Another group of researchers has simulated how **Japan**'s energy composition would change if the country were to achieve carbon neutrality by 2050, suggesting that a well-balanced policy and energy mix to decarbonise the economy would help achieve Japan's goal without a sole focus on nuclear. A study from the **Netherlands** assessed the impacts of circular economy on climate change mitigation, using the first, global long-term model on plastic production and waste management (PLAIA).

The fourth section of the report is dedicated to developments linked to the **Sustainable Development Goals (SDGs)**. An article led by researchers in **Portugal** focused on the impact of projected climate change and land cover development on specific vulnerable species distribution. Another one from researcher in **Australia**, explored the sustainability progress to 2100 using a system dynamics model. Finally, research led by the University of Ottawa in **Canada** showed that it is very unlikely for a developing country like Iran to achieve all the Sustainable Development Goals (SDGs) due to a number of socio-economic, political, and environmental obstacles.

Introduction

This report is the second quarterly report of 2022 under the series "Climate change modelling information" financed by the European Commission. The objective of this series is to inform the European Commission and the wider climate change and energy modelling community about recent and relevant modelling developments. The data presented in this report were collected through an open survey sent to more than 200 modelling teams worldwide and open from 29 July to 31 August 2022.

The survey asked modellers to report relevant developments with a focus on the implementation of Nationally Determined Contributions (NDCs), mid-century strategies, the Sustainable Development Goals and the employment impacts of climate mitigation policies.

Although the objective of this report is to present a list of the most recent developments, it cannot be considered exhaustive. For this quarterly report, responses came from two countries (The Netherlands and Kenya) and provided seven different modelling developments and projects. Additional desk research was undertaken to complement the survey results.

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

Modelling developments linked to the employment impact of climate mitigation policies:

- Coupling environmental transition and social prosperity: a scenario-analysis of the Italian case (Italy)
- Climate Change Mitigation Policies: Aggregate and Distributional Effects (United Kingdom)
- Does it pay to be green? An exploratory analysis of wage differentials between green and non-green industries (Barbados)

Modelling developments linked to Nationally Determined Contributions (NDCs):

- Cleaner the better: Macro-economic assessment of ambitious decarbonisation pathways across Indian states (USA)
- Updated nationally determined contributions collectively raise ambition levels but need strengthening further to keep Paris goals within reach (The Netherlands)
- Decarbonizing China's Road Transport Sector: Strategies Toward Carbon Neutrality | World Resources Institute (China)

Modelling developments linked to mid-century strategies:

- Mitigating greenhouse gas emissions in hard-to-abate sectors (The Netherlands)
- Impact on the power mix and economy of Japan under a 2050 carbon-neutral scenario: Analysis using the E3ME macro-econometric model (Japan)
- The plastics integrated assessment model (PLAIA): Assessing emission mitigation pathways and circular economy strategies for the plastics sector (The Netherlands)

Modelling developments linked to Sustainable Development Goals (SDGs):

- Tackling climate change impacts on biodiversity towards integrative conservation in Atlantic landscapes (Portugal)

- Early systems change necessary for catalyzing long-term sustainability in a post-2030 agenda (Australia)
- Achieving sustainable development goals: Fact or Fiction? (Canada)

Modelling developments linked to the employment impact of climate mitigation policies

- A research group from the University of Pisa in Italy conducted a study, available on the journal *Structural Change and Economic Dynamics*, assessing the extent to which green growth can promote social equity. The group developed a dynamic macrosimulation model to explore the short-term and log-term socio-economic consequences of green growth, using the Italian Integrated National Energy and Climate Plan as an example of green growth strategy. The study evaluates the social outcomes generated by the interactions of environmental and social policies; in particular, it looks at the impacts of two social policies expected to improve income distribution and employment levels: a basic income programme and a working time reduction. This integration is done to investigate whether the interactions and dynamics activated by these social policies can improve the social outcomes of the energy policies and/or complement them by providing favourable conditions to achieve the environmental goals.

