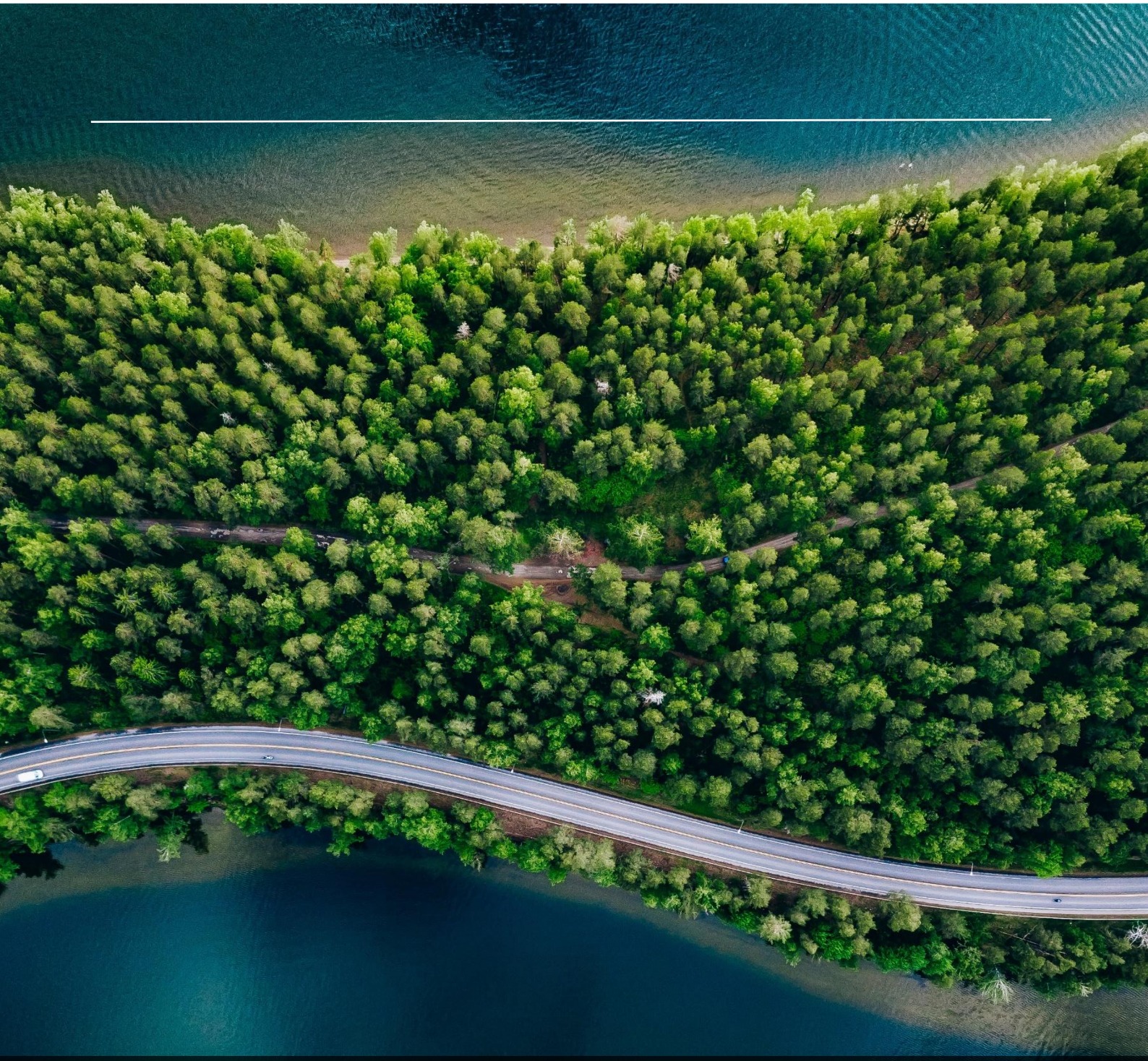

CLIMATE CHANGE MODELLING INFORMATION

Quarterly report – Q3 2021 report

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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 an emphasis on the **finance 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 **finance sector**. The finance sector is key for achieving the green transition and must therefore transform rapidly. The research featured in this section highlights that there is growing demand by the business and finance community for reliable climate information; the articles assess the impact of higher cost of green finance on developing economies and the impact of 2°C and 1.5°C scenarios have on banks' portfolios in **Australia.** Another article from Australian researchers highlights the need to improve climate models to enable business and financial organisations better integrate climate risks (such as extreme weather events, risks to supply chain infrastructure) into financial decisions. Echoing the view that current economic and climate models are not designed to assess climate-related financial risks, a set of a high-level reference scenarios have been presented in a guide developed by the Network for Greening the Financial System (NGFS). Researchers from **University College London** study implications of unequal access to finance across countries. They show that earlier action to improve financial conditions in developing economies could have a significant impact on the speed of the mitigation transition. For example, it would allow countries in **Africa** to reach net zero emissions 10 years earlier. Finally, analysis from the International Monetary Fund suggests that green investments can guide the Covid-19 recovery in a more sustainable direction.

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 developing new scenarios and combining various data sources to improve prediction capacities. Researchers from **Germany and Brazil** have updated the Model of Agricultural Production and its Impact on the Environment, a modular open-source framework for modelling global land systems. A research team in **China** find that energy-saving retrofitting technologies help short-term CO2 emissions reduction, but breakthrough technologies (e.g., CCS) are crucial in achieving carbon neutrality. An interdisciplinary team from Italy and the USA has combined species distribution and climate modelling with historical land use records to reconstruct changes in plant species distribution in **Central Italy.** Australian researchers have implemented scenarios representing a more diverse range of decarbonisation pathways for **Australia**. Their study shows that net zero emissions by 2050 are hard to achieve and requires potentially unrealistic levels of action in the latter end of the 2040s.

