PARIS
REINFORCE

29/05/2020

D5.2 INTERLINKAGES OF NATIONAL/REGIONAL MODELS FOR EUROPE WITH I²AM PARIS

WP5 – Transforming Europe

Version: 1.01R

www.paris-reinforce.eu

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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 (May 2020), and then slightly updated to further elaborate on the newly developed I²AM PARIS harmonisation heatmaps, in September 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, to know about the modelling interlinkages between the national/regional level in countries and regions in Europe and the global level, within the PARIS REINFORCE consortium. It will also be used by policymakers and other stakeholder groups as a documentation of said interlinkages, serving as a means of facilitating their participation in the co-creation process envisaged in the project.

3. Short summary of results (<250 words)

WP5 focuses on the European low-carbon transformation projected to take place in the following decades. Five models are used with national or regional coverage within the EU-28 as well as some other European countries. The purpose of the first round of modelling is to provide a global context of where we are heading with current policies around the world, where we are supposed to be heading to comply with the Paris goals for temperature change, and what this means for the climate efforts required per country or region, including the EU. Therefore, all models will be run simultaneously, providing a model inter-comparison exercise, using harmonised input variables. This harmonisation has been twofold: (i) globally, i.e. harmonising a large set of inputs among all PARIS REINFORCE modelling tools, and (ii) at European level with more EU-specific and detailed inputs. After the first modelling round, the outputs from the European models will flow into the global models, to provide a more robust estimate on the gaps between stated climate and sustainable development goals, and the simulated progress in reaching such goals. For the second modelling round, three types of model interlinkage will be applied: from global model outcomes to European model inputs; using some model outcomes as drivers/inputs for others models; and taking advantage of each model specificities to establish a chain of modelling tools. Finally, the I²AM PARIS platform will share and display data, in a stepwise form, a sequence of presenting our processes of harmonisation; interlinkages; and our data portal.

4. Evidence of accomplishment

This report.

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Preface

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

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

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Executive Summary

Work package 5, "Transforming Europe", focuses on the European low-carbon transformation that is projected to take place in the following decades. Five models are used with national or regional coverage within the EU-28 as well as some other European countries. The purpose of the first round of modelling is to provide a global context of where we are heading with current policies around the world, where we are supposed to be heading to comply with the Paris goals for temperature change, and what this means for the climate efforts required per country or region, including the EU. Therefore, all models will be run simultaneously, providing a model inter-comparison exercise, using harmonised input variables. This harmonisation has been twofold: (i) at the global scale, i.e. harmonising a large set of inputs among all PARIS REINFORCE modelling tools (e.g. socioeconomic and technoeconomic parameters, fossil fuel prices), and (ii) at European scale with more EU-specific and detailed inputs (e.g. sectoral growth, building floorspace projections, etc.). After the first modelling round, the outputs from the European models will flow into the global models, to provide a more robust estimate on the gaps between stated climate and sustainable development goals, and the simulated progress in reaching such goals. For the second modelling round, three types of model interlinkage will be applied: (1) from global model outcomes to European models; (2) through input harmonisation, using some model outcomes as drivers/inputs for others models; and (3) a multi-model interlinkage, taking advantage of each model specificities to establish a chain of modelling exercises and tools. Finally, the I^{2}AM PARIS platform will share and display data, in a stepwise form, a sequence of presenting our processes of a) harmonisation; b) interlinkages; and c) our PARIS REINFORCE scenario data portal.

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Contents

Table of Figures

Table of Tables

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

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1 Introduction / Working structure

PARIS REINFORCE is a stakeholder-led project to assess low-carbon transition pathways compliant with the goals of the Paris Agreement. A major focus of the project is to undertake detailed global and country-level energy system and integrated assessment modelling, to understand technically, economically, politically and socially acceptable transition pathways within different countries and regions around the globe.

Work package 5, "Transforming Europe", focuses on the European low-carbon transformation that is projected to take place in the following decades. Five models are used with national and/or macro-regional coverage within the EU-28 as well as some other European countries (Norway, Iceland, Switzerland). Table 1 shows the features of the diverse modelling equipment, consisting of bottom-up sectoral, energy system, and macroeconometric models. Apart from these five models, some global models with national coverage within the EU, such as ICES and E3ME, or regional coverage for the entire EU-28 (GEMINI-E3 and GCAM) will also be used for the modelling exercises in WP5, further enriching the diversity of modelling equipment for the European region.

Table 1: Details of models for EU to be used in Work Package 5 (Source: Deliverable 5.1)

		ALADIN	FORECAST	EU-TIMES	LEAP	NEMESIS
Type of model		Bottom-up sector perspective	Bottom-up sector perspective	Energy system model	Energy-Environment System	Macro-econometric model
Team running the model		Fraunhofer ISI	Fraunhofer ISI	E4SMA	NTUA	SEURECO
Time horizon (final simulation year)		2050	2050	2060	2050	2050
Time steps in solution (years)		1	1	Flexible (up to 12)	Flexible (usually 1)	1
Regional granu-larity	**EU 28 as a whole**	Yes	Yes	Yes	Yes	Yes
	Other non-EU28 countries	Norway & Switzerland	Norway & Switzerland	Norway, Switzerland & Iceland	All (if consolidated dataset available)	
Sectoral granu-larity	**Macro-economic**	No	Exogenous (as drivers)	Exogenous (as drivers)	Exogenous (as drivers)	Yes
	Agriculture	No	No	Energy requirements only	No	As economic activity
	Energy supply	No	No	Very detailed	Detailed	As economic activities with detailed technologies for power generation
	Industry	No	Very detailed	Detailed	Detailed	As economic activities
	Transpor-tation	Detailed for road (passenger and freight)	No	Detailed	Detailed	As economic activities and Households expenditures
	Buildings	No	Detailed	Detailed	Detailed	As economic activities & Households expenditures
	Land use	No	No	No	No	No

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The overall work plan for PARIS REINFORCE is summarised in Figure 1. In a first iteration, the European models listed in Table 1 will be used to explore potential futures, towards which we are headed with current policies in Europe, with stated National Energy and Climate Plans (NECPs), and where Europe should head for the desired goal of net zero emissions by 2050, which is required to keep global temperature increase well below 2ºC, as promised in the Paris Agreement. Depending on stakeholder inputs, different scenarios will be run for each of those futures. These European scenarios should feed into global scenarios to kick off a second modelling iteration. After global scenarios are redefined based on these European pathways as well as pathways in other major and minor emitting countries around the world, a new interlinkage structure will be designed with outputs from the global scenarios feeding into the European models, making use of the complementarities of the different models in this project. In addition to the link between global modelling tools (WP7) and European ones (WP5), the latter will also be interlinked with one another to provide a consistent modelling framework for PARIS REINFORCE scenarios in the EU besides individual model assessments. First attempts of WP5 modelling interlinkage will take place during the first modelling round, in order to experiment with them, identify relevant interlinkages according to models and research questions and make them fully operational for the second iteration. Indeed, the implementation of modelling interlinkage requires a mutual understanding of each model capabilities and of their strengths and weaknesses.

