PARIS
REINFORCE

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D7.3 – REPORT ON STAKEHOLDER NEEDS AND RESEARCH CAPACITY NEEDED

WP7 – Model Inter-Comparisons, Global Stocktake & Scientific Assessments

Version: 1.10R

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Responsible Author	Ida Sognnæs		Email		ida.sognnas@cicero.oslo.no
	CICERO		Phone		
Contributors	Alexandros Nikas, Anastasios Karamaneas, Eleni Kanellou, Konstantinos Koasidis (NTUA); Glen Peters (CICERO)				
Reviewer(s)	Dirk-Jan van de Ven (BC3); Ajay Gambhir, Adam Hawkes (Imperial Grantham); Haris Doukas, Alecos Kelemenis (NTUA)				
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EC Summary Requirements

1. Changes with respect to the DoA

No changes with respect to the work described in the DoA. Leadership of sub-tasks 7.1.1 and 7.1.2 and, therefore, of the literature review of Sections 3.1, 3.2 and 3.4 of this deliverable was passed from Cambridge to NTUA. The deliverable was submitted on time (July 2020), and then slightly updated in November 2020 to add key takeaways in the focused mini-reviews for the reader, and to expand on the stakeholder needs (Section 2.2).

2. Dissemination and uptake

This deliverable summarises the findings of Task 7.1, "Listening", of PARIS REINFORCE. Building on the stakeholder engagement strategy and activities of WP3, this task aimed to make use of the knowledge gained in Tasks 3.1-3.3, to understand the stakeholder needs and capacities needed for global analysis. It also reviews the modelling literature during the past five years, to see to what extent these needs have been addressed and how the PARIS REINFORCE models can be used to make further contributions to address them. As such, it should serve as a reference document among consortium members, as well as other researchers and members of the scientific (modelling and otherwise) community, to identify research needs, their reflection in literature, and therefore the capacity needed. It will also be used by policymakers and other stakeholder groups as a documentation of said needs and gaps, serving as a means of providing our modelling exercises with legitimacy.

3. Short summary of results (<250 words)

We set out to understand the needs of policymakers and stakeholders, as reflected in our stakeholder engagement and knowledge co-creation processes, then review the extent to which these have been addressed in the recent modelling literature following the Paris Agreement, before examining how our modelling armoury can respond to these needs. In the first step to capturing the research capacity needed, during our first interactions with policymakers and other stakeholder groups, we identify the stakeholders' priorities, which oriented on key technologies; lifestyle and behavioural changes; the European Green Deal (EGD); carbon border adjustments; assessment of national energy and climate plans (NECP) submissions; and increasing ambition in nationally determined contributions in consideration of various sustainability dimensions, as reflected in the Sustainable Development Goals (SDGs). The literature review across these dimensions showed that much energy- and climate-economy modelling has been done in response to the Paris Agreement. However, there has been little progress in endogenously representing behavioural change aspects in models, while very limited modelling has been carried out in support of the NECP impacts across different sustainability dimensions, or in support of the EGD and carbon taxation explicitly on imports and exports. Finally, a lot of modelling has been directed at examining trade-offs between low-carbon transitions and sustainable development, although mostly without explicit reference to the SDGs, but little has been done in placing climate action in a broader framework of sustainability. Finally, our modelling ensemble is well-equipped to deal with most aspects of the topics highlighted.

4. Evidence of accomplishment

This report.

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Preface

PARIS REINFORCE will develop a novel, demand-driven, IAM-oriented assessment framework for effectively supporting the design and assessment of climate policies in the European Union as well as in other major emitters and selected less emitting countries, in respect to the Paris Agreement. By engaging policymakers and scientists/modellers, PARIS REINFORCE will create the open-access and transparent data exchange platform I2AM PARIS, in order to support the effective implementation of Nationally Determined Contributions, the preparation of future action pledges, the development of 2050 decarbonisation strategies, and the reinforcement of the 2023 Global Stocktake. Finally, PARIS REINFORCE will introduce innovative integrative processes, in which IAMs are further coupled with well-established methodological frameworks, in order to improve the robustness of modelling outcomes against different types of uncertainties.

NTUA - National Technical University of Athens	GR	
BC3 - Basque Centre for Climate Change	ES	
Bruegel - Bruegel AISBL	BE	
Cambridge - University of Cambridge	UK	
CICERO - Cicero Senter Klimaforskning Stiftelse	NO	
CMCC - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	IT	
E4SMA - Energy Engineering Economic Environment Systems Modeling and Analysis	IT	
EPFL - École polytechnique fédérale de Lausanne	CH	
Fraunhofer ISI - Fraunhofer Institute for Systems and Innovation Research	DE	
Grantham - Imperial College of Science Technology and Medicine - Grantham Institute	UK	
HOLISTIC - Holistic P.C.	GR	
IEECP - Institute for European Energy and Climate Policy Stichting	NL	
SEURECO - Société Européenne d'Economie SARL	FR	
CDS/UnB - Centre for Sustainable Development of the University of Brasilia	BR	
CUP - China University of Petroleum-Beijing	CN	
IEF-RAS - Institute of Economic Forecasting – Russian Academy of Sciences	RU	
IGES - Institute for Global Environmental Strategies	JP	
TERI - The Energy and Resources Institute	IN	

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Executive Summary

In this deliverable, we review the needs of policymakers and stakeholders reflected in our stakeholder engagement and knowledge co-creation processes, the extent to which these have been addressed in the modelling literature following the Paris Agreement (PA), and the collective capabilities of the models in the PARIS REINFORCE modelling ensemble. The majority of the deliverable is dedicated to the review of the modelling literature, which provides a detailed and comprehensive overview of the modelling work that has been conducted since the PA.

The first stakeholder workshop showed that stakeholders were in favour of topics and policy questions that revolved around potential failures of key technologies, lifestyle and behavioural changes, and just transitions in a climate emergency or extreme decarbonisation potential under a European Green Deal. At the EU level, the most highly rated topics included carbon border adjustment and alternatives, capacity and flexibility of electrification in Europe in light of the NECP submissions, and EU-internal taxation policies (increasing ambition in terms of ETS coverage and expanding harmonisation of taxation in non-ETS sectors). On the socioeconomic and sustainability front, stakeholders voted in favour of questions related to employment and other socioeconomic dimensions resulting from removing public support on emissions-intensive sectors (e.g. coal), evolution in terms of sectoral redeployment and skill requirements, and increasing ambition in NDCs in consideration of various sustainability dimensions reflected in the Sustainable Development Goals (SDGs).

The first round of interviews with policymakers moreover showed that successful scenario use is not necessarily just about participation, but also trust and institutional ties. It showed that policymakers in general are critical recipients of scenario information who want uncertainties and assumptions to be clearly communicated, and also that policymakers often look for pathways that fit their preferences.

The literature review showed that much energy- and climate-economy modelling has been done in response to the Paris Agreement. However, there has been little progress in endogenously representing behavioural change in models, and very little modelling has been carried out in support of the NECP impacts across different sustainability dimensions, or in support of the EGD and carbon taxation explicitly on imports and exports (CBA). This highlights a gap in the literature regarding topics of special interest to stakeholders. Negative emissions technologies have also dominated the literature, driving pathways towards achieving the ambitious PA targets. This is intertwined with the stakeholders' concerns of limitations of key technologies, in terms of socioeconomic trade-offs, cross-sectoral impacts, feasibility, window of opportunity, learning and expected breakthroughs, etc. Finally, a lot of modelling has been done to examine trade-offs of low-carbon transitions and sustainable development, although mostly without explicit reference to the SDGs, but little work has been done in placing climate action in a broader framework of sustainability. The SDGs that interested many researchers were SDGs 3 (human health), 2 (food security), 7 (sustainable and affordable energy), 6 (water security), 15 (biodiversity preservation), 8 (economic growth) and, not surprisingly, SDG 13, related to climate action, which was the subject of almost every scientific paper reviewed.

The last section of the deliverable presents the modelling capabilities offered by the eight global models in the PARIS REINFORCE modelling ensemble. In addition to classifying the eight models, the section presents mitigation and adaptation measures, SDGs, policy options, and output variables captured by the models. Overall, the PARIS REINFORCE modelling ensemble appears well-equipped to deal with most aspects of the topics highlighted by stakeholders as most critical.

The document at hand is the revised version (v1.10R) of deliverable D7.3. The deliverable has been revised with the aim of:

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a) introducing a thorough list of acronyms at the beginning of the document (Abbreviations)
b) briefly explaining the logic behind selecting the themes for discussion with the stakeholders (Section 2.1.2)
c) discussing in detail the scope and results of the EU regional workshop final session, to help the reader to the interpret results, while better explaining Table 4 (Section 2.1.4)
d) heavily revising the text on stakeholder needs on the use and perception of scenarios, by better outlining the motivation/aims of, and method used for, the in-depth semi-structured interviews and discussing plans for interviews in the UK (Section 2.2)
e) adding further explanations of the key findings and insights from the interviews with Norwegian stakeholders (Section 2.2.2)
f) revising the text on implications for modelling to clarify the conclusions of this exercise (Section 2.2.3)
g) introducing Table 21 to summarise the research gaps identified in the massive literature review carried out in the deliverable, which along with the key takeaways at the end of each review sub-section are now better fleshed out, and to map these gaps onto the approach of the project, including what efforts have been and will be done in these respects (Section 3.4.2).

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Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
AIM	Asian-Pacific Integrated Model
ALADIN	Aire Limitée Adaptation dynamique Développement InterNational
BAU	Business-As-Usual
BC	Black Carbon
BECCS	Bio-Energy with Carbon Capture and Storage
BGR	German Federal Institute for Geosciences and Natural Resources
CAIT	Climate Analysis Indicators Tool
CAPRI	Common Agricultural Policy Regional Impact
CBA	Carbon Border Adjustment
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CE3METL	Chinese Energy-Economy-Environmental Model with Endogenous Technological change by employing Logistic curves
CEMF	Chinese Energy Modeling Forum
CGE	Computable General Equilibrium
CHP	Combined Heat and Power
ClimGEN	Climatic Data Generator
CMIP5	Coupled Model Intercomparison Project Phase 5
CNG	Compressed Natural Gas
COFFEE	COmputable Framework For Energy and the Environment
CSP	Concentrating Solar Power
DAC	Direct Air Capture
DACCS	Direct Air Capture and Carbon Sequestration
DG	Directorate–General
DICE	Dynamic Integrated Climate-Economy
DNE21+	Dynamic New Earth 21 Model
E3ME	Energy-Environment-Economy Global Macro-Economic
EC	European Council
ECN	Energy research Centre of the Netherlands

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EDGAR	Emission Database for Global Atmospheric Research
EGD	European Green Deal
EMF	Stanford's Energy Modeling Forum
EMP-E	Energy Modelling Platform for Europe
EPC	Energy Performance Certificate
ETS	Emission Trading System
EU	European Union
EV	Electric Vehicles
FORECAST	FORecasting Energy Consumption Analysis and Simulation Tool
FUND	The Climate Framework for Uncertainty, Negotiation and Distribution
GATT	General Agreement on Tariffs and Trade
GCAM	Global Change Analysis Model
GDP	Gross Domestic Product
GEM-E3	General Equilibrium Model for Economy-Energy-Environment
GEMINI-E3	General Equilibrium Model of International–National Interactions between Economy, Energy and the Environment
GENeSYS-MOD	Global Energy System Model
GHG	Greenhouse Gases
GLOBIOM	IIASA's Global Biosphere Management Model
GRAPE	Global Relationship Assessment to Protect the Environment
GSA	Global Sensitivity Analysis
GST	Global Stocktake
GTAP	Global Trade Analysis Project
I^2AM	Integrating Integrated Assessment Models
IAM	Integrated Assessment Model
IAMC	Integrated Assessment Modeling Consortium
ICCT	International Council on Clean Transportation
ICES	Intertemporal Computable Equilibrium System
IEA	International Energy Agenc
IIM	India Institute of Management
IMAGE	Integrated Model to Assess the Global Environment
IMED	Model of Energy, Environment and Economy for Sustainable Development

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IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre
LEAP	Long-range Energy Alternatives Planning
LNG	Liquefied Natural Gas
LPJmL	Lund-Potsdam-Jena managed Land
MAC	Marginal Abatement Cost
MAED	Model for Analysis of Energy Demand
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MAGNET	Modular Applied GeNeral Equilibrium Tool
MAgPIE	Model of Agricultural Production and its Impact on the Environment
MARIA	Multiregional Approach for Resource and Industry Allocation
MCDA	Multi-Criteria Decision Aid
MEG4C	Modelo de Equilibrio General Computable de Cambio Climático para Colombia
MERGE	Model for Evaluating Regional and Global Effects of GHG reductions policies
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MICA	Model of International Climate Agreements
MUSE	ModUlar energy system Simulation Environment
NBM	Nordic Balancing Model
NDC	Nationally Determined Contributions
NECP	National Energy and Climate Plan
NEMESIS	New Econometric Model for Environment and Strategies Implementation and Sustainable development
NET	Negative Emission Technology
NUTS	Nomenclature of Territorial Units for Statistics
OC	Organic Carbon
OECD	Organisation for Economic Co-operation and Development
OSeMOSYS	Open Source energy MOdelling SYStem
PA	Paris Agreement
PAGE-ICE	Policy Analysis of Greenhouse Effect - Ice, Climate, Economics

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PLASIM-ENTS	Planet Simulator coupled with the Efficient Numerical Terrestrial Scheme
PM	Particulate Matter
POLES	Prospective Outlook on Long-term Energy Systems
PPMs	Planned Policies and Measures
PRIMES	Price-Induced Market Equilibrium System
PV	Photovoltaic
Q&A	Questions and Answers
RCP	Representative Concentration Pathway
REMIND	REgional Model of Investment and Development
RES	Renewable Energy Source
SDG	Sustainable Development Goal
SDH	Solar Dominance Hypothesis
SRM	Solar Radiation Management
SSP	Shared Socioeconomic Pathway
THERESIA	Toward Holistic Economy, Resource and Energy Structure for Integrated Assessment
TIAM	TIMES Integrated Assessment Model
TIMES	The Integrated MARKAL-EFOM System
UCL	University College London
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United states Dollar
USGS	US Geological Survey
VOC	Volatile Organic Compounds
WITCH	World Induced Technical Change Hybrid
WTO	World Trade Organization

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1 Introduction

This deliverable summarises the findings of Task 7.1, "Listening", of PARIS REINFORCE. Building on the stakeholder engagement strategy and activities of WP3, this task aimed to make use of the knowledge gained in Tasks 3.1-3.3, to understand the stakeholder needs and capacities needed for global analysis.

Task 7.1.1, "Where are we?" aimed to summarise the work done on the Paris Agreement (PA) goals, nationally determined contributions (NDCs) and global stocktake (GST) so far and identify knowledge gaps and needs. It mapped the links between the PA goals and the GST, as well as their links to the mid-century strategies, other EU policies and sustainable development goals (SDGs) (WP5 and WP6).

Task 7.1.2, "Where do we want to go?" aimed to identify the needs and expectations of stakeholders, via the mobilisation of the Stakeholder council in WP3, by addressing the following questions: What are their needs and expectations from the modelling community, in answering the questions posed by the PA and the GST and their links to the mid-century strategies, other EU policies and SDGs? What are the specific questions they would like answered? How do policymakers interpret the PA goals (such as peaking of emissions and balance between anthropogenic emission sources and sinks), and what are the implications for modelling?

Task 7.1.3, "How do we get there?" aimed to build on insights from WPs 2-6, and tasks 7.1.1 & 7.1.2, to identify combinations of tools that are best suited to answer the questions laid out in Task 7.1.2. Additional tools used by partners to support global analyses were also identified.

Initially, we set out to understand the needs of policymakers and stakeholders, as reflected in our stakeholder engagement and knowledge co-creation processes, then review the extent to which these have been addressed in the recent modelling literature following the PA, before examining how our modelling armoury can respond to these needs. In the first step to capturing the research capacity needed, during our first interactions with policymakers and other stakeholder groups, we identify the stakeholders' priorities, which oriented on key technologies; lifestyle and behavioural changes; the European Green Deal; carbon border adjustments; assessment of NECP submissions; and increasing ambition in NDCs in consideration of various sustainability dimensions, as reflected in the Sustainable Development Goals (SDGs). The literature review across these dimensions showed that much energy- and climate-economy modelling has been done in response to the Paris Agreement. However, there has been little progress in endogenously representing behavioural change aspects in models, while very limited modelling has been carried out in support of the NECP impacts across different sustainability dimensions, or in support of the EGD and carbon taxation explicitly on imports and exports (CBA). Finally, a lot of modelling has been done to examine trade-offs of low-carbon transitions and sustainable development, although mostly without explicit reference to the SDGs, but little work has been done in placing climate action in a broader framework of sustainability. Finally, the PARIS REINFORCE modelling ensemble is well-equipped to deal with most aspects of the topics highlighted by stakeholders as most critical.

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2 Where do we want to go?

2.1 Stakeholder needs: first regional EU workshop

The 1st PARIS REINFORCE Stakeholder Council Dialogue workshop, entitled "Enhancing climate policy through co-creation", took place on the 21st of November 2019, at the premises of Bruegel, in Brussels, Belgium. This workshop was the first of a series of stakeholder events to be held over the duration of the PARIS REINFORCE project.

The workshop was a Pan-European initiative for the co-creation of research underpinning new climate policies at the EU and national levels, drawing from the results of six-month exhaustive consultations at national and European level, which followed innovative participatory processes, under the Talanoa Dialogue spirit adopted in the recent UN Climate Change Conferences.

High-level staff of the EC Directorates–General (DGs) for Energy, Climate, and Research, Ministries and climate–related governmental bodies from EU Member States, representatives of international organisations, scientists, and researchers representing relevant projects and initiatives attended the workshop.

During the morning sessions, a detailed policy brief on what the PARIS REINFORCE models can and cannot do was handed out, presented, and discussed with stakeholders. Furthermore, the I^{2}AM PARIS platform was thoroughly presented and discussed with the audience, leading to a Q&A session, in which preferences over the content, design and directions for the modelling analyses visualisation were gathered.

The afternoon consultation, broken down into three thematic sessions, resulted in the main policy questions to be further investigated by the ensemble of Integrated Assessment Models (IAMs) of PARIS REINFORCE, by participating stakeholders prioritising the topics they would like to discuss in detail with the consortium members and, after discussions, selecting the policy questions they would like PARIS REINFORCE to seek to address, via a polling and voting platform. The lists of suggested topics for each session were put together after discussions with high-level policymakers at the EU and European-national level as well as included one question (per session) that drew from recommendations from the public in a crowdsourcing platform set up for the purposes of the workshop.

The results from the voting (pre- and post-discussion) are shown in this section. A detailed description of the stakeholder engagement process leading up to and during the live event in Brussels can be found in Deliverable D3.3. In summary, the stakeholder engagement consisted of three stages:

1. Initial discussions (August-November 2019) with ‘core stakeholders’ leading to a list of potential research areas as defined by core stakeholders.
2. Pre-discussion vote: participants in the Brussels workshop were asked to vote on what topics they would like to discuss in each of the three thematic sessions (‘prioritisation vote’). This was based on the initial list of potential research areas plus additional questions ‘crowd-sourced’ via the online platform 24 hours before the event.
3. Post-discussion vote: following discussions in each thematic session, participants in the Brussels workshop were asked to score the different topics (‘final topic prioritisation vote’).

The three sessions were split up according to the three research areas laid out in the initial list of potential research areas:

Session 1: Global threat, global pathways: designing policy-relevant scenarios

Session 2: A Paris-consistent Europe: aligning national (NECPs), regional (EU NDC) & global action

Session 3: Sustainable climate action: socioeconomic implications, distributional effects & SDGs

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In each session, following a ten-minute explanation of the initial list of potential research areas, the workshop participants were asked to vote (via sli.do) on which questions they would be most interested in discussing during the sessions ('prioritisation vote'). Following the discussion, stakeholders were again asked to vote on a scale from 1 to 5 for each of the initially proposed research questions ('final topic prioritisation vote'). They were asked to vote according to how relevant they would see it for PARIS REINFORCE to follow up on and conduct modelling research in this area.

Results of the list of research areas presented in each session, the 'discussion prioritisation' vote, and the 'final topic prioritisation' vote are presented below. Physical attendance was 57 individuals.

In summary, at the global level, stakeholders appeared in favour of the project taking on topics and policy questions that revolved around **potential failures of key technologies**, significantly focusing on **lifestyle and behavioural changes**, as well as **just transitions** in a climate emergency or extreme decarbonisation potential under a **European Green Deal**. At the EU level, the most interesting topics included **carbon border adjustment** and alternatives, capacity and flexibility of electrification in Europe in light of the **NECP** submissions, and **EU-internal taxation policies** (increasing ambition in terms of ETS coverage and expanding harmonisation of taxation in non-ETS sectors). Finally, on the socioeconomic and sustainability front, participants voted in favour of the project taking on questions related to employment and other socioeconomic dimensions resulting from removing public support on **emissions-intensive sectors** (e.g. coal); evolution in terms of **sectoral redeployment and skill requirements**; and increasing ambition in NDCs in consideration of various sustainability dimensions, as reflected in the **Sustainable Development Goals (SDGs)**.

2.1.1 Session 1: Global threat, global pathways: designing policy-relevant scenarios

This session essentially covered the global aspects of climate change and action. It was introduced by presenting seven topics, which had been pre-selected by the consortium on the basis of bilateral interviews with key policy stakeholders, and one topic drawing from those suggested via the public crowd-sourcing process (on sli.do). The eight topics were:

- ***Where are we heading***: Given current policy, social, and technological understanding, what is the most likely emission pathway through to 2050, including raising ambition through the Paris Agreement emission pledges?

- ***Regional mitigation scenarios:*** How does regional mitigation change with different levels of emissions trading or financial transfers? How do the regional mitigation rates map back to different burden sharing schemes?

- ***Potential failure of key technologies***: How do mitigation costs, energy mix, and feasibility of ambitious mitigation targets change if selected technologies do not reach their full potential?

- ***Lifestyle and behavioural change***: What share of mitigation can realistically be achieved via lifestyle and behavioural change?

- ***Climate migration***: How does climate migration affect future pathways?

- ***Extreme decarbonisation***: Is it possible to model a climate emergency requiring net-zero emissions in 2030?

- ***Game changers across the globe***: Globally, where may new low-carbon technological breakthroughs be achieved? And where will demand for such innovations emerge?

- ***Green New Deal – Just transition (crowd-sourced question)***: Is it possible to model a climate emergency or ambitious green new deal/package requiring drastic transformations by 2030? If so, how can we ensure that the associated transitions are just for all societal groups?

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The results of the pre- and post-discussion voting are shown in Table 1 below.

Table 1. Pre- and post-discussion voting in the Brussels workshop Session 1

Proposed Topics	Post discussion 'final topic prioritisation vote'			Pre discussion 'prioritisation vote'
	Score / 5	Non-Academic voters	Academic voters	Prioritisation
Potential failures of key technologies	4.16	4.31 (n=16)	4.05 (n=21)	48%
Lifestyle and behavioural change	3.97	3.56 (n=16)	4.29 (n=21)	57%
Green New Deal – just transition	3.65	3.75 (n=16)	3.57 (n=21)	50%
Regional mitigation scenarios	3.42	3.67 (n=15)	3.23 (n=21)	38%
Where are we heading	3.24	3.16 (n=15)	3.33 (n=21)	14%
Extreme decarbonisation	2.74	2.93 (n=15)	2.60 (n=20)	33%
Climate migration	2.57	2.67 (n=15)	2.50 (n=20)	14%
Game changers across the globe	2.57	3.00 (n=15)	2.25 (n=20)	24%

The potential failure of key technologies, lifestyle and behavioural change, and the European Green Deal (and a just transition) emerge as the three top priorities within this area of research for the stakeholders participating in the vote in the Brussels workshop.

2.1.2 Session 2: A Paris-consistent Europe: aligning national (NECPs), regional (EU NDC) & global action

This session, although focused on Europe-relevant policy areas, also captured areas of interest for global modelling. There were six research themes provided for consideration in this area, of both policy and technological nature:

- **Carbon Border Adjustment (CBA):** Do models provide economic justification for the implementation of CBA? Can losses/leakages be mitigated effectively by CBA? What are alternative measures?
- **EU Internal Taxation Policies:** What is the scope for increasing ambition in terms of coverage in the ETS (incl. non-ETS, reduction of permits)?
- **Robustness of NECPs:** Are the individual NECPs realistic? Do they hold true for different model? Do they conform to EU targets?
- **Electrification:** How can we provide enough renewable energy generation storage and distribution capacity in an extreme electrification scenario? What is the role for flexibility options in such a scenario?
- **Non-energy CO_2 sources:** What kind of mitigation options exist for the reduction of CO_2 sources?
- **Hydrogen (crowd-sourced question):** Can models investigate scenarios in which hydrogen plays a big role in the future? What would this mean for industry, transport, and energy?

The results of the pre- and post-discussion voting is shown in Table 2 below.

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Table 2. Pre- and post-discussion voting in the Brussels workshop Session 2

Proposed Topics	Post discussion 'final topic prioritisation vote'			Pre discussion 'prioritisation vote'
	Score / 5	Non-Academic voters	Academic voters	Prioritisation
Carbon Border Adjustment	4.11	4.06 (n=17)	4.15 (n=20)	60%
EU Internal Taxation Policies	3.54	3.35 (n=17)	3.70 (n=20)	50%
Electrification	3.47	3.50 (n=18)	3.45 (n=20)	60%
Robustness of NECPs	3.42	3.50 (n=18)	3.35 (n=20)	60%
Hydrogen	3.41	3.76 (n=17)	3.10 (n=20)	38%
Non-energy CO_2 sources	2.84	2.61 (n=18)	3.05 (n=20)	25%

Carbon border adjustment, EU internal taxation policies, and electrification emerge as the three top priorities within this area of research for the stakeholders participating in the vote in the Brussels workshop.

2.1.3 Session 3: Sustainable climate action: socioeconomic implications, distributional effects & SDGs

This session covered the socioeconomic aspects of climate change mitigation actions. It was introduced by presenting seven topics that had been pre-selected by the consortium on the basis of bilateral interviews with key policy stakeholders and one topic drawing from the crowd-sourcing process. The eight topics were:

➢ ***Air quality indicators***: what are the air quality/pollution co-benefits of regulating GHGs in transport & housing & other sectors? How significant are these co-benefits and what are the trade-offs?

➢ ***Declining carbon intensive sectors:*** Climate policies and removing public support on emission intensive energy sectors (e.g. coal). What will be the outcome in terms of employment and other socio-economic dimensions? How can adverse social effects of policies be mitigated in particular regions taking advantage of regional assets (energy resources, human resources)?

➢ ***Cross-sectoral impacts***: In specific mitigation scenarios, and future worlds, how do prices and employment vary across sectors compared with today? How employment will/should evolve in terms of sectoral redeployment and skill requirements to support carbon neutral economies?

➢ ***Impacts by EU Member State***: Will all countries within the EU benefit from a decarbonisation push? Or will there be some losers? What are the general heterogeneous effects of decarbonisation pushes for decarbonisation at the country-level?

➢ ***NECPs and their societal acceptance***: How realistic is it that proposed NECPs can be implemented when taking into consideration societal consequences and concerns? What are the behavioural & value-system changes implied by NECPs?

➢ ***Socioeconomic consequences of climate investment***: What are the range of socioeconomic impacts stemming from a range of investment scenarios aimed at achieving decarbonisation? What are the impacts from

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the most pessimistic to most optimistic scenarios?

- ***Fair/Just transition***: for the current policy and decarbonisation scenarios what are the distributional, health, gender and ethnic impacts?

- ***2°C with less cooperation (sli.do-crowdsourced)***: How will mitigation cost be redistributed with major emitters (e.g. the USA) withdrawing from the Paris Agreement?

The results of the pre- and post-discussion voting is shown in Table 3 below.

Table 3. Pre- and post-discussion voting in the Brussels workshop Session 3

Proposed Topics	Post discussion 'final topic prioritisation vote'			Pre discussion 'prioritisation vote'
	Score / 5	Non-Academic voters	Academic voters	Prioritisation
Declining carbon-intensive sectors	3.97	3.68 (n=19)	4.28 (n=18)	23%
Cross-sectoral impacts	3.92	4.00 (n=19)	3.82 (n=17)	44%
Impacts by EU Member State	3.78	3.68 (n=19)	3.89 (n=18)	38%
Socioeconomic consequences of climate investment	3.46	3.68 (n=19)	3.22 (n=18)	36%
Air Quality Indicators	3.43	3.53 (n=19)	3.33 (n=18)	31%
Fair/Just Transition	3.43	3.16 (n=19)	3.72 (n=18)	36%
NECPs and their societal acceptance	3.35	3.05 (n=19)	3.67 (n=18)	36%
2°C with less cooperation	3.05	2.95 (n=19)	3.17 (n=18)	36%

Declining carbon-intensive sectors, cross-sectoral impacts, and impacts by EU member state emerge as the three top priorities within this area of research for the stakeholders participating in the vote in the Brussels workshop.

Overall, across the three research areas, two topics received a score above 4: potential failure of key technologies and carbon border adjustment. After this, three topics received a score above 3.9: declining carbon-intensive sectors, cross-sectoral impacts, and lifestyle and behavioral change. While the results from the workshop are sensitive to the definition and presentation of different topics in the sessions and the relatively low number of stakeholders (especially outside of academia) who participated in the voting, it gives an indication of what issues are of most interest to stakeholder and thus provides a starting point for further analysis, especially in the first modelling iteration.

2.1.4 Final session: Sustainable development goals

Lastly, in the final workshop session, stakeholders were asked to offer their opinion of the urgency to fulfil the targets of each SDG for sustainability, the relevance of each SDG to climate change and action (i.e. perceived interlinkages between climate change/action and each of the other SDGs), and the trend of progress, aiming to

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capture stakeholders' knowledge and perception of the efforts made so far towards selected SDGs. 32 participants took part in this vote. The results are shown in Table 4.

Table 4. Prioritisation of SDGs in relation to climate action in the final Brussels workshop

SDG Goal	Urgency	Relevance	Trend
Goal 1: No Poverty	3.9	3.4	2.4
Goal 2: End Hunger	3.7	3.9	2.5
Goal 3: Good Health and Well-Being	3.5	3.6	2.6
Goal 4: Quality Education	3.4	3.3	2.5
Goal 5: Gender Equality	3.3	3.1	2.4
Goal 6: Clean Water and Sanitation	4.0	3.8	2.6
Goal 7: Affordable and Clean Energy	4.0	4.3	3.0
Goal 8: Decent Work and Economic Growth	3.4	3.4	3.0
Goal 9: Industry, Innovation and Infrastructure	3.6	3.8	2.8
Goal 10: Reduced Inequality	3.8	3.9	1.9
Goal 11: Sustainable Cities and Communities	3.9	3.7	2.8
Goal 12: Responsible Consumption and Production	4.1	4.2	2.8
Goal 14: Life Below Water	4.4	3.8	2.3
Goal 15: Life on Land	4.1	4.2	2.3
Goal 16: Peace and Justice Strong Institutions	3.6	3.6	2.2

Based on these preliminary results, it is evident that the stakeholders show great interest in biodiversity issues as expressed by SDGs 14 (conserving and sustainably using the oceans, seas and marine resources for sustainable development) and 15 (protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably managing forests, combatting desertification, and halting and reversing land degradation and halting biodiversity loss). They consider that there is an urgent need to prioritise action towards achieving these goals, in conjunction with action for the climate crisis. The very low score in the "trend of progress" of these SDGs also enhances this remark. A detailed analysis is performed as part of the MCDA activities of PARIS REINFORCE deliverable D4.3, with a dedicated case on prioritising the SDGs based on the stakeholders' assessments from this session, where the outputs are extensively discussed. Based on the outputs of this session, the structure of the questionnaire will be adapted and expanded for the following regional and national workshops.

2.2 Stakeholder needs: use and perception of scenarios

As part of PARIS REINFORCE, a series of in depth semi-structured interviews are being conducted with scenario users to better understand the use and perception of scenarios, and the models used to generate scenarios. These interviews complement other stakeholder engagement activities in PARIS REINFORCE, many of which are aimed more at obtaining inputs to the modelling exercises. The semi-structured interviews, rather than providing direct inputs to the modelling, are aimed at getting a deeper understanding of how scenarios are used and perceived

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by different stakeholders. Such an understanding among modellers is beneficial for the engagement with stakeholders in general and for informing the communication of results more specifically. Lastly, the interviews aim to begin to fill an important gap in the scientific literature, regarding the use of scenarios, as detailed in section 3.3.1 of this deliverable.

The interviews conducted so far have been with Norwegian stakeholders. Seven in-depth interviews with civil servants in government bodies in Norway have so far been transcribed and analysed. In addition to these, interviews with private sector energy companies in Norway are currently being conducted. Interviews with policymakers in the UK have also been planned, although these have been delayed due to COVID-19. In addition to this, outside of the PARIS REINFORCE consortium, our then preliminary results, which were presented at the Joint Annual Meeting of the Society for Social Studies of Science (4S) and the European Association for the Study of Science and Technology (EASST) on August 21 (2020) also spurred interests in conducting similar interviews in Germany, Sweden, and the US.

The key insights from the seven interviews conducted with Norwegian civil servants are summarised below. These insights are preliminary and partly aimed to guide the next round of Norwegian interviews, to be undertaken during 2021, after which a full analysis of the Norwegian interview material will be performed. The insights will also guide the interviews that are yet to be undertaken in the UK as part of PARIS REINFORCE. Although the number of interviews on which these insights are based is limited to seven, the findings also provide useful preliminary information regarding the ways in which scenarios are used and understood by stakeholders, which will be useful for the ongoing engagement with stakeholders in PARIS REINFORCE.

The method used to conduct the interviews is based on the general method of semi-structured interviews. Semi-structured interviews differ from structured interviews (and questionnaire surveys) by being open, allowing ideas to be brought up during the interview following on from what the interviewee says. Rather than having a fixed and precise set of questions, the interviewer starts out with a looser set of questions and prompts. The interview guide for the interviews with the Norwegian civil servants is provided in English in Appendix A. Interviewees were based on existing contacts and snowballing from these. All interviews have been anonymised by the interviewer.

2.2.1 Interviewees and country context

The seven interviewees come from five different Norwegian ministries and agencies dealing with climate and energy policy. These may be seen as 'expert users'. Questions remain with regards to what happens in the further translation of scenarios to e.g. politicians, media, and the public, and how civil servants differ in their responses from private-sector decisionmakers.

The Norwegian context for climate and energy policymaking differs in important ways from the context in many other countries:

- There have been stated ambitions on climate policy and active involvement in multilateral settings (IPCC, UNFCCC) over many years.
- Oil and gas production dominates the economy, which is increasingly difficult to reconcile with climate ambitions (Bang & Lahn, 2019).
- Economists have a strong role in most government bodies (Christensen & Holst, 2017).

The particular Norwegian context should be taken into account when interpreting the interviews and drawing comparisons to other countries and care should be taken in generalising the insights from this particular set of interviews. National differences relate to different civic epistemologies, policy priorities, and dominant forms of expertise are to be expected.

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2.2.2 Key findings from interviews with Norwegian civil servants

This section presents the preliminary findings and initial insights from the seven interviews conducted with Norwegian civil servants.

What do respondents use scenarios for?

- Scenarios are used in analysis informing or justifying policy. Examples include white papers, budget documents, and information provided in response to Parliamentary inquiries.
- The primary use of scenarios is in assessments of consequences of specific policy targets or pathways towards specific policy targets – in particular the Paris Agreement.
- Specific information drawn from scenarios, mentioned by the respondents, includes carbon prices, energy prices (oil in particular), and emission levels/carbon budgets.

What scenario providers do respondents prefer?

- IEA scenarios are the most prominent.
- IPCC scenarios are the second most prominent.
- Other multilateral sources include IMF, OECD, and IRENA.
- There is also a range of private scenario providers (including BP, Bloomberg, NEF, DNV GL, and Equinor).

How are scenarios selected and evaluated?

The respondents clearly indicate that scenarios are not adopted uncritically by the civil service. Different scenarios are actively gathered, compared, and evaluated using in-house experts. Respondents use their own judgment to evaluate what they consider to be the "realism" of scenarios. It also appears important to respondents that the scenarios that are used do not differ too much from the "majority view" in the scenario literature.

- Different scenarios from different sources are often compared to provide a comprehensive picture.
- Often, 'consensus' estimates are sought, and perceived outliers are disregarded.
- Model outputs are assessed in relation to other results and in-house expertise (on modelling, energy markets, etc.).
- Several respondents emphasise the importance of "realism" of the scenarios and indicate that "realism" is evaluated when considering what scenarios to use.

What determines the choice of scenarios and scenario providers?

Although there are many different scenario providers, certain providers are used much more than others (see above). The IEA and IPCC stand out as the most prominently used by the seven interviewees.

Several factors appear to determine the choice of scenario providers. In particular, institutional connections appear to be important for civil servants.

- Agencies/ministries trust institutions with similar problem-definition and approach.
    - E.g. IEA is favoured by energy actors, IPCC and IRENA is favoured by climate and environmental actors.

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- Agencies/ministries trust institutions with which they have existing relationships:
  - Ministries of oil and finance work closely with IEA and OECD, respectively
  - Environment Agency as national IPCC focal point

The connections to and standing of different scenario institutions also appears to impact on what scenarios are seen as more authoritative and thus more 'citeable' by civil servants, the IEA being a prime example. The reputation and standing in the policy community of the institution that provide scenarios, such as the IEA, appears to carry more weight than scientific publications and credentials (which applies to many other scenario providers).

In addition to this, the choice of scenarios is also political. Different agencies appear to choose scenarios that back up their own views vis-à-vis other government bodies:

- Ministry of Finance favours 'prudent' oil price scenarios
- Ministry of Climate favours 'more ambitious' RE scenarios

Lastly, a number of other factors relating to the clarity of the scenarios themselves, the process of scenario production, and the standing of scenario producers are also mentioned by several respondents:

- Transparency and clarity of underlying assumptions is important.
- Understanding of the processes matters (e.g. the IEA scenarios stem from a known and understood process of scenario development).
- The frequency, predictability, and regularity of scenario publications matter (allows expertise to be built up and sustained within agencies/ministries).
- Independence of research is also mentioned by some.

How are scenario outputs perceived, understood, and interpreted?

Respondents clearly acknowledge fundamental uncertainties and limitations by using statements such as "all model results are wrong", "no one can predict the future", "nobody has the answer", and "garbage in, garbage out". At the same time, they also convey that numbers are useful in the policy making process because quantification "makes things more concrete" and because numbers are important to "have something to show to". This suggests that most civil servants take a pragmatic approach to the use of scenario information, guided by multiple considerations (as indicated above) and an awareness of the scientific limitations of scenario outputs.

2.2.3 Implications for modelling

Based on the findings from the seven interviews with Norwegian civil servants, several modelling-relevant insights can be drawn. While many of these insights are not new, the empirical backing of these insights has so far been limited (see section 3.3.1). Our interviews thus offer empirical support to these insights and confirms their continued relevance for modelling and communication of scenario results.

- Scenario users in agencies and ministries are well-informed and able to critically evaluate scenario results. They demand transparency and clear information about underlying assumptions and associated uncertainties. This is therefore important to provide.
- Too much variation in results *without* explanations of why results differ appears to discourage the use of scenarios. It is therefore crucial to explain *why* results differ when they do.

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- Most users look for pathways to specific targets, "likely" ranges, and "what-if" scenarios based on *clear storylines*. This again highlights the importance of conveying underlying assumptions and explaining why results are what they are.
- Successful scenario use is not necessarily just about *participation*, but also *trust* and *institutional ties*. This indicates that the *processes* and *formats* of stakeholders engagement and interaction are important. Rather than being based on one-off events, it is beneficial if the stakeholder engagement is ongoing.
- Most users also look for pathways that *fit their own preferences*. As such, the use of scenarios is political. Clarity around not only assumptions, but also the appropriate use of scenarios and models, as well as their limitations, is therefore important also to prevent misuse of scenarios for political purposes.

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3 Where are we?

Section 3.1 presents a broad review of the modelling literature, covering several dimensions relevant to stakeholder needs. This review provides a landscape view of the modelling literature since the Paris Agreement, including where most of the focus has been placed. Section 3.2 then presents four in-depth mini reviews, which are guided more directly by the topics that emerged as top priorities for stakeholders in the Brussels workshop.

3.1 Literature review of modelling

The following literature review takes a critical look at what has been done in the literature **since 2016 and up until mid-2020**,

The broad literature review was conducted based on the following search queries, on Google Scholar, which oriented on the literature review on modelling ever since the Paris Agreement and terms related to some of the key issues emerging from the Brussels workshop (see below mini reviews):

- "1.5 C" +"Paris agreement" +"integrated assessment" +model
- "1.5 C" +"Paris agreement" +"integrated assessment" +model +review
- "1.5 C" +"Paris agreement" +"integrated assessment" +model +"behavioural change"
- "1.5 C" +"Paris agreement" +"integrated assessment" +model +SDG
- "1.5 C" +"Paris agreement" +"integrated assessment" +"model inter-comparison"
- model +IAM +"national energy and climate plan"
- model +IAM +NECP
- model +NECP
- "energy modelling" +NECP
- "energy modelling" +"Green Deal" +Europe
- "energy model" +"Green Deal" +Europe
- "integrated assessment model" +"Green Deal" +Europe
- "integrated assessment model" +"Green New Deal" +Europe
- "energy model" +"Green New Deal" +Europe
- "energy modelling" +"Green New Deal" +Europe
- model +IAM +"carbon border"
- model +IAM +"border tax"
- "Carbon Border Adjustment" +Europe
- "Carbon Border Tax" +Europe.

Although we focused on peer-reviewed literature, we also considered grey literature (such as project reports, etc.). In total, 524 publications were included in the review, after selection and filtering to ensure that the reviewed publications match the needs of the exercise. 509 publications were peer-reviewed papers published in scientific journals, 15 constitute pieces of grey literature (such as scientific reports); however, theses and dissertations were not considered.

Based on the results from the first stakeholder workshop in Brussels, the literature review focused on aspects of

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modelling that speaks to a diversity of topics, inter alia including:

1. Key technologies
2. Regional coverage
3. Representation of behavioural changes
4. European Green Deal
5. Carbon border tax adjustments
6. NECPs

In addition to summarising the publications, identifying the key policy questions and findings, the literature review notes in particular the:

- IAM(s) used
- Time horizon
- Regions covered
- Technologies covered
- Other mitigation options covered
- Emissions coverage
- SDG co-benefits explored

Data Analysis

IAMs have been used in hundreds of studies to investigate and assess the impact and progress of the Paris Agreement goals. These models can be separated in five main categories (Nikas et al., 2019):

1. Welfare Maximisation (e.g. WITCH and DICE)
2. Computable General Equilibrium (CGE) (e.g. AIM and GTAP-E)
3. Partial Equilibrium (e.g. TIAM and GCAM)
4. Energy system (e.g. TIMES and POLES)
5. Macroeconometric (e.g. E3ME)

There is also a variety of models that cannot be included in any of the above categories, that have different characteristics. Some popular models of this sixth "category" are FUND and many versions of the PAGE model.

In the reviewed scientific work, models from all the above categories are used. Some of them are well known and widely employed models, massively dominating the literature, and others not so widely used. Moreover, many researchers have developed ad hoc modelling tools and frameworks, which sometimes are not even named in their papers. Also, commonly, researchers refer to (or use for comparison purposes) other models and results in relation to specific research question, with the most common example being IPCC's 5th Assessment Report. There are also many papers that use more than one modelling tool to generate results, either for a broader investigation of the scenarios examined (e.g. combining different types of models to increase coverage and robustness of results) or for model inter-comparison purposes. Figure 1 shows the number of papers a model was used in. Each

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model may correspond to different versions. Models used less than three times are omitted from Figure 1.

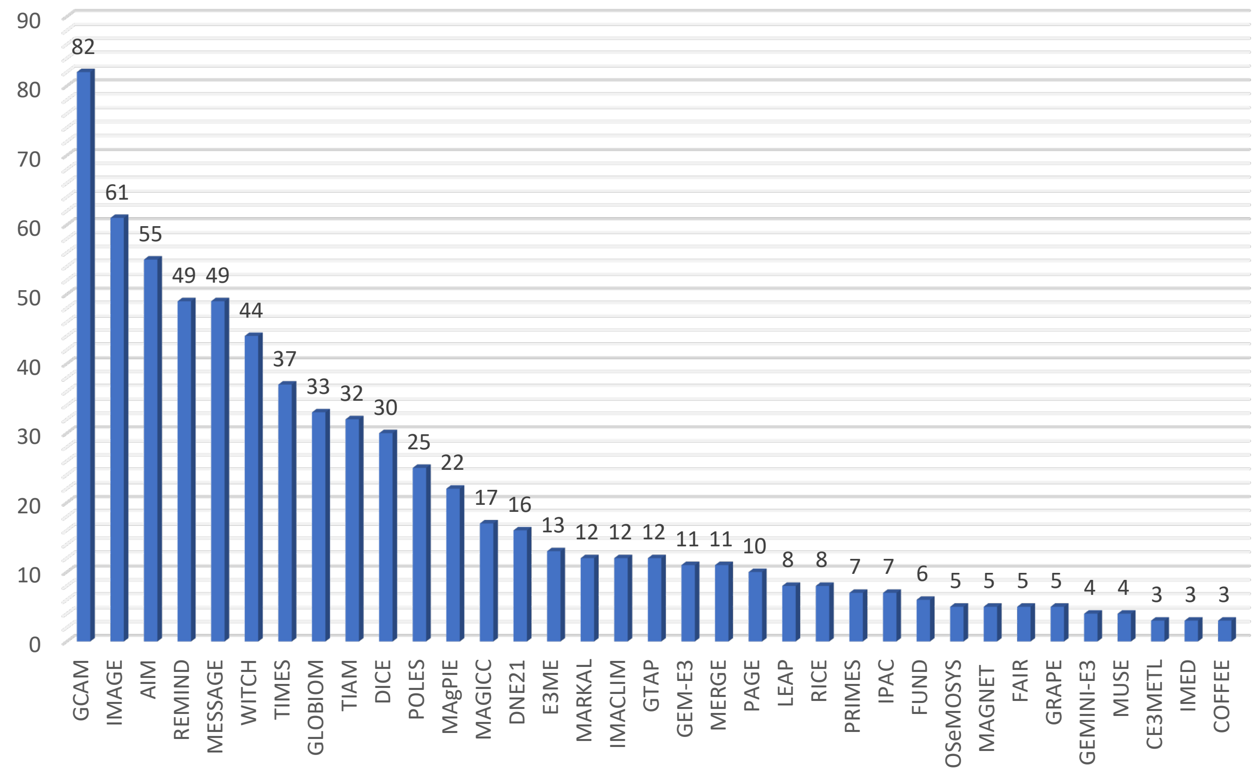

Figure 1. Number of papers reflecting research where each model is used

Evidently, the most widely used model throughout the reviewed literature is GCAM: an open source fully integrated assessment model (Calvin et al., 2019) supported by a dedicated and active community, with global coverage and significant geographic detail. Some of the instances in the literature include modified versions of GCAM, focusing on the biggest economies, such as GCAM-USA (Shi et al., 2017), GCAM-China (Yu et al., 2014) and GCAM-Korea (Jeon et al., 2020). GCAM has also been one of the main models used for the projection of the Shared Socioeconomic Pathways (SSP) scenarios of the IPCC reports (O'Neill et al., 2017), namely SSP4 (Calvin et al., 2017).

IMAGE, AIM, MESSAGE, REMIND and WITCH follow, among the models most widely used, and like GCAM, have been used in the SSP exercise: IMAGE for SSP1 (van Vuuren et al., 2017), MESSAGE for SSP2 (Fricko et al., 2017), AIM for SSP3 (Fujimori et al., 2017), and REMIND and WITCH for SSP5 (Kriegler et al., 2017). This highlights that these models are among the most highly harmonised models. They are also available on several versions that focus on different regions and aspects of climate change mitigation policies.

Some of the models illustrated in the Figure 1 are land use models such as GLOBIOM and MAgPIE, which are usually interlinked with energy or CGE models (e.g. MESSAGE-GLOBIOM, WITCH-GLOBIOM and REMIND-MAgPIE).

Another important aspect of the reviewed literature that used modelling tools and frameworks is the regions that they examine. Figure 2 examines the continent of focus in each paper (even if a single country is examined) and Figure 3 demonstrates the number of papers that investigate each of the high emitting countries/regions.

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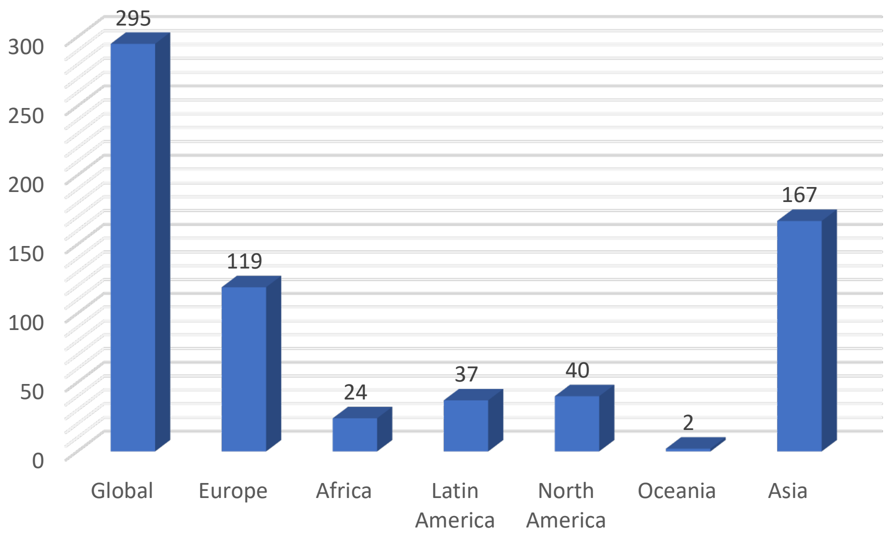

Figure 2. Number of papers examining each continent

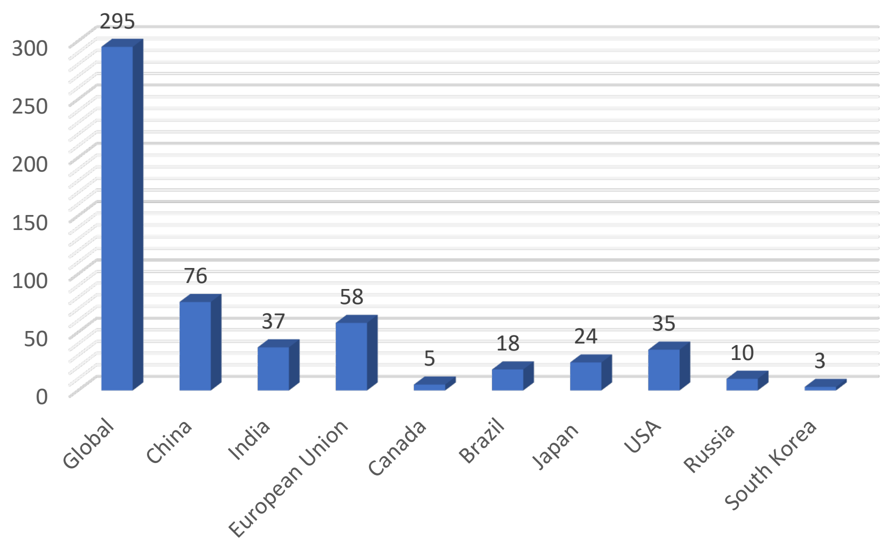

Figure 3. Number of papers examining each country/region

It is important to mention that most papers (more than 56%) investigate the impact of certain policies on a global level with some of them simultaneously focusing on highest emitting countries or regions. On a continental scale, we observe that Asia is the region that most focus is given. This can be attributed to the fact that, apart from being the most populous continent on the planet, Asia is the continent where some of the biggest and highest emitting economies are located, such as China, Japan and India. This is also reflected in Figure 3, in which China, India and Japan are all presented to be examined by several papers. Furthermore, Asia at the same time hosts many developing countries with constantly increasing emissions. The second continent with the most research focusing on it is Europe, either at the EU level or at national level of Member States (e.g. Italy and Germany) or even non-European countries, such as Russia and Norway.

