PARIS REINFORCE

26/12/2019

D2.2 – Protocol for model use, scenarios and stakeholder engagement

WP2 – I^{2}AM PARIS

version: 1.01R

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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. The deliverable was submitted on time, in December 2019, but was slightly updated with additional harmonisation information (in Section 3.2) in November 2020.

2. Dissemination and uptake

This deliverable will serve as a reference document among consortium partners (experts and non-experts), as well as other researchers and members of the scientific (modelling and otherwise) community, regarding the protocol for scenario design; stakeholder engagement; and model harmonisation, integration and application at the national, regional and global level, within the PARIS REINFORCE consortium. It can also be used by policymakers and other stakeholder groups as a documentation of the PARIS REINFORCE modelling interlinkage principles, towards addressing the policy questions and concerns that emerged from the Brussels regional stakeholder workshop, which took place on the 21st of November, 2019, in Brussels, Belgium.

3. Short summary of results (<250 words)

This living document is to be used as a tentative protocol (submitted M7 and updated M18), indicating timelines and preliminary activities regarding harmonisation and interlinkages on the first round of modelling attempts, focusing on global and regional models.

This deliverable also describes the other tools present within the consortia that add to the robustness of all the approaches we link together across Work Packages 3-7.

Additionally, it serves as a follow-up on lessons learnt from, and a short summary of, the regional stakeholder workshop held in November 2019, at Bruegel in Brussels, regarding stakeholders' preferences and rankings of topics (or policy questions), in preparation of future national stakeholder workshops. The results of prominent policy concerns that have emerged have been categorised as global emerging concerns, regional European concerns, and socio-economic concerns and priority areas of action.

The deliverable has been updated as dates and roadmaps have taken shape and form within the first half of the PR Project. Modelling capabilities, baseline scenario references and projections, and the extent of harmonisation competencies across variables across our multi-model ensemble within the PARIS REINFORCE consortium have been updated based on new roadmaps and new dates of modelling runs and scenarios. Stakeholder engagement and local workshops and their integration to the platform has also been slightly delayed as well as prolonging of events due to COVID-19 implications.

Finally, we conclude with advancements in the I^{2}AM PARIS Platform, the central tool with which the PARIS REINFORCE project will seek to engage stakeholders in mitigation scenario inputs, results and implications, and upcoming steps for its continued improvement for the next months.

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 I^{2}AM 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	EPU N·T·U·A
BC3 - Basque Centre for Climate Change	ES	bc3
Bruegel - Bruegel AISBL	BE	bruegel
Cambridge - University of Cambridge	UK	UNIVERSITY OF CAMBRIDGE
CICERO - Cicero Senter Klimaforskning Stiftelse	NO	°CICERO
CMCC - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	IT	cmcc
E4SMA - Energy, Engineering, Economic and Environment Systems Modelling Analysis	IT	E4SMA
EPFL - École polytechnique fédérale de Lausanne	CH	EPFL
Fraunhofer ISI - Fraunhofer Institute for Systems and Innovation Research	DE	Fraunhofer ISI
Grantham - Imperial College of Science Technology and Medicine - Grantham Institute	UK	Grantham Institute Climate Change and the Environment
HOLISTIC - Holistic P.C.	GR	HOLISTIC
IEECP - Institute for European Energy and Climate Policy Stichting	NL	IEECP
SEURECO - Société Européenne d'Economie SARL	FR	SEURECO ERAΣME
CDS/UnB - Centre for Sustainable Development of the University of Brasilia	BR	Centro de Desenvolvimento Sustentável UnB
CUP - China University of Petroleum-Beijing	CN	
IEF-RAS - Institute of Economic Forecasting – Russian Academy of Sciences	RU	IEF RAS
IGES - Institute for Global Environmental Strategies	JP	IGES
TERI - The Energy and Resources Institute	IN	teri

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Executive Summary

Deliverable 2.2. is to be used as *Protocol*, indicating timelines and guiding activities regarding harmonisation and the first round of modelling attempts, focusing on Global and Regional Models. The deliverable has been a live document and has been updated (M7 and M18) as dates and roadmaps have taken shape and form based on the IPCC AR6 dates and the COVID-19 outbreak. The first section summarizes modelling capabilities, baseline scenario references and projections, and the extent of harmonisation competencies across variables across our multi-model ensemble within the PARIS REINFORCE consortium. Baseline scenarios that are to be used for the first round of modelling runs focus on Current Policies and NDC commitments in a time range of until 2030 and post 2030.

This deliverable also describes the other tools present within the consortia that add to the robustness of all the approaches we link together across Work Packages 3-7.

Additionally, it serves as a follow-up on lessons learnt from, and a short summary of, the regional stakeholder workshop held in November 2019, at Bruegel in Brussels, regarding stakeholders' preferences and rankings of topics (or policy questions), in preparation of future national stakeholder workshops. The results of prominent policy concerns that have emerged have been categorised as global emerging concerns, regional European concerns, and socio-economic concerns and priority areas of action. Due to COVID-19, several of the local/case study workshops have been postponed but will be integrated into the platform as executed.

Finally, we conclude with advancements in the I^{2}AM PARIS Platform, the central tool with which the PARIS REINFORCE project will seek to engage stakeholders in mitigation scenario inputs, results and implications, and upcoming steps for its continued improvement for the next months.

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1 Introduction

This document, D2.2 Protocol for model use, scenarios and stakeholder engagement, draws the preliminary guidelines of the modelling workflow to begin hereafter, stemming from the feedback received from stakeholders from our first Regional Workshop (November 21, 2019). This document is to be updated as advancements continue until M18. The conclusions drawn from the sessions with stakeholders will have a twofold objective: i) to primarily produce relevant mitigation pathways based on different scenario input assumptions and datasets and ii) to ensure that the unique ensemble of modelling tools, where possible, respond to priority areas of action that stakeholders require additional information, for strengthening the bond between science for policymaking. The 22 global, regional, national and sectoral modelling tool capabilities within the consortia, will provide a comprehensive policy insight to ensure that robust, technically feasible and socially desirable transition agendas are responded to in a timely manner.

Below, Figure 1 summarises how the work packages (WPs) in PARIS REINFORCE are linked with each other, structuring a workflow of modelling (WPs 5, 6 and 7) and robustification (WP 4) activities, driven by a stakeholder engagement module (WP 3), which are simultaneously interacting, displayed and disseminated through the I^{2}AM PARIS platform (WP 2). This protocol, D2.2, determines how these activities are specifically interlinked. As Figure 1 shows, after the first stakeholder engagement activity, the first modelling runs will be carried out using global, national and sectoral models. The impact of the decarbonisation pathways in national and regional territories will then be presented to policymakers and other stakeholders to incorporate additional feedback. The new batch of comments will support the production of national and regional pathways, which will be fed back into a second mitigation modelling process, to produce more co-creative and realistic global mitigation pathways. This feedback will ensure usefulness and validity of the assumptions and results that are provided, and the second round of the iterative process will reassure the incorporation of new elements for the second modelling round.

Section 2 covers the co-creation process for stakeholder engagement, addressing the ongoing implementation of the stakeholder engagement plan. It gives special emphasis to the 1st Regional Workshop held in Brussels on November 21, 2019, where a preliminary version of the I^{2}AM Paris Platform was presented to—and the final version co-designed with—stakeholders, and numerous policy concerns of stakeholders were gathered.

Section 3 outlines the modelling protocol. The section starts by identifying the coverage, capabilities and overlap between models by taking information from deliverable D2.1. This overview gives a sense of the harmonisation and interlinkage possibilities between models. Next, the modelling workflow is outlined, displaying how WPs 5, 6 and 7 are related to each other, and specifies how they are driven by WP 3. Then, more detail is provided on the specific strategy for model harmonisation and interlinkage. Finally, a harmonised set of modelling outputs is defined that is eventually to be streamlined and displayed as a part of the modelling documentation within the I^{2}AM PARIS platform.

Section 4 highlights the range and scope of additional tools, related both to stakeholder engagement and modelling activities, throughout the course of the project that is to add to the robustification of all the outputs of the activities. These tools include socio-technical analysis frameworks along with stakeholder preference elicitation methodologies, which will result in better informed and co-created modelling scenarios, as well as uncertainty/robustness analysis approaches, thereby allowing us to deliver more robust policy prescriptions and results.

Finally, *Section 5* defines the structure of the I^{2}AM PARIS platform, outlining the use of the platform for modelling activities within the platform, as well as the structure of the different interfaces for modelling outcomes.

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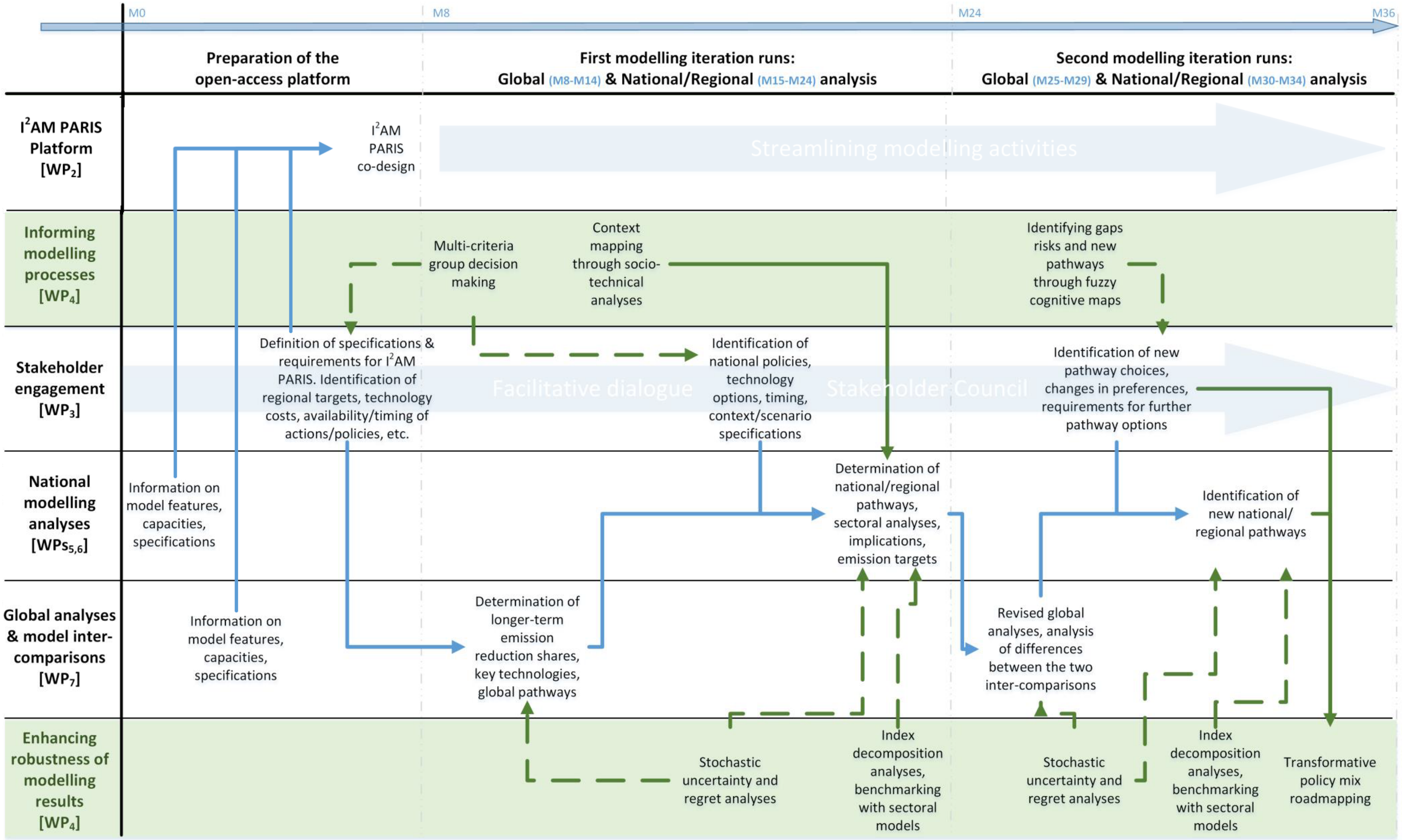

Figure 1: Activity flow and interactions between stakeholder engagement activities; global, regional and national level modelling; and robustification and socio-technical analysis activities in Paris Reinforce.

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2 The Co-Creation Process

Co-creation and stakeholder engagement has become a keystone of sustainability science, arguing that to deal with complex sustainability issues touching societal, economic and political interests like the energy transition or climate policy, the scientific community needs to go beyond conventional scientific methods and incorporate non-academic actors' views in the research process (Mielke et al., 2016). The co-creation or co-production theory provides a framework to rethink science and its connection to and relevance for society, emphasising the public benefit of science and presenting it as a tool to achieve today's challenges (Wyborn et al., 2019).

There are multiple definitions of co-creation within sustainability science:

- "The processes of co-production in which scholars and stakeholders interact to define important questions, relevant evidence, and convincing forms of argument." (Kates et al., 2000, 2)
- "Co-production of science and policy (…) requires substantial commitment to (…) interdisciplinarity, stakeholder participation, and the production of knowledge that is demonstrably usable." (Lemos and Morehouse, 2005, 66)
- "When viewed as a learning process, sustainability research can be conceptualised as the co-production of knowledge arising from the engagement of multiple knowledge producers." (Cornell et al., 2013, 63)

However, probably the most comprehensive definition of co-creation is a "process that iteratively brings together diverse groups and their ways of knowing and acting to create new knowledge and practices to transform societal outcomes" (Wyborn et al., 2019, 4). Therefore, the co-creation process implies not only to **transform how knowledge is created**, but also **how decisions are made**, acting across all spheres of social, economic, and political life (Lang et al., 2012; Miller and Wyborn, 2018; Wyborn et al., 2019).

Understood this way, co-creation implies several ambitions: involving multiple stakeholders (scientists, policymakers, civil society, etc.) to produce new knowledge, but also new ways of integrating knowledge into decision making and action.

2.1 Lesson learnt: previous projects and succesful stories

In recent years, there has been an increase in stakeholder involvement techniques within H2020 Projects as well as in scientific publications (Welp et al., 2006; Carney et al., 2009; Mielke et al., 2016; Wamsler, 2017). More often, on the spectrum of different intensities of stakeholder dialogue, engagement methods have been shifting toward active involvement of a multiplicity of stakeholder groups, working towards the collaborative and cooperative elements of co-creation. Active involvement of stakeholders (Figure 2) not only adds to the usefulness of the scientific results that are generated, but also increases the impact of the decisions that are made, adding elements of ownership and empowerment for the required and desired change at large.

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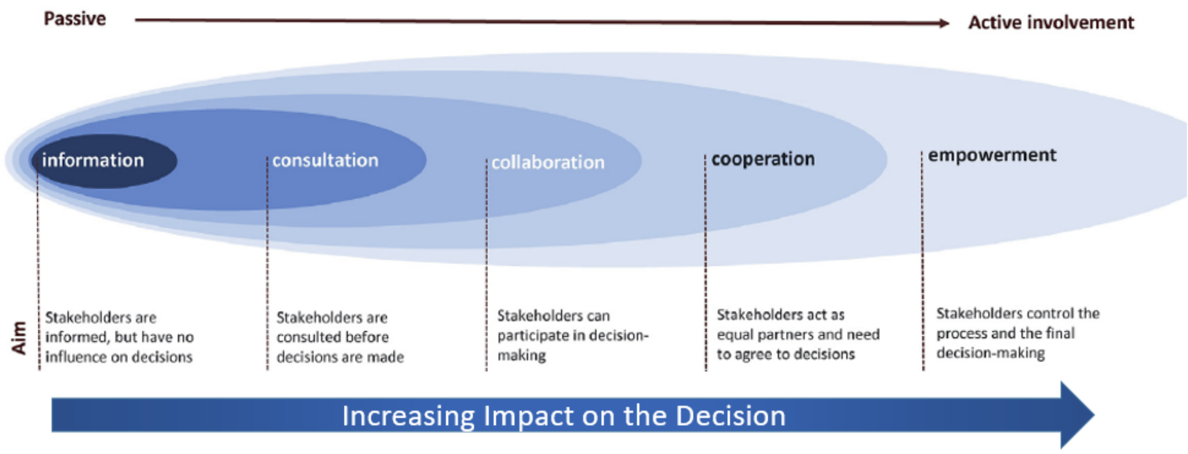

Figure 2. Different Intensities of Stakeholder Involvement (adapted from Grygoruk and Rannow, 2017)

The H2020 TRANSrisk Project[1] for example, used a diverse range of stakeholder engagement techniques at the national scale, for understanding the risks and uncertainties involved in large-scale technology systems, renewable electricity systems, energy efficient buildings and renewable energy at the community level (Hanger-Kopp et al. (Eds.)., 2019).

More recently, the H2020 Deeds Project[2] published their findings on Research and Investment (R&I) Priorities as the results of an online survey to collect feedback from over 180 respondents running from March to June 2019. Their stakeholder consultation eventually showed that R&I action needed to focus primarily on decarbonising the power sector, urban zero-carbon mobility, circular economy in industry and agriculture, smart cities, and cross-country and cross-sectoral partnerships[3].