  The study finds that pursuing economic growth exclusively through energy efficiency plans does not improve well-being indicators and does not contribute to reducing economic inequality. Both simulated social policies, when coupled with the environmental ones, results in reductions of income inequality; however, the basic income policy may also hinder progress towards environmental goals due to increased aggregate demand and production. Conversely, the combination of environmental policies and the working time reduction policy leads to both higher employment and lower emissions.

  Policy implications: The socio-economic and structural impacts of environmental policies are not negligible. Policymakers should look at the social and ecological crisis together to design more effective and lasting solutions to achieve social prosperity and environmental sustainability.

- The Energy Policy Research Group of the University of Cambridge published a study on the effects of climate change mitigation policies on labour within and across countries. Specifically, they focused on the impacts of the introduction of carbon taxes, assessing the reallocation of inputs and labour across the different sectors of the economy. The researchers developed a framework that integrates the workers' skill distribution with the economy's sectoral composition, building on the Roy model of occupational choice, where workers choose sectors depending on relative wages and their comparative advantage. Researchers used a multi-sector equilibrium model to evaluate the impacts of the carbon tax to various sectors, including the oil, coal, and natural gas energy producers. In the model, the carbon tax is of 32.3% - which is the estimated tax needed for the United States to achieve its original Paris Agreement pledge of a 26% reduction in emissions. The same model is used for seven countries: Brazil, Canada, China, India, Mexico, and the United States to capture the differences of the effects in various countries.

  The results of the study show that the so-called "dirty energy" sectors (oil, coal, natural gas) face the largest drop in wages and, consequently, the largest labour outflow.

Relatively less-talented workers, which indicates workers with a lower comparative advantage (i.e. the ability to produce something at lower cost than anyone else) in "dirty energy" production choose to reallocate away from the taxed sectors, while workers with a strong comparative advantage in the dirty energy production remain working in this sector and end up bearing the cost of the drop in wages, a welfare loss that is 12 times higher than workers in non-dirty sectors. Overall, the needed carbon tax causes a drop in GDP of at most 0.6% in the USA, while the same climate policy yields drops in output ranging from 0.5% (Brazil) to 2.1% (China).

Policy implications: The study shows that the same climate policy applied in different countries brings heterogeneous impacts, depending on the economic importance of the taxed sectors in each country. The adverse effects on GDP and labour markets that the carbon tax could bring can be partially or completely offset through tax rebates policy.

- A study conducted at the University of the West Indies Cave Hill, Barbados and published on the Journal of *Economics and Development* analyses the labour market effects of a shift to more environmentally sustainable production patterns. The aim of the research is to evaluate the potential wage impacts on workers in both green and non-green industries. The researchers use a micro-database for Barbados, an island that has been actively pursuing green economy policies for over ten years, using data from the labour market survey and interval regressions. This enables them to evaluate trends over the years 2004-2014 in reported relative wages in green industries.

  The study finds that the transition of the labour force from non-green to green industries might result in inequality and labour market rigidities with higher negative impact on less skilled workers in non-green industries workers, as green jobs tend to require more specialised skills. Additionally, it shows that workers in green industries appear to earn a wage premium – earning about 7% more than those working in non-green industries.

  Policy implications: When developing policies to promote green jobs, policymakers need to introduce specific support and incentives to help workers in non-green industries transition to green industries more easily. In particular, re-skilling will be crucial, hence support in the form of educational loans, grants or incentives to companies to help reskill their employees should be considered.

Modelling developments linked to Nationally Determined Contributions (NDCs)

- The *Renewable and Sustainable Energy Transition* journal has published a study led by the Regulatory Assistance Project on the socio-economic impacts of decarbonisation pathways for India. Researchers consider two ambitious pathways, one aligned with India's NDCs – negotiated through Paris agreement in 2015 – and another one with a more ambitious NDC plus a decarbonisation trajectory aligned with India's COP26 commitments at subnational level. A newly developed dynamic macro-econometric regional simulation model - E3-India is used to evaluate changes in key economic and emission parameters due to energy transition at both national and state level.