Narrowing our scope down, we observe that the country with most research done is China, the biggest emitter worldwide that, as an ANEX II country, has been taking slower mitigation steps compared to developed regions. Then, the supranational body of the EU follows, being one of the biggest emitters and economies. The EU has

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consistently taken a leading role in international climate policy (Parker et al., 2017), adopting relevant strategies in as early as 1992, and currently pushing forward an ambitious Green Deal towards achieving climate neutrality by 2050 (European Commission, 2019). Other countries that have recently been of significant interest to the modelling community include the USA, India, Japan and Brazil, which also are among the biggest emitters worldwide.

Modelling research also varies regarding the examined time horizon. Regarding the starting point of scenario modelling, we distinguish three categories. There is literature taking reference from years even earlier than 1980. There is some scientific work that runs scenario projections with new reference data from previous years (e.g. Pedde et al., 2019 and Siebers et al., 2020). Nevertheless, the majority of the start their analysis taking into consideration reference data with a starting point between 1980 and 2020. This is also demonstrated in Figure 4.

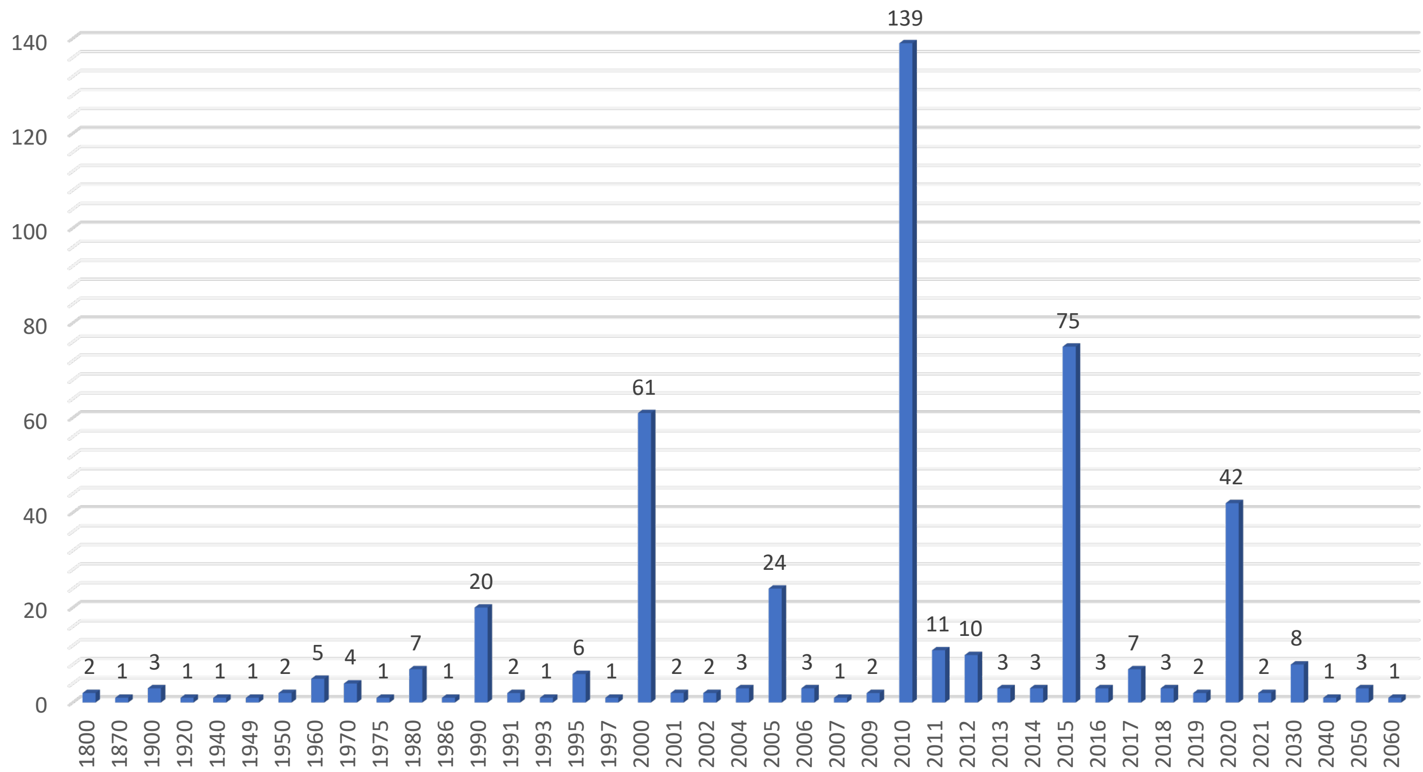

Figure 4. Distribution of the starting year of the papers reviewed

Regarding the ending year of modelling analysis in the literature reviewed, we distinguish five different categories:

1. Short-term analysis: Examining scenarios until 2030
2. Medium-term analysis: Examining scenarios ending between 2031 and 2050
3. Long-term analysis: Examining scenarios ending between 2051 and 2099
4. Extra-long-term analysis: Examining scenarios ending in 2100
5. Super-long-term analysis: Examining scenarios ending after 2100

The distribution of the literature reviewed among the aforementioned time periods is demonstrated as follows.

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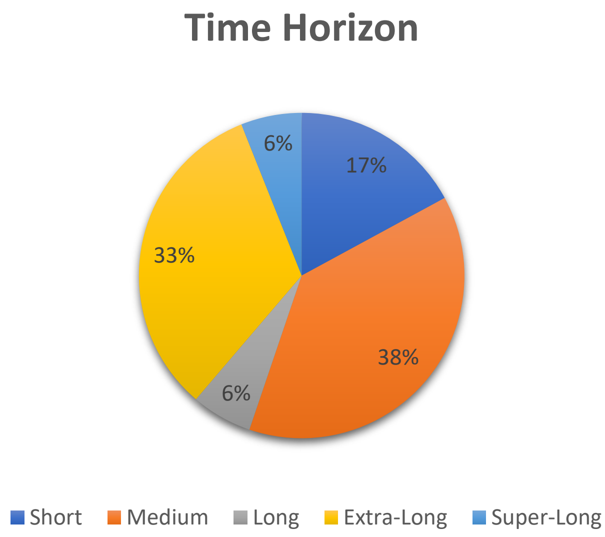

Figure 5. Distribution of the ending year of the papers reviewed

We observe that most papers focus on a medium-term and an extra-long term analysis, which is also in line with the targets being set at the policy level: mid-century strategies (2050) and end-of-century strategies (2100). The medium-term analysis is usually linked with a country's or region's ambition to achieve its emission goals set by the Paris Agreement and its NDCs, or in the case of the EU its NECP. The second most popular category are the extra-long-term analyses. These papers usually examine the impact of climate policies even after the end of the Paris Agreement commitments. The other category that has drawn some attention from researchers is the short-term analysis with a time horizon until 2020. This usually examines possible alternative outcomes of policies that could have taken place but did not (e.g. Feijó and Kuik, 2018) or examine the accuracy and consistency of modelling tools by investigating time horizons ending before 2020 (e.g. Hdom et al., 2020). Expectedly, the super-long-term analysis papers are an insignificant portion of the literature reviewed. It is important to mention that there is only one paper the time horizon of which surpasses the year 2400 and examines a time span of millennia since its time horizon ends in the year 4000; in said research, Rickels et al. (2018) examine the impact of CDR technologies on climate change and the carbon cycle long after the termination of any suggested policies.

Although the time horizon and regional focus of the policies examined are critical, of equal importance are the measures taken to achieve the mitigation goals. These measures are linked to specific technologies used across different sectors. The most examined sector on mitigation policies is electricity generation since it is one of the most emission-intensive sectors.

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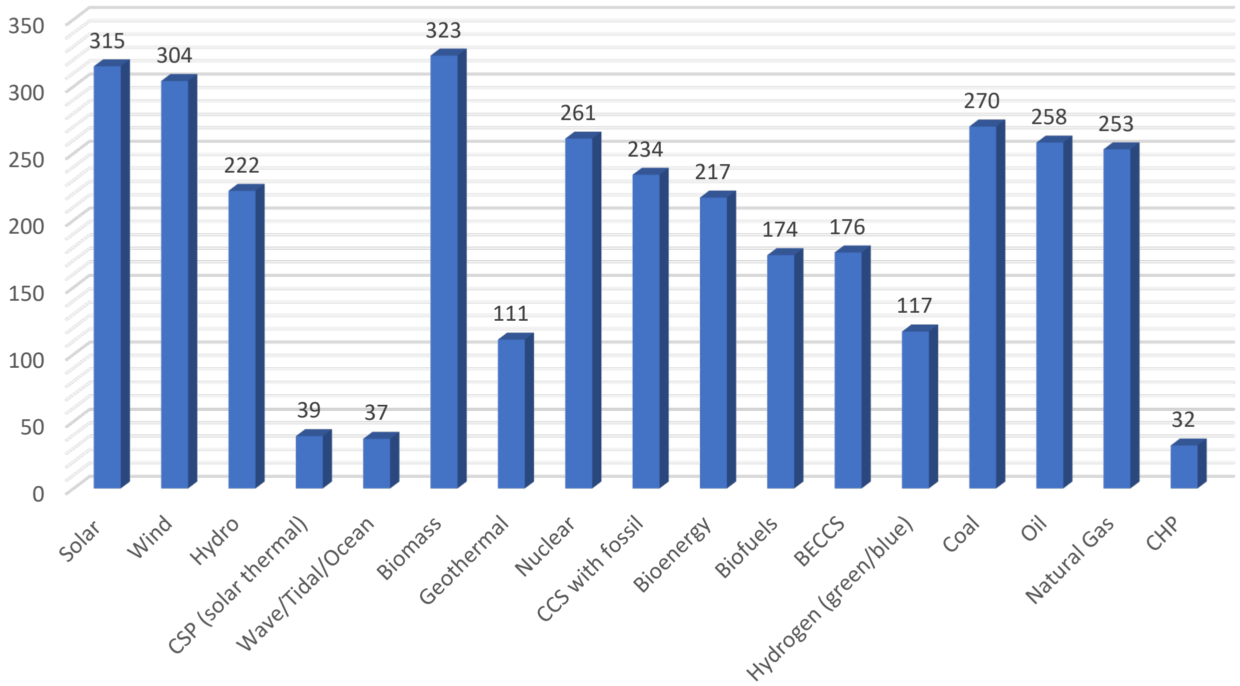

Figure 6. Number of papers examining each electricity generation technology

In a total of 524 papers included in this review, we observe that the most examined technology is biomass followed by solar (PV plants) and wind power. Biomass is the most "trending" concept in the literature reviewed, as it can be used both in electricity plants and for household applications. Furthermore, bioenergy's combined impact with carbon capture and storage (CCS) technologies, i.e. BECCS, is considered an important future application towards the mitigation of climate change, along with other negative emissions technologies heavily dominating the modelling literature. There is increasing focus on the realism of such solutions, in light of large-scale feasibility uncertainties (Van Vuuren et al., 2017), window of opportunity (Rogelj et al., 2015), resource requirements (Smith et al., 2016), and potential to induce prevarication (Anderson and Peters, 2016; McLaren and Markusson, 2020).

On the other hand, solar and wind power are at the core of almost every climate mitigation policy examined, which is also the case for research. The use of hydropower is also common ground among mitigation policies. Moreover, nuclear energy is another topic usually investigated from energy policy researchers: because of its emissions-free technology, nuclear energy is also considered an important technology in the transition to a more sustainable energy system; however, in light of recent nuclear accidents, its use is usually examined in countries that already have nuclear plants (e.g. France, USA, China) with little ambition for further diffusion. Scenarios of further diffusion are mostly examined for the case of China, in a scenario in which its energy demand is significantly increased (Yu et al., 2020). Geothermal energy has also been investigated in more than a fifth of the reviewed literature, since it can be used for electricity generation as well as for household heating. It is highlighted, however, that its current diffusion and potential/availability as a resource is quite limited. Less work focuses on solar thermal power plants (CSP) and ocean energy technologies (including tidal and wave energy): CSP plants are currently installed in few countries and ocean energy applications are still in their infancy.

Apart from emission-free technologies, many papers also investigate the use of fossil fuels, since they are currently the most important energy resources. Many researchers examine not only the reduction of fossil fuels but also the impact of CCS technologies on the existent fossil-fuel power fleets, looking at continued operation with lesser carbon footprint.

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The use of hydrogen is examined in research as an alternative to fossil fuels such as natural gas, while some scientific work also examines the carbon footprint of the produced hydrogen (green/blue).

Apart from electricity generation technologies, climate mitigation policies also examine a variety of other measures and technologies to achieve the ambitious goals of the Paris Agreement (Figure 7), such as reforestation and afforestation as a solution to increased CO_2 sequestration in order to reach net-zero emissions; direct air capture (DAC) used to absorb CO_2 from the atmosphere through chemical reaction; heat pumps (examined in 5% of the literature), which can be powered by either electricity or geothermal power (Chen et al., 2019); and energy efficiency measures that do not refer solely to household applications but investigate sectors like transportation or industry (e.g. Fisch-Romito et al., 2019). There is also a small share of research assessing the impact of miscellaneous technologies such as soil or ocean sequestration (other NETs) (e.g. Walsh et al., 2017) and measures to control livestock emissions (other AFOLU) (e.g. Reisinger and Clark, 2017), while a modest 4% also examine the impact of solar geoengineering or solar radiation management (SRM) on the decrease of temperature rise (e.g. Roshan et al., 2020).

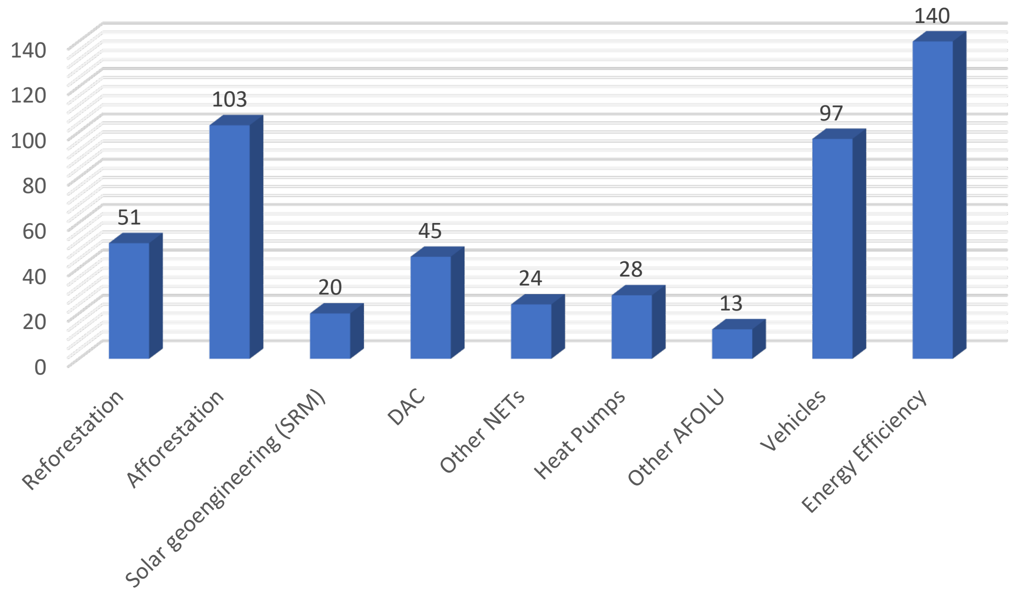

Figure 7. Number of papers examining each non-electricity generation mitigation technology

The last investigated technology linked with energy consumption is the transportation sector. Specifically, vehicle technologies are examined in almost 20% of the reviewed scientific work, including electrification (EV), hybrid electric vehicles, and hydrogen (fuel cells), other than efficiency (Figure 8). Out of the 97 papers that also investigate the transportation sector, almost half assess the impact of the diffusion of electric vehicles. Furthermore, some of them examine the increased penetration of hybrid or hydrogen cars.

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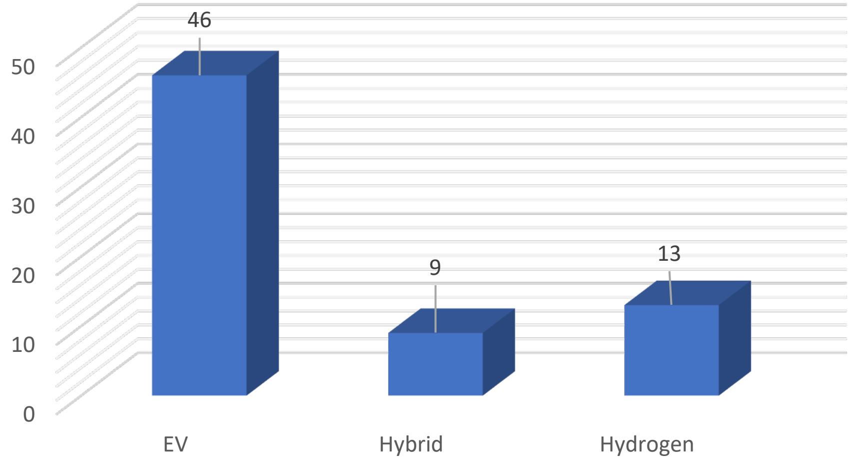

Figure 8. Number of papers examining new technologies in transportation

Although most modelling tools concentrate on reporting main greenhouse gases, like carbon dioxide (CO_2) and methane (CH_4), climate action entails mitigation of all GHG emissions, including nitrous oxide (N_2O) and fluorinated gases (F-*). Global IAMs tend to also calculate land-use carbon dioxide emissions, but many models have in the recent past adequately calculated and reported on main air pollutants, including organic carbon, black carbon (BC), nitrogen oxides (NO_x), non-methane volatile organic compounds (VOC), carbon monoxide (CO), and sulphur dioxide (SO_x), which constitute the main precursors of the two main health-harmful air pollutants linked to fossil fuel combustion and GHG emissions: fine particulate matter (PM) and ozone (Markandya et al., 2018). The investigation of different emissions is dependent on the examined policies but also on the capabilities of the tools used. Some of the most common emissions found in the literature are demonstrated in Figure 9.

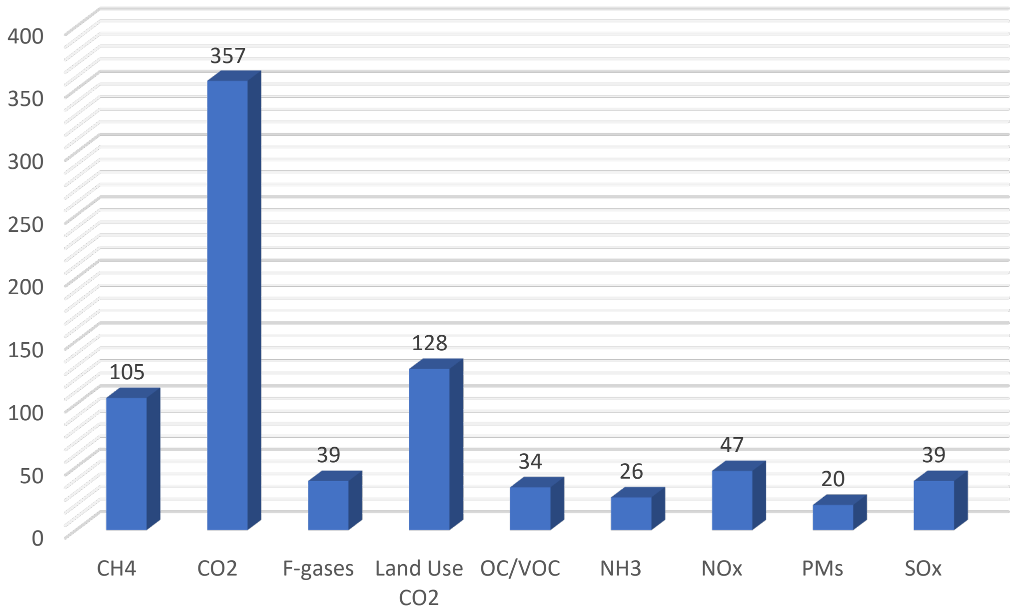

Figure 9. Number of papers examining each type of emissions

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As expected, the emissions that dominate the literature reviewed are CO_2, emitted from almost every energy-related human activity. Furthermore, there are many references to CO_2 since the total GHG emissions are more frequently than not estimated in CO_2-equivalent. However, the importance of accounting for non-CO_2 components is also recently stressed due to their strong, yet short-term impact in sectors like aviation (Lee et al., 2020). In fact, reducing short-lived climate forcers have the potential to reduce warming by around 0.5°C (Smith et al., 2020). From these gases, methane (CH_4) receives significant attention, since it is linked to various sectors of the economy, such as agriculture and transportation, which are important emitters. CH_4 is considered the second most important GHG gas with strong warming potential despite its shorter atmospheric lifetime (Saunois et al., 2020). From that perspective, numerous studies highlight the importance to re-evaluate the calculations of metrics such as the global warming potential and global temperature-change potential to include both short-term and long-term estimations separating the contribution of each GHG (Gasser et al., 2017; Balcombe et al., 2018). The rest of the gases, such as F-gases, ammonia (NH_3), organic carbon (OC), nitrous oxides (NO_x) etc. are investigated in significantly fewer papers, mainly because they are emitted from fewer activities. Land use CO_2 emissions are related to agricultural activities as well as land use change, usually related to afforestation and reforestation.

Another aspect of modelling work is the impact of policies and climate change on socioeconomic parameters, such as health, food security, energy production etc. Although mostly remembered for the Paris Agreement, the year 2015 featured the UN-wide adoption of the 2030 Agenda for Sustainable Development, embodied in the 17 distinct yet highly intertwined SDGs. These inter alia include poverty and hunger elimination, social and gender equalities, quality education and decent work, strong institutions and responsible production, environmental and biodiversity protection, good health, and climate action. Seemingly two separate agendas, sustainable development and climate action are highly intertwined (von Stechow et al., 2016): the former is an explicit part of the Paris Agreement, while the latter constitutes #13 of the 17 SDGs.

Despite having been designed and/or adapted to support climate policy, integrated assessment modelling frameworks have been found well-equipped to deal with most other goals of sustainable development (van Soest et al., 2019). And, yet, the need to assess climate action in conjunction with the other sixteen sustainable development goals has in the literature been addressed mostly by means of treating SDGs as trade-offs of low-carbon mitigation pathways, either explicitly (e.g. Zhou et al., 2020) or implicitly (e.g. Doelman et al., 2020), as also reflected in most chapters of the upcoming IPCC 6th Assessment Report on the Mitigation of Climate Change.

In this literature review, we examined if there is a direct reference to a specific SDG and if there are also indirect investigation of the policies impact on these goals set by the UN. The quantities demonstrated in Figure 10 refer to both types of references. It is also important to mention that specifically for SDG13 (Climate Action), we counted only direct reference to this particular SDG since every paper examining the goals of the Paris Agreement is relevant to climate action, with emissions mitigation being the number one objective.

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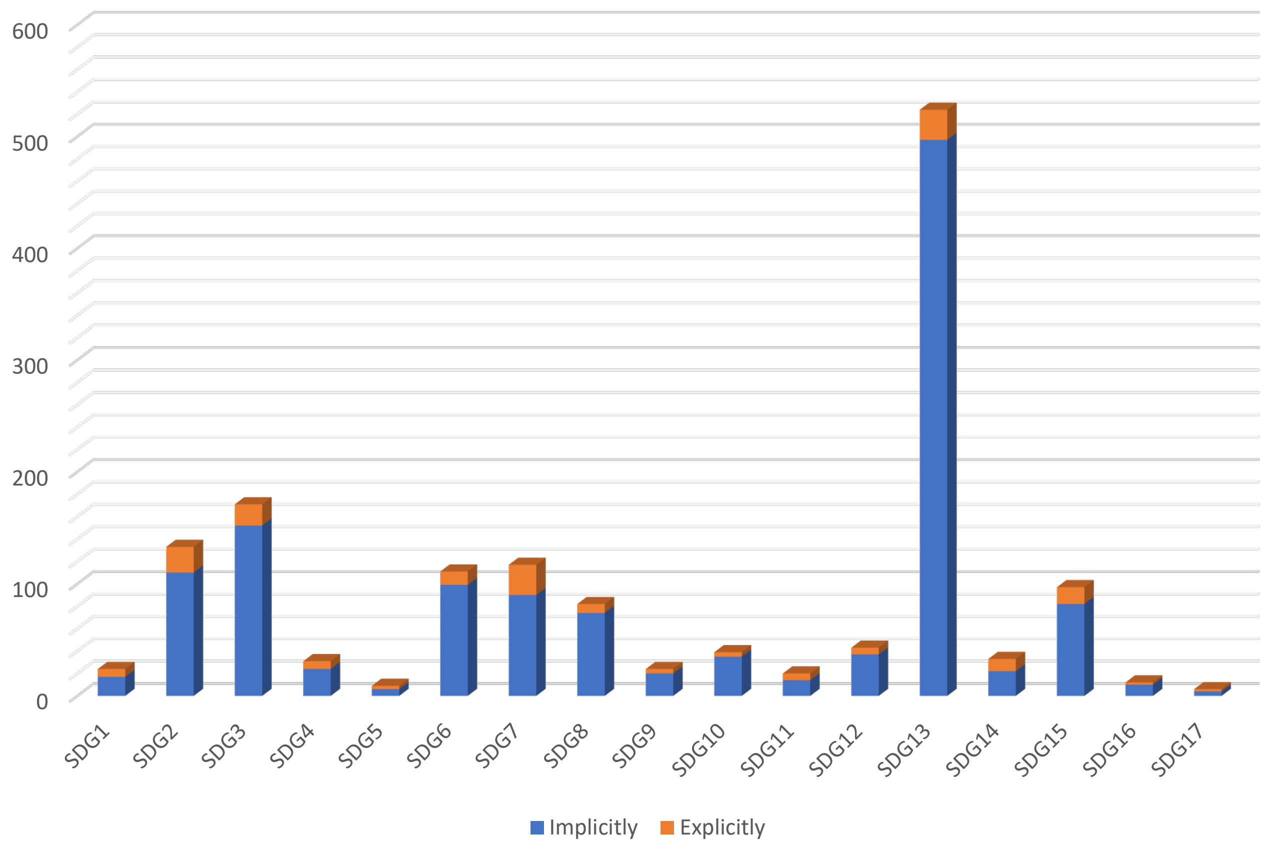

Figure 10: Number of papers investigating each SDG (referring to it implicitly or explicitly)

We observe that (excluding SDG13, which is relevant for all reviewed papers) the most examined SDG is SDG3, related to human health and well-being. This correlation between climate action and human health is two-fold. On the one hand, GHG emissions can cause respiratory and cardiovascular health issues and on the other hand the deterioration of climate change causes several physical destructions that can be proven fatal for many people. Three other SDGs that are investigated in more than 20% of the literature included in this review include SDGs 2, 6 and 7. SDG2 is related to food security, whereas SDG6 to clean water and sanitation: progress of these two goals is mainly affected by the increase of crops used for biomass cultivation, since they require high amounts of water and because they could be used to cultivate crop yields (e.g. Santos da Silva et al., 2018). From a different perspective, SDG7 (Affordable and clean energy) is also studied on many papers, with more explicit references than the previous two. The main linkage to this goal is the investigation of low-carbon electricity measures that can also affect the price of energy. Another SDG that is commonly investigated is SGD15 (Life on land), related to biodiversity preservation. According to Favaro et al. (2020) the intensification of biomass exploitation can reduce forestlands and result in biomass losses. The last SDG that is investigated in a considerable percentage of papers (more than 15%) is SDG8 (Decent Work and Economic Growth), related to the economic growth of countries. The GDP of each country may be affected by various reasons related to climate change. On the one hand, the change of the energy mix may affect the economy of countries heavily dependent on fossil fuels; on the other hand, the consequences of climate change can also result in reduced GDP. According to Alestra et al. (2020) the higher GDP loss is observed in a business-as-usual scenario in which policy is quite passive, despite environmental constraints in models being costlier than scenarios in their absence (Antosiewicz et al., 2020). The remainder of the SDGs are examined in significantly fewer papers. Specifically, the SDGs with the lower interlinkage with climate policies according to this review are SDG17, SDG5 and SDG16. SGD17 is focusing on the partnerships achieved for the

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completion of the UN's goals, which in relation to climate action implicitly includes technological and financial transfer for sustainability of developing countries. SDG5 is related to gender equality: The gender dimension is largely underrepresented in the literature (Fathallah and Pyakurel, 2020) yet central in formation, response and responsibility bearing of energy transitions (Clancy et al., 2007) and intertwined with climate justice itself (Terry, 2009). Lastly, SDG16 (Peace, Justice and Strong Institutions) is a goal that appears not to share common grounds with climate change mitigation; one of the few papers connecting climate change action and the progress of SDG16 is conducted by Pielke and Ritchie (2020), who state that some events are generally excluded from modelling scenarios since they are socially unacceptable, such as a regional nuclear wars that would affect the progress of SDG16. It is noteworthy that all of the aforementioned SDGs have sub-goals. This does not mean that every paper examining an SDG is investigating every sub-goal of the relevant SDG, since these sub-goals are not always useful in terms of mitigation analysis. Refining the interpretation of SDGs and their respective goals for the IAM community and incorporating them in modelling exercises comes as a key challenge in future studies.

Important findings

Bioenergy and other electricity generation technologies and conflicts with food-water-biodiversity nexus

As mentioned above, one subject that concerns many researchers is the impact of biomass exploitation on the preservation of biodiversity as well as its impact on food and water scarcity. For example, Wu et al. (2019) examine bioenergy exploitation scenarios that have no impact on food production. Furthermore, they investigate multiple scenarios to assess the impact of bioenergy crops increase on forestlands. Using the AIM model, they found that the total potential of bioenergy production must remain under 149 EJ/year in order that biodiversity is fully protected. Moreover, estimation from the GRAPE model state that lower biomass yield due to biodiversity and food supply protection results in decreased biofuels production, since BECCS technologies are highly efficient (Kato et al., 2017). Similarly, Humpenöder et al. (2018) suggest that bioenergy exploitation without control policies can lead to increased food prices, decreased water availability, decreased forestlands, and increased CO_2 emissions due to land use changes. Another suggestion is that bioenergy crops should mainly be cultivated on waste lands or on crops that cannot produce sufficient amounts of food (Shepherd et al., 2020). Miralles-Wilhelm and Muñoz (2017) used the GCAM model to examine the impact of bioenergy exploitation on food and water security in Latin America and the Caribbean. According to their research, water availability is further threatened by increased power generation from thermal power plants that require significant amounts of water for cooling purposes. Similar findings have also been presented by Santos da Silva et al. (2018), who used GCAM to estimate that such risks are likely especially for Mexico, Argentina, Brazil and Colombia, i.e. the four biggest emitters in Latin America. A slightly different approach is present by Favero et al. (2016), who found that the conflict between forestlands and bioenergy crops is also dependent on the price of CO_2 emissions, arguing for low forestland expansion in case of low CO_2 prices, in order to achieve higher sequestration. On the other hand, when carbon prices are increased the use of BECCS technology for electricity generation is favoured in conflict with forestry.

The importance of these conflicts has encouraged modelling teams to examine the accuracy of modelling tools regarding bioenergy simulations. Welfle et al. (2020), examining the results of seven models (such as GCAM and WITCH) and highlighting each model's own strengths and weaknesses, suggested that a more accurate estimation of bioenergy requirements can only be conducted by using multi-model analyses. Johnson et al. (2019), in a similar multi-model setting, stated that models require a variety of modifications to better represent bioenergy scenarios, including the economic resolution of the models, the balancing of energy and land needs, and efficient adaptation assessment. The significance of the models' accuracy is further highlighted by scenarios claiming the important

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role of bioenergy to a "green" transition of the energy sector: Mintenig et al. (2017) found that bioenergy can be crucial if delayed action is taken towards climate mitigation; Butnar et al. (2019) claim that the exploitation of sustainable biomass is an important measure for achieving the Paris Agreement goals, and that avoidance of land use change would require international collaboration and significant regulation.

Similar conflicts appear with regard to the exploitation of other energy resources like the trade-offs between climate and water, since the cultivation of biomass crops is a water-intensive process. For example, van der Zwaan et al. (2018a), using a TIAM version (TIAM-ECN) investigate the interlinkage between hydropower, water availability and food security in Ethiopia. On the one hand, they claim that the country should not become completely dependent on hydroelectric power since lower precipitation rates may lead to severe power shortages, while, on the other, they argue that hydropower exploitation must consider the water requirements of the people of Ethiopia since water is a crucial resource for human development. In a similar context, Li and Chen (2019), using the China-TIMES model, estimated that strict climate policies can result in increased water usage on the energy sector. Coal and gas power plants equipped with CCS technologies require significant amounts for water. Moreover, the diffusion of solar thermal plants will also lead to increased water usage.

Climate policies and health impacts

The over-abundant use of fossil fuel resources has led to the significantly increased concentration of GHG and other emissions. On the one hand, GHG and particularly CO_2 are related to the deterioration of climate due to increased temperature and, on the other hand, other emissions lead to severe health problems linked to the respiratory and cardiovascular systems. For instance, the implementation of an ETS in China results in significantly reduced disease and mortality rates (Chang et al., 2020). A similar research work conducted by Vandyck et al. (2018), using the POLES-JRC model, claims that the transition to a sustainable energy system leads to reduced premature deaths. Improved air quality results in 178-346 thousand less premature deaths in 2030 and in more than 750 thousand less premature deaths in 2050 on a global scale. Xie et al. (2018) estimations deriving from the combination of the AIM CGE model and an air quality model seem even more ambitious. They claim that by 2050 climate mitigation policies would reduce premature deaths by 800,000 people only in Asia. This estimation also leads to significant economic benefits and savings of approximately 2 trillion USD. Similarly, Rauner et al. (2020), who used the REMIND model, find that the health impact of pollution and climate change is so severe that the cost for phasing out coal globally is lower than the cost of the health impacts related to its combustion. The LEAP model has also been used for the calculation of health externalities. The findings of Chen et al. (2020) demonstrate that mitigation scenarios can lead to preventing up to 290,000 premature deaths in China in 2050 and saving more than 200 billion USD. Other researchers have also found that mitigating climate change has significant health benefits. Specifically, the ratio of health benefits to mitigation costs can reach up to 2.19, with India and China being the most benefitted (Sampedro et al., 2020). Markandya et al. (2018), also using the GCAM model, estimate that this ratio can even reach up to 2.45 with India being the most benefitted country, since the economic benefit if this effort can reach up to more than 8 trillion dollars (USD) in 2050. GCAM has been used in various other such applications (e.g. Forouli et al., 2020; and van de Ven et al., 2019). Similar results are also presented by Wang et al. (2020) on a narrower scope: they examined the state of California and found that the ratio of health benefits to mitigation costs is approximately 2 and that in 2050 mitigation efforts can reduce premature deaths by 14,000 cases. The prevention of premature deaths through mitigation is also proven economically beneficial for the case of South Korea: using AIM/CGE and IMED, it was found that the South Korean economy can benefit in multiple ways from mitigation due to reduced GDP loss linked to mortality, reduced hospital expenditures and reduced labor loss (Kim et al., 2020). Although most scientific papers, state that the health benefits of mitigation are clearly more than the costs of mitigation, there is also a different approach. According to Howard et al. (2020), the health

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benefits in Brazil would be greater than the mitigation costs only if the price of carbon is higher than 20 USD per ton of emissions. Similar findings are also demonstrated by Schmid et al. (2020) on a European level: with the TIMES PanEU model, they found that health benefits can save only a portion of the mitigation costs, but that there are important variations among EU countries.

Climate policies and economic impacts

As already mentioned in the previous section, the implementation of mitigation policies also affects the economy of a country/region; this is not only due to health benefits from emissions mitigation but also from the direct impact of the policies to each economy. Vandyck et al. (2016), using the JRC-POLES and JRC-GEM-E3 models, state that the achievement of mitigation goals agreed on the Paris Agreement are consistent with economic growth since they only slightly reduce the projected GDP on a global scale. It is also important to mention that this slight decrease of GDP will occur if the mitigation policies are taken immediately and properly. In an IMED model use for China, it is estimated that proper and swift implementation of the 2 ˚C target can reduce GDP loss from 11.6% to only 1.6% for China. Hence, climate mitigation policies do not necessarily constitute a barrier to economic development. The importance of a swift implementation of mitigation policies is also demonstrated with the DICE model, which estimated that the global cost of mitigation policies is increased by 500 billion USD for every year that action is not taken (Sanderson and O'Neil, 2020). Moreover, Winning et al. (2019), using a modified version of the TIAM model, also state that if immediate and innovative action is taken, there will be no difference on the GDP trajectory between an NDC pathway and a more drastic/ambitious one. Researchers have also further examined the importance of co-benefits. According to Liu et al. (2020), leaving the Paris Agreement may seem financially beneficial but, when co-benefits of mitigation are also taken into consideration, remaining a signatory to the Agreement is not only environmentally beneficial but also demonstrates economic gains. Specifically, for India, Gupta et al. (2019), using the models IMACLIM-IND and AIM/Enduse, estimated that the economic growth rate of a scenario that attempts to achieve the 2 ˚C target is similar to the growth projected on a business-as-usual scenario. An even more ambitious target achieves even higher growth rated but requires quite stricter policies and more efficient synergies. Similarly, using the E3ME model at a global scale, mitigation policies were found to slightly boost global GDP, employment rates but also general welfare (Garcia-Casals et al., 2019). This low impact of mitigation policies on GDP is also observed on the work of Reis et al. (2016). Using the WITCH model, they estimated that countries in the developing Asia would require to spend only 2% of their GDP until 2050 to achieve the 2 ˚C target. This would also lead to 600,000 less premature deaths. This 2% of their GDP may seem significant but concerns the whole transformation of the energy sector of these developing countries. Similar results are produced with the IMACLIM-S BR model, which estimates that the economic losses of a mitigation policy will be minor for the Brazilian economy. Moreover, employment will hardly be affected since people will be employed on the services sector (Groterra et al., 2020).

In contrast to research demonstrating clear economic benefits from mitigation policies, there are also other scientific papers that do not produce optimistic results. For example, Wu et al. (2019) used the Taiwanese version of AIM/CGE and projected that the implementation of an ETS on Taiwan could lead to around 1.8% GDP loss. These losses can be even greater if mitigation policies are applied to countries/regions that are heavily dependent on their fossil fuels, mainly resulting from stranded fossil fuel assets after the transition to a "greener" energy system, the value of which is higher than 1 trillion USD. According to an E3ME simulation, the most impacted countries will be Canada, Russia and the USA (Mercure et al., 2018). On the other hand, countries/regions such as China and the EU are considered less affected. This is also demonstrated in an application of the IMAGE model, which claimed that the USA and Canada could bear some of the highest costs (in relation to their GDP) for achieving their NDCs (Hof et al., 2017). The same issue was observed with the MERGE model for the case of the

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Russian Federation. According to Digas et al. (2016), Russia's GDP is heavily dependent on fossil fuels; hence, in order for a "green" transition not to impact it, innovative, climate-friendly innovations are required. Similar results are also observed at a global scale with the evaluation of several modelling tools from Vrontisi et al. (2018). They demonstrated that mitigation policies may lead to 0.4% to 3.3% of GDP median losses until 2030. Some of the models employed were AIM, POLES and REMIND.

Another issue related to economic growth and GDP was found to be the ability of developing countries to swiftly transition into a renewable energy system. Van der Zwaan et al. (2018b) used TIAM-ECN to examine the case of Africa. They found that developing countries in Africa may not be able to achieve the current objective of the additional 300 GW of RES until 2030 since there is insufficient funding. This goal was considered unrealistic even if high growth rates were accomplished. Nevertheless, there are situations in which RES investments appear to be more financially sustainable than fossil fuel investments.

Another important parameter on the calculation of GDP loss is the impact of climate change (i.e. insufficient action or inertia) on the economy. An interesting example is presented by Bastien-Oliviera (2018), who examined mitigation scenarios in Mexico with the TIMES-MX model and demonstrated that climate change affects access to energy and technological progress; hence climate change externalities must be an important parameter in scenario modelling in order to estimate accurately the economic impact of mitigation policies. The significance of climate change impacts on the economy is further stressed by Chen et al. (2020), who used the PAGE-ICE model and estimated that climate change costs are increasing much more swiftly than the GDP; indicatively, if no action is taken climate change costs will be 47% of global GDP in 2100. An important aspect that has not been adequately assessed is the distributional impacts of climate change in the economy (e.g. distribution of income, global inequalities (Mideksa, 2010)).

Impact of renewables on achieving Paris Agreement goals

The use of RES (especially solar, wind and hydro) has drawn the attention of most researchers since they have an important role in the decarbonisation of electricity generation. Renewables, such as solar and wind power, are considered one of the major mitigation strategies on a global scale since they can decarbonise the electricity mix leading also to health benefits. Moreover, they are favoured over bioenergy since their exploitation poses less conflicts with water and land usage (Luderer et al., 2019). Furthermore, renewables are favoured against nuclear energy as well, because there are no waste management issues: according to a GCAM application, finding that 90% of the mitigation targets set by the EU can be achieved implying the need for more ambitious national goals (Lazarou et al., 2019). According to Marcucci et al. (2019), although the Paris Agreement targets are feasible on a global level with the increased deployment of RES, their penetration must be accompanied with other mitigation measures. Such measures are the early decommissioning of fossil fuel energy plants, diffusion of negative emissions technologies and investments in energy efficiency. It is also noteworthy that the efficient deployment of negative emissions technologies such as BECCS and DACCS is heavily dependent on the penetration of RES, especially for DACCS systems that can be powered from RES (Creutzig et al., 2019).

Recent research has also suggested the significant impact of RES on accomplishing mitigation targets at the national/regional level. For instance, according to LEAP simulations, if high penetration of RES is combined with a swift phase-out of coal, China can achieve its NDC but also accomplish even higher targets such as reducing its emissions by 42% compared to 2010 levels until 2050. This is very important because 76% of China's emissions are due to coal combustion (Zhou et al., 2019). In the same context, Burandt et al. (2019) estimated that in order for China to achieve its NDC it must reduce coal usage by at least 60% until 2050. This objective can be supported by the penetration of solar and wind power that showcase decreasing costs. India is another major emitter

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struggling to achieve its RES targets, considering that the country's NDC is considered weak and achievable even without ambitious policies. A MESSAGE application showed that India must have installed a total of 175 GW of RES in order to accomplish the 40% non-fossil fuel electricity mix target by 2022. In addition, if it achieves a 45% rate of non-fossil capacity it will reduce its emissions by 11% in comparison with a business-as-usual scenario (Thambi et al., 2018). This objective requires that a significant amount of coal power plants be shut down and that India gradually rely only on newly built plants. This goal demands an important increase of RES penetration and a policy framework in this direction (Malik et al., 2020): according to TIAM-UCL simulations, emissions trading schemes and the intention of stranding coal-fired plants lead to the increasing installation of solar PV plants, which are demonstrated to be the most efficient solution for India and, unless not properly diffused, in which case the cost of electricity in India will significantly increase and may also lead to a coal technological lock-in (Gadre and Anandarajah, 2019). According to Gerbaulet et al. (2017), nuclear power is facing many difficulties in Europe, such as high costs and contesting technologies with lower prices. Therefore, the major driver of "green" European transition is the increased penetration of RES. Simulations also suggest the use of CCS but only if innovative breakthroughs are introduced. On the other hand, nuclear power plants can survive only if national policies subsidise them. This advantage of solar and wind power has also resulted in more stable CO_2 prices but also increased social acceptance, local employment and improved local economies in the European Union (Victoria et al., 2020). Japan is also a country that is dependent on nuclear energy. Simulations based on AIM/Enduse demonstrate that the achievement of Japan's INDC is feasible even with a total phase-out of nuclear energy until 2030 if increased penetration of RES occurs accompanied by supporting policies. Similar results are also presented for 2050 but the achievement of goals require the large diffusion of intermittent renewable energy, energy efficiency investments and CCS penetration (Oshiro et al., 2017). The role of RES is similar in the case of Mexico: decarbonisation of the Mexican electricity sector was found feasible if high RES penetration is achieved; however, heavy dependence on and investments in natural gas are underway establishing it as an interim/transition fuel and policymakers must control natural gas investments so that the Mexican energy sector is not led into a carbon lock-in (Solano-Rodríguez et al., 2018). A similar situation is examined with the LEAP modelling software regarding Indonesia: four alternative scenarios have been proposed, taking into consideration different options such as substituting coal with natural gas and increasing the penetration of RES, finding mitigation costs of 14.9-41.8 USD per ton of CO_2 mitigated (Handayani et al., 2017).

On the other hand, when examining the case of Africa with the TIAM model, renewables were observed to be undermined because of disadvantageous financial policies (Sweerts et al., 2019). In a narrower analysis, focusing on the Sub-Saharan Africa, Musonye et al. (2020) found that increasing RES diffusion requires a variety of measures, such as the improvement of electricity grids, energy storage, technological learning as well as effective collaboration among local institutions, stakeholders and international modelling teams.

There are also many other issues covered in the literature reviewed regarding the use of RES. For example, Granata and Gagliano (2016) investigate the importance of RES (mainly solar PV) in the reduction of emissions at an urban level, in an effort to increase household energy efficiency. Moreover, renewable energy has been demonstrated to be an important factor for energy security. For example, Anwar (2016), using MARKAL, found that increase of RES by 24% can reduce dependence on imported energy in Pakistan by a modest 3%. A slightly different situation is examined by Paim et al. (2019) using the E3ME model: Brazil, heavily dependent on water availability-vulnerable hydro, invested in fossil-fuel power plants in order to secure electricity supply, demonstrating important electricity costs increase during the 2012-2016 droughts; modelling showed that the most efficient policy lies in augmented penetration of non-hydro RES, which can also contribute to lessening the energy-water conflicts.

Nevertheless, like all technologies, renewables demonstrate disadvantages as well. For instance, onshore wind

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turbines are usually a matter of discussion due to low social acceptance. This phenomenon leads to the installation of other RES (e.g. solar or offshore wind turbines), while social and economic factors, e.g. low social acceptance, may slow down the transition to "greener" electricity sectors (Bolwig et al., 2020). Another issue that has drawn the attention of researchers is the dependence of RES (especially of solar and wind power) on weather conditions. According to Matsuo et al. (2020), weather conditions do not only affect the necessary capacity of energy storage required but also have an impact on the price of electricity. Van Zuijlen et al. (2020) examine the impact of weather instability on portfolios including RES power plants: using the PLEXOS model, they found that such portfolios are more susceptible to increased CO_2 emissions in comparison with portfolios based on BECCS and nuclear energy, which are not affected by weather fluctuations.

Uncertainties during modelling

Results discussed above are dependent on the accuracy of the modelling tools used. Therefore, it is important to examine if the literature on models is concerned about occurring uncertainties on the data provided on the models. The first type of uncertainty observed is related to the input parameters given by the user but also on the model chosen for the scenarios examined. According to Yue et al. (2018) it is common that modellers may use input parameters that are characterised by uncertainties or even the models themselves have some uncertain parameters. This may result in limited insights or even lead decision makers to wrong decisions. Moreover, input data are commonly biased, leading to quantitative results being misleading. Such examples are data related to new technologies such as CCS (Pye et al., 2018). Mori et al. (2018) were led to similar findings but also state that modelling results may differ from one another because of the structure of each model. For example, the estimation of crop yields regionally demonstrated important variation among the examined model. In the same context, Anadon et al. (2017) claimed that data from new technologies usually lead to uncertainties. Hence, the accuracy of input parameters requires the collaboration of scientists of various fields to reduce *some* of these uncertainties (there exist types of uncertainty that may be irreducible). A characteristic example is nuclear fusion, a new technology currently in its experimental infancy; thus, the costs of its implementation are not clear yet. For this reason, it is usually deployed later in the 21st century in models (e.g. Gi et al., 2018; 2020). A similar issue is observed for BECCS (Gambhir et al., 2019), which is also a non-commercial technology. For this reason, Haikola et al. (2019) conducted a series of interviews with IAM researchers in order to examine their performance regarding this specific technology. Shale gas exploitation is another non-widely used option used in several policy scenarios; Few et al. (2017), using the TIAM model, ran several scenarios with different input parameters regarding shale gas diffusion in order to examine its impact on mitigation policies under several scenarios for its progress.

Rogelj et al. (2017) presented another type of uncertainty, related to NDCs and in general to policy targets. These uncertainties are usually derived from the way that NDCs are expressed politically and can lead to reduced robustness of the modelling scenarios. Duan et al. (2018), using the CE3METL, examine the uncertainties deriving from the Chinese NDCs and policies. They claimed that achieving the NDC of 2030 with the business-as-usual efforts is unlikely and stressed on adopting additional mitigation measures. Another important aspect of uncertainty is the trajectory of carbon prices, which may vary significantly.

The last type of uncertainty observed is related to climate change. Mori and Shiogama (2018) attempted to find which global emissions pathway scenario is less susceptible to uncertainties and investigated how much expenditure is acceptable in order to reduce uncertainties related to climate change Using the MARIA model combined with an uncertainty elimination process, they concluded that scientific knowledge produced is useful even if characterised by some uncertainty, and this knowledge becomes even more valuable as climate policies become stricter. From a similar point of view, Nordhaus (2018) and Hafeez et al. (2017) used two different versions

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of the DICE model to examine climate uncertainties. Nordhaus (2018) developed several climate change scenarios and policies and compared them with results from other modelling exercises, claiming that probabilities of achieving the 2 ˚C target are slim even if strict policies are implemented. On the other hand, Hafeez et al. (2017) used an approach that separated the simplistic climate model of DICE and combined it with a state-of-the-art climate model to examine the climate uncertainty caused by the model. Herran et al. (2019), using GCAM-SOUSEI, investigate the impact of climate uncertainty on several policies, stressing that even when climate change demonstrates uncertainties climate action is required. Nevertheless, climate change uncertainties affect the diffusion rate of several technologies: for example, CCS penetration may vary up to 100% depending on the effect of climate-related uncertainties. On the other hand, socioeconomic factors are demonstrating significantly lower variations.

Conclusions

In this literature review, we observed that there are dozens of models used for policy analysis, each of those having different traits and weaknesses. Moreover, policy modelling can examine different types of regions varying from city-level analysis (e.g. Brozynski and Leibowicz, 2018) to global analysis (e.g. Vandyck et al., 2018). Another categorisation of modelling analyses is based on the time horizon examined. Apart from modelling focal points, another issue that was examined was the technologies investigated in each scientific paper. We concluded that the most studied technologies were solar and wind power as well as biomass. Furthermore, since modelling tools calculate the impact of policies on climate change, they calculate the emission of several air pollutants, starting from CO_2 as a minimum. Another important aspect of climate policy is its trade-offs with sustainable development. Therefore, focus was also given on reviewing which SDGs were examined by each paper in the reviewed literature. We concluded that the SDGs that interested many researchers were SDGs 3 (human health), 2 (food security), 7 (sustainable and affordable energy), 6 (water security), 15 (biodiversity preservation), 8 (economic growth) and of course SDG 13, related to climate action which was the subject of almost every scientific paper reviewed.