Other projects like the H2020 Shape Energy[4] Initiatives have undertaken storytelling workshops at the local level to engage in/with the use of storytelling through 17 multi-stakeholder city workshops to tackle Europe's local Energy Challenges, stories and research priorities via conflict solving, as well as inclusion and participation of different voices.

2.2 Co-creation in PARIS REINFORCE

PARIS REINFORCE, as a demand-driven and innovative project, seeks to go beyond engaging with stakeholders, but rather co-create with them.

This approach is being applied in PARIS REINFORCE through two ways:

- The **co-design** of the specifications of the I^{2}AM PARIS platform: content and utility, interface,

[1] Transition pathways and risk analysis for climate change policies, http://transrisk-project.eu/
[2] The DialoguE on European Decarbonisation Strategies (DEEDS), https://deeds.eu/
[3] Deeds. D2.2 – Results of online consultation
[4] https://shapeenergy.eu/index.php/tag/storytelling/

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visualisation, etc. This participatory design of the platform is to ensure that both modelling documentation and analysis that are streamlined via the I^{2}AM PARIS platform meet their needs and demands of all potential users: policymakers, public and experts (see Section 5).

- The **co-creation** of modelling the policy needs (e.g. EU legislation policies, trade-offs, timing of actions, feasibility/implications of 1.5°C trajectories, interactions with SDGs, co-benefits, etc.) through roundtable discussions; presenting intended approaches to addressing these needs with our modelling ensemble; and then prioritising relevant modelling tasks.

Both components, the co-design of the I^{2}AM PARIS platform and the co-creation of policy questions for modelling started at the beginning of the project (June 2019) and have been sustained through continued dialogue and effort with stakeholders in the 1st regional Workshop (Figure 3). Several local workshops have been conducted, either in person (in Greece) or online (in Kenya and India) within 2020. However, others will resume in 2021.

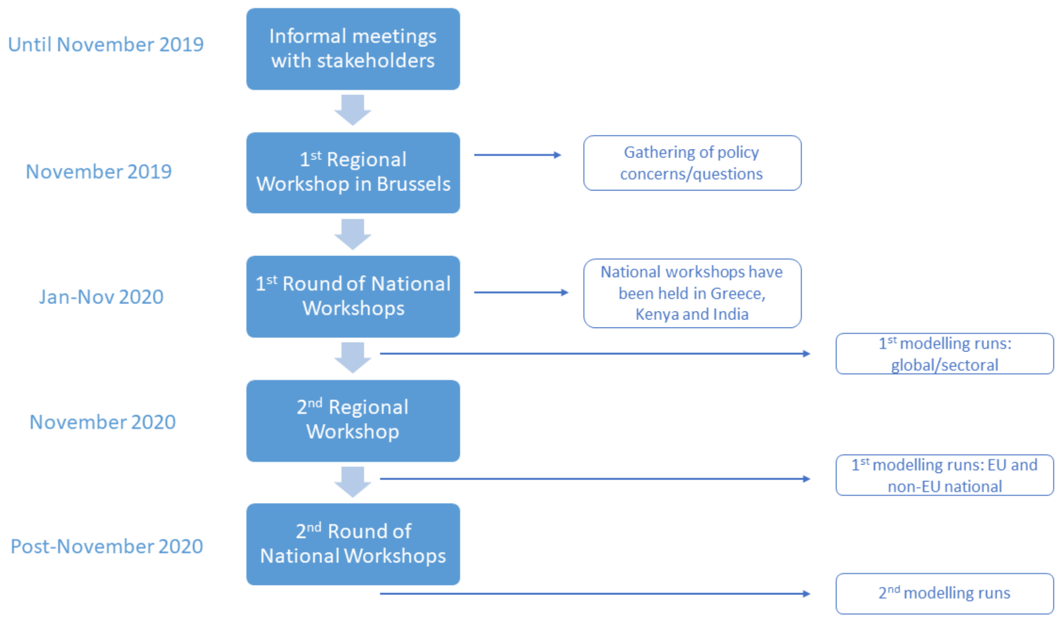

Figure 3. Planned timeline and coverage of Regional and National Workshops in accordance with 1st and 2nd Modelling Runs

Until our first regional workshop in November 2019, policy concerns were gathered via informal meetings with key EU and global stakeholders, such as (but not limited to):

- European Commission DG ENERGY
- European Commission DG CLIMA
- European Commission DG RTD
- Ministry for the Ecological Transition – Spanish Government
- Ministry of Environment – Government of Portugal
- Ministry of Economic Development – Government of Italy
- Ministry for the Environment – Government of Germany

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- Ministry for Foreign Affairs – Government of Finland
- Ministry of Energy – Government of Hungary
- Ministry of Energy and Environment – Government of Ukraine
- Ministry of Environment and Energy – Government of Greece
- Department for Business, Energy & Industrial Strategy, Government of the United Kingdom
- United Nations Economic Commission for Africa
- Korean Institute for Energy Research

After that, the most common policy concerns were selected and presented to the stakeholders in our **1st regional workshop** held on the 21st of November 2019 in Brussels. During this workshop, stakeholders ranked the policy areas and topics they felt more concerned about and the modelling teams discussed several options on how the models could address them.

The engagement with stakeholders will continue during the project, drawing from the creation of the **Stakeholder Council** as well as through a series of National Workshops, with the objective of taking the Global Policy Questions and initial model outputs of the Global and Regional runs down to the national level, therefore acquiring more detailed feedback on the policy concerns and also how they may vary by country. Additionally, in the national workshops, the emphasis on a wide variety of stakeholders (considering NGOs, Trade Unions, businesses, civil society etc.) will be higher than in Brussels, where our main target audience is EU decision-makers.

Based on the 1st regional workshop, the modelling teams have run their models trying to respond to stakeholders' policy concerns. However, due to the Covid-19 pandemic, the process has been delayed several months and the results will finally be ready in November 2020. The pandemic has also impacted the organization of the several of the other national workshops planned, with Greece being the only country that celebrated an in-person workshop in January 2020. Despite this, the consortium has still managed to overcome these issues and has started to organize online workshops with several stakeholders in countries such as Kenya or India. As the possibility to organize more in-person events is still unclear during the next months, the consortium envisages to continue the co-creation process (including the 2nd regional workshop with EU stakeholders and other national workshops and case studies) through online events, making use of several innovative online tools. Due to the uncertainties of this moment, the exact dates are still to be define, and Figure 3 presents only an estimate.

2.3 Feedback from the First Regional Workshop

2.3.1 The Live Event at Bruegel

The first Regional Stakeholder Workshop took place at the premises of Bruegel, in Brussels, on the 21st of November, with a foremost audience of policymakers, academics, and some representation from businesses and NGOs (57 participants). The main objective was to host a live event where stakeholders could identify the gaps between current modelling research and climate policy.

The live event was a foremost introduction of the I^{2}AM PARIS platform's first mock-up launch to the public in order to get feedback and co-design with all interested parties (morning sessions) (see section 5 for more details) as well as to harvest policy relevant themes and priority areas of concern to which modelling efforts can be based around (afternoon sessions).

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Both the co-design and co-creation will be kept up as a continuous goal along the duration of the PARIS REINFORCE project. In the upcoming months, a detailed write-up of lessons learnt and policy questions and answers will be carried out by Bruegel.

2.3.2 Relevant policy and research questions

During the afternoon sessions, three roundtable discussions took place to discuss relevant policy concerns covering three different areas of action:

Session 1: Global threats, 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

To find out the policy areas that were of most concern, the tool Sli.do was used. Sli.do is an online survey tool that serves to collect real-time insights from a given audience. Several topics were presented to the stakeholders at the beginning of each session (proposed by certain key stakeholders themselves via the preliminary bilateral meetings), and then they used Sli.do to select topics among them to discuss. The most voted options were afterwards discussed with the modelling teams in order to start thinking about how they could be approached by the PARIS REINFORCE modelling ensemble. Within the policy questions collected, there was also a crowdsourced question that was also gathered from a general audience 48 hours before the initiation of the workshop.

To reflect the potential impact of the policy question discussions on stakeholder preferences, another vote took place after each session in which the public ranked the different policy questions from 1 (least relevant) to 5 (most relevant).

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

Figure 4 illustrates the ranking of topics in Session 1 (ranking in % next to options by most voted option). The top three have been listed for discussion within the session.

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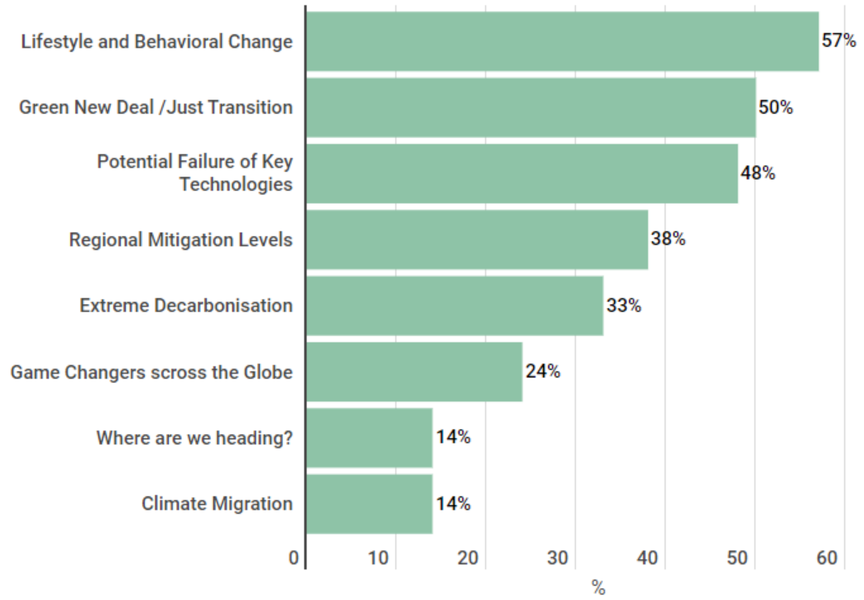

Figure 4. Ranking Results of Global Concerns and Priority Areas of Action for discussion

1. Lifestyle and behavioural change (post-discussion score: 4.0):

In line with IPCC's Special Report on meeting the 1.5°C (IPCC, 2018) and in preparation of its upcoming AR6, aside from legislative and progressive policy changes, citizens innately also have a responsibility in driving change for achieving different mitigation pathways for meeting 1.5-2 degrees' targets as well. Several of the emerging themes from this topic are listed as below:

- Emissions per capita: Where do emissions come from? Example of Denmark, green as a country but not per capita. Do they come from the industries or from the people? Consumption- vs. production-based approach. How is justice incorporated here?
- How to account for equity considerations?
- Circular economy, recycling and reuse of products
- How do we consider for cross-sectoral aspects? E.g. if we stop travelling by plane, how would it affect emissions in other transport sectors? If we stop consuming meat, what would be the effects in agriculture?
- How to differentiate between voluntary behavioural change and response to policy interventions?
- Is the burden on the supply or on the demand side? How to balance off the two?
- Is well-being without growth feasible?

2. Green New Deal/Just Transition (post-discussion score: 3.6):

Following the Green New Deal resolution of Alexandria Ocasio-Cortez in the United States of America, the Green New Deal for Europe is gaining utmost attraction as well, brining community empowerment leading the transition with elements of environmental justice and equality being on the front burner.

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Several of the following discussion points have emerged from the session:

- It is a challenge to model the just transition with quantitative data, but it is possible to try to give responses to some questions.
- The context of justice and transition varies by region: we need to address challenges in hotspots such as coal-intensive regions
- Impact of decarbonisation strategies on labour metrics: job creation, job conversion
- CO_2 prices and their impact on the different sectors of the society; carbon pricing and carbon credits.
- Necessary investments by sector to achieve a just transition
- Carbon farming and the potential of adequate land management to both preserve traditional jobs and also mitigate climate change, turning agriculture into a net sequester of CO_2.

3. Potential Failure of Key Technologies (post-discussion score: 4.2):

Despite the rise of abundant and relatively cheap(er) renewable energy technologies, certain key technologies, such as CCS, indeed maintain a crucial role both within the modelling community and in terms of narratives for achieving negative emissions targets and their role in fossil-fuel based electricity generation prospects. Several of the aspects emerging around this theme in the discussion are as follows:

- Cost of financing: interest rate by region
- Responsibility for importing and exporting of: bioenergy, hydrogen, cheap renewable electricity
- Carbon Capture and Storage (CCS) availability, Direct Air Capture (DAC) as a real Game Changer (how credible is it? How feasible is it to deploy it at massive scale?)
- Which technologies are "essential" for mitigation, and which are "nice-to-have"?
- How to account for risk derived from not including a technology yet to be developed/mature?
- Taking into account materials and minerals extraction and their availability.

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

Figure 5 highlights the most voted topic (in %) related to Session 2 "A Paris-consistent Europe: aligning national (NECPs), regional (EU NDC) & global action". The top four topics were discussed in the session in some detail, see below.

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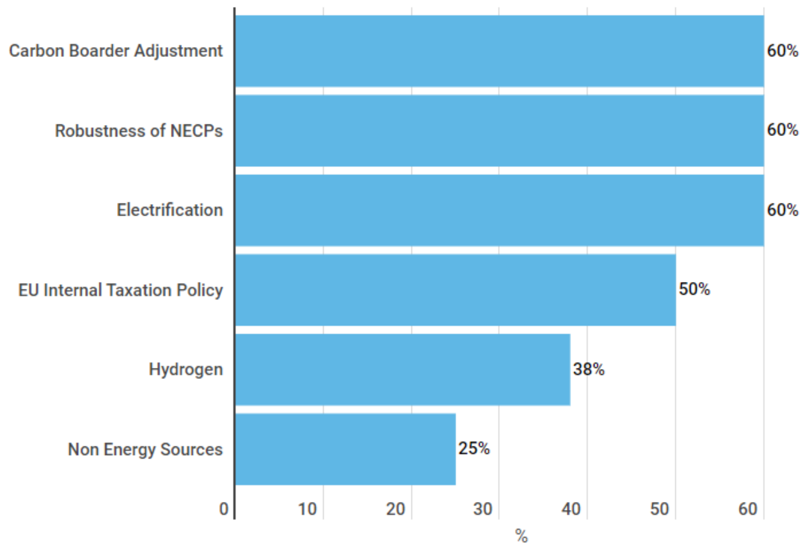

Figure 5. Ranking Results of Regional/National Concerns and Priority Areas of Action

1. Carbon border adjustments (post-discussion score: 4.1):

Carbon boarder adjustments have been discussed as a potential tool for avoiding carbon leakage (EU companies to move their activities abroad) as a foremost agenda of a European Green Deal[5] while also designing real world accounting on avoided emissions in compliance with the World Trade Organization's legal framework [6]. Several of the themes here have revolved around:

- Addressing issues of national protectionist approaches (e.g. tax on imports/exports)
- Addressing particular impacts on specific sectors (e.g. car production)
- How will prices impact the rest of the countries?
- Costs and impacts on neighbouring non-EU countries?

2. Robustness of NECPs (post-discussion score: 3.4):

Alternative mitigation plans with different modelling tools have been discussed to strengthen the robustness of NECPs. Among the themes discussed were:

- Consistency of NECPs towards EU targets (also consistency of NECPs of regions inside the countries)
- The importance and relevance of competition.
- Representation of the financial sector and investment needs should be improved (rate of interest)

[5] https://www.europarl.europa.eu/resources/library/media/20190716RES57231/20190716RES57231.pdf
[6] https://www.europarl.europa.eu/resources/library/media/20190716RES57231/20190716RES57231.pdf

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3. Electrification (post-discussion score: 3.5):

Although broad in category, electrification is a central aspect for net zero carbon emission targets for mid-century goals. Several of the discussed themes around the central role that electrification is to play in the near future were:

- The importance of the hydrogen industry in the future. Hydrogen vs Electrification
- What is the role of electrification in the transportation sector?
- Electrification, Infrastructure and its linkage with material extraction
- Implications of electrification in competition (possibility of the EU becoming a key technology exporter)
- Management of intermittency of renewable energy (including the role of storage)

4. EU Internal taxation (post-discussion score: 3.5):

The Energy Taxation Directive and the EU Emissions Trading System (EU ETS) are two essential tools in the EU policy framework to combat climate change. However, the way they should be best implemented to achieve 2030 targets is still under discussion. Some of the topics that emerged were:

- What would be more efficient? Differences between EU-wide or nation-wide taxation.
- The impact of these policies on the emission reduction efforts per country (potentially not in line with agreed division of efforts).
- The use of the taxes charged to fossil fuels – Should the funds be invested in sustainability initiatives?

