



Climate change modelling information

Quarterly report – Q3 2019 report

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Quarterly report – Q3 2019 report

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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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Prepared by	Yann Verstraeten, Ralitsa Donkova
Checked by	Jérôme Kisielewicz
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1 High-level executive summary

This report under the “Climate change modelling information” series, presents relevant developments reported by key international climate modelling institutions. This issue sets a particular emphasis on mid-century strategies, nationally determined contributions (NDCs) and modelling covering energy and climate modelling integrating behavioural changes.

The first section of the report is dedicated to modelling developments linked to the implementation of **mid-century strategies**. The majority of developments in this section are dedicated to enhancing existing models with new sectoral coverage and/or new data. The PBL Netherlands Environmental Assessment Agency has added a number of industrial manufacturing sectors in the Integrated Model to Assess the Global Environment (IMAGE) model. The Carbon Dioxide Removal Model Intercomparison Project has made available new data to support IPCC science and climate mitigation strategies. Researchers at COPPE/UFRJ have expanded the Brazilian Land Use and Energy System (BLUES) model with data on advanced biofuels conversion routes and land use aspects in Brazil. Another key development is the meta-analysis of how scenarios are used to improve models and long-term strategies. A paper by WRI takes stock of how long-term strategies perceive and handle uncertainty and suggests the use of scenarios to improve the robustness of policies. A new report by The Shift Project provides an introduction to the concepts, principles, and structures of energy-climate models for a lay audience.

Various developments linked to the implementation of the **NDCs** are reported on in the second section. Two of the modelling developments make the process of modelling and analysing NDCs more streamlined and therefore easier – the FRAMES modelling framework for energy-economy policy analysis in developing countries and the TIMES-Starter Model Management Platform. The other research reported in the section enhances the NDCs analysis for specific countries – Brazil, China and Costa Rica.

Lastly, a range of other recent climate modelling developments are reported on in the third section. At the University College Cork, researchers have for a first time used deep machine learning architectures to model transport service demands. And at Imperial College London, researchers have integrated energy systems and gas infrastructure optimisation models to assess the need for investment in regional gas infrastructure in Southern Brazil.

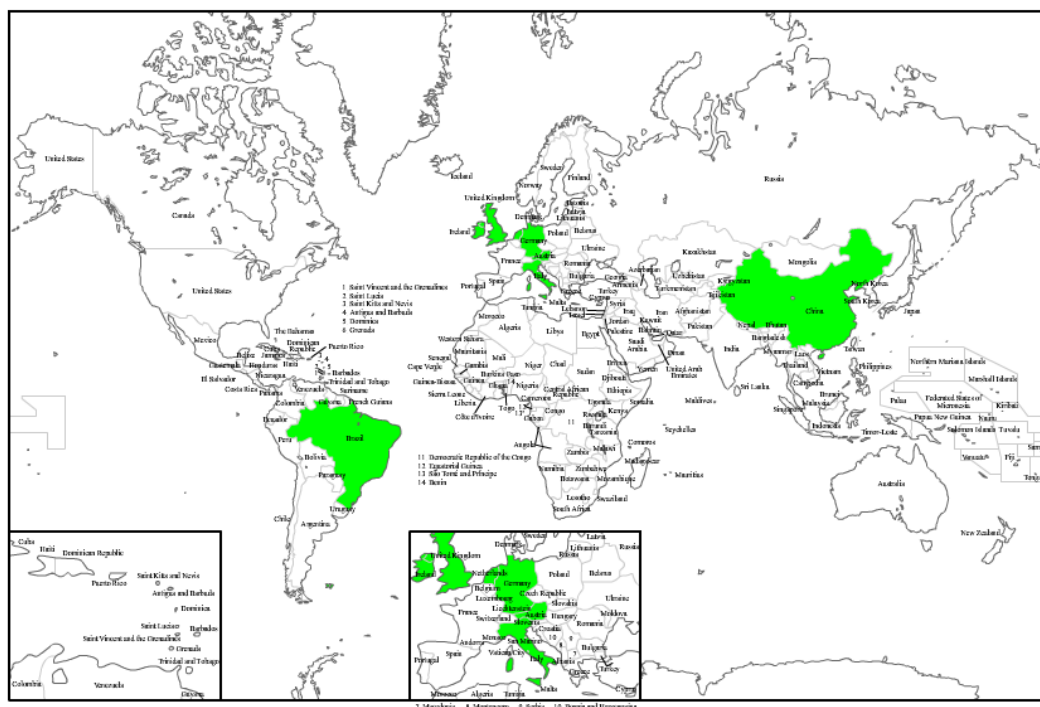
2 Introduction

This report is the third quarterly report of 2019 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 10 October to 24 October 2019.