  The study suggests that the socio-economic impacts of committing to an ambitious decarbonisation trajectory, primarily articulated through NDCs for India, will be

positive; yet, the transition trajectory will have unequal distributive impacts in terms of employment and GDP across states and sectors. In particular, states with coal-intensive economies will be worse off as they rely primarily on the expansion of primary and extractive mining sectors, while states with high renewable energy potential will see an expansion in technology-focussed and high-skilled sectors.

Policy implications: Although the transition aligned with ambitious decarbonisation pathways will create economic opportunities for certain states thanks to increased investments in renewables, smaller coal bearing states will be negatively impacted by the transition in absence of 'Just transition' policies. Hence, there will be a need for policy interventions at both central and state levels for reskilling and employment generation.

- Researchers from the Netherlands, Austria and Greece conducted a study led by PBL Netherlands Environmental Assessment Agency to evaluate the ambition level of updated NDCs submitted by 156 countries under the Paris Agreement by January 2022. Researchers consider seven different scenarios, using the integrated assessment model IMAGE – which includes the TIMER energy system model – to project the impact of implemented policies on GHG emissions in all sectors up to 2030 and find that the NDCs still fail to meet the Paris Agreement goal of keeping global temperature increase to well below 2 °C, and the gap is seven times greater for a 1.5 °C trajectory. Socio-economic impacts, in form of GDP losses, will be small in major economies (G20) and will largely depend on the emission reduction effort included in the NDCs. Considering the NDCs submissions at the time of the publication of the study, collective commitments still fail to put us on the pathway required to meet the Paris' targets. There is an urgent need for countries to increase ambition and further scale up action.

- The World Resources Institute of China conducted a study to explore how the Chinese road transport sector could be decarbonised to meet the carbon neutrality goal by 2060 and other targets before then. The authors modelled five different scenarios using the Low Emissions Analysis Platform (LEAP) model, an integrated assessment model used to simulate current and future GHG and air pollutant emissions. The study focuses on the transport sector, without including endogenous interactions with supply chain sectors.

  Results show that if China implements all its stated policies, road transport's GHG emissions in 2060 would decline by 50 percent from 2020 levels. With full vehicle electrification and additional radical structural changes, such as by managing vehicle fleet growth and kilometres travelled through, for example, the promotion of Mobility-as-a-Service and ride sharing or improving vehicle occupancy rates, road transport's GHG emissions would reduce by 95 percent by 2060 compared to 2020's level, thus meeting China's 2060 carbon neutrality commitment.

  Policy implications: in the long term, vehicle electrification seem to be the option with the highest decarbonisation potential for the transport sector, followed by structural changes, fuel efficiency improvements, and the decarbonisation of power and hydrogen generation sectors, which play a role in vehicle electrification and decarbonising the transport sector. Conversely, in the near term (until 2035), structural changes have the largest decarbonisation potential due to the fact that the diffusion of electric vehicle technologies would have not yet reached a tipping point by then.

Modelling developments linked to mid-century strategies

- PBL Netherlands Environmental Assessment Agency recently published a study in cooperation with Utrecht University on the efforts needed to mitigate the emissions of hard-to-abate sectors, such as industry, the built environment, agriculture, aviation, and shipping. Based on the rationale that relying heavily on carbon dioxide removal is a risky strategy, in particular for food security and biodiversity, the research group developed a set of scenarios based on measures that can reduce the emissions and at the same time reduce the need to remove CO2 from the atmosphere, limiting bioenergy use to sustainable levels. The study is performed using the process-oriented integrated assessment modelling framework, IMAGE model, that simulates the interactions of human activity with both the economic development and the environment.

  The study shows that both technological innovation and structural changes can contribute to reducing emissions in hard-to-abate sectors and limit global warming to 1.5°C. Some examples of promising technological measures include the deployment of alternative fuel technologies and the development of cultured meat; promising structural changes include, more circular use of raw materials, more efficient waste processing, and lifestyle changes such as diet change.