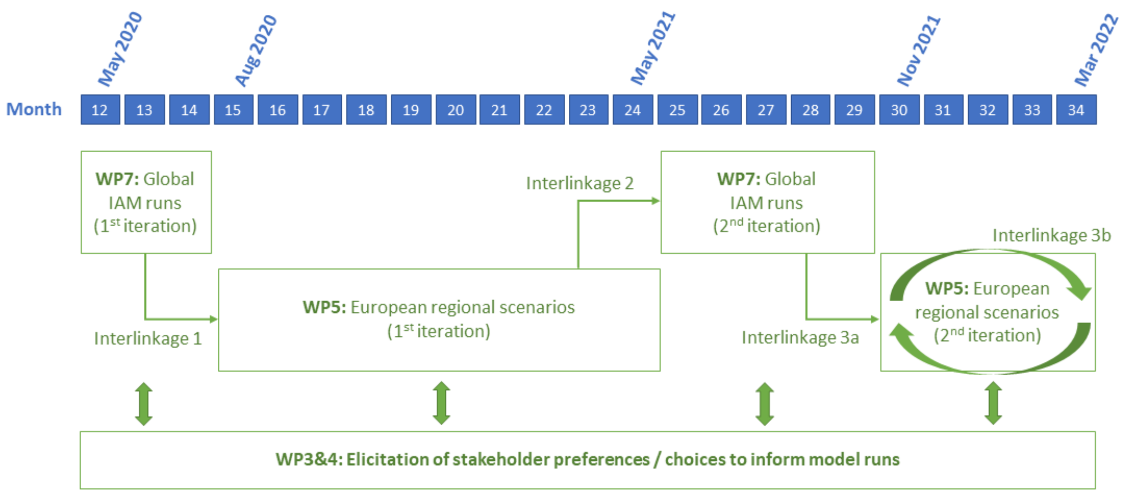

Figure 1: High-level workflow setting out interaction between global and national/regional modelling, informed by stakeholder engagement and stakeholder preference elicitation exercises

Regarding Figure 1, it should be noted that each stage of modelling is driven by inputs from stakeholders comprising policy and decision makers from a range of countries that are relevant to the modelling exercises. An "Ongoing stakeholder dialogue" Work Package (WP3) is used to organise meetings, discussions and polls with stakeholders in order to facilitate a two-way exchange of information around modelling practices, assumptions and limitations; as well as to elicit inputs from stakeholders on their particular modelling questions and views/preferences around modelling assumptions and scenario design. Results of our first Stakeholder Workshop in November 2019 resulted in some initial stakeholder preferences of pathways for European low-carbon transformations. These focus primarily on carbon border adjustments, the robustness of NECPs, the possibility of electrification of the energy system, and internal taxation within the EU. Scenario modelling will try to respond to surfacing concerns to the best extent possible.

Work Package 4 ("Robustification and socio-technical analysis toolbox") is used to explore specifics of technological and societal transformations, and to utilise stakeholder inputs to identify pathways that are realistic

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and robust, in the context of a range of uncertainties about the future. Robustification of national scenarios via WP4 is to add overall coherence to global modelling runs as well. The objective of WP3 and WP4 are to ensure that the modelling attempts are not done in isolation but rather orient on what stakeholders deem necessary for analysis via the modelling capabilities and ensembles of the PARIS REINFORCE consortium. WP2, the I²AM PARIS platform, acts as our main knowledge synthesis and dissemination channel. It currently has a detailed interface of all modelling documentation. Future steps on harmonisation and interlinkages (See section 4) will be detailed within the platform along with results on modelling runs.

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2 Harmonisation and Interlinkage flows

Based on the harmonisation and interlinkage possibilities of each model (see Appendix for possibilities in WP5, and appendices of D6.2 and D7.2 for WP6 and WP7 respectively), this section outlines a structure for harmonisation and interlinkage efforts in the different modelling rounds of WP5.

2.1 Modelling round I: Interlinkage through harmonising exogenous variables

The purpose of the first round of global modelling is to provide a global context of where we are heading with current policies and where we are supposed to be heading to comply with the Paris goals for temperature change. To ensure the comparability of the results, harmonised data has been used for the most crucial drivers of the models. This harmonisation has been twofold: (i) at the global scale, i.e. harmonising large sets of input among the entire PARIS REINFORCE modelling mechanism, and (ii) at European scale with more EU specific and detailed inputs. Harmonisation at global scale ensures a consistent storyline among the modelling outcomes and scales (global, WP7; European, WP5; or non-European national, WP6) whereas harmonisation at European scale reinforces the coherency at EU level with EU-specific data. Figure 2 shows the overall structure of the first modelling round, in which some outputs of global models will also flow into European models in WP5.

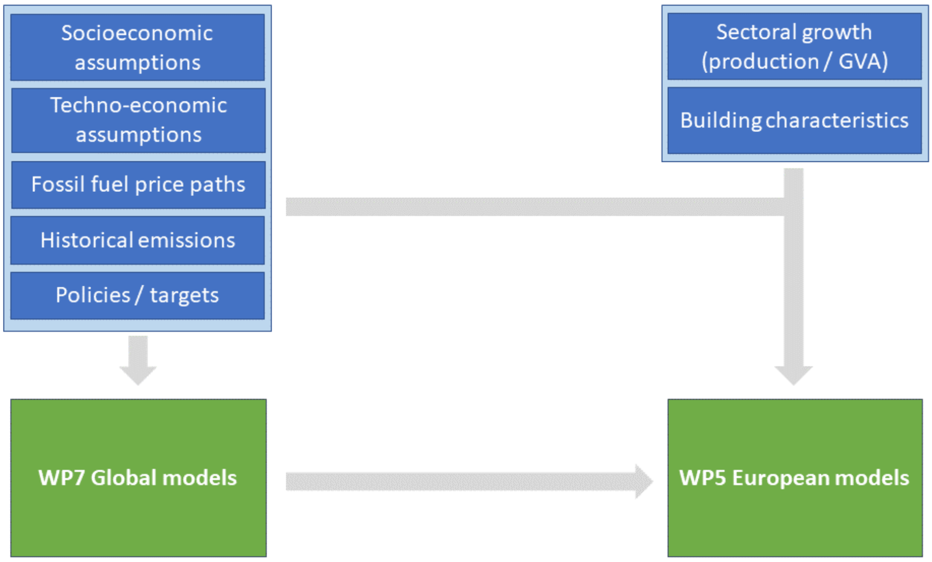

Figure 2: The same modelling assumptions flow into global models (WP7) and European models (WP5), to ensure consistent outputs in all modelling WPs. Some more specific European assumptions are harmonised within WP5. See Section 3 for specific details on all harmonised variables.

European models will consider global model outputs as inputs or as important elements for their scenario design. This is the case for GHG emissions from LULUCF (not represented in the European models) and fossil fuel prices. For the former, considering LULUCF emissions will allow European models to complete the GHG emission picture in all PARIS REINFORCE scenarios and even to define the cap for non-LULUCF emission reductions when the target is on the total GHG emissions. For fossil fuel prices, European models will use the PARIS REINFORCE harmonised assumptions, but it could be relevant to consider fossil fuel prices deviations observed in global models for some scenarios, especially for global decarbonisation scenarios showing large decline in global fossil energy demands. At this step, no formalised protocol exists; the methodology will be adapted ad hoc for each case and may lead to a more standardised protocol for the second iteration (see Section 2.3).