Apart from the data analysis conducted in this review, we also examined some particular issues that seemed to draw the attention of many researchers. The interlinkage between the energy sector and water, land and biodiversity, especially due to the increased requirements of BECCS, is one of the subjects that was thoroughly examined. Moreover, two other topics that were investigated in many papers are health and economic impacts of climate change policies. The uncertainties related to modelling tools was also investigated by many researchers since it can lead to less robust results, which may result in decision-makers promoting insufficiently underpinned policies. Nevertheless, the most investigated issue was further deployment of RES power plants. We examined their impact on electricity generation, their advantages regarding energy security but also their weakness related to weather fluctuations. It is noteworthy that, there were also many other topics that are less investigated in the literature reviewed, such as the impact of livestock on climate change or the diffusion of hydrogen.

Model Inter-Comparisons

As the envisaged energy transitions require radical socioeconomic, technological, institutional and structural changes (Temper et al., 2018) in energy supply and demand (Grubler et al., 2018), there is an ever-pressing need for a diversified set of strongly coordinated modelling approaches, with collectively improved capacity and detail, to support the development of new knowledge. In this respect, towards enhancing robustness and consistency of resulting policy prescriptions and following climate modellers' example, IAM researchers have been instigating model inter-comparison projects (Nature Climate Change, 2015), i.e. multi-model exercises aimed at addressing given research questions based on numerous models of different theory, structure, approach and coverage

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(Doukas and Nikas, 2020). Major model inter-comparison studies have, for example, been organised and successfully carried out in the context of recent EU-funded projects, like ADVANCE (Luderer et al., 2018) or CD-LINKS (McCollum et al., 2018), essentially forming the bedrock of IPCCs' 1.5 °C Special Report (Fujimori et al., 2019b). In coordinating such efforts, energy system and climate-economy modelling teams have been organised in structured, multilateral communication initiatives and consortia. Among these initiatives, Stanford's Energy Modeling Forum (EMF) has the longest history and reputation of conducting multi-model exercises with a thematic (e.g. Bauer et al., 2018) or regional focus (e.g. Sugiyama et al., 2019), and bridging the policy-science gap (Barron et al., 2018). The second largest modelling consortium is the Integrated Assessment Modeling Consortium (IAMC), which was developed to coordinate research activities within the IAM community and convene the process of producing the current generation of reference modelling scenarios (Cointe et al., 2019), such as the SSPs (O'Neill et al., 2014) and the Representative Concentration Pathways (RCPs) (van Vuuren et al., 2011). Motivated by EMF and IAMC, similar regional efforts have been mobilised and initiated in other parts of the world, like the Chinese Energy Modeling Forum (CEMF), hosted by Tsinghua University and guided by openness, fairness, transparency and neutrality principles, recently publishing its first inter-comparison results (Lugovoy et al., 2018). Numerous EU research projects have supported the development of such platforms in the energy field, like EMP-E (Müller et al., 2018), or carried out inter-comparison work that has inter alia contributed to major assessments—like ADAM (Edenhofer et al., 2010), AMPERE (Riahi et al., 2014) and LIMITS (Kriegler et al., 2013) in IPCC AR5.

Technical improvements of technoeconomic and socioeconomic representation in models are not enough to ensure robustness of resulting trajectories if the datasets driving the simulations that lead to specific policy prescriptions are not fully disclosed, the latter being the case in I^{2}AM PARIS. Simply looking under the hood of modelling tools and exercises (Krey et al., 2019) says little if these datasets are not authoritative and shared within the modelling community, as is the limited case of a few major socioeconomic parameters (Shiraki and Sugiyama, 2020). Even among different or improved versions of the same model, assumptions over these parameters influence projections produced (Nordhaus, 2018). For example, DICE-RD introduces a rate of temperature increase, which influences the calculated damages compared to DICE-2016R, which relies only on absolute temperature values (Michaelis and Wirths, 2020).

Towards better understanding modelling outputs, meta-analyses of scenarios included in established databases have been extensively performed (Kumar et al., 2019). Wachsmuth and Duscha (2019) built on scenarios provided in IPCC AR5 to investigate compatibility of EU policies with the Paris Agreement goals, suggesting the importance of ambitious demand-side mitigation options. Fuss et al. (2016) also used IPCC AR5 scenarios related to the implementation of BECCS, observing significant variance among IAM results, which is attributed to the limited associated technology portfolios in some models. This spread underlines the need to obtain a better techno-economic understanding of the implementation of negative emissions technologies in IAMs. Multiple studies also built on the results provided by activities of the EMF: Bachmann (2020) estimated marginal abatement cost (MAC) curves to assess CO_2 tax policies, while Jakob et al. (2019) compared results from EMF27 for carbon pricing under a 450ppm scenario. In EMF33, a fixed global carbon budget of 1,000 Gt CO_2 for fossil fuels and industry was selected to compare IAM scenarios across bioenergy technologies for Europe, to conclude that EU biomass production holds potential to meet future bioenergy demand. The effect of different modelling assumptions is reflected in Schwerhoff and Sy (2019), who used results from the LIMITS database to calculate the optimal energy mix in Africa: MESSAGE, REMIND and TIAM-ECN emphasised the role of renewable energy sources and especially solar, while IMAGE relied on combining coal with CCS on a large scale assuming optimistic prices and storage availability for CCS; in contrast, GCAM was more optimistic on the potential for nuclear energy.

These differences showcase the importance of understanding the assumptions driving the results to increase

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robustness of the proposed pathways. However, without performing modelling exercises it is difficult to deeply engage with the efforts required to harmonise scenario inputs. As a step towards this direction studies have employed models to cross-validate the results with other sources. Hafeez et al., (2017) used DICE to calculate the social cost of CO_2 and then compared the resulted yields with the average of the models used in CMIP5. They showcased that the different time horizon of the models results in uncertainty since SC-CO_2 is a time dependent quantity, which caused DICE to calculate a value that was 20% lower than the ensemble in CMIP5. Calvin et al (2017) assessed the agriculture and land-use functions of GCAM with data from the Food and Agriculture Organization (FAO), to harmonise crop yields forecasted by the model. For the case of China, GCAM-China has also been compared with other studies in relation to the share of nuclear electricity generation (Yu et al., 2020) and the trend towards CCS technologies concerning the uncertainty over infrastructural delays (Yu et al., 2019). In fact, structural differences between the global models and models applied within the national studies can have significant influence on sectoral analysis, with Duscha et al. (2019) suggesting that global models assess cumulative technological innovation differently, while regional models tend to exploit mitigation potential at the level of sectors. From that perspective, Rao et al. (2019) used a service-driven energy accounting model to evaluate decent living standards through energy demand in Brazil, India and South Africa and compared the results with SSP2.6 from GCAM and IMAGE, attributing the differences in energy demand associated with affluence captured by the regional models.

Although the previous comparative approaches offer insights into structural modellings differences, the capacity for harmonisation processes to establish common assumptions remains limited. In this respect, multi-model approaches attempted to define each socioeconomic, technoeconomic and historical emissions parameter (glossary, units, definition) and their data sources (organisation, time span, database), towards harmonising—when feasible—modelling inputs across all models used in a given exercise, for a given research question. From a techno-economic aspect, Krey et al. (2019) identified three key differences across models: the applied methodologies and the structure of the model (e.g. optimisation vs simulation, discrete technology representation or production functions with elasticities); representation of different technology options; and specific techno-economic assumptions (capital and operational/management cost, lifetime, conversion efficiency, levelised cost).

Inter-comparisons through multi-model approaches do not necessarily involve harmonisation processes by default (Table 5). On the contrary, many studies deliberately opt out of harmonising their inputs in order to capture the uncertainty and extract information from the variance of the outputs. Arango-Aramburo et al. (2019) attempted to capture these uncertainties for the electric generation sector of Colombia. Despite marginal losses in hydropower, the models varied significantly on the energy mix that compensates for the increased demand, with TIAM-ECN relying on solar and wind energy, GCAM increased fossil resources with CCS, while Phoenix and MEG4C opted for significant power demand reductions showcasing the need for synergies among alternative expansion pathways. Oshiro et al. (2019) also avoided harmonising assumptions to assess the policy efforts in Japan, while including several options for energy system transformation especially in light of the uncertainty surrounding the nuclear policy of the country. They showcased the different behaviour of national and global models with the former assuming larger economic growth, which resulted in deeper emission cuts. In a similar approach for the mitigation policy in Japan, Sugiyama et al. (2019) attributed their difficulties in explaining the difference in emissions and power generation mixes to the lack of harmonisation of input assumptions. Stability of regional coalitions has been examined by Emmerling et al. (2020) to establish a temperature threshold that avoids creating high damage costs in GDP without forcing countries to defect from their pledges. The results from MICA and WITCH were compared with this threshold being placed in the range of 2.5 to 3.5°C in MICA and 2.5°C in WITCH. The differences observed when examining national and global policies are also present in sectoral analysis: Edelenbosch et al. (2020) projected carbon dioxide emissions of the three largest energy demand sectors:

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buildings, industry and transport. The employed models (GCAM, IMAGE, AIM/CGE and MESSAGE-GLOBIOM) internally represent these sectors differently, which lead to a significantly large range, especially in SSP3, which showed highest increase for industrial emissions, while SSP2 for the transport sector. GHG emissions also differed in Aldy et al. (2016) since the models (WITCH, DNE21+, MERGE, GCAM) used different energy prices and techno-economic specifications for the energy technologies regarding the assessment of the pledges for some of the wealthiest regions (USA, EU28, Japan, Russia, China, India, South Africa). However, BAU scenarios and global emissions remained on similar levels among models.

Table 5. Inter-comparison studies without harmonisation

Study	Models	Region	Focal Point	Time Horizon	Consortium	EU Project
(Arango-Aramburo et al., 2019)	TIAM-ECN and GCAM, MEG4C, Phoenix	Colombia	Power Generation	2020-2050		CLIMACAP
(Oshiro et al., 2019)	AIM/CGE, COPPE-COFFEE, DNE21+, GEM-E3, IMAGE, POLES, REMIND-MAgPIE, AIM/Enduse, DNE21+	Japan	NDC policies	2011-2100		CD-LINKS
(Sugiyama et al., 2019)	AIM/CGE, AIM/Enduse, DNE21, DNE21+ (MILES Version), IEEG, TIMES-Japan	Japan	Decarbonisation of energy sector	2005-2050	EMF	
(Emmerling et al., 2020)	MICA, WITCH	Global	Temperature Thresholds	2020-2100		
(Edelenbosch et al., 2020)	GCAM, IMAGE, AIM/GCE, MESSAGE-GLOBIOM	Global	Emissions in buildings, transport, industry	2030-2050		REINVENT, COBHAM
(Aldy et al., 2016)	WITCH, DNE21+, MERGE, GCAM	USA, EU28, Japan, Russia, China, India, South Africa	NDC pledges	1990-2030		

To increase the ability to interpret the results and understand the drivers of the produced ranges among the results of the models, many studies attempted to partially harmonise assumptions especially those related with

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socio-economic parameters like GDP and population growth (Table 6). Lugovoy et al. (2018) combined bottom-up and top-down models to investigate CO_2 emissions peaking in China. In their study, parameters like GDP and population were harmonised within groups of models of the same theory. This caused national emissions and energy balance to be on similar levels among models, however sector-level projections were completely different in bottom-up models from top-down models. After a decomposition of the reasons behind emission growth, it was determined that at least 50% of simulated emissions dynamics were caused by assumptions of economic development, while there were difficulties in separating the exogenous and endogenous effect of the rest. Similarly, Srinivasan et al. (2018) examined implication of policy mitigation on water resources for the electricity generation sector in India by harmonising GDP and population growth. The different model structures led to varying energy mixes and rates of growth. Bauer et al. (2018) derived to the same conclusion to examine the effect of fossil fuel infrastructure on a global level, with the models (TIAM-UCL, REMIND) responding differently to climate policies (with REMIND generally responding faster than TIAM). To improve socio-economic harmonisation, alignment with established scenarios is a pathway to create common qualitative narratives for the models to follow in their calculations. Wang et al. (2020) harmonised assumptions based on two scenarios aligned with a 2°C pathway regarding coal capacity of the Chinese power sector, with REMIND being the only model that did not underestimate solar power. Van Sluisveld et al. (2018) also based their analysis in two basic scenarios (presence or absence of mitigation policy) indicating that it would be difficult with richer narratives to clearly trace model responses to the differences in the model structure. Modelling results were compared with expert assessments concluding that models consistently preferring fossil fuels or bioenergy combined with CCS and nuclear energy rather than renewables. To create more comprehensive narratives, the SSPs have been extensively used. Gambhir et al. (2017) based population and economic growth assumption on SSP2 with a median level of GDP growth, which is more compatible with recent trends. They concluded that delays in globally coordinated mitigation action have the potential to lead to large CO_2 price shocks (WITCH and TIAM-Grantham), while only two models (WITCH, MESSAGE-GLOBIOM) can maintain the pathway the 21st century CO_2 budget. Rogelj et al. (2018) aligned scenarios with an increase of 1.5 °C in 2100, while using the model versions and assumptions used for the development of the SSPs. Despite this partial harmonisation, they suggested that direct model comparisons were difficult due to techno-economic reasons (e.g. some models did not include afforestation as a mitigation policy): improved consistency through socio-economic parametrisation is not always the case. Guivarch and Rogelj (2017) examined the effect on carbon pricing of a 2°C pathway in full alignment with the narrative of the SSPs, to reach the conclusion that 90% of the pricing variation was due to inter-model differences. Paladugula et al. (2018) attempted to harmonise population growth and GDP from the median values of the UN projections. However, modelling inconsistencies were enhanced in the focal point of the study, which was the transport sector of India, since in developing regions there is little data for modelling calibration. Therefore, models had difficulties distinguishing between passenger and freight transport, on type of fuel. The feasibility of 1.5°C or even 2°C was questioned by Emori et al. (2018), who suggested a net-zero emission goal in the second half of the century, employing multiple models aligned with the SSPs, illustrating the uncertainties caused by different model structures and assumptions.

Table 6. Inter-comparison studies with harmonisation of socioeconomic parameters

Study	Models	Region	Focal Point	Time Horizon	Consortium	EU Project
(Lugovoy et al., 2018)	SICGE, PIC-Macro, MAPLE, NCSC-ELC, SIC-IIS, PRCEE-	China	Carbon Emission Peaking	2015-2050	CEMF	

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Study	Models	Region	Focal Point	Time Horizon	Consortium	EU Project
	CEMENT, LEAP-TRA					
(Srinivasan et al., 2018)	TIMES, IRADe-IAM, TERI-MARKAL, GCAM-IIM, GCAM	India	Water Resources	2010-2050		
(Bauer et al., 2018)	TIAM-UCL, REMIND	Global	Fossil Fuel Infrastructure	2005-2050		
(Wang et al., 2020)	MESSAGE-GLOBIOM, POLES CDL, REMIND-MAgPIE, China-TIMES, IPAC-AIM/technology	China	Coal power generation	2010-2030		CD-LINKS
(Van Sluisveld et al., 2018)	AIM/Enduse, GCAM, MESSAGE, WITCH, REMIND, IMAGE, TIAM-ECN	Global	Expert and IAM comparisons for five technologies (solar, wind, biomass, nuclear, and carbon capture and storage or CCS)	By 2050		LIMITS, PATHWAYS, REINVENT, ADVANCE, TRANSrisk
(Gambhir et al., 2017)	TIAM-Grantham, MESSAGE-GLOBIOM, WITCH	Global	Long-term mitigation scenarios	2010-2100		
(Rogelj et al., 2018)	AIM, GCAM, IMAGE, MESSAGE-GLOBIOM, REMING-MAgPIE, WITCH-GLOBIOM	Global	Impact of SSPs on climate change	2000-2100	IAMC	CD-LINKS, ADVANCE
(Guivarch and Rogelj, 2017)	AIM/CGE, GCAM, IMAGE, MESSAGE-GLOBIOM, REMIND, WITCH	Global	Carbon pricing	2000-2100		
(Paladugula et al., 2018)	MARKAL, GCAM-IIM, Activity Analysis model, an excel based macro tool model, ICCT road map	India	Transport Sector	2010-2050		

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Study	Models	Region	Focal Point	Time Horizon	Consortium	EU Project
(Emori et al., 2018)	MARIA-14, EMEDA, GRAPE, AIM	Global	Comparison of Temperature and Emissions Goals	2000-2100		

As previously showcased, extending harmonisation to include common technoeconomic or scenario input assumptions along with shared socioeconomic parameters is vital for understanding modelling outputs (Table 7). Towards this direction, Harmsen et al., (2019a) aligned socio-economic assumptions with SSP2, but also assessed climate parameters using MAGICC6 universally for all different models to calculate non-CO_2 emissions. However, even with these adjustments, impacts of CH_4 were more robust, while aerosols tended to show significant variance. Assessing the impact of CH_4, Harmsen et al. (2019b) observed an agreement of the models on a similar scenario (multi-model analysis coupled with MAGICC6 and SSP parameterisation), with projected emissions decreasing by 10–36% less in or increasing by 150% by 2100, with or without policy respectively. Vrontisi et al. (2018) examined the short-term (2030) effectiveness of INDCs with harmonised scenarios aligned with a narrative of well-below 2^{o}C. However, instead of calculating the climate parameters with MAGICC6 like in the previous studies, they used data from different sources (EDGAR, UNFCCC, CAIT and PRIMAP), which were harmonised by using average 2005 global GHG emissions of all models as a reference value to adjust all GHG projections. The different data sources can provide an indication of the adjacent uncertainty ranges, since modelling results led to systematically lower median values.

Regarding scenario inputs related to carbon assumptions, Luderer et al. (2018) attempted to harmonise carbon prices among seven IAMs to assess the impact of residual fossil CO_2 emissions on 1.5^{o}C and 2^{o}C pathways. Similarly, Kim et al. (2020) used the carbon prices from the IAMC database to calculate a universal value that quantifies the GDP loss of achieving the 2 °C target in South Korea, while also measuring the health impact of mitigation policies. They concluded that achieving climate targets would reduce costs from the valuation of avoided premature mortality, health expenditures, and from reduced lost work hours. Using a global uniform carbon tax on GHG emissions from different sectors and harmonised SSP storylines, Hasegawa et al., (2018) found that stringent climate mitigation policy, if not designed carefully, can cause negative impacts in vulnerable, low-income regions where food security problems are already acute. These impacts are created mainly through three channels: increased production costs, due to the carbon tax on agricultural GHG emissions; the carbon tax makes expansion of agricultural land more expensive; and increase in biofuels, which increase demand for more expensive land. The concept of food security has also been examined by Fujimori et al. (2019a) who also indicated the adverse side effects of strict climate mitigation. A uniform carbon price was also applied, with the agricultural sector included in the carbon-pricing scheme. Since models include different inherent assumptions, like a deforestation policy (not present in IMAGE), demand reaction to food price shocks (not in REMIND–MAgPIE) and number of people at risk of hunger, a hunger estimation tool was used to harmonise the models that do not have a representation of the risk of hunger. Efforts have also been placed on the assumptions related to the demand side, despite receiving less attention in modelling exercises. Evaluating future energy-related investment needs, McCollum et al. (2018) followed SSP2, but also harmonised demand-side energy efficiency investments, but not the actual energy efficiency technical and cost parameters, across the main end-use sectors: buildings, transport and industry. Portfolios regarding deep energy transformations could potentially increase the costs of achieving the goals of energy access and food security, negatively impacting the transition.

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Importance has also been given in literature on the representation of both older and more recent innovative technologies. Mouratiadou et al. (2018) focused on hydropower and specifically the effects of deep electricity decarbonisation on global electricity water demand. The input data for electricity water demand were harmonised, with the parameters of water withdrawal and consumption coefficients drawn from other studies. Despite this alignment, the variability of the water demand coefficients provides technological insights over the uncertainty associated with the thermal and water efficiency improvements. Butnar et al. (2019), focusing on BECCS, attempted to establish transparent and easily perceived assumptions through comparisons rather than harmonisation over this technology; the key assumptions identified included the biomass potential, BECCS technological advance and costs, and CO_2 transport and storage infrastructure. In the area of innovative technologies, Realmonte et al. (2019) directly attempted to to harmonise technoeconomic parameters incorporate detailed technical and economic characteristics of a range of DACCS technologies into two IAMs (WITCH and TIAM-Grantham) to address uncertainty over this new technology. Harmonising input assumptions and representing a variety of DACCS technologies (in WITCH, only DAC fuelled by natural gas was incorporated), proved to be critical in determining model outcomes, which also validated the uncertainty of energy requirements and investment costs for DACCS. Another study that directly harmonised technological costs for solar power, nuclear power, biofuels, bioelectricity and carbon capture and storage was performed by Bosetti et al. (2015), who compared results from WITCH, GCAM and MARKAL-US. Harmonisations of technoeconomic parameters, to the extent that these were possible (e.g. nuclear waste management required significant simplifications), allowed the structural differences of the models to emerge highlighting how these parameters influence the outputs.

Depending on the sector or the models and the case studies employed, more complex harmonisation processes also exist to exploit the full information deriving from the analysis. In the agricultural sector, Van Meijl et al (2018) used a variety of climate and agro-economic models (IMAGE, CAPRI, GLOBIOM, MAgPIE, MAGNET), to assess the range of potential economic impacts of climate change on the agricultural sector by 2050. Key modelling inputs like GDP and population growth were harmonised in respect to the SSP narratives but, additionally, relative biophysical crop yield changes due to climate change were also aligned among the models. Despite the structural differences, results were consistent with the SSP and RCP scenarios, with and without mitigation policies. Mori et al. (2018) also focused significantly on the harmonisation process as part of the risk assessment analysis of mitigation pathways. In their study, AIM provided output data for key parameters like population, GDP in market exchange rate, final energy consumption, and GHG emission pathways by country. These outputs were then provided to the rest of the models (EMADA, GRAPE, and MARIA). Crop yields were also standardised. Despite harmonisation being different for each model, ranges in the BAU did not surpass 15%, while after a statistical analysis based on regression equations showed a consistent relationship through models, even if the model structure and technological assumptions differed. Exchanges between model inputs and outputs was also the case in Roelfsema et al. (2020) assessing the impact of national policies on climate change mitigation. The tools used referred to specific regions, so no direct inter-comparison took place. However, aspects that were differently represented in each model were harmonised. For example, since DNE21+ does not include projections for the AFOLU sector, averages from the rest of the global models were used. Similarly, AFOLU CO_2 emissions in POLES were calculated from FAO projections, while F-gas emissions in COPPE-COFFEE were also estimated from the averages of the global models. Information lacking in regional models was also supplemented by average values. From the results of this process, the implementation of current policies left a median emission gap of 22.4 to 28.2 GtCO2eq by 2030. Hof et al. (2020) also used global models (IMAGE and WITCH) to inform regional models about variables such as fuel prices, biomass availability, and electricity demand, which are highly dependent on developments in the rest of the world or in other sectors that could be outside the scope of a regional model. However, combining IAMs with sectoral models provided more detailed insights on a geographical scale.

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Assumptions over the two global IAMs were not harmonised, since the intension was to capture the different energy mixes among different scenarios, rather than absolute value comparisons. Contrary, Fofrich et al. (2020), just like the SSP exercise, used the six highly harmonised IAMs (AIM/CGE, GCAM, IMAGE, MESSAGE-GLOBIOM, REMIND-MAgPIE, and WITCH-GLOBIOM) to analyse coal- and natural gas-fired power plant utilisation rates and lifetimes aligning models with detailed data from existing power plants. To avoid the different regional representation of each model, data were aggregated on a global scale to find that coal-fired power plants retire earlier that anticipated without building new plants to avoid being incompatible with the well-below 2°C narrative. Kriegler et al. (2016) studied the dependence of future energy transformation pathways on assumptions provided to IAMs as part of the activities of the RoSE project. Population and GDP growth were harmonised using the medium population projections from the 2008 Revision of the UN World Population Prospects and the SSP narratives. The total size of the fossil resource base were aligned with data from various sources like the US Geological Survey (USGS) and the German Federal Institute for Geosciences and Natural Resources (BGR), while the calibration based on historical trends limited the variance in energy intensity improvements. However, CO_2 emissions varied significantly due to differences in the energy system representations of the models and the fossil fuel use-price relationships they include. As such, model differences had a larger impact on the variations, while mitigation characteristics related to the examined assumptions were more robust. Key output distinctions between the models included IPAC and WITCH relying more on energy intensity improvements than REMIND and GCAM, while the latter projected a more rapid and deeper reduction of carbon intensity through net negative CO_2 emissions.

Table 7. Inter-comparison studies with harmonisation of socioeconomic, technoeconomic or scenario input assumption data

Study	Models	Region	Focal Point	Time Horizon	Consortium	EU Project
(Harmsen et al., 2019a)	AIM/CGE, DNE21+, ENV-Linkages, IMAGE, MESSAGE-GLOBIOM, POLES, REMIND, WITCH-GLOBIOM	Global	Non-CO_2 gases	2010-2055	EMF	
(Harmsen et al., 2019b)	AIM/CGE, DNE21+, ENV-Linkages, GCAM, IMAGE, MESSAGE-GLOBIOM, POLES, REMIND, and WITCH-GLOBIOM	Global	CH_4 projections	2010-2100	EMF	
(Vrontisi et al., 2018)	AIM/CGE, GEM-E3-ICCS, IMACLIM, IMAGE, MESSAGE-GLOBIOM, POLES, REMIND, WITCH-GLOBIOM	Global	NDCs	2010-2050		CD-LINKS, ADVANCE, AMPERE

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(Luderer et al., 2018)	AIM/CGE, GCAM, IMAGE, MESSAGE, POLES, REMIND, WITCH	Global	Residual fossil fuel emissions	2010-2100		ADVANCE
(Kim et al., 2020)	AIM/CGE, IMED/CGE	South Korea	Health impact of mitigation actions	2015-2050		
(Hasegawa et al., 2018)	AIM/CGE, CAPRI, GCAM, GLOBIOM, IMAGE, IMPACT, MAGNET	Global, focus on Sub-Saharan and Southeastern Asia, China and India and rest of Asia	Risk of hunger	2000-2050		SUSFANS, SIM4NEXUS, AGCLIM50
(Fujimori et al., 2019a)	AIM, IMAGE, MESSAGE-GLOBIOM, POLES, REMIND-MAgPIE, WITCH	Global	Food security	2000-2050		CD-LINKS
(McCollum et al., 2018)	AIM/CGE, IMAGE, MESSAGEix-GLOBIOM, POLES, REMIND-MAgPIE, WITCH-GLOBIOM20,21, GCAM-USA	Global	Impact of climate mitigation on SDGs	2015-2050		CD-LINKS
(Mouratiadou et al., 2018)	GCAM, POLES, REMIND, WITCH, IMAGE	Global	Water Demand	2005-2050		ADVANCE
(Realmonte et al., 2019)	TIAM-Grantham, WITCH	Global	DACCS	2005-2100	IAMC	
(Butnar et al., 2019)	IMAGE, MESSAGE-GLOBIOM, GCAM, REMIND/MAgPIE, AIM, TIAM-UCL	Global	BECCS	2010-2100		
(Van Meijl et al., 2018)	IMAGE, CAPRI, GLOBIOM, MAgPIE, MAGNET	Global	Agricultural Sector	2015-2080		
(Mori et al., 2018)	MARIA-14, EMEDA, GRAPE, AIM	Global	Risk Management	2010-2100		

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(Roelfsema et al., 2020)	China-Times, IPAC, CGAM-USA, PRIMES, AIM, Markal India, RU-TIMES, BLUES, AIM/Enduse, DNE21+	China, United States, India, EU, Japan, Brazil, Russian Federation	NDCs	2015-2030		CD-LINKS, ENGAGE, COMMIT
(Hof et al., 2020)	IMAGE, WITCH, Enertile	Global	Low-carbon electricity generation scenarios	2010-2050		PATHWAYS, MERCURY
(Fofrich et al., 2020)	AIM/CGE, GCAM, IMAGE, MESSAGE, GLOBIOM REMIND MAgPIE, WITCH-GLOBIOM	Global	Fossil Fuel infrastructure	2017-2050		
(Kriegler et al., 2016)	REMIND, GCAM, WITCH, IPAC	Global	Representation of energy transformation pathways in models	2010-2100	TIES TO: AMPERE, LIMITS, EMF27 (through RoSE)	

Finally, integration of different models in a combined framework has also been attempted. Warren et al. (2019) created harmonised links between multiple models (GEMINI-E3, TIAM-WORLD, MAGICC6, PLASIM-ENTS and ClimGEN, LPJmL) depending on each model's focal point and outputs to explore economic instruments and technical solutions necessary for transitioning from RCP6 to RCP2.6 as part of SSP2. They suggested that early policy actions are necessary to avoid carbon pricing mechanisms increasing prices, as well as effort sharing between multiple regimes and agricultural intensification through investments in yield-increasing technologies.

3.2 Focused mini reviews

Drawing from the stakeholder needs reflected in the Brussels workshop and the above literature review, four mini reviews focused on topics of high interest to stakeholders were conducted. The findings from these reviews are presented in this section.

National Energy and Climate Plans (NECPs)

To meet EU's energy and climate targets for 2030, each EU Member State drafted an integrated national energy and climate plan (NECP), for 2021-2030, laying out how they will contribute to achieving those targets. According to Regulation 2018/1999 of the European Parliament and the Council of the European Union (2018), the integrated national energy and climate plans should cover ten-year periods and the nations are obliged to submit biennial progress reports. The European Commission's subsequent assessment of national contributions and monitoring of the overall EU progress towards achieving its energy and climate targets is underway.

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This focused review examines the literature of the last five years (2016 – 2020), following the Paris Agreement in December 2015. The review includes the Individual NECPs of each member state as well as peer-reviewed papers covering the topic. The peer reviewed papers were found by querying in Google Scholar the following keywords:

- model +NECP
- "energy modelling" +NECP
- . model +IAM +"national energy and climate plan"
- . model +IAM +NECP

This search after filtering its results provided 11 peer-reviewed publications. The aim of this subsection is to present the models used and the extent to which the modelled NECPs have outlined sustainable pathways in line with the European energy and climate targets set for 2030 with a view on 2050.

Assessment of NECPs

Several assessments (Buchmann et al., 2019; De Paoli, 2019; Haas, 2019; Pluta et al., 2019; Zachariadis et al., 2019) have been conducted on draft integrated NECPs to evaluate their ability to achieve the envisaged energy and climate targets. It is recognised that different key factors interact in a complex interconnected framework that affects NECPs and the associated policymaking processes (Ćetković and Buzogány, 2020). The integrated NECPs are setting the national renewable energy and energy efficiency goals, due to the commitment of achieving shared EU targets (Aboltins and Blumberga, 2019; Bart et al., 2018; Trotta, 2020). Under this complex framework, individual limitations have been incorporated into the respective NECPs of each country member.

A well-balanced interaction among renewable and conventional energy sources is considered to be a key element to achieving ambitious energy and climate targets (Zigurs et al., 2019). It has also been communicated in a number of NECPs that further development of nuclear power production (Mezős et al., 2020) and carbon capture and storage (CCS) technologies can play a significant role in realising national targets towards carbon neutrality (Huttunen, 2017; Tatarewicz et al., 2019). Alternative fuels, such as hydrogen, can also fill the gap of the energy transformation pathways to deliver on the national contributions (Navas-Anguita et al., 2020).

Many NECPs received negative feedback by experts and stakeholders seeking more stringent pledges and/or greater commitment if these plans are to yield tangible results (De Paoli & Geoffron, 2019; Galgóczi, 2019; Kearney et al., 2019; Sofia et al., 2020; Vasilakos, 2019). Several integrated NECPs were found inadequate in clearly defining and quantifying their contribution to EU's climate neutrality, although they constitute national roadmaps towards a sustainable future. In recent assessments of NECPs, it is suggested that the Planned Policies and Measures (PPMs) are not expected to fully meet the targets set at the EU level (Zachariadis et al., 2019).

A serious objection to the implementation of more ambitious energy and climate policies is the vulnerability of energy security. Being a key element in NECPs, energy security is highly reliant on the national energy sources, and the decarbonisation process could in some cases jeopardise it. This raises concerns among Member states and forces them to pursue more stringent control over their own energy mix by adopting insufficiently ambitious NECPs (Dudău and Cătuţi, 2019). Increase of energy security has been denoted as a priority in the EU that prompts for diversification of its energy mix and energy infrastructure expansion (Dumitrescu and Şincai, 2018). Su et al. (2020) investigated the period 2005-2016 and highlighted the progress in sustainable energy development of certain EU members, including the increase in security of energy supply. Therefore, a low-carbon economy can deliver energy security as long as NECPs provide flexible and tailored solutions.

Another issue that NECPs have to address is energy poverty, by establishing a framework of dedicated measures,

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coordinated actions (Dimitrova et al., 2016), and implementation of best practices. Creutzfeldt et al. (2020) argue that the current disputes at EU and national level do not address the reality of the problem. A related study (Gouveia and Palma, 2019) showed that a significant emissions' increase is occurred, while bridging the gap between the current status and the optimal thermal comfort in the national dwelling stock, indicating a potential gap in the emissions reduction target of the corresponding NECP. This confirms that NECPs need to be flexible, adaptable, and feasible, committed to a just transition.

A growing body of literature has evaluated the economic impacts of integrated NECP implementation. Highly ambitious NECPs outline radical energy and climate policy transformations. Nikas et al. (2020) argue that the inclusion of ambitious targets in the Greek NECP affects almost every economic sector but there is potential for a socially just transition. International electricity markets have been identified as one of the most affected sectors by the national-level climate change mitigation policies (Farsaei et al., 2020). For instance, the challenges of the renewable energy transition require investments in new transmission facilities to increase the network power capacity (Corona, 2019), and increased electricity storage capacity to enhance system flexibility (Fattori et al., 2019). By applying multi-criteria analysis, (Rozentale and Blumberga, 2019) showed that NECPs have a positive impact on climate, rather than electricity consumers or other stakeholders.

Economic prosperity is also a key factor to setting highly ambitious transformation goals. This fact was taken into account by the European Commission during the initial evaluation of EU members' NECPs (Andreoni, 2020). According to the European Parliament and the Council of the European Union (2018), an impact assessment of planned policies and measures in the EU economies was a prerequisite to be included in NECPs (Novikova et al., 2016). However, given the considerable amounts of investments assumed in most NECPs and the ongoing economic damage due to covid-19 pandemic, social and employment effects are now of high priority.

Energy system and integrated assessment modelling in final NECPs

Countries used one or more different models, each one employing the model(s) better suiting their needs. An overview of the models employed is presented in Table 8, which summarises the models used in final NECPs as of 24 June 2020, as retrieved from the EC website (European Commission, 2020a)

Table 8. Models employed in the NECP submissions

NECP	Models
Austria	N/A
Belgium	N/A
Bulgaria	(B)EST model, E3-Modelling
Croatia	MAED, MESSAGE, PLEXOS, input-output model
Cyprus	OSeMOSYS
Czech Republic	PLEXOS, MESSAGE, Phoenix
Denmark	Nordic Balancing Model (NBM)
Estonia	N/A

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NECP	Models
Finland	TIMES, general equilibrium model
France	N/A
Germany	PRIMES, TREMOD
Greece	TIMES, PRIMES
Hungary	PRIMES, TIMES, ESCO, EPC, SSC
Ireland	N/A
Italy	TIMES, GEM-E3, PRIMES, GTAP-GDyn-E, input/output model
Latvia	MARKAL-Latvia
Lithuania	PPM
Luxembourg	PRIMES
Malta	PAM, VAM
The Netherlands	KEV
Poland	N/A
Portugal	TIMES_PT
Romania	EPC, PRIMES
Slovakia	PRIMES
Slovenia	REES-SLO
Spain	PRIMES
Sweden	EMEC
United Kingdom	N/A

In some countries, the models employed to construct the NECP are not mentioned.

Each modelling assessment in support of the NECP submissions outlined in Table 8 included different technologies, an overview of which is presented in Table 9.

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Table 9. Overview of the technologies employed in the NECPs

Countries	Solar	Wind	Hydro	CSP	Wave	Biomass	Geothermal	Nuclear	CCS with fossil	Bioenergy	Biofuels	Reforestation	Afforestation	BECCS	Solar geoengineering	DAC	Other NETs	Hydrogen (green/blue)	Heat Pumps	Other AFOLU	Vehicles	Energy Efficiency	Coal	Oil	Natural Gas	CHP
Austria	√	√				√	√	√		√	√					√		√	√	√	√	√		√	√	√
Bulgaria	√	√				√	√	√	√	√	√		√					√	√		√	√	√	√	√	√
Croatia	√	√	√			√	√	√	√	√	√	√						√	√	√	√	√	√	√	√	
Cyprus	√	√	√	√		√	√	√	√	√	√							√			√	√	√	√	√	√
Czech Republic	√	√				√	√	√	√	√	√		√					√	√		√	√	√	√	√	√
Denmark	√	√	√		√	√	√	√	√	√	√		√						√			√	√	√	√	√
Estonia	√	√	√			√	√	√	√	√	√	√	√						√	√	√	√	√	√	√	
Finland	√	√	√			√	√	√	√	√	√	√	√						√		√	√	√	√	√	√
Germany	√	√	√	√		√	√	√	√	√	√	√				√		√	√		√	√	√	√	√	√
Greece	√	√	√		√	√	√			√	√		√					√	√		√	√		√	√	
Hungary	√	√	√			√	√	√		√	√							√	√		√	√	√	√	√	√
Italy	√	√	√	√	√	√	√	√		√	√	√						√	√		√	√	√	√	√	
Latvia	√	√	√		√	√		√		√	√		√					√	√		√	√	√	√	√	√
Lithuania	√	√	√		√	√	√	√		√	√	√	√					√	√		√	√	√	√	√	

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Countries	Solar	Wind	Hydro	CSP	Wave	Biomass	Geothermal	Nuclear	CCS with fossil	Bioenergy	Biofuels	Reforestation	Afforestation	BECCS	Solar geoengineering	DAC	Other NETs	Hydrogen (green/blue)	Heat Pumps	Other AFOLU	Vehicles	Energy Efficiency	Coal	Oil	Natural Gas	CHP
Luxembourg	√	√			√	√	√	√		√	√	√						√	√		√	√	√	√	√	
Malta	√	√			√	√				√	√		√					√	√		√	√	√	√	√	√
The Netherlands	√	√			√	√		√		√	√		√				√	√	√		√	√	√	√	√	
Poland	√	√	√		√			√			√									√						
Portugal	√	√	√	√	√	√	√	√		√	√							√	√		√	√	√	√	√	
Romania	√	√				√	√	√		√	√		√					√	√		√	√	√	√	√	
Slovakia	√	√	√		√	√	√	√		√	√							√	√		√	√	√	√	√	√
Slovenia	√	√	√		√	√	√	√		√	√							√	√		√	√	√	√	√	
Spain	√	√		√	√	√	√	√		√	√							√	√		√	√	√	√	√	
Sweden	√	√			√	√		√		√	√							√	√		√	√			√	√

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In Table 10 the different pollutants as mentioned in each individual NECP are presented. All countries seem to mention CO_2 emissions and to consider the policy mix that would reduce them. Most of them also focus on CH_4 and NH_3. PMs and SO_x are less mentioned, as are land use CO_2 emissions.

Table 10. Overview of the pollutants mentioned in the NECPs

Country	CH_4	CO_2	F-gases	Land Use CO_2	CO/VOC	NH_3	NO_x	PMs	SO_x
Austria		√	√		√	√	√		√
Bulgaria	√	√			√	√	√	√	√
Croatia		√				√	√		√
Cyprus	√	√	√		√	√	√	√	
Czech Republic	√	√			√	√	√		
Estonia	√	√							
Finland		√	√			√			
Germany		√	√						
Greece		√			√	√			
Hungary	√	√	√		√	√	√		√
Italy		√			√	√	√		√
Latvia	√	√	√	√					
Lithuania	√	√	√	√					
Luxembourg		√		√		√			
Malta	√	√				√			
The Netherlands	√	√	√	√					
Poland		√							
Portugal		√							
Romania		√		√					
Slovakia	√	√		√		√			
Slovenia		√		√					
Spain	√	√		√					
Sweden	√	√		√					

Very few of the NECPs mention the SDGs clearly, however all of them touch upon them and take them into consideration and cover them in their description. In Table 11, a √ is used when, in a country's NECP, SDGs in general or a particular SDG are clearly mentioned and a (√) is used when the policies mentioned within the NECP cover an SDG but do not clearly mention it. Expectedly, all NECPs cover SDG 13 "Climate action" as they contain the plans and actions to be taken across all sectors in each country to achieve the energy and climate targets set

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by the Commission. The Portuguese NECP clearly mentions and aims to cover many SDGs. Another SDG that seems to be mentioned in all the NECPS is SDG 3 “Good health and well-being”, since all actions mentioned in the NECPs aim at reducing negative emissions that deter human health as well as improve issues that affect the well-being as, for instance, tackle energy poverty. That is also evident by the fact that many countries also cover SDG 7 “Affordable and clean energy”.

Table 11. The SDGs clearly referred to or implicitly covered in the NECPs, annotated by √ and (√) respectively

Country	SDGs	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
Austria	√			(√)				(√)						(√)		(√)		
Bulgaria	(√)			(√)	(√)			(√)						(√)				
Croatia	√			(√)	(√)			(√)						(√)				
Cyprus				(√)	(√)			(√)						(√)				
Czech Republic				(√)				(√)						(√)				
Estonia	√			(√)	(√)			(√)	(√)					(√)				
Finland	(√)			(√)					(√)					(√)		(√)		
Germany	√			(√)	(√)	(√)			(√)	(√)				(√)				
Greece	√			(√)				(√)						(√)				
Hungary	√			(√)				(√)	(√)	(√)				(√)				
Italy				(√)					(√)	(√)				(√)				
Latvia		(√)		(√)	(√)		(√)	(√)	(√)			(√)		(√)		(√)		
Lithuania		(√)		(√)		(√)		(√)	(√)			(√)		(√)				(√)
Luxembourg	(√)	(√)				(√)								(√)				
Malta		(√)		(√)		(√)								(√)				
the Netherlands		(√)		(√)	(√)		(√)		(√)			(√)		(√)		(√)		
Poland				(√)	(√)				(√)	(√)				(√)				
Portugal	√	√		√	√	√		√		√	√			√		√		
Romania		(√)	(√)	(√)		(√)				(√)				(√)				
Slovakia		(√)		(√)	(√)		(√)		(√)					(√)				
Slovenia		(√)		(√)					(√)					(√)				
Spain	√	(√)		(√)		(√)		√					(√)	√	(√)			
Sweden		(√)		(√)	(√)	(√)	(√)	(√)		(√)	(√)	(√)		(√)				

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Overall, following EU guidelines, all European countries aim to implement targets to reach carbon neutrality by 2050. Binding targets are set at the EU level, reinforcing international cooperation for energy and climate under the Paris Agreement (Oberthür, 2019). The integrated NECPs are supposed to operate as a dynamic governance tool under constant evaluation for future updates. Despite the lack of binding national targets, the European Commission must be equipped with the necessary mechanisms to ensure the enforcement of the 2030 collective targets (Monti & Martinez Romera, 2020). Interestingly, Balthasar et al. (2020), compared the EU to the USA and found that, although a sturdy contrast exists at the federal level, at the subnational level similar targets have been identified. Thus, NECPs largely depend on national initiatives and successful management of national pledges.

Key takeaways: Various modelling tools are used for the evaluation of NECPs, but the literature does not focus solely on that. It also investigates the advantages and disadvantages of these plans as well as the actions required for achieving each nation's goals. For example, many researchers, as presented above, have examined alternative sources of energy such as nuclear energy, hydrogen, or the higher penetration of RES such as offshore wind power. Other issues that have heavily concerned the scientific community are energy security, which can be increased by higher penetration of RES, and energy poverty. Moreover, numerous studies have also examined the impact of energy transitions proposed in NECPs on other economic and societal sectors such as GDP, employment rate or even some of the SDGs set by the UN. The focus on SDGs is also reflected on the interests of the stakeholders, who participated in the project's workshops. Therefore, the progress of SDGs through energy and climate planning is a subject that concerns not only academia, but also institutional stakeholders involved in electricity generation and other relevant economic sectors.

European Green Deal (EGD)

In order to tackle climate change and environmental degradation, the European Commission drafted a roadmap aiming at transforming Europe to a modern, resource-efficient and competitive economy that has no net emissions of greenhouse gases by 2050 and economic growth is decoupled from resource use, while no person or place is left behind in the process (European Commission, 2020c). Said roadmap, widely referred to as the European Green Deal (EGD), aims at making EU's economy sustainable. It focuses on turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for all.

The EGD includes actions aimed at boosting efficient use of resources by moving to a clean, circular economy while restoring biodiversity and mitigating pollution. It also outlines investments needed and financing tools available as well as explains how to ensure a just and inclusive transition. The aspiration is that the EU will be climate-neutral by 2050. To make this aspiration a reality, the European Climate Law changed so that the political commitment can be turned into a legal obligation and into a factor triggering or boosting investments. Reaching the climate neutrality target will require simultaneous action by all sectors of the economy, including investments in environment-friendly technologies, supporting industry to innovate, rolling out cleaner, cheaper and healthier forms of private and public transport, decarbonising the energy sector, ensuring buildings are more energy efficient, working with international partners to improve global environmental standards, and so on (EC, 2020). The EU will also provide financial support and technical assistance to assist people, businesses and regions that are affected the most by this transition to a greener economy, in the form of a Just Transition Mechanism, aimed at helping mobilise at least €100 billion over the period 2021-2027 in the most affected regions.

The EGD has not been very often represented in modelling studies to evaluate its impacts with regard to specific policies for the economy, when it comes to reaching climate neutrality. Here we present an overview of relevant pieces in the literature that model the EGD. The literature is retrieved from reviewing relevant queries in Google Scholar for the years 2016 to 2020. These queries are presented below:

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- "energy modelling" +"Green Deal" +Europe
- "energy model" +"Green Deal" +Europe
- "integrated assessment model" +"Green Deal" +Europe
- "integrated assessment model" +"Green New Deal" +Europe
- "energy model" +"Green New Deal" +Europe
- "energy modelling" +"Green New Deal" +Europe

18 publications resulted from this mini-review, of which 16 were included in peer-reviewed journals and only 2 of them were considered as grey literature. An overview of the relevant articles, reports and policy briefs, as well as the models employed and the specific countries or regions they refer to, is presented in Table 12.

Table 12. Models employed in the studies and regions they refer to

Authors	Models	Regions
Gupta et al., 2017	DECoRuM	UK
Goodstein and Lovins, 2019	SDH	Global
Badiei et al., 2019	RdDEM	Global
Broad et al., 2020	TIMES model for the UK	UK
Victoria et al., 2020	Partial equilibrium model	Europe
Mastrucci et al., 2020	engineering-based energy model as input to global sensitivity analysis (GSA)	Luxembourg
Scamman et al., 2020	MARKAL, TIMES	UK
Damman et al., 2020	REMES	Norway
Yue et al., 2020	ESOM model, Irish TIMES	Ireland
Hainsch et al., 2020	GENeSYS-MOD, anyMOD	Europe
Garcia-Casals et al., 2019	E3ME	Global
Baudry et al., 2020	EUCalc	Europe
Mauleón et al., 2017	N/A	Global
Calvillo et al., 2017	TIMES	Scotland
Dafnomilis et al., 2017	Green-X	Europe
Dalla Longa, et al., 2020	TIAM-ECN	Europe
Urquizo et al., 2018	DEM	UK

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With some exceptions (like Dalla Longa et al., 2020; Garcia-Casals et al., 2019), most studies used energy system or sectoral models, rather than integrated assessment models.

For the UK, the residential sector and the relevant interventions that can lead to decarbonisation were investigated. Gupta et al. (2017) described the methodology and application of a new localised and data-driven energy mapping approach for targeting and modelling energy interventions in urban areas. They aim to offer their application to local authorities and housing associations on the basis that they would save money overall by specifically targeting those most in need. Broad et al. (2020) combined long-term system-wide optimisation modelling with heat and electricity network models of representative residential locations, investigating key heating alternatives across futures with dwindling carbon budgets but lowering restrictions on residential investment options, finding that decarbonising the residential sector in the UK through electrified heat can be done and is supported by low-carbon grid power and more efficient homes. Urquizo et al. (2018) described the development of a spatial database for an annual energy consumption framework; they tested different energy measures (fabric and heating supply systems) for the same property type and produced insights into community energy analysis by aggregating individual building energy consumption. Scamman et al. (2020) undertook a review of existing energy models for heat decarbonisation finding that a range of models exist that have strengths across different features, suggesting that multi-modelling approaches are needed in order to adequately address the heat decarbonisation challenge. However, given the opportunities to improve existing models and develop new approaches, they proposed a research agenda.

The residential sector was also investigated for Luxembourg. Mastrucci et al. (2020) presented a generic model simplification approach using uncertainty propagation and stochastic sensitivity analysis to derive fast simplified modelling to estimate the current building stock's energy use for improved urban planning in the country. They mentioned that current models rarely consider uncertainty associated to building usage and characteristics within the stock, resulting in potentially biased results, and showed that the parameters explaining most of the variability in final energy use for heating and domestic hot water are floor area, set-point temperature, external walls U-values, windows and heating system type. At the EU level, Badiei et al. (2019) described a new method to swiftly model the dynamics of heating energy demand and indoor air temperatures of houses and housing stocks, providing a dynamic housing stock model using the data already collected from millions of houses to generate Energy Performance Certificates (EPCs).

Regarding decarbonisation, Victoria et al. (2020) investigated how, for a given carbon budget over several decades, different transformation rates for the energy system yield starkly different results across Europe. They found that following an early and steady path in which emissions are strongly reduced in the first decade is more cost-effective than following a late and rapid path, in which low initial reduction targets quickly deplete the carbon budget and require a sharp reduction later. Garcia-Casals et al. (2019) explored a higher deployment of low-carbon technologies, mostly renewable energy and energy efficiency, and developed a methodology to measure the socio-economic footprint of energy transition roadmaps using the E3ME macroeconometric model.

Goodstein and Lovins (2019) reviewed the Solar Dominance Hypothesis (SDH) and argued that local, regional and national policy could either impede or substantially support the speed at which solar dominance materialises. Mauleón et al. (2017) analyse the potential contributions of photovoltaics to sustainable development in its three dimensions (environmental, economic, and social).

Damman et al. (2020) aimed at strengthening the knowledge base on how transitioning to a low-emission society will influence the energy, power and transmission systems, mapped economic ripple effects, and provided recommendations as to how relevant measures may be realised and implemented in Norway. Yue et al. (2020)

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explored optimal pathways towards 100% renewable energy in Ireland by 2050 and found that 100% renewable energy can be achieved by multiple pathways with similar cost levels; however, much greater efforts than current national action plans are required.

With references to the EGD, Calvillo et al. (2017) described the generic structure of the TIMES modelling framework to help a wider audience to understand the capabilities of this type of model, before reviewing energy efficiency-related work in TIMES and assessing its main strengths and limitations. Hainsch et al. (2020) argued that the EGD, a package of measures "to put Europe on a pathway to a sustainable future, while leaving no one behind", can combine climate neutrality with a sustainable economic recovery of Europe coming out of the Corona pandemic crisis. They mentioned that learning from lessons of past transitions and avoiding one-way decisions to strengthen the status quo is as important as combining the decarbonisation challenge with economic recovery.

Baudry et al. (2020) found that several options are available for evaluating potential agriculture and land use interventions by 2050, including: climate smart production systems for crops, livestock and forestry products, land management, alternative protein sources for livestock, bioenergy, and the management of organic wastes and residues. Dafnomilis et al. (2017) provided an up-to-date view of bioenergy supply demand and trade in Northwest Europe up to 2030, claiming that projections might be under- or overestimating the biomass potential in certain cases, depending on whether they are derived from national reports or regional models and whether future policy developments were considered. Dalla Longa et al. (2020) expanded and adapted the TIAM-ECN model to reflect geothermal energy potentials more adequately, and to better represent the various sectors in which geothermal energy could possibly be used.