  Policy implication: achieving the complete decarbonisation in all sectors is a difficult task, however, combining technological innovation and structural changes can enable significant decarbonisation in hard-to-abate sectors to support the net-zero target. Technological innovation and structural changes can be promoted through financial policy instruments, such as taxes (e.g., on airline tickets and meat) and grants, as well as through regulation and direct investment in research and training.

- A group of researchers from Japan and the UK, led by the University of Nagoya, analysed the changes in Japan's energy composition if the country were to achieve carbon neutrality by 2050. The study is available on the *Climate Policy* journal. To simulate what Japan's macroeconomy would look like, researchers used the E3ME macro-econometric model to create two policy scenarios: one with continuous nuclear power use and the other with nuclear power phase out by 2040. The two scenarios were compared with a baseline scenario, which consider current policies without additional special measures.

  The study shows that switching to renewable energy can provide better economic opportunities; in fact, the scenario with nuclear phase out by 2040 results into a GDP growth of 4.0%–4.5% compared with the baseline scenario and an improvement in employment levels by 1.5%–2.0%. Furthermore, it is estimated that energy bills would be 45% lower for consumers and 11% lower for industry in 2050 compared to the baseline.

  Policy implications: the fast reduction of global renewable costs for wind and solar technologies means that the net zero transition does not have to rely on relatively more expensive nuclear power, but more investments in electricity storage should be prioritised. Additionally, a well-balanced decarbonisation policy mix is required, and a combination of pricing incentives, regulations and R&D support should be considered.

- A new study conducted by Utrecht University and published on *MethodsX* explore the impacts of the circular economy on mitigating climate change. Researchers assess circular economy strategies for the plastic sector using an Integrated Assessment Model

(IAM) called the Plastics Integrated Assessment model (PLAIA). This model allows for the inclusion of plastic production, use, and end-of-life and is one of the first global, long-term models on plastic production and waste management integrated in an IAM. The model allows for the assessment of the global plastics sector up to 2100, including its interactions with other socio-economic and natural systems.

Due to the many assumptions made for the model, **the study finds** that it is difficult to make clear projections on the development of the recycling sector. Nonetheless, the findings clearly suggest that the most significant improvements come from policy interventions rather than from technological solutions.

Policy implications: the study shows that policy-related improvements such as, enhancing circular product design and implement a better sorting of plastics, have the highest potential compared to technical progress in sorting or recycling technologies.

Modelling developments linked to Sustainable Development Goals (SDGs)

- A research paper available on the *Global Ecology and Conservation* journal, led by the Capacity Building, and Sustainability of Agri-food Production of the Universidade de Trás-os-Montes e Alto Douro, presented an integrated assessment of how species respond to climate change and the resulting habitat loss. The paper analyses the effects of climate change in the spatial distribution of selected species in the past (1950–2018) and in the future (2041–2070). Results of the spatial distribution were compared to predicted future climate projections (2041–2070), based on two IPCC scenarios (RCP4.5 and RCP8.5), using a 5-model ensemble developed under the EURO-CORDEX project. Land cover maps were developed using the Forecasting Landscape Scenarios Model. Overall, researchers assessed the impact of projected climate change and land cover developments on specific vulnerable species distribution for four case studies of watersheds in the Atlantic region.

  Results showed a temperature increase in all case studies and for both IPCC scenarios, although these are more pronounced for southern catchments (Portugal and Spain) compared to northern catchments (France and Northern Ireland). A shift in potential habitat area of species addressed to areas upstream of the catchments is also noted.

  Policy implications: Predictions on the impact of future climate change scenarios and land cover changes on ecosystems and biodiversity can provide insights for conservation strategies and landscape management. The design of innovative incentive-based policies for biodiversity protection, improve conservation and can help species thrive across their entire natural habitat while also contributing to building more resilient ecosystems.