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

Figure 6 shows the ranking of topics on socio-economic implications of climate action in Session 3 (ranking in % next to options by most voted option). The top ranking topics have been discussed as follows:

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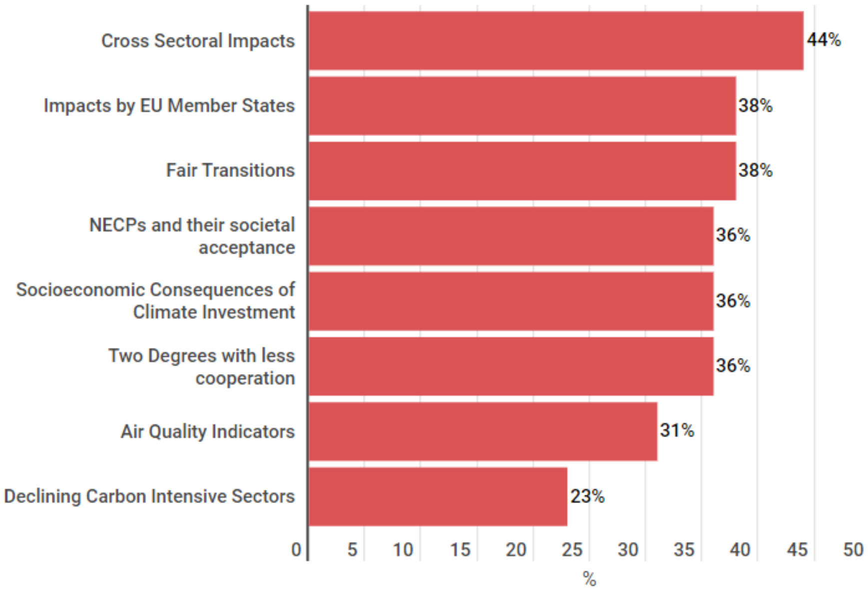

Figure 6. Ranking Results of Socio-economic Concerns and Priority Areas of Action

1. Cross-sectoral impacts (post-discussion score: 3.9):

Rearrangements, shifts, or up-/downscaling within one sector is directly or indirectly to influence the way other sectors and resources are managed. Discussions have revolved around:

- Labour migration, transferability of skills and labour relocation inside the country
- Competitive advantage countries with high renewable resources
- Competition between EU countries for inversions from "Game-Changers" (e.g. Tesla)

2. Impacts by EU Member State (post-discussion score: 3.8):

Regional policies, and more recently the European Green Deal have had or are going to have implications for non-EU regions. Issues that have emerged were:

- Security of supply. Does this give the right to continue polluting and importing from other countries?
- Carbon leakage by outsourcing production due to lower salaries in other EU countries.
- How to push investment towards technologies for them to mature in short time and have an impact?
- Social implications such as gender equality.
- Going green more cost-effective than importing fossil fuels?

3. Fair Transitions (post-discussion score: 3.4)

Distributional Impacts of a transition agenda/the Green New Deal and its consequences on vulnerable populations have been discussed.

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- How to account for distributional impacts within a transition agenda?

4. NECPs and their social acceptance (post-discussion score: 3.4):

Aside from being based on sound science and evidence, National Energy and Climate Plans (NECPs) need to be discussed and accepted with national stakeholders and with neighbouring Member States both for ownership of transition plans and acceptance and effectiveness of plans to take action.

- How can this be accounted for via modelling? Not properly represented in IAMs
- Considering other aspects such as: "Going green" by 2050 would be cheaper than importing hydrocarbons?

5. Declining carbon-intensive sectors (post-discussion score: 4.0)

The role of carbon-intensive sectors was also discussed in the context of fair energy transitions and was finally voted as the most relevant policy concern.

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3 The Modelling Protocol

3.1 Overview of the modelling ensemble

The detailed information on all models in this consortium, outlined in deliverables D5.1 (European national models), D6.1 (non-European national models), and D7.1 (global/regional models), and summarised in deliverable D2.1, is crucial for defining a modelling protocol that is suitable from this point on for this project. Therefore, this subsection provides an overview of the information in reference to these working packages by defining the capabilities, approaches and regional coverage of the models in the project.

3.1.1 Modelling capabilities

Integrated Assessment Models (IAMs) are models that pull together information from different disciplines in order to better understand trade-offs and interactions between parts of society through the modules inside the models (e.g. economy, climate, land use). The process of gathering the modelling capabilities synthesised in deliverable D2.1, 'Map of models, tools and stakeholder knowledge', has allowed the consortium to identify a wide variety of capabilities in terms of geographical reach, sectoral coverage and policy instruments, which are available for research to be carried out within PARIS REINFORCE.

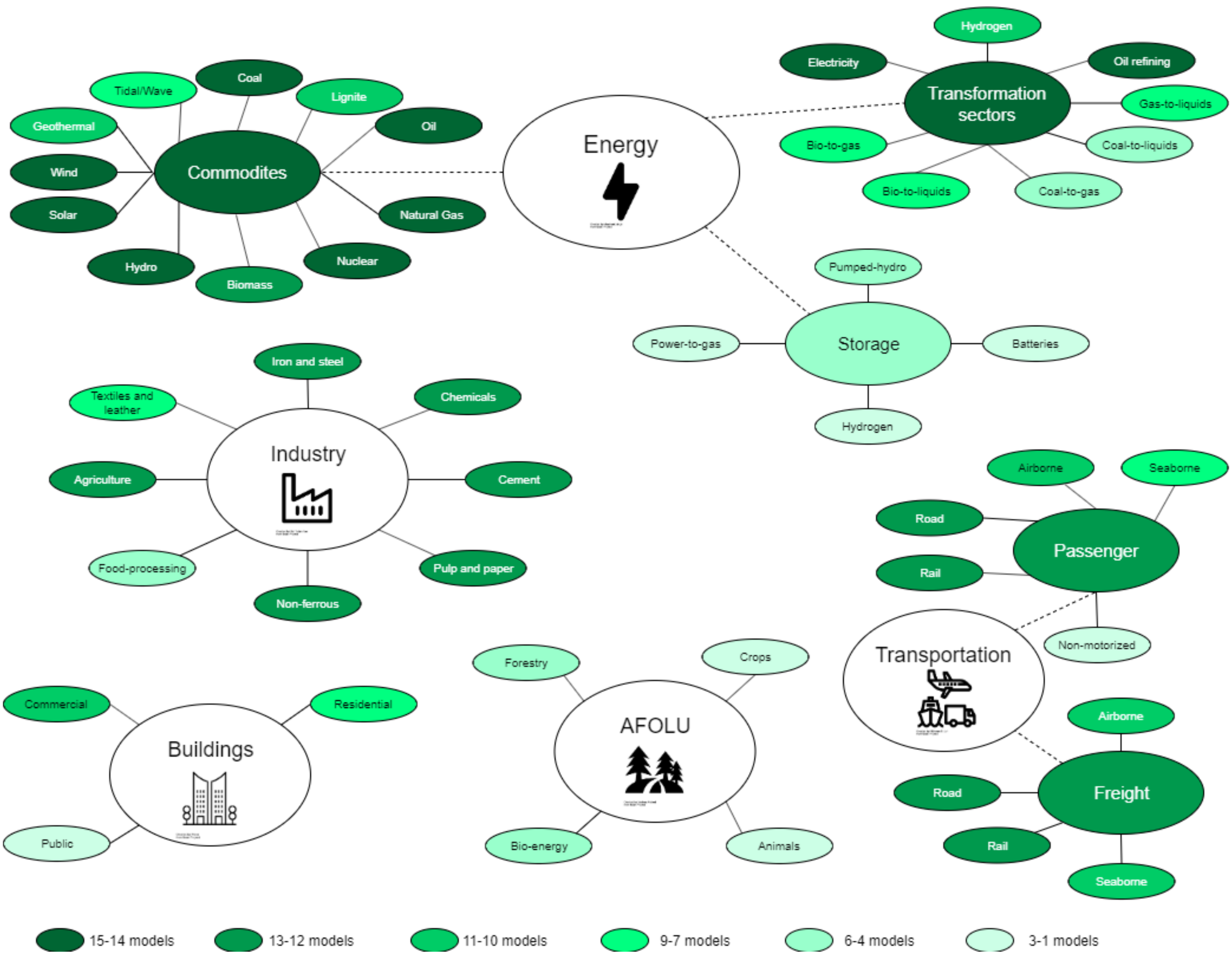

Figure 7 Sectoral coverage of the available models in PARIS REINFORCE

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The sectors, which the models in the project cover, are represented – as shown in Figure 7 – through five main categories: Energy, Industry, Transportation, Building, and Agriculture, Forestry and Other Land Use (AFOLU). The energy sector further disaggregates into commodities, transformation sectors and storage. The structure is aimed at covering the entire cycle of the energy system, from the commodity production to the phase of storage and the transformation into energy types. The industry category includes, among others, relevant sectors, such as cement, agriculture, textile and leathers, iron and steel, chemicals, pulp and paper, non-ferrous metals and food-processing. Transportation differentiates between passenger and freight and includes airborne, seaborne, road and rail transports. Finally, the buildings sector covers public, commercial and residential buildings, and AFOLU includes the sub-categories animals, crops, forestry and bio-energy.

The darker the green in Figure 7 the higher the number of models that can cover that specific category. Most of the models are able to address energy commodities in many forms, such as wind, solar, coal, oil and gas and transformation processes as oil refining and electricity. Some models cover passenger and freight transport and most of the industry sectors, such as cement, iron and steel and chemical, and only a limited number of models are able to cover/represent energy storage, land use and public buildings. Nevertheless, all of the shown categories are covered by at least one model in the consortium.

Additionally, the policy instruments, which can be input into the models to adjust the projections, are represented along the categories of Emissions, Energy, Land Use and Trade (Figure 8). Emissions include not only financial instruments such as taxes and financial support, but also targets on emissions, temperature and regulations. Energy also covers the mentioned financial instruments plus targets on efficiency, energy mix and regulations. Land use policy instruments are addressed through production quotas, protected lands, afforestation targets and carbon sink pricing, and trade policy instruments include carbon border taxes on imports, exports and regulations.

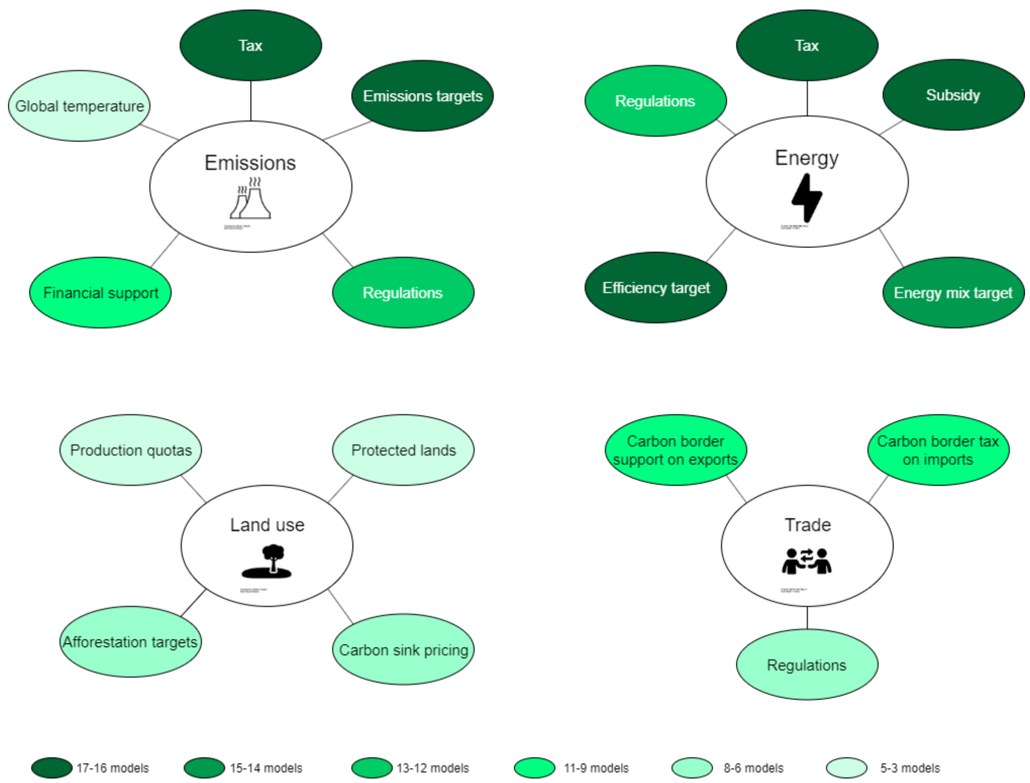

Figure 8. Policy granularity of the available models in PARIS REINFORCE

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Similarly, a darker green in Figure 8 indicates more models covering that specific policy instrument. It becomes clear that energy and emission targets have a heavy presence along with economic instruments such as taxes and subsidies.

Finally, a consideration of which SDGs can be covered by models (through their output metrics related to SDG targets) has also been undertaken. Each SDG has several metrics influenced by a range of factors, e.g. changes in energy prices are relevant to SDG 7 (Affordable and Clean Energy) and also indirectly to SDG 1 (No Poverty) if considered a driver of poverty. Additionally, the coverage of a particular SDG does not imply the use of the same metric, so different metrics can be used to cover the same SDG, e.g. mortality due to air pollutants and healthy life expectancy for SDG 3 (Good Health and Well-being) or access to electricity and renewable electricity share for SDG 7 (Affordable and Clean Energy). Table 1 shows the SDGs covered by each geographical set of models in the consortium.

Table 1: List of Sustainable Development Goals (SDGs) and their model coverage for each geographic scale

SDGs → / Models by geo-graphic coverage	**SDG 1:**No Poverty	**SDG 2:** Zero Hunger	**SDG 3:** Good Health Well-Being	**SDG 4:** Quality Education	**SDG 5:** Gender Equality	**SDG 6:** Clean Water Sanitation	**SDG 7:** Affordable Clean Energy	**SDG 8:** Decent Work Growth	**SDG 9:** Innovation Infrastruct.	**SDG 10:** Reduced Inequalities	**SDG 11:** Sustainable Communities	**SDG 12:** Responsible Cons./Prod.	**SDG 13:** Climate Action	**SDG 14:** Life Below Water	**SDG 15:** Life on Land	**SDG 16:** Peace, Justice Institutions
European national						✓	✓	✓	✓	✓	✓	✓	✓			
Non-European national	✓		✓	✓			✓	✓	✓		✓	✓	✓		✓	
Global / regional	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	

The combination between the different types of models ensures that PARIS REINFORCE is able to provide a comprehensive level of policy insight that would not be possible with a single modelling exercise. The comparability and the complementarity of the models allow the consortium to produce results with different levels of aggregation and account for the many interactions between sectors.

3.1.2 Modelling approaches

In order to understand how the modelling outcomes can be harmonised and interlinked, models falling into the same category in terms of their modelling approach and regional coverage have been identified as a first step. This will allow us to initiate the discussion on the comparability of results and the creation of synergies.

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The 22 models used in PARIS REINFORCE fall into these five broad categories:

- **Computable General Equilibrium** (CGE) models are large-scale models describing the entire economy and the interactions between its sectors. Prices adjust to achieve equilibrium in the entire economy.
- **Partial equilibrium** models zoom in upon specific sectors (e.g land use, energy, etc.) while holding other sectors constant. Within the sector modelling iterations are computed until equilibrium is reached.
- **Macroeconometric** models offer multiple-sector representations of the economy. They make no assumptions that markets or agents behave optimally. Agent interactions across the economy are instead modelled based upon historical data and econometrically estimated parameters.
- **Energy System** models are sub-categories of partial equilibrium models and they focus specifically on energy sector processes. They contain detailed representations of fuel extraction, transformation into useful energy forms, delivery of this energy to end users, and the consumption of this energy to provide consumer services.
- **Sectoral focused** models used in Paris Reinforce are techno-economic bottom-up models that model sectors based on technological learning and economic optimisation under side conditions. They can be used to examine climate action in particular sectors, e.g. the transportation, building and AFOLU sectors, and inform global modelling scenarios.

The consortium includes five models covering the EU region and European countries at the national level, nine models covering major regions outside of Europe, and eight global models. Models shown in Table 2 with light green background correspond to global models, in grey the ones focused on the European territory and in dark green background to models covering major regions outside the European territory.

Table 2: List of global/regional, European national, and non-European national models by type

General Equilibrium	Partial Equilibrium	Macro-econometric	Energy System	Sectoral focus
DICE	TIAM	NEMESIS	JRC-EU-TIMES	ALADIN
ICES	GCAM	E3ME	LEAP	FORECAST
GEMINI E3	(- USA)		MARKAL	CONTO
	(-CHINA)		MAPLE	SISGEMA
	(-SOUSEI)		NATEM	
			TIMES-CAC	
			MUSE	
			42	

Global/regional	European national	Non-European national

3.1.3 Models by regional coverage

By looking at the regional coverage capabilities of the modelling ensemble, it was possible to assess which models are able to produce results aggregated for the whole world, by region and at national level (Table 3). The global models produce aggregated projections for the whole world, at continental

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level and some of them also at national level, which, added up to the countries covered by the national models, account for a total disaggregated country coverage of 76 countries. For countries outside of Europe with a crucial role in the implementation of the Paris Agreement, the consortium includes also a significant number of models covering the main major emitting countries as well as other less emitting countries, making it possible to produce robust results. In Europe, results can also be disaggregated at national level for not only countries inside the EU-28, but also countries inside the European Economic Area (Norway, Switzerland and Iceland) and other countries in Eastern Europe.