The different technologies employed in each paper are presented in Table 13.

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Table 13. The different technologies employed in studies referring to the EGD

Authors	Solar	Wind	Hydro	CSP	Wave	Biomass	Geotherm	Nuclear	CCS	Bioenergy	Biofuels	Reforestat	Afforestat	BECCS	(SRM)	DAC	Other	Hydrogen	Heat	Other	Vehicles	Energy	Coal	Oil	Natural	CHP
Gupta et al., 2017	√														√							√				
Goodstein and Lovins, 2019	√	√	√					√															√	√	√	
Badiei et al., 2019	√	√																	√			√				
Broad et al., 2020	√					√			√	√		√						√	√		√	√	√	√	√	
Victoria et al., 2020	√	√	√			√		√		√				√		√		√	√		√		√	√		√
Mastrucci et al., 2020	√																					√		√	√	
Scamman et al., 2020	√	√					√	√	√	√								√	√			√			√	√
Damman et al., 2020	√	√	√			√		√	√	√	√							√			√	√	√	√	√	√
Yue et al., 2020	√	√	√		√	√		√		√	√							√	√		√	√	√	√	√	
Hainsch et al., 2020	√	√	√			√		√		√	√					√		√	√		√	√	√	√	√	
Garcia-Casals et al., 2019						√		√	√													√	√	√		
Baudry et al., 2020						√				√	√												√	√		

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Authors	Solar	Wind	Hydro	CSP	Wave	Biomass	Geotherm	Nuclear	CCS	Bioenergy	Biofuels	Reforestat	Afforestat	BECCS	(SRM)	DAC	Other	Hydrogen	Heat	Other	Vehicles	Energy	Coal	Oil	Natural	CHP
Mauleón et al., 2017	√	√				√																	√	√	√	
Calvillo et al., 2017	√	√	√			√		√	√	√	√			√				√	√	√	√	√	√	√	√	√
Dafnomilis et al., 2017	√	√				√				√	√								√		√	√	√	√	√	√
Dalla Longa, et al., 2020	√	√	√			√	√	√	√																√	
Urquizo et al., 2018	√	√																				√	√	√		

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The various pollutants considered in the different studies are presented in Table 14. Aside from CO_2, only three studies report on methane, while Broad et al. (2020) also look into air pollutants, and Dafnomilis et al. (2017) into fluorinated gases.

Table 14. Pollutants investigated in the studies delving into the EGD

Authors	CH4	CO2	F-gases	Land Use CO2	CO/VOC	NH3	NOx	PMs	SOx
Gupta et al., 2017		√							
Badiei et al., 2019		√							
Broad et al., 2020	√	√			√	√	√	√	√
Victoria et al., 2020		√							
Scamman et al., 2020	√	√							
Damman et al., 2020		√							
Yue et al., 2020		√							
Hainsch et al., 2020	√	√							
Garcia-Casals et al., 2019		√							
Baudry et al., 2020		√							
Mauleón et al., 2017		√							
Calvillo et al., 2017		√							
Dafnomilis et al., 2017		√		√					
Dalla Longa, et al., 2020		√							
Urquizo et al., 2018		√							

Except Baudry et al. (2020), none of the studies explicitly discusses SDGs either in general or a particular dimension. However, they do share the same goals with or cover the topic of some of the SDGs as presented Table 15. Aside from SDG13, most additionally gain insights into SDG7 "Affordable and clean energy", especially those touching upon the issue of residential heating or energy efficiency (Gupta et al., 2017, Broad et al., 2020, Urquizo et al., 2018, Scamman et al., 2020). A lot of the studies also include the health and wellbeing of people, as they present pathways that improve the current practices that negatively affect the health and wellbeing of people, thus covering SDG3 "Good health and well-being".

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Table 15. SDGs covered by the studies with explicit reference to the EGD

Authors	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG14	SDG15	SDG16	SDG17
Gupta et al., 2017	(√)						(√)									
Goodstein and Lovins, 2019							(√)		(√)							
Badiei et al., 2019						(√)	(√)	(√)				(√)				
Broad et al., 2020	(√)		(√)			(√)			(√)			(√)				(√)
Victoria et al., 2020	(√)						(√)		(√)							
Mastrucci et al., 2020							(√)									
Scamman et al., 2020											(√)					
Damman et al., 2020							(√)									
Yue et al., 2020			(√)			(√)	(√)								(√)	
Hainsch et al., 2020			(√)				(√)									
Garcia-Casals et al., 2019			(√)				(√)	(√)				(√)				
Baudry et al., 2020								√								
Mauleón et al., 2017			(√)				(√)									
Calvillo et al., 2017	(√)	(√)		(√)		(√)	(√)									
Dafnomilis et al., 2017							(√)									
Dalla Longa, et	(√)							(√)	(√)							

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Authors	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG14	SDG15	SDG16	SDG17
al., 2020																
Urquizo et al., 2018							(√)	(√)								
Gupta et al., 2017								(√)								
Goodstein and Lovins, 2019							(√)									

Overall, the European Commission's Just Transition Mechanism is the first part of a decade-long Green Deal funding package. The mechanism is set to run from 2021 to 2030 and is focused on providing support to those countries most financially and practically affected by the transition away from fossil fuels. The deal has been receiving criticism by environmental advocacy groups that insist that the funds should be given to countries that are really committed to phasing out fossil fuels, especially as it currently stands after the coronavirus-related economic recovery funding was finalised, in July 2020. However, the deal sets out a new growth strategy by tackling some of the most important environmental and climate-related problems. The transformation it aims to achieve will make EU's economy more resilient to climate and environment-related risks in the future while contributing to the well-being of its residents.

Key takeaways: Few scientific papers focus on the EGD, but most examine various subjects in relation to the EGD. One of the most prominent ones is the importance of the household sector in achieving climate change mitigation targets, highlighting that the EU has started a significant endeavour to support households towards this direction. Another aspect analysed in the reviewed literature is the importance of immediate action with initiatives relevant to the Green Deal. For example, delayed action may lead to more stringent policies in order to achieve the emissions targets set at the EU level. Another subject investigated by several researchers is achieving a transition leaving no one behind. This is an issue that has also been among the priorities of the stakeholders involved in the PARIS REINFORCE project, as reflected in the regional workshop, stressing once again that scientific, institutional, and financial stakeholders are heavily concerned about achieving a just transition with the slightest consequences on the nations' economies.

Carbon Border Adjustments (CBA)

It is generally accepted, notably in Europe and the US, that the differentiation in policies to reduce carbon emissions could engender carbon leakage and weaken domestic industrial competitiveness. Since a worldwide carbon tax with a uniform rate might not be accepted by some major countries, unilateral initiatives are needed (Majocchi, 2018). Carbon border tax is therefore highlighted as a way of solving the carbon leakage problem and as a simple way for Europe to move towards a global level pricing of carbon and impose an import tax on the CO_2 content of all goods imported into the EU from countries that do not put a price on the use of carbon. This ensures that the price of imports reflects more accurately their carbon content. Due to the vulnerability of the Paris Agreement to the withdrawal of the US, or any other major party, a more regional approach with punitive carbon

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border tax adjustments could be taken to help US-proof an alternative climate agreement (Kemp, 2017).

A search for publications in peer-reviewed literature was performed with Google Scholar, with the queries below:

- model +IAM +"carbon border"
- model +IAM +"border tax"
- "Carbon Border Adjustment" +Europe
- "Carbon Border Tax" +Europe.

The timeframe of publication was limited to the last five years (2016 – 2020). 51 publications were included in this mini-review with 45 being published in peer-reviewed journals and only 6 being considered as grey literature.

After presenting the concept of CBA and its applications, a thorough literature review of modelling scientific work follows. Throughout this review we use the acronym CBA to refer to the term 'Carbon Border Adjustment', which is also found in literature as 'Border Carbon Adjustment' or 'Carbon Border Tax Adjustment' or 'Border Tax Adjustment'. The study of carbon border adjustments—taxing the carbon content embedded in imported goods—is considered one of the top three trends in climate change economics as of the last years (Vale, 2016).

Carbon Border Adjustment and Carbon Leakage

'Carbon leakage' is a term used to describe a problem that countries may face when imposing carbon tariffs or taxes on carbon-intensive products. Companies prefer to shift their production in countries with less stringent climate regulations in order to be competitive in a global market (Palacková, 2019). In the face of this possibility, introduction of a carbon border tax as a countermeasure against deterioration in EU competitiveness was one among other possible climate policies to be introduced in the EGD (Vis, 2019). It is generally assumed that CBA, despite its drawbacks, is one of the best solutions to mitigate carbon leakage (Dao, 2018).

As reported in the EGD (European Commission, 2019), should differences in levels of ambition worldwide still exist, as the EU sets higher emission mitigation targets, the European Commission should propose a CBA mechanism for selected sectors, to reduce the risk of carbon leakage. This is why this topic has received much attention after the announcement of the EGD by President Ursula von der Leyen. Within the next few years, CBA is likely to become an important component in EU climate policy. In this context, Claeys et al. (2019) suggested that the EU's future climate policy should not rely on successful implementation of CBA but instead hold off from implementing it, while closely monitoring the evolution of carbon leakage risks in Europe, and ultimately implement it if the risks become visual It would be another course of action to address the risk of carbon leakage in the EU's Emissions Trading System (ETS), but moreover it would provide motivation to producers elsewhere to decarbonise their production.

Different types of CBA have been proposed in recent years to address carbon leakage, for example carbon tariffs on imports or export rebates/subsidies. Larch and Wanner (2017) showed that carbon tariffs are able to reduce world emissions, mainly via altering the production composition within and across countries, hence reducing carbon leakage, which is done at the cost of lower world trade flows and lower welfare, especially for developing countries. On the other hand, Antimiani et al. (2016) used an adjusted dynamic CGE model to assess the rate of carbon leakage and the adverse impacts of carbon border tax on competitiveness, in a number of scenarios over the period 2010–2050, and their results indicate serious carbon leakage and negative effects on competitiveness.

Carbon Border Adjustment and World Trade

Our present literature review found that it has not yet been confirmed whether CBA fully complies with the legal

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framework of the World Trade Organization (WTO) rules. Recent evidence by Dröge et al. (2019) suggest that a border adjustment can be made WTO-compatible in principle, notably by the general exemption clause of the General Agreement on Tariffs and Trade (GATT), but the European Commission will have to investigate its economic, legal, and administrative viability and implementation timeline. In its EGD, the EU pledged to design CBA to comply with WTO rules and other international obligations of the EU.

It is suggested that, with proper design, border adjustments for carbon taxes can be shaped as a WTO-consistent policy tool that can be used as part of a toolbox to address climate change and emissions targets (Porterfield, 2019). Mehling et al. (2019) provide a substantial analysis of the particular design and economics of CBA and propose a way to design them so as to balance legal, administrative, and environmental considerations. In more general wording, Majocchi (2018) highlights that the border tax adjustment not only increases global welfare but could also be shaped to be compatible with WTO rules.

Gains, Benefits and Drawbacks by CBA Implementation

According to Mclaughlin (2019), implementing CBA would achieve two main purposes. First, it would bring to an end the ability of European or overseas emitters to avoid the costs of emissions that might be applied within the EU ETS by relying on production abroad, where such costs are not applied. Secondly, a carbon border tariff would flatten the market for emitters that operate and produce within the EU ETS without offshoring production and prevent price undercutting at those firms' expense. On the other hand, Palacková (2019) argues that imposing a carbon tariff on imports from the EU's trading partners could have a positive impact on climate results, but would also provoke strong trade repercussions, and that CBA could prove a debatable yet better option.

It is suggested that an important reason to use global carbon pricing, whether through a carbon tax or emissions trading, is environmental effectiveness at a relatively low cost, which in turn contributes to enhancing social and political acceptability of climate policy. CBA could reduce freeriding and promote wide participation in an international agreement (Baranzini et al., 2017). However, one of the major concerns lies in establishing an accurate way for the foreign producers to report their true carbon content in the same way as domestic producers. Zhang and Zhu (2017) proposed that size and component of carbon footprints are relevant to environmental policy; however, the frequency of border-crossing associated with carbon footprints also has implications, especially given the fragmentation of production across national boundaries developing quickly in recent years.

As Marceau (2016) notes, exporting countries are likely to prefer imposing their own carbon export duties rather than facing import CBA measures, since the revenue generated through a carbon export duty stays in the exporting country and thus allows the exporting country to retain the revenue instead of allowing their exporters to be exposed to CBA measures in the importers. Moreover, while carbon pricing is a production-oriented approach, in theory it can be transformed into a consumption-oriented approach, by applying the carbon tax on embodied emissions for imports and cutting it for exports (Girod, 2016). By using a set of numeric simulations calibrated to data, Balistreri et al. (2019) suggested that border adjustments on carbon content should be set below domestic carbon prices, while countries imposing CBA at the domestic carbon price will be extracting rents from unregulated regions at the expense of efficient (international) environmental policy.

Given different assumptions about the development of the carbon intensity of non-EU production and different CBA designs, Krenek et al. (2019) found that estimated revenues would suffice to finance between a third and all of current EU expenditures by 2027, thus allowing countries to reduce their current contributions to the EU budget accordingly. However, after the establishment of a CBA on imports of energy-intensive and trade-exposed goods, the Union could be subjected to trade retaliation, for example in AFOLU. Nevertheless, Fouré et al. (2016) suggested that macroeconomic consequences for the EU and its trade partners could be small, if trade partners

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ever decided to have recourse to these different trade measures. The same reality applies to the other side of the Atlantic, where the prospect of CBA could elicit adverse reactions from trade partners, such as imposing import tariffs on US goods, thereby adversely affecting manufacturers (Aldy, 2017).

Literature Review

This review does not solely examine modelling applications of CBA but also implementations of national/regional carbon tax systems, such as the EU ETS, to examine the impact of carbon taxing in general. Many research papers using IAMs tend to use CGE models to assess the economic and environmental impact of carbon tax systems. Some specific examples of such models are GTAP-E (Zhu et al., 2020; Zhang, 2019; Feijó and Kuik, 2018) and IMED (Xie et al., 2018). Another type of IAMs that is commonly used is energy system optimisation models such as OSeMOSYS (English, 2017; Jones et al., 2019) and TIMES (Bachner et al., 2019; Dioha and Kumar, 2020).

Carbon tax systems are applied in many countries and regions worldwide (Figure 11); thus, there are scientific papers investigating their application in a variety of regions. Many of them examine global scenarios whereas others focus on national or regional scenarios (e.g. the European Union).

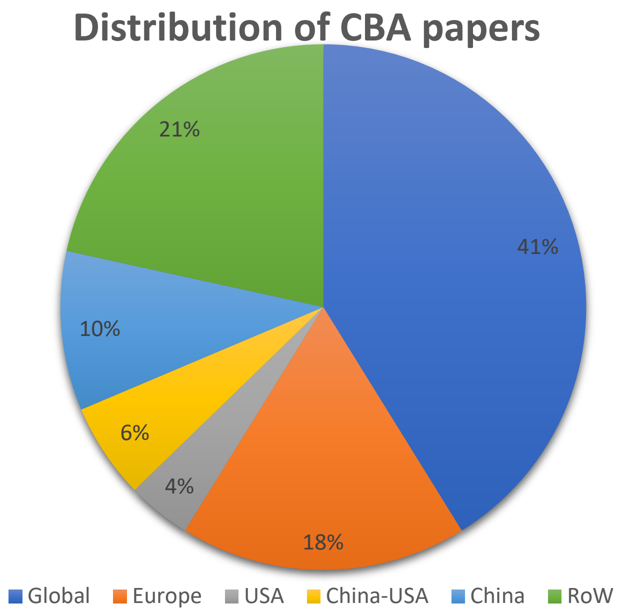

Figure 11. Distribution of carbon taxation systems papers per region

Almost half of the papers included in this mini-review investigate the effect of carbon tax systems on a global scale. The second most common region is Europe and the EU, which already applies the EU ETS carbon pricing scheme. Afterwards, China is also a country that many researchers focus on, since it is the biggest emitter worldwide. Another important emitter that is not however examined infrequently is the USA, despite being one of the biggest emitters. An interesting finding of this mini-review is the fact that some scientific papers examine the impact of a CBA scheme on the trade between USA and China. This is mainly due to China exporting cheaper products to the USA, having less emission control schemes; hence Chinese factories spend less money on emission reduction investments. Finally, more than one fifth of the literature examines other countries, such as Australia (Meng et al., 2018), Brazil (Feijó and Kuik, 2018) or even specific European countries such as Austria (Nabernegg et al., 2018) and Belgium (Gonne, 2016).

Moreover, it is important to examine the model used in each scientific publication (Table 16).

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Table 16. Overview of the models (name or type) used in the carbon taxation systems literature

Authors	Model
Meng et al., 2018	Integrated electricity-CGE modelling
Zhao et al., 2017	CGE
Li and Jia, 2016	CGE
Joseph et al. , 2019	N/A
Deane et al., 2018	PLEXOS
Wong , 2016	PAGE09
Favero et al., 2016	GTM
Truger, 2017	CGE
Stifter et al., 2016	SGAM
Gonne, 2016	Input-output (IO) analysis
Feijó and Kuik, 2018	GTAP-E
Xie et al., 2018	IMED
Liu et al., 2020	CGE
Zhu et al., 2020	GTAP-E
Zhang , 2019	GTAP-E
Antimiani , 2016	CGE
Sommer and Kratena, 2019	DYNK
Perdana and Tyers, 2017	Gdyn-E
Böhringer et al., 2016	multi-sector CGE
English, 2017	OSeMOSYS
Li and Jia , 2016	CGE
Wang et al. , 2018	CGE
Nabernegg et al., 2018	CGE
Wellman et al., 2016	DICE, PAGE

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Authors	Model
Pollitt et al., 2019	E3ME
Zeshan et al., 2016	CGE
Hdom and Fuinhas, 2020	DOLS
Tol, 2019	Matlab code combining the results of various studies using models
Philippidis et al., 2018	MAGNET
Larsen et al., 2018	NEMS
Mori , 2016	THERESIA
Matar and Elshurafa, 2017	KAPSARC
Ginkel et al., 2018	COACCH
Zeng , 2017	MARKAL
Jones and Leibowicz, 2019	OSeMOSYS
Capros et al., 2016	PRIMES
Brand et al., 2019	STEAM
Guzman et al., 2016	LUTI
Dioha and Kumar, 2020	TIMES model generator
Bachner et al., 2019	TIMES
Petterson Molina Vale, 2016	N/A
Qi et al. , 2016	C-GEM
Faehn et al., 2020	CGE
Rissman et al., 2020	N/A
Price et al., 2018	Energy model integrated with cost-benefit analysis, cost effectiveness analysis, multi-level perspective and life cycle assessment
Zhang et al. , 2020	CGE, GEEPA, C3IAM
Elliott et al. , 2020	DICE
Wood et al. , 2019	E3ME

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Authors	Model
Liu et al., 2020	G-Cubed
Blanco et al., 2017	SIM4NEXUS, E3ME-FTT
Dees et al., 2016	LIDAR

In all modelling research examined, the starting point is either the end of the 20th century (e.g. 1990) or the very beginning of the 21st century. A couple of papers set as a starting point the current year (2020). The starting point mainly serves as a point of reference for the proposed scenarios. The important aspect of the timeframe examined is the ending year. Regarding this criterion, we separate the papers on three different periods: the short-term, which mainly investigate current situations (until 2020), the mid-term, investigating the period of 2030-2050 and long-term which have a time horizon ending after 2050. The distribution of the papers is depicted in Figure 12.

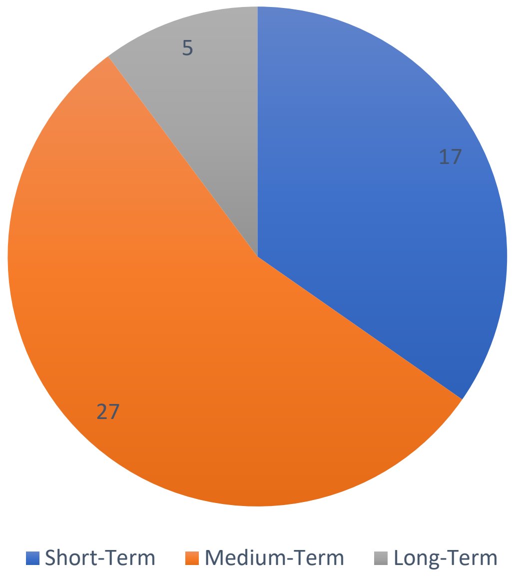

Figure 12. Distribution of papers according to the examined time period

The short-term papers mainly focus on the ongoing impacts of already existent measures. For example, Matar and Elshurafa (2017) examined the current impact of two alternative policies on the Saudi cement industry. The medium-term time horizon mainly served the examination of the possible trajectories of national NDCs and the probability of achieving the Paris Agreement goals. In this context, Antimiani et al. (2017) examined the impact of various carbon policies (including EU-ETS and CBA scenarios) on EU's environmental goals. Finally, the long-term scientific work aims at examining a post-Paris reality in which many countries are supposed to be almost carbon-neutral. For example, Favero et al. (2016) investigated the impact of bioenergy and forestry on reducing carbon emissions until 2100.

Furthermore, most of the scientific papers in this review examined the impact of carbon tax schemes (including CBA) on the energy sector, since it is a carbon-intensive sector. According to Meng et al. (2018) the introduction of an ETS in Australia would greatly boost the installation of new wind turbines and greatly reduce electricity generation from brown coal and natural gas. A surprising finding was that electricity generation from black coal was predicted to be just slightly affected by the same policy. Furthermore, Favero et al. (2016), using the WITCH

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model, concluded that at a global level, high carbon taxing contributes to the diffusion of BECCS technologies in the electricity mix, whereas a lower taxation leads to increasing forestland for CO_2 sequestration. The interaction between a carbon taxing policy and the energy sector is also examined by Zhao et al. (2017), who found that, although a carbon tax policy can significantly reduce CO_2 emissions, it does not optimise the energy system in the short run. Hence, they proposed a combination of a carbon tax policy with an emissions trading scheme. Li and Jia (2017) came to the same conclusion, proposing a mixed policy for developed countries and large emitters, but also stressed the implication of an ETS on countries that are characterised by low per capita emissions. Similarly, Joseph et al. (2019) supported that there is no ideal policy and that each country has to choose differently according to national or regional circumstances in order to provoke the necessary behavioural changes. Wong (2016), examining the case of Malaysia, went one step further stating that the efficacy of a carbon tax policy is also linked with the implementation of a further tax reform and other policies, since Malaysia is a developing country. These carbon policies do not affect only the energy mix itself but also the price of production, since electricity is a significant resource for production. Deane et al. (2018), using the PLEXOS model, calculated that a carbon tax can significantly increase the price of electricity—in some countries, the price of electricity may reach 20% of the total cost of production.

Another important aspect of carbon taxation policies is their direct impact on emissions reduction, which is the main objective of the Paris Agreement. Zhang et al. (2020) used a multi-sector multi-region CGE model in order to assess the impact of a CBA scheme and two carbon tariff mechanisms. They concluded that the CBA scheme is more effective for reducing CO_2 emissions since it makes non-cooperative regions to comply with emissions reduction policies and techniques. In the same context, Larsen et al. (2018) stated that a CBA mechanism can significantly contribute to reducing emissions in a short- and medium-term period, in order to support the goals of the Paris Agreement. On a broader analysis, Page et al. (2018), concluded that carbon tax policy can be a part of a wider set of policies and measures, such as the diffusion of NETs, leading to emissions reduction. Some other measures proposed are land use changes, CCS on fossil fuels and bioenergy (BECCS), which can be further promoted if a carbon tax policy is active. These techniques and policies do not have to be applied on every sector but only focus on a dozen of industries, which account for 90% of GHG emissions worldwide (Rissman et al., 2020). Although few sectors are required to adapt to Paris Agreement goals, they need to materialise innovative and radical transformations to sufficiently abate their emissions. These findings were supported by 17 state-of-the-art CGE models that simulate various scenarios for the energy sector, which usually include the introduction of some kind of carbon taxation policy (Faehn et al., 2020). The implementation of a carbon taxation policy, and especially of a CBA scheme, is also considered necessary for the transition to a new era of climate policy economics which do not solely focus on investing in RES (Petterson Molina Vale, 2016). The necessity of this transition is ever evident when examining the case of China's mitigation goals until 2030. Specifically, in order for China to peak its emissions before 2030 a carbon price of at least 25 USD per ton of CO_2 should be set, according to simulations from the C-GEM model (Qi et al., 2016).

The implementation of CBA or other carbon taxation policy does not only contribute to the progress of the Paris Agreement targets, but also affects other socioeconomic dimensions and sectors, since it leads to increased energy prices. An interesting example is the case of Tianjin, China: after thorough examination with a CGE model, Wang et al. (2018) found that air pollution can lead to casualties resulting in labour force loss, thereby decreasing GDP. Therefore, the implementation of carbon taxes can contribute to the increase of GDP since medical costs, as well as labour force loss, will decrease. Wellman et al. (2016), using the DICE and PAGE models, investigated the impact of low-probability but high-impact climate change effects. In their research, they examined risks such as glacial melting which can lead to severe economic damage. They proposed that to avoid this kind of catastrophic incidents, swift climate change mitigation action must take place, including several policies such as introducing

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carbon taxing schemes. Other studies examined solely the economic impacts with no direct linkage to health or climate disasters. For example, Pollitt et al. (2019), using the E3ME model, investigated the impact of a materials charge on emissions-intensive industries. This measure could lead to a 10% reduction of emissions, a small increase of GDP because of the increased products' prices and a small employment decrease in the European Union. Larsen et al. (2018) conducted a similar study regarding the USA using the NEMS model, investigating the amount of federal revenue, the impact of a carbon tax policy on the country's GDP and the efficiency of various policies on the abatement of CO_2 emissions, as well as the response ability of several sectors of the American economy on the implementation of such policies. Other researchers have used different models to examine similar economic impacts. For instance, Mori (2016) used the THERESIA model to assess the impact of carbon policies on OECD countries on various energy and non-energy sectors. This impact was mainly found to be a small decrease of industrial GDP. Philippidis et al. (2018) produced several scenarios to examine the simulation ability of the MAGNET model. They tested many economical, biological, demographic indexes on different policy scenarios that also included carbon taxation. Similar analyses took place for poor and developing countries and regions. Zeshan et al. (2016) investigated the progress of South Asia regarding policymaking and carbon taxation, finding that the region is an emerging polluter and that some countries have not committed to any specific goals or polices, including Pakistan and Nepal. Moreover, it was estimated that large, poor countries, such as Pakistan, have the highest social carbon costs and that income elasticity is a crucial parameter for accurate modelling results (Tol, 2019). A more targeted research work conducted by Matar and Elshurafa (2017) investigated the impact of policies on the cement industry of Saudi Arabia, concluding that CO_2 prices and behavioural conditions have a major impact on decision-making of the industry's stakeholders. This interlinkage between policies and sectors was also examined by Nabernegg et al. (2018), who focused on the carbon footprint of the supply chain. Another interesting aspect of the economic impacts of carbon policies is the amount of free emissions. Li and Jia (2017) found that an amount of free emissions permits does not affect the GDP or other aspects of the economy but only the price of carbon itself. On the other hand, Hdom and Fuinhas (2020), investigating the Brazilian economy, argued that there are also other factors affecting the energy sector of a country apart from energy policies, such as trade openness. These parameters can be important towards the transition to a low carbon economy.

The above analysis makes clear that the implementation of CBA or other carbon policies affects the economy as well as other sectors of the society, but there is a specific issue that is very common among researchers and even among policymakers: competitiveness of countries that have stricter emissions policies against countries that do not impose so strict policies. One of the most characteristic examples is the trade friction between the two biggest economies, the USA and China, during the Trump administration when the USA introduced an import tax on Chinese carbon-intensive products. This measure had three major consequences. First, the GDP of both countries decreased since they are important trading partners; secondly, the GHG emissions of both countries also dropped; and, third, both countries strengthened their trading relation with other economies, pinpointing the introduction of a carbon tax scheme, such as CBA, as a solution for reducing emissions while retaining welfare (Liu et al., 2020). Similarly, Zhu et al. (2020) examined two different scenarios on carbon policies to respond to US carbon tariffs, in order to reduce its emissions but also stabilise its exports towards the USA. Zhang (2019) assessed the efficacy of current Chinese carbon tariffs on US imports and found that they are not as effective compared to the US Trump administration, proposing two different policy measures in order to adapt to US policies. The EU faced similar problems: its emission policies (e.g. the EU ETS) have reduced its products' competitiveness against imported goods, but also created a serious carbon leakage on other countries that have less strict emissions policies, cultivating grounds for an effective CBA scheme (Antimiani, 2016). Sommer and Kratena (2019), in an inconclusive analysis, examined two alternative taxation schemes: direct emission taxation and an indirect scheme related to the total carbon footprint of trading goods. Similarly, Perdana and Tyers (2017), investigated the impact of carbon

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taxation and freeriding on several regions, taking into account various parameters including climate change consequences on health and national economies, and concluding that China and Europe appear more sensitive as they slightly benefit depending on the discount rate. Another aspect of this issue is the threat of carbon taxation on imports from regions that do not comply with GHG emissions reduction policies., for which Böhringer et al. (2016) used a multi-sector CGE model and estimated that the threat of import taxes can lead non-cooperating countries to reducing their emissions. A more specific case study was examined by Feijó and Kuik (2018) with the GTAP-E model, investigating the impact of a European CBA scheme on the economy of Brazil, a main exporter, and finding that the CBA implementation can result in reducing carbon leakage as well as in an opportunity for Brazil to adapt its industry towards a more sustainable model of production that would benefit its climate-vulnerable environment. In the same context, Gonne (2016) examined the competitiveness of the Belgian economy if a carbon taxation policy was implemented, finding that it would affect various sectors differently. A more local case study was conducted by Xie et al. (2018) for Chongqing, China, an inland city not depending on exports but on trading with other Chinese cities: a carbon tax policy was suggested to contribute to China's endeavour to achieve its 2030 goals, with a negative aspect lying in the macroeconomic impact on the region, reducing competitiveness, which could be countered with parallel reduction in other taxes.

Apart from the electricity sector, there also exist other energy sectors, such as transportation and buildings. Regarding the former, there are various studies comparing the introduction of carbon taxation with other more focused measures. For example, an OSeMOSYS application concluded that introduction of SAVs (Shared Autonomous Vehicles) can be more effective than the implementation of a transport carbon tax (Jones and Leibowicz, 2019). A broader study, using PRIMES, was conducted by Capros et al. (2016), which investigated various policies for the abatement of GHG emissions on the transportation sector, proposing taxation of fossil fuels (such as diesel and gasoline) for internal combustion engine vehicles. The implementation of carbon policies such as the already existent EU ETS is also investigated and specifically for two reasons: sub-sectors like aviation are affected by this carbon pricing scheme and electric vehicles are now becoming a trend; hence the electricity generation mix is also affecting the transportation sector. Brand et al. (2019) also suggested a total transition of the transportation sector by promoting electrification, radical change in travel patterns and other measures accompanied by a carbon budget policy. There are also a couple of modelling studies examining national or urban transportation strategies. Guzman et al. (2016) investigated policies for emissions reduction in transport in the city of Madrid, examining carbon taxes on the fuel combusted by conventional cars, to reduce fuel consumption. In the same context, Dioha and Kumar (2020) used a TIMES model and estimated that the implementation of a carbon tax on transportation in Nigeria can contribute to the abatement of GHG emissions by 25.9% until 2050.

The building sector has also drawn limited attention from modellers regarding the implication of CBA or other carbon taxation policies. For example, Truger (2017) examined the impact of carbon taxation on household energy efficiency, leading to reduced fossil fuel consumption and contributing to the reduction of CO_2 emissions. Along those lines, the impact of an electricity tax on households was also examined, leading to reduced consumption (Stifter et al., 2016).

There are also some scientific papers regarding CBA or other carbon taxation policies that cannot be easily categorised. An interesting example is the use of OSeMOSYS model in the case of the provinces of Alberta and British Columbia, in Canada (English, 2017), investigating the impact of increasing RES on already existent carbon taxes, and proposing that the carbon tax in Alberta may be significantly reduced if the interconnection between the two provinces' electricity networks was enriched. A different issue examined by Zheng (2017) is the co-existence of different carbon policies in the same region: the MARKAL model was used to examine the cases of China and the EU, which both have a tax on coal-fired plants as well as an ETS also affecting coal-fired stations,

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leading to distortions on one another, which can be mitigated by introducing a tax that considering the energy content of the fuel combusted.

The literature of this mini-review also includes a paper focusing on the pandemic of Covid-19 and its consequences, linking a carbon tax policy to a recovery plan (Elliot et al., 2020): the lockdown led to a reduction of global GDP by approximately about 5%, while resulting in a significant reduction of GHG emissions, as many people avoided transportation means for a couple of months and because many firms had to temporarily shut down.

CBA and other carbon taxation policies are affecting various sectors, such as the economy, transportation, households etc. According to our review, more than 40% of the reviewed papers at least referred to the importance of behavioural change on GHG mitigation. Apart from behavioural change, carbon taxation was also related to broader policies at a national or regional level. In order to examine the interlinkage of these two notions, we examined the percentage of papers referring to or even explicitly analysing the EGD, one of the most significant environmental policies worldwide: 1 out of 3 papers is somehow related to this policy, demonstrating the importance of carbon taxation on policymaking towards a transition to a more sustainable energy system.

Key takeaways: CBA has been the focal point of various scientific papers. One of the most important aspects covered is carbon leakage, since countries' implementing carbon taxes tend to demonstrate lower export rates, with importers preferring cheaper products from countries whose industries are not equally burdened. This has also affected the competitiveness of several economies with the interactions between China and USA being extensively examined in the literature. Moreover, many scientific papers focused on the impact of CBA on the transition to a cleaner economic model, since carbon taxation leads to higher prices on "traditional" and polluting procedures forcing industries to invest in cleaner technologies. One of the most affected sectors appears to be the energy sector, as it is heavily dependent on fossil fuels. Evidently, this kind of taxation contributes to delivering on the PA goals, resulting in reduced CO_2 emissions. Finally, although the majority of papers examining the impact of CBA did not investigate the progress of SDGs, many of the CBA's impacts evidently affect the progress towards these goals.

Behavioural change in models

The demand side is largely underrepresented in modelling, and that predominantly via technological options in energy efficiency improvements. Values, choices, cohesion, culture, and lifestyle shifts are only indirectly narrated as assumptions not interacting with, and marginalised from, the vividly modelled flows between technology, economy, environment, and policy. Even modelling scenarios looking at end-use transformations, like digitalisation of daily life and pervasive integration of new information technologies into energy services, mostly explore the maximum potential of technological breakthroughs taking into account a number of behavioural changes but not fully exploring how they could come about or how realistic they are, and overlooking that, without the necessary behavioural and societal transformations, the world is very possibly looking at a generalised, society-wide rebound effect. This diverse range of possible, potentially large rebound effects is hardly ever fully explored (Nikas et al., 2020). Given the over-reliance on supply-side solutions to address climate change, there is increasing focus on the realism of demand-side solutions, especially making IAMs more adaptable to mitigation actions that include behavioural changes and patterns in lifestyles (Mercure et al., 2018). Therefore, the scientific community has acknowledged that more research is needed in behavioural change in multiple sectors affected by individual choices.

In order to examine the modelling work so far on behavioural change in models we examined all the literature

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retrieved for the main literature review (using all the queries presented in Section 3.1) and filtered it. After this process, 30 publications focusing on this matter were distinguished, all of which were included in peer-reviewed journals.

One of the main emitting sectors regarding final end-use is the household sector (Table 17). This sector is characterised by significant uncertainty since it is dependent on people's habits and lifestyle. Therefore, modelling tools need to simulate these actions with robustness taking into consideration probable changes. For example, Broad et al. (2020) examined the impact of energy savings related to heating habits towards the achievement of the decarbonisation target of the UK in 2050, while Mastrucci et al. (2017) examine the impact of occupants' behaviour regarding energy savings. Their behaviours were expressed with parameters such as desired temperature of their dwellings. Zeng (2017), using the MARKAL model, also examined the impact of choosing more efficient cooling and heating systems for households, while Urquizo et al. (2018) claimed that the energy saving behaviour of residents is heavily dependent on the energy efficiency of their houses. People with more efficient cooling and heating systems tend to be less considerate of how to use their appliances efficiently. In the literature review, we also spotted modelling work that conducted a broader analysis of behavioural scenarios regarding the household sector. For instance, Hainsch et al. (2020) proposed energy savings scenarios combining increased efficiency with energy saving habits. A broader analysis was presented by Levesque et al. (2019) proposing a scenario with a wide set of behavioural change options such as water heating, cooling, and heating savings. Gambhir and Tavoni (2019) developed a similar scenario, using the models TIAM and WITCH, in which the behavioural changes and energy efficiency investments can be sufficient for the achievement of the 2050 goals rendering the wide-scale deployment of BECCS unnecessary. Finally, some modellers have also argued that the implementation of carbon taxation policies may lead to reduced energy demand in households due to increased energy prices (Sommer and Kratena, 2019; Niamir et al., 2020; Meng et al., 2018).

Table 17. Representation of behavioural changes in household studies

Study	Models	Region	Focal Point	Time Horizon
(Sommer et al., 2019)	DYNK	Global	Impact of ETS on energy demand	2015-2030
(Broad et al., 2020)	TIMES model for UK	UK	Energy savings	1970-2016
(Mastrucci et al., 2017)	engineering-based energy model as input to global sensitivity analysis (GSA) using the elementary effects (EE) screening and Sobol's method for key parameters identification and regression analysis to derive simplified models for entire building stocks.	Luxembourg	Energy savings	1949-1994
(Zeng Y., 2017)	MARKAL	Europe	Energy efficiency and savings	2001-2015

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Study	Models	Region	Focal Point	Time Horizon
(Hainsch et al., 2020)	GENeSYS-MOD, anyMOD framework	Europe	Energy efficiency and savings	2015-2050
(Meng et al., 2018)	Integrated electricity-CGE modelling	Australia	Impact of ETS on energy demand	2009-2020
(Urquizo et al., 2018)	DEM	UK	Energy savings	Undefined
(Gambhir and Tavoni, 2019)	TIAM, WITCH	Global	Energy efficiency and savings	2020-2100
(Levesque et al., 2019)	EDGE (energy demand model)	Europe and 10 other regions	Cooling and heating savings	2050-2100
(Niamir et al., 2020)	BENCH v.2	Netherlands	Impact of ETS on energy demand	2017-2030

Changes in lifestyle also affect emissions of the transport sector depending on the choice of transport means. Including assumptions in models related to mitigation actions that incorporate behavioural change can contribute to broader mitigation targets (Gota et al., 2019). Incorporating behavioural habits in modelling exercises usually requires the development of specific scenarios that implement a decrease in transport demand. Gil et al. (2020) included such assumptions as part of the NECP of Portugal and the roadmap for carbon neutrality by 2050. Similar scenarios were established by Brand et al. (2019) who compared behavioural changes with EV diffusion and a combinational pathway, to conclude that meeting targets requires both measures, since each individual strategy has limits. Deep transformations in mobility behaviour can also be driven by carbon pricing policies to allow green innovation to emerge (Cassen et al., 2018). Switching to shared autonomous vehicles has also been suggested, since they reduce total passenger-km demand, leading to lower cost and emissions, while accelerating the diffusion of electric vehicles (Jones et al., 2019). As part of the efforts to streamline global policies at the national level, Hof et al. (2020) evaluated multiple policies including several behavioural changes, such as lower demand for travelling, less car ownership, and shifts to public transportation.

Table 18. Representation of behavioural changes in transport studies

Study	Models	Region	Focal Point	Time Horizon
(Gil et al., 2020)	PRIMES	Portugal	Transport behavioural changes as part of the NECP	2020-2050
(Brand et al., 2019)	STEAM	Scotland	Comparison of behavioural change with EVs	2012-2070
(Cassen et al., 2018)	IMACLIM-R	EU	Carbon pricing and mobility behaviour	2010-2050
(Jones et al., 2019)	OSeMOSYS	Global	SAVs	2020-2050

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Study	Models	Region	Focal Point	Time Horizon
(Hof et al., 2020)	IMAGE, WITCH, Enertile	Global, EU	Translating global policies to national scale	2010-2050

Another aspect of behavioural change that is examined in the reviewed literature includes dietary habits. According to Karlsson et al. (2018), the increase of human population is a significant challenge towards the achievement of mitigation goals, since it results in higher energy and land use demands. Specifically, the scenarios run in the TIAM-WORLD model suggested that the adoption of a diet characterised by low meat consumption is essential for accomplishing mitigation targets, since meat is a type of food characterised by high-CO_2 intensity but also requires significant amounts of land that could be used for other purposes. In the same context, Lee et al. (2019) evaluated the results of many scenario runs based on several models, and concluded that the sole manner of achieving Europe's mitigation goals is the reduction of meat consumption in order to achieve food security in combination with forestland preservation, which is crucial for the sequestration of GHG emissions. According to Pye et al. (2018), scenarios taking into consideration human dietary choices are subject to uncertainty since human behavioural change is not easily affected by mitigation policies. Kriegler et al. (2017), using the REMIND-MAgPIE model combination, suggested that human consumption habits must markedly change, with parallel adoption of a less materialistic way of living, in order for goods production and consumption to decrease.

Table 19. Representation of behavioural changes in diet studies

Study	Models	Region	Focal Point	Time Horizon
(Pye et al., 2018)	ESME	United Kingdom	Uncertainty of dietary changes	2010-2050
(Kriegler et al., 2017)	REMIND-MAgPIE	Global	Dietary changes and reduced material consumption	1980-2100
(Lee et al., 2019)	Results from IAP	EU-28, Switzerland, Norway	Dietary changes	2010-2050
(Karlsson et al., 2018)	TIAM-World	Global	Dietary changes	1960-2100

Efforts to include behavioural patterns in IAMs are not limited to sectoral approaches but can be present in multi-sectoral studies, which can be distinguished in two categories: specifically focusing on lifestyles (Groterra et al., 2020; van der Berg et al., 2019), general energy demand reduction (Napp et al., 2019; Grubler et al., 2018) or even non-optimal behaviour (Li et al., 2017); and overall low-carbon pathways incorporating actions related to behaviour change (Gupta et al. 2019; van Vuuren et al. 2018; Roe et al. 2018; Capros et al. 2019; Strapasson et al., 2020; van de Ven et al., 2018). Trutnevyte et al. (2019) highlight the lack of representation of societal transformations in IAMs and suggest an empirical agenda to assess the interactions between the intertwined pillars of technology, economy, environment, policy, and society. Table 20 presents an overview of recent studies including behavioural change action from a multi sector perspective.

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Table 20. Multi-sectoral modelling approaches to behavioural change representation

Study	Models	Region	Focal Point (related to behavioural change)	Time Horizon
(Groterra et al., 2020;)	IMACLIM-S BR	Brazil	Lifestyle changes in low-emissions development strategies (Improved efficiency, smaller houses, reduced mobility, public transport	2005-2050
(van der Berg et al., 2019)	IMAGE, GCAM, MARKAL	Global	Improvement of IAMs in order to include lifestyle factors (diet, public transport, thermostat, circular economy)	2020-2050
(Napp et al., 2019)	TIAM-Grantham	Global	Deep carbon intensity reductions in the energy demand sectors (increase of public transport, better operation of heating)	2020-2100
(Li and Strachan, 2017)	BLUE	Global	Non-optimal behaviour (Behavioural model, environmentally bad choices from consumers, building heating, transport)	
(Gupta et al. 2019)	AIM/Enduse, IMACLIM-IND	India	Low carbon pathways in India (More public transport, dematerilazaton, recycling)	2012-2050
(van Vuuren et al. 2018)	IMAGE	Global	Alternative pathways to the 1.5 °C (Assumption of better use of appliances, dietary, public transport)	2000-2100
(Roe et al. 2018)	AIM/CGE, GCAM, IMAGE, MESSAGE-GLOBIOM, REMIND-MAgPIE, WITCH-GLOBIOM	Global	Impact of land sector towards climate change mitigation (land use, diet, wood procucts and waste)	By 2050
(Capros et al. 2019)	PRIMES	EU	Zero-carbon energy system in EU (Circular economy, transport)	1995-2070
(Strapasson et al., 2020)	Global Calculator	Global	Mitigation pathways in various sectors (diet, sustainable transport)	2005-2055

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Study	Models	Region	Focal Point (related to behavioural change)	Time Horizon
(Grubler et al., 2018)	$MESSAGE_{ix}$-GLOBIOM	Global	Establishing the Low Energy Demand (LED) scenario	1990-2100
(van de Ven et al., 2018)	GCAM	EU-15, EU-12	EU climate mitigation potential by behavioural change in EU without any personal up-front investment (food, mobility, housing demand)	1990-2050

Key takeaways: Behavioural change is another issue that has concerned modelling scientists but also institutional stakeholders being one of their priorities. Specifically, the reviewed literature highlights that the main issues examined regarding lifestyle and behavioural changes are related to the household sector, the transportation sector and dietary habits. Regarding the household sector, behaviour change is paramount, as the achievement of policy targets is closely related to the desirability of residents to invest on energy-saving applications but also on the availability of people to change some of their habits. On the same scope, emissions reduction in transportation is heavily dependent on people's choices and behaviour (e.g. modal shifts). Dietary habits have also been the focus of a few studies, since meat production is interlinked with high emissions compared with other types of food; hence, some studies suggest a low meat consumption diet in order to further reduce CO_2 emissions and align with the PA goals.

3.3 Literature review of scenario use

Scenario planning first took off in the years after the first oil crises in 1973. While a number of studies on the use of scenarios for business planning (notably Shell) were conducted in the 1980s (2005) few studies have been conducted on the use of global emissions scenarios in the last decades. There are, however, many papers that discuss how scenarios *should* be used. Many papers discuss the usefulness and, related, the misuse of scenarios. Related to this, many studies also emphasise the important role played by users. In an ideal world, the literature agrees, the user (and the use) should be identified in the early stages of scenario development (Parson et al., 2007; Parson, 2008)

Craig et al. (2002) discuss the usefulness of long-term energy forecasts. In particular, they list seven distinct uses of long-range energy forecasts: as bookkeeping devices; as aids in selling ideas of achieving political ends; as training aids; in automatic management systems (e.g. traffic control); as aids in communication and education; to understand the bounds on the range of possible outcomes; and as aids to thinking and hypothesising. Among other things, they write "thousands of person-hours are wasted each year because people asking for forecasts have no clear idea of what decision they are trying to influence or who will make that decision. No forecasting exercise should be undertaken without clearly defining the audience and the decision they will be called upon to make. What decisions are being considered? Who will make them, and when? Answering these questions can allow for more effective use of forecasting resources." (Craig et al., 2002).

Börjeson et al. (2006) provide the first step towards a guide not only for how scenarios can be developed but how scenarios can be used. Among other things different future studies can be distinguished based on the function of the knowledge they generate: technical, hermeneutical/practical, and emancipatory. Users include those who

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generate scenarios, those who use already existing scenarios, and those to whom scenarios are directed, even though they have not asked for them. Their typology is based on the principal question they believe a user may want to ask about the future: i) *What will happen?*, ii) *What can happen*, and iii) *How can a specific target be reached?*. Although Börjeson et al. (2006) recommend different kinds of scenarios for different kinds of users, these users remain hypothetical (and "the user" ultimately boils down to "the purpose" of a scenario). The user's rationale for using a scenario comes out as one of the most important factors.

Parson (2008) notes that the connection between global-change scenarios and decisions is weak and indirect. This has to do, in part, with the greater number and variety of potential scenarios users, and thus also needs, relative to scenarios used in other domains. Morgan and Keith (2008) ask how projections of future energy and emissions can be made useful. They present evidence that suggests that highly detailed scenarios are likely to mislead scenario users and propose a strategy in which scenarios are developed tailored to the needs of specific decision makers.

O'Neill and Nakicenovic (2008) assess a number of past efforts to develop and learn from sets of global greenhouse gas emissions scenarios and conclude that while emissions scenario exercises have likely had substantial benefits for participating modeling teams, learning from the exercises as a whole has been more limited. They note that model comparison exercises have typically focused on the production of large numbers of scenarios while investing little in assessing the results or the production process. Moreover, they note, scenario assessments have been most informative when they have gone to extra lengths to carry out more specific comparison exercises. They recommend, based on this, that scenario comparison exercises build in time and resources for assessing scenario results in more detail at the time when they are produced and that the exercises focus on more specific questions to improve the prospects for learning. They also recommend, at a minimum, that better databases of scenario results and comprehensive scenario inventories become a high priority during scenario development and comparison exercises.

Kriegler et al. (2012) discuss the needs of two different kinds of users: "end users" (policy- and decision-makers who use scenario outputs and insights in various decision processes) and "intermediate users" (researchers who use scenarios from a segment of the research community other than their own as inputs into their work). They focus on the intermediate users and discuss some of the major challenges associated with the use of socio-economic scenarios.

Lempert (2013) proposes a use of scenarios as tools that illuminate vulnerabilities of proposed policies, i.e. summaries of the future states of the world in which a proposed policy fails; as well as the decision support literature to provide a foundation for understanding and evaluating the effectiveness of different scenario approaches. This is based primarily on the National Research Council's (2009) elements of effective decision support: usefulness of information; relationship between knowledge producers and users; and quality of decisions. Hulme and Dessau (2008) similarly propose evaluation criteria for scenarios: predictive success, decision success (have 'good' decisions been made?), and learning success. They use examples of UK climate scenarios to illustrate the three approaches to evaluating success. Several authors have distinguished between decision support (including scenarios) as *products* versus *processes* (Hulme and Dessai, 2008); O'Neill and Nakicenovic, 2008), suggesting the latter might be at least as important as the content of the scenarios.

Iyer and Edmonds (2018) warn that scenario users may place too much or too little confidence in scenario assumptions and results. Energy scenarios are, they note, prone to misconceptions because of a lack of guidance from modellers about underlying assumptions and missing information on how to interpret results.

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3.3.1 Few studies of scenario use

With a few exceptions, studies of the use and success of global emissions and energy scenarios remain rare. The lack of understanding of how scenarios are used has also been pointed out by others (O'Neill & Nakicenovic, 2008). In all the studies reviewed above, the scenario users remain hypothetical. The interviews conducted with scenario users as part of PARIS REINFORCE (reported in section 2.2) aim to begin to fill this gap. Only a handful of papers have been published that analyse the actual use of scenarios.

Volker and Ribeiro (2009) offer one of the few studies that focuses on the use, impacts, and effectiveness of scenario planning in public policymaking. This was part of the BLOSSOM project of the European Environment Agency, which aimed to build a platform for discussion, evaluation and learning amongst environmental scenario practitioners and policymakers about new forms of long-term strategic policymaking and their enabling conditions. Volkery and Ribeiro review what they call the "evaluative scenario literature" covering 52 publications that deal with one or several aspects of using scenario planning in the realm of environmental policy. They merge the findings from this review with the results from a workshop with environmental scenario practitioners and policymakers. Their preliminary finding is that scenario planning is still often executed in a rather ad-hoc and isolated manner and is mostly geared towards indirect decision support such as agenda-setting and issue-framing. They reach two conclusions. The first is the need for broadening the empirical base to better understand how and to which effect scenario planning is used and how it can deliver on its promises. The second is the need to study institutional arrangements that are put in place to make scenario planning work. Overall, they conclude, the potential of scenario planning to prepare public policymaking for the uncertainties and surprises of future developments and better manage complex decisions involving conflicting societal interests is not fully utilised.