In the third section, the report features research linked to **mid-century strategies**. As part of the **REINVENT** project, a research team is modelling decarbonisation pathways for industry and analysing the contribution of industry within a net-zero context on a global scale. Their key finding is that "net-zero" emission pathways for the global industry sector are needed before or by 2050 to remain aligned with the Paris Agreement. In **Germany**, a research team has developed a model to underpin the first National Energy and Climate Plan (NECP) of EU candidate countries **Albania and Montenegro** providing the analytical basis to the first NECPs in the two countries. And finally, a new model used by the **New Zealand** government indicates that as emissions fall over time, the impact of carbon prices on economic activity also diminishes; therefore, the overall impact of climate policy on New Zealand's GDP is modest.

Introduction

This report is the third 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 19-31 July 2021.

The survey asked modellers to report relevant developments with a focus on the finance 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 seven countries (see Figure 2.1), ten organisations and covered eleven 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 = 10)

Source: ICF, 2021. Climate change modelling information Q3 2021 survey.

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

Modelling developments linked to the finance sector:

- Impact of higher cost of green finance on developing economies (UK)
- Climate scenarios for banks' sectoral decarbonisation trajectories (Australia)
- Business risk and the emergence of climate analytics (Australia)
- Guide to climate scenario analysis for central banks and supervisors (EU)
- Green investments and the global Covid-19 recovery (USA)

Modelling developments linked to Nationally Determined Contributions:

- A new open-source framework for modelling land systems (Germany)
- Low-carbon transition pathways for China's iron and steel industries (China)
- Historical ecology data for climate change modelling (Italy)
- Scenarios for decarbonisation pathways in Australia (Australia)

Modelling developments linked to mid-century strategies:

- Modelling energy and non-energy emissions in Albania and Montenegro (Germany)
- Decarbonisation pathways for industry within a net-zero context (Netherlands)
- C-PLAN: a new CGE model for New Zealand (New Zealand)