The survey asked modellers to report relevant developments with a focus on the implementation of Nationally Determined Contributions (NDCs), mid-century strategies and modelling covering energy and climate modelling integrating behavioural changes. 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 8 countries (see Figure 2.1), 14 different organisations and covered 12 different modelling developments and projects.

Additional research was also undertaken to complement the survey results.

Figure 2.1 Geographical coverage of climate change modelling developments reported through the online survey (n = 14)



Source: ICF, 2019. Climate change modelling information Q3 2019 survey.

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

Modelling developments linked to the implementation of mid-century strategies:

- [Expanded coverage of industrial manufacturing sectors in the IMAGE model](#) (The Netherlands)
- [New data for the Carbon Dioxide Removal Model Intercomparison Project](#) (Germany)
- [Analysis of the energy investment needs for fulfilling the Paris Agreement and achieving the SDGs](#) (Italy)
- [Potential for deployment of biodiesel production based on forestry residue](#) (Brazil)
- [Taking stock of long-term low-emission strategies of the UNFCCC to handles uncertainties](#) (International)
- [An introduction to energy-climate modelling for a lay audience](#) (France)

Modelling developments linked to nationally determined contributions (NDCs):

- [Testing different scenarios to reach Brazil's NDCs](#) (Brazil)
- [New empirical tool for energy-economy analysis in developing countries](#) (United Kingdom)
- [TEA model augmented with simulation scenarios on achieving NDCs](#) (Brazil)
- [New analysis of climate mitigation policies and possibility to reach NDCs in Taiwan](#) (China)

- [TIMES-Starter Model Management Platform streamlines setting up national energy system optimisation models](#) (Italy)

Modelling covering energy and climate modelling integrating behavioural changes:

- [First-time generation of physical demand for transport using machine learning](#) (Ireland)
- [Integration of energy systems and gas infrastructure optimisation models in Brazil](#) (United Kingdom)

3 Modelling developments linked to implementation of mid-century strategies

- Researchers at [PBL Netherlands Environmental Assessment Agency](#) have developed new features for the Integrated Model to Assess the Global Environment ([IMAGE](#)). Through the [REINVENT](#) project the IMAGE modelling team expanded the number of industrial manufacturing sectors covered by the model. They included the food processing and the pulp and paper sectors to the model which already included the steel, cement and chemical sectors. Industrial sectors face particular challenges in view of the global climate mitigation objectives as they are dealing with both energy-related and process emissions, the long lifetime of technical assets and their high capital costs, high temperature requirements limiting fuel substitution opportunities and complex (heterogeneous) value chains spread across the world. The IMAGE model, and the IAM community in general, can only represent future developments to a limited extent on these issues.¹ Given how industry and academia are also not able to connect all the dots on a global and integrated level, this leaves a large opportunity for IAMs to open new avenues of research.

Policy makers may also be interested to see the available pathways for this sector, showing potential to uncover where windows of opportunity may arise for mitigation (e.g. age of capital stock, process integration options, responsibilities for society (e.g. demand reductions)). Including new production technologies to current models may also present avenues to improve sector representations (e.g. hydrogen steelmaking). In line with its whole value chain approach the REINVENT team plans to analyse the demand for raw materials and how to better project it in the future. The latest paper on these modelling developments is available [online](#).

- New data for the Carbon Dioxide Removal Model Intercomparison Project ([CDRMIP](#)) is available to support IPCC science and climate mitigation strategies. The new dataset has been collected by researchers at the [GEOMAR Helmholtz Centre for Ocean Research Kiel from modelling teams around the world](#). The [data](#) is in the Network Common Data Form (NetCDF) format and includes variables such as Net carbon mass flux out of atmosphere due to net ecosystem productivity on land, Surface downward CO₂, and Net downward flux at top of model. This research will provide information critical for understanding whether carbon dioxide removal or "negative emissions" are a feasible climate change mitigation strategy. The CDRMIP data will be available on the Earth System Grid

¹ DG CLIMA has commissioned a number of studies on innovation and pathways to deep decarbonisation of industry. The reports are available at https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/industrial_innovation_part_1_en.pdf and https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/industrial_innovation_part_2_en.pdf

Federation platform ([ESGF](#)). The rationale and experimental protocol for the CDEMIP project are available [here](#).