McDowall et al. (2014) report on a project that aimed to reflect on the ways in which scenarios have been produced, used, and communicated in the UK. This project, which was focused on the UK MARKAL model, included analyses of key texts and semi-structured interviews with scenario developers, other researchers, and civil servant users. The interviews focused on the perceptions of the insights generated by scenarios and experiences of communicating (for scenario producers) and using (for scenario users) the outputs of scenario modelling processes. The project aimed to examine whether models are used in the way that their producers intend them to be used. They did a total of 11 interviews with model producers and 6 with model consumers (working with policy) and conclude that MARKAL has generally been used and communicated appropriately, in part because of a good working relationship between government analysts and UKERC researchers. But they also note three areas of improvement: the need for an improved representation of uncertainty; the importance and challenges of transparency; and generally improved communication.

Scheer (2017) studies communication of energy scenario modelling to the wider public by conducting a media coverage analysis, concluding that energy scenarios appear vulnerable to strategic and tactical use in media, but also that, in cases of high media coverage, chances arise for transparent and objective science communication on modelling.

Braunreiter and Blumer (2018) explore how researchers, who represent one key stakeholder group in shaping the energy future, use energy scenarios. They conduct 16 structured in-depth interviews with researchers from different disciplinary backgrounds in Switzerland and identify two contrasting user types: The first group, labelled divers, primarily uses scenarios as a data source. The second group, the sailors, refers to scenarios as plausible energy futures. Among other things, they find, the choice of the model structure (such as whether top-down or bottom-up) hardly plays a role for users. This is especially true for sailors, but also divers, who tend to be more interested in the data rather than the models. This, Braunreiter and Blumer argue, shows that the preferences,

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needs and behaviour of scenario users do not necessarily follow the course expected by scenario developers. To improve the accessibility and relevance of scenarios, modellers thus need to make the perspectives and constraints of different potential user groups a key factor in the development of energy scenarios. Overall, they find, due to a lack of guidance from modellers and missing qualitative information, energy scenarios are prone to misconceptions and distortions in their interpretation by external users. The fact that they only interviewed researchers, many of whom were not able to evaluate underlying assumptions of scenarios suggests that the interpretation of model-based energy scenarios is even more challenging for the majority of users, who are outside academia. They therefore suggest that modellers put more effort into the presentation and communication of their modelling activities to improve the explanatory power of their scenarios. One could, for instance, provide instructions on how to use and interpret energy scenarios and highlight typical mistakes or misconceptions. This could reduce the risk of misinterpretation or distortion of energy scenarios in public debates.

Skelton et al. (2019) use survey and group interviews to find out how Swiss climate scenarios have been used by the Swiss adaptation community. They suggest a new typology consisting of observers, sailors, and divers to explain the differences in uses. Through their typology and analysis, they aim to clarify the often vague notion of 'user' circulating in discussions around climate scenarios and knowledge co-production. Using the same iceberg metaphor as Volkery and Ribeiro (2009), they find that most respondents were sailors, accessing only key findings above the waterline. Only a quarter of respondents were labelled divers. Lastly, another quarter were labeled observers. The latter respondents were interested in the iceberg from afar, without applying the information directly to their work. They find observers, sailors and divers in both research and practice and demonstrate that numeracy among users is generally much higher than perceived, as many sailors and observers of future climate scenarios are skilled in using quantitative data. Finally, they call for more nuanced discussions of how use(r)s are imagined, portrayed and characterised.

3.4 Knowledge gaps and needs

3.4.1 Research capacity needed from a methodological perspective

The design of a multi-dimensional set of policy instruments and measures of technological, economic, and legislative nature that altogether comprise the European energy and climate policy agenda is supported by an equally diverse set of energy system, sectoral and climate-economy modelling activities (Trutnevyte et al., 2019) Integrated assessment modelling (IAM) exercises constitute the backbone of numerous research and innovation projects (Overland and Sovacool, 2020), aimed at assessing how specific actions can steer the world, including Europe, towards climate neutrality goals, by embracing the complex interplay between energy, economy, and environment (Forouli et al., 2019).

These modelling frameworks have undoubtedly contributed to both knowledge and policy, but the extent to which they have decisively helped policymakers and supported effective governance of climate policy has long been debated (e.g. (Schneider, 1997)). Models have been criticised over being detached from policymakers (van Vliet et al., 2010), featuring inflexibility to represent the diversity of policy instruments and the national focus (Agrawala et al., 2011), displaying limited interconnectivity among the represented subsystems (Capellán-Pérez et al., 2020), having little capacity to assess different types of uncertainty (Ackerman et al., 2009), or being opaque about modelling mechanisms and assumptions. And, although the knowledge produced is contingent on the modelling perspective and carries meaning in the scientific discourse, it is nonetheless used in policy, business, and other processes outside the boundaries of the modelling world (Ellenbeck and Lilliestam, 2019).

In addressing these challenges, voices within the scientific community have been calling for transformations

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towards a new generation of advanced modelling frameworks (Gambhir et al., 2019) and complementarities with other analytical approaches (Steg, 2018). These voices have been heard, as reflected in a series of new, ongoing research initiatives funded by the European Commission (EC), like LOCOMOTION or NAVIGATE and PARIS REINFORCE or ENGAGE, respectively. But, as the envisaged energy transitions in Europe and worldwide require radical socioeconomic, technological, institutional, and structural changes (Temper et al., 2018) in energy supply and demand (Grubler et al., 2018), there is an ever-pressing need for a diversified set of strongly coordinated modelling approaches, with collectively improved capacity and detail, to support the development and use of plural knowledge in this field. Following climate modellers' example, IAM researchers have been trying to enhance robustness and consistency of resulting policy prescriptions by instigating model inter-comparison projects (Nature Climate Change, 2015). These constitute exercises aimed at addressing specific research questions based on numerous models of different theory, structure, approach, and coverage (Doukas and Nikas, 2020).

Major model inter-comparison studies have been organised and successfully carried out in the context of recent EC-funded projects, like ADVANCE (Luderer et al., 2020) or CD-LINKS (McCollum et al., 2018), essentially forming the bedrock of the recent IPCC 1.5°C Special Report (Fujimori et al. ,2019b). In coordinating such efforts, energy system and climate-economy modelling teams have been organised in international, multilateral communication initiatives and consortia. Among these initiatives, Stanford's Energy Modeling Forum (EMF) has the longest history and reputation of conducting multi-model exercises with a thematic (e.g. (Bauer et al., 2018)) or regional focus (e.g. (Sugiyama et al., 2019)), and bridging the policy-science gap (Barron et al., 2018). The Integrated Assessment Modeling Consortium (IAMC) was later developed to coordinate research activities within the IAM community and convene the process of producing the current generation of reference modelling scenarios (Cointe et al., 2019), including the Shared Socioeconomic Pathways (SSPs) (O'Neill et al., 2014) and Representative Concentration Pathways (RCPs) (Van Vuuren et al., 2011). Motivated by EMF and IAMC, regional efforts have been mobilised, like the China Energy Modeling Forum (CEMF), which recently published its first inter-comparison results (Lugovoy et al., 2018).

But, while numerous EU research projects have also oriented on or eventually produced model inter-comparison exercises, inter alia contributing to major assessments like ADAM (Edenhofer et al., 2010), AMPERE (Riahi et al., 2015) and LIMITS (Kriegler et al., 2013) in IPCC AR5, there currently is no structured, multilateral communication among European integrated assessment modellers, and between them and other stakeholders, as is the case for the global scene and other regions. Even the Energy Modelling Platform for Europe (EMP-E) (Müller et al., 2018) is supported by some EC-funded projects and orients only on energy system modelling.

Hundreds of climate-economy energy, electricity, and sectoral models have been established in the literature (Connolly et al., 2010; Lund et al., 2017; Nikas et al., 2019a) and used across research and innovation projects, for the purposes of underpinning climate and energy policy. This is also evident in the number of literature reviews on modelling frameworks (e.g. (Schwanitz, 2013)) as well as the different scope and focus of each of these reviews (e.g. (Prina et al., 2020; Després et al., 2015)). This diversity is embedded in the range of scientific disciplines and methodologies involved in their development and use. It reflects that no single model can cover the broad spectrum of issues relevant to policymaking, like effort sharing under the Paris Agreement principles (Pozo et al., 2020; Xexakis et al., 2020), synergistic effects across policies corresponding to different sustainability dimensions (von Stechow et al., 2016), quantification of costs associated with realistically covering the gaps between cumulative NDC contributions and 1.5 °C trajectories (Doukas et al., 2018), realistic interpretation of the potential of negative emissions technologies (Hilaire et al., 2019), and so on. But, despite the high proliferation of modelling tools designed to cover vastly different or similar aspects in varying levels of detail, it is a consistent core of highly harmonised global models that have dominated the literature (Corbere et al., 2016). Model inter-comparison

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projects based on these models have long been used as justification of exploring a broad part of the future possibility space but may end up hampering policy action (McLaren and Markusson, 2020), showing huge ranges of outcomes without elaborating in detail the origins of these ranges.

To help policymakers act in the face of such huge possibility sets, the modelling world should start investigating whether a more diversified portfolio of modelling tools can answer specific questions through targeted sensitivity or stochastic parameter perturbations, to identify genuinely robust patterns of mitigation, whilst exploring a genuinely large possibility space (Michas et al., 2020). As different types of modelling structure focus on specific sectors/aspects thereby offering different types of insights, establishing connections between models that deploy different methodologies and structures in multi-model analyses can produce better, more robust policy prescriptions (Stanton et al., 2009), in contrast to individual modelling exercises (Toth, 2005). This is why effective climate policy must be underpinned by modelling ensembles that altogether draw from different structures and methodologies, provide insights for different geographic scales, as well as cover in detail all economic sectors, represent different types of policies, and provide insights for the broad range of greenhouse gases and aerosols, thereby capturing the multiplicity of aspects of climate-economy interactions and enlightening the origin of uncertainties and ranges by means of inter-comparison projects.

The motivation driving international consortia can be summarised in four principles. These begin from the fundamental basis that decision support is effective when (a) addressing targeted policy and research questions, and (b) when no single perspective is favoured over others. More importantly, they extend to the need of data being (c) open and comprehensive, requiring assumptions, parameters, data sources, and uncertainty sensitivities be fully disclosed; and produced knowledge being (d) comprehensible, with downloadable datasets, customisable visualisations, and detailed and focused policy prescriptions. This is contrary to the norm of crisp data decoupled from the assumptions driving modelling runs and detached from the policy context and understanding, as well as of graphs labelled with naming conventions that probably mean nothing outside a core group of modelling experts.

These principles mean more than facilitating knowledge exchange among modellers and extend to involving non-experts into the scientific processes, since complex societal challenges imply multidimensional trade-offs and require science diplomacy, i.e. coordinated action of vastly different stakeholders and, across nations, scales and discourses (Fedoroff, 2009). Corresponding political choices must be based on thorough analyses of the complex interactions; and stakeholders need to trust said analyses. Otherwise, policy and other decision makers will adopt inefficiently low levels of trust in the modelling results and associated policy/decisions. Successful decarbonisation dictates that the modelling community interact with science's end-users in industry, government, and civil society, and develop strategies that transcend their traditional disciplinary boundaries (Pade-Khene et al., 2013), thereby incorporating political and societal realities (Miler and Wyborn, 2018) spanning all sectors of industry, government, and society, and producing recommendations to be trusted by a majority of stakeholders within the climate science-policy interface (Lacey et al., 2018). Involving all relevant stakeholders is aligned with the concept of responsible science (Owen et al., 2012), promoting socially acceptable, robust, and sustainable transitions, and is proven to increase the level of trust on both ends (Turnheim et al., 2015), while helping make modelling findings both intelligible in terms of real-world implications and actionable in terms of concrete recommendations.

Dating back decades (Schneider, 1997), however, a growing concern associated with climate- and energy-economy modelling tools orbits on their legitimacy: why should scenario users, i.e. policymakers and other decision makers using modelling insights in decision processes (Kriegler et al., 2012), have confidence in modelling outputs, and in what levels (Iyer and Edmonds, 2018)? As also reflected in one of the four scientific working groups of the IAMC, the modelling community has lately attempted to respond to such concerns: diagnostic indicators

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(Kriegler et al., 2015) and evaluation methods (Wilson et al., 2017) have been defined for IAMs, efforts have been made to document models in less technical language (e.g. the ADVANCE/IAMC and the openmod initiative wiki pages), and research initiatives have been carried out to improve model development, evaluation and inter-comparisons (e.g. (Weyant, 2010)). And yet little progress can be claimed in opening the black box (Pfenninger et al., 2018) to the extent of non-experts' acknowledging inputs and showing trust in outputs of modelling processes (Doukas et al., 2018).

Among relevant efforts, the I²AM PARIS platform includes concise, dynamic summaries of this documentation by mapping these capabilities in interactive infographics, towards boosting understanding and ownership among non-expert audiences. These efforts, however, must be extended to represent and compare the multiplicity and diversity of models with one another, for all audiences to appreciate why each model can be used to address specific policy questions. Documentation of model characteristics and capabilities will also enable scientists from different disciplines and viewpoints to share a common language. Any attempt to promote legitimacy must entail transparency of the knowledge production process for stakeholders to understand why modelling tools can be trusted to address each question. This goes beyond using open source tools and implies that scientists develop and implement open protocols for interpreting scenarios and parameters, harmonising datasets of input sources across models in multi-model analyses, defining diagnostics indicators, and designing shared formats for documenting outputs.

Technical improvement of technoeconomic and socioeconomic representation in models is a good starting point, yet insufficient in ensuring robustness of resulting trajectories, if the datasets driving the simulations that lead to specific policy recommendations are not fully disclosed. Simply looking under the hood of modelling tools and exercises (Krey et al., 2019) says little if these datasets are not authoritative and shared within the modelling community, as is the case of a few major socioeconomic parameters (Shiraki and Sugiyama, 2020). Efforts must be put into defining each socioeconomic, technoeconomic and historical emissions parameter (glossary, units, definition) and their data sources (organisation, time span, database), towards harmonising inputs across models, for given questions, so that outcomes can be tied to modelling assumptions, and the broad spectrum of cross-scale insights across boundaries and disciplines can be effectively communicated (Trutnevyte et al., 2018).

Furthermore, not much progress has hitherto been done to ensure that those involved in scenario design are fully aware of whether their motivation and intentions are reflected in the produced knowledge, upon communication to policy and society, or whether their scenarios are indeed linked to the research and societal needs (Xexakis et al., 2020; Pidgeon and Fischhoff, 2011). Except for high media coverage cases (Scheer, 2017), lack of guidance from modellers renders scenarios prone to misconceptions and distortions in their interpretation by external users (Braunreiter et al., 2018). During the last decade, literature, as reflected in major scientific assessments and consortia, has been swarmed by thousands of scenarios, many of which may have been developed and modelled on the basis of scientists' interpretations of scenarios that they themselves perceive as useful (Trutnevyte, 2016). There appears to be misinterpretation of scenarios, not only in policy but also among scientists and experienced users of these scenarios (McMahon et al., 2015). This interpretation-driven production of knowledge partly explains why for example SSP2 (Fricko et al., 2017), narrating an extrapolation of historical trends in the future, has been applied significantly more than other socioeconomic scenarios, with hundreds of studies featuring its combination with selected RCPs. It also means that no scenario or modelling exercise is necessarily meaningful. For example, specific SSP-RCP combinations are presumed implausible and yet count hundreds of recent studies, with RCP8.5 being in principle inconsistent with most SSPs (Ritchie and Dowlatabadi, 2017; Bauer et al., 2016). Despite the clock ticking the window of opportunity for climate action away, it could take years of modelling work to validate or invalidate these scenarios along the way (Tebaldi and O'Neil, 2020), unless a more pragmatic

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evaluation of scenarios, or outputs (Fujimori et al., 2016; Chaturvedi et al., 2013), is carried out. Recent qualitative efforts, for example, include applying a risk lens coupled with different methodologies (e.g. (Nikas et al., 2019b)) or enabling expert elicitation that reflects policy perspectives of what can go right or wrong in the future (van Vliet et al., 2020).

Acknowledging these challenges, the European and international modelling community must put significant effort into ensuring that their scenario frameworks match the policy needs at all levels and address the actual research capacity needed. For Europe, in particular, employing and coupling integrated assessment models with EU-wide representation and models with more detailed granularity, at the Member State or sub-national (e.g. NUTS-3 and NUTS-2) level (Thellufsen et al., 2020; Sasse and Trutnevyte, 2020), should be a core aim. Upon streamlining research at different scales, which is critical to bridging EU-wide and national-level modelling analyses and policymaking, coordination among different research projects must be enhanced, providing improved scientific basis for multi-model and/or inter-comparison exercises. Among others, this first requires harmonisation of data inputs across models regardless of theory, including socioeconomic and technoeconomic parameters, fossil fuel prices, and historical emissions, with data source selection driven by reliability and consistency of the assumptions at all scales. Assumptions shared across policy pledges must be considered, making use of the best available science, including matching global datasets (O'Neil et al., 2017; Riahi et al., 2017) and their national-level disaggregation, e.g. on the human (Samir and Lutz, 2017), urbanisation (Jiang and O'Neil, 2017) and economic dimensions (Dellink et al., 2017), without overlooking the associated localisation and downscaling challenges potentially leading to several-fold increases of plausible futures (Frame et al., 2018).

Fostering inter-comparison projects that are globally and regionally meaningful finally requires a harmonised interpretation of actual climate policies for the EU and other countries (NDC level) and for national action pledges within the EU (NECP level), despite potential differences across pledges in terms of target type, base year, and horizon. Significant progress was made in the CD-LINKS project (Riahi et al., 2019) contributing to capacity building for national modelling teams; as the climate agenda progresses fast, modellers must ramp up efforts to ensure up-to-date representation of both current policies and future action pledges worldwide. This will allow for model inter-comparison exercises, where models provide a more robust response to research needs and where differences among trajectories resulting from different models can be attributed to their specificities alone (Pauliuk et al., 2017). Efforts must also be put into clearly exploring the scope of modelling interlinkages, by defining capacity for data exchange, and enabling integration of models; by combining, for example, long-range IAMs with short-term models of the macro-economy, useful insights can be gleaned on the full range of potential impacts of shocks, such as COVID-19 and associated policy and societal responses (Nikas et al., 2020).

3.4.2 Research capacity needed from an empirical perspective

Our focused literature review showed that much energy- and climate-economy modelling has been done in response to the Paris Agreement, since 2016 and until today. However, as also highlighted in the Brussels workshop and this literature review, there has been little progress in endogenously representing behaviour change aspects in models, while very limited modelling has been carried out in support of the NECP impacts across different sustainability dimensions, or in support of the EGD and carbon taxation explicitly on imports and exports.

Several studies oriented on the penetration of RES and their contribution to reducing electricity-related emissions, as well as on resource requirements emerging from high use of bioenergy for clean electricity. Negative emissions technologies have dominated the literature, driving pathways towards achieving the ambitious PA targets. This is intertwined with the stakeholders' concerns of limitations of key technologies, in terms of socioeconomic trade-offs, cross-sectoral impacts, feasibility, window of opportunity, learning and expected breakthroughs, etc.

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Uncertainties inherent in climate change, policy, as well as modelling tools and frameworks, can lead to mistaken assessments of mitigation policies. These may be related to input parameters, targets set by the national/regional policies, projections of reference scenarios used across modelling exercises, etc. This is reflected in stakeholders' research prioritisation around robustness of NECPs, technoeconomic assumptions, and where we are heading.

The policy and market responses to the coronavirus pandemic led to temporary reductions of emissions, which have been comparable to the annual decrease rates that are in turn compliant with the Paris Agreement (Le Quéré et al., 2020). Discussions have focused on governments' efforts to recover, make up for lost economic ground and even push towards rebounds with even higher emission pathways compared to pre-pandemic trajectories, with implications for progress in climate action. This pandemic reminds us of the need to actively engage with extreme events (Otto et al., 2020), which may not be part of typical scenarios underpinning mitigation strategies. Game-changing disruptions may be positive or negative but, regardless of the direction of their impact, it is critical that energy and integrated assessment modelling encompass considerations of a large range of possible events in the coming years and decades (McCollum et al., 2020). Failure to do so risks developing mitigation or adaptation plans that do not pass the resilience test.

Example issues that modellers must seek to explore through the deployment of a combination of appropriate modelling tools across fit-for-purpose scenarios include the implications of services digitalisation on energy demand and supply, through considering shifting consumer demand patterns (Stavrakas and Flamos, 2020), as well as electricity and other energy vector supply changes resulting from increasingly smart and interconnected energy networks. But they should also include energy citizenship and sustainable lifestyles as well as economic shocks resulting, for example, from changing trade relations, oil and other commodity price changes, or penetration of artificial intelligence and robotics into manufacturing; and implications of rapid political and societal changes in sentiment towards urgency of tackling the climate crisis, for example in response to climate shocks, which raise the issue to the top of society's agenda. Moreover, there is a critical need to reflect on the technological progress that confounded all expectations over the last decade, particularly concerning the cost reductions and market penetration of solar PV, wind, and electric vehicles, as well as battery electric storage. Other such technological innovation "miracles" (be they in ultra-cheap and scalable amines for CO2 capture and atmospheric removal, or electrolysers for hydrogen production) are almost inevitable in the coming years. Modelling activities, which fail to explore the plausible extremes of cost reductions in such technologies, will be redundant or misleading in the face of these inevitable breakthroughs.

Considering that the need to assess climate action in conjunction with the other SDGs has in the literature been addressed mostly by means of treating SDGs as trade-offs of low-carbon mitigation pathways, as we observed in the previous section, the modelling community must instead place climate action in the entire framework of sustainable development, by exploring co-benefits of working across the broad sustainability spectrum. Dealing with sustainable development questions that transcend the boundaries of global, EU, or national climate action can contribute to exploring decarbonisation pathways that are beneficial from multiple perspectives (Van de Ven et al., 2019) and more robust against different plausible futures (Forouli et al., 2020).

Finally, there are very few papers on how scenarios are used. The interviews with decision-makers in government and private industry (reported in section 2.2) that are conducted as part of PARIS REINFORCE aim to begin to fill this gap in the literature and to inform the use of scenarios in PARIS REINFORCE itself. In Table 21, research gaps extracted by the extensive literature review are presented, as well as how PARIS REINFORCE aims to address them (detailed information is provided in section 4).

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Table 21 Research gaps and how PARIS REINFORCE aims to address them

Research Gaps	PARIS REINFORCE approach
Harmonisation Process	• A comprehensive harmonisation protocol for global integrated assessment modelling studies (Giarola et al.) • Documentation of the harmonisation process in the I²AM PARIS platform
Concerns over modelling scenario use, design and communication	• Exploration of stakeholder inclusion in modelling studies from consultation to co-creation (Galende-Sánchez and Sorman, 2021), and need to include non-scientists in the scientific process (Doukas and Nikas, 2021) • Co-design of scenarios and research questions with stakeholders, as reflected in the project's first EU-wide model-intercomparison study (Nikas et al.) • A reflection on how reference scenarios can be misleading (Hausfather and Peters, 2020) and how they should be used in modelling (Grant et al., 2020), as well as a more realistic reference/baseline scenario, accurately reflecting current policies in the world and their implications if projected in the future without raising policy ambition (Sognnaes et al.)
Underrepresentation of behavioural change in modelling	• Development of prospects and strategies for behavioural and lifestyle changes (Nikas et al., 2020) • Efforts to incorporate behavioural change and relevant issues into the project's modelling exercises
• Lack of clear representation of sustainable development in NECP modelling assessments • Heterogeneity in modelling assessment of different NECPs	Efforts to assess NECPs and further ambitions with uniform modelling approaches across the EU (EU-TIMES, NEMESIS, FORECAST, ALADIN); and to place NECP action into the sustainability spectrum
Limited assessment of the EGD in modelling studies	Inclusion of EGD aspects in mitigation actions of the project

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4 How do we get there?

In order to understand how PARIS REINFORCE may begin to analyse and answer some of the topics and questions prioritised by the stakeholders and highlighted as gaps in the literature review, this section provides an overview of the modelling capabilities offered by the PARIS REINFORCE modelling ensemble. Detailed information about mitigation and adaptation measures, as well as SDG measures, in the eight global models are presented. Examples of how policies may be implemented are also provided.

4.1 General modelling capabilities

In order to effectively inform and enhance climate policymaking, PARIS REINFORCE relies upon an extensive modelling ensemble comprising:

- 5 national/regional models for Europe (ALADIN, FORECAST, LEAP, EU-TIMES, NEMESIS),
- 9 models covering major and less emitting regions and countries outside of Europe (CONTO, GCAM-China, GCAM-SOUSEI, GCAM-USA, MARKAL-India, MAPLE, NATEM, SISGEMA, and TIMES-CAC), and
- 8 global models (GCAM, TIAM, MUSE, 42, GEMINI-E3, ICES, DICE, and E3ME).

The combination and interaction between different types of models ensures that PARIS REINFORCE is able to provide a comprehensive level of policy insight that would not be possible with any single modelling exercise. **This deliverable is aimed at the stakeholder needs and capacities needed for global analysis and therefore focuses on the eight global models in the PARIS REINFORCE model ensemble.**

In general, models provide a testing ground for hypothetical climate policy decisions within structured frameworks. The value they add comes from a better understanding and subsequently more informed implementation of decarbonisation policies.

PARIS REINFORCE has access to a broad range of modelling types differing in the ways and levels of detail in which they assume economies behave, e.g. how they represent economic behaviour and the sectors to which they devote particular attention. Each modelling type has its advantages and limitations. Therefore, models are often able to offer the most powerful insights in combination or via comparison on the same issue.

The global models in our modelling ensemble comprises energy system, partial and general equilibrium, and macroeconometric models. They all have integrated climate or emissions modules, making them integrated assessment models.

4.1.1 Policy options

Both mitigation and adaptation policy options can be considered by the models in the PARIS REINFORCE model ensemble. Models have historically focused predominantly upon mitigation measures; however, adaption capabilities are being steadily introduced in line with their increasing relevance given ongoing climate change.

Mitigation measures

Macro-measures

Certain models investigate policies implemented at the macro-level. Such policies can be expected to have wide-ranging effects throughout the economy. Examples include:

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- Carbon (emission) taxation. This can be international, nation-wide, and/or regional, e.g. a carbon border tax on imports in one region, as well as the imposition of carbon taxes by neighbouring countries.
- Tradable carbon permits.
- Annual emission targets or quotas.

Sectoral/technology-specific policies

Models are also able to assess the impacts of policies specific to an individual sector or technology. The impact of such measures can be evaluated at the sectoral level *(in energy system and partial equilibrium models*) whilst also at the broader national and regional level (*in general equilibrium or macro-econometric models*). Some examples include:

- Efficiency targets (for certain industries) or minimum energy performance standards.
- Regulations (standards) – the imposition of specific regulations limiting the use of certain technologies or energy generation within a chosen sector.
- Financial support, for individual technology mixes through R&D or direct subsidies for investments into low-carbon areas such as renewable energy capacity or hydrogen production.
- Energy mix targets.
- Capacity factor limits on certain generation plants, e.g. closing coal plants by a certain year.
- Particular energy taxes for end users.

Sectoral/technological-policy options can be applied into a range of sectors. One can investigate the effects of interventions into sectors in isolation or as part of a broad-ranging economy-wide 'Green Deal'. Several models represent economies in detailed sectoral depth. Listed below are some examples of sectors that may be considered important for investigation:

- Upstream technologies (e.g. Synthetic fuel production, such as Coal to Gas; Hydrogen production).
- Electricity and heat generation (e.g. Coal/Gas with CCS, Nuclear fission, Solar PV, Offshore wind).
- Electricity storage.
- Transport (Road, such as Gas vehicles, Hybrids, Hydrogen fuel cells; Rail; Aviation; Shipping, such as LNG, Biofuels).
- Buildings (Heating, such as gas replacing oil, electricity, hydrogen; lighting, efficiency; Appliances, efficiency; cooling).
- Industry (Process heat; machine drives; steam; CHP).
- Agriculture (Energy use; Land practices; Animal husbandry).
- Land use (payments to landowners for holding carbon stocks, e.g. trees)

Adaptation measures

Specific adaptation measures can be implemented for some sectors, particularly relating to the management of land use, water systems, and urban environments. As an example, one could consider the consequences of afforestation levels on land-use change.

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4.1.2 Output Variables

Models record changes to economic and climate indicators caused by policy or scenario change and provide a range of outputs. Examples include:

- Energy indicators: how does energy demand change? How is the energy supply mix likely to be altered in order to meet changing energy demand, under different climate policies?
- Economic indicators: what will the predicted effects be on GDP, employment, and income?
- How will a specific technological policy affect deployment of that technology?
- How will investment spill over into complementary technologies or industries (e.g. what will the effects of investment into electric charging infrastructure be on consumer EV demand)?
- Trade flows: how does the volume and composition of imports/exports vary?

The effects on a range of GHG emissions and other pollutants are also calculated. This allows for a better understanding of how a particular policy can contribute towards NDCs, for example, and of what further measures must be taken beyond such policies to ensure full Paris compliance, as well as complementary benefits in reducing air pollution. The GHGs covered by the full PARIS REINFORCE model ensemble include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (HFCs, PFCs, SF_6 and NF_3). The pollutants covered include particulate matter (PMs), sulphur oxides (SOx), nitrogen oxides (NO_x), ammonia (NH_3), and others (e.g. CO, VOC).

Finally, the models can analyse the sensitivity of transition pathways and mitigation costs to particular technological assumptions, e.g. how realistic GHG reductions in the steel industry are, under a range of assumptions as to when CCS will become technologically mature.

The full PR modelling ensemble can work at the global level with aggregate predictions but can be further dissected to the national level, covering 76 disaggregated countries.

4.2 Specific capabilities for the global models

The eight global models in PARIS REINFORCE are GCAM, TIAM, MUSE, 42, GEMINI-E3, ICES, DICE, and E3ME. All eight models are global integrated assessment models, covering the world as one or multiple regions, with some models featuring the capacity to also cover a multitude of specific countries. Although the models are significantly different from one another, they can be grouped into five categories, following the classification found in the literature.

GCAM and TIAM are partial equilibrium models, in that they provide a detailed analysis of the interactions between environmental impacts and particular economic sectors, by trying to achieve market equilibrium separately in each and every sector of focus. In essence, they have a detailed representation of the energy system and feature economic agents who indicate intended supply and/or demand for goods and services, and who are simulated to interact with one another so that supply and demand is balanced in all markets and for every time step. In other words, market equilibrium is assumed to take place in each one of these markets (partial equilibrium) in the short-term.

MUSE and 42 are energy system models, and can therefore be considered as a subcategory of the partial equilibrium modelling group, providing a detailed account of the energy sector, i.e. energy technologies and their associated costs, in order to determine the least-cost ways of attaining GHG emission reductions or the costs of alternative climate policies. They both are bottom-up models that assume short-term microeconomic equilibrium on the energy system, which is achieved by iterating market clearance across all of the sector modules,

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interchanging price and quantity of each energy commodity in each region. MUSE, in addition, is also an agent-based model, as it tries to determine a mitigation pathway by providing an as realistic as possible description of the investment and operational decision making in each geographical region within a sector.

GEMINI-E3 and ICES are computable general equilibrium models, and therefore have a more detailed, multiple-sector representation of the economy and, rather than seeking optimal policies, they consider the impacts of specific policies on economic, social and environmental parameters. Their operation is similar to that of GCAM and TIAM, but differs in that market equilibrium is assumed to take place in the entire economy. Their richer representation of the economy comes at a cost in that the growth of the economy is harder to model and its structure more complex; as such, they require calibration to data on national and international socio-accounting information, as well as input in the form of a series of elasticities of substitution. Contrary to all other models, they also calculate economic indices endogenously.

Although DICE can also be considered as part of the general equilibrium family, it is distinguished as an optimal growth, or welfare optimisation, model which does not feature the same level of sectoral or geographic detail (it covers the entire global economy as one sector). It determines the climate policy and investment levels that maximise welfare (future against present consumption) over time, by identifying the emission abatement levels for each time step; its social welfare function represents the world's well-defined set of preferences and accordingly ranks different consumption paths, with welfare increasing in per capita consumption for each generation but with diminishing marginal utility of consumption (the wealthier the world is, the less valuable an additional unit of consumption is).

Finally, E3ME is a macroeconometric model. Like general equilibrium models, it is detailed in terms of energy technologies and geographic scope but differs in that it does not assume that consumers and producers behave optimally or that markets clear and reach equilibrium in the short term. Instead, it uses historical data and econometrically estimated parameters and relations to dynamically and more realistically simulate the behaviour of the economy, by assuming that markets achieve equilibrium in the longer run.

The diversity of the modelling tools allows the consortium to consider a large set of mitigation measures in electricity and heat generation technologies, buildings, transport, industry and to a lesser extent in agriculture. They cover a large set of technological options along with other features, such as behavioural changes. Furthermore, the models can deal with different policy instruments: emissions mitigation policy instruments (e.g. taxation, cap-and-trade mechanisms and standards), energy policy instruments (e.g. taxation, efficiency and regulation), trade policy instruments (carbon border taxation, green funds, etc.) and, by a smaller subset of these models, land policy instruments.

4.2.1 Mitigation and adaptation measures in the global models

Upstream technologies like hydrogen production and synthetic fuel production are covered in detail as mitigation options in MUSE, which covers almost all existing technologies. GCAM and TIAM only include coal and biomass to liquids production, with and without carbon capture and storage/sequestration (CCS); but, like MUSE, both models include most hydrogen production technologies. GCAM however additionally features thermal splitting but not biomass to hydrogen (with CCS). It should be noted that E3ME also includes a limited number of upstream technologies but not to the same detail as the other three models.

With the exception of DICE, all models cover a large set of mitigation options in the electricity generation sectors, ranging from nuclear to renewables: CCS, hydro, solar photovoltaic (PV) and concentrating solar power (CSP), onshore and offshore wind turbines, biomass (with and without CCS) and geothermal; the general equilibrium

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models (GEMINI-E3 and ICES), however, feature less technological detail, while contrary to most other models 42 also includes nuclear fusion (along with TIAM) and do not distinguish onshore and offshore wind. Regarding heat generation, only 42, MUSE and TIAM feature significant detail, while GCAM includes heat from biomass.

In the building sector, the energy system (42 and MUSE) and partial equilibrium (GCAM and TIAM) models include mitigation options to lesser or larger extent; while GEMINI-E3 includes building technologies as an aggregated parameter; and ICES only covers behavioural changes and electricity for cooling as exogenous shifts in households' energy demand.

In the transport sector, GCAM, TIAM, MUSE and 42 again cover all or almost all technologies for road transportation, while GEMINI-E3 only includes fully electric vehicles. The technological options for GHG emission reductions in aviation and shipping are relatively limited, and only in the four abovementioned models, covering biofuels (GCAM, TIAM, MUSE, 42), hydrogen (TIAM), electricity (MUSE) and efficiency (TIAM, 42) in aviation; and gas (MUSE, 42), hydrogen (TIAM, MUSE), biofuel (all four) and efficiency (42) in shipping. Railways electrification is also available in all four models (and GEMINI-E3), while MUSE also includes hydrogen fuel cell rail. Finally, modal shift can be used to favour low-carbon transports in GCAM and GEMINI-E3, which two along with ICES also include behavioural changes in the transport sector.

For the manufacturing sectors, GCAM, TIAM, MUSE and 42 include various mitigation options for heat processing, machine drives, steam, combined heat and power (CHP); while GEMINI-E3 covers some of them as an aggregate. In addition, MUSE also includes CCS options in industry, as is the case for TIAM as well, which however also includes direct air capture (DAC).

To mitigate GHG emissions from agriculture, MUSE, 42, TIAM and GEMINI-E3 cover energy use in detail, whereas GCAM includes mitigation options for land yield maximisation and improved feeding. GCAM, GEMINI-E3 and ICES also cover behavioural change mitigation options, such as reductions in demand.

In land use, land-use change and forestry, the available mitigation options in the modelling ensemble are afforestation (GCAM, TIAM and MUSE), land protection (GCAM and MUSE) and biomaterials (GCAM).

The global models in PARIS REINFORCE do not in general produce outputs that are directly relevant to adaptation considerations but can offer indirect insights to inform adaptation planning. The GCAM model has some consideration of adaptation, directly allowing the set-aside of protected land, as well as directly calculating the additional cooling requirement of buildings as the climate warms, while ICES covers restrictions to water use.

In principle, adaptation measures could be included as a consideration in all models' simulations of mitigation pathways, through for example limiting bioenergy resources (e.g. to represent adaptation to crop yield reductions in a warming climate), or increasing building cooling requirements exogenously given the expectation of a warmer climate. However, these models do not project the impacts of a changing climate, so they are of limited use for adaptation considerations.

The coverage of mitigation and adaptation measures by model is shown in Tables 22-25 below.

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Table 22. Mitigation options in each model for upstream technologies, electricity and heat generation technologies and buildings

				GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
Mitigation measures	Upstream technologies	*Synthetic fuel production*		√	√	√					√
		Hydrogen production		√	√	√					√
	Electricity and heat generation technologies	*Electricity generation*	CCS	√	√	√	√	√			√
			Nuclear fission	√	√	√	√	√			√
			Nuclear fusion		√		√				
			Hydro	√	√	√	√	√	√		√
			Biomass	√	√	√	√				√
			Biomass with CCS	√	√	√					√
			Geothermal	√	√	√	√				√
			Solar PV & CSP	√	√	√	√	√	√		√
			Wind onshore & offshore	√	√	√	√	√	√		√
		Heat generation	CCS			√	√				
			Geothermal			√	√				
			Biomass	√	√	√	√				
	Buildings	*Heating*	Gas replacing oil / coal	√	√	√	√	√*			
			Biofuels	√	√	√	√				
			Electricity	√	√	√	√	√*			
			Hydrogen		√	√	√				
			Solar thermal		√	√	√				
			Building shell efficiency				√	√*			
		Lighting	Efficient lighting		√	√		√*			
		Appliances	Efficient appliances		√	√		√*			
		Cooling	Electricity	√	√	√			√		
		Behaviour change (less energy service demand)		√					√		

*: Aggregated parameters for GEMINI-E3 model

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Table 23. Mitigation options in each model for transport

				GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
Mitigation measures	Transport	*Road*	Gas (LNG / CNG) vehicles	✓	✓	✓	✓				
			Hybrid electric vehicles	✓	✓	✓	✓				
			Fully electric vehicles	✓	✓	✓	✓	✓			
			Hydrogen fuel cell vehicles	✓	✓	✓					
			Biofuels in fuel mix	✓	✓	✓	✓				
			Efficiency		✓		✓				
		Rail	Electric rail	✓	✓	✓	✓	✓			
			Hydrogen fuel cell rail			✓					
			Efficiency	✓	✓		✓				
		Aviation	Biofuels in fuel mix	✓	✓	✓	✓				
			Hydrogen planes		✓						
			Electric planes			✓					
			Efficiency		✓		✓				
		Shipping	Gas (LNG / CNG)			✓	✓				
			Hydrogen		✓	✓					
			Biofuels in fuel mix	✓	✓	✓	✓				
			Efficiency				✓				
		Modal shifts		✓				✓			
		Other behaviour changes (e.g. travelling less)		✓				✓	✓		

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Table 24. Mitigation options in each model for industry and agriculture

				GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
Mitigation measures	Industry	*Process heat*	Gas replacing oil / coal	✓	✓	✓	✓	✓*			
			Biomass	✓	✓	✓	✓				
			Hydrogen	✓	✓	✓					
			Electricity	✓	✓	✓	✓	✓*			
		Machine drives	Gas replacing oil / coal		✓	✓	✓	✓*			
			Electricity		✓	✓	✓	✓*			
		Steam	Gas replacing oil / coal		✓	✓		✓*			
			Electricity		✓	✓		✓*			
		CHP	Gas replacing oil / coal	✓	✓		✓	✓*			
			Biomass	✓	✓	✓	✓	✓*			
		Overall industry	CCS		✓	✓					
		Behaviour changes (lower mat. consumption)						✓	✓		
	Agriculture & LULUCF	*Energy use*	Gas replacing oil / coal		✓	✓	✓	✓			
			Biomass		✓	✓	✓				
			Electricity		✓	✓	✓	✓			
		Land practices	*Land yield maximisation*	✓							
		Animal husbandry	*Improved feeding*	✓							
		Behaviour changes (less product demand)		✓				✓	✓		
		Afforestation, land protection, biomaterials		✓	✓	✓					

*: Aggregated parameters for GEMINI-E3 model

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Table 25. Adaptation options in each model

			GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
Adaptation measures	*Land*	Water use restrictions						✓		
		Land use adaptation/planning	✓							
	Urban	Additional cooling of buildings	✓							

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4.2.2 Policies included in the global models

All models (can) include some form of emissions mitigation policy instruments, like taxation, emissions target quotas, standards, financial support and global temperature or radiative forcing targets; as well as, with the exception of DICE, some form of energy policy instruments, including taxes and subsidies, energy mix and efficiency targets and specific regulations (e.g. building codes, vehicle technology bans, etc.).

Land policy instruments, on the other hand, such as land protection, production quotas and land-use change emissions taxation are only included in the GCAM model, while TIAM, ICES and DICE can be modified to include some of these instruments. Afforestation targets, as a policy option, are only feasible with minor modifications to some of the models (GCAM, TIAM and DICE).

Finally, carbon border taxes (on imports) and subsidies (on exports) are only included in GEMINI-E3, ICES and (potentially) in TIAM and E3ME; while TIAM and E3ME can also be modified to include some regulation policies (like certifications).

Table 26 summarises policy coverage in the eight global models.

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Table 26. Mapping of policy options in each model (parentheses imply conditional coverage with adjustments to the model)

		GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
Emissions mitigation policy instruments	Tax	✓	✓	✓	✓	✓	✓	(✓)	✓
	Emissions target / quota (annual)	✓	✓	✓	✓	✓	✓	✓	(✓)
	Emissions target / quota (cumulative)		✓	(✓)	✓	(✓)	✓	✓	(✓)
	Regulations (emissions standards, etc…)	(✓)	✓		✓				(✓)
	Financial supports (e.g. negative emissions, Green Climate Fund)		✓		✓	(✓)	(✓)		(✓)
	Global temperature/radiative forcing target	✓	✓			(✓)	(✓)	✓	
Energy policies instruments	Tax	✓	✓	✓		✓	✓		✓
	Subsidy	✓	✓	✓		✓	✓		✓
	Energy mix target	✓	✓		✓	(✓)	✓		(✓)
	Efficiency target	(✓)	✓		✓	(✓)	✓		(✓)
	Regulations (thermal regulation in buildings, bans on diesel cars, etc.)		✓		✓				(✓)
Land policies instruments	Protected lands	✓							
	Production quotas	✓					(✓)	(✓)	
	Carbon sink pricing / Land use change emissions tax	✓	(✓)						
	Afforestation targets	(✓)	(✓)					(✓)	
Trade policies instruments	Carbon border tax on imports		(✓)			✓	✓		(✓)
	Carbon border supports on exports		(✓)			✓	✓		(✓)
	Regulation policies (certifications, best-available technologies, etc.)		(✓)						(✓)

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4.2.3 SDGs in the global models

The next table details sixteen of the seventeen SDGs set by the United Nations in 2015 for the year 2030. SDG17 on revitalising global partnership for sustainable development is excluded, as out of the scope of the featured modelling tools. Among these SDGs and with the exception of ICES, which can provide insights into all SDGs, the other seven models can deliver indicators to track directly or indirectly eleven of the SDGs.

All of the models are able to report on emissions and therefore on climate action (SDG13). All models can also offer direct insights into affordable and clean energy (SDG7), with the exception of DICE: this entails analyses of renewable energy (all models), access to electricity and primary energy intensity (ICES), traditional biomass use (42 and GCAM), and a full assessment of energy commodities (TIAM, E3ME and MUSE). The same can be said for industry, innovation and infrastructure (SDG9), with the exception of GCAM and 42 that do not feature direct implications. Decent work and economic growth (SDG8) is also covered by five models, mainly via GDP (per capita) growth and employment impacts. SDG2 (zero hunger) is also included in half of the models, be looking into food prices (GCAM, GEMINI-E3 and E3ME) and overall undernourishment (ICES).

Other covered SDGs include SDG1 on poverty prevalence (ICES); SDG3 on health through physical density and life expectancy (ICES) and pollution levels linked to mortality (GCAM, TIAM and E3ME); SDG4 on literacy rate (ICES); SDG5 on gender inequality based on income distribution (E3ME); SDG6 on water and sanitation via freshwater withdrawals (ICES) and groundwater depletion (GCAM); SDG10 on inequalities (E3ME and ICES); SDG11 on sustainable cities (ICES); SDG12 on responsible production and consumption through material productivity (ICES), and footprint impacts (GCAM); SDG15 on life on forest land (ICES and GCAM) and land use change (GCAM); and SDG16 on peace, justice and institution (ICES).

Regarding ICES, a dedicated module aims at offering a comprehensive assessment of future sustainability up to 2030 (with the capacity to extend the analysis to 2050) based upon 27 indicators related to the seventeen SDGs, under different socioeconomic and policy scenarios, by combining the ICES modelling framework with a regression approach (based on historical data) to offer an internally-consistent set-up for analysing future patterns of sustainability indicators and their inter-linkages.

Table 27. Details of SDG (other than SDG13: climate action) measures that can be analysed

Measure	GCAM	TIAM	MUSE	42	GEMINI-E3	ICES	DICE	E3ME
§1. No Poverty						✓		
§2. Zero hunger	✓				✓	✓		✓
§3. Health	✓	✓				✓		✓
§4. Quality education						✓		
§5. Gender equality								✓
§6. Clean water and sanitation	✓					✓		
§7. Affordable and clean energy	✓	✓	✓	✓	✓	✓		✓
§8. Decent work & economic growth		✓			✓	✓	✓	✓
§9. Industry, innovation & infrastructure		✓	✓		✓	✓	✓	✓

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§10: Reduced inequalities						✓		✓
§11: Sustainable Cities & Communities						✓		
§12: Responsible production & consumption	✓					✓		
§13: Climate action	✓	✓	✓	✓	✓	✓	✓	✓
§14: Life below water								
§15: Life on land	✓					✓		
§16: Peace, Justice and institutions						✓		

4.3 Interface: I^{2}AM PARIS platform

The information provided in the previous section is also provided in the open-access data exchange I^{2}AM PARIS platform (http://paris-reinforce.epu.ntua.gr/main) along with more detailed information on each of the eight global models, as well as the regional models in the PARIS REINFORCE ensemble. All future modelling activities, including scenario inputs and assumptions, datasets, modelling outputs, and visualisation will be streamlined on this platform. The I^{2}AM PARIS platform is the central tool with which the PARIS REINFORCE project will seek to engage stakeholders in mitigation scenario inputs, results, and implications. The platform was launched live at the first regional workshop in Brussels and has been continually improved since its launch.

There already exist a "graveyard of tools", which were established by previous projects but did not last beyond the project end-date. The I^{2}AM PARIS platform aspires to be unique in describing a variety of modelling types and a variety of uses—beyond simply mitigation, into SDGs as well other emissions apart from CO_2, and focusing on the research questions and assumptions.

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Bibliography

Aaheim, A., Wei, T., & Romstad, B. (2017). Conflicts of economic interests by limiting global warming to+ 3 C. Mitigation and Adaptation Strategies for Global Change, 22(8), 1131-1148.

Aboltins, R., & Blumberga, D. (2019). *Key Factors for Successful Implementation of Energy Efficiency Policy Instruments: A Theoretical Study and the Case of Latvia*. *23*(2), 187. https://doi.org/10.2478/rtuect-2019-0063

Ackerman, F., DeCanio, S. J., Howarth, R. B., & Sheeran, K. (2009). Limitations of integrated assessment models of climate change. Climatic change, 95(3-4), 297-315.

Agrawal, N., Ahiduzzaman, M., & Kumar, A. (2018). The development of an integrated model for the assessment of water and GHG footprints for the power generation sector. Applied Energy, 216, 558-575.

Agrawala, S., Bosello, F., Carraro, C., De Bruin, K., De Cian, E., Dellink, R., & Lanzi, E. (2011). Plan or react? Analysis of adaptation costs and benefits using integrated assessment models. Climate Change Economics, 2(03), 175-208.

Aldy, J. E. (2017). Frameworks for evaluating policy approaches to address the competitiveness concerns of mitigating greenhouse gas emissions. National Tax Journal, 70(2), 395–420. https://doi.org/10.17310/ntj.2017.2.06

Aldy, J. E., & Zeckhauser, R. (2020). Three prongs for prudent climate policy. Southern Economic Journal.

Aldy, J., Pizer, W., Tavoni, M., Reis, L. A., Akimoto, K., Blanford, G., ... & McJeon, H. C. (2016). Economic tools to promote transparency and comparability in the Paris Agreement. Nature Climate Change, 6(11), 1000-1004.

Alestra, C., Cette, G., Chouard, V., & Lecat, R. (2020). Long-term growth impact of climate change and policies: the Advanced Climate Change Long-term (ACCL) scenario building model.

Alvarez, J., Yumashev, D., & Whiteman, G. (2020). A framework for assessing the economic impacts of Arctic change. Ambio, 49(2), 407-418.

Anadon, L. D., Baker, E., & Bosetti, V. (2017). Integrating uncertainty into public energy research and development decisions. Nature Energy, 2(5), 1-14.

Anderson, K., & Peters, G. (2016). The trouble with negative emissions. Science, 354(6309), 182-183.

Andersson, M., and Baccianti, C., (2020) Climate Change and the Macro Economy. ECB Occasional Paper No. 2020243, Available at SSRN: https://ssrn.com/abstract=3632832

Antanasijević D, Pocajt V, Ristić M, Perić-Grujić A. A differential multi-criteria analysis for the assessment of sustainability performance of European countries: Beyond country ranking. Journal of cleaner production. 2017 Nov 1;165:213-20.

Antimiani, A., Costantini, V., Kuik, O., & Paglialunga, E. (2016). Mitigation of adverse effects on competitiveness and leakage of unilateral EU climate policy: An assessment of policy instruments. Ecological Economics, 128, 246–259. https://doi.org/10.1016/j.ecolecon.2016.05.003

Antosiewicz, M., Nikas, A., Szpor, A., Witajewski-Baltvilks, J., & Doukas, H. (2020). Pathways for the transition of the Polish power sector and associated risks. Environmental Innovation and Societal Transitions, 35, 271-291.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Anwar, J. (2016). Analysis of energy security, environmental emission and fuel import costs under energy import reduction targets: A case of Pakistan. Renewable and Sustainable Energy Reviews, 65, 1065-1078.

Arango-Aramburo, S., Turner, S. W., Daenzer, K., Ríos-Ocampo, J. P., Hejazi, M. I., Kober, T., ... & van der Zwaan, B. (2019). Climate impacts on hydropower in Colombia: A multi-model assessment of power sector adaptation pathways. Energy Policy, 128, 179-188.

Babonneau, F. L. F., Haurie, A., & Vielle, M. (2019, May). Potentials of Negative Emissions in the Design of Climate Agreements. In 42rd International Association for Energy Economics Annual Conference (No. CONF).

Babonneau, F., Bernard, A., Haurie, A., & Vielle, M. (2018). Meta-Modeling to Assess the Possible Future of Paris Agreement. Environmental Modeling & Assessment, 23(6), 611-626.

Babonneau, F., Haurie, A., & Vielle, M. (2019). Assessment of Climate Agreements over the Long Term with Strategic Carbon Dioxyde Removal Activity.

Bachmann, T. M. (2020). Considering environmental costs of greenhouse gas emissions for setting a CO2 tax: A review. Science of The Total Environment, 137524.

Bachner, G., Mayer, J., & Steininger, K. (2019). Costs or benefits? Assessing the economy-wide effects of the electricity sector's low carbon transition – The role of capital costs, divergent risk perceptions and premiums. Energy Strategy Reviews, 26, 100373. doi: 10.1016/j.esr.2019.100373

Badiei, A., Allinson, D., & Lomas, K. J. (2019). Automated dynamic thermal simulation of houses and housing stocks using readily available reduced data. Energy and Buildings, 203, 109431.