Modelling developments linked to the finance sector

- Researchers at University College London have analysed the impact of higher cost of green finance on developing economies. Access to low-cost finance is vital for developing economies' transition to green energy but is often hampered by underdeveloped financial markets and domestic risk. This results in high premiums, increasing the cost of capital for low-carbon investments, thus delaying the energy system transition and the reduction of carbon emissions in these countries. Using TIAM_UCL energy system integrated assessment model, researchers show how modelled decarbonization pathways for developing economies (with a particular focus on Africa) are disproportionately impacted by different weighted average cost of capital (WACC) assumptions. The authors first introduce regionally differentiated WACC for power generation instead of using a global value. Then, they analyse the regional WACC convergence over different time horizons toward a global value over the rest of the century. For example, representing regionally specific WACC values indicates 35% lower green electricity production in Africa for a cost optimal 2°C pathway.

  The results of the study show that early convergence of WACC values for green and brown technologies in 2050 would allow Africa to reach net-zero emissions approximately 10 years earlier than when convergence is not considered. A "climate investment trap" arises for developing economies when climate-related investments remain chronically insufficient. The article published in Nature Communications is available online.

  Policy Implications: The article examines the implications of unequal access to finance across countries and shows that earlier action to improve financial conditions in developing economies could have a significant impact on the speed and timing of the mitigation transition. Changes in elements of sustainable finance frameworks are needed to better allocate capital to the regions that most need it. This can be backed by institutional support from both local governments and international development banks. Other players such as the International Monetary Fund (IMF) and central banks also have a role to promote enabling macroeconomic environments through better surveillance of climate-related financial risks and opportunities, enhanced policy and financial assistance.

- Researchers at ClimateWorks Australia have applied data and models from pre-existing climate scenarios[1] to actors in the financial sector, specifically banks looking to know what sectoral decarbonisation trajectories look like for their clients under 2°C and 1.5°C scenarios. There appears to be increased momentum in this space for banks to embed decarbonisation trajectories, and potentially use these scenarios to set 2°C or 1.5°C-aligned emission targets for their portfolios. Two of the Decarbonisation Futures scenarios were applied to five selected segments of the National Australia Bank's lending portfolios (agriculture, residential (mortgages), commercial real estate (office and retail), power generation, and resources (including coal, oil and gas). The two scenarios model two different pathways: the 1.5°C "All-in" pathway and a 2°C "Innovate" pathway. In the latter pathway, some sectors decarbonise faster than others.

  One key finding from the application of the scenarios to the National Australia Bank lending portfolio is that a net zero economy following the 1.5°C scenario achieves net zero emissions 15 years faster (in 2035) than a trajectory which follows the 2°C pathway.

  Policy implications: The scenarios have informed the Sustainability Report 2020 of National Australia Bank and supported them in aligning their lending portfolio to the Paris Agreement. Applying the scenarios to the banking sector helps business customers understand their footprint and transition their own businesses towards a low emissions future and provides an overall understanding of the timeline needed to achieve a net zero economy.

- Researchers from the University of Sydney and the Centre of Excellence for Climate Extremes (CLEX) in Australia have published an article highlighting the growing demand by the business and finance community for reliable climate information, and the potential and limitations of such information. Authors indicate that information from global general circulation models (GCMs) and regional climate models (RCMs) is commonly a key input for examining climate risks at various timescales and geographical scales. However, despite open access to GCM and to a lesser degree RCM projections, including data sets from the Coupled Model Intercomparison Project (CMIP), using information generated by climate models in business is still complex. This leads financial institutions to heavily rely on external climate service providers (CSPs) for measuring financial risk. The complexity and increasing and unsupervised use of the large quantities of complex open-source information generated by climate models might lead to the potential misuse and abuse of climate models creating risks such as heightened vulnerability of business to climate change, overconfidence in assessments of risk, material misstatement of risk in financial reports and the creation of greenwash.