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2.2 Post-Modelling round I: Feeding regional outputs into global models

For the second interlinkage shown in Figure 3, the main purpose of the interaction between the regional models and the global models will be to constrain the global models with adjusted input assumptions into, and results from, the regional models. This is a critical element of the PARIS REINFORCE work programme, since it specifically reflects stakeholder choices and preferences around those inputs and resulting pathways that they deem to be most realistic, consistent and preferred, given the national contexts.

Figure 3: Stakeholder filtered modelling outputs flow from the European models in WP 5 to global models in WP7 for a second interlinkage exercise

We cannot expect that global models will take into account the precise technological detail, behavioural trends and detailed energy and land policies in the first modelling run, even if we intend to run current policy scenarios that provide a broad idea of where we are headed. Therefore, the feedback from the European models in WP5, in combination with feedback from WP6 models, will serve for fine-tuning the quality of the global scenarios, enabling them to provide a better picture of where we are really headed, and what is really necessary to keep global temperature increase "well below 2 °C".

2.3 Modelling round II

For the second modelling round, we can distinguish three kinds of modelling interlinkages:

(i) the interlinkage taking place from global modelling outcomes to European models
(ii) an enhanced interlinkage through inputs harmonisation, using some modelling outcomes as drivers for others models and
(iii) a multi-model interlinkage, taking advantage of each model's specificities to establish a harmonised chain of modelling tools/exercises.

2.3.1 Using global model outputs as European model inputs

The outcomes from the second global modelling round, whether from one specific model or a robust average resulting from multiple models, will be important to inform the second and last European modelling exercise. Importantly, the global models need to check whether the policies and ambitions coming out of the first European modelling round are sufficient to keep global temperature increase well below 2°C and do not conflict with other global policy goals, such as Sustainable Development Goals (SDGs). We expect that this may not be a sufficiently

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ambitious pathway and this second iteration of global modelling will set the European models up for the final round of modelling, while identifying the gap between what is provided in the first modelling round and what is needed to reach the Paris Agreement and SDGs. The combination of outputs from the global models, in terms of global context variables such as fossil fuel prices, and the identified global policy gaps, should provide a good base for the European models to design Paris-compatible pathways that limit global temperature increase to well-below 2°C, while also meeting other local and global policy goals.

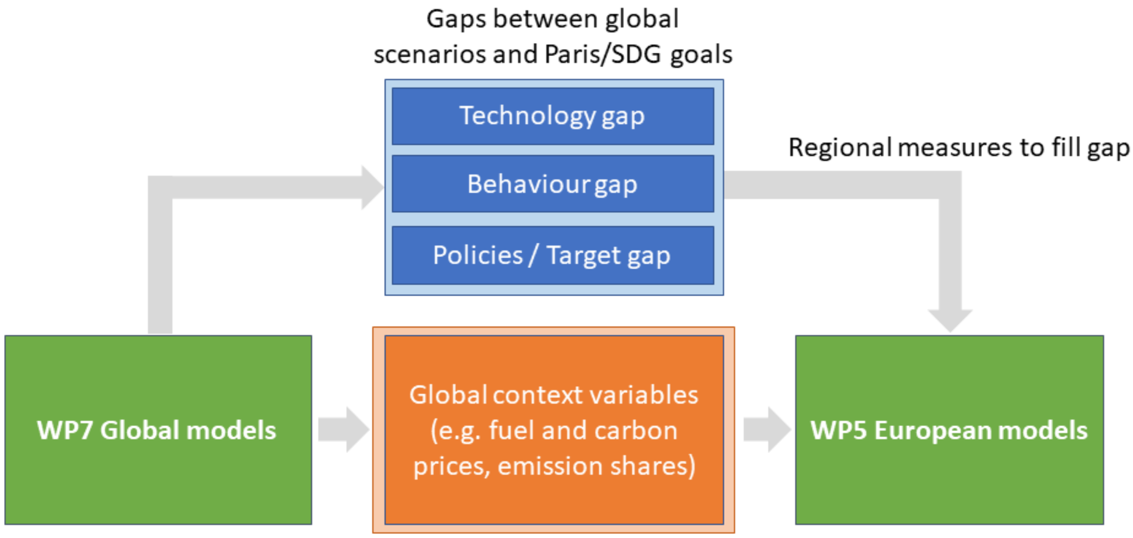

Figure 4: Modelling assumptions flow from WP7 (global) models to the European models in WP5 in a second modelling iteration

2.3.2 Interlinkage through enhanced harmonising exogenous variables

Besides harmonised inputs already implemented in the first iteration, which to some extent cover interlinkages from global models to European models, WP5 will enhance the harmonisation of the European modelling inputs by better integration of modelling inputs and outputs. As WP5 models have different modelling approaches and capabilities, it will be possible to use output of some models as inputs for others. For example, economic variables such as sector gross value added or production are outputs of the NEMESIS model as well as inputs for the energy system and sectoral models (e.g. EU-TIMES and FORECAST). Similarly, households' disposable income is an input of the EU-TIMES model and an outcome of the NEMESIS model. End-consumer energy prices (electricity, coal, oil, natural gas, biomass, district heating) are inputs of the FORECAST model and outputs of the EU-TIMES model. This type of interlinkage will be applied in the second iteration.

2.3.3 Interlinkage via a model chain

There will exist some overlaps in the modelling results, allowing for an enrichment of the analysis by comparing modelling outputs. However, the five models can be complementary also due to their different focus. In this last kind of interlinkage, we will take advantage of each WP5 model's specificities and capabilities: NEMESIS covers macroeconomic aspects as inter-sectoral economic exchange; LEAP and EU-TIMES cover the entire energy system allowing for balancing between supply and demand and a detailed analysis of technological options; FORECAST provides for in-depth analysis of mitigation options in the industrial, tertiary and residential sectors; and ALADIN completes the puzzle with a very detailed analysis of alternative fuel vehicles diffusion.

For instance, the NEMESIS model could switch off its energy-climate module and consider energy demand and costs from the EU-TIMES model, which will update sector' or agents' activity variables with some NEMESIS outputs

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such as sector value added, households' income and GDP. Similarly, the FORECAST model, which is detailed enough to model energy demand from manufacturing industries, could provide energy demand to EU-TIMES that balances energy demand and supply and sends back to FORECAST updated end-consumer energy prices for different energy commodities. Configurations can be numerous and there is no intention of detailing them here, but Figure 5 attempts to illustrate an overall scheme of potential linkages of WP5 models in the second modelling round.

This kind of linkage requires a well-established data exchange process between models and mobilises all WP5 modelling teams. It therefore increases the risk of bottleneck if one element of the models' chain encounters some difficulties. Furthermore, it is not always relevant to mobilise all models for each scenarios or research questions explored by WP5. This is why we propose to be pragmatic and examine the relevance of the different models' chain configuration on a case-by-case assessment basis.