Baek, M., Chai, Q., & Kim, S. (2018). Would China be the sole winner in the Northeast Asian ETS market. Unpublished Manuscript, currently under peer review for publication, 1-19.

Baklanov, A., Cárdenas, B., Lee, T. C., Leroyer, S., Masson, V., Molina, L. T., ... & Voogt, J. A. (2020). Integrated urban services: Experience from four cities on different continents. Urban Climate, 32, 100610.

Balcombe, P., Speirs, J. F., Brandon, N. P., & Hawkes, A. D. (2018). Methane emissions: choosing the right climate metric and time horizon. Environmental Science: Processes & Impacts, 20(10), 1323-1339.

Baldwin, E., Cai, Y., & Kuralbayeva, K. (2020). To build or not to build? Capital stocks and climate policy∗. Journal of Environmental Economics and Management, 100, 102235.

Balistreri, E. J., Kaffine, D. T., & Yonezawa, H. (2019). Optimal Environmental Border Adjustments Under the General Agreement on Tariffs and Trade. Environmental and Resource Economics, 74(3), 1037–1075.

Balthasar, A., Schreurs, M. A., & Varone, F. (2020). Energy Transition in Europe and the United States: Policy Entrepreneurs and Veto Players in Federalist Systems.

Bang G and Lahn B (2019) From oil as welfare to oil as risk? Norwegian petroleum resource governance and climate policy. Climate Policy, 20(8), 997-1009.

Baranzini, A., van den Bergh, J. C. J. M., Carattini, S., Howarth, R. B., Padilla, E., & Roca, J. (2017). Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. Wiley Interdisciplinary Reviews: Climate Change, 8(4), e462.

Barazza, E., & Strachan, N. (2020). The co-evolution of climate policy and investments in electricity markets: Simulating agent dynamics in UK, German and Italian electricity sectors. Energy Research & Social Science, 65, 101458.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Barron, A. R., Fawcett, A. A., Hafstead, M. A., McFarland, J. R., & Morris, A. C. (2018). Policy insights from the EMF 32 study on US carbon tax scenarios. Climate Change Economics, 9(01), 1840003.

Bart, I., Csernus, D., & Sáfián, F. (2018). Analysis of climate-energy policies & implementation in Hungary. *National Society of Conservationists–Friends of the Earth Hungary*.

Bastien-Olvera, B. A. (2019). Business-as-usual redefined: Energy systems under climate-damaged economies warrant review of nationally determined contributions. Energy, 170, 862-868.

Bataille, C., Waisman, H., Briand, Y., Svensson, J., Vogt-Schilb, A., Jaramillo, M., ... & Lallana, F. (2020). Net-zero deep decarbonization pathways in Latin America: Challenges and opportunities. Energy Strategy Reviews, 30, 100510.

Battiston, S., & Monasterolo, I. (2019). A Climate Risk Assessment of Sovereign Bonds. Available at SSRN 3376218.

Bauer, N., Hilaire, J., Brecha, R. J., Edmonds, J., Jiang, K., Kriegler, E., ... & Sferra, F. (2016). Assessing global fossil fuel availability in a scenario framework. Energy, 111, 580-592.

Bauer, N., McGlade, C., Hilaire, J., & Ekins, P. (2018). Divestment prevails over the green paradox when anticipating strong future climate policies. Nature Climate Change, 8(2), 130-134.

Bauer, N., Rose, S. K., Fujimori, S., Van Vuuren, D. P., Weyant, J., Wise, M., ... & Kitous, A. (2018). Global energy sector emission reductions and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison. Climatic Change, 1-16.

Bednar, J., Obersteiner, M., & Wagner, F. (2019). On the financial viability of negative emissions. Nature communications, 10(1), 1-4.

Binsted, M., Iyer, G., Edmonds, J., Vogt-Schilb, A., Arguello, R., Cadena, A., ... & Miralles-Wilhelm, F. (2020). Stranded asset implications of the Paris Agreement in Latin America and the Caribbean. Environmental Research Letters, 15(4), 044026.

Blanco, M., Koopman, E. S., Janse, J., Avgerinopoulos, G., Conradt, T., & Bodirsky, B. (2017). D3. 1: REPORT ON THE "FIRST RUN" SIMULATION RESULTS OF THE THEMATIC MODELS: IDENTIFYING THE GAPS.

BMVI. (2020). BMVI - Germany's 2020 EU Council Presidency. Bmvi.de. Retrieved 27 July 2020, from https://www.bmvi.de/EN/The-Ministry/Germany-EU-Council-Presidency/germany-eu-council-presidency.html.

Böhringer, C., Carbone, J. C., & Rutherford, T. F. (2016). The strategic value of carbon tariffs. American Economic Journal: Economic Policy, 8(1), 28-51.

Bolwig, S., Bolkesjø, T. F., Klitkou, A., Lund, P. D., Bergaentzlé, C., Borch, K., ... & Skytte, K. (2020). Climate-friendly but socially rejected energy-transition pathways: The integration of techno-economic and socio-technical approaches in the Nordic-Baltic region. Energy Research & Social Science, 67, 101559.

Börjeson, L., Höjer, M., Dreborg, K. H., Ekvall, T., & Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. Futures, 38(7), 723–739. https://doi.org/10.1016/j.futures.2005.12.002

Bosetti, V., Marangoni, G., Borgonovo, E., Anadon, L. D., Barron, R., McJeon, H. C., ... & Friley, P. (2015). Sensitivity to energy technology costs: A multi-model comparison analysis. Energy Policy, 80, 244-263.

Bradfield, R., Wright, G., Burt, G., Cairns, G., & Van Der Heijden, K. (2005). The origins and evolution of scenario techniques in long range business planning. Futures, 37(8), 795–812.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

https://doi.org/10.1016/j.futures.2005.01.003

Bramstoft, R., Pizarro-Alonso, A., Jensen, I. G., Ravn, H., & Münster, M. (2020). Modelling of renewable gas and renewable liquid fuels in future integrated energy systems. Applied Energy, 268, 114869.

Brand, C., Anable, J., & Morton, C. (2019). Lifestyle, efficiency and limits: modelling transport energy and emissions using a socio-technical approach. Energy Efficiency, 12(1), 187-207.

Braunreiter, L., & Blumer, Y. B. (2018). Of sailors and divers: how researchers use energy scenarios. Energy research & social science, 40, 118-126.

Breyer, C., Bogdanov, D., Aghahosseini, A., Gulagi, A., Child, M., Oyewo, A. S., ... & Vainikka, P. (2018). Solar photovoltaics demand for the global energy transition in the power sector. Progress in Photovoltaics: Research and Applications, 26(8), 505-523.

Breyer, C., Fasihi, M., & Aghahosseini, A. (2020). Carbon dioxide direct air capture for effective climate change mitigation based on renewable electricity: a new type of energy system sector coupling. Mitigation and Adaptation Strategies for Global Change, 25(1), 43-65.

Broad, O., Hawker, G., Dodds, P. (2020), Decarbonising the UK residential sector: The dependence of national abatement on flexible and local views of the future, Energy Policy, Volume 140, 111321, ISSN 0301-4215, doi: 10.1016/j.enpol.2020.111321

Brown, S., Nicholls, R. J., Lázár, A. N., Hornby, D. D., Hill, C., Hazra, S., ... & Tompkins, E. L. (2018). What are the implications of sea-level rise for a 1.5, 2 and 3° C rise in global mean temperatures in the Ganges-Brahmaputra-Meghna and other vulnerable deltas?. Regional environmental change, 18(6), 1829-1842.

Brozynski, M. T., & Leibowicz, B. D. (2018). Decarbonizing power and transportation at the urban scale: An analysis of the Austin, Texas Community Climate Plan. Sustainable cities and society, 43, 41-54.

Buchmann, M., Kusznir, J., & Brunekreeft, G. (2019). *Assessment of the drafted German Integrated National Energy and Climate Plan*. Bremen Energy Research. https://econpapers.repec.org/RePEc:bei:00bewp:0030

Budinis, S., Krevor, S., Mac Dowell, N., Brandon, N., & Hawkes, A. (2018). An assessment of CCS costs, barriers and potential. Energy strategy reviews, 22, 61-81.

Burandt, T., Xiong, B., Löffler, K., & Oei, P. Y. (2019). Decarbonizing China's energy system–Modeling the transformation of the electricity, transportation, heat, and industrial sectors. Applied Energy, 255, 113820.

Butnar, I., Broad, O., Solano Rodriguez, B., & Dodds, P. E. (2020). The role of bioenergy for global deep decarbonization: CO2 removal or low-carbon energy?. GCB Bioenergy, 12(3), 198-212.

Butnar, I., Li, P. H., Strachan, N., Pereira, J. P., Gambhir, A., & Smith, P. (2019). A deep dive into the modelling assumptions for biomass with carbon capture and storage (BECCS): A transparency exercise. Environmental Research Letters.

Byers, E., Gidden, M., Leclère, D., Balkovic, J., Burek, P., Ebi, K., ... & Johnson, N. (2018). Global exposure and vulnerability to multi-sector development and climate change hotspots. Environmental Research Letters, 13(5), 055012.

Cai, Y., Lenton, T. M., & Lontzek, T. S. (2016). Risk of multiple interacting tipping points should encourage rapid CO 2 emission reduction. Nature Climate Change, 6(5), 520-525.

Calvillo, C., Turner, K., Bell, K., McGregor, P., & Hawker, G. (2017). Potential for the Use of TIMES in Assessing Energy

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

System Impacts of Improved Energy Efficiency: Using the TIMES Model in Developing Energy Policy.

Calvin, K., Bond-Lamberty, B., Clarke, L., Edmonds, J., Eom, J., Hartin, C., ... & McJeon, H. (2017). The SSP4: A world of deepening inequality. Global Environmental Change, 42, 284-296.

Calvin, K., Patel, P., Clarke, L., Asrar, G., Bond-Lamberty, B., Cui, R. Y., ... & Hejazi, M. (2019). GCAM v5. 1: representing the linkages between energy, water, land, climate, and economic systems. Geoscientific Model Development (Online), 12(PNNL-SA-137098).

Calvin, K., Wise, M., Kyle, P., Clarke, L., & Edmonds, J. (2017). A hindcast experiment using the GCAM 3.0 agriculture and land-use module. Climate Change Economics, 8(01), 1750005.

Capellán-Pérez, I., de Blas, I., Nieto, J., de Castro, C., Miguel, L. J., Carpintero, Ó., ... & Frechoso, F. (2020). MEDEAS: a new modeling framework integrating global biophysical and socioeconomic constraints. Energy & Environmental Science, 13(3), 986-1017.

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., ... & Paroussos, L. (2016). EU Reference Scenario 2016-Energy, transport and GHG emissions Trends to 2050.

Capros, P., Zazias, G., Evangelopoulou, S., Kannavou, M., Fotiou, T., Siskos, P., ... & Sakellaris, K. (2019). Energy-system modelling of the EU strategy towards climate-neutrality. Energy Policy, 134, 110960.

Carrara, S. (2019). Assessing the Techno-economic Effects of the Delayed Deployment of CCS Power Plants.

Carraro, C., Tavoni, M., Longden, T., & Marangoni, G. (2017). The Potential Role of Gas in Decarbonizing Europe: A Quantitative Assessment. In The European Gas Markets (pp. 25-48). Palgrave Macmillan, Cham.

Cassen, C., Hamdi-Chérif, M., Cotella, G., Toniolo, J., Lombardi, P., & Hourcade, J. C. (2018). Low Carbon Scenarios for Europe: An Evaluation of Upscaling Low Carbon Experiments. Sustainability, 10(3), 848.

Ćetković, S., & Buzogány, A. (2020). Between markets, politics and path-dependence: Explaining the growth of solar and wind power in six Central and Eastern European countries. *Energy Policy*, *139*, 111325. https://doi.org/10.1016/j.enpol.2020.111325

Chang, S., Yang, X., Zheng, H., Wang, S., & Zhang, X. (2020). Air quality and health co-benefits of China's national emission trading system. Applied Energy, 261, 114226.

Chapman, A., Itaoka, K., Hirose, K., Davidson, F. T., Nagasawa, K., Lloyd, A. C., ... & Lewis, M. C. (2019). A review of four case studies assessing the potential for hydrogen penetration of the future energy system. International journal of hydrogen energy, 44(13), 6371-6382.

Chaturvedi, V., Kim, S., Smith, S. J., Clarke, L., Yuyu, Z., Kyle, P., & Patel, P. (2013). Model evaluation and hindcasting: An experiment with an integrated assessment model. Energy, 61, 479-490.

Chen, H., Wang, L., & Chen, W. (2019). Modeling on building sector's carbon mitigation in China to achieve the 1.5 C climate target. Energy Efficiency, 12(2), 483-496.

Chen, H., Wang, L., Chen, W., Luo, Y., Wang, Y., & Zhou, S. (2018). The global impacts of US climate policy: a model simulation using GCAM-TU and MAGICC. Climate Policy, 18(7), 852-862.

Chen, H., Wang, Z., Xu, S., Zhao, Y., Cheng, Q., & Zhang, B. (2020). Energy demand, emission reduction and health co-benefits evaluated in transitional China in a 2° C warming world. Journal of Cleaner Production, 121773.

Chen, H., Yang, L., & Chen, W. (2020). Modelling national, provincial and city-level low-carbon energy transformation pathways. Energy Policy, 137, 111096.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Chen, J., Gao, C., Zeng, X., Xiong, M., Wang, Y., Jing, C., ... & Su, B. (2017). Assessing changes of river discharge under global warming of 1.5 C and 2 C in the upper reaches of the Yangtze River Basin: Approach by using multiple-GCMs and hydrological models. Quaternary International, 453, 63-73.

Chen, Y., Liu, A., & Cheng, X. (2020). Quantifying economic impacts of climate change under nine future emission scenarios within CMIP6. Science of The Total Environment, 703, 134950.

Cheng, F., Porter, M. D., & Colosi, L. M. (2020). Is hydrothermal treatment coupled with carbon capture and storage an energy-producing negative emissions technology?. Energy Conversion and Management, 203, 112252.

Christensen J and Holst C (2017) Advisory commissions, academic expertise and democratic legitimacy: the case of Norway. Science and Public Policy 44(6): 821-833.

Chunark, P., & Limmeechokchai, B. (2018). Thailand Energy System Transition to Keep Warming Below 1.5 Degrees. Carbon Management, 9(5), 515-531.

Claeys, G., Tagliapietra, S., & Zachmann, G. (2019). How to make the European Green Deal work. Bruegel Policy Contribution, No 14 November, 21.

Clancy, J., Ummar, F., Shakya, I., & Kelkar, G. (2007). Appropriate gender-analysis tools for unpacking the gender-energy-poverty nexus. Gender & Development, 15(2), 241-257.

Cointe, B., Cassen, C., & Nadai, A. (2019). Organising Policy-Relevant Knowledge for Climate Action: Integrated Assessment Modelling, the IPCC, and the Emergence of a Collective Expertise on Socioeconomic Emission Scenarios. Science & Technology Studies.

Cointe, B., Cassen, C., & Nadai, A. (2019). Organising Policy-Relevant Knowledge for Climate Action: Integrated Assessment Modelling, the IPCC, and the Emergence of a Collective Expertise on Socioeconomic Emission Scenarios. Science & Technology Studies.

Connolly, D., Lund, H., Mathiesen, B. V., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. Applied energy, 87(4), 1059-1082.

Corbera, E., Calvet-Mir, L., Hughes, H., & Paterson, M. (2016). Patterns of authorship in the IPCC Working Group III report. Nature Climate Change, 6(1), 94-99.

Cormack, C., Donovan, C., Koberle, A., & Ostrovnaya, A. (2020). Estimating Financial Risks from the Energy Transition: Potential Impacts from Decarbonisation in the European Power Sector. Available at SSRN.

Costantini, V., Markandya, A., Paglialunga, E., & Sforna, G. (2018). Impact and distribution of climatic damages: a methodological proposal with a dynamic CGE model applied to global climate negotiations. Economia Politica, 35(3), 809-843.

Craig, P., Gadgil, A., & Koomey, J. G. (2002). What Can History Teach Us? A Retrospective Examination of Long-Term Energy Forecasts for the United States*. Annual Review of Energy and the Environment, 27, 83–118. https://doi.org/10.1146/annurev.energy.27.122001.083425

Creutzfeldt, N., Gill, C., McPherson, R., & Cornelis, M. (2020). The Social and Local Dimensions of Governance of Energy Poverty: Adaptive Responses to State Remoteness. *Journal of Consumer Policy*. https://doi.org/10.1007/s10603-019-09442-z

Creutzig, F., Breyer, C., Hilaire, J., Minx, J., Peters, G. P., & Socolow, R. (2019). The mutual dependence of negative emission technologies and energy systems. Energy & Environmental Science, 12(6), 1805-1817.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Cronin, J., Pye, S., Price, J., & Butnar, I. (2020). Biomass, afforestation and energy demand reduction: trade-offs in the route to decarbonisation.

Cronin, J., Zabel, F., Dessens, O., & Anandarajah, G. (2020). Land suitability for energy crops under scenarios of climate change and land-use. GCB Bioenergy.

Cui, R. Y., Hultman, N., Edwards, M. R., He, L., Sen, A., Surana, K., ... & Nace, T. (2019). Quantifying operational lifetimes for coal power plants under the Paris goals. Nature communications, 10(1), 1-9.

Dafnomilis, I., Hoefnagels, R., Pratama, Y. W., Schott, D. L., Lodewijks, G., & Junginger, M. (2017). Review of solid and liquid biofuel demand and supply in Northwest Europe towards 2030–A comparison of national and regional projections. Renewable and Sustainable Energy Reviews, 78, 31-45.

Daggash, H. A., & Mac Dowell, N. (2019). Higher Carbon Prices on Emissions Alone Will Not Deliver the Paris Agreement. Joule, 3(9), 2120-2133.

Daggash, H. A., & Mac Dowell, N. (2019). Structural Evolution of the UK Electricity System in a below 2° C World. Joule, 3(5), 1239-1251.

Daggash, H. A., & Mac Dowell, N. (2019). The implications of delivering the UK's Paris Agreement commitments on the power sector. International Journal of Greenhouse Gas Control, 85, 174-181.

Dagnachew, A. G., Hof, A. F., Lucas, P. L., & van Vuuren, D. P. (2020). Scenario analysis for promoting clean cooking in Sub-Saharan Africa: Costs and benefits. Energy, 192, 116641.

Dagnachew, A. G., Lucas, P. L., Hof, A. F., & van Vuuren, D. P. (2018). Trade-offs and synergies between universal electricity access and climate change mitigation in Sub-Saharan Africa. Energy Policy, 114, 355-366.

Dai, H., Xie, Y., Zhang, H., Yu, Z., & Wang, W. (2018). Effects of the US withdrawal from Paris Agreement on the carbon emission space and cost of China and India. Frontiers in Energy, 12(3), 362-375.

Dalla Longa, F., & van der Zwaan, B. (2017). Do Kenya's climate change mitigation ambitions necessitate large-scale renewable energy deployment and dedicated low-carbon energy policy?. Renewable Energy, 113, 1559-1568.

Dalla Longa, F., Nogueira, P., Limberger, J., van Wees, J., van der Zwaan, B., (2020). Scenarios for geothermal energy deployment in Europe, Energy, Volume 206, 118060, ISSN 0360-5442, doi: 10.1016/j.energy.2020.118060.

Dalla Longa, F., Strikkers, T., Kober, T., & van der Zwaan, B. (2018). Advancing energy access modelling with geographic information system data. Environmental Modeling & Assessment, 23(6), 627-637.

Damman, S., Sandberg, E., Rosenberg, E., Pisciella, P., Johansen, U. (2020), Largescale hydrogen production in Norway - possible transition pathways towards 2050. Research Council of Norway. SINTEF Digital. ISBN: 978-82-14-06295-3

Dao, P. G. (2018). The Fourth Industrial Evolution and the Fight Against Carbon Leakage and the Issue of Climate Change. Journal of US-China Public Administration, 15(1), 43–54.

de Blas, I., Miguel, L. J., & Capellán-Pérez, I. (2019). Modelling of sectoral energy demand through energy intensities in MEDEAS integrated assessment model. Energy Strategy Reviews, 26, 100419.

De Paoli, L. (2019). The Italian draft National Energy-Climate Plan. *Economics and Policy of Energy and the Environment*.

De Paoli, L., & Geoffron, P. (2019). Introduction. A critical overview of the European National Energy and Climate

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Plans. *Economics and Policy of Energy and the Environment*, *1*, 31–41. https://doi.org/10.3280/EFE2019-001002

Deane, P., McInerney, C., O'Connor, E., & Power, B. (2018). The Impact of a Carbon Price Floor on European Electricity Markets.

Dees, M., Elbersen, B., Fitzgerald, J., Vis, M., Anttila, P., Forsell, N., Datta, P., Gallaun, H., Dawar, S., Glavonjic, B., Garcia, D., Verkerk, H., Schardt, M., Ramirez-Almeyda, J., Monti, A. Prinz, R., Lindner, M., Pantic, D., Borota, D., Höhl, M., Leduc, S (2017): Best practice guidelines on the maintenance and regular up-date of the biomass cost supply data for EU, Western Balkan Countries, Moldavia, Turkey and Ukraine. Project Report. S2BIOM – a project funded under the European Union 7th Framework Programme for Research. Grant Agreement n°608622. Chair of Remote Sensing and Landscape Information Systems, Institute of Forest Sciences, University of Freiburg, Germany. 191 p.

Dellink, R., Chateau, J., Lanzi, E., & Magné, B. (2017). Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change, 42, 200-214.

Den Elzen, M., Admiraal, A., Roelfsema, M., van Soest, H., Hof, A. F., & Forsell, N. (2016). Contribution of the G20 economies to the global impact of the Paris agreement climate proposals. Climatic Change, 137(3-4), 655-665.

Denison, S., Forster, P. M., & Smith, C. J. (2019). Guidance on emissions metrics for nationally determined contributions under the Paris Agreement. Environmental Research Letters, 14(12), 124002.

Després, J., Hadjsaid, N., Criqui, P., & Noirot, I. (2015). Modelling the impacts of variable renewable sources on the power sector: Reconsidering the typology of energy modelling tools. Energy, 80, 486-495.

Dhar, S., Pathak, M., & Shukla, P. R. (2018). Transformation of India's transport sector under global warming of 2 C and 1.5 C scenario. Journal of cleaner production, 172, 417-427.

Diachuk, O., Podolets, R., Yukhymets, R., Pekkoiev, V., Balyk, O., & Simonsen, M. B. (2019). Long-term Energy Modelling and Forecasting in Ukraine: Scenarios for the Action Plan of Energy Strategy of Ukraine until 2035.

Diaz, F., & Cilinskis, E. (2019). Use of Multi-Criteria TOPSIS Analysis to Define a Decarbonization Path in Colombia. Environmental and Climate Technologies, 23(3), 110-128.

Dietz, S., van der Ploeg, R., Rezai, A., & Venmans, F. (2020). Are economists getting climate dynamics right and does it matter?.

Digas, B., Rozenberg, V., & Kuklin, A. (2016). Application of integrated assessment model MERGE to studying ecological-economic indices. Modeling Earth Systems and Environment, 2(3), 129.

Dimitrova, A., Egenhofer, C., & Behrens, A. (2016). A Roadmap to Enhanced Regional Energy Policy: Cooperation in South East Europe. *CEPS Special Report*, *134*.

Dioha, M. O., & Kumar, A. (2020). Exploring the energy system impacts of Nigeria's Nationally Determined Contributions and low-carbon transition to mid-century. Energy Policy, 144, 111703. doi:10.1016/j.enpol.2020.111703

Doelman, J. C., Stehfest, E., Tabeau, A., & van Meijl, H. (2019). Making the Paris agreement climate targets consistent with food security objectives. Global Food Security, 23, 93-103.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Doelman, J. C., Stehfest, E., Tabeau, A., van Meijl, H., Lassaletta, L., Gernaat, D. E., ... & van der Sluis, S. (2018). Exploring SSP land-use dynamics using the IMAGE model: Regional and gridded scenarios of land-use change and land-based climate change mitigation. Global Environmental Change, 48, 119-135.

Doelman, J. C., Stehfest, E., van Vuuren, D. P., Tabeau, A., Hof, A. F., Braakhekke, M. C., ... & van Meijl, H. (2020). Afforestation for climate change mitigation: Potentials, risks and trade-offs. Global Change Biology, 26(3), 1576-1591.

Dooley, K., Christoff, P., & Nicholas, K. A. (2018). Co-producing climate policy and negative emissions: trade-offs for sustainable land-use. Global Sustainability, 1.

Doukas, H., & Nikas, A. (2020). Decision support models in climate policy. European Journal of Operational Research, 280(1), 1-24.

Doukas, H., & Nikas, A. (2021). Involve citizens in climate-policy modelling. Nature, 590(7846), 389.

Doukas, H., Nikas, A., González-Eguino, M., Arto, I., & Anger-Kraavi, A. (2018). From integrated to integrative: Delivering on the Paris Agreement. Sustainability, 10(7), 2299.

Drake, H., Rivest, R. L., Deutch, J., & Edelman, A. (2020). A multi-control climate policy process for a trusted decision maker.

Drews, M., Larsen, M. A. D., & Balderrama, J. G. P. (2020). Projected water usage and land-use-change emissions from biomass production (2015–2050). Energy Strategy Reviews, 29, 100487.

Dröge, S., Neuhoff, K., Egenhofer, C., & Elkerbout, M. (2019). How EU Trade Policy Can Enhance Climate Action: Options to Boost Low-Carbon Investment and Address Carbon Leakage. CEPS Policy Priorities for 2019-2024.

du Pont, Y. R., & Meinshausen, M. (2018). Warming assessment of the bottom-up Paris Agreement emissions pledges. Nature communications, 9(1), 1-10.

du Pont, Y. R., Jeffery, M. L., Gütschow, J., Christoff, P., & Meinshausen, M. (2016). National contributions for decarbonizing the world economy in line with the G7 agreement. Environmental Research Letters, 11(5), 054005.

du Pont, Y. R., Jeffery, M. L., Gütschow, J., Rogelj, J., Christoff, P., & Meinshausen, M. (2017). Equitable mitigation to achieve the Paris Agreement goals. Nature Climate Change, 7(1), 38-43.

Duan, H., & Wang, S. (2018). Potential impacts of China's climate policies on energy security. Environmental Impact Assessment Review, 71, 94-101.

Duan, H., Mo, J., Fan, Y., & Wang, S. (2018). Achieving China's energy and climate policy targets in 2030 under multiple uncertainties. Energy Economics, 70, 45-60.

Duan, H., Zhang, G., Wang, S., & Fan, Y. (2019). Integrated benefit-cost analysis of China's optimal adaptation and targeted mitigation. Ecological Economics, 160, 76-86.

Dudău, R., & Cătuţi, M. (2019). The Decarbonisation Challenge of Southeast Europe: A Case Study of Romania. *Intereconomics*, *54*(6), 341–346. https://doi.org/10.1007/s10272-019-0851-y

Dumitrescu, A. L., & Şincai, I. M. O. (2018). Reinforcing the EU Energy Security by Strengthening External Cooperation. *Global Economic Observer*, *6*(1), 25–32.

Duscha, V., Denishchenkova, A., & Wachsmuth, J. (2019). Achievability of the Paris Agreement targets in the EU:

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

demand-side reduction potentials in a carbon budget perspective. Climate Policy, 19(2), 161-174.

Edelenbosch, O. Y., Van Vuuren, D. P., Blok, K., Calvin, K., & Fujimori, S. (2020). Mitigating energy demand sector emissions: The integrated modelling perspective. Applied Energy, 261, 114347.

Edenhofer, O., Flachsland, C., Kalkuhl, M., Knopf, B., & Pahle, M. (2019). Assessment of the German climate package and next steps: Carbon pricing, social balance, Europe, monitoring.

Edenhofer, O., Knopf, B., Barker, T., Baumstark, L., Bellevrat, E., Chateau, B., ... & Leimbach, M. (2010). The economics of low stabilization: model comparison of mitigation strategies and costs. The Energy Journal, 31.

Ellenbeck, S., & Lilliestam, J. (2019). How modelers construct energy costs: discursive elements in energy system and integrated assessment models. Energy Research & Social Science, 47, 69-77.

Emmerling, J., Kornek, U., Bosetti, V., & Lessmann, K. (2020). Climate thresholds and heterogeneous regions: Implications for coalition formation. The Review of International Organizations, 1-24.

Emori, S., Takahashi, K., Yamagata, Y., Kanae, S., Mori, S., & Fujigaki, Y. (2018). Risk implications of long-term global climate goals: overall conclusions of the ICA-RUS project. Sustainability science, 13(2), 279-289.

ENERGY, C. S. C. O. G., LARSEN, P. B. J., MOHAN, S., MARSTERS, P., & HERNDON, W. (2018). ENERGY AND ENVIRONMENTAL IMPLICATIONS OF A CARBON TAX IN THE UNITED STATES.

English, J., Niet, T., Lyseng, B., Palmer-Wilson, K., Keller, V., Moazzen, I., ... & Rowe, A. (2017). Impact of electrical intertie capacity on carbon policy effectiveness. Energy Policy, 101, 571-581.

Ens, E., & Johnston, C. (2020). Scenario Analysis and the Economic and Financial Risks from Climate Change (No. 2020-3). Bank of Canada.

Eriksson, M. (2016). Mitigating Climate Change with Forest Climate Tools.

Eriksson, M. (2020). Afforestation and avoided deforestation in a multi-regional integrated assessment model. Ecological Economics, 169, 106452.

Esmeijer, K., den Elzen, M., & van Soest, H. (2020). ANALYSING INTERNATIONAL SHIPPING AND AVIATION EMISSION PROJECTIONS.

European Commission. (2019). Clean energy for all Europeans. *Euroheat and Power*, *14*(2), 3. https://doi.org/10.2833/9937

European Commission. (2019). The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, 24.

European Commission. (2020a). *Final National Energy and Climate Plans (NECPs)*. https://ec.europa.eu/info/energy-climate-change-environment/overall-targets/national-energy-and-climate-plans-necps_en

European Commission. (2020b). *The EU budget powering the recovery plan for Europe. COM(2020) 442 final*. https://eur-lex.europa.eu/resource.html?uri=cellar:4524c01c-a0e6-11ea-9d2d-01aa75ed71a1.0003.02/DOC_1&format=PDF

European Commission. (2020c). *A European Green Deal*. European Commission - European Commission. Retrieved from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

European Parliament and the Council of the European Union. (2018). *Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council*. https://eur-lex.europa.eu/resource.html?uri=cellar:f9f04518-b7dc-11e6-9e3c-01aa75ed71a1.0001.02/DOC_1&format=PDF

European-calculator.eu. 2020. [online] Available at: <http://www.european-calculator.eu/wp-content/uploads/2020/03/EUCalc_PB_no5_Agriculture_Landuse.pdf> [Accessed 14 July 2020].

EuropeanCommission. (2019). The European Green Deal; COM(2019) 640 final.

Eyl-Mazzega, M. A., & Mathieu, C. (2020). The European Union and the Energy Transition. In The Geopolitics of the Global Energy Transition (pp. 27-46). Springer, Cham.

F. Fattori, L. Tagliabue, G. Cassetti and M. Motta, "Enhancing Power System Flexibility Through District Heating - Potential Role in the Italian Decarbonisation," 2019 IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Genova, Italy, 2019, pp. 1-6, doi: 10.1109/EEEIC.2019.8783732.

F. Lanati, A. Gelmini and G. Viganò, (2019) "The evolution of the Italian power system in 2030 to support more than 55% of renewables on electricity consumption," 2019 AEIT International Annual Conference (AEIT), Florence, Italy, pp. 1-6, doi: 10.23919/AEIT.2019.8893430

Fæhn, T., Bachner, G., Beach, R. H., Chateau, J., Fujimori, S., Ghosh, M., ... & Cunha, B. (2020). Capturing Key Energy and Emission Trends in CGE Models: Assessment of Status and Remaining Challenges.

Farrell, J., Morris, J., Kheshgi, H., Thomann, H., Paltsev, S., & Herzog, H. (2019). The role of industrial carbon capture and storage (CCS) in emission mitigation.

Farsaei, A., Syri, S., Olkkonen, V., & Khosravi, A. (2020). Unintended Consequences of National Climate Policy on International Electricity Markets—Case Finland's Ban on Coal-Fired Generation. *Energies*, *13*(8), 1930. https://doi.org/10.3390/en13081930

Fathallah, J., & Pyakurel, P. (2020). Addressing gender in energy studies. Energy Research & Social Science, 65, 101461.

Fattori, F., Tagliabue, L., Cassetti, G., & Motta, M. (2019). Enhancing Power System Flexibility Through District Heating-Potential Role in the Italian Decarbonisation. *2019 IEEE International Conference on Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)*, 1–6.

Favero, A., Daigneault, A., & Sohngen, B. (2020). Forests: Carbon sequestration, biomass energy, or both?. Science advances, 6(13), eaay6792.

Favero, A., Mendelsohn, R., & Sohngen, B. (2016). Carbon Storage and Bioenergy: Using Forests for Climate Mitigation. SSRN Electronic Journal. doi: 10.2139/ssrn.2741005

Fedoroff, N. V. (2009). Science diplomacy in the 21st century. Cell, 136(1), 9-11.

Feijó, F. T., & Kuik, O. (2018). Brazilian competitiveness of energy-intensive and trade-exposed industrial sectors vis-à-vis the adoption of border carbon adjustments by the EU: an approach using the GTAP-EP model. In Anais do XLIV Encontro Nacional de Economia [Proceedings of the 44th Brazilian Economics Meeting] (No. 100). ANPEC-AssociaÃ § Ã£ o Nacional dos Centros de PÃ³s-GraduaÃ § Ã£ o em Economia

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

[Brazilian Association of Graduate Programs in Economics].

Feijoo, F., Iyer, G., Binsted, M., & Edmonds, J. (2020). US energy system transitions under cumulative emissions budgets. Climatic Change, 1-17.

Feijoo, F., Mignone, B. K., Kheshgi, H. S., Hartin, C., McJeon, H., & Edmonds, J. (2019). Climate and carbon budget implications of linked future changes in CO2 and non-CO2 forcing. Environmental Research Letters, 14(4), 044007.

Few, S., Gambhir, A., Napp, T., Hawkes, A., Mangeon, S., Bernie, D., & Lowe, J. (2017). The impact of shale gas on the cost and feasibility of meeting climate targets—a global energy system model analysis and an exploration of uncertainties. Energies, 10(2), 158.

Fisch-Romito, V., & Guivarch, C. (2019). Transportation infrastructures in a low carbon world: An evaluation of investment needs and their determinants. Transportation Research Part D: Transport and Environment, 72, 203-219.

Fofrich, R. A., Tong, D., Calvin, K. V., de Boer, H. S., Emmerling, J., Fricko, O., ... & Davis, S. J. (2020). Early retirement of power plants in climate mitigation scenarios. Environmental Research Letters.

Forouli, A., Doukas, H., Nikas, A., Sampedro, J., & Van de Ven, D. J. (2019). Identifying optimal technological portfolios for European power generation towards climate change mitigation: a robust portfolio analysis approach. Utilities Policy, 57, 33-42.

Forouli, A., Nikas, A., Van de Ven, D. J., Sampedro, J., & Doukas, H. (2020). A multiple-uncertainty analysis framework for integrated assessment modelling of several sustainable development goals. Environmental Modelling & Software, 131, 104795.

Fouré, J., Guimbard, H., & Monjon, S. (2016). Border carbon adjustment and trade retaliation: What would be the cost for the European Union? Energy Economics, 54, 349–362.

Fragkos, P., & Kouvaritakis, N. (2018). Model-based analysis of Intended Nationally Determined Contributions and 2° C pathways for major economies. Energy, 160, 965-978.

Fragkos, P., Fragkiadakis, K., Paroussos, L., Pierfederici, R., Vishwanathan, S. S., Köberle, A. C., ... & Oshiro, K. (2018). Coupling national and global models to explore policy impacts of NDCs. Energy policy, 118, 462-473.

Frame, B., Lawrence, J., Ausseil, A. G., Reisinger, A., & Daigneault, A. (2018). Adapting global shared socio-economic pathways for national and local scenarios. Climate Risk Management, 21, 39-51.

Frank, S., Beach, R., Havlík, P., Valin, H., Herrero, M., Mosnier, A., ... & Obersteiner, M. (2018). Structural change as a key component for agricultural non-CO 2 mitigation efforts. Nature communications, 9(1), 1-8.

Frank, S., Havlík, P., Soussana, J. F., Levesque, A., Valin, H., Wollenberg, E., ... & Smith, P. (2017). Reducing greenhouse gas emissions in agriculture without compromising food security?. Environmental Research Letters, 12(10), 105004.

Fricko, O., Havlik, P., Rogelj, J., Klimont, Z., Gusti, M., Johnson, N., ... & Ermolieva, T. (2017). The marker quantification of the Shared Socioeconomic Pathway 2: A middle-of-the-road scenario for the 21st century. Global Environmental Change, 42, 251-267.

Fuglestvedt, J., Rogelj, J., Millar, R. J., Allen, M., Boucher, O., Cain, M., ... & Shindell, D. (2018). Implications of possible interpretations of 'greenhouse gas balance'in the Paris Agreement. Philosophical Transactions of the Royal

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Society A: Mathematical, Physical and Engineering Sciences, 376(2119), 20160445.

Fuhrman, J., McJeon, H., Doney, S., Shobe, W., & Clarens, A. F. (2019). From Zero to Hero?: Why Integrated Assessment Modeling of Negative Emissions Technologies Is Hard and How We Can Do Better. Frontiers in Climate, 1, 11.

Fujimori, S., Dai, H., Masui, T., & Matsuoka, Y. (2016). Global energy model hindcasting. Energy, 114, 293-301.

Fujimori, S., Hasegawa, T., Krey, V., Riahi, K., Bertram, C., Bodirsky, B. L., ... & Drouet, L. (2019). A multi-model assessment of food security implications of climate change mitigation. Nature Sustainability, 2(5), 386-396.

Fujimori, S., Hasegawa, T., Masui, T., Takahashi, K., Herran, D. S., Dai, H., ... & Kainuma, M. (2017). SSP3: AIM implementation of shared socioeconomic pathways. Global Environmental Change, 42, 268-283.

Fujimori, S., Hasegawa, T., Takahashi, K., Dai, H., Liu, J. Y., Ohashi, H., ... & Hijioka, Y. (2020). Measuring the sustainable development implications of climate change mitigation. Environmental Research Letters.

Fujimori, S., Iizumi, T., Hasegawa, T., Takakura, J., Takahashi, K., & Hijioka, Y. (2018). Macroeconomic impacts of climate change associated with changes in crop yields.

Fujimori, S., Rogelj, J., Krey, V., & Riahi, K. (2019). A new generation of emissions scenarios should cover blind spots in the carbon budget space. Nature Climate Change, 9(11), 798-800.

Fujimori, S., Su, X., Liu, J. Y., Hasegawa, T., Takahashi, K., Masui, T., & Takimi, M. (2016). Implication of Paris Agreement in the context of long-term climate mitigation goals. SpringerPlus, 5(1), 1620.

Fuss, S., Jones, C. D., Kraxner, F., Peters, G. P., Smith, P., Tavoni, M., ... & Moreira, J. R. (2016). Research priorities for negative emissions. Environmental Research Letters, 11(11), 115007.

Fuss, S., Lamb, W. F., Callaghan, M. W., Hilaire, J., Creutzig, F., Amann, T., ... & Luderer, G. (2018). Negative emissions—Part 2: Costs, potentials and side effects. Environmental Research Letters, 13(6), 063002.

Gadre, R., & Anandarajah, G. (2019). Assessing the evolution of India's power sector to 2050 under different CO2 emissions rights allocation schemes. Energy for Sustainable Development, 50, 126-138.

Galende-Sánchez, E., & Sorman, A. H. (2021). From consultation toward co-production in science and policy: A critical systematic review of participatory climate and energy initiatives. Energy Research & Social Science, 73, 101907.

Galgóczi, B. (2019). Phasing out coal–a just transition approach. *ETUI Research Paper-Working Paper*.

Gallagher, K. S., Zhang, F., Orvis, R., Rissman, J., & Liu, Q. (2019). Assessing the Policy gaps for achieving China's climate targets in the Paris Agreement. Nature communications, 10(1), 1-10.

Galli, A., Iha, K., Pires, S. M., Mancini, M. S., Alves, A., Zokai, G., ... & Wackernagel, M. (2020). Assessing the ecological footprint and biocapacity of Portuguese cities: Critical results for environmental awareness and local management. Cities, 96, 102442.

Gambhir, A., & Tavoni, M. (2019). Direct Air Carbon Capture and Sequestration: How It Works and How It Could Contribute to Climate-Change Mitigation. One Earth, 1(4), 405-409.

Gambhir, A., Butnar, I., Li, P. H., Smith, P., & Strachan, N. (2019). A review of criticisms of integrated assessment models and proposed approaches to address these, through the lens of BECCS. Energies, 12(9), 1747.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Gambhir, A., Drouet, L., McCollum, D., Napp, T., Bernie, D., Hawkes, A., ... & Lowe, J. (2017). Assessing the feasibility of global long-term mitigation scenarios. Energies, 10(1), 89.

Gambhir, A., Napp, T., Hawkes, A., Höglund-Isaksson, L., Winiwarter, W., Purohit, P., ... & Lowe, J. (2017). The contribution of non-CO2 greenhouse gas mitigation to achieving long-term temperature goals. Energies, 10(5), 602.

Gambhir, A., Rogelj, J., Luderer, G., Few, S., & Napp, T. (2019). Energy system changes in 1.5 C, well below 2 C and 2 C scenarios. Energy Strategy Reviews, 23, 69-80.

Garcia Kerdan, I., Giarola, S., & Hawkes, A. (2020). Implications of future natural gas demand on sugarcane production, land use change and related emissions in Brazil. Journal of Sustainable Development of Energy, Water and Environment Systems, 8(2), 304-327.

Garcia-Casals, X., Ferroukhi, R., & Parajuli, B. (2019). Measuring the socio-economic footprint of the energy transition. Energy Transitions, 3(1-2), 105-118.

Gasser, T., Peters, G. P., Fuglestvedt, J. S., Collins, W. J., Shindell, D. T., & Ciais, P. (2017). Accounting for the climate-carbon feedback in emission metrics. Earth System Dynamics, 8(2), 235-253.

Geiges, A., Parra, P. Y., Andrijevic, M., Hare, W., Nauels, A., Pfleiderer, P., ... & Schleussner, C. F. (2019). Incremental improvements of 2030 targets insufficient to achieve the Paris Agreement goals. Earth System Dynamics Discussions, 1-18.

Gerbaulet, C., von Hirschhausen, C., Kemfert, C., Lorenz, C., & Oei, P. Y. (2017, June). Scenarios for decarbonizing the European electricity sector. In 2017 14th international conference on the European Energy Market (EEM) (pp. 1-6). IEEE.

Gerboni, R., Grosso, D., Carpignano, A., & Dalla Chiara, B. (2017). Linking energy and transport models to support policy making. Energy Policy, 111, 336-345.

Gi, K., Sano, F., Akimoto, K., Hiwatari, R., & Tobita, K. (2018). Contribution of fusion energy to low-carbon development under the Paris Agreement and accompanying uncertainties. In 27th IAEA Fusion Energy Conference.

Gi, K., Sano, F., Akimoto, K., Hiwatari, R., & Tobita, K. (2020). Potential contribution of fusion power generation to low-carbon development under the Paris Agreement and associated uncertainties. Energy Strategy Reviews, 27, 100432.

Gi, K., Sano, F., Hayashi, A., & Akimoto, K. (2019). A model-based analysis on energy systems transition for climate change mitigation and ambient particulate matter 2.5 concentration reduction. Mitigation and Adaptation Strategies for Global Change, 24(2), 181-204.

Giannakis, E., Serghides, D., Dimitriou, S., & Zittis, G. (2020). Land transport CO2 emissions and climate change: evidence from Cyprus. International Journal of Sustainable Energy, 1-14.

Giarola, S., Mittal, S., Vielle, M., Perdana, S., Campagnolo, L., Delpiazzo, E., Bui, H., Anger-Kraavi, A., Kolpakov, A., Sognnaes, I., Peters, G.P., Hawkes, A., Koberle, A., Grant, N., Gambhir, A., Nikas, A., Doukas, H., Moreno, J., & Van de Ven, D.J. (Reviewed & Revised). Challenges in the harmonisation of global integrated assessment models: a comprehensive methodology to reduce model response heterogeneity. Science of the Total Environment.

Gidden, M., Riahi, K., Smith, S., Fujimori, S., Luderer, G., Kriegler, E., ... & Calvin, K. (2019). Global emissions pathways

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century. Geoscientific model development discussions, 12(4), 1443-1475.

Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R. The role of renewable energy in the global energy transformation. Energy Strategy Reviews. 2019 Apr 1;24:38-50.

Gil, J. D., Daioglou, V., van Ittersum, M., Reidsma, P., Doelman, J. C., van Middelaar, C. E., & van Vuuren, D. P. (2019). Reconciling global sustainability targets and local action for food production and climate change mitigation. Global Environmental Change, 59, 101983.

Gil, L., Bernardo, J., (2020). An approach to energy and climate issues aiming at carbon neutrality, Renewable Energy Focus, Volume 33, Pages 37-42, ISSN 1755-0084, https://doi.org/10.1016/j.ref.2020.03.003.

Girod, B. (2016). Product-oriented climate policy: learning from the past to shape the future. Journal of Cleaner Production, 128, 209–220. https://doi.org/10.1016/j.jclepro.2015.07.010

Gkonis, N., Arsenopoulos, A., Stamatiou, A., & Doukas, H. (2020). Multi-perspective design of energy efficiency policies under the framework of national energy and climate action plans. *Energy Policy*, *140*, 111401. https://doi.org/10.1016/j.enpol.2020.111401

Glanemann, N., Willner, S. N., & Levermann, A. (2020). Paris Climate Agreement passes the cost-benefit test. Nature communications, 11(1), 1-11.

Godinez, G., Victor-Gallardo, L., Angulo-Paniagua, J., Ramos, E., Howells, M., Usher, W., ... & Quirós-Tortós, J. (2020). How Modelling Tools Can Support Climate Change Policy: The Case of Costa Rica in the Energy Sector. Available at SSRN 3560584.

Golub, A. A., Lubowski, R. N., & Piris-Cabezas, P. (2020). Business responses to climate policy uncertainty: Theoretical analysis of a twin deferral strategy and the risk-adjusted price of carbon. Energy, 117996.

Golub, A., Lugovoy, O., & Potashnikov, V. (2019). Quantifying barriers to decarbonization of the Russian economy: real options analysis of investment risks in low-carbon technologies. Climate Policy, 19(6), 716-724.

Gonne, N. (2016). Assessing the Impact of Carbon Taxation on Sectoral Competitiveness: the Case of Belgium. Reflets et perspectives de la vie économique, 55(2), 27-40.

González-Eguino, M., Capellán-Pérez, I., Arto, I., Ansuategi, A., & Markandya, A. (2017). Industrial and terrestrial carbon leakage under climate policy fragmentation. Climate Policy, 17(sup1), S148-S169.

González-Eguino, M., Neumann, M. B., Arto, I., Capellán-Perez, I., & Faria, S. H. (2017). Mitigation implications of an ice-free summer in the Arctic Ocean. Earth's Future, 5(1), 59-66.

Goodstein, E., Lovins, L. H., (2019) A pathway to rapid global solar energy deployment Exploring the solar dominance hypothesis, Energy Research & Social Science, Volume 56, 101197, ISSN 2214-6296, doi: 10.1016/j.erss.2019.05.007

Gota, S., Huizenga, C., Peet, K., Medimorec, N., & Bakker, S. (2019). Decarbonising transport to achieve Paris Agreement targets. Energy Efficiency, 12(2), 363-386.

Goulder, L. H. (2020). Timing Is Everything: How Economists Can Better Address the Urgency of Stronger Climate Policy. Review of Environmental Economics and Policy.

Gouveia, J. P., & Palma, P. (2019). Harvesting big data from residential building energy performance certificates: retrofitting and climate change mitigation insights at a regional scale. *Environmental Research Letters*, *14*,

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

095007. https://doi.org/10.1088/1748-9326/ab3781

Granata, M. F., & Gagliano, F. (2016, April). An Integrated Assessment Model on Local Aptitudes for Green-Energy Self-sustainability. In Seminar of the Italian Society of Property Evaluation and Investment Decision (pp. 313-326). Springer, Cham.

Grant, N., Hawkes, A., Napp, T., & Gambhir, A. (2020). The appropriate use of reference scenarios in mitigation analysis. Nature Climate Change, 10(7), 605-610.

Grigoroudis, E., Kanellos, F., Kouikoglou, V. S., & Phillis, Y. A. (2017). The challenge of the Paris Agreement to contain climate change. Intelligent Automation & Soft Computing, 1-12.

Gross, S., & Matsuo, Y. (2017). Towards More Pragmatic Global Climate Goals and Policies. The King Abdullah Petroleum Studies and Research Center (KAPSARC).

Grottera, C., La Rovere, E. L., Wills, W., & Pereira Jr, A. O. (2020). The role of lifestyle changes in low-emissions development strategies: an economy-wide assessment for Brazil. Climate Policy, 20(2), 217-233.

Grubb, M., & Wieners, C. (2020). Modeling myths: on the need for dynamic realism in DICE and other equilibrium models of global climate mitigation. Institute for New Economic Thinking Working Paper Series, (112).

Grubler, A., Wilson, C., Bento, N., Boza-Kiss, B., Krey, V., McCollum, D. L., ... & Cullen, J. (2018). A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies. Nature energy, 3(6), 515-527.

Gu, G., & Wang, Z. (2018). Research on global carbon abatement driven by R&D investment in the context of INDCs. Energy, 148, 662-675.

Guivarch, C., & Rogelj, J. (2017). Carbon price variations in 2 C scenarios explored.

Guo, J. X., & Huang, C. (2020). Feasible roadmap for CCS retrofit of coal-based power plants to reduce Chinese carbon emissions by 2050. Applied Energy, 259, 114112.

Gupta, D., Ghersi, F., Vishwanathan, S. S., & Garg, A. (2019). Achieving sustainable development in India along low carbon pathways: Macroeconomic assessment. World Development, 123, 104623.

Gupta, D., Ghersi, F., Vishwanathan, S. S., & Garg, A. (2019). Macroeconomic assessment of India's development and mitigation pathways. Climate Policy, 1-21.

Gupta, R., & Gregg, M. (2018). Targeting and modelling urban energy retrofits using a city-scale energy mapping approach. Journal Of Cleaner Production, 174, 401-412. doi: 10.1016/j.jclepro.2017.10.262

Gütschow, J., Jeffery, M. L., Schaeffer, M., & Hare, B. (2018). Extending Near-Term Emissions Scenarios to Assess Warming Implications of Paris Agreement NDCs. Earth's Future, 6(9), 1242-1259.

Guzman, L., de la Hoz, D., & Monzón, A. (2015). Optimization of transport measures to reduce GHG and pollutant emissions through a LUTI modeling approach. International Journal Of Sustainable Transportation, 10(7), 590-603. doi: 10.1080/15568318.2015.1033039

Haas, R. (2019). On the draft of the Austrian National Energy and Climate Plan. *ECONOMICS AND POLICY OF ENERGY AND THE ENVIRONMENT.*

Hafeez, S., Weller, S. R., & Kellett, C. M. (2017). Impact of climate model parametric uncertainty in an MPC implementation of the DICE integrated assessment model. IFAC-PapersOnLine, 50(1), 959-965.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Haga, C., Maeda, M., Hotta, W., Inoue, T., Matsui, T., Machimura, T., ... & Saito, O. (2020). Scenario Analysis of Renewable Energy–Biodiversity Nexuses Using a Forest Landscape Model. Frontiers in Ecology and Evolution, 8, 155.