  The study shows that advances in modelling are essential to address the complexity and limitations of existing models and allow these models to be made available at smaller resolutions and be more operational for businesses. The authors also call for qualified "climate translators" to help regulators, investors and companies make better use of science. This needs to be complemented with direct engagement between climate scientists and business to both enable the appropriate use of robust data as well as drive the scientific innovation business needs. The article published in Nature Climate Change is available online.

  Policy Implications: As the desire of governments, regulators, standard-setters and business to assess climate risk becomes widespread, there is strong role for policy-

[1] ClimateWorks have been featured in previous reports (see, for example, Q1 2019 report) for their work on the Decarbonisation Futures project. Two of the modelled scenarios from their 'Decarbonisation Futures' report have been applied to the five most carbon intensive segments of National Australia Bank's Australian lending portfolio.

makers to support the advances called upon in climate modelling, facilitate access to and use of models, and foster interaction between business and science.

- The Central Banks and Supervisors' Network for Greening the Financial System (NGFS) has issued a guide to climate scenario analysis. Echoing the above view that climate scenarios are not entirely appropriate for central banks and supervisors' purposes, the NGFS has collaborated with the academic community to publish a set of high-level reference scenarios that can be used for macro-financial analysis in a comparable way across different jurisdictions. These can also be used to assess the impact of climate risks on a wide-ranging set of economic and financial variables (e.g. GDP, inflation, equity and bond prices, loan valuations).

  The guide distinguishes four broad steps for scenario analysis from identifying objectives and exposures to choosing scenarios, assessing impacts and communicating results. While conducting their macroeconomic and financial impact assessment central banks and supervisors need to approach scenario analysis with different questions (for example, the types of risks explored, the number of scenarios, granularity, time horizon and calibration). Three emission reduction scenarios are presented in the guide with varied emission prices, use of carbon dioxide removal (CDR) technologies and global warming reduction ambitions and using multiple models (GCAM, REMIND-MAgPIE, and MESSAGEix-GLOBIOM). The full guidance document is available online.

  Policy Implications: While the NGFS scenarios provide a foundation for decision-useful financial and economic analysis by central banks and supervisors, but also financial firms and corporates seeking to manage their exposure to these risks, challenges and shortcomings remain. Some of the main issues include the lack of integration of physical risk, transition risk and macro-financial transmission channels; lack of available data and research to calibrate the scenarios and assess impacts; and lack of technical expertise on climate science and environmental economics within the financial sector. As the use of climate-related scenario analysis is relatively new and methodologies are still developing, the NGFS will leverage further insights from the practical experiences of central banks and supervisors as an increasing number undertake scenario analysis.

- The International Monetary Fund (IMF) has dedicated its 2020 World Economic Outlook report to the Covid-19 effects and recovery. Chapter 3 focuses on the effects green investments can have on GHG emissions and the economic recovery, and the analysis is based on the G-Cubed global macroeconomic model developed by McKibbin and Wilcoxen (2013). The model features 10 regions, 20 detailed energy sectors, forward-looking agents, real and nominal rigidities, and fiscal and monetary policies. The model accounts for stocks and flows of physical and financial assets. The full report, including the data and accompanying methodological annexes, is available online.

  The study suggests that an initial green investment push in combination with rising carbon prices over time could lead to the needed emissions reductions at reasonable effects on key macroeconomic outputs (i.e., growth, employment and inequality) in the short term. A green fiscal stimulus can strengthen the economy in the short term and help lower the cost of adjusting to higher carbon prices. Such a combination of early green investments and rising carbon prices will also lead to a more sustainable economy in the medium term. Another key finding is that the distributional impacts of carbon pricing vary by country.

  Policy Implications: Carbon pricing is considered one of the key policy tools for climate mitigation policy, but it has considerable effects on economic growth and inequality. The results of this report show that green investments can help ease up the transitional costs.