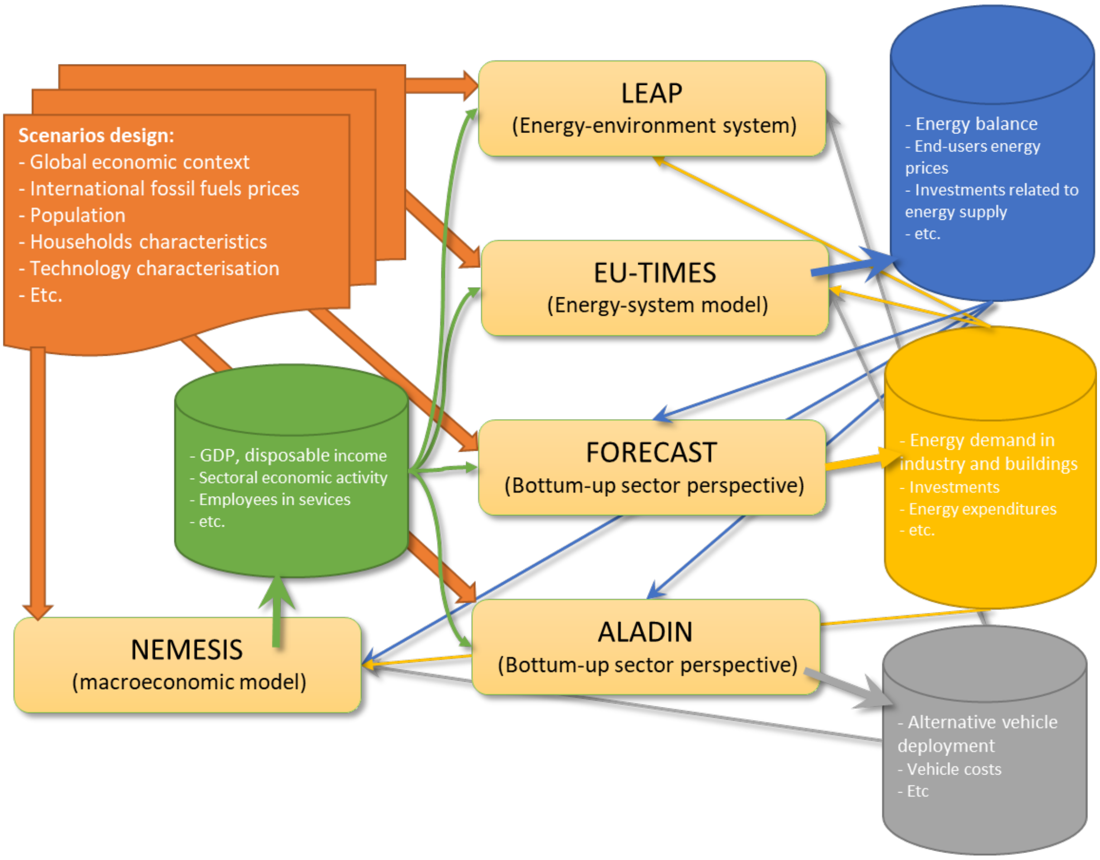

Figure 5: Illustrative scheme of potential linkages of WP5 models in the second modelling round.

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3 Parameter assumptions used in the European models

3.1 Harmonised modelling inputs

As mentioned in Section 2.1, the first modelling round will be using harmonised external assumptions for key modelling variables. Based on the outcomes of a questionnaire identifying the role of different modelling parameters in each model (see outcome in Appendix) and on internal discussions on which assumptions constitute the most important drivers for modelling outcomes, while also taking into account other factors such as the availability of reliable input data and the homogeneity in which a certain parameter is represented in different models, an overview of the selected assumptions and their details are outlined in Table 2.

It should be noted that harmonisation concerns different types of variables, and the degree or capability of harmonisation differs by both models and types of variables. While all WP5 models are able to use the harmonised socioeconomic variables, this is not the case for technoeconomic assumptions, because either a model does not represent them or because complete alignment is not applicable. In WP5, there are no specific technoeconomic assumptions to use, but each modelling team is required to check whether the assumptions used are comparable with the ones provided by the consortium and, if not, to update them or to be able to justify their own assumptions. The last column of Table 2 shows which European models are either updating or checking their outputs for which harmonised variables, which indicates that all WP5 models will use all the PARIS REINFORCE harmonised socioeconomic parameters. Nevertheless, in a macroeconomic model like NEMESIS, GDP is an output. So, in this case, harmonisation will take place through a calibration procedure for one PARIS REINFORCE scenario that will be used as reference. For other scenarios, GDP will be modified by the design of the scenario and may then diverge from PARIS REINFORCE harmonised assumptions. For technoeconomic assumptions, as explained above, all WP5 modelling teams will check the consistency of their own assumptions with the ones proposed by PARIS REINFORCE as a whole. Table 2 does not include historical emissions data (unlike Table 2 in D7.2), as European models will not harmonise emissions data, since all models use official datasets, like those submitted to the UNFCCC (EEA, 2019), which is unavailable as an option at the global scale. Finally, other assumptions on households' characteristics or sectoral growth will be used by some WP5 models. We must notice that the FORECAST model will also use production projections in physical units for some industrial sectors. Even if these datasets are specific to the FORECAST model, they will also be shared to other PARIS REINFORCE modelling teams.

The data in Table 2 has been put together considering an optimal balance between reliability and consistency. Consistency has been ensured where applicable, by using the same source for data. For example, in socioeconomics, the same source has been used for population and GDP data for each country during the same time period, as these parameters are strongly interrelated. Reliability has been enforced by expert judgement within different modelling teams cooperating in PARIS REINFORCE. Some discussions that have led to the selection of the assumptions in Table 2 can be summarised as follows:

- Socioeconomics: For EU countries, EUROPOP2018 (Eurostat, 2019a) has been used for population projections until 2100, while the Ageing Report (EC, 2017), which is based on a previous version of EUROPOP population projections, has been identified as the most reliable projection for EU GDP per (working age) capita growth rates until 2070, and SSP2 growth rates have been assumed from 2070 onwards.
- Technoeconomic parameters: Since technology plays a major role in PARIS REINFORCE, an up-to-date source for these parameters is of high importance for the modelling activities. For power generation and transport technologies, estimates from Napp et al (2019) have been shared, which is based on a relatively

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recent literature review and is used by default in the TIAM global model. For consistency reasons, the technoeconomic assumptions for the industry, residential and commercial sectors have also been shared with other models, although the different representation of these sectors in the different models complicates the harmonisation of these assumptions, and less weight is given to them compared to the assumptions for power generation and transport technologies. Furthermore, for EU-level parameters, the consortium has also shared recommended assumptions by the European Commission for modelling exercises related to the European NECP reports, based on Mantzos et al (2017). Here, we did not impose European modelling groups to use one or another set of technoeconomic parameters but we let each modelling team compare their own assumptions with both alternatives and ensure that they are in line with them or are able to justify potential divergence. We have chosen this approach because (i) we cannot assume that one set of technoeconomic parameters is better than another, (ii) some modelling tools such as FORECAST (mainly industry sector) or ALADIN (transport sector) are too detailed to directly implement more aggregated parameters, and (iii) we assume that diversity in technoeconomic parameters could also enrich the analysis, as long as differences are acceptable and justifiable.