- A research led by the Centre for Integrative Ecology, School of Life and Environmental Sciences of Deakin University in Melbourne Australia, explored the sustainability progress to 2100 using a system dynamics model. Researchers analyse the drivers of sustainability progress and their role at different timescales (2030, 2050, and 2100) and under different development pathways and quantitative targets. They use an established model, the Functional Enviro-economic Linkages Integrated Nexus (FeliX), to model indicators representing eight SDGs related to sustainable food (SDG 2), health and well-being (SDG 3), quality education (SDG 4), clean energy (SDG 7), economic

growth (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13), and life on land (SDG 15).

Researchers find that for systems change to shift from business as usual to more sustainable pathways, early planning is important for accelerating progress toward ambitious targets by 2030, 2050, and 2100. These highlight the importance of using longer-term timeframes and pathways for sustainability beyond the 2030 Agenda.

Policy implications: Understanding the complex system dynamics is crucial to enable the required systems change. The model can provide policymakers with insights around SDGs synergies as well as trade-offs to be able to design policies that exploit the interdependencies and overcome challenges, leading to more successful sustainability outcomes.

- Researchers from Australia and Iran, led by the Telfer School of Management of the University of Ottawa, conducted a study to assess the achievability of the Sustainable Development Goals (SDGs) in a developing country, Iran. The study, published on *the Journal of Cleaner Production,* uses a conceptual system dynamics model that consist of 14 casual loops, highlighting direct and indirect interdependencies among the 17 SDGs. In the first stage, data from research papers was collected to identify direct and indirect linkages among SDGs and the challenges of their implementation. In the second stage, an expert panel was consulted to get additional data to conceptualise the system dynamics models.

  The study argues that there are many obstacles which make it impossible to achieve several of the SDGs. These obstacles are, among others, regional conflicts and environmental concerns, internal conflicts of interests among key stakeholders, sanctions, and absence of recent data and credible evaluation mechanisms. Looking at the case study, Iran, the study highlights that national efforts have been only successful in making progress towards the following SDGs: quality education for all (SDG 4), resilient infrastructures and sustainable industrialisation (SDG 9), and partnerships for the goals (SDG 17); however, it found that the remaining SDGs, about 82% of the goals, cannot be achieved by 2030 through the current national strategies and local plans.

  Policy implications: to implement the 2030 Agenda, the study suggests Iran should engage with governmental and non-governmental organizations, private companies, financial investors, and civil society to establish a prioritised national plan based on its capacities (financial resources, natural resources, human capitals, infrastructures, social and cultural considerations, etc.). Iran's example could also help other developing countries in understanding the systematic relationships among SDGs and develop a bespoke plan based on national resources.

Event	Date and location	Objectives	Topics covered / relevance to climate change modelling	Number of participants and deadlines
Energy Modelling Forum Snowmass Workshop	TBC	The Energy Modelling Forum brings together climate change experts to discuss the state of the art in climate policy analysis. These annual workshops take place in Snowmass, Colorado.	The workshop covers the latest developments in energy and environment modelling, with specific topics changing annually	n/a
15th IAMC Annual Meeting 2022	28 November – 2 December 2022, College Park Marriott Hotel & Conference Center, College Park, MD, USA	The purpose of IAMC Annual Meetings is to: • Present and discuss the state of the art in integrated assessment modelling; • Review the status of ongoing community activities including both multi-model studies and the activities of the IAMC Scientific Working Groups; • Facilitate interaction with collaborating communities; • Evaluate and revisit the priorities of the integrated assessment community.		Registration closed on November 25th, 2022.
The International Society for Ecological Modelling Global Conference	2-6 May 2023, University of Toronto, Scarborough, Canada	ISEM 2023 aims to provide insights into the current state of the field of ecological modelling, and also highlight the major challenges in supporting adaptive management implementation.	The conference welcomes contributions that present novel strategies to improve the contribution of models to environmental management, including the development of ecological model ensembles, novel uncertainty analysis techniques, Bayesian inference methods, emerging techniques of data assimilation and model optimization.	Abstract submission timeframe is 5 October - 25 November 2022