Modelling developments linked to Nationally Determined Contributions (NDCs)

- Researchers from Germany and Brazil have updated the Model of Agricultural Production and its Impact on the Environment (MAgPIE 4). MAgPie is a modular open-source framework for modelling global land systems. It is coupled with the grid-based dynamic vegetation model (LPJmL).°. The framework takes regional economic conditions such as demand for agricultural commodities, technological development and production costs as well as spatially explicit data on potential crop yields, land and water constraints (from LPJmL) into account. Based on these, the model derives specific land use patterns, yields and total costs of agricultural production for each grid cell. The objective function of the land use model is to minimize total cost of production for a given amount of regional food and bioenergy demand. Regional food energy demand is defined for an exogenously given population in 10 food energy categories, based on regional diets. Future trends in food demand are derived from a cross-country regression analysis, based on future scenarios on GDP and population growth. The model, together with all documentation and a paper describing the framework, is available online.

  Policy Implications: The open-source model will contribute to greater transparency and collaboration in land use research. Land use activities play an important role in the emission and removal of greenhouse gases. Enhanced research in this area can help policymakers finetune their working assumptions and future predictions.

- A forthcoming article in *Applied Energy* explores low-carbon transition pathways for China's iron and steel industry under the carbon-neutrality target. The researchers from Peking University, the National Institute for Environmental Studies in Japan, University College Cork, and Columbia University develop an integrated method consisting of a top-down IMED/CGE model and a bottom-up technology-optimization module. Low-carbon measures from both the consumption side and production side are incorporated into the integrated model. Breakthrough technologies (e.g., carbon capture and storage (CCS) and hydrogen-based direct reduction (DR) are involved in the optimization model, making it possible to explore the deep decarbonization of the iron and steel industry under the carbon-neutrality target. Moreover, the upstream energy supply, including electricity and hydrogen, is also included in the optimization procedures to determine optimal cross-sectoral technology portfolios from a system-wide view.

  They find that energy-saving retrofitting technologies help short-term CO2 emissions reduction, but breakthrough technologies (e.g., carbon capture and storage, hydrogen-based direct reduction) are crucial in achieving carbon neutrality.

  Policy Implications: Iron and steel production contributes to 14% of China's energy-related CO2 emissions. This research project provides clear indications to policymakers on the potential of different technological pathways to decarbonise these industries and bring us to climate neutrality faster.

- An interdisciplinary team from Italy and the USA has published a journal article in the journal *Landscape Ecology* combining species distribution and climate modelling with historical land use records to reconstruct changes in plant species distribution in Central Italy. The article combines historical ecology data with species distribution modelling (SDM) to reconstruct the impact of land use changes, invasive pathogens, and climate change on the landscape of the Monte Pisano in Italy, and more specifically the impact

on the distribution of pine and chestnut forests since 1850. Anthropologists and historians have a crucial role to play in helping climate scientists understand possibilities of transformation, rapid change, and catastrophe that are often ignored in scientific predictions of global environmental change. Using local ecological data from the past can broaden the range of environmental futures contemplated by climate change modellers.

The results show that the changes in the distribution of pine and chestnut forests since 1850 cannot be explained solely by climactic changes, and that land use change brought about by socioeconomic changes is the biggest contributor to the shifts in species populations.

Policy Implications: The researchers seek to build collaborations across disciplines to describe possible future local scenarios to help policymakers and local stakeholders in decision-making. Through the combination of multi-disciplinary methodologies researchers can make better predictions for how land use, climate change and ecological change will interact in the future.

- Researchers at the Australian Energy Market Operator (AEMO) have implemented scenarios representing a more diverse range of decarbonisation pathways for Australia. The study shows the level of ambition that would be needed if Australia were to only target its current NDC before transitioning to Net Zero emissions by 2050. For recent scenarios in the energy sector, the researchers have sought to present 1.5°C and 2°C scenarios that show a divergent range of outcomes on grid electricity demand, particularly through electrification and uptake of hydrogen electrolysis. They also sought to model a scenario in which action is deferred until after 2030. This was done using an imposed emissions trajectory set as a constraint. More information on the modelling details is available here.