- Fossil fuel prices: The projections provided by the IEA in the World Energy Outlook 2019 for oil, coal and natural gas prices have been considered to be the most up-to-date source for such estimates. The "Current Policies" projections are well in line with the objectives in the first modelling round of this project, which are largely based on the modelling of current climate policies around the world. Also, the regional disaggregation of coal and natural gas prices allows for specific European price estimates, while keeping consistency with the non-European modelling efforts. A comparison has been done with estimates provided by the European NECPs, but the latter seems to be relatively outdated compared to IEA's.
- Exchange and interest rates: As projections from the OECD's Economic Outlook 103 have been used for medium-term economic growth projections in the major economies (62.8% of global GDP in 2018), projections for exchange and interest rates have been extracted from the same source for consistency considerations within the consortium.
- Household characteristics: Projections of households' characteristics, i.e. their number and their size are made consistent with European population projections. Two models will use these specific inputs: FORECAST and EU-TIMES, which will assess their compatibility.
- Sectoral growth: The projections of sector growth are twofold: for all economic activities in the EU for value added and production in monetary units and for some industrial energy-intensive sectors in physical units. For the former, we use Eurostat National accounts aggregates by industry (Eurostat ,2019b) and project value added and production (in constant million-euro 2010) up to 2060, following national EU GDP projections; this data will be used by the FORECAST and EU-TIMES models. For sector production projections in physical units, required for the FORECAST model, different sources have been used from scientific publications, trade unions or employers' federations publications or stakeholders' consultations. These projections have also been comforted to sector projections in monetary units to ensure their compatibility.

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Table 2: Characteristics of harmonised parameters and use in WP 5 models

	Variable	Definition	Time span	Source	Units	Comments	Used in models (Update / *check differences*)
Socio-economics	Population	Total country population	2010-2100	EUROPOP, OECD and UN (short- & mid-term) SSP2 (long-term; KC & Lutz 2017)	Million people, Growth rate	Switch from short- & mid-term to long-term projections depending by country, ensuring smooth transitions between projected growth levels, and consistency between (working) population and GDP growth rates.	ALADIN, FORECAST, EU-TIMES, LEAP, NEMESIS
	Working Population	Total population between 15 and 64 years old	2010-2100	Ageing Report (EC, 2017), OECD and UN (short- & mid-term) SSP2 (long-term; KC & Lutz 2017)	Million people, Growth rate		NEMESIS
	GDP	Gross domestic product based on purchasing-power-parity valuation	2010-2100	Ageing Report (EC, 2017), OECD (Economic Outlook No. 103 and 106) (short- & mid-term), IMF (short-term), SSP2 (long-term Dellink et al, 2017)	PPP (constant billion 2010 International $), PPP (constant billion 2010 €), Growth rate		ALADIN, FORECAST, EU-TIMES, LEAP, NEMESIS
Power generation costs	Key technological attributes of renewable and non-renewable technologies	Costs of investment, fixed and variable operation & maintenance (O&M), capacity factors, conversion efficiencies and technical lifetimes	2003 - 2048	TIAM (Napp et al, 2019)	Costs in US$2010/kW, Lifetime in years	Technologies included are wind, solar, nuclear, geothermal, hydro, coal, gas, biomass	*EU-TIMES, LEAP, NEMESIS*
	Key technological attributes of renewable and non-renewable technologies	Costs of investment, fixed and variable O&M, conversion efficiencies, self-consumption share, capacity factors, technical lifetimes and O&M costs growth	2020 - 2050	NECPs (Mantzos et al, 2017)	Costs in EUR'13/MWh, Lifetime in years	No global coverage. Costs are estimated for Europe. No regional disaggregation	*EU-TIMES, LEAP, NEMESIS*
Transport costs	Key technological attributes of cars, buses and trucks	Costs of investment, fixed O&M, efficiencies and technical lifetimes	2006 - 2050	TIAM (Napp et al, 2019)	Costs in M 2010 US$/Billion vehicle km, Efficiency in B vehicle km/PJ, Lifetime in years	Attributes available by fuel technology (diesel, fuel, electric, hydrogen, hybrid, natural gas) and by efficiency categories	*ALADIN, EU-TIMES, LEAP*
	Key technological attributes of cars, trucks, trains and planes	Costs of investment and efficiency ratio	-	NECPs (Mantzos et al, 2017)	Costs in EUR'13/MWh, Efficiency in liters/100 vehicle km	No global coverage. Costs are estimated for Europe. No regional disaggregation Fuel technology disaggregation	*ALADIN, EU-TIMES, LEAP*

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Residential and commercial costs	Key technological attributes of main household appliances, lighting, heating and cooling	Costs of investment, fixed O&M, capacity factors and efficiencies.	2006 - 2048	TIAM	Costs in Million US$2010/PJ	Attributes available by fuel technology (bio, coal, diesel, electric, kerosene, LPG, Natural gas, solar) and by efficiency categories	*FORECAST, EU-TIMES, LEAP*
	Key technological attributes of main household appliances, heating appliances, and cooling	Costs of investment and efficiency ratios.	-	NECPs (Mantzos et al, 2017)	Costs in EUR'13/MWh	No global coverage. Costs are estimated for Europe. No regional disaggregation	*FORECAST, EU-TIMES, LEAP*
Industry costs	Key technological attributes of steel and cement industries	Costs of investment, fixed and variable O&M, capacity factor, technical lifetime and input material requirements	2006-2030	TIAM	Costs in $2010USD/Mt, Lifetime in years, Input requirements in PJ/Mt and t/t	Attributes available by process type	*FORECAST, EU-TIMES*
	Key technological attributes by type of process	Costs of investment and efficiency ratios.	-	NECPs (Mantzos et al, 2017)	Costs in EUR'13/MWh	No global coverage. Costs are estimated for Europe. No regional disaggregation	*FORECAST, EU-TIMES*
Fossil fuel prices	Fossil fuel price paths	Price projections in the main regions for oil, gas and coal	2010-2050	2019 World Energy Outlook by International Energy Agency	Oil: $2018USD per barrel/per GJ Gas: $2018USD per Mbtu/per GJ Coal: $2018USD per tonne GJ	Figures available at global level and for 4 regions: EU, USA, China and Japan	ALADIN, FORECAST, EU-TIMES, LEAP, NEMESIS
Exchange rates	Exchange rates	Exchange rates between US$ and national currency	2000-2100	Economic Outlook No. 103 (July 2018) by OECD	US$/National currency	Long-term baseline projections + constant after 2060 except Bulgaria, Cyprus, Croatia, Malta and Romania from Eurostat	NEMESIS, LEAP
Interest rates	Interest rates	Short- and long-term interest rates			%		NEMESIS, *EU-TIMES*
Household charac-teristics	Household characteristics	Building-related projections in the Residential and Commercial sector	2010-2060	EU-TIMES	Residential: thousands of units by house type ((semi-)detached, flat) Commercial: Million square meters by sector	European country coverage only. For periods between the milestone years, values are linearly interpolated	EU-TIMES
Sectoral growth	Production and value added	Production and gross value added by sector	2005-2100	Eurostat and GDP projections of Paris Reinforce	Chain linked volume (2010), million €	European country coverage only. 90 sectors covered	FORECAST, EU-TIMES, LEAP

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3.2 Current policies and NDCs

As well as the socioeconomic, technoeconomic and other parameters described above, all models in the PARIS REINFORCE consortium are intended to be set up in such a way that their reference scenarios reflect current levels of climate policy ambition in different world regions. This will include a reference scenario reflecting the implementation of (*i*) **current policies** at a national or regional level, (*ii*) as well as a distinct reference scenario including the implementation of **Nationally Determined Contributions** (NDCs). In both cases this implementation of ambition will be input to 2030 (the period for which NDCs are most frequently stated and for which current policy impact can reasonably be projected), but with assumptions around how these levels of current policy and NDC "effort" being extended beyond 2030. These reference scenarios are then labelled "**where are we heading**" set of scenarios (WWH, thereafter).