Table 3: List of global/regional, European national, and non-European national models for major emitters and less emitting countries by regional coverage

WP	Region / Country	Models with geographical coverage							
5	**Individual EU-28 Countries**	NEMESIS	JRC-EU-TIMES	FORE-CAST	ALADIN	E3ME	42		
	Norway, Switzerland	JRC-EU-TIMES	FORE-CAST	ALADIN	E3ME				
	Iceland, Balkan countries	JRC-EU-TIMES							
	Ukraine, Belarus, Turkey	42							
6	**Brazil**	SISGEMA	GCAM	ICES	GEMINI-E3	MUSE	E3ME	42	
	China	MAPLE	GCAM-CHINA	ICES	GEMINI-E3	TIAM	MUSE	E3ME	42
	Japan	GCAM-SOUSEI	ICES	TIAM	MUSE	E3ME	42		
	India	MARKAL	GCAM	ICES	GEMINI-E3	TIAM	MUSE	E3ME	42
	USA	NATEM	GCAM-USA	ICES	GEMINI-E3	TIAM	MUSE	E3ME	42
	Russia	CONTO	GCAM	ICES	GEMINI-E3	MUSE	E3ME	42	
	Canada	NATEM	GCAM	ICES	TIAM	MUSE	E3ME	42	
	Mexico	NATEM	GCAM	ICES	TIAM	MUSE	E3ME	42	
	Indonesia	GCAM	ICES	E3ME	42				
	Kenya	ICES							
	Kazakhstan, Uzbekistan, Azerbaijan	TIMES-CAC	42						
	Gulf Cooper-ation Council	GEMINI-E3	E3ME						
7	**World**	GCAM	TIAM	ICES	GEMINI-E3	E3ME	MUSE	42	DICE
	EU-28	NEMESIS	JRC-EU-TIMES	GCAM	GEMINI-E3	ICES	MUSE	E3ME	42

Global/regional	European national	Non-European national

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The information detailed in this section is captured in the model dynamic documentation of the I^{2}AM Paris Platform (Figure 9). Upon selection of a specific model by the user, details on the geographic, sectoral and SDG coverage are displayed in a user-friendly colour-coded layout which allows the viewer to seize the information at a glance.

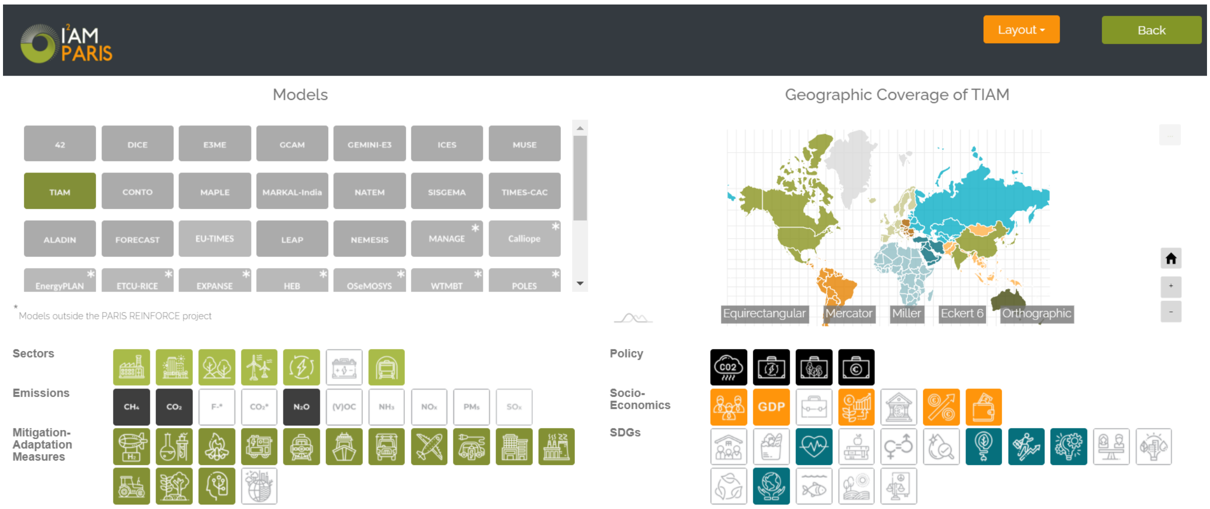

Figure 9: Consortium modelling capabilities shown on the I^{2}AM PARIS Platform

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3.2 Structure of modelling workflow

3.2.1 Modelling Workflow Task Plan

While Figure 1, in the introduction, shows broadly how modelling activities in WPs 5, 6 and 7 are connected and interrelated with stakeholder engagement in WP3, this subsection goes into more detail. Specifically, Figure 10 shows graphically when every modelling task in the project starts and ends, and where modelling inputs will come from. Based on harmonised modelling inputs, the model preparations for global and European reference scenarios (using global and European models specified in Table 3) start in February 2020. Also, specific policy concerns gathered in the first stakeholder event on the 21st of November 2019 (see Section 2.3.3), the initial discussions with key stakeholders in the months before this event, and the interviews with Norwegian civil servants (see D7.3) will be modelled in the global scenarios and also taken into account in the design of these reference scenarios. Outputs from these first modelling activities should be ready by early December 2020, and feed into the non-European national modelling exercises (for countries and using models as specified in Table 3), as well as the various stakeholder events in European and non-European countries, and the IPCC AR6 cycle in time.

Apart from the defined set of harmonised inputs, outputs from the global and European reference scenarios will be used as inputs for the first set of national scenarios. Apart from the global and European policy concerns gathered during the first stakeholder event, and used for the scenarios in the national modelling exercises, additional policy questions will be gathered for the national scenarios for several country case studies during the national workshops that are to take place during October 2020 and onward (see Figure 3). The outputs of the national modelling exercises will be ready by June 2021 and will be shared with stakeholders through the I^{2}AM PARIS platform. These outputs will also be used, in combination with feedback from stakeholders, to adjust the global scenarios, taking into account specific policies and priorities in the EU and other large emitting countries/regions. These adjusted global outputs, to be ready by October 2021, will then be used as inputs for the adjusted national scenarios, along with the feedback from national/regional stakeholders. These outcomes will then again be shared with stakeholders through the I^{2}AM PARIS platform by March 2022.

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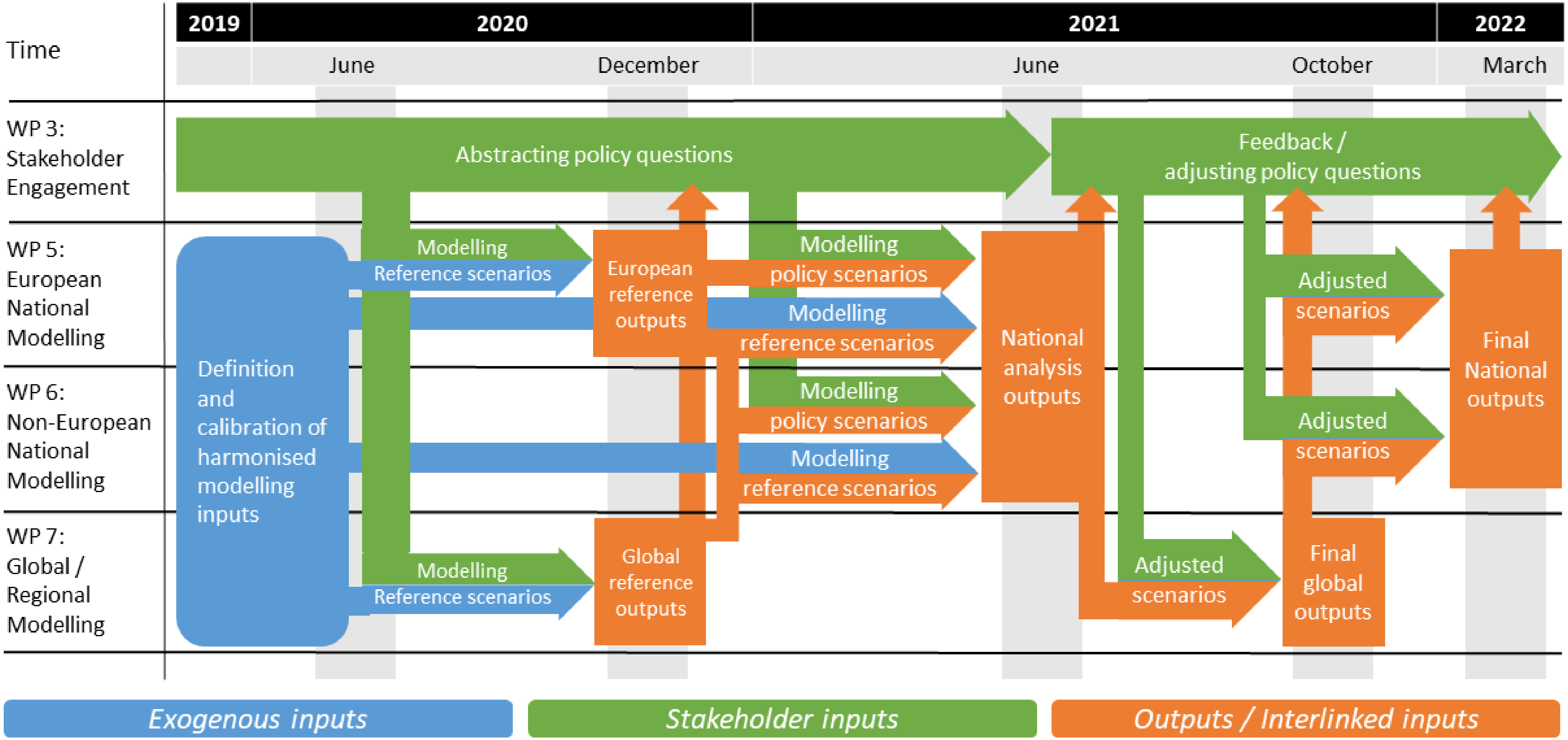

Figure 10. Modelling workflow with task dates and specified model input use until end of project

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3.2.2 Model input harmonisation

Figure 10 shows that the models used in this project are largely driven by harmonised inputs, either through exogenous pre-defined inputs, or by interlinking inputs to outputs from other models. Therefore, an excel template is constructed with a list of preliminary variables that models can cover to reflect each model's capabilities. The variables on this template have been selected based on the views from modellers of each type of model in the consortium (see Table 2), indicating the set of variables that could potentially be meaningful to harmonise. Once the template is filled by the consortium modellers, it will indicate whether the variables are represented at all in the models, whether they are an output of the models simulation or whether they can be treated as harmonisable input variables. When considered as harmonisable inputs, a further disaggregation is made depending on whether they are/can be harmonised or not (and to what extent) during the course of the exploratory project (**Table 4**).

Table 4: Variable selection for potential harmonisation or interlinkage

Categories	Sub-categories	Examples	
Socio-economics	Demography	Population, Urbanisation	Each modelling team selects one of the following options for each variable:
	Macro-economy	GDP, discount rates, income and price elasticities	
	Demand drivers	Industrial goods, passenger transport, building services	
Technology parameters (cost, efficiency, etc., depending on model)	Upstream	Biomass to liquids, gas to hydrogen	
	Electricity / heat	Nuclear fission, PV, wind, biomass, batteries	Extractable model output
	Transport	Diesel vehicles, electric vehicles	
	Buildings	Gas heating, solar heat pumps	Model input: can be harmonised for project purposes
	Industry	Process heat (gas, hydrogen etc), Steam, CCS	
Commodity prices	Energy prices	Oil, bio-energy global market / import prices	Model input: cannot be harmonised for project purposes
	Other prices	Food, steel global market prices	
Other	Emissions	(land use) CO_2	Not represented in model
	Potential	Solar, Wind energy potential	
	Energy mix	Electricity mix, building energy mix	

Once filled by all models in the consortium, the information from this template will be used for reference regarding input harmonisation, transparency, and modelling outputs for the I^{2}AM PARIS platform. In order to support these processes, the platform incorporates both a customisable and a general overview of this information through a colour-coded heat map (see Figure 11).

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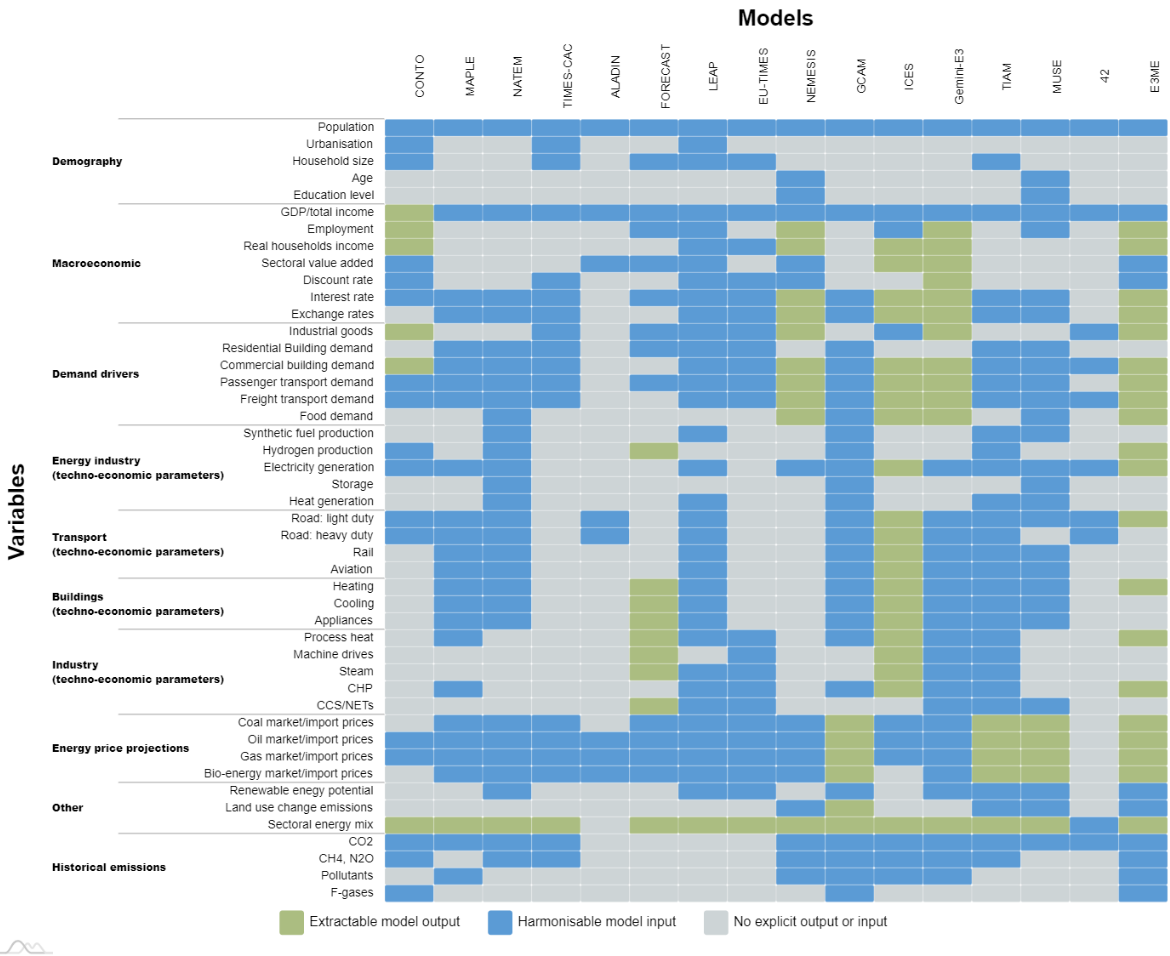

Figure 11: General overview of the heat map in the I²AM PARIS platform with harmonisable input variables and corresponding modelling capabilities

The harmonisation of model inputs is crucial for a meaningful comparison. Hence, without harmonisation of key input drivers, it is impossible to know which differences between modelling outcomes are driven by the modelling structure and which are driven by the use of different inputs. Also, when interlinking two models with a different structure or geographical cover (i.e., through "soft-links", using the output of one model as input of another model), harmonisation of those inputs that both models have in common is crucial for the consistency of the soft-linking process. Therefore, the excel template in Table 4 should indicate the parameters that are relevant for harmonisation. The precise variables to be harmonised depend on each model´s harmonisable inputs and outputs that follow from the harmonisation template, but for the most obvious variables, like socioeconomics, key technology parameters, and historical emissions, the harmonised values have been determined.

3.2.2.1 Parameter harmonisation: socioeconomics

Due to the high uncertainty of long-term population and GDP growth rates, global GDP projections that range up to 2100 are scarce. The only known source with a global range is the SSP database, which has been developed to feed IAMs (Dellink et al 2017; KC & Lutz 2017). One important problem with this database is that it has not been updated over time, and projections in the 2010-2020 period diverge from actually observed trends. Although this could be overcome by replacing short-term growth rates with observed and more actual projections, e.g. these provided periodically by the UN (population) and

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IMF (GDP), there is a problem with serial consistency: for both population and GDP growth rates, serial correlation can be assumed, meaning that values in one year depend on all preceding years. Therefore, directly replacing short-term values by observed values in a long-term projection, but without adapting the subsequent annual growth rates, will eventually lead to inconsistent growth paths.