Haikola, S., Hansson, A., & Fridahl, M. (2019). Map-makers and navigators of politicised terrain: Expert understandings of epistemological uncertainty in integrated assessment modelling of bioenergy with carbon capture and storage. Futures, 114, 102472.

Hainsch, K., Brauers, H., Burandt, T., Göke, L., von Hirschhausen, C., Kemfert, C., ... & Wealer, B. (2020). Make the European Green Deal Real–Combining Climate Neutrality and Economic Recovery. DIW Berlin: Politikberatung kompakt, 153.

Handayani, K., Filatova, T., Krozer, Y., & Anugrah, P. (2020). Seeking for a climate change mitigation and adaptation nexus: Analysis of a long-term power system expansion. Applied Energy, 262, 114485.

Handayani, K., Krozer, Y., & Filatova, T. (2017). Trade-offs between electrification and climate change mitigation: An analysis of the Java-Bali power system in Indonesia. Applied energy, 208, 1020-1037.

Harmsen, M., Fricko, O., Hilaire, J., van Vuuren, D. P., Drouet, L., Durand-Lasserve, O., ... & Reis, L. A. (2019). Taking some heat off the NDCs? The limited potential of additional short-lived climate forcers' mitigation. Climatic Change, 1-19.

Harmsen, M., van Vuuren, D. P., Bodirsky, B. L., Chateau, J., Durand-Lasserve, O., Drouet, L., ... & Hilaire, J. (2019). The role of methane in future climate strategies: mitigation potentials and climate impacts. Climatic Change, 1-17.

Harper, A. B., Powell, T., Cox, P. M., House, J., Huntingford, C., Lenton, T. M., ... & Comyn-Platt, E. (2018). Land-use emissions play a critical role in land-based mitigation for Paris climate targets. Nature communications, 9(1), 1-13.

Harrison, P. A., Dunford, R. W., Holman, I. P., Cojocaru, G., Madsen, M. S., Chen, P. Y., ... & Sandars, D. (2019). Differences between low-end and high-end climate change impacts in Europe across multiple sectors. Regional Environmental Change, 19(3), 695-709.

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., ... & Mason-D'Croz, D. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change, 8(8), 699-703.

Hayashi, A., Sano, F., & Akimoto, K. (2020). On the feasibility of cropland and forest area expansions required to achieve long-term temperature targets. Sustainability Science, 1-18.

Hayman, G. D., Comyn-Platt, E., Huntingford, C., Harper, A. B., Powell, T., Cox, P. M., ... & House, J. I. (2020). Regional variation in the effectiveness of methane-based and land-based climate mitigation options. Earth System Dynamics Discussions, 1-41.

Hausfather, Z., & Peters, G. P. (2020). Emissions–the 'business as usual'story is misleading. Nature 577, 618-620.

Hdom, H. A., & Fuinhas, J. A. (2020). Energy production and trade openness: Assessing economic growth, CO2 emissions and the applicability of the cointegration analysis. Energy Strategy Reviews, 30, 100488.

He, C., Jiang, K., Chen, S., Jiang, W., & Liu, J. (2019). Zero CO2 emissions for an ultra-large city by 2050: case study for Beijing. Current opinion in environmental sustainability, 36, 141-155.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Held, H., Khabbazan, M. M., & Roshan, E. A Scheme for Jointly Trading-off Costs and Risks of Solar Radiation Management and Mitigation Under Long-tailed Climate Sensitivity Probability Density Distributions.

Helmke, H., Hafner, H. P., Gebert, F., & Pankiewicz, A. (2020). Provision of Climate Services—The XDC Model. In Handbook of Climate Services (pp. 223-249). Springer, Cham.

Helwegen, K. G., Wieners, C. E., Frank, J. E., & Dijkstra, H. A. (2019). Complementing CO2 emission reduction by solar radiation management might strongly enhance future welfare. Earth System Dynamics, 10(3), 453-472.

Herran, D. S., Tachiiri, K., & Matsumoto, K. I. (2019). Global energy system transformations in mitigation scenarios considering climate uncertainties. Applied Energy, 243, 119-131.

Heuberger, C. F., Staffell, I., Shah, N., & Mac Dowell, N. (2018). Impact of myopic decision-making and disruptive events in power systems planning. Nature Energy, 3(8), 634-640.

Hilaire, J., Minx, J. C., Callaghan, M. W., Edmonds, J., Luderer, G., Nemet, G. F., ... & del Mar Zamora, M. (2019). Negative emissions and international climate goals—learning from and about mitigation scenarios. Climatic Change, 1-31.

Ho, E., Budescu, D. V., Bosetti, V., van Vuuren, D. P., & Keller, K. (2019). Not all carbon dioxide emission scenarios are equally likely: a subjective expert assessment. Climatic Change, 155(4), 545-561.

Hof, A. F., Carrara, S., De Cian, E., Pfluger, B., van Sluisveld, M. A., de Boer, H. S., & van Vuuren, D. P. (2020). From global to national scenarios: Bridging different models to explore power generation decarbonisation based on insights from socio-technical transition case studies. Technological Forecasting and Social Change, 151, 119882.

Hof, A. F., den Elzen, M. G., Admiraal, A., Roelfsema, M., Gernaat, D. E., & Van Vuuren, D. P. (2017). Global and regional abatement costs of Nationally Determined Contributions (NDCs) and of enhanced action to levels well below 2 C and 1.5 C. Environmental Science & Policy, 71, 30-40.

Howard, D. B., Soria, R., Thé, J., Schaeffer, R., & Saphores, J. D. (2020). The energy-climate-health nexus in energy planning: A case study in Brazil. Renewable and Sustainable Energy Reviews, 132, 110016.

Huang, H., Roland-Holst, D., Wang, C., & Cai, W. (2020). China's income gap and inequality under clean energy transformation: A CGE model assessment. Journal of Cleaner Production, 251, 119626.

Huang, W., Chen, W., & Anandarajah, G. (2017). The role of technology diffusion in a decarbonizing world to limit global warming to well below 2 C: An assessment with application of Global TIMES model. Applied energy, 208, 291-301.

Hulme, M., & Dessai, S. (2008). Predicting, deciding, learning: can one evaluate the "success" of national climate scenarios? Environmental Research Letters, 3, 1–7. https://doi.org/10.1088/1748-9326/3/4/045013

Humpenöder, F., Popp, A., Bodirsky, B. L., Weindl, I., Biewald, A., Lotze-Campen, H., ... & Rolinski, S. (2018). Large-scale bioenergy production: how to resolve sustainability trade-offs?. Environmental Research Letters, 13(2), 024011.

Huppmann, D., Rogelj, J., Kriegler, E., Krey, V., & Riahi, K. (2018). A new scenario resource for integrated 1.5 C research. Nature climate change, 8(12), 1027-1030.

Huttunen, R. (2017). *Government report on the National Energy and Climate Strategy for 2030.*

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf?sequence=1&isAllowed=y

Iida, S., & Sakata, K. (2019). Hydrogen technologies and developments in Japan. Clean Energy, 3(2), 105-113.

Iyer, G., & Edmonds, J. (2018). Interpreting energy scenarios. Nature Energy, 3(5), 357-358.

Iyer, G., Calvin, K., Clarke, L., Edmonds, J., Hultman, N., Hartin, C., ... & Pizer, W. (2018). Implications of sustainable development considerations for comparability across nationally determined contributions. Nature Climate Change, 8(2), 124-129.

Iyer, G., Ledna, C., Clarke, L., Edmonds, J., McJeon, H., Kyle, P., & Williams, J. H. (2017). Measuring progress from nationally determined contributions to mid-century strategies. Nature Climate Change, 7(12), 871-874.

Jakob, M., Edenhofer, O., Kornek, U., Lenzi, D., & Minx, J. (2019). Governing the Commons to Promote Global Justice-Climate Change Mitigation and Rent Taxation.

Jeon, S., Roh, M., Oh, J., & Kim, S. (2020). Development of an Integrated Assessment Model at Provincial Level: GCAM-Korea. Energies, 13(10), 2565.

Jiang, K. (2020). Energy Transition Toward Paris Targets in China. In Future Energy (pp. 693-709). Elsevier.

Jiang, L., & O'Neill, B. C. (2017). Global urbanization projections for the Shared Socioeconomic Pathways. Global Environmental Change, 42, 193-199.

Jianlong, Y., & Haigh, M. (2020). Special Report 2: Research on China's Energy Demand Revolution. In China's Energy Revolution in the Context of the Global Energy Transition (pp. 213-285). Springer, Cham.

Jin, G., Shi, X., Zhang, L., & Hu, S. (2020). Measuring the SCCs of different Chinese regions under future scenarios. Renewable and Sustainable Energy Reviews, 130, 109949.

Johnson, N., Burek, P., Byers, E., Falchetta, G., Flörke, M., Fujimori, S., ... & Langan, S. (2019). Integrated solutions for the water-energy-land nexus: Are global models rising to the challenge?. Water, 11(11), 2223.

Jones, C. D., Ciais, P., Davis, S. J., Friedlingstein, P., Gasser, T., Peters, G. P., ... & Jackson, R. B. (2016). Simulating the Earth system response to negative emissions. Environmental Research Letters, 11(9), 095012.

Jones, E.C., Leibowicz,B. D., (2019). Contributions of shared autonomous vehicles to climate change mitigation, Transportation Research Part D: Transport and Environment, Volume 72, Pages 279-298, ISSN 1361-9209, doi: 10.1016/j.trd.2019.05.005

Kainuma, M., Pandey, R., Masui, T., & Nishioka, S. (2017). Methodologies for leapfrogging to low carbon and sustainable development in Asia. Journal of Renewable and Sustainable Energy, 9(2), 021406.

Kang, S., Selosse, S., & Maïzi, N. (2018). Contribution of global GHG reduction pledges to bioenergy expansion. Biomass and Bioenergy, 111, 142-153.

Karlsson, K., Nørgård, J., Bermúdez, J. G., Balyk, O., Wackernagel, M., Glynn, J., & Kanudia, A. (2018). The Role of Population, Affluence, Technological Development and Diet in a Below 2° C World. In Limiting Global Warming to Well Below 2° C: Energy System Modelling and Policy Development (pp. 85-102). Springer, Cham.

Kato, E., & Kurosawa, A. (2019). Evaluation of Japanese energy system toward 2050 with TIMES-Japan–deep decarbonization pathways. Energy Procedia, 158, 4141-4146.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Kato, E., Moriyama, R., & Kurosawa, A. (2017). A sustainable pathway of bioenergy with carbon capture and storage deployment. Energy Procedia, 114, 6115-6123.

Kearney, P. (2019). Re: Submission on Ireland's Draft National Energy and Climate Plan 2021-2030.

Kearney, P., Massi, C., Oliver, P., Osborne, J., Pierce, J., Poynton, G., Stanley-Smith, C., & Sweeney, J. (2019). *An Taisce's Response to the DCCAE Public Consultation on: Ireland's Draft National Energy and Climate Plan 2021-2030*.

Kefford, B. M., Ballinger, B., Schmeda-Lopez, D. R., Greig, C., & Smart, S. (2018). The early retirement challenge for fossil fuel power plants in deep decarbonisation scenarios. Energy policy, 119, 294-306.

Kemp, L. (2017). US-proofing the Paris Climate Agreement. Climate Policy, 17(1), 86–101. https://doi.org/10.1080/14693062.2016.1176007

Kerdan, I. G., Giarola, S., & Hawkes, A. (2019). A novel energy systems model to explore the role of land use and reforestation in achieving carbon mitigation targets: A Brazil case study. Journal of Cleaner Production, 232, 796-821.

Kessler, L. (2017). Estimating the economic impact of the permafrost carbon feedback. Climate Change Economics, 8(02), 1750008.

Kim, R. M., & Pathak, P. S. (2020). The Economic Implications of Eliminating Coal Subsidies in G7 Countries. Undergraduate Economic Review, 16(1), 23.

Kim, S. E., Xie, Y., Dai, H., Fujimori, S., Hijioka, Y., Honda, Y., ... & Yi, K. (2020). Air quality co-benefits from climate mitigation for human health in South Korea. Environment International, 136, 105507.

Klausbruckner, C., Henneman, L. R., Rafaj, P., & Annegarn, H. J. (2018). Energy policy, air quality, and climate mitigation in South Africa: The case for Integrated Assessment. In Systems Analysis Approach for Complex Global Challenges (pp. 113-138). Springer, Cham.

Knobloch, F., Hanssen, S. V., Lam, A., Pollitt, H., Salas, P., Chewpreecha, U., ... & Mercure, J. F. (2020). Net emission reductions from electric cars and heat pumps in 59 world regions over time. Nature Sustainability, 1-11.

Knodt, M., & Ringel, M. (2019). Creating Convergence of National Energy Policies by Increased Cooperation: EU Energy Governance and Its Impact on the German Energy Transition. In E. Gawel, S. Strunz, P. Lehmann, & A. Purkus (Eds.), *The European Dimension of Germany's Energy Transition: Opportunities and Conflicts* (pp. 123–145). Springer International Publishing. https://doi.org/10.1007/978-3-030-03374-3_8

Köberle, A. C. (2019). The Value of BECCS in IAMs: a Review. Current Sustainable/Renewable Energy Reports, 6(4), 107-115.

Köberle, A. C., Garaffa, R., Cunha, B. S., Rochedo, P., Lucena, A. F., Szklo, A., & Schaeffer, R. (2018). Are conventional energy megaprojects competitive? Suboptimal decisions related to cost overruns in Brazil. Energy Policy, 122, 689-700.

Kompas, T., Pham, V. H., & Che, T. N. (2018). The effects of climate change on GDP by country and the global economic gains from complying with the Paris climate accord. Earth's Future, 6(8), 1153-1173.

Korkmaz, P., Cunha Montenegro, R., Schmid, D., Blesl, M., & Fahl, U. (2020). On the Way to a Sustainable European Energy System: Setting Up an Integrated Assessment Toolbox with TIMES PanEU as the Key Component. Energies, 13(3), 707.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Kotchen, M. J. (2020). On the scope of climate finance to facilitate international agreement on climate change. Economics Letters, 109070.

Kotzebue, J. R., & Weissenbacher, M. (2020). The EU's Clean Energy strategy for islands: A policy perspective on Malta's spatial governance in energy transition. *Energy Policy*, *139*, 111361. https://doi.org/10.1016/j.enpol.2020.111361

Krenek, A., Sommer, M., & Schratzenstaller, M. (2019). Sustainability-oriented Future EU Funding A European Border Carbon Adjustment. http://www.wifo.ac.at/

Krey, V., Guo, F., Kolp, P., Zhou, W., Schaeffer, R., Awasthy, A., ... & He, C. (2019). Looking under the hood: A comparison of techno-economic assumptions across national and global integrated assessment models. Energy, 172, 1254-1267.

Kriegler, E., Bauer, N., Popp, A., Humpenöder, F., Leimbach, M., Strefler, J., ... & Mouratiadou, I. (2017). Fossil-fueled development (SSP5): an energy and resource intensive scenario for the 21st century. Global environmental change, 42, 297-315.

Kriegler, E., Luderer, G., Bauer, N., Baumstark, L., Fujimori, S., Popp, A., ... & Van Vuuren, D. P. (2018). Pathways limiting warming to 1.5° C: a tale of turning around in no time?. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 376(2119), 20160457.

Kriegler, E., Mouratiadou, I., Luderer, G., Bauer, N., Brecha, R. J., Calvin, K., ... & Edenhofer, O. (2016). Will economic growth and fossil fuel scarcity help or hinder climate stabilization?. Climatic Change, 136(1), 7-22.

Kriegler, E., O'Neill, B. C., Hallegatte, S., Kram, T., Lempert, R. J., Moss, R. H., & Wilbanks, T. (2012). The need for and use of socio-economic scenarios for climate change analysis: a new approach based on shared socio-economic pathways. Global Environmental Change, 22(4), 807-822.

Kriegler, E., Petermann, N., Krey, V., Schwanitz, V. J., Luderer, G., Ashina, S., ... & Paroussos, L. (2015). Diagnostic indicators for integrated assessment models of climate policy. Technological Forecasting and Social Change, 90, 45-61.

Kriegler, E., Tavoni, M., Aboumahboub, T., Luderer, G., Calvin, K., Demaere, G., ... & Van Vuuren, D. P. (2013). What does the 2 C target imply for a global climate agreement in 2020? The LIMITS study on Durban Platform scenarios. Climate Change Economics, 4(04), 1340008.

Kumar, P., Mishra, T., & Banerjee, R. (2019). Review of Indian Low Carbon Scenarios. In Climate Change Signals and Response (pp. 177-196). Springer, Singapore.

Kumari, S., Hiloidhari, M., Naik, S. N., & Dahiya, R. P. (2019). Social cost of methane: Method and estimates for Indian livestock. Environmental Development, 32, 100462.

Kuramochi, T., Höhne, N., Schaeffer, M., Cantzler, J., Hare, B., Deng, Y., ... & Mir, G. U. R. (2018). Ten key short-term sectoral benchmarks to limit warming to 1.5 C. Climate Policy, 18(3), 287-305.

Kuramochi, T., Roelfsema, M., Hsu, A., Lui, S., Weinfurter, A., Chan, S., ... & Höhne, N. (2020). Beyond national climate action: the impact of region, city, and business commitments on global greenhouse gas emissions. Climate Policy, 20(3), 275-291.

Kypreos, S., Glynn, J., Panos, E., Giannakidis, G., & Ó Gallachóir, B. (2018). Efficient and Equitable Climate Change Policies. Systems, 6(2), 10.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Kypreos, S., Glynn, J., Panos, E., Giannidakis, G., & Gallachóir, B. Ó. (2017). Energy, Climate Change and Local Atmospheric Pollution Scenarios Evaluated with the TIAM-MACRO Model.

Lacey, J., Howden, M., Cvitanovic, C., & Colvin, R. M. (2018). Understanding and managing trust at the climate science–policy interface. Nature Climate Change, 8(1), 22-28.

Lamperti, F., Dosi, G., Napoletano, M., Roventini, A., & Sapio, A. (2018). Faraway, so close: coupled climate and economic dynamics in an agent-based integrated assessment model. Ecological Economics, 150, 315-339.

Larch, M., & Wanner, J. (2017). Carbon tariffs: An analysis of the trade, welfare, and emission effects. Journal of International Economics, 109, 195–213.

Larkin, A., Kuriakose, J., Sharmina, M., & Anderson, K. (2018). What if negative emission technologies fail at scale? Implications of the Paris Agreement for big emitting nations. Climate policy, 18(6), 690-714.

Lazarou, S., Christodoulou, C., & Vita, V. (2019, September). Global Change Assessment Model (GCAM) considerations of the primary sources energy mix for an energetic scenario that could meet Paris agreement. In 2019 54th International Universities Power Engineering Conference (UPEC) (pp. 1-5). IEEE.

Lazarou, S., Ekonomou, L., & Dagoumas, A. (2018). Correlation between representative concentration pathways and paris agreement. International Journal of Renewable Energy Research, 8(2).

Lazarou, S., Vita, V., Diamantaki, M., Karanikolou-Karra, D., Fragoyiannis, G., Makridis, S., & Ekonomou, L. (2018). A simulated roadmap of hydrogen technology contribution to climate change mitigation based on R epresentative C oncentration P athways considerations. Energy Science & Engineering, 6(3), 116-125.

Le Quéré, C., Jackson, R. B., Jones, M. W., Smith, A. J., Abernethy, S., Andrew, R. M., ... & Friedlingstein, P. (2020). Temporary reduction in daily global CO 2 emissions during the COVID-19 forced confinement. Nature Climate Change, 1-7.

Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., ... & Wilcox, L.J. (2020). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmospheric Environment, 117834.

Lee, H., Brown, C., Seo, B., Holman, I., Audsley, E., Cojocaru, G., & Rounsevell, M. (2019). Implementing land-based mitigation to achieve the Paris Agreement in Europe requires food system transformation. Environmental Research Letters, 14(10), 104009.

Leimbach, M., & Giannousakis, A. (2019). Burden sharing of climate change mitigation: global and regional challenges under shared socio-economic pathways. Climatic Change, 155(2), 273-291.

Leimbach, M., Roming, N., Schultes, A., & Schwerhoff, G. (2018). Long-term development perspectives of Sub-Saharan Africa under climate policies. Ecological Economics, 144, 148-159.

Lempert, R. (2013). Scenarios that illuminate vulnerabilities and robust responses. Climatic Change, 117(4), 627–646. https://doi.org/10.1007/s10584-012-0574-6

Levesque, A., Pietzcker, R. C., & Luderer, G. (2019). Halving energy demand from buildings: The impact of low consumption practices. Technological Forecasting and Social Change, 146, 253-266.

Li, F. G. (2017). Actors behaving badly: exploring the modelling of non-optimal behaviour in energy transitions. Energy Strategy Reviews, 15, 57-71.

Li, F. G., & Strachan, N. (2019). Take me to your leader: Using socio-technical energy transitions (STET) modelling to explore the role of actors in decarbonisation pathways. Energy Research & Social Science, 51, 67-81.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Li, F. G., & Trutnevyte, E. (2017). Investment appraisal of cost-optimal and near-optimal pathways for the UK electricity sector transition to 2050. Applied energy, 189, 89-109.

Li, J., Hamdi-Cherif, M., & Cassen, C. (2017). Aligning domestic policies with international coordination in a post-Paris global climate regime: A case for China. Technological Forecasting and Social Change, 125, 258-274.

Li, N., & Chen, W. (2019). Energy-water nexus in China's energy bases: From the Paris agreement to the Well Below 2 Degrees target. Energy, 166, 277-286.

Li, N., Chen, W., Rafaj, P., Kiesewetter, G., Schöpp, W., Wang, H., ... & Riahi, K. (2019). Air quality improvement co-benefits of low-carbon pathways toward well below the 2° C climate target in China. Environmental science & technology, 53(10), 5576-5584.

Li, W., & Jia, Z. (2016). The impact of emission trading scheme and the ratio of free quota: A dynamic recursive CGE model in China. Applied Energy, 174, 1-14.

Li, W., & Jia, Z. (2017). Carbon tax, emission trading, or the mixed policy: which is the most effective strategy for climate change mitigation in China?. Mitigation and Adaptation Strategies for Global Change, 22(6), 973-992.

Liu, J. Y., Fujimori, S., Takahashi, K., Hasegawa, T., Su, X., & Masui, T. (2018). Socioeconomic factors and future challenges of the goal of limiting the increase in global average temperature to 1.5 C. Carbon Management, 9(5), 447-457.

Liu, J. Y., Fujimori, S., Takahashi, K., Hasegawa, T., Wu, W., Takakura, J. Y., & Masui, T. (2019). Identifying trade-offs and co-benefits of climate policies in China to align policies with SDGs and achieve the 2° C goal. Environmental Research Letters, 14(12), 124070.

Liu, L. J., Creutzig, F., Yao, Y. F., Wei, Y. M., & Liang, Q. M. (2020). Environmental and economic impacts of trade barriers: The example of China–US trade friction. Resource and Energy Economics, 59, 101144.

Liu, W., McKibbin, W. J., Morris, A. C., & Wilcoxen, P. J. (2020). Global economic and environmental outcomes of the Paris Agreement. Energy Economics, 104838.

Liu, W., Sun, F., Lim, W. H., Zhang, J., Wang, H., Shiogama, H., & Zhang, Y. (2018). Global drought and severe drought-affected populations in 1.5 and 2 C warmer worlds. Earth System Dynamics, 9(1), 267.

Lomborg, B. (2020). Welfare in the 21st century: Increasing development, reducing inequality, the impact of climate change, and the cost of climate policies. Technological Forecasting and Social Change, 156, 119981.

Lopion, P., Markewitz, P., Robinius, M., & Stolten, D. (2018). A review of current challenges and trends in energy systems modeling. Renewable and sustainable energy reviews, 96, 156-166.

Lovins, A. B., Ürge-Vorsatz, D., Mundaca, L., Kammen, D. M., & Glassman, J. W. (2019). Recalibrating climate prospects. Environmental Research Letters, 14(12), 120201.

Lowe, J. A., Arnell, N. W., Warren, R., Gambhir, A. J., Bernie, D., & Thompson, E. (2017). Avoiding dangerous climate: results from the AVOID2 programme. Weather, 72(11), 340-345.

Lucas, P. L., Hilderink, H. B., Janssen, P. H., Samir, K. C., van Vuuren, D. P., & Niessen, L. (2019). Future impacts of environmental factors on achieving the SDG target on child mortality—A synergistic assessment. Global Environmental Change, 57, 101925.

Luderer, G., Pehl, M., Arvesen, A., Gibon, T., Bodirsky, B. L., de Boer, H. S., ... & Mima, S. (2019). Environmental co-

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

benefits and adverse side-effects of alternative power sector decarbonization strategies. Nature communications, 10(1), 1-13.

Luderer, G., Vrontisi, Z., Bertram, C., Edelenbosch, O. Y., Pietzcker, R. C., Rogelj, J., ... & Fujimori, S. (2018). Residual fossil CO 2 emissions in 1.5–2 C pathways. Nature Climate Change, 8(7), 626-633.

Lugovoy, O., Feng, X. Z., Gao, J., Li, J. F., Liu, Q., Teng, F., & Zou, L. L. (2018). Multi-model comparison of CO2 emissions peaking in China: Lessons from CEMF01 study. Advances in Climate Change Research, 9(1), 1-15.

Luh, S., Budinis, S., Giarola, S., Schmidt, T. J., & Hawkes, A. (2020). Long-term development of the industrial sector–Case study about electrification, fuel switching, and CCS in the USA. Computers & Chemical Engineering, 133, 106602.

Lund, H., Arler, F., Østergaard, P. A., Hvelplund, F., Connolly, D., Mathiesen, B. V., & Karnøe, P. (2017). Simulation versus optimisation: theoretical positions in energy system modelling. Energies, 10(7), 840.

Majocchi, A. (2018). Carbon Pricing and Border Tax Adjustments: The Compatibility with WTO Rules.

Malik, A., Bertram, C., Després, J., Emmerling, J., Fujimori, S., Garg, A., ... & Shekhar, S. (2020). Reducing stranded assets through early action in the Indian power sector. Environmental Research Letters.

Mander, S., Anderson, K., Larkin, A., Gough, C., & Vaughan, N. (2017). The role of bio-energy with carbon capture and storage in meeting the climate mitigation challenge: A whole system perspective. Energy Procedia, 114, 6036-6043.

Mandley, S. J., Daioglou, V., Junginger, H. M., van Vuuren, D. P., & Wicke, B. (2020). EU bioenergy development to 2050. Renewable and Sustainable Energy Reviews, 127, 109858.

Manoussi, V., Shayegh, S., & Tavoni, M. (2017). Optimal Carbon Dioxide Removal in Face of Ocean Carbon Sink Feedback.

Marceau, G. (2016). The World Trade Organization and Export Restrictions. In Emerging Issues in Sustainable Development (pp. 99–137). Springer.

Marcucci, A., Kypreos, S., & Panos, E. (2017). The road to achieving the long-term Paris targets: energy transition and the role of direct air capture. Climatic Change, 144(2), 181-193.

Marcucci, A., Panos, E., Kypreos, S., & Fragkos, P. (2019). Probabilistic assessment of realizing the 1.5° C climate target. Applied Energy, 239, 239-251.

Marin, G., & Zoboli, R. (2016). The integrated economic and environmental footprint of the EU: domestic and global effects of a transition to services (No. 0816). SEEDS, Sustainability Environmental Economics and Dynamics Studies.

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., & González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. The Lancet Planetary Health, 2(3), e126-e133.

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., & González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. The Lancet Planetary Health, 2(3), e126-e133.

Mastrucci, A., Pérez-López, P., Benetto, E., Leopold, U., Blanc, I., (2017). Global sensitivity analysis as a support for

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

the generation of simplified building stock energy models, Energy and Buildings, Volume 149, Pages 368-383, ISSN 0378-7788, doi: 10.1016/j.enbuild.2017.05.022

Matar, W., & Elshurafa, A. M. (2017). Striking a balance between profit and carbon dioxide emissions in the Saudi cement industry. International Journal of Greenhouse Gas Control, 61, 111-123.

Matsuo, Y., Endo, S., Nagatomi, Y., Shibata, Y., Komiyama, R., & Fujii, Y. (2020). Investigating the economics of the power sector under high penetration of variable renewable energies. Applied Energy, 267, 113956.

Mauleón, I., (2017) Photovoltaic investment roadmaps and sustainable development, Journal of Cleaner Production, Volume 167, Pages 1112-1121, ISSN 0959-6526, doi: 10.1016/j.jclepro.2017.08.148

McCollum, D. L., Echeverri, L. G., Busch, S., Pachauri, S., Parkinson, S., Rogelj, J., ... & Riahi, K. (2018). Connecting the sustainable development goals by their energy inter-linkages. Environmental Research Letters, 13(3), 033006.

McCollum, D. L., Gambhir, A., Rogelj, J., & Wilson, C. (2020). Energy modellers should explore extremes more systematically in scenarios. Nature Energy, 5(2), 104-107.

McCollum, D. L., Zhou, W., Bertram, C., De Boer, H. S., Bosetti, V., Busch, S., ... & Fricko, O. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. Nature Energy, 3(7), 589-599.

Mcdowall, W., Trutnevyte, E., Tomei, J., & Keppo, I. (2014). Reflecting on scenarios. UKERC energy systems theme working paper (Issue June). http://discovery.ucl.ac.uk/1457412/1/McDowall_Reflecting on Scenarios Working Paper-3.pdf

McLaren, D., & Markusson, N. (2020). The co-evolution of technological promises, modelling, policies and climate change targets. Nature Climate Change, 1-6.

McLaren, D., & Markusson, N. (2020). The co-evolution of technological promises, modelling, policies and climate change targets. Nature Climate Change 10, 392–397.

Mclaughlin, O. (2019). Market-driven Climate Policy in Two Systems Strategic Development, Implementation, and Effectiveness of Emissions Trading Systems in the European Union and China.

McMahon, R., Stauffacher, M., & Knutti, R. (2015). The unseen uncertainties in climate change: reviewing comprehension of an IPCC scenario graph. Climatic change, 133(2), 141-154.

Mehling, M. A., Van Asselt, H., Das, K., & Droege, S. (2018). Beat protectionism and emissions at a stroke comment. In Nature (Vol. 559, Issue 7714, pp. 321–324). Nature Publishing Group. https://doi.org/10.1038/d41586-018-05708-7

Mehling, M. A., Van Asselt, H., Das, K., Droege, S., & Verkuijl, C. (2019). Designing Border Carbon Adjustments for Enhanced Climate Action. American Journal of International Law, 113(3), 433–481.

Meng, S., Siriwardana, M., McNeill, J., & Nelson, T. (2018). The impact of an ETS on the Australian energy sector: An integrated CGE and electricity modelling approach. Energy Economics, 69, 213-224.

Mengel, M., Nauels, A., Rogelj, J., & Schleussner, C. F. (2018). Committed sea-level rise under the Paris Agreement and the legacy of delayed mitigation action. Nature communications, 9(1), 601.

Mercure, J. F., Lam, A., Billington, S., & Pollitt, H. (2018). Integrated assessment modelling as a positive science: private passenger road transport policies to meet a climate target well below 2∘ C. Climatic change, 151(2),

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

109-129.

Mercure, J. F., Pollitt, H., Edwards, N. R., Holden, P. B., Chewpreecha, U., Salas, P., ... & Vinuales, J. E. (2018). Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE. Energy Strategy Reviews, 20, 195-208.

Mercure, J. F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., ... & Knobloch, F. (2018). Macroeconomic impact of stranded fossil fuel assets. Nature Climate Change, 8(7), 588-593.

Mezősi, A., Felsmann, B., Kerekes, L., & Szabó, L. (2020). Coexistence of nuclear and renewables in the V4 electricity system: Friends or enemies?. Energy Policy, 140, 111449.

Mi, Z., Liao, H., Coffman, D. M., & Wei, Y. M. (2019). Assessment of equity principles for international climate policy based on an integrated assessment model. Natural Hazards, 95(1-2), 309-323.

Michaelis, P., & Wirths, H. (2020). DICE-RD: an implementation of rate-related damages in the DICE model. Environmental Economics and Policy Studies, 1-30.

Michas, S., Stavrakas, V., Papadelis, S., & Flamos, A. (2020). A transdisciplinary modeling framework for the participatory design of dynamic adaptive policy pathways. Energy Policy, 139, 111350.

Mideksa, T. K. (2010). Economic and distributional impacts of climate change: The case of Ethiopia. Global Environmental Change, 20(2), 278-286.

Millar, R., Allen, M., Rogelj, J., & Friedlingstein, P. (2016). The cumulative carbon budget and its implications. Oxford Review of Economic Policy, 32(2), 323-342.

Miller, C. A., & Wyborn, C. (2018). Co-production in global sustainability: histories and theories. Environmental Science & Policy, in press.

Mintenig, J., Khabbazan, M. M., & Held, H. (2017). The role of Bioenergy and Carbon Capture and Storage (BECCS) in the case of delayed climate policy–insights from cost-risk analysis. Earth System Dynamics Discussions In review: doi: https://doi. org/10.5194/esd-2017-117.

Miralles-Wilhelm, F., & Muñoz, R. (2017). An analysis of the Water-Energy-Food Nexus in Latin America and the Caribbean Region: identifying synergies and tradeoffs through integrated assessment modeling. The International Journal of Engineering and Science, 7(1).

Monier, E., Paltsev, S., Sokolov, A., Chen, Y. H. H., Gao, X., Ejaz, Q., ... & Scott, J. (2018). Toward a consistent modeling framework to assess multi-sectoral climate impacts. Nature communications, 9(1), 1-8.

Monti, A., & Martinez Romera, B. (2020). Fifty shades of binding: Appraising the enforcement toolkit for the EU's 2030 renewable energy targets. *Review of European, Comparative & International Environmental Law*. https://doi.org/10.1111/reel.12330

Morgan, M. G., & Keith, D. W. (2008). Improving the way we think about projecting future energy use and emissions of carbon dioxide. Climatic Change, 90(3), 189–215. https://doi.org/10.1007/s10584-008-9458-1

Mori, S. (2016). A new approach of carbon emission allocation among stakeholders: an expansion of Multiregional and Multisectoral Dynamic Energy-Economic Model THERESIA. Journal Of Economic Structures, 5(1). doi: 10.1186/s40008-016-0036-9

Mori, S., & Shiogama, H. (2018). The value of knowledge accumulation on climate sensitivity uncertainty: comparison between perfect information, single stage and act then learn decisions. Sustainability

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

science, 13(2), 351-368.

Mori, S., Washida, T., Kurosawa, A., & Masui, T. (2018). Assessment of mitigation strategies as tools for risk management under future uncertainties: a multi-model approach. Sustainability science, 13(2), 329-349.

Mouratiadou, I., Bevione, M., Bijl, D. L., Drouet, L., Hejazi, M., Mima, S., ... & Luderer, G. (2018). Water demand for electricity in deep decarbonisation scenarios: a multi-model assessment. Climatic change, 147(1-2), 91-106.

Moya, D., Budinis, S., Giarola, S., & Hawkes, A. (2020). Agent-based scenarios comparison for assessing fuel-switching investment in long-term energy transitions of the India's industry sector. Applied Energy, 274, 115295.

Müller, B., Gardumi, F., & Hülk, L. (2018). Comprehensive representation of models for energy system analyses: Insights from the Energy Modelling Platform for Europe (EMP-E) 2017. Energy strategy reviews, 21, 82-87.

Mulvaney, K. M., Selin, N. E., Giang, A., Muntean, M., Li, C. T., Zhang, D., ... & Karplus, V. J. (2020). Mercury Benefits of Climate Policy in China: Addressing the Paris Agreement and the Minamata Convention Simultaneously. Environmental Science & Technology, 54(3), 1326-1335.

Muñoz Castillo, R., & Miralles-Wilhelm, F. (2020). Energy-Water-Land Nexus in Latin America and the Caribbean: A Perspective from the Paris Agreement Climate Mitigation Pledges (No. 8961). Inter-American Development Bank.

Musonye, X. S., Davíðsdóttir, B., Kristjánsson, R., Ásgeirsson, E. I., & Stefánsson, H. (2020). Integrated energy systems' modeling studies for sub-Saharan Africa: A scoping review. Renewable and Sustainable Energy Reviews, 128, 109915.

Nabernegg, S., Bednar-Friedl, B., Munoz, P., Titz, M., & Vogel, J. (2018). GEP.

Napp, T. A., Few, S., Sood, A., Bernie, D., Hawkes, A., & Gambhir, A. (2019). The role of advanced demand-sector technologies and energy demand reduction in achieving ambitious carbon budgets. Applied energy, 238, 351-367.

National energy and climate plans (NECPs) - Energy European Commission. (2020). Retrieved 31 July 2020, from https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en

National Research Council. (2009). Informing Decisions in a Changing Climate. Panel on Strategies and Methods for Climate-Related Decision Support (Issue January). National Academies Press. https://doi.org/10.17226/12626

Nature Climate Change (2015). IAM helpful or not? Nature Climate Change 5, 81. https://doi.org/10.1038/nclimate2526

Nauels, A., Rogelj, J., Schleussner, C. F., Meinshausen, M., & Mengel, M. (2017). Linking sea level rise and socioeconomic indicators under the Shared Socioeconomic Pathways. Environmental Research Letters, 12(11), 114002.

Navas-Anguita, Z., García-Gusano, D., Dufour, J., & Iribarren, D. (2020). Prospective techno-economic and environmental assessment of a national hydrogen production mix for road transport. *Applied Energy*, *259*, 114121. https://doi.org/10.1016/j.apenergy.2019.114121

Nerini, F. F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., ... & Milligan, B. (2019). Connecting climate

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

action with other Sustainable Development Goals. Nature Sustainability, 2(8), 674-680.

Niamir, L., Kiesewetter, G., Wagner, F., Schöpp, W., Filatova, T., Voinov, A., & Bressers, H. (2020). Assessing the macroeconomic impacts of individual behavioral changes on carbon emissions. Climatic change, 158(2), 141-160.

Nie, Y., Cai, W., Wang, C., Huang, G., Ding, Q., Yu, L., ... & Ji, D. (2019). Assessment of the potential and distribution of an energy crop at 1-km resolution from 2010 to 2100 in China–The case of sweet sorghum. Applied Energy, 239, 395-407.

Nienaber, M. (2019). France persuades Germany to consider EU carbon border tax. Reuters. Retrieved 27 July 2020, from https://www.reuters.com/article/us-france-germany-carbonbordertax/france-persuades-germany-to-consider-eu-carbon-border-tax-idUSKBN1W42BL.

Nieto, J., Carpintero, Ó., Miguel, L. J., & de Blas, I. (2020). Macroeconomic modelling under energy constraints: Global low carbon transition scenarios. Energy Policy, 137, 111090.

Nikas, A., Doukas, H., & Papandreou, A. (2019a). A detailed overview and consistent classification of climate-economy models. In Understanding Risks and Uncertainties in Energy and Climate Policy (pp. 1-54). Springer, Cham.

Nikas, A., Lieu, J., Sorman, A., Gambhir, A., Turhan, E., & Doukas, H. (2020). The desirability of transitions in demand: Incorporating behavioural and societal transformations into energy modelling. Energy Research & Social Science, 70, 101780.

Nikas, A., Neofytou, H., Karamaneas, A., Koasidis, K., & Psarras, J. (2020). Sustainable and socially just transition to a post-lignite era in Greece: a multi-level perspective. *Energy Sources, Part B: Economics, Planning, and Policy*, 1–32. https://doi.org/10.1080/15567249.2020.1769773

Nikas, A., Ntanos, E., & Doukas, H. (2019b). A semi-quantitative modelling application for assessing energy efficiency strategies. Applied Soft Computing, 76, 140-155.

Nikas, A., Stavrakas, V., Arsenopoulos, A., Doukas, H., Antosiewicz, M., Witajewski-Baltvilks, J., & Flamos, A. (2020). Barriers to and consequences of a solar-based energy transition in Greece. Environmental Innovation and Societal Transitions, 35, 383-399.

Nikas, A., et al. (submitted). Implications of stagnated climate policy effort in the EU: a stakeholder-driven model-intercomparison project. Energy.

Nordhaus, W. (2018). Projections and uncertainties about climate change in an era of minimal climate policies. American Economic Journal: Economic Policy, 10(3), 333-60.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. American Economic Review, 109(6), 1991-2014.

Novikova, A., Stelmakh, K., Klinge, A., & Stamo, I. (2016). Climate and energy investment map of Germany. *Status Report*.

O'Neill, B. C., Jiang, L., Samir, K. C., Fuchs, R., Pachauri, S., Laidlaw, E. K., ... & Ren, X. (2020). The effect of education on determinants of climate change risks. Nature Sustainability, 1-9.

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., ... & Levy, M. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Environmental Change, 42, 169-180.

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., ... & van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic change, 122(3), 387-400.

O'Neill, B., & Nakicenovic, N. (2008). Learning from global emissions scenarios. Environmental Research Letters, 3(4). https://doi.org/10.1088/1748-9326/3/4/045014

Oberthür, S. (2019). Hard or soft governance? The EU's climate and energy policy framework for 2030. *Politics and Governance*, *7*(1), 17–27.

Obringer, R., Kumar, R., & Nateghi, R. (2020). Managing the water–electricity demand nexus in a warming climate. Climatic Change, 159(2), 233-252.

Orthofer, C. L., Huppmann, D., & Krey, V. (2019). South Africa After Paris—Fracking Its Way to the NDCs?. Frontiers in Energy Research, 7, 20.

Oshiro, K., Gi, K., Fujimori, S., van Soest, H. L., Bertram, C., Després, J., ... & Vrontisi, Z. (2019). Mid-century emission pathways in Japan associated with the global 2 C goal: national and global models' assessments based on carbon budgets. Climatic Change, 1-15.

Oshiro, K., Kainuma, M., & Masui, T. (2017). Implications of Japan's 2030 target for long-term low emission pathways. Energy Policy, 110, 581-587.

Oshiro, K., Masui, T., & Kainuma, M. (2018). Transformation of Japan's energy system to attain net-zero emission by 2050. Carbon Management, 9(5), 493-501.

Otto, C., Piontek, F., Kalkuhl, M., & Frieler, K. (2020). Event-based models to understand the scale of the impact of extremes. Nature Energy, 5(2), 111-114.

Otto, I. M., Wiedermann, M., Cremades, R., Donges, J. F., Auer, C., & Lucht, W. (2020). Human agency in the Anthropocene. Ecological Economics, 167, 106463.

Overland, I., & Sovacool, B. K. (2020). The misallocation of climate research funding. Energy Research & Social Science, 62, 101349.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. Science and public policy, 39(6), 751-760.

Pade-Khene, C., Luton, R., Jordaan, T., Hildbrand, S., Proches, C. G., Sitshaluza, A., ... & Moloto, N. (2013). Complexity of stakeholder interaction in applied research. Ecology and Society, 18(2).

Paim, M. A., Dalmarco, A. R., Yang, C. H., Salas, P., Lindner, S., Mercure, J. F., ... & Viñuales, J. E. (2019). Evaluating regulatory strategies for mitigating hydrological risk in Brazil through diversification of its electricity mix. Energy Policy, 128, 393-401.

Palacková, E. (2019). Saving face and facing climate change: Are border adjustments a viable option to stop carbon leakage? European View, 18(2), 149–155.

Paladugula, A. L., Kholod, N., Chaturvedi, V., Ghosh, P. P., Pal, S., Clarke, L., ... & Qamar, S. (2018). A multi-model assessment of energy and emissions for India's transportation sector through 2050. Energy Policy, 116, 10-18.

Pan, X., & Teng, F. (2017). Assessment of China's Mitigation Targets in an Effort-Sharing

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Framework. Sustainability, 9(7), 1104.

Pan, X., Chen, W., Wang, L., Lin, L., & Li, N. (2018). The role of biomass in China's long-term mitigation toward the Paris climate goals. Environmental Research Letters, 13(12), 124028

Pan, X., den Elzen, M., Höhne, N., Teng, F., & Wang, L. (2017). Exploring fair and ambitious mitigation contributions under the Paris Agreement goals. Environmental Science & Policy, 74, 49-56.

Pan, X., Wang, H., Wang, L., & Chen, W. (2018). Decarbonization of China's transportation sector: in light of national mitigation toward the Paris Agreement goals. Energy, 155, 853-864.

Pan, X., Wang, L., Dai, J., Zhang, Q., Peng, T., & Chen, W. (2020). Analysis of China's oil and gas consumption under different scenarios toward 2050: An integrated modeling. Energy, 195, 116991.

Papadimitriou, L., Holman, I. P., Dunford, R., & Harrison, P. A. (2019). Trade-offs are unavoidable in multi-objective adaptation even in a post-Paris Agreement world. Science of the Total Environment, 696, 134027.

Parker, C. F., Karlsson, C., & Hjerpe, M. (2017). Assessing the European Union's global climate change leadership: from Copenhagen to the Paris Agreement. Journal of European Integration, 39(2), 239-252.

Parkinson, S., Krey, V., Huppmann, D., Kahil, T., McCollum, D., Fricko, O., ... & Raptis, C. (2019). Balancing clean water-climate change mitigation trade-offs. Environmental Research Letters, 14(1), 014009.

Parson, E. A. (2008). Useful global-change scenarios: Current issues and challenges. Environmental Research Letters, 3(4). https://doi.org/10.1088/1748-9326/3/4/045016

Parson, E., Burkett, V., & Fisher-vanden, K. (2007). Global-change scenarios: Their development and use. US Department of Energy Publications, 7.

Patrizio, P., Leduc, S., Kraxner, F., Fuss, S., Kindermann, G., Mesfun, S., ... & Lundgren, J. (2018). Reducing US coal emissions can boost employment. Joule, 2(12), 2633-2648.

Pauliuk, S., Arvesen, A., Stadler, K., & Hertwich, E. G. (2017). Industrial ecology in integrated assessment models. Nature Climate Change, 7(1), 13-20.

Pedde, S., Kok, K., Hölscher, K., Frantzeskaki, N., Holman, I., Dunford, R., ... & Jäger, J. (2019). Advancing the use of scenarios to understand society's capacity to achieve the 1.5 degree target. Global Environmental Change, 56, 75-85.

Pehl, M., Arvesen, A., Humpenöder, F., Popp, A., Hertwich, E. G., & Luderer, G. (2017). Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling. Nature Energy, 2(12), 939-945.

Peng, P., Ren, X., Zhu, L., Fan, Y., & Massimo, T. (2019). A Comparison of Two Approaches for Damage Evaluation on Optimal Mitigation and Adaptation Responses in China. Journal of Systems Science and Complexity, 32(6), 1641-1658.

Perdana, S., & Tyers, R. (2017). Global Climate Change Mitigation: Strategic Interaction or Unilateral Gains?. In Meeting the Energy Demands of Emerging Economies, 40th IAEE International Conference, June 18-21, 2017. International Association for Energy Economics.

Peters, G. P. (2018). Beyond carbon budgets. Nature Geoscience, 11(6), 378-380.

Peters, J. C. (2016). GTAP-E-Power: an electricity-detailed economy-wide model. Journal of Global Economic Analysis, 1(2), 156-187.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Petterson Molina Vale, (2016) The changing climate of climate change economics, Ecological Economics, Volume 121, Pages 12-19, ISSN 0921-8009, doi: 10.1016/j.ecolecon.2015.10.018

Pezzey, J. C. (2018). High unknowability of climate damage valuation means the social cost of carbon will always be disputed. Centre for Climate Economics & Policy, Crawford School of Public Policy, The Australian National University.

Pfeiffer, A., Hepburn, C., Vogt-Schilb, A., & Caldecott, B. (2018). Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement. Environmental Research Letters, 13(5), 054019.

Pfenninger, S., Hirth, L., Schlecht, I., Schmid, E., Wiese, F., Brown, T., ... & Hilpert, S. (2018). Opening the black box of energy modelling: Strategies and lessons learned. Energy Strategy Reviews, 19, 63-71.

Philippidis, G., Bartelings, H., Helming, J., M'barek, R., Ronzon, T., Smeets, E., ... & Shutes, L. (2018). The MAGNET model framework for assessing policy coherence and SDGs.

Pidgeon, N., & Fischhoff, B. (2011). The role of social and decision sciences in communicating uncertain climate risks. Nature climate change, 1(1), 35-41.

Pielke, R., & Ritchie, J. (2020). Systemic Misuse of Scenarios in Climate Research and Assessment.

Pluta, M., Suwala, W., & Wyrwa, A. (2019). Review of the Polish integrated National Energy and Climate draft Plan 2021-2030. *ECONOMICS AND POLICY OF ENERGY AND THE ENVIRONMENT*.

Pollitt, H., Neuhoff, K., & Lin, X. (2020). The impact of implementing a consumption charge on carbon-intensive materials in Europe. Climate Policy, 20(sup1), S74-S89.

Porfirio, L. L., Newth, D., Finnigan, J. J., & Cai, Y. (2018). Economic shifts in agricultural production and trade due to climate change. Palgrave Communications, 4(1), 1-9.

Porterfield, M. C. (2019). Border adjustments for carbon Taxes, PPMS, and the WTO. University of Pennsylvania Journal of International Law, 41(1), 1–41.

Portugal-Pereira, J., Koberle, A., Lucena, A. F., Rochedo, P. R., Império, M., Carsalade, A. M., ... & Rafaj, P. (2018). Interactions between global climate change strategies and local air pollution: lessons learnt from the expansion of the power sector in Brazil. Climatic Change, 148(1-2), 293-309.

Pozo, C., Galán-Martín, Á., Reiner, D. M., Mac Dowell, N., & Guillén-Gosálbez, G. (2020). Equity in allocating carbon dioxide removal quotas. Nature Climate Change, 10, 640-646.

Pradhan, B. B., Shrestha, R. M., & Limmeechokchai, B. (2020). Achieving the Paris Agreement's 2 degree target in Nepal: the potential role of a carbon tax. Climate Policy, 20(3), 387-404.

Price, P., McGeever, A., Jones, M., McMullin, B., A Post-Paris Literature Review of Negative Emissions Technology, and Potential for Ireland. Working Paper, Dublin City University and Trinity College Dublin, January 2018. http://ienets.eeng.dcu.ie/documents/Lit-Review-2018-01.pdf

Prina, M. G., Manzolini, G., Moser, D., Nastasi, B., & Sparber, W. (2020). Classification and challenges of bottom-up energy system models-A review. Renewable and Sustainable Energy Reviews, 129, 109917.

Prina, M. G., Manzolini, G., Moser, D., Vaccaro, R., & Sparber, W. (2020). Multi-Objective Optimization Model EPLANopt for Energy Transition Analysis and Comparison with Climate-Change Scenarios. Energies, 13(12), 3255.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Purohit, P., Amann, M., Kiesewetter, G., Rafaj, P., Chaturvedi, V., Dholakia, H. H., ... & Schöpp, W. (2019). Mitigation pathways towards national ambient air quality standards in India. Environment international, 133, 105147.

Pye, S., Li, F. G., Petersen, A., Broad, O., McDowall, W., Price, J., & Usher, W. (2018). Assessing qualitative and quantitative dimensions of uncertainty in energy modelling for policy support in the United Kingdom. Energy research & social science, 46, 332-344.

Qi, T., Winchester, N., Karplus, V. J., Zhang, D., & Zhang, X. (2016). An analysis of China's climate policy using the China-in-Global Energy Model. Economic Modelling, 52, 650-660.

Qimin, C., Sha, F., & Xinyuan, W. (2020). Modeling the implementation of NDCs and the scenarios below 2° C for the Belt and Road countries. Ecosystem Health and Sustainability, 1766998.