- A research team across 13 institutions have published a paper on the “Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals” in [Nature Energy](#). As part of the CD-LINKS Scenario Database they developed new datasets and new applications of existing models. In a multi-model exercise using national and global IAMs, they analysed the energy investment required to achieve the international goals to limit the rise in global temperatures and meet the SDGs. The findings show that policies linked to energy transformation have varying effects on the costs of achieving the SDGs. For example, they would increase the cost of expanding energy access and food security, but they would reduce the cost of achieving air quality goals. These research developments allow to measure emissions gaps and to understand the cost of the NDCs better, and thus it provides input for the global stocktaking process.
- A recently published [paper](#) in *Biomass and Bioenergy* by researchers at COPPE/UFRJ investigated the potential for the deployment of diesel biofuel production based on forestry residues conversion through Fischer-Tropsch synthesis (FTS)² in Brazil. They found that the country, major bioenergy producer and consumer, is in a privileged position in terms of forestry residues availability, and these residues indicate bioenergy potentials between 297 and 987 PJ for pine and eucalyptus forests. The key modelling development in the research project is the addition of land use and land use aspects to the IAM [BLUES](#) model and the data on advanced biofuels conversion routes (with and without carbon capture) generated for the model data set. The researchers are currently working on including water requirement aspects in the model. The study has provided estimates on the production of FTS diesel with and without carbon capture, and identified 21 production hotspots for the development of this technological route throughout Brazil.
- At the [World Resources Institute](#) (WRI), researchers have published a [working paper](#) taking stock of the long-term strategies (LTSs) submitted to the United Nations Framework Convention on Climate Change. The paper proposes a classification framework for how countries model uncertainties, and reviews how scenarios and pathways are used in LTSs to understand and deal with those uncertainties. The key finding is that many countries identify uncertainty, but defer the analysis of these uncertainties due to lack of data, appropriate models, etc.. Since most countries use quantitative models to project GHG emissions, the researchers suggest that it is feasible to incorporate uncertainty in LTS analyses through the development and use of scenarios. Of special interest for policy-makers is the hypothetical example of a LTS to reduce national GHG emissions to 80 percent below 2005 level by 2050.
- The [Shift Project](#) has published a [report](#) which tries to present the energy-climate models and scenarios in simple terms and make it accessible to non-modelers. The report defines the main concepts and theoretical assumptions used in energy-climate models and explains the utility and limitations of these models. The report is only available in French.

² Fischer-Tropsch synthesis is the process by which synthesis gas can be converted into ultra-clean fuels and value-added chemicals.