Another important condition that socioeconomic drivers should meet is that population and GDP projections are consistent with each other. A relevant variable for GDP growth is the size of the working age population, which is directly related to population trends. These conditions make it difficult to use population projections such as those from the UN (which are global and go up to 2100), as there are no existent long-term GDP growth trajectories that are consistent with that specific population trajectory. SSP2 socioeconomic trends have been criticised for diverging strongly in some cases from projections assumed by national or regional authorities, which likely have the best picture on population and GDP tendencies. For example, in the European Union (EU), the Ageing Report (EC, 2018) is generally used as a reference for socioeconomic drivers, but when compared with SSP2 trajectories differ significantly in terms of both population and GDP growth (more detailed analysis in Annex I). Meanwhile, there is also a need for geographic consistency: in a globalised world, GDP growth rates in one place affect growth rates in all other places, and immigration waves affect population growth rates in multiple countries simultaneously (positively and negatively). Therefore, using different sources for every country or region can be problematic, since in each source assumes certain global conditions, which affect the projection. This means that it might not be consistent to take the official numbers used by government agencies in each country, although it would avoid discrepancies with national or regional projections.

For the sake of constructing a socioeconomic trajectory that is up to date with the latest observations and near-term projections, we follow a set of priorities to which this trajectory has to fulfil. However, since not all priorities can be met simultaneously, we have ordered them based on importance:

1. Up-to-date: since the focus is to draw realistic scenarios based on current conditions, the assumed socioeconomic trajectories have to be consistent with recent population and GDP growth rates, and the short-term projections based on such observations.
2. Reliability: for future projections, it is important that the projections used come from reliable sources.
3. Mutual consistency between (working age) population and GDP growth rates: for the realism of the trajectories, we avoid using population and GDP projections from different sources, given their interrelatedness.
4. Serial consistency over time: population and GDP trajectories tend to follow certain paths over time (e.g. based on fertility and mortality for population, and business cycles for GDP), so we try to safeguard this consistency in the way different sources are chosen and combined.
5. Geographic consistency: we avoid taking a very wide range of sources to safeguard some kind of geographic consistency

Maximising among these conditions, we use three different approaches for the following sets of countries:

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European Union + United Kingdom + Norway: representing 8.2% of global population, 17.2% of global GDP.	EUROPOP (2018) for population projections until 2100 Ageing Report (2018) for GDP per capita projections until 2070 SSP2 Env-Growth (Dellink et al 2017) for GDP per capita projections after 2070
Rest of countries in OECD database *(rest of OECD + Argentina, Brazil, Colombia, Costa Rica, India, Indonesia, Saudi Arabia & South Africa)*: representing 57.8% of global population, 62.8% of global GDP	OECD.stat (2020) for short-to-medium term population projections OECD Economic Outlook 106 (2019) for GDP growth until 2021 OECD Economic Outlook 103 (2018) for GDP growth on medium term (>2021) SSP2 IIASA (KC & Lutz 2017) for long-term population projections SSP2 Env-Growth (Dellink et al 2017) for long term GDP growth projections *Switch from "short-to-medium" term to "long-term" projections depending on country, ensuring smooth transitions between projected growth levels.*
Other countries: representing +/- 34% of global population, +/- 20% of global GDP by 2010)	UN database (2019) for population estimates until 2020 IMF WEO database (2019) for GDP growth estimates until 2020 SSP2 IIASA (KC & Lutz 2017) for post-2020 population projections SSP2 Env-Growth (Dellink et al 2017) for post-2020 GDP growth projections

In the case of the countries belonging to the group "Rest of countries in OECD database" a case by case approach is followed in line with priorities 1-5 outlined previously to ensure a smooth growth rate figure transition between databases.

3.2.2.2 Parameter harmonisation: techno-economic assumptions

An effort is done to harmonise also technoeconomic assumptions for the power and transport sectors. Harmonisation in the power and transport sector is facilitated by close representation of technologies across the models. In the remaining sectors, the harmonisation aims for a benchmarking of advanced technologies compared to the traditional ones in industry, residential, and commercial sectors.

For each of the harmonised technologies, the harmonisation approach follows these steps:

- Selection of representative technologies with the wider description shared across the models.
- Critical comparison of base year and projected costs (capital and operating and maintenance), efficiencies, and lifetime from the internal TIAM database against the up-to-date databases. At the EU-level, shared recommended assumptions by the European Commission for modelling exercises the European NECP reports are used, based on Mantzos et al. (2017).
- Regional cost modelling using regional cost factors reflecting labour costs

The power sector technologies whose parameters are defined are: onshore wind, offshore wind, solar photovoltaics utility and rooftop, solar concentrated solar panel, pulverised coal, oxyfuel coal, coal

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integrated gasification combined cycle, natural gas combined cycle, natural gas combined cycle oxyfuel, geothermal, nuclear, and biomass combustion.

The transport sector technologies whose parameters are defined identify the key transport modes to target for the decarbonisation of the sector, such as buses, cars, light trucks, medium trucks, commercial trucks, and heavy trucks. Each transport mode is characterised using conventional fuels (either petrol, diesel, LPG, or natural gas) or biofuels (either ethanol, methanol, or hydrogen), or electricity (battery of hybrid vehicles). As a general assumption to move from a cost per vehicle to vehicle-km, it was assumed an average travelled distance in Europe equal to 13,000-37,000-52,000 km per year respectively for light, medium, and heavy trucks.

3.2.2.3 Parameter harmonisation: historical emissions

In order for the emissions at the start of the projection period to be in line across models, base year emissions are to be kept aligned with a consistent global, country-level disaggregated dataset for historical emissions of major greenhouse gases: the Community Emissions Data System (CEDS) for Historical Emissions (Hoesly et al., 2018; van Marle et al., 2017).

3.2.3 Reference scenarios design

Figure 10 also indicates that throughout the project, different reference scenarios will be run in each modelling WP. Reference scenarios will be harmonised among all three modelling WPs, while policy concerns are specific to each WP. Stakeholder-gathered policy concerns will be modelled as specific alternatives to the reference scenarios.

The goal of the reference scenario design of the first modelling round is to explore the cumulative impact of current energy and climate policies and current emissions reduction ambitions until 2030, and where the world is headed in the long term assuming an extrapolation of current climate efforts and ambitions after 2030.

Like with input parameters, modelling teams make policy assumptions, which are broadly in line where transparency is another important issue for policy assumptions. Current policies (CPs) and Nationally Determined Contributions (NDCs) are implemented according to the CD-Links policies database (Roelfsema et al., 2020) and the NDC commitments submitted by each country to the UNFCCC. Two reference scenarios are then designed until 2030 with this information:

- A **CP** scenario including the model implementation of current policies
- An **NDC** scenario including the model implementation of current policies <u>and</u> NDCs. Current policies are also added to this scenario as the intention is to capture the <u>additional effort</u> (if any), which is required to be aligned with NDC commitments.

In addition to the CD-Links policies database, updated current policies for key emitting countries were identified and feedback was received from national modelling groups in the consortium. Specifically, policies were updated for Russia, India, the European Union, U.S., Japan, Brazil, and China. Precise information on applied policies and ambitions by region will be recorded as outputs of this first modelling rounds.

Through current policies and NDCs, it is possible to capture efforts up until 2030; however, some level

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of policy after 2030 in line with CPs and NDCs need to be modelled to explore where continuously increasing ambition might lead to and whether they will be sufficient to reach temperature targets consistent with the Paris Agreement. From a modelling perspective, there are many potential ways of extending CPs and NDCs beyond 2030 based on some form of 'continued ambition'. The metric choice to drive ambition in post-2030 scenarios (carbon price, emissions intensity, absolute emissions, etc.) matters because it reflects different assumptions regarding how climate policy is likely to progress. There are also different ways of how the chosen metric can be extended forward in time. While the intention is not to predict future policies (or technologies), the scenario design aims to represent a more systematic analysis of possible emissions pathways based on extending current trends with reasonable policy (and technology) trajectories. This can provide an improved basis for identifying how ambitions will need to be accelerated in order to limit global warming to well-below 2^{0}C, and thus for informing the ratcheting up of ambition inherent to the Paris Agreement.

Based on these considerations as well as on the characteristics and capabilities of the models involved, two methodologies for post-2030 ambition extrapolation are selected:

- Obtain model-specific regional carbon prices until 2030 by simulating the implementation of NDCs and/or CPs and **extend these carbon prices** post 2030 based on regional GDP per capita growth rates.
- Obtain regional emissions until 2030 by simulating the implementation of NDCs and/or CPs and **extend emission caps** post 2030 based on the improved emissions intensity of GDP during the 2020-2030 period (following Fawcett et al., 2015).

The motivation behind these scenarios is to explore the use of different metrics to extend ambition and project climate change mitigation scenarios into the future. The resulting outputs stemming from the different models will then be compared and the resulting modelled pathways can be compared and assessed.

3.2.4 Model Interlinkage

While model harmonisation is relevant when several models are using the same exogenous inputs, it is not a straightforward solution if some variables are inputs to one model but outputs of another model. In such cases, a soft-linking of models can be set up for variables that are important for the final modelling outcomes. Soft-linking can be achieved by running models in sequence instead of in parallel, and in which outputs of one model will be used as inputs in another model. In combination with the harmonisation of inputs that are exogenous for both models, this practice guarantees a consistent set of model outcomes from a heterogeneous set of models.

Figure 10 shows that model interlinkage will take place between the different modelling WPs, specifically using outputs from the regional/national scenarios for the global scenarios in the second round, transforming outputs from the first national modelling round into inputs for the second round, and using global outputs from the second modelling round for national scenarios in the same round. Apart from that, within each WP, there might be additional soft-links between models of different types (see Table 2)[7]. Based on the outcomes of the excel template (Table 4), variables will be selected that will be

[7] See for example Figure 1 in D5.1

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harmonised and interlinked within and between the different modelling WPs.

For the modelling of specific policy concerns expressed by stakeholders, a specific modelling plan can in some cases be designed with possible soft-links between models. This will be done by strategically connecting those models in the consortium to provide a specific answer on a policy question or concern. See Figure 12 for an example of how model resources within the consortium can be used to answer a specific policy concern that could come up. In this example, models with land use modules (GCAM, SISGEMA) would be used for in-depth analysis, as the question is related to land impacts. In policy concerns related to for example income distribution, macroeconomic models would be used instead. Note that, specific interlinkages cannot be defined before it is decided exactly which national, regional and global policy concerns will be answered.

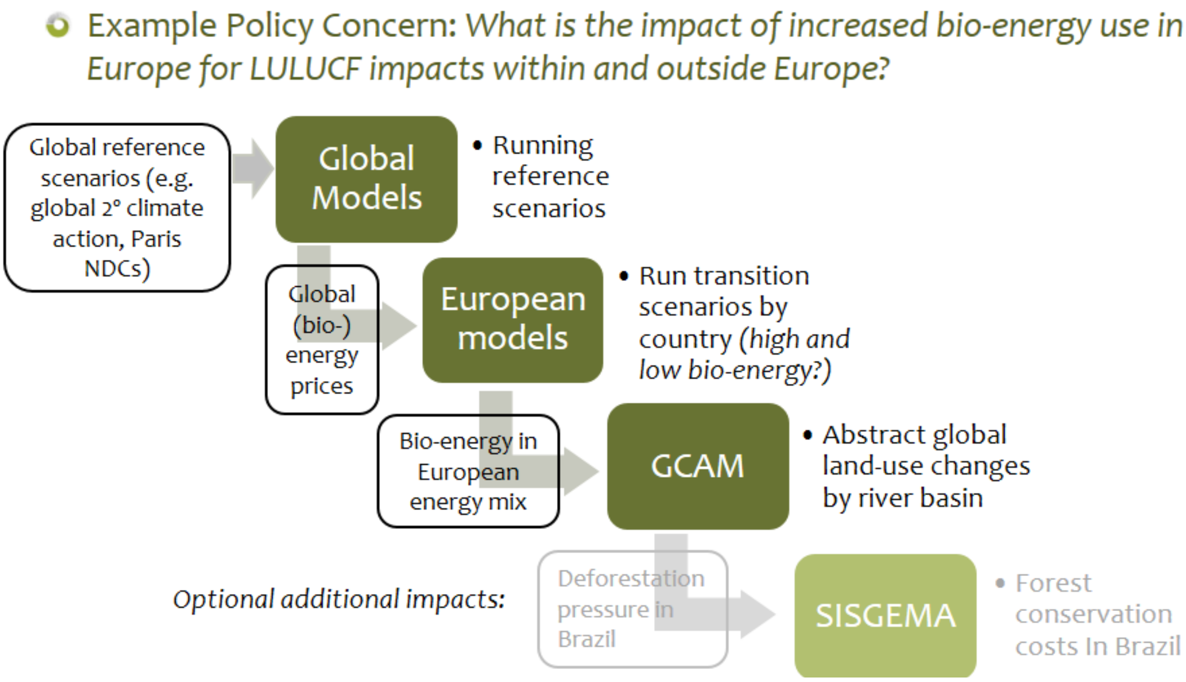

Figure 12: Example for model utilisation for an example policy concern

Source: Bruegel stakeholder event, presentation: “what can our models deliver?” (21 November 2019)

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4 The use of additional tools

As part of the robustification module of the project, a portfolio of tools will be used in addition to (complementing) the modelling tools and frameworks, towards helping bridge the science-stakeholder interface, co-designing well-informed modelling scenarios, and leading to modelling outcomes and resulting prescriptions that are robust in terms of uncertainties.

4.1 Capturing a well-informed context

It is imperative that the overall socio-technical context of countries be comprehensively captured in detail and inform national modelling activities. Drawing from recent examples (Moallemi et al., 2017; Edsand, 2017), the PARIS REINFORCE project will first and foremost carry out such analyses based on the Technological Innovation System (TIS) and/or Multi-Level Perspective (MLP) frameworks, for specific countries and sectors. A tentative list of case studies includes: one study of a just energy transition to a post-lignite Greece; one comparative case study of an industrial technological transition in the iron and steel sectors of Germany and the Russian Federation; and one comparative case study of a transition to a low-carbon transport sector in Norway and the United Kingdom. The analyses will be extended to capture a concrete overview of the national priorities across several relevant SDG dimensions, as well as the synergies and conflicts of these priorities in respect to the necessary transitions, the enabling environment in terms of policy mixes, institutions and networks, the relevant innovation system functions, as well as the various levels in which the transitions must take place. The implementation of Systems of Innovation frameworks will be complemented by system mapping of the innovation systems in the face of climate change and in light of the Paris Agreement commitments (Nikas et al., 2017).

4.2 Co-creating modelling scenarios

Before the beginning of the first modelling iteration, PARIS REINFORCE will seek to determine specific modelling input parameters as well as prioritise risks and objectives that modellers should consider in their analyses, based on the tacit knowledge embedded in the various stakeholder groups. After selecting the key input parameters, appropriate Multiple-Criteria Decision Aid (MCDA) methodologies will be selected to support the elicitation and exploitation of stakeholders' preferences and expertise, tailored to fit the requirements of each task and the nature of each parameter (Song et al., 2020). The analyses will be extended to capture the views of policymakers and other stakeholder groups with regard to risks associated with policy and technological options, as well as the different priorities (e.g. as expressed in the 2030 Agenda for Sustainable Development) in the context of the EU and/or each country. A significant aspect of MCDA, on which the selection of the appropriate frameworks largely depends, lies in the featured capacity to support a large number of stakeholders; given that the participation of different stakeholder groups with different types and levels of knowledge of different aspects of the problem domain is both desired and a core aim of the PARIS REINFORCE project, it is of vital importance that the group decision making aspect of MCDA be highlighted (Nikas et al., 2018). In this respect, PARIS REINFORCE will tailor to its needs and make use of different tools, such as FLINTSTONES, a TOPSIS-based computational MCDA software suite (Labella and Martinez, 2020) with the ability to capture and simulate stakeholders' assessments; and AFRYCA, a simulation-based analysis framework for the resolution of group decision making problems in terms of different consensus models (Labella et al., 2017).

In between the two national modelling exercise iterations envisaged in the project, stakeholders will be

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asked to help identify new pathway choices as well as define the requirements for further pathway options. Among other engagement and elicitation approaches aiming to capture changes in preferences that will constitute the basis of productive feedback into modelling tasks, fuzzy cognitive mapping will be used at the national level, in order to evaluate different policy strategies from the stakeholders' point of view (Nikas et al., 2020b; Antosiewicz et al., 2020). In this direction, the FCM framework will be extended, from comparing individual choices against one another, to assessing policy mixes comprising multiple policy instruments (Nikas and Doukas, 2016) against different socioeconomic developments, in order not only to evaluate different strategies but also to assess their vulnerability to uncertainties (Nikas et al., 2019).