In WP5, the European models will take advantage of the high-level of ambition in climate mitigation in the EU and, therefore, of the well-established set of existing policies, to implement current policies in the PARIS REINFORCE scenarios. Two main axes for the design of the PARIS REINFORCE "where are we heading - current policies" scenarios must be defined: the EU climate mitigation ambition before and after 2030, and the modelling frameworks of the current polices scenarios: either a "backcasting" or a "forecasting" approach. Up to 2030, European models will implement, when feasible, the set of existing climate mitigation policies existing in EU, *i.e.* the "EU Climate & Energy framework 2021-2030". It includes a large set of policies: like targets for greenhouse gas emissions, for renewable energy share and for energy efficiency improvement or policy instruments such as Energy Performance of Buildings Directive (EPBD), CO_2 emission performance standards for cars and vans, EU Emissions Trading System (EU-ETS), Effort sharing regulation (ESR), etc.

According to the policies instruments implemented, we cannot necessarily assume that targets will be reached with the current EU policy instruments as for the EU GHG emissions reduction target, -40% in 2030 compared with 1990. On the one hand, this includes the EU Emissions Trading System (EU-ETS) in which covered sectors should reduce their emissions by 43% compared to 2005. As EU-ETS is a cap-and-trade climate mitigation instrument, this EU-ETS target will be reached in 2030. On the other hand, it also concerns non-EU ETS sectors that are covered by the Effort Sharing Regulation (ESR), which establishes a GHG emission reduction target for each Member State, in 2030 (EU, 2018). For ESR, the policy instruments that are mainly stated at the national level do not ensure, unlike for EU-ETS, that each Member State will reach its ESR reduction target. So, here, the two modelling frameworks can be implemented. On the one hand, following the "backcasting" approach, European models will assume that each EU Member State (or regionally at the EU level) will reach the target by implementing the appropriate policy instruments (such as carbon prices). On the other hand, and in a "forecasting" approach, EU models will implement national climate mitigation policies of each Member State, as described in the National Energy and Climate Plans (NECPs)[1]. In this later approach, nothing ensures *a priori* that the ESR GHG emissions reduction will be reached by each Member State and at the aggregated EU level. While this approach seems more relevant to describe scenarios of where we are heading with current policies, there are also several limits. Even if NECPs allow the identification of

[1] https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en#final-necps

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national climate change mitigation policies in each Member State, nothing ensures that NECPs include effective policy instruments and not policy objectives. Furthermore, such a "forecasting" approach requires more modelling work to implement national climate mitigation policy instruments as accurately as possible. So, in WP5, this "forecasting" approach will not be mandatory to all WP5 modelling teams but will be implemented on a voluntary basis.

For the "where are we heading – NDCs" scenarios, up to 2030, only the EU GHG emissions targets and its burden sharing between EU-ETS and ESR sectors with be implemented in the models.

After 2030, the scenarios will be more exploratory, as there is no yet legal framework in the EU for climate mitigation policies after 2030, even if there exist some political objectives and an ongoing proposal. So, in WP5, we have decided to propose different options to mark out the boundaries of what could be "where we are heading with current policies" scenarios in the EU. So, we will implement different metrics to consider what could be the EU climate action after 2030 reflecting current policies. As a benchmark, a scenario projecting implicit carbon prices following GDP per capita growth will be performed by the EU models as done by global models in WP7, whereas other interpretations of post 2030 EU policies will also be tested.

In the case of the "where we are heading - NDC" scenarios, WP5 will only focus on GHG emissions reduction and maintain the EU climate mitigation effort after 2030 in line with EU 2030 NDC (EC, 2015). It will assume the same EU emissions reduction effort for each decade after 2030 than between 2020 and 2030, i.e. -20pp per decade at EU level in comparison with 1990 (further details on the targets calculation are provided on Appendix).

Table 3 summarises the protocol for the PARIS REINFORCE "where are we heading" scenarios for EU models.

Table 3: "Where are we heading" scenarios general description for WP5

<table>
<tr><th colspan="2"></th><th colspan="3">"Where are we heading" scenarios</th></tr>
<tr><th colspan="2"></th><th colspan="2">Current Policies</th><th>NDCs</th></tr>
<tr><th colspan="2"></th><th>Backcasting approach</th><th>Forecasting approach</th><th>Backcasting approach</th></tr>
<tr><td></td><td>Inputs</td><td colspan="3">Harmonised Inputs</td></tr>
<tr><td rowspan="2">Climate change mitigation actions</td><td>up to 2030</td><td>EU policies as close as possible of legal texts</td><td>EU and national policies as closed as possible of legal texts and final NECPs</td><td>Reduction of EU GHG emissions by 40% in 2030 in comparison with 1990, following EU-ETS and ESR burden sharing</td></tr>
<tr><td>After 2030</td><td>Project EU climate action using different metrics and/or scenario design</td><td>Project climate action using different metrics and/or scenario design</td><td>Prolongation of 2020-2030 EU climate change mitigation efforts (-20pp of GHG emissions per decade in comparison with 1990)</td></tr>
</table>

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4 Links with the I²AM PARIS platform

The I²AM PARIS platform will share and display data, in a stepwise form, a sequence of presenting our processes of a) harmonisation, b) interlinkages, and c) our PARIS REINFORCE scenario data portal.

4.1 Platform interfaces

The I²AM PARIS platform aims to have two interfaces:

- The *public interface* is directed/targeted to non-modelling expert stakeholders, such as policymakers, or non-profit organisations. Through this interface, the user will be able to learn about the capabilities of the models, and the list of variables behind them, as well as the different scenarios that have been considered.

- The *advanced user (or scientific) interface* will present data in a more detailed manner, where access to the databases themselves will be illustrated. All harmonised datasets will be gathered in the platform online and these will eventually be presented in a format that is, over time, built towards the IPCC scenario templates[2].

Additionally, the platform will count with a video presentation of the capabilities of the platform and how to use it.

4.2 Model variable linkages

The potential linkages between model variables are presented through two features in the platform:

i) A harmonisation heatmap is included with different model variables on the rows (e.g. demographic, macroeconomic or technoeconomic) and the different models of the PARIS REINFORCE consortium on the columns (with the possibility to add other models in the future). The different colour codes, as presented in the legend, indicate if the variables are an extractable model output, a harmonisable model input or non-explicit output or input for each model (see Figure 6). This heatmap is thought to be a relatively simple tool to see at a glance what variables have the potential to be harmonised across the different PARIS REINFORCE models.

   The user may select ad hoc which models they would like, for illustrative purposes, to compare against one another.

ii) For each modelling project/exercise, a separate heatmap is included, with information on which parameters have actually been harmonised or interlinked in each model. The design is similar to the heatmap discussed above (Figure 6), but the blue cells will be divided in different blue shades, separating variables that have been harmonised in that specific modelling exercise, and those that are not. Similarly, extractable model outputs will be divided into different green shades, separating those outputs to be used as inputs to other models, and those that are not.

[2] https://data.ene.iiasa.ac.at/ar6-scenario-submission/#/about

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iii) For each modelling project/exercise, tables with harmonised variables (see e.g. Table 2 in this deliverable) corresponding to the three different subgroups of models of the PARIS REINFORCE consortium (i.e. European models, non-European models and global models). These tables show the characteristics of the harmonised parameters in detail, including the description of the parameter, the timespan, the source and in which models they have been applied.