  The modelling outcomes show that net zero emission by 2050 is particularly hard to achieve and requires potentially unrealistic levels of action in the latter end of the 2040s. A major part of this was the fact that even under relatively unambitious settings, the electricity grid tends to steadily decarbonise under all scenarios, driving emissions reductions even if the other sectors do nothing.

  Policy Implications: These scenarios are being used by stakeholders in the energy system for network planning purposes in Australia.

Modelling developments linked to Mid-century strategies

- Researchers at the Fraunhofer ISI in Germany have developed a model to underpin the National Energy and Climate Plan (NECP) of Albania and Montenegro. The model has been implemented in the LEAP framework (Low Emissions Analysis Platform, the software tool for energy policy, climate change mitigation and air pollution abatement planning developed by the Stockholm Environment Institute) to describe energy and non-energy emissions and other indicators, covering the whole economy until 2050. The model has provided the analytical basis to the first NECPs in the two countries.

  Policy Implications: NECPs are one of the key tools helping EU countries meet their energy and climate targets for 2030. The elaboration of the NECPs is an important step in the EU accession processes for EU candidate counties Albania and Montenegro.

- In the context of the H2020 REINVENT project, researchers at Lund University and PBL Netherlands Environmental Assessment Agency have attempted to model

decarbonisation pathways for industry and analyse the contribution of industry within a net-zero context on a global scale. In order to do this, they have improved the resolution of the technology portfolio in IMAGE for the steel industry (including now H-DRI, Electrowinning), the chemical industry (including now 2 CCUS routes and electric cracking) and used the newly added pulp and paper module in the analysis. Additionally, they have co-created four archetypical decarbonisation narratives in a transdisciplinary setting where transition scientists, industrial systems experts and stakeholders have discussed the futures of various energy-intensive industries in the context of the H2020 REINVENT project. The key scientific policy challenges the researchers have attempted to address within the H2020 REINVENT project were (1) to study plausible pathways for industry in a climate neutrality context, and (2) to consider if zero emission pathways can be plotted for the various energy and carbon intensive industry sectors. The paper is currently under review and available online.

The outcome of this research underscores that "net-zero" emission pathways for the global industry sector are needed before or by 2050 to remain aligned with the Paris Agreement. However, this result can only be met with 'smart emission accounting' of negative indirect emissions found in scope 2 emissions.[2] .In the absence of negative indirect emissions, the majority of regions and scenarios depict that residual emissions persist for the majority of carbon intensive industries and regions in the IMAGE model.

Policy Implications: As only very specific technology portfolios can result in zero emission pathways, policymakers need to carefully consider the reliance on such pathways in planning the transition to a climate neutral economy.

- Researchers at the Auckland University of Technology have developed a new model to help New Zealand make better informed climate policy. The Climate PoLicy ANalysis (C-PLAN) model is a global, recursive dynamic computable general equilibrium (CGE) model tailored to the economic and emissions characteristics of New Zealand. Distinguishing features in the model include methane-reducing technologies for livestock, bioheat from forestry residues, and explicit representation of output-based allocations of emissions permits. A working paper documenting the model and presenting the results of the baseline and one policy scenario is available online.

  The results of the simulations indicate that in both the baseline and policy scenarios the impact on New Zealand's GDP is modest (between 0.15% - 0.34%). The reason for the modest impact is that as emissions fall over time the impact of carbon prices on economic activity also diminishes.

  Policy Implications: The model was built for the New Zealand Climate Change Commission (CCC) to inform policy advice provided to the government. The computer code for the model and instructions for reproducing results used by the CCC are publicly available, which increases the transparency behind climate policy development and decisions. The model is used by the New Zealand government to set emission budgets and examine the impact of climate policies out to 2050.

[2] Scope 2 emissions are indirect emissions generated from the electricity purchased and used by an organisation.