4.3 Enhancing robustness of modelling outcomes

The Index Decomposition Analysis (IDA) method will be used to identify the main levers used to reduce energy-related CO_2 emissions in the scenarios developed for Europe (Wachsmuth and Duscha, 2018). To this end, the CO_2 emissions in each end-use sector (buildings, industry, transportation and energy supply) will be decomposed into the product of a sectoral activity variable, the energy use per activity and the CO_2 emissions per energy use, which is further split up based on the shares of different energy carriers. Based on the resulting decomposition, the ranges of the contributions to emission reductions for sufficiency, energy efficiency, direct renewable energy use, hydrogen, nuclear, electrification and fossil fuel switch will be derived, enabling the identification of similarities and differences between model results (with smaller ranges indicating agreement between the models, and larger ranges pointing to uncertainties). Another way to judge the robustness of the IAM results will be to benchmark them with the results from the bottom-up sectoral models (Duscha et al., 2018) for Europe. Both IAMs and bottom-up sectoral models will be applied to build scenarios for the EU; to use the latter as a benchmark, the ranges of the IDA results for the evolution of sectoral activities, energy intensities, fossil carbon intensities and the share of renewables and electrification in the IAM scenarios will be compared to those in the bottom-up sectoral scenarios. The robustness of the IAM results will require that the IAM ranges cover the sectoral modelling results, and the distance of the sectoral model results to the IAM results will be used to classify the IAM scenarios as either progressive or conservative for the various sectoral levers.

Furthermore, PARIS REINFORCE will aim to analyse the uncertainty of the modelling results, acting at all post-modelling exercise stages, and based on the principles of portfolio analysis, by assuming that uncertainty is of probabilistic nature (Forouli et al., 2019b; Van de Ven et al., 2019): considering that different plausible futures may encompass a large range of uncertain factors, which can have various effects on the variables of importance (e.g. emissions reductions), systematic decision making approaches will be developed, using multi-objective programming (Nikas et al., 2020a), Monte Carlo simulations and the Iterative Trichotomic Approach (Forouli et al., 2019a) in order to deal with the inherent probabilistic uncertainty in the objective functions' coefficients (Forouli et al., 2020).

Finally, the quantitative national modelling results will be extended to socio-technical transformation pathways, by adding policy narratives to the quantitative scenarios based on the analysis of the related innovation systems, enabling to derive guardrails about how to govern the relevant transformation processes. In this respect, PARIS REINFORCE will focus on dialogue between models and qualitative approaches for comparing and contrasting insights in the five national case studies, for which the socio-technical context will have been analysed (see Section 4.1). After identifying transition bottlenecks (Geels et al., 2018), socio-technical storylines exploring how these bottlenecks can be overcome will be co-

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created by scientists and stakeholders (Rogge et al., 2018), and policy guardrails will be communicated to policymakers, showing how plausible and extreme situations jeopardising the realisation of the resulting transitions can be addressed in order to keep these transitions on track, through social interactions, proper institutional settings and learning processes.

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5 The I²AM PARIS platform

All modelling activities, including scenario inputs and assumptions, datasets, modelling outputs, and visualisation are currently being and will be streamlined in our open-access data exchange platform: The I²AM PARIS platform (http://paris-reinforce.epu.ntua.gr/main)

The platform's initial live launch was successfully conducted at the 1st Regional Workshop in Brussels, in M6 (6 months prior to its contractual release date). The first launch of the platform, temporarily hosted on an NTUA domain, covers the following information on modelling components:

Dynamic documentation: This dynamic documentation was exclusively based on an initial template for gathering/standardising certain inputs on Models, Geographic Coverage, Sectors, Emissions, Mitigation/Adaptation Measures, Policy, Socio-economics and SDGs. It serves as an Interactive Map of Models and Tools (deliverable D2.3).

Comparative assessment: This section is a summary of Sections 1 and 2 of deliverables D5.1, D6.1 and D7.1, presenting a comparative overview of Global, National/Regional for Europe and for countries outside of Europe.

Detailed documentation: Once again, based on Inputs from D5.1, D6.1 and D7.1, detailed information on each specific model here is covered in detailed for the user to be informed.

5.1 Feedback to the Platform at Live Launch

The feedback from the platform prototype was overall very positive. All stakeholders participating in the regional workshop—and consortium partners—agreed on the quality as well as its user-friendly interface and visualisation, and considered it a valuable foundation for further elaboration of the platform in the course of the project.

5.1.1 General feedback

Analysing the platform and its content more in detail, these were some of the topics raised during our discussions with stakeholders:

- The platform may be useful to decide on emissions ambition and analyse inter-sectoral dependencies.
- One of the strongest points is the transparency of input variables, assumptions and datasets.
- The platform should go beyond quantitative tools and incorporate qualitative techniques and social aspects
- The portfolio of quantitative (modelling) and qualitative tools is useful for stakeholders for informed decision making

5.1.2 How is the I²AM PARIS Platform different?

Another topic of concern for stakeholders was what makes our platform different from other platforms out on the web and what novelty it can offer. This question has also been raised within the consortium, and all partners agree that ensuring the uniqueness and impact of the I²AM PARIS platform is of utmost importance.

Some of the foremost principles we embark on to ensure its continuity during and after the project are:

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1. Embracing complexity and diversity and embark on this **plurality of models** in PARIS REINFORCE Consortium presented through the **I^{2}AM Paris platform.**

- 22 Integrated Assessment Models, Energy System and Sectoral Models.
- Interlinkages between them (where possible) for complementary, multi-scale vision.
- Different granularities of analysis (not just Mitigation and Adaptation but SDGs) categorised by theme.

Within M6-18 there has also been an open call connecting different modelling groups from across the globe that work with Integrated assessment and energy system modellers to submit documentation of their models. Apart from the original PR consortium models, there has been an addition of 21 non-PR models, promising the platform's success and consolidation efforts.

2. **Transparency and User-Friendliness**: Highlighting assumptions behind models, being transparent with what they can and cannot deliver.

3. **Visually easy, Intuitive and Informative**: A tool that can be useful for both experts and non-experts.

4. The **stakeholder-led policy questions** will be a form of ensuring that the platform delivers responses to "socially relevant and legitimate" questions.

5.2 New updates on the platform

5.2.1 The inclusion of a Variable Harmonisation Heat Map

The **Variable Harmonisation Heat Map** is thought to be a relatively simple tool to see at a glance in a user-friendly way what variables have the potential to be harmonised across the different models (initially only Paris Reinforce consortium models, with the possibility to be feed by other models in the future). The different variables appear on the rows (e.g. demographic, macroeconomic or technoeconomic) and the different models. The different colour codes, as presented in the legend, indicate if the variables are an extractable model output, an interlinkable model input or non-explicit output or input for each model (see Figure 11 above)

A comparative, on-demand selection across particular models, for illustrative purposes is also added for ease.

5.2.2 Design of separate interfaces

The access to the different interfaces of the platform will be presented similarly to the current Documentation page (an illustrative example can be seen below on Figure 13).

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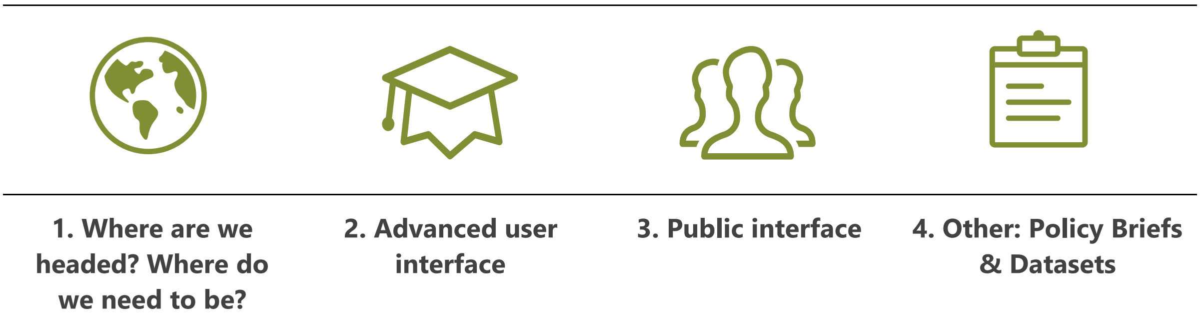

Figure 13. A scheme of the future visualization of the different interfaces in the I2AM Paris Platform.

1. Where are we headed? Where do we need to be?

Greenhouse gas emissions are directly and indirectly regulated by a vast number of public policies directly targeting climate, but also non-climate related issues in most if not all sectors of the economy across scales of time, space, and political constituencies.

The first round of modelling provides context on where we are heading with current policies and where we are supposed to be heading to comply with the Paris goals for temperature change. **Where we are headed?** scenario, includes current policies in place and formal pledges submitted as National Determined Contributions (NDCs) to the UNFCCC. Additionally, it also describes the alternative metrics to extrapolate these efforts and explore the impact of these policies in the mid- and long-term.

2. Advanced user Interface

The advanced user interface will present all harmonised datasets and these will eventually be presented in a format that is, over time, built towards the IPCC scenario templates.

It is envisaged as an a-la-carte selection of quantitative variables from model-based climate change mitigation pathways.

3. Public Interface

The public interface is targeted to non-modelling expert stakeholders, such as policy-makers, or non-profits. This page will track a selection of vital indicators from the IPCC key variable template responding to priority climate concerns as co-created via our 1st stakeholder workshop (Nov, 2019). It provides a visual representation of the climate concerns of where we are heading and where we need to be.

Some of the questions will have responses in one simple explanatory graph and others will allow the user to play and select the different models and the different scenarios proposed.

4. Other: Policy Briefs/Datasets

Downloadable datasets (or links) from harmonization table format.

5.2.3 Futures scenario data portal

Once the PARIS REINFORCE consortium finalise reference scenarios, we then will display modelling runs, round 1 and 2, based on potential elaborations and visualisations of Current policies (CPs) and Nationally Determined Contributions (NDCs). In the second round of modelling, different projections might be included reflecting COVID-19 implications and the Green New Deal.

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Those scenarios, as well as the variables, will be named in a simple and accessible manner so non-experts could also understand and extract key insights. For instance, scenario names could be clear-cut questions such as "Where are we heading?".

Finally, the visualization of the results will be done using different graphs and infographics. Several webpages have served as an inspiration; see an example on the Global Stocktake[8], the SENSES toolkit[9] or the REINVENT decarbonisation portal[10].

5.2.4 Outreach and Platform Support

In an effort to communicate and disseminate the utility of the I^{2}AM PARIS Platform, the possibility of organising webinars with stakeholders for platform support was discussed. This could be conducted as a stand-alone event or as a joint event with other platforms already running to create synergies.

The prospect of using the platform (the comments/communication section) was also discussed to engage with external stakeholders and new visitors to the site, and incorporate feedback in order to take ideas and conversations forward for a co-constructed understanding of the utility of the Platform.

[8] https://themasites.pbl.nl/global-stocktake-indicators/
[9] https://climatescenarios.org/
[10] https://www.reinvent-project.eu/decarbonisation-portal

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Annex I

Comparing GDP and population projections from the 2018 Ageing Report of the European Commission and the Shared Socioeconomic Pathways (SSP2)

We present below a short summary and comparison of the GDP and population projections from SSP (Riahi *et al.*, 2017), the 2018 Ageing report (EC, 2017) and the EUROPOP2018 for population (Eurostat, 2019). In fact, we would like to compare the socio-economic assumptions from the SSPs and the ones used for the "EU reference scenario" (EC, 2016). But the European Commission is currently updating the "EU reference scenario", and usually, EC also updates the socio-economic assumptions of the scenario by using the most recent GDP and population projections done by the EC, that are the 2018 Ageing Report (EC, 2017). This later uses the EUROPOP15 population projections realised by Eurostat (2017) but Eurostat has updated its population projections in 2019 (Eurostat, 2019), with EUROPOP2018 (the one available on Eurostat website).

Below the data used refer to the following dataset:

- GDP projections from SSP:
  - SSP-GDP-OECD: Dellink et al. (2017), GDP database downloaded here: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about
  - SSP-GDP-IIASA: Crespo Cuaresma (2017) - GDP database downloaded here: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about
  - SSP-GDP-PIK: Leimbach et al. (2017) - GDP database downloaded here: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about
- GDP projections from the 2018 Ageing Report:
  - EC (2018) - GDP database downloaded here: https://ec.europa.eu/info/publications/economy-finance/2018-ageing-report-economic-and-budgetary-projections-eu-member-states-2016-2070_en
- Population projections:
  - From SSP: SSP-POP-IIASA: KC and Lutz (2017) - Population database downloaded here: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about
  - From the 2018 Ageing Report: POP-AR2018: (EC, 2018), Population database downloaded here: https://ec.europa.eu/info/publications/economy-finance/2018-ageing-report-economic-and-budgetary-projections-eu-member-states-2016-2070_en
  - From EUROPOP2018: EUROPOP18: Eurostat (2019) - Population database downloaded here: https://ec.europa.eu/eurostat/data/database

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Population projections

We present only population projections from the SSP2 scenario.

As shown by Figure A1, all EU population projections expect a decline of the European population growth. The average annual growth of the EU-28 population was of +0.27%/y. between 1990 and 2015. SSP2 projection halves the growth rate, with +0.14%/y. between 2020 and 2050. In the 2018 Ageing Report, the growth rate is lower with +0.08%/y. and it even more weak for EUROPOP18, with +0.06%/y. Thus, the EU population is expected to be lower in EUROPOP18 of 30 million in 2050 in comparison with SSP2 and of 10 million in comparison with the 2018 Ageing Report.

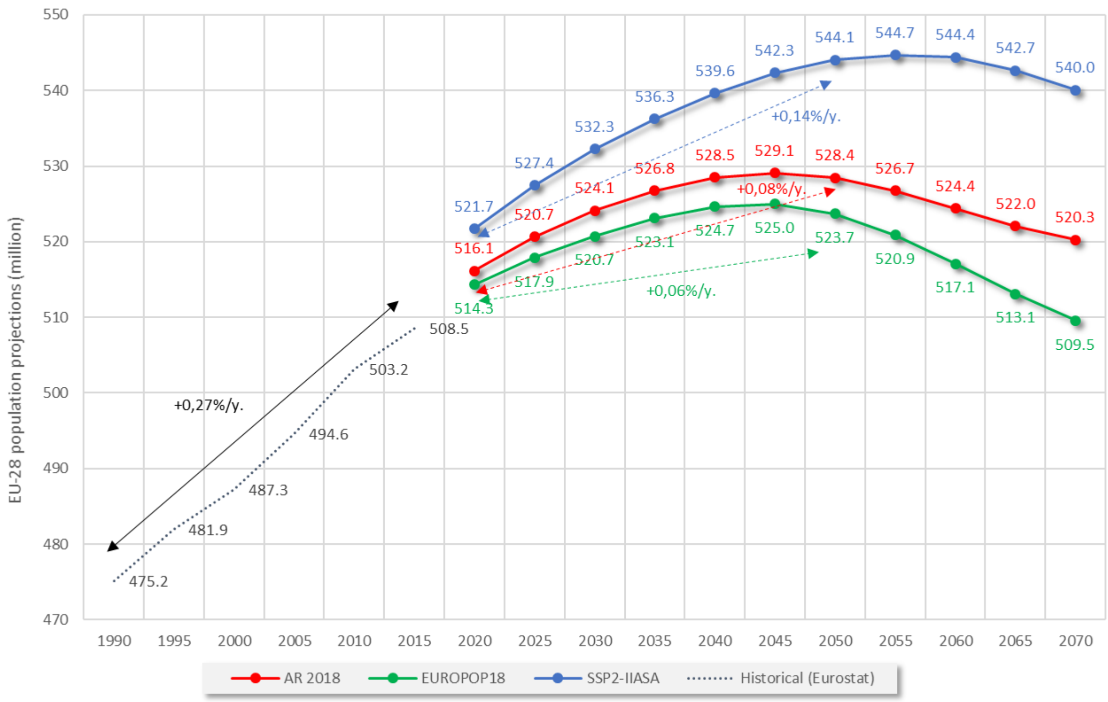

Figure A13: EU-28 population projections (million)

Source: Authors calculation based on EC (2017), Eurostat (2019) and KC and Lutz (2017)

Table A1 presents some demographic indicators on the EU-28 population projections. We can notice that SSP2 population projections provide an older European population in 2050 than other projections. And if working age population in EU-28 are almost the same in all projections in 2050, about 300 billion, the share of people older than 65 years is significantly higher in the SSP2 projections, with 56%, in comparison with the two other projections, around 50%.

Table A2 shows that there are significant deviations between the population projections at Member state level, and even more for the smallest countries. Finally, Figure A2 confirms the insights from Table 1, for the seven largest Member States, the working age population are relatively similar among projections but SSP2-IIASA projections shows lower child population in 2050 (below 15 years old) than AR 2018 and EUROPOP18, and a largest number of old people (above 65 years old).