Rafaj, P., Kiesewetter, G., Gül, T., Schöpp, W., Cofala, J., Klimont, Z., ... & Cozzi, L. (2018). Outlook for clean air in the context of sustainable development goals. Global Environmental Change, 53, 1-11.

Randt, N. P. (2016). Aircraft technology assessment using fleet-level metrics (Doctoral dissertation, Technische Universität München).

Rao, N. D., Min, J., & Mastrucci, A. (2019). Energy requirements for decent living in India, Brazil and South Africa. Nature Energy, 4(12), 1025-1032.

Rasmussen, D. J., Bittermann, K., Buchanan, M. K., Kulp, S., Strauss, B. H., Kopp, R. E., & Oppenheimer, M. (2018). Extreme sea level implications of 1.5 C, 2.0 C, and 2.5 C temperature stabilization targets in the 21st and 22nd centuries. Environmental Research Letters, 13(3), 034040.

Rauner, S., Bauer, N., Dirnaichner, A., Van Dingenen, R., Mutel, C., & Luderer, G. (2020). Coal-exit health and environmental damage reductions outweigh economic impacts. Nature Climate Change, 10(4), 308-312.

Rauner, S., Hilaire, J., Klein, D., Strefler, J., & Luderer, G. (2020). Air quality co-benefits of ratcheting up the NDCs. Climatic Change, 1-20.

Realmonte, G., Drouet, L., Gambhir, A., Glynn, J., Hawkes, A., Köberle, A. C., & Tavoni, M. (2019). An inter-model assessment of the role of direct air capture in deep mitigation pathways. Nature communications, 10(1), 1-12.

Reis, L., Emmerling, J., Tavoni, M., & Raitzer, D. (2016). The Economics of Greenhouse Gas Mitigation in Developing Asia. Asian Development Bank Economics Working Paper Series, (504).

Reisinger, A., & Clark, H. (2018). How much do direct livestock emissions actually contribute to global warming?. Global change biology, 24(4), 1749-1761.

Report of the High-Level Commission on Carbon Prices — Carbon Pricing Leadership Coalition. (2020). Retrieved 16 July 2020, from https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices

Riahi, K., Krey, V., Bertram, C., Kriegler, E., Luderer, G., van Vuuren, D., ... & Pahle, M. (2019). Linking Climate and Sustainable Development: Policy insights from national and global pathways. International Institute for Applied Systems Analysis (IIASA).

Riahi, K., Kriegler, E., Johnson, N., Bertram, C., Den Elzen, M., Eom, J., ... & Longden, T. (2015). Locked into Copenhagen pledges—implications of short-term emission targets for the cost and feasibility of long-term climate goals. Technological Forecasting and Social Change, 90, 8-23.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Riahi, K., Van Vuuren, D. P., Kriegler, E., Edmonds, J., O'neill, B. C., Fujimori, S., ... & Lutz, W. (2017). The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. Global Environmental Change, 42, 153-168.

Ribas, A., Lucena, A. F., & Schaeffer, R. (2017). Bridging the energy divide and securing higher collective well-being in a climate-constrained world. Energy Policy, 108, 435-450.

Ribas, A., Lucena, A. F., & Schaeffer, R. (2019). Closing the energy divide in a climate-constrained world: A focus on the buildings sector. Energy and Buildings, 199, 264-274.

Richard S.J. Tol, (2019) A social cost of carbon for (almost) every country, Energy Economics, Volume 83, Pages 555-566, ISSN 0140-9883, doi:10.1016/j.eneco.2019.07.006

Ricke, K. L., Millar, R. J., & MacMartin, D. G. (2017). Constraints on global temperature target overshoot. Scientific reports, 7(1), 1-7.

Rickels, W., Reith, F., Keller, D., Oschlies, A., & Quaas, M. F. (2018). Integrated Assessment of Carbon Dioxide Removal, 6 org/10.1002/2017EF000724 Received 26 OCT 2017 Accepted 19 FEB 2018 Accepted article online 23 FEB 2018 2018 The Authors. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distri-bution in any medium, provided the original work is properly cited, the use is non-commercial and no modifica-tions or adaptations are made. RICKELS ET AL. Earth's Future.

Ringel, M., & Knodt, M. (2018). The governance of the European Energy Union: Efficiency, effectiveness and acceptance of the Winter Package 2016. *Energy Policy*, *112*, 209–220. https://doi.org/10.1016/j.enpol.2017.09.047

Rissman, J., Bataille, C., Masanet, E., Aden, N., Morrow III, W. R., Zhou, N., ... & Cresko, J. (2020). Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070. Applied Energy, 266, 114848.

Ritchie, J., & Dowlatabadi, H. (2017). Why do climate change scenarios return to coal?. Energy, 140, 1276-1291.

Robert J R Elliott & Ingmar Schumacher & Cees Withagen, 2020. "Suggestions for a Covid-19 post-pandemic research agenda in environmental economics," Discussion Papers 20-15, Department of Economics, University of Birmingham.

Rochedo, P. R., Soares-Filho, B., Schaeffer, R., Viola, E., Szklo, A., Lucena, A. F., ... & Rathmann, R. (2018). The threat of political bargaining to climate mitigation in Brazil. Nature Climate Change, 8(8), 695-698.

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., ... & Hausfather, Z. (2019). Contribution of the land sector to a 1.5 C world. Nature Climate Change, 1-12.

Roelfsema, M., Fekete, H., Höhne, N., den Elzen, M., Forsell, N., Kuramochi, T., ... & van Vuuren, D. P. (2018). Reducing global GHG emissions by replicating successful sector examples: the 'good practice policies' scenario. Climate Policy, 18(9), 1103-1113.

Roelfsema, M., Harmsen, M., Olivier, J. J., Hof, A. F., & van Vuuren, D. P. (2018). Integrated assessment of international climate mitigation commitments outside the UNFCCC. Global Environmental Change, 48, 67-75.

Roelfsema, M., van Soest, H. L., Harmsen, M., van Vuuren, D. P., Bertram, C., den Elzen, M., ... & Luderer, G. (2020). Taking stock of national climate policies to evaluate implementation of the Paris Agreement. Nature

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Communications, 11(1), 1-12.

Rogelj, J., Fricko, O., Meinshausen, M., Krey, V., Zilliacus, J. J., & Riahi, K. (2017). Understanding the origin of Paris Agreement emission uncertainties. Nature Communications, 8(1), 1-12.

Rogelj, J., Huppmann, D., Krey, V., Riahi, K., Clarke, L., Gidden, M., ... & Meinshausen, M. (2019). A new scenario logic for the Paris Agreement long-term temperature goal. Nature, 573(7774), 357-363.

Rogelj, J., Luderer, G., Pietzcker, R. C., Kriegler, E., Schaeffer, M., Krey, V., & Riahi, K. (2015). Energy system transformations for limiting end-of-century warming to below 1.5 C. Nature Climate Change, 5(6), 519.

Rogelj, J., Popp, A., Calvin, K. V., Luderer, G., Emmerling, J., Gernaat, D., ... & Krey, V. (2018). Scenarios towards limiting global mean temperature increase below 1.5 C. Nature Climate Change, 8(4), 325.

Rosenzweig, C., Arnell, N. W., Ebi, K. L., Lotze-Campen, H., Raes, F., Rapley, C., ... & Schewe, J. (2017). Assessing inter-sectoral climate change risks: the role of ISIMIP. Environmental Research Letters, 12(1), 010301.

Roth, M. B., Adams, P. J., Jaramillo, P., & Muller, N. Z. (2020). Near term carbon tax policy in the US Economy: limits to deep decarbonization. Environmental Research Communications, 2(5), 051004.

Rozentale, L., & Blumberga, D. (2019). Methods to Evaluate Electricity Policy from Climate Perspective. *Environmental and Climate Technologies*, *23*(2), 131–147. https://doi.org/10.2478/rtuect-2019-0060

Sachs, J., Meng, Y., Giarola, S., & Hawkes, A. (2019). An agent-based model for energy investment decisions in the residential sector. Energy, 172, 752-768.

Sakaue, S., Yamaura, K., & Washida, T. (2018). Economic Analyses of Regional Impacts with Adaptation to Climate Change for the Paris Agreement. American Journal of Climate Change, 7(03), 452.

Samir, K. C., & Lutz, W. (2017). The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Global Environmental Change, 42, 181-192.

Sampedro, J., Smith, S. J., Arto, I., González-Eguino, M., Markandya, A., Mulvaney, K. M., ... & Van Dingenen, R. (2020). Health co-benefits and mitigation costs as per the Paris Agreement under different technological pathways for energy supply. Environment International, 136, 105513.

Sanderson, B. M., & O'Neill, B. C. (2020). Assessing the costs of historical inaction on climate change. Scientific Reports, 10(1), 1-12.

Sanderson, B. M., O'Neill, B. C., & Tebaldi, C. (2016). What would it take to achieve the Paris temperature targets?. Geophysical Research Letters, 43(13), 7133-7142.

Sasse J. P., Trutnevyte, E. (2020). Regional impacts of electricity system transition in Central Europe until 2035. Nature Communications, in press, DOI: 10.1038/s41467-020-18812-y.

Saunois, M., Stavert, A. R., Poulter, B., Bousquet, P., Canadell, J. G., Jackson, R. B., ... & Zhu, Q. (2020). The global methane budget 2000–2017. Earth System Science Data, 12(3), 1561-1623.

Scamman, D., Solano-Rodríguez, B., Pye, S., Chiu, L. F., Smith, A. Z. P., Gallo Cassarino, T., … Lowe, R. (2020). Heat Decarbonisation Modelling Approaches in the UK: An Energy System Architecture Perspective. Energies, 13(8), 1869. doi:10.3390/en13081869

Scheer, D. (2017). Communicating energy system modelling to the wider public: An analysis of German media coverage. Renewable and Sustainable Energy Reviews, 80, 1389-1398.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Schellnhuber, H. J., Rahmstorf, S., & Winkelmann, R. (2016). Why the right climate target was agreed in Paris. Nature Climate Change, 6(7), 649-653.

Schinko, T., Drouet, L., Vrontisi, Z., Hof, A., Hinkel, J., Mochizuki, J., ... & Lincke, D. (2020). Economy-wide effects of coastal flooding due to sea level rise: A multi-model simultaneous treatment of mitigation, adaptation, and residual impacts. Environmental Research Communications, 2(1), 015002.

Schmid, D., Korkmaz, P., Blesl, M., Fahl, U., & Friedrich, R. (2019). Analyzing transformation pathways to a sustainable European energy system—Internalization of health damage costs caused by air pollution. Energy Strategy Reviews, 26, 100417.

Schneider, S. H. (1997). Integrated assessment modeling of global climate change: Transparent rational tool for policy making or opaque screen hiding value-laden assumptions?. Environmental Modeling & Assessment, 2(4), 229-249.

Schwanitz, V. J. (2013). Evaluating integrated assessment models of global climate change. Environmental modelling & software, 50, 120-131.

Schwerhoff, G., & Sy, M. (2019). Developing Africa's energy mix. Climate policy, 19(1), 108-124.

Selosse, S. (2019). Bioenergy with Carbon Capture and Storage: how carbon storage and biomass resources potentials can impact the development of the BECCS. In Bioenergy with Carbon Capture and Storage (pp. 237-256). Academic Press.

Sferra, F., Krapp, M., Roming, N., Schaeffer, M., Malik, A., Hare, B., & Brecha, R. (2019). Towards optimal 1.5° and 2° C emission pathways for individual countries: A Finland case study. Energy Policy, 133, 110705.

Sharma, T., Gallachóir, B. Ó., & Rogan, F. (2020). A new hybrid approach for evaluating technology risks and opportunities in the energy transition in Ireland. Environmental Innovation and Societal Transitions.

Shepherd, A., Littleton, E., Clifton-Brown, J., Martin, M., & Hastings, A. (2020). Projections of global and UK bioenergy potential from Miscanthus× giganteus—Feedstock yield, carbon cycling and electricity generation in the 21st century. GCB Bioenergy, 12(4), 287-305.

Shi, W., Ou, Y., Smith, S. J., Ledna, C. M., Nolte, C. G., & Loughlin, D. H. (2017). Projecting state-level air pollutant emissions using an integrated assessment model: GCAM-USA. Applied energy, 208, 511-521.

Shiogama, H., Hirata, R., Hasegawa, T., Fujimori, S., Ishizaki, N. N., Chatani, S., ... & Lo, Y. E. (2020). Historical and future anthropogenic warming effects on droughts, fires and fire emissions of CO2 and PM2. 5 in equatorial Asia when 2015-like El Niño events occur. Earth Syst. Dynam, 11, 435-445.

Shiraki, H., & Sugiyama, M. (2020). Back to the basic: toward improvement of technoeconomic representation in integrated assessment models. Climatic Change, 1-12.

Siebers, P. O., Lim, Z. E., Figueredo, G. P., & Hey, J. (2020). An Innovative Approach to Multi-Method Integrated Assessment Modelling of Global Climate Change. Journal of Artificial Societies and Social Simulation, 23(1), 1-10.

Siljander, R., & Ekholm, T. (2018). Integrated scenario modelling of energy, greenhouse gas emissions and forestry. Mitigation and Adaptation Strategies for Global Change, 23(5), 783-802.

Skelton, M., Fischer, A. M., Liniger, M. A., & Bresch, D. N. (2019). Who is 'the user' of climate services? Unpacking the use of national climate scenarios in Switzerland beyond sectors, numeracy and the research–practice

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

binary. Climate Services, 15(August), 100113. https://doi.org/10.1016/j.cliser.2019.100113

Smith, C. J., Forster, P. M., Allen, M., Fuglestvedt, J., Millar, R. J., Rogelj, J., & Zickfeld, K. (2019). Current fossil fuel infrastructure does not yet commit us to 1.5 C warming. Nature communications, 10(1), 1-10.

Smith, C. J., Forster, P. M., Allen, M., Leach, N., Millar, R. J., Passerello, G. A., & Regayre, L. A. (2018). FAIR v1. 3: A simple emissions-based impulse response and carbon cycle model. Geoscientific Model Development, 11(6), 2273-2297.

Smith, P., Davis, S. J., Creutzig, F., Fuss, S., Minx, J., Gabrielle, B., ... & Van Vuuren, D. P. (2016). Biophysical and economic limits to negative CO 2 emissions. Nature climate change, 6(1), 42-50.

Smith, S. J., Chateau, J., Dorheim, K., Drouet, L., Durand-Lasserve, O., Fricko, O., ... & Wada, K. (2020). Impact of methane and black carbon mitigation on forcing and temperature: a multi-model scenario analysis. Climatic Change, 1-16.

Sofia, D., Gioiella, F., Lotrecchiano, N., & Giuliano, A. (2020). Cost-benefit analysis to support decarbonization scenario for 2030: A case study in Italy. *Energy Policy*, *137*, 111137. https://doi.org/10.1016/j.enpol.2019.111137

Sognnaes, I., Gambhir, A., Van de Ven, D.-J., Nikas, A., Anger-Kraavi, A., Bui, H., Campagnolo, L., Delpiazzo, E., Doukas, H., Giarola, S., Grant, N., Hawkes, A., Koberle, A., Kolpakov, A., Mittal, S., Moreno, J., Perdana, S., Rogelj, J., Vielle, M., & Peters, G.P. (Reviewed & Revised). A multi-model analysis of long-term emissions and warming implications of current mitigation efforts. Nature Climate Change.

Solano-Rodríguez, B., Pizarro-Alonso, A., Vaillancourt, K., & Martin-del-Campo, C. (2018). Mexico's transition to a net-zero emissions energy system: Near term implications of long term stringent climate targets. In Limiting Global Warming to Well Below 2° C: Energy System Modelling and Policy Development (pp. 315-331). Springer, Cham.

Sommer, M., & Kratena, K. (2019). Consumption and production-based CO2 pricing policies: macroeconomic trade-offs and carbon leakage. Economic Systems Research, 32(1), 29-57. doi: 10.1080/09535314.2019.1612736

Song, J., Yang, W., Wang, S., Higano, Y., & Fang, K. (2018). Exploring potential pathways towards fossil energy-related GHG emission peak prior to 2030 for China: an integrated input-output simulation model. Journal of Cleaner Production, 178, 688-702.

Srikrishnan, V., Guan, Y., Tol, R. S., & Keller, K. (2019). Fossil fuel resources, decarbonization, and economic growth drive the feasibility of Paris climate targets. arXiv preprint arXiv:1908.01923.

Srinivasan, S., Kholod, N., Chaturvedi, V., Ghosh, P. P., Mathur, R., Clarke, L., ... & Liu, B. (2018). Water for electricity in India: a multi-model study of future challenges and linkages to climate change mitigation. Applied Energy, 210, 673-684.

Stanton, E. A., Ackerman, F., & Kartha, S. (2009). Inside the integrated assessment models: Four issues in climate economics. Climate and Development, 1(2), 166–184.

Stavrakas, V., & Flamos, A. (2020). A modular high-resolution demand-side management model to quantify benefits of demand-flexibility in the residential sector. Energy Conversion and Management, 205, 112339.

Steg, L. (2018). Limiting climate change requires research on climate action. Nature climate change, 8(9), 759-761.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Strapasson, A., Woods, J., Pérez-Cirera, V., Elizondo, A., Cruz-Cano, D., Pestiaux, J., ... & Chaturvedi, R. (2020). Modelling carbon mitigation pathways by 2050: Insights from the Global Calculator. Energy Strategy Reviews, 100494.

Su, W., Zhang, D., Zhang, C., & Streimikiene, D. (2020). Sustainability assessment of energy sector development in China and European Union. *Sustainable Development*. https://doi.org/10.1002/sd.2056

Su, X., Shiogama, H., Tanaka, K., Fujimori, S., Hasegawa, T., Hijioka, Y., ... & Liu, J. (2018). How do climate-related uncertainties influence 2 and 1.5° C pathways?. Sustainability science, 13(2), 291-299.

Sugiyama, M., Arino, Y., Kosugi, T., Kurosawa, A., & Watanabe, S. (2018). Next steps in geoengineering scenario research: limited deployment scenarios and beyond. Climate Policy, 18(6), 681-689.

Sugiyama, M., Fujimori, S., Wada, K., Endo, S., Fujii, Y., Komiyama, R., ... & Sano, F. (2019). Japan's long-term climate mitigation policy: Multi-model assessment and sectoral challenges. Energy, 167, 1120-1131.

Sweerts, B., Dalla Longa, F., & van der Zwaan, B. (2019). Financial de-risking to unlock Africa's renewable energy potential. Renewable and Sustainable Energy Reviews, 102, 75-82.

Tàbara, J. D., Cots, F., Pedde, S., Hölscher, K., Kok, K., Lovanova, A., ... & Etherington, J. (2018). Exploring institutional transformations to address high-end climate change in Iberia. Sustainability, 10(1), 161.

Takakura, J. Y., Fujimori, S., Takahashi, K., Hasegawa, T., Honda, Y., Hanasaki, N., ... & Masui, T. (2018). Limited Role of Working Time Shift in Offsetting the Increasing Occupational-Health Cost of Heat Exposure. Earth's Future, 6(11), 1588-1602.

Taliotis, C., Giannakis, E., Karmellos, M., Fylaktos, N., & Zachariadis, T. (2020). Estimating the economy-wide impacts of energy policies in Cyprus. Energy Strategy Reviews, 29, 100495.

Tamaki, T., Nozawa, W., & Managi, S. (2019). Controlling CO 2 emissions for each area in a region: the case of Japan. Carbon Balance and Management, 14(1), 1-13.

Tan, X., Liu, Y., Cui, J., & Su, B. (2018). Assessment of carbon leakage by channels: An approach combining CGE model and decomposition analysis. Energy Economics, 74, 535-545.

Tanaka, K., & O'Neill, B. C. (2018). The Paris Agreement zero-emissions goal is not always consistent with the 1.5 C and 2 C temperature targets. Nature Climate Change, 8(4), 319.

Tanaka, K., Boucher, O., Ciais, P., & Johansson, D. J. (2020). Cost-effective implementation of the Paris Agreement using flexible greenhouse gas metrics. arXiv preprint arXiv:2006.01901.

Tatarewicz, I., Lewarski, M., & Skwierz, S. (2019). Scenarios of low-emission Energy sector for Poland and the EU until 2050. *Institute of Environmental Protection - National Research Institute / National Centre for Emissions Management (KOBiZE), Warsaw*.

Tebaldi, C., & O'Neill, B. C. (2020). Climate scenarios and their relevance and implications for impact studies. In Climate Extremes and Their Implications for Impact and Risk Assessment (pp. 11-29). Elsevier.

Temper, L., Walter, M., Rodriguez, I., Kothari, A., & Turhan, E. (2018). A perspective on radical transformations to sustainability: resistances, movements and alternatives. Sustainability Science, 13(3), 747-764.

Terrenoire, E., Hauglustaine, D. A., Gasser, T., & Penanhoat, O. (2019). The contribution of carbon dioxide emissions from the aviation sector to future climate change. Environmental research letters, 14(8), 084019.

Terry, G. (2009). No climate justice without gender justice: an overview of the issues. Gender & Development, 17(1),

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

5-18.

Thambi, S., Bhatacharya, A., & Fricko, O. (2018). India's energy and emissions outlook: Results from India energy model.

Thellufsen, J. Z., Lund, H., Sorknæs, P., Østergaard, P. A., Chang, M., Drysdale, D., ... & Sperling, K. (2020). Smart energy cities in a 100% renewable energy context. Renewable and Sustainable Energy Reviews, 129, 109922.

Thompson, R. (2017). Whither climate change post-Paris?. The Anthropocene Review, 4(1), 62-69.

Tol, R. S. (2019). A social cost of carbon for (almost) every country. Energy Economics, 83, 555-566.

Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., ... & Davis, S. J. (2019). Committed emissions from existing energy infrastructure jeopardize 1.5 C climate target. Nature, 572(7769), 373-377.

Toth, F. L. (2005). Coupling climate and economic dynamics: recent achievements and unresolved problems. In The coupling of climate and economic dynamics (pp. 35-68). Springer, Dordrecht.

Trotta, G. (2020). Assessing energy efficiency improvements and related energy security and climate benefits in Finland: An ex post multi-sectoral decomposition analysis. *Energy Economics*, *86*, 104640. https://doi.org/10.1016/j.eneco.2019.104640

Truger, B. (2017). Instruments for a low carbon energy transformation in Austria.

Trutnevyte, E. (2016). Does cost optimization approximate the real-world energy transition?. Energy, 106, 182-193.

Trutnevyte, E., Guivarch, C., Lempert, R., & Strachan, N. (2016). Reinvigorating the scenario technique to expand uncertainty consideration. Climatic change, 135(3-4), 373-379.

Trutnevyte, E., Hirt, L. F., Bauer, N., Cherp, A., Hawkes, A., Edelenbosch, O. Y., ... & van Vuuren, D. P. (2019). Societal transformations in models for energy and climate policy: the ambitious next step. One Earth, 1(4), 423-433.

Turner, P. A., Field, C. B., Lobell, D. B., Sanchez, D. L., & Mach, K. J. (2018). Unprecedented rates of land-use transformation in modelled climate change mitigation pathways. Nature Sustainability, 1(5), 240-245.

Turner, S. W., Hejazi, M., Kim, S. H., Clarke, L., & Edmonds, J. (2017). Climate impacts on hydropower and consequences for global electricity supply investment needs. Energy, 141, 2081-2090.

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., & van Vuuren, D. (2015). Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. Global Environmental Change, 35, 239-253.

Ueckerdt, F., Frieler, K., Lange, S., Wenz, L., Luderer, G., & Levermann, A. (2019). The economically optimal warming limit of the planet. Earth System Dynamics, 10(4).

Unger, N., Zheng, Y., Yue, X., & Harper, K. L. (2020). Mitigation of ozone damage to the world's land ecosystems by source sector. Nature Climate Change, 10(2), 134-137.

Urquizo, J., Calderón, C., James, P., (2018) Understanding the complexities of domestic energy reductions in cities: Integrating data sets generally available in the United Kingdom's local authorities, Cities, Volume 74, Pages 292-309, ISSN 0264-2751, doi:10.1016/j.cities.2017.12.019.

Vaillancourt, K., Bahn, O., & El Maghraoui, N. (2020). History and Recent State of TIMES Optimization Energy

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Models and Their Applications for a Transition Towards Clean Energies. In Accelerating the Transition to a 100% Renewable Energy Era (pp. 113-130). Springer, Cham.

Vailles, C., Alberola, É., Farrokhi, B., Cassisa, C., & Bonnefous, J. (2018). Mind th Gap: Aligning the 2030 EU climate and energy policy framework to meet long-term climate goals. *Institute for Climate Economics (I4CE), Climate Brief n°52*.

Vale, P. M. (2016). The changing climate of climate change economics. In Ecological Economics (Vol. 121, pp. 12–19).

van de Ven, D. J., González-Eguino, M., & Arto, I. (2018). The potential of behavioural change for climate change mitigation: A case study for the European Union. Mitigation and Adaptation Strategies for Global Change, 23(6), 853-886.

Van de Ven, D. J., Sampedro, J., Johnson, F. X., Bailis, R., Forouli, A., Nikas, A., ... & Doukas, H. (2019). Integrated policy assessment and optimisation over multiple sustainable development goals in Eastern Africa. Environmental Research Letters, 14(9), 094001.

van den Berg, N. J., Hof, A. F., Akenji, L., Edelenbosch, O. Y., van Sluisveld, M. A., Timmer, V. J., & van Vuuren, D. P. (2019). Improved modelling of lifestyle changes in Integrated Assessment Models: Cross-disciplinary insights from methodologies and theories. Energy Strategy Reviews, 26, 100420.

van der Bles, Robin, Heleen van Soest, and Michel den Elzen. "TRACKING CLIMATE POLICY PROGRESS." (2020).

van der Ploeg, F., & Rezai, A. (2019). Simple rules for climate policy and integrated assessment. Environmental and Resource Economics, 72(1), 77-108.

van der Zwaan, B., & Dalla Longa, F. (2019). Integrated assessment projections for global geothermal energy use. Geothermics, 82, 203-211.

van der Zwaan, B., Boccalon, A., & Dalla Longa, F. (2018a). Prospects for hydropower in Ethiopia: An energy-water nexus analysis. Energy Strategy Reviews, 19, 19-30.

van der Zwaan, B., Kober, T., Dalla Longa, F., van der Laan, A., & Kramer, G. J. (2018b). An integrated assessment of pathways for low-carbon development in Africa. Energy Policy, 117, 387-395.

van Ginkel, K, Jeuken, A., Haasnoot M., Botzen, W., Tesselaar, M., Hunt, A., Watkiss, P., Cimato, F., Steininger, K., Bachner, G., Troeltzsch, J., Lincke, D., Hinkel, J., Boere, E., Sainz de Murieta, E., Scoccimarro, E., Bosello, F. (2018). D3.1 Operationalizing socio-economic and climate tipping points. Deliverable of the H2020 COACCH project.

van Kooten, G. C. (2020). Climate Change and Agriculture. Working Paper-Resource Economics and Policy Analysis (REPA) Research Group, Department of Economics, University of Victoria, (2020-01).

Van Meijl, H., Havlik, P., Lotze-Campen, H., Stehfest, E., Witzke, P., Domínguez, I. P., ... & Humpenöder, F. (2018). Comparing impacts of climate change and mitigation on global agriculture by 2050. Environmental Research Letters, 13(6), 064021.

Van Sluisveld, M. A., Harmsen, M. J., Van Vuuren, D. P., Bosetti, V., Wilson, C., & Van Der Zwaan, B. (2018). Comparing future patterns of energy system change in 2° C scenarios to expert projections. Global Environmental Change, 50, 201-211.

van Soest, H. L., de Boer, H. S., Roelfsema, M., Den Elzen, M. G., Admiraal, A., van Vuuren, D. P., ... & Forsell, N.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

(2017). Early action on Paris Agreement allows for more time to change energy systems. Climatic Change, 144(2), 165-179.

Van Soest, H. L., Reis, L. A., Drouet, L., Van Vuuren, D. P., Den Elzen, M. G., Tavoni, M., ... & Luderer, G. (2017). Low-emission pathways in 11 major economies: comparison of cost-optimal pathways and Paris climate proposals. Climatic Change, 142(3-4), 491-504.

van Soest, H. L., van Vuuren, D. P., Hilaire, J., Minx, J. C., Harmsen, M. J., Krey, V., ... & Luderer, G. (2019). Analysing interactions among sustainable development goals with integrated assessment models. Global Transitions, 1, 210-225.

van Soest, H., Den Elzen, M., Forsell, N., Esmeijer, K., & van Vuuren, D. (2018). Global and Regional Greenhouse Gas Emissions Neutrality.

van Vliet, M., Kok, K., & Veldkamp, T. (2010). Linking stakeholders and modellers in scenario studies: The use of Fuzzy Cognitive Maps as a communication and learning tool. Futures, 42(1), 1-14.

van Vliet, O., Hanger, S., Nikas, A., Spijker, E., Carlsen, H., Doukas, H., & Lieu, J. (2020). The importance of stakeholders in scoping risk assessments—Lessons from low-carbon transitions. Environmental Innovation and Societal Transitions 35, 400-413.

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., ... & Masui, T. (2011). The representative concentration pathways: an overview. Climatic change, 109(1-2), 5.

Van Vuuren, D. P., Hof, A. F., Van Sluisveld, M. A., & Riahi, K. (2017). Open discussion of negative emissions is urgently needed. Nature energy, 2(12), 902.

Van Vuuren, D. P., Stehfest, E., Gernaat, D. E., Doelman, J. C., Van den Berg, M., Harmsen, M., ... & Girod, B. (2017). Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm. Global Environmental Change, 42, 237-250.

Van Vuuren, D. P., Stehfest, E., Gernaat, D. E., Van Den Berg, M., Bijl, D. L., De Boer, H. S., ... & Hof, A. F. (2018). Alternative pathways to the 1.5 C target reduce the need for negative emission technologies. Nature climate change, 8(5), 391-397.

van Zuijlen, B., Zappa, W., Turkenburg, W., Van der Schrier, G., & van den Broek, M. (2018, October). Assessment of the role of CCS in the provision of long-term security of power supply and deep CO2 emission reduction. In 14th Greenhouse Gas Control Technologies Conference Melbourne (pp. 21-26).

Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., & Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. Nature communications, 9(1), 1-11.

Vandyck, T., Keramidas, K., Saveyn, B., Kitous, A., & Vrontisi, Z. (2016). A global stocktake of the Paris pledges: implications for energy systems and economy. Global Environmental Change, 41, 46-63.

Vandyck, T., Keramidas, K., Tchung-Ming, S., Weitzel, M., & Van Dingenen, R. (2020). Quantifying air quality co-benefits of climate policy across sectors and regions. Climatic Change, 1-17.

Vasilakos, N. (2019). Energy Transition Challenges and Development Priorities for the Greek Energy Sector in the Coming Decade. *Robert Schuman Centre for Advanced Studies Research Paper No. RSCAS 2019/37.* https://doi.org/10.2139/ssrn.3393561

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Vaughan, N. E., Gough, C., Mander, S., Littleton, E. W., Welfle, A., Gernaat, D. E., & Van Vuuren, D. P. (2018). Evaluating the use of biomass energy with carbon capture and storage in low emission scenarios. Environmental Research Letters, 13(4), 044014.

Vedachalam, N. (2018). Assessment of the decarbonization capabilities of solar energy in the strategic Indian electricity generation sector. The Electricity Journal, 31(7), 20-25.

Vedachalam, N., Surendar, S., & Srinivasalu, S. (2017). An assessment of decarbonization in the strategic Indian electricity generation sector. The Electricity Journal, 30(5), 47-53.

Victoria, M., Zhu, K., Brown, T., Andresen, G. B., & Greiner, M. (2020). Early decarbonisation of the European energy system pays off. arXiv preprint arXiv:2004.11009.

Vilchez, J. J. G., & Jochem, P. (2020). Powertrain technologies and their impact on greenhouse gas emissions in key car markets. Transportation Research Part D: Transport and Environment, 80, 102214.

Vinca, A., Emmerling, J., & Tavoni, M. (2018). Bearing the cost of stored carbon leakage. Frontiers in Energy Research, 6, 40.

Vinca, A., Rottoli, M., Marangoni, G., & Tavoni, M. (2018). The role of carbon capture and storage electricity in attaining 1.5 and 2° C. International Journal of Greenhouse Gas Control, 78, 148-159.

Vis, P. (2019). Policy Brief. European University Institute. Issue 2019/08.

Volkery, A., & Ribeiro, T. (2009). Scenario planning in public policy: Understanding use, impacts and the role of institutional context factors. Technological Forecasting and Social Change, 76(9), 1198–1207. https://doi.org/10.1016/j.techfore.2009.07.009

von Stechow, C., Minx, J. C., Riahi, K., Jewell, J., McCollum, D. L., Callaghan, M. W., ... & Baiocchi, G. (2016). 2° C and SDGs: united they stand, divided they fall?. Environmental Research Letters, 11(3), 034022.

Vrontisi, Z., Luderer, G., Saveyn, B., Keramidas, K., Lara, A. R., Baumstark, L., ... & Fricko, O. (2018). Enhancing global climate policy ambition towards a 1.5 C stabilization: a short-term multi-model assessment. Environmental Research Letters, 13(4), 044039.

Wachsmuth, J., & Duscha, V. (2019). Achievability of the Paris targets in the EU—the role of demand-side-driven mitigation in different types of scenarios. Energy Efficiency, 12(2), 403-421.

Wachsmuth, J., Denishchenkova, A., Fekete, H., Parra, P., Schaeffer, M., Ancygier, A., & Sferra, F. (2019). Fairness- and cost-effectiveness-based approaches to effort-sharing under the Paris agreement (No. S04/2019). Working Paper Sustainability and Innovation.

Walsh, B., Ciais, P., Janssens, I. A., Penuelas, J., Riahi, K., Rydzak, F., ... & Obersteiner, M. (2017). Pathways for balancing CO 2 emissions and sinks. Nature communications, 8(1), 1-12.

Walsh, C., Lazarou, N. J., Traut, M., Price, J., Raucci, C., Sharmina, M., ... & Larkin, A. (2019). Trade and trade-offs: Shipping in changing climates. Marine Policy, 106, 103537.

Wang, B., Liu, B., Niu, H., Liu, J., & Yao, S. (2018). Impact of energy taxation on economy, environmental and public health quality. Journal of environmental management, 206, 85-92.

Wang, H., Chen, W., Bertram, C., Malik, A., Kriegler, E., Luderer, G., ... & Krey, V. (2020). Early transformation of the Chinese power sector to avoid additional coal lock-in. Environmental Research Letters, 15(2), 024007.

Wang, L., Chen, H., & Chen, W. (2019). Co-control of carbon dioxide and air pollutant emissions in China from a

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

cost-effective perspective. Mitigation and Adaptation Strategies for Global Change, 1-21.

Wang, L., Chen, W., Pan, X., Li, N., Wang, H., Li, D., & Chen, H. (2018). Scale and benefit of global carbon markets under the 2° C goal: integrated modeling and an effort-sharing platform. Mitigation and Adaptation Strategies for Global Change, 23(8), 1207-1223.

Wang, R., Moreno-Cruz, J., & Caldeira, K. (2017). Will the use of a carbon tax for revenue generation produce an incentive to continue carbon emissions?. Environmental Research Letters, 12(6), 064001.

Wang, R., Saunders, H., Moreno-Cruz, J., & Caldeira, K. (2019). Induced energy-saving efficiency improvements amplify effectiveness of climate change mitigation. Joule, 3(9), 2103-2119.

Wang, T., Jiang, Z., Zhao, B., Gu, Y., Liou, K. N., Kalandiyur, N., ... & Zhu, Y. (2020). Health co-benefits of achieving sustainable net-zero greenhouse gas emissions in California. Nature Sustainability, 1-9.

Wang, X., Tang, X., Zhang, B., McLellan, B. C., & Lv, Y. (2018). Provincial carbon emissions reduction allocation plan in China based on consumption perspective. Sustainability, 10(5), 1342.

Warren, R. F., Edwards, N. R., Babonneau, F., Bacon, P. M., Dietrich, J. P., Ford, R. W., ... & Hiscock, K. (2019). Producing policy-relevant science by enhancing robustness and model integration for the assessment of global environmental change. Environmental Modelling & Software, 111, 248-258.

Wei, Y. M., Han, R., Liang, Q. M., Yu, B. Y., Yao, Y. F., Xue, M. M., ... & Mi, Z. F. (2018). An integrated assessment of INDCs under Shared Socioeconomic Pathways: an implementation of C 3 IAM. Natural Hazards, 92(2), 585-618.

Wei, Y. M., Han, R., Wang, C., Yu, B., Liang, Q. M., Yuan, X. C., ... & Yan, J. (2020). Self-preservation strategy for approaching global warming targets in the post-Paris Agreement era. Nature communications, 11(1), 1-13.

Welfle, A., Thornley, P., & Röder, M. (2020). A review of the role of bioenergy modelling in renewable energy research & policy development. Biomass and Bioenergy, 136, 105542.

Wellman, J. and A. Hunt (2016) Methods for the assessment of systemic change, Deliverable 3.3. EC DG Research ECONADAPT Project. Grant Agreement no 603906

Wen-Ray Su, Hongey Chen, Wei-Bo Chen, Chih-Hsin Chang, Lee-Yaw Lin, Jiun-Huei Jang, Yi-Chiang Yu, (2018), Numerical investigation of wave energy resources and hotspots in the surrounding waters of Taiwan, Renewable Energy, Volume 118, Pages 814-824, ISSN 0960-1481, doi: 10.1016/j.renene.2017.11.080.

Weyant, J. (2010). Program on Integrated Assessment Model Development, Diagnostics and Inter-Model Comparison (PIAMDDI): an overview. In IAMC Annual Meeting.

Wiebe, K. S., Bjelle, E. L., Többen, J., & Wood, R. (2018). Implementing exogenous scenarios in a global MRIO model for the estimation of future environmental footprints. Journal of Economic Structures, 7(1), 20.

Wilson, C., Kriegler, E., van Vuuren, D. P., Guivarch, C., Frame, D., Krey, V., ... & Thompson, E. L. (2017). Evaluating Process-based integrated assessment models of climate change mitigation. International Institute for Applied Systems Analysis (IIASA).

Wilson, C., Pettifor, H., Cassar, E., Kerr, L., & Wilson, M. (2019). The potential contribution of disruptive low-carbon innovations to 1.5 C climate mitigation. Energy Efficiency, 12(2), 423-440.

Winning, M., Price, J., Ekins, P., Pye, S., Glynn, J., Watson, J., & McGlade, C. (2019). Nationally Determined

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Contributions under the Paris Agreement and the costs of delayed action. Climate Policy, 19(8), 947-958.

Wong, K., Chuah, J., Hope, C. (2016). Carbon taxation in Malaysia: insights from the enhanced PAGE09 integrated assessment model. Carbon Management, 7(5-6), 301-312. doi: 10.1080/17583004.2016.1237179

Wood, R., Grubb, M., Anger-Kraavi, A., Pollitt, H., Rizzo, B., Alexandri, E., ... & Tukker, A. (2020). Beyond peak emission transfers: historical impacts of globalization and future impacts of climate policies on international emission transfers. Climate Policy, 20(sup1), S14-S27.

Wu, J., & Thill, J. C. (2018). Climate change coalition formation and equilibrium strategies in mitigation games in the post-Kyoto Era. International Environmental Agreements: Politics, Law and Economics, 18(4), 573-598.

Wu, L., Liu, C., Ma, X., Liu, G., Miao, C., & Wang, Z. (2019). Global carbon reduction and economic growth under autonomous economies. Journal of Cleaner Production, 224, 719-728.

Wu, W., Hasegawa, T., Ohashi, H., Hanasaki, N., Liu, J., Matsui, T., ... & Takahashi, K. (2019). Global advanced bioenergy potential under environmental protection policies and societal transformation measures. GCB Bioenergy, 11(9), 1041-1055.

Wu, Y. H., Dai, H., Xie, Y., & Masui, T. (2019). The efforts of Taiwan to achieve NDC target: an integrated assessment on the carbon emission trading system. Natural Hazards, 99(3), 1295-1310.

Xexakis, G., Hansmann, R., Volken, S. P., & Trutnevyte, E. (2020). Models on the wrong track: Model-based electricity supply scenarios in Switzerland are not aligned with the perspectives of energy experts and the public. Renewable and Sustainable Energy Reviews, 134, 110297.

Xie, J., Dai, H., Xie, Y., & Hong, L. (2018). Effect of carbon tax on the industrial competitiveness of Chongqing, China. Energy For Sustainable Development, 47, 114-123. doi: 10.1016/j.esd.2018.09.003

Xie, Y., Dai, H., Xu, X., Fujimori, S., Hasegawa, T., Yi, K., ... & Kurata, G. (2018). Co-benefits of climate mitigation on air quality and human health in Asian countries. Environment international, 119, 309-318.

Xie, Y., Liu, X., Chen, Q., & Zhang, S. (2020). An integrated assessment for achieving the 2° C target pathway in China by 2030. Journal of Cleaner Production, 122238.

Xing, R., Roney, C., Chiappori, D. V., Binsted, M. T., Arbuckle, E., & Davies, E. G. (2019). MODELING OIL SANDS PRODUCTION IN AN INTEGRATED ASSESSMENT MODEL: ENERGY CONSUMPTION AND CO2 EMISSIONS.

Xu, Y., & Ramanathan, V. (2017). Well below 2 C: Mitigation strategies for avoiding dangerous to catastrophic climate changes. Proceedings of the National Academy of Sciences, 114(39), 10315-10323.

Xunzhang, P., Wenying, C., Clarke, L. E., Lining, W., & Guannan, L. (2017). China's energy system transformation towards the 2° C goal: implications of different effort-sharing principles. Energy Policy, 103, 116-126.

Yang, P., Yao, Y. F., Mi, Z., Cao, Y. F., Liao, H., Yu, B. Y., ... & Wei, Y. M. (2018). Social cost of carbon under shared socioeconomic pathways. Global Environmental Change, 53, 225-232.

Yang, S., & Cui, X. (2019). Building Regional Sustainable Development Scenarios with the SSP Framework. Sustainability, 11(20), 5712.

Yang, S., Liu, C., Dong, W., Chou, J., Tian, D., Wei, T., & Tian, Y. (2018). Quantifying the climate impact of the US policy choices using an economic and earth system model. Sustainability, 10(6), 1884.

Yu, L., Gu, F., Huang, M., Tao, B., Hao, M., & Wang, Z. (2020). Impacts of 1.5° C and 2° C Global Warming on Net Primary Productivity and Carbon Balance in China's Terrestrial Ecosystems. Sustainability, 12(7), 2849.

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Yu, S., Eom, J., Evans, M., & Clarke, L. (2014). A long-term, integrated impact assessment of alternative building energy code scenarios in China. Energy Policy, 67, 626-639.

Yu, S., Horing, J., Liu, Q., Dahowski, R., Davidson, C., Edmonds, J., ... & Clarke, L. (2019). CCUS in China's mitigation strategy: insights from integrated assessment modeling. International Journal of Greenhouse Gas Control, 84, 204-218.

Yu, S., Yarlagadda, B., Siegel, J. E., Zhou, S., & Kim, S. (2020). The role of nuclear in China's energy future: Insights from integrated assessment. Energy Policy, 139, 111344.

Yue, X., Patankar, N., Decarolis, J., Chiodi, A., Rogan, F., J.P. Deane, O'Gallachoir, B., (2020). Least cost energy system pathways towards 100% renewable energy in Ireland by 2050, Energy, Volume 207, 118264, ISSN 0360-5442, doi:10.1016/j.energy.2020.118264"

Yue, X., Pye, S., DeCarolis, J., Li, F. G., Rogan, F., & Gallachóir, B. Ó. (2018). A review of approaches to uncertainty assessment in energy system optimization models. Energy strategy reviews, 21, 204-217.

Yumashev, D., Hope, C., Schaefer, K., Riemann-Campe, K., Iglesias-Suarez, F., Jafarov, E., ... & Whiteman, G. (2019). Climate policy implications of nonlinear decline of Arctic land permafrost and other cryosphere elements. Nature communications, 10(1), 1-11.

Zachariadis, T., Sotiriou, C., Taliotis, C., Karmellos, M., Fylaktos, N., Giannakis, E., & Andreou, S. (2019). *Comprehensive Impact Assessment of the Planned Policies and Measures of the National Energy and Climate Plan of Cyprus Draft Report: Comprehensive Impact Assessment of the Planned Policies and Measures of the National Energy and Climate Plan of Cyprus*.

Zahasky, C., & Krevor, S. (2020). Global geologic carbon storage requirements of climate change mitigation scenarios. Energy & Environmental Science.

Zeng, Y., (2017). Indirect double regulation and the carbon ETSs linking: The case of coal-fired generation in the EU and China, Energy Policy, Volume 111, Pages 268-280, ISSN 0301-4215, doi:10.1016/j.enpol.2017.09.038. http://www.sciencedirect.com/science/article/pii/S0301421517305980)

Zeshan, M., & Ko, J. H. (2016). An analysis of the economic impact of implementing the INDCs of the 2015 Paris Climate Conference: a CGE approach. International Trade Research, 2(4), 81-110.

Zhang, D., Liu, G., Chen, C., Zhang, Y., Hao, Y., & Casazza, M. (2019). Medium-to-long-term coupled strategies for energy efficiency and greenhouse gas emissions reduction in Beijing (China). Energy Policy, 127, 350-360.

Zhang, K., Liang, Q. M., Liu, L. J., Xue, M. M., Yu, B. Y., Wang, C., ... & Tan, J. (2020). Impacts of mechanisms to promote participation in climate mitigation: border carbon adjustments vs uniform tariff measures. Climate Change Economics.

Zhang, L., Jiang, D., & Imran, M. (2019). Feasibility analysis of China's carbon taxation policy responding to the carbon tariff scheme of USA. Carbon Letters, 29(1), 99-107.

Zhang, S., Bauer, N., Yin, G., & Xie, X. (2020). Technology learning and diffusion at the global and local scales: A modeling exercise in the REMIND model. Technological Forecasting and Social Change, 151, 119765.

Zhang, Z., & Zhu, K. (2017). Border carbon adjustments for exports of the United States and the European Union: Taking border-crossing frequency into account. Applied Energy, 201, 188–199. https://doi.org/10.1016/j.apenergy.2017.05.065

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Zhao, Y., Li, H., Xiao, Y., Liu, Y., Cao, Y., & Zhang, Z. et al. (2018). Scenario analysis of the carbon pricing policy in China's power sector through 2050: Based on an improved CGE model. Ecological Indicators, 85, 352-366. doi: 10.1016/j.ecolind.2017.10.028

Zhou, N., Price, L., Yande, D., Creyts, J., Khanna, N., Fridley, D., ... & Tian, Z. (2019). A roadmap for China to peak carbon dioxide emissions and achieve a 20% share of non-fossil fuels in primary energy by 2030. Applied Energy, 239, 793-819.

Zhou, S., Wang, Y., Yuan, Z., & Ou, X. (2018). Peak energy consumption and CO2 emissions in China's industrial sector. Energy strategy reviews, 20, 113-123.

Zhou, W., McCollum, D. L., Fricko, O., Fujimori, S., Gidden, M., Guo, F., ... & Liu, C. (2020). Decarbonization pathways and energy investment needs for developing Asia in line with 'well below'2° C. Climate Policy, 20(2), 234-245.

ZHU, L., CUI, L., & SCHLEICH, J. (2020). DESIGNING A GLOBALLY ACCEPTABLE CARBON TAX SCHEME TO ADDRESS COMPETITIVENESS AND LEAKAGE CONCERNS. Climate Change Economics, 2050008.

Zhu, L., Peng, P., Wang, X., & Fan, Y. (2018). Exploring optimal mitigation and adaptation investment strategies in China. Climate Policy, 18(6), 781-793.

Zhu, N., Qian, L., Jiang, D., Mbroh, N., (2020). A simulation study of China's imposing carbon tax against American carbon tariffs, Journal of Cleaner Production, Volume 243, 118467, ISSN 0959-6526, doi:10.1016/j.jclepro.2019.118467

Zigurs, A., Balodis, M., Ivanova, P., Locmelis, K., & Sarma, U. (2019). National Energy and Climate Plans: Importance of Synergy. *Latvian Journal of Physics and Technical Sciences*, *56*(6), 3–16. https://doi.org/10.2478/lpts-2019-0031

Zwartkruis, J. V., Berg, H., Hof, A. F., & Kok, M. T. (2020). Agricultural nature conservation in the Netherlands: Three lenses on transition pathways. Technological Forecasting and Social Change, 151, 119235.

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Appendix A

Interview guide on scenario use

For interviews with decision-makers in government and business

Version 2
19.06.2020

These questions concern the use of scenarios that seek to describe future developments in energy and climate related quantities such as energy use, energy or CO_2 prices, or energy-related emissions.

We are interested in the way such scenarios are used by you and more broadly in your organization, and in your thoughts about the models and organizations that produce such scenarios.

USES OF SCENARIO DATA

- Do you relate to *scenarios for e.g. future energy use, energy or CO_2 prices, or emissions* in your work?
  - For what purposes do you use these kinds of data?
  - In what specific processes?
  - How? (as relevant)

- What sources do you use for such scenarios?
  - Prompts:
    - IEA
    - IPCC
    - Business actors (Norway: Equinor, Statkraft, DNVGL, other)
    - Professional analysts (Bloomberg NEF, Rystad, Point Carbon...)
    - Government data (Norway: Statistics Norway, Ministry of Finance, other)
    - Other?

- What kind of data do you usually use / find interesting from the different sources?
  - E.g. emission data, energy mix, prices/costs, cost curves, other...
- Where do you find these data?
  - E.g. IEA or IPCC reports, commercial analysis, scientific literature, online/databases, media or other sources...

- Do you use scenario data to find out i) What will happen, ii) What can happen, or iii) How to reach a specific target?

PERCEPTIONS OF SCENARIO DATA

- Why do you use these specific scenarios / sources of scenario data, and not others?
  - Level and mode of contact with the producer (member/formal cooperation with the organization)
  - Status of producer organization (public institution / government source / market actor)
  - Alignment of focus or priorities (e.g. focuses specifically on REs, oil prices, etc...)
  - The models they rely on are good/useful

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    - The expertise they rely on is trustworthy (same background as myself etc)
    - other

- What are the advantages / strengths of using such scenarios?
- What are the downsides / weaknesses?

- (If time permits: Can you think of examples where scenarios have been particularly helpful or unhelpful, either in your work or in energy and climate policy debates generally?

- What would make scenarios more useful for you in your work?
- How important is your trust in scenario information for your use of such information?
    - What determines your trust in different sorts of scenario information?

PERCEPTIONS OF MODELS

- Regarding the scenarios you use (as discussed above):
  Do you know what kind of models they derive from?
    - Type of model: IAM, energy system model, general equilibrium model etc.
    - More specific, e.g. name of model, who built it…
    - Have you personally interacted with the modellers? Have your colleagues?
    - Other follow-up questions to get to the level of understanding of different models

- What kind of questions do you think these models are able to answer?
- What kind of questions are they not well suited to answer?

- To what extent do you trust these models?
    - …and why?
        - What determines your trust in models?

- Are there aspects of these models that you currently miss, would like to see developed or changed?

SCENARIOS IN THE CURRENT SITUATION (if time permits)

Given the unexpected and unprecedented circumstances following the Coronavirus outbreak and the following economic downturn…

- Has this situation changed your use of scenario data?
- Has this situation changed your trust in models and scenario information?

- To what extent is this situation something you think
    - is captured in existing scenarios?
    - should be captured in scenario modelling?
    - is possible to capture in these models, or any models?

- (What kind of scenario modelling might be useful to you in the current situation?)

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