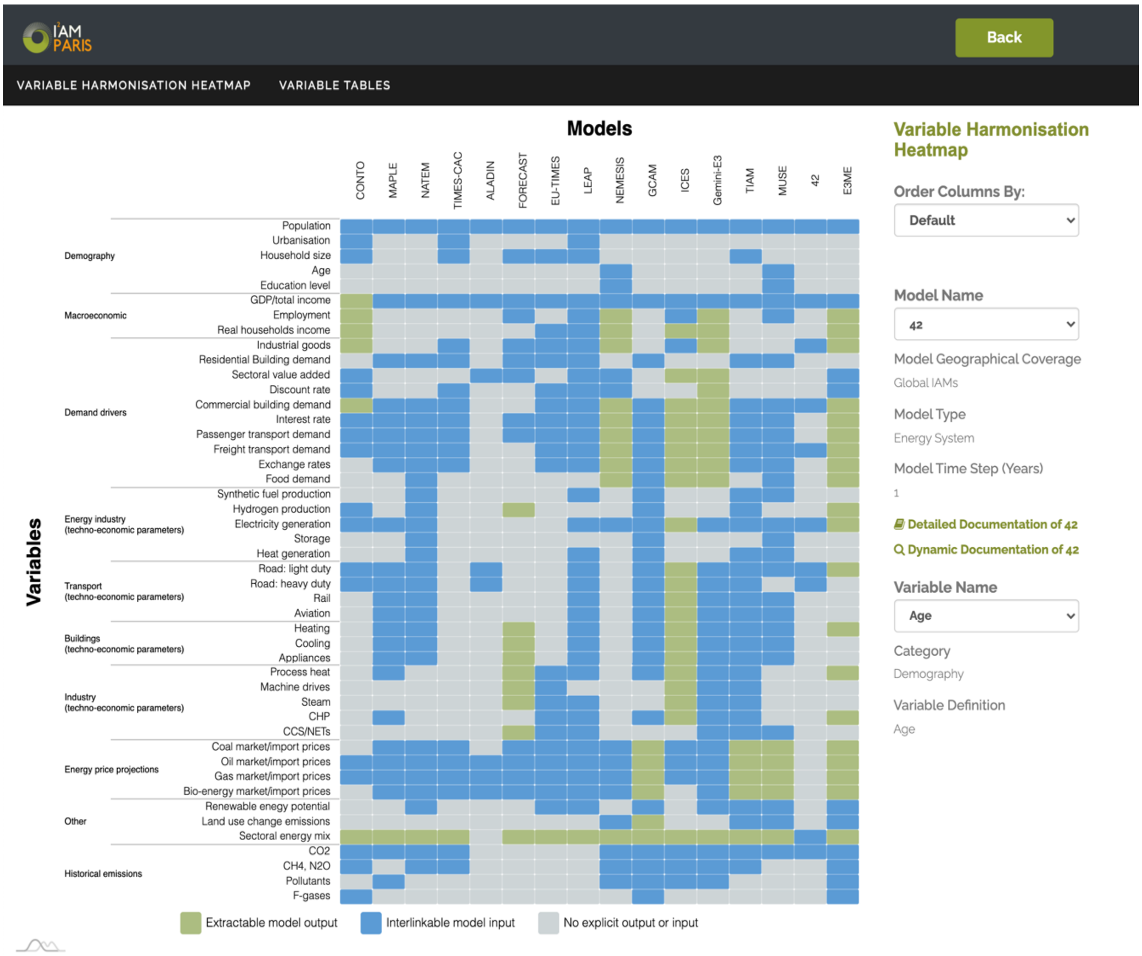

Figure 6: Variable Harmonisation Heatmap

4.3 Futures scenario data portal

Once the PARIS REINFORCE consortium finalise reference scenarios, we then will display modelling runs 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. 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 visualisation of the results will be done using different graphs and infographics. Several webpages have served as an inspiration; see for example the Global Stocktake[3] or the SENSES toolkit[4].

[3] https://themasites.pbl.nl/global-stocktake-indicators/
[4] https://climatescenarios.org/

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Appendix – Ability for Interlinkage and harmonisation of global models in WP5

Since each model in the consortium has a different overall structure, the set of variables that can be interlinked also differs for each model. For this purpose, each modelling team has indicated, for a list of variables, whether they constitute outputs, inputs or not represented in their model. In the case of an input, each team have indicated whether they are able or not to adapt this variable to outputs from other models in the consortium, or with harmonised inputs. Table A1 shows the outcome of this questionnaire for the regional models in WP5.

Table 4: WP5 modelling capability to harmonise/interlink to a central set of assumptions

	Model name:	*ALADIN*	*FORECAST*	*EU-TIMES*	*LEAP*	*NEMESIS*
Demography	Population	2	2	2	2	2
	Urbanisation	4	4	4	2	4
	Household size	3	2	2	2	4
	Age	3	4	4	4	2
	Education level	3	4	4	4	2
Macro-economic	GDP / total income (reference)	2	2	2	2	2
	Employment (reference)	4	2	4	2	1
	Real household disposable income	4	4	2	2	1
	Sectoral value added	4	2	2	2	1
	Discount rate	4	2	2	2	4
	Interest rate	2	2	4	2	2
	Exchange rates	4	4	2	2	2
Demand drivers	Industrial goods	4	3	2	2	1
	Domestic Building serv. demand	4	2	2	2	1
	Commercial building serv. dem	4	2	2	2	1
	Passenger transport demand	3	4	2	2	1
	Freight transport demand	3	4	2	2	1
	Food demand	4	3	4	4	1
Technology - techno-economic parameters						
	Synthetic fuel production	4	4	2	2	4
Energy industry	*Hydrogen production*	4	1	2	4	4
	Electricity generation	4	4	2	2	2
	Storage	4	4	2	4	4
	Heat generation	4	4	2	2	3
Transport	*Road: light duty*	2	4	2	2	4
	Road: heavy duty	2	4	2	2	4
	Rail	4	4	2	2	3
	Aviation	4	4	2	2	3
Buildings	*Heating*	4	1	2	2	3
	Cooling	4	1	2	2	3
	Appliances	4	1	2	2	3
Industry	*Process heat*	4	1	2	2	3
	Machine drives	4	1	2	4	3
	Steam	4	1	2	2	3
	CHP	4	4	2	2	3
	CCS/NETs	4	1	2	2	4
Energy price projections	Coal market/import prices	4	2	2	2	2
	Oil market/import prices	2	2	2	2	2
	Gas market/import prices	2	2	2	2	2
	Bio-energy market/import prices	2	2	2	2	2
Renewable energy potential (e.g. physical maximum)		2	4	4	2	2
Land use change emissions		1	4	4	3	4
Sectoral energy mix		1	4	1	1	1

Key: 1 = Model output; 2 = Model input that can be harmonised;
3 = Model input that cannot be harmonised; 4 = variable not represented in the model

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Appendix – Detailed calculation of GHG and CO_2 emissions for the EU-ETS and ESR sectors in the "where are we heading – NDC" scenario

We present below the quantification of the EU GHG (and CO_2) emissions targets for 2040 and 2050 and for the "where are we heading – NDC" scenario. As displayed in Table 5, the EU GHG emissions reduction in 2040 should reach -50% (with respect to 1990), *i.e.* 2.3 $GtCO_2$eq. (excluding LULUCF). This reduction is equivalent to the one planned between 2020 and 2030, from -20% to -40% (w.r.t. 1990), *i.e.* -20 percentage points (pp) in a decade. The same logic applies to the 2050 targets with -80% of GHG emissions (w.r.t. 1990), corresponding to 1.15 $GtCO_2$eq. (excluding LULUCF).