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Table A5 : Summary statistics on European population projections

	AR 2018	EUROPOP18	SSP2 - IIASA
Total population in 2030 *(million)*	524.1	520.7	532.3
Total population in 2050 *(million)*	528.4	523.7	544.1
Working age population in 2030 *(15-64, million)*	319.7	320.6	325.7
Working age population in 2050 *(15-64, million)*	299.2	298.9	300.7
Dependency ratio in 2050 *(below 15 years old + above 65 years old on working age population)*	76.6%	75.2%	80.9%
Child dependency ratio *([0-15[on working age population)*	26.2%	25.3%	24.8%
Old dependency ratio *(65 years old and over on working age population)*	50.4%	49.9%	56.1%

Source: Authors calculation based on EC (2017), Eurostat (2019) and KC and Lutz (2017)

Table A6: Population projections by Member State in 2050 and deviation with respect to AR 2018

	AR 2018 - Population in 2050 (million)	EUROPOP18 - Population in 2050 (million)	SSP2 - Population in 2050 (million)	Difference of EUROPOP18 in comparison with AR 2018	Difference of SSP2 in comparison with AR 2018
AT	10.2	9.8	9.2	4.2%	11.2%
BE	13.3	12.6	12.6	5.7%	5.5%
BG	5.5	5.6	6.3	-1.0%	-12.1%
CY	1.0	1.1	1.6	-11.3%	-37.5%
CZ	10.5	10.6	11.7	-1.3%	-10.5%
DE	82.6	82.7	78.9	-0.1%	4.6%
DK	6.7	6.5	6.6	3.3%	1.7%
EE	1.3	1.3	1.3	0.3%	-0.3%
EL	8.9	9.6	11.2	-7.6%	-21.0%
ES	49.3	49.9	52.8	-1.3%	-6.6%
FI	5.7	5.5	6.2	4.0%	-7.9%
FR	74.4	71.6	79.5	4.0%	-6.3%
HR	3.7	3.4	4.1	7.8%	-9.7%
HU	9.3	9.0	8.9	2.6%	4.3%
IE	5.7	5.9	6.4	-3.3%	-10.2%
IT	58.9	55.9	61.5	5.4%	-4.2%
LT	2.0	2.2	2.7	-10.3%	-28.1%
LU	0.9	0.9	0.8	1.9%	13.3%
LV	1.5	1.6	1.8	-5.2%	-18.1%
MT	0.5	0.7	0.4	-26.2%	15.9%
NL	19.2	17.8	18.6	8.2%	3.6%
PL	34.3	34.9	35.2	-1.6%	-2.5%
PT	9.1	9.2	11.3	-1.2%	-19.6%
RO	16.3	16.7	17.8	-2.6%	-8.2%
SE	12.7	13.4	12.5	-5.1%	1.6%
SI	2.0	2.0	2.2	0.9%	-7.1%
SK	5.3	5.1	5.5	3.3%	-5.0%
UK	77.7	78.3	76.6	-0.8%	1.4%
EU-28	528.4	523.7	544.1	0.9%	-2.9%

Source: Authors calculation based on EC (2017), Eurostat (2019) and KC and Lutz (2017)

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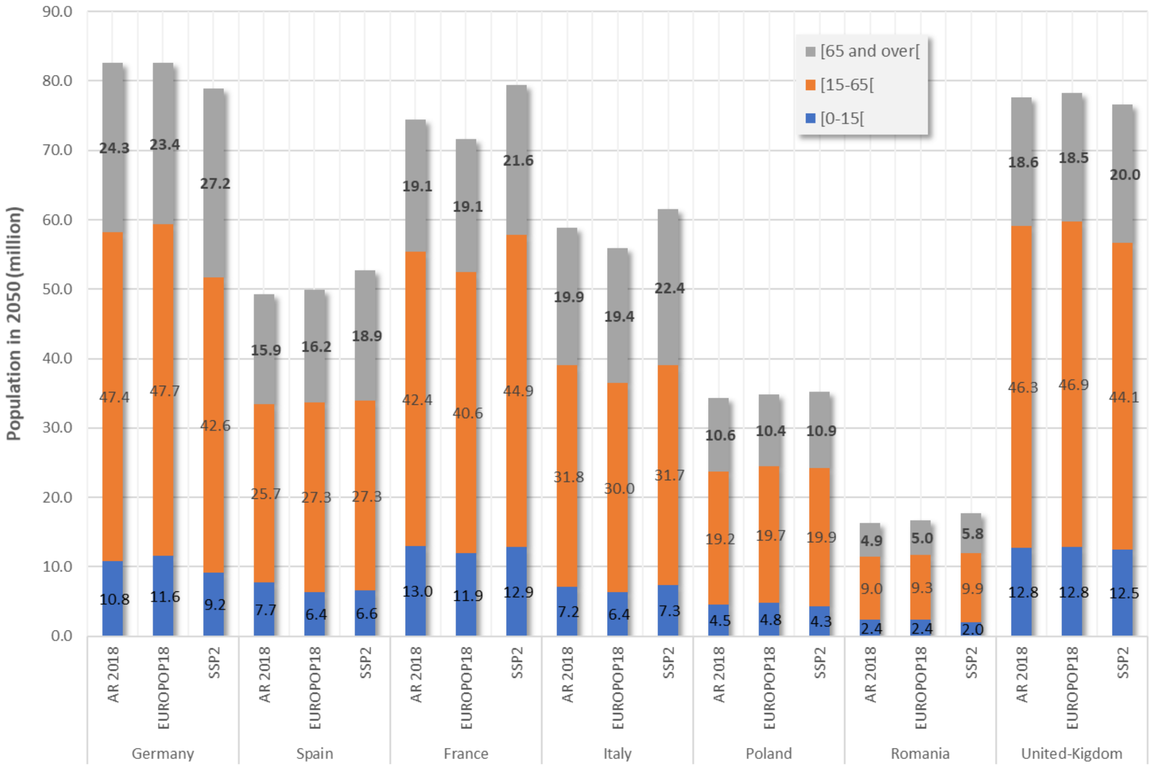
Figure A2: Population projections for the seven biggest EU countries in 2050 and by age group



Source: Authors calculation based on EC (2017), Eurostat (2019) and KC and Lutz (2017)

GDP projections

We present only GDP projections for the SSP2 scenario.

Comparison of the three GDP projections from SSP2 scenario

Figure A3 and Figure A4 show the real GDP of aggregated regions of the World in the SSP2 scenario and according to the three GDP projections. If there are some important differences between these projections, there is no major divergence in the average growth rate of the real GDP and it seems very difficult to find specificities in the differences between projections.

Figure A17 shows that the GDP projections for India in 2050 are significantly different with 27,500 billion US$2005 in 2050 in the OECD projections (Dellink *et al.* ,2017) and almost $45,000 billion in the PIK projections (Leimbach et al. ,2017). Real GDP deviation between projections are also relatively important for Africa.

Similarly, in Figure 4, the main difference in the real GDP projection in 2100 appears for India, Africa and OCSA (Other Central and Southern Asian countries). But in 2100, it seems that GDP projections from IIASA (Crespo Cuaresma ,2017) are more pessimistic than the two others, except for EU and USA.

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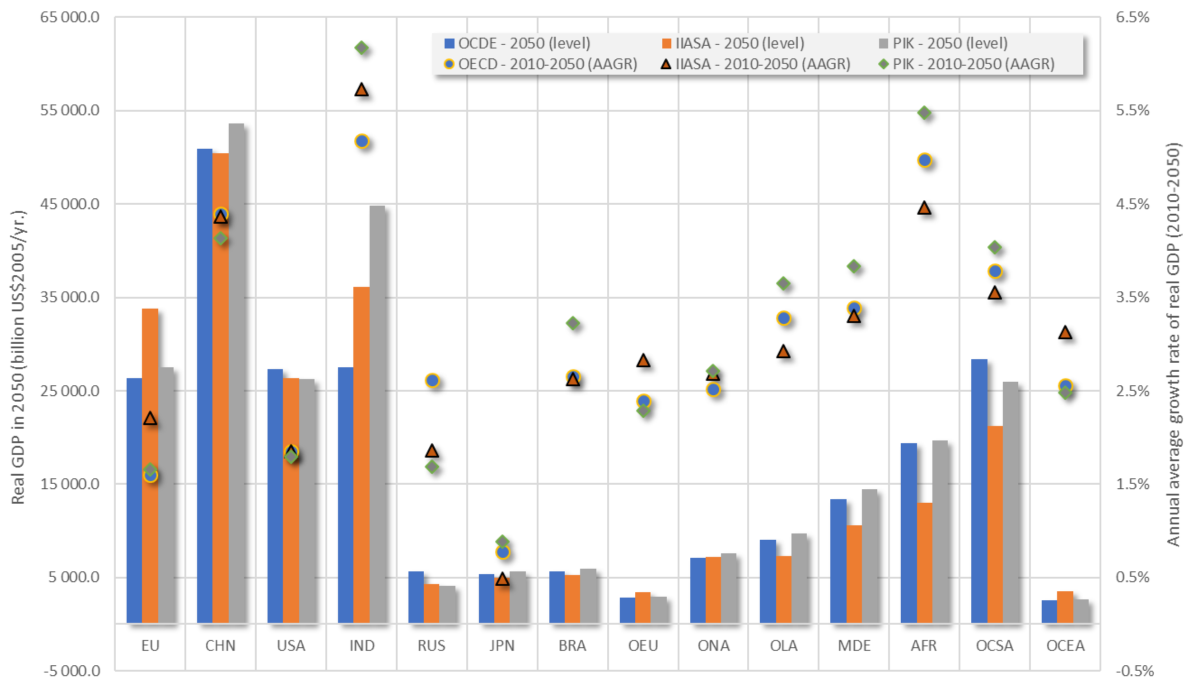

Figure A3: SSP2 GDP projections in 2050 (billion $US2005) and average annual real GDP growth rate between 2010 and 2050 (%), for aggregated regions.

Source: Authors calculation based on Dellink et al. (2017), Crespo Cuaresma (2017) and Leimbach et al. (2017). NB: OEU: Other Europe, ONA: Other North America, OLA: Other Latin America; MDE: Middle-East, AFR: Africa, OCSA: Other Central and Southern Asia, OCEA: Other Oceania.

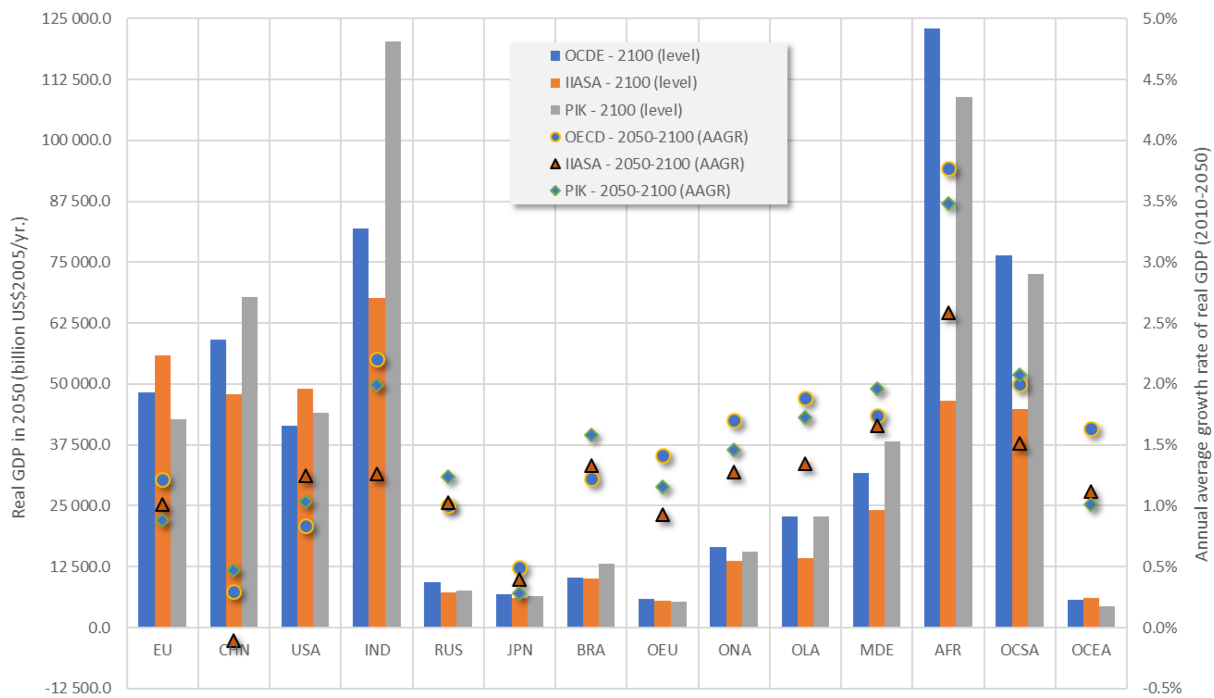

Figure A4: SSP2 GDP projections in 2100 (billion $US2005) and average annual real GDP growth rate between 2010 and 2050 (%), for aggregated regions.

Source: Authors calculation based on Dellink et al. (2017), Crespo Cuaresma (2017) and Leimbach et al. (2017)

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NB: OEU: Other Europe, ONA: Other North America, OLA: Other Latin America; MDE: Middle-East, AFR: Africa, OCSA: Other Central and Southern Asia, OCEA: Other Oceania.

As it is not really possible to rank these three GDP projections, we will use the OECD one thereafter, as it is the most currently used in the literature.

Comparison of GDP projections for EU-28 countries from SSP2 – OECD and the 2018 Ageing Report

Figure A5 shows the growth rate of the EU-28 real GDP between 2015 and 2070 from SSP2-OECD and AR2018 projections. We see that the SSP2 projections provide the highest real EU GDP growth at the beginning, with +1.6% on average between 2021 and 2030 in SSP2-OECD against 1.3% in AR 2018. In 2050, both projections cross with 1.5% on average between 2041 and 2050 and thereafter, the EU GDP projection from the 2018 Ageing Report grows slightly more rapidly than SSP2-OECD one, with, between 2061 and 2070, 1.5% against 1.4%.

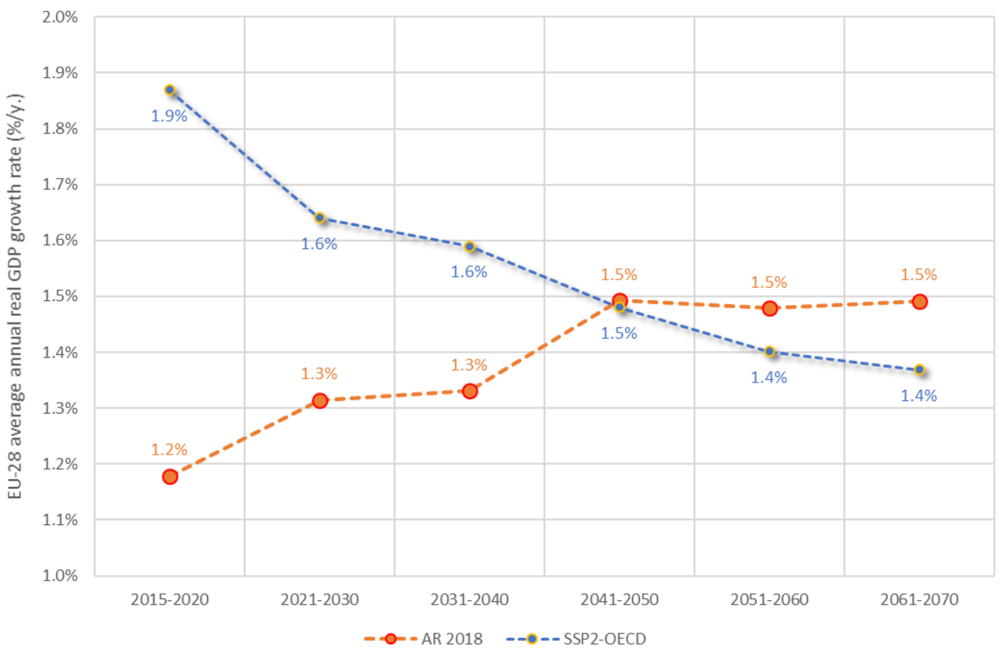

Figure A5: Average annual growth rate of EU-28 real GDP (%/y.)
Source: Authors calculation based on Dellink et al. (2017) and EC. (2017).