4 Modelling developments linked to the implementation of Nationally Determined Contributions (NDCs)

- Another research development from COPPE/UFRJ is the transformation of the hybrid CGE IMACLIM-BR model into a dynamic model and improving its connections to bottom-up models. The objective of the project is to test different scenarios to reach Brazil's NDC - with and without carbon pricing. The researchers are currently running the scenarios and results are expected to be published in the first semester of 2020.
- [Cambridge Econometrics](#) has developed a new empirical tool, called the FRAMES modelling framework to carry out energy-economy policy analysis in developing countries. The framework is based on the underlying structure of the E3ME model but has been simplified and reprogrammed to operate with a flexible number of sectors - i.e. to match national data sets. Key characteristics for FRAMES are similar to E3ME - it is based on post-Keynesian macroeconomic theory and does not include assumptions about optimisation. In the model, the economy is dynamic and operates out of equilibrium. There is spare capacity in labour and capital markets (e.g. unemployed workers), meaning that double dividend results are possible. Developing countries (including Least Developed Countries) typically have limited data available to inform their policies and currently have few options for assessing their climate and energy policies, including the ones informing NDC commitments. FRAMES has been developed to meet the current gap in capability - it can be used for any geographical region which has basic data. A first example of FRAMES's application was its use in 2019 to assess the impact of potential [environmental tax reform in Bangladesh that may be implemented in the future](#).
- At COPPE/UFRJ, researchers have augmented the capabilities of the IAM Total-Economy integrated Assessment Model ([TEA model](#)) by incorporating national greenhouse gas emission reduction targets and conducting simulations on how these targets can be achieved via extended carbon pricing. They have created simulations of different counterfactual scenarios based on two different baseline projections (i.e., Independent Evaluation Office and World Economic Outlook). The scenarios include estimates of alternative NDCs (i.e., regional reduction requirements from the baselines (NDC targets)) and different degrees of cooperation for carbon markets (i.e. sectoral, regional or global trading) derived through simulation. The results include real GDP, welfare, CO₂ emissions per sector, CO₂ prices and CO₂ tax revenues. The outcome also includes regional Marginal Abatement Curves (MAC), derived from simulation runs with carbon prices from 1 USD to 200 USD in incremental steps of 5 USD. Simulation was performed for each individual region. The modelling development was conducted as part of the [Energy Modelling Forum](#) 36 exercises that include the simulation of MAC and the simulation of different degrees of cooperation among regional carbon markets to achieve NDC scenarios.
- Researchers at [Peking University](#) applied the IMED-CGE (Integrated Model of Energy, Environment and Economy for Sustainable Development-Computable General Equilibrium) model to evaluate the current climate mitigation policies and the possibility to reach the declared NDC targets in Taiwan, China. The focus of the study is on the current status and possible impacts of the NDC targets' implementation in Taiwan. The results indicate that Taiwan's NDC target is achievable under certain policy scenarios but with different economic costs. The researchers find that a well-designed ETS mechanism could significantly reduce the abatement costs to achieve the NDC targets in Taiwan and cut CO₂

emissions in a more cost-effective way, and thus could improve the overall economic performance and welfare of the economy. The paper is available online in [Natural Hazards](#).

- The [TIMES-Starter Model Management Platform](#) has recently supported the development of the [TIMES-COSTARICA](#) model to identify least-cost NDC roadmaps for Costa Rica towards becoming a net GHG sink. By streamlining the process of initial model assembly, the TIMES-Starter Platform dramatically cuts the time needed to develop a model, greatly improves the quality of first-time TIMES models for NDC, and provides all the facilities needed to effectively and efficiently carry out an energy systems analysis to support better informed decision-making. The platform provides an integrated full-sector energy system model (with the option to include water use) in the form of a set of Excel workbook templates that are easily transformed by a base-year energy balance, resource supply and power generation mix, and then calibrated. It includes a rich set of future technology options for all sectors of the energy and sample sensitivity scenarios.

5 Modelling covering energy and climate modelling integrating behavioural changes

- At the University College Cork researchers are developing a new global energy model using TIMES framework with upgraded spatial and temporal resolution and inclusion of high-performance computing. They are generating physical demand for transport using machine learning algorithms that use custom deep learning architectures. The transport sector data set is currently generated for OECD countries with yearly resolution. The key modelling challenge addressed by the project is to project demands using Shared Socioeconomic Pathways (SSP) scenario drivers. A prototype Neural Network architecture³ was developed to project transport demands. This is the first application of deep learning architectures in transport service demand. The generated energy service demands is expected to feed into the CHIMERA (China Ireland Modelling Energy Research Assessments) project to build a global energy model using TIMES (presentation [online](#)).
- Researchers at Imperial College London have published an [article](#) in *Applied Energy* on the integration of energy systems and gas infrastructure optimisation models in Brazil. They have developed a novel soft-link integration of the simulation-based integrated assessment model MUSE (ModUlar energy systems Simulation Environment) and a new Gas INfrastructure Optimisation model (GINO), which contains details on the position and availability of gas resources in five Brazilian states. The model was applied to assess whether the existing gas infrastructure in the five southern states of Brazil could meet the expected increase in gas demand by 2050. Results suggest that additional investments in the regional gas infrastructure would be required. Depending on the outcome of the ongoing gas imports renegotiations between Brazil and Bolivia (i.e. either maintaining constant, reducing by half, or halting altogether the imports of Bolivian gas), natural gas demand could be covered by a share of alternative supply options, such as an increase in pre-salt production, LNG imports, and imports from a new Argentinian pipeline. The research aids policy makers by modelling cost-effective natural gas infrastructure pathways. Energy planning

³ A set of algorithms, modelled loosely after the human brain, that are designed to recognize patterns.

decisions based on up-to-date models and data can contribute to better planning for climate change mitigation actions.