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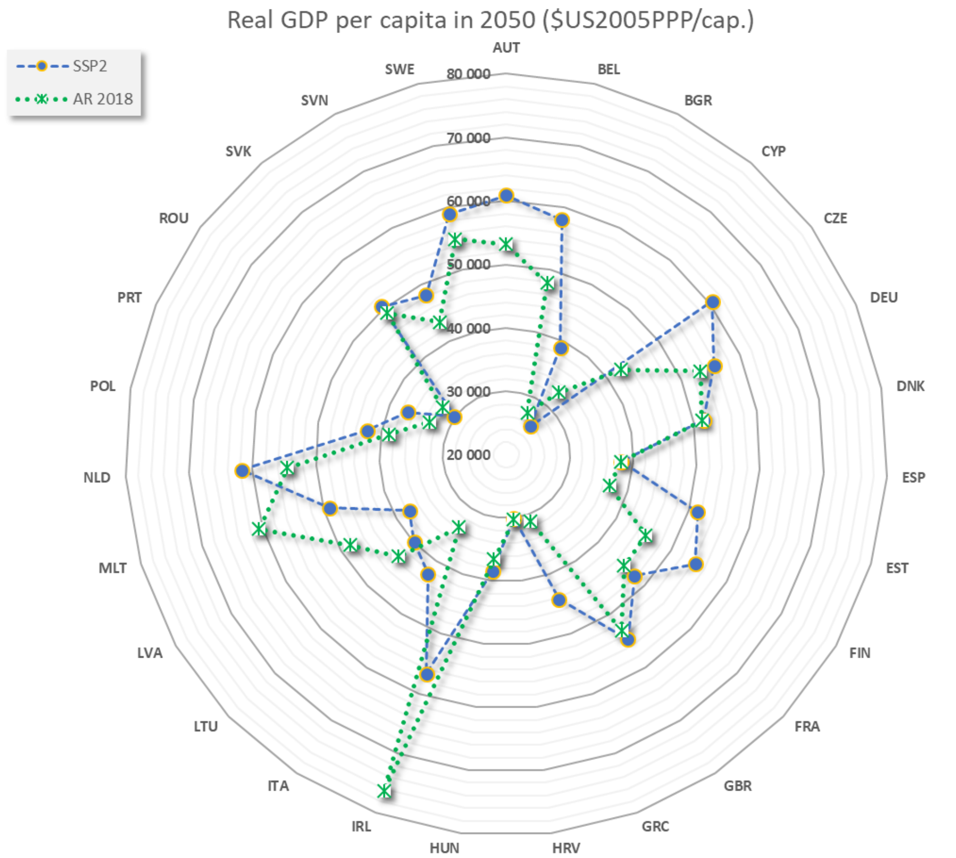

Figure A6: Real GDP per capita in 2050 for EU Member States (US$2005PPP/cap.)

Source: Authors calculation based on Dellink et al. (2017) and EC. (2017).

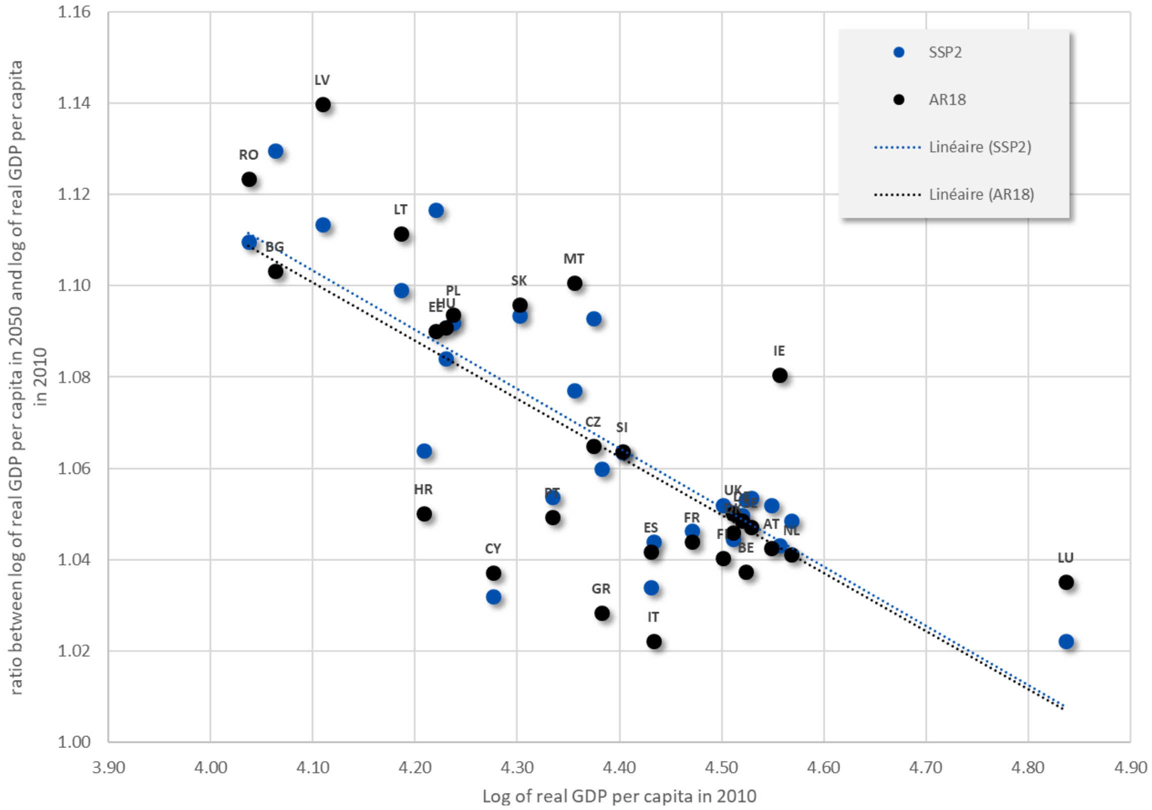

Figure A7: GDP convergence analysis in 2050 for EU Member States

Source: Authors calculation based on Dellink et al. (2017) and EC. (2017).

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Finally, Figure A6 displays the difference between both GDP projections in terms of real GDP per capita in 2050. The projections are relatively close especially for the largest EU economies. Indeed, the differences of real GDP per capita in 2050 are about 4% in Germany, 7% in United Kingdom, 5% in France and almost nil for Spain. For Italy, the difference is larger with around 20%. We observe also large differences in Ireland (35%) and Czech Republic (25%) for instance. For the former, 2015 high GDP growth was not considered in SSP2-OECD projections whereas it is probably included in the 2018 Ageing Report.

Even if there are some important differences between GDP projections, Figure A7, shows that the logic of the projections is similar, especially in terms of GDP per capita convergence. The less advanced EU economies in 2010, such as Romania and Bulgaria, are the ones that face, in both GDP projections, the highest real GDP growth rates. And globally at EU level, the rate GDP convergence seems similar in both GDP projections.

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Bibliography

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.

Carney, S. & Whitmarsh, L., Nicholson-Cole, S., Shackley, S., 2009. A Dynamic Typology of Stakeholder Engagement Within Climate Change Research. Tyndall Centre for Climate Change Research.

Crespo Cuaresma, J. C. 2017. Income projections for climate change research: A framework based on human capital dynamics. Global Environmental Change, 42, 226-236. doi:10.1016/j.gloenvcha.2015.02.012

Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J.D., Jäger, J., Chabay, I., de Wit, B., Langlais, R., Mills, D., Moll, P., Otto, I.M., Petersen, A., Pohl, C., van Kerkhoff, L., 2013. Opening up knowledge systems for better responses to global environmental change. Environ. Sci. Policy 28, 60–70. https://doi.org/10.1016/j.envsci.2012.11.008

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. doi:10.1016/j.gloenvcha.2015.06.004European Commission, 2016, "Energy, transport and GHG emissions : trends to 2050". Doi: 10.2833/001137

Duscha, V., Denishchenkova, A., & Wachsmuth, J. (2018). Achievability of the Paris Agreement targets in the EU: demand-side reduction potentials in a carbon budget perspective. Climate Policy, 1-14.

Edsand, H. E. (2017). Identifying barriers to wind energy diffusion in Colombia: A function analysis of the technological innovation system and the wider context. Technology in Society, 49, 1-15.

European Commission, 2016, "Energy, transport and GHG emissions : trends to 2050". Doi: 10.2833/001137

European Commission, 2018, "The 2018 Ageing Report – Underlying assumptions & projections methodologies", European Economy Institutional Papers n°065. doi: 10.2765/286359

Eurostat, 2017, Summary methodology of the 2015-based population projections. https://ec.europa.eu/eurostat/cache/metadata/Annexes/proj_esms_an1.pdf

Eurostat, 2018, Summary methodology of the 2018-based population projections, https://ec.europa.eu/eurostat/cache/metadata/Annexes/proj_esms_an2.pdf

Fawcett, A. A., Iyer, G. C., Clarke, L. E., Edmonds, J. A., Hultman, N. E., McJeon, H. C., ... & Creason, J. (2015). Can Paris pledges avert severe climate change?. Science, 350(6265), 1168-1169. Grygoruk, M., Rannow, S., 2017. Mind the gap! Lessons from science-based stakeholder dialogue in climate-adapted management of wetlands. J. Environ. Manage. 186, 108–119. https://doi.org/10.1016/j.jenvman.2016.10.066

Forouli, A., Gkonis, N., Nikas, A., Siskos, E., Doukas, H., & Tourkolias, C. (2019a). Energy efficiency promotion in Greece in light of risk: Evaluating policies as portfolio assets. Energy, 170, 818-831.

Forouli, A., Doukas, H., Nikas, A., Sampedro, J., & Van de Ven, D. J. (2019b). 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.

Geels, F. W., McMeekin, A., & Pfluger, B. (2018). Socio-technical scenarios as a methodological tool to explore social and political feasibility in low-carbon transitions: Bridging computer models and the multi-level perspective in UK electricity generation (2010–2050). Technological Forecasting and Social Change.Hanger-Kopp, S., Lieu, J., Nikas, A. (Eds.)., (2019). Narratives of Low-Carbon Transitions (Open Access): Understanding Risks and Uncertainties. Routledge.

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

Hoesly, R.M., Smith, S.J., Feng, L., Klimont, Z., Janssens-Maenhout, G., Pitkanen, T., Seibert, J.J., Vu, L., Andres, R.J., Bolt, R.M., Bond, T.C., Dawidowski, L., Kholod, N., Kurokawa, J.I., Li, M., Liu, L., Lu, Z., Moura, M.C.P., O'Rourke, P.R., Zhang, Q., (2018). Historical (1750-2014) anthropogenic emissions of reactive gases and aerosols from the community emissions data system (ceds). Geoscientific Model Development 11, 369{408. URL: https://gmd.copernicus.org/articles/11/369/2018/, doi:10.5194/gmd-11-369-2018.

IPCC (2018) Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

Kates, R.W., Clark, W.C., Corell, R., Hall, M., Jaeger, C.C., Lowe, I., Schellnhuber, H.J., Bolin, B., Dickson, M., Faucheux, S., Gallopin, G.C., Huntley, B., Jäger, J., Jodha, N.S., Kasperson, E., Mabogunje, A., Matson, P., Iii, B.M., O'Riordan, T., Svedin, U., 2000. Belfer Center for Science & International Affairs 17.

KC, S., & 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. doi:10.1016/j.gloenvcha.2014.06.004Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., Thomas, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain. Sci. 7, 25–43. https://doi.org/10.1007/s11625-011-0149-x

Labella Á., Estrella, J. F., Martínez L. (2017). AFRYCA 2.0: an improved analysis framework for consensus reaching processes. Progress in Artificial Intelligence, 6(2), 181-194.

Labella Á., Martínez L. (2020). FLINTSTONES 2.0 an Open and Comprehensive Fuzzy Tool for Multi-criteria Decision Analysis. In: Kahraman C., Cebi S., Cevik Onar S., Oztaysi B., Tolga A., Sari I. (eds) Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making. INFUS 2019. Advances in Intelligent Systems and Computing, vol 1029. Springer, Cham.

Mantzos, L., Wiesenthal, T., Matei, N. A., T.M.S., Rozsai, M., Russ, P., Ramirez, A.S., (2017). JRC-IDEES: Integrated Database of the European Energy Sector: Methodological note (No. JRC108244). Technical Report.Joint Research Centre.

Moallemi, E. A., de Haan, F. J., Webb, J. M., George, B. A., & Aye, L. (2017). Transition dynamics in state-influenced niche empowerments: Experiences from India's electricity sector. Technological Forecasting and Social Change, 116, 129-141.

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.

Mielke, J., Vermaßen, H., Ellenbeck, S., Fernandez Milan, B., Jaeger, C., 2016. Stakeholder involvement in sustainability science—A critical view. Energy Res. Soc. Sci. 17, 71–81. https://doi.org/10.1016/j.erss.2016.04.001

Miller, C.A., Wyborn, C., 2018. Co-production in global sustainability: Histories and theories. Environ. Sci. Policy S1462901117306366. https://doi.org/10.1016/j.envsci.2018.01.016

Nikas, A., & Doukas, H. (2016). Developing robust climate policies: a fuzzy cognitive map approach. In Robustness analysis in decision aiding, optimization, and analytics (pp. 239-263). Springer, Cham.

Nikas, A., Doukas, H., & López, L. M. (2018). A group decision making tool for assessing climate policy risks against multiple criteria. Heliyon, 4(3), e00588.

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

Nikas, A., Doukas, H., Lieu, J., Alvarez Tinoco, R., Charisopoulos, V., & van der Gaast, W. (2017). Managing stakeholder knowledge for the evaluation of innovation systems in the face of climate change. Journal of Knowledge Management, 21(5), 1013-1034.

Nikas, A., Ntanos, E., & Doukas, H. (2019). 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. (2020b). Barriers to and consequences of a solar-based energy transition in Greece. Environmental Innovation and Societal Transitions 35, 383-399.

Nikas, A., Fountoulakis, A., Forouli, A., & Doukas, H. (2020a). A robust augmented ε-constraint method (AUGMECON-R) for finding exact solutions of multi-objective linear programming problems. Operational Research, in press.

Riahi, K., Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J. Crespo Cuaresma, S. KC, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling, K. Ebi, T. Hasegawa, P. Havlik, F. Humpenöder, .L. Aleluia Da Silva, S. Smith, E. Stehfest, V. Bosetti, J. Eom, D. Gernaat, T. Masui, J. Rogelj, J. Strefler, L. Drouet, V. Krey, G. Luderer, M. Harmsen, K. Takahashi, L. Baumstark, J. C. Doelman, M. Kainuma, Z. Klimont, G. Marangoni, H. Lotze-Campen, M. Obersteiner, A. Tabeau and Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change, 42, 153-168. doi:10.1016/j.gloenvcha.2016.05.009

Roelfsema, M., van Soest, H.L., Harmsen, M., van Vuuren, D.P., Bertram, C., den Elzen, M., Höhne, N., Iacobuta, G., Krey, V., Kriegler, E., Luderer, G., Riahi, K., Ueckerdt, F., Despr_es, J., Drouet, L., Emmerling, J.,Frank, S., Fricko, O., Gidden, M., Humpenöder, F., Huppmann, D., Fujimori,S., Fragkiadakis, K., Gi, K., Keramidas, K., Köberle, A.C., Aleluia Reis, L., Rochedo, P., Schae_er, R., Oshiro, K., Vrontisi, Z., Chen, W., Iyer, G.C., Edmonds, J., Kannavou, M., Jiang, K., Mathur, R., Safonov, G., Vishwanathan, S.S., (2020). Taking stock of national climate policies to evaluate implementation of the Paris Agreement. Nature Communications 11, 2096. URL: https://doi.org/10.1038/s41467-020-15414-6,doi:10.1038/s41467-020-15414-6.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., ... & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 C. Nature, 534(7609), 631-639.Wamsler, C., 2017. Stakeholder involvement in strategic adaptation planning: Transdisciplinarity and co-production at stake? Environ. Sci. Policy 75, 148–157. https://doi.org/10.1016/j.envsci.2017.03.016

Rogge, K. S., Pfluger, B., & Geels, F. W. (2018). Transformative policy mixes in socio-technical scenarios: The case of the low-carbon transition of the German electricity system (2010–2050). Technological Forecasting and Social Change.

Song, L., Lieu, J., Nikas, A., Arsenopoulos, A., Vasileiou, G., & Doukas, H. (2020). Contested energy futures, conflicted rewards? Examining low-carbon transition risks and governance dynamics in China's built environment. Energy Research & Social Science, 59, 101306.

Van de Ven, D. J., Sampedro, J., Johnson, F. X., Bailis, R., Forouli, A., Nikas, A., Yu, S., Pardo, G., de Jalón, S.G., Wise, M., & Doukas, H. (2019). Integrated policy assessment and optimisation over multiple sustainable development goals in Eastern Africa. Environmental Research Letters, 14(9), 094001.

Van Marle, M. J., Kloster, S., Magi, B. I., Marlon, J. R., Daniau, A. L., Field, R. D., Arneth, A., Forrest, M., Hantson, S., Kehrwald, N.M., & Knorr, W. (2017). Historic global biomass burning emissions based on merging satellite observations with proxies and fire models (1750-2015). Geoscientific Model Development, 10, 3329-3357.

Wachsmuth, J., & Duscha, V. (2018). Achievability of the Paris targets in the EU—the role of demand-side-driven mitigation in different types of scenarios. Energy Efficiency, 1-19.

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

Welp, M., de la Vega-Leinert, A., Stoll-Kleemann, S., Jaeger, C.C., 2006. Science-based stakeholder dialogues: Theories and tools. Glob. Environ. Change 16, 170–181. https://doi.org/10.1016/j.gloenvcha.2005.12.002

Wyborn, C., Datta, A., Montana, J., Ryan, M., Leith, P., Chaffin, B., Miller, C., van Kerkhoff, L., 2019. Co-Producing Sustainability: Reordering the Governance of Science, Policy, and Practice. Annu. Rev. Environ. Resour. 44, 319–346. https://doi.org/10.1146/annurev-environ-101718-033103

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