Table 5: EU GHG emissions targets for the EU-ETS and ESR sectors in the "where are we heading - NDC" scenario

(Mt CO_2 eq./y.)	1990	2005	2020	2030	2040	2050
EU-ETS*	--	2 340.3	1 848.8	1 334.0	782.9	242.6
ESR	--	3 021.7	2 729.5	2 110.6	1 506.3	901.9
Total	5 722.9	5 362.0	4 578.3	3 444.6	2 289.2	1 144.6
Reduction Total (w.r.t. 1990)	0%	-6%	-20%	-40%	-60%	-80%
Reduction EU (w.r.t. 2005)		0%	-21%	-43%	-67%	-90%
Reduction ESR (w.r.t. 2005)		0%	-10%	-30%	-50%	-70%

*Source: authors' calculation based on EEA (2019a) and EEA (2018b). *: Covers only EU member states including UK.*

The burden sharing between the EU-ETS and ESD sectors is calculated on the basis of the national binding annual greenhouse gas emission targets for Member States for 2030 (EU, 2018) by applying on each national reduction target a 20pp GHG emissions reduction per decade (see Table 6). Then the EU-ETS targets are deduced to meet global EU GHG emissions reduction targets.

For the models without mitigation options for non-CO_2 emissions, they should use the results of the *EC EUCO3232.5* scenario (EC, 2019) for national non-CO_2 emissions up to 2030 and use EU global non-CO_2 emissions projections from EC (EC, 2018) defining EU long-term strategy for climate change mitigation action (see Table 7). This later reaches around 340 $MtCO_2$eq./y. in 2050 in scenarios labelled as "*well below 2°C ambition*". The resulting national ESR targets for CO_2 emissions are shown in Table 8.

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Table 6: National GHG emissions targets for ESR sector in the "where are we heading - NDC" scenario

		GHG emissions (excluding LULUCF) reduction in the ESR sector					
	2005	2030		2040		2050	
	GHG emissions ($MtCO_2eq./y.$)	Reduction with respect to 2005*	GHG emissions target ($MtCO_2eq./y.$)	Reduction with respect to 2005	GHG emissions target ($MtCO_2eq./y.$)	Reduction with respect to 2005	GHG emissions target ($MtCO_2eq./y.$)
Belgium	82.3	-35%	53.5	-55%	37.0	-75%	20.6
Bulgaria	26.6	0%	26.6	-20%	21.3	-40%	15.9
Czechia	63.4	-14%	54.5	-34%	41.8	-54%	29.2
Denmark	42.4	-39%	25.8	-59%	17.4	-79%	8.9
Germany	501.6	-38%	311.0	-58%	210.7	-78%	110.3
Estonia	6.5	-13%	5.6	-33%	4.3	-53%	3.0
Ireland	49.2	-30%	34.5	-50%	24.6	-70%	14.8
Greece	65.2	-16%	54.8	-36%	41.7	-56%	28.7
Spain	252.4	-26%	186.8	-46%	136.3	-66%	85.8
France	416.6	-37%	262.5	-57%	179.1	-77%	95.8
Croatia	17.8	-7%	16.6	-27%	13.0	-47%	9.5
Italy	341.6	-33%	228.9	-53%	160.6	-73%	92.2
Cyprus	5.1	-24%	3.9	-44%	2.9	-64%	1.8
Latvia	8.7	-6%	8.2	-26%	6.4	-46%	4.7
Lithuania	11.5	-9%	10.4	-29%	8.1	-49%	5.8
Luxembourg	11.4	-40%	6.8	-60%	4.6	-80%	2.3
Hungary	46.6	-7%	43.4	-27%	34.0	-47%	24.7
Malta	1.2	-19%	1.0	-39%	0.7	-59%	0.5
The Netherlands	134.2	-36%	85.9	-56%	59.1	-76%	32.2
Austria	58.5	-36%	37.4	-56%	25.7	-76%	14.0
Poland	183.0	-7%	170.2	-27%	133.6	-47%	97.0
Portugal	49.7	-17%	41.3	-37%	31.3	-57%	21.4
Romania	79.9	-2%	78.3	-22%	62.3	-42%	46.4
Slovenia	11.8	-15%	10.1	-35%	7.7	-55%	5.3
Slovakia	22.2	-12%	19.6	-32%	15.1	-52%	10.7
Finland	35.6	-39%	21.7	-59%	14.6	-79%	7.5
Sweden	45.1	-40%	27.1	-60%	18.0	-80%	9.0
The United-Kingdom	451.5	-37%	284.4	-57%	194.1	-77%	103.8
EU-28	3 021.7	-30%	2 110.6	-50%	1 506.3	-70%	901.9

*Source: authors calculation based on EEA (2019a) and EEA (2019b) except *: EU (2018)*

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Table 7: National non-CO_2 emissions projections in the "where are we heading scenario - NDCs" scenarios for EU models without mitigation options for non-CO_2 emissions.

	Non-CO_2 emissions (in $MtCO_2eq./y.$)		
	2030	2040	2050
Austria	9.4	6.7	4.8
Belgium	15.2	10.9	7.8
Bulgaria	9.3	6.7	4.8
Czechia	14.9	10.7	7.6
Denmark	12.3	8.8	6.3
Germany	85.7	61.4	43.9
Estonia	1.6	1.1	0.8
Ireland	23.8	17.0	12.2
Greece	14.0	10.0	7.2
Spain	57.1	40.9	29.3
France	101.1	72.4	51.8
Croatia	5.0	3.6	2.6
Italy	64.2	46.0	32.9
Cyprus	1.5	1.1	0.8
Latvia	2.8	2.0	1.4
Lithuania	5.9	4.2	3.0
Luxembourg	1.0	0.7	0.5
Hungary	8.8	6.3	4.5
Malta	0.2	0.1	0.1
The Netherlands	27.2	19.5	13.9
Poland	62.1	44.5	31.8
Portugal	12.8	9.2	6.6
Romania	34.9	25.0	17.9
Slovenia	2.5	1.8	1.3
Slovakia	6.0	4.3	3.1
Finland	8.4	6.0	4.3
Sweden	10.0	7.2	5.1
The United-Kingdom	65.7	47.0	33.7
EU-28	663.4	474.9	340.0

Source: 2030: EC (2019) – Scenario ECO3232.5; 2040 and 2050: authors' calculation based on EC (2018)

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Table 8: National CO_2 emissions targets for ESR sector in the "where are we heading - NDC" scenario, for EU models without mitigation options for non-CO_2 emissions.

		CO₂ emissions (excluding LULUCF) reduction in the ESR sector					
	2005	2030		2040		2050	
	CO_2 emissions ($MtCO_2$/y.)	Reduction with respect to 2005*	CO_2 emissions target ($MtCO_2$/y.)	Reduction with respect to 2005	CO_2 emissions target ($MtCO_2$/y.)	Reduction with respect to 2005	CO_2 emissions target ($MtCO_2$/y.)
Belgium	62.5	-39%	38.3	-58%	26.2	-80%	12.8
Bulgaria	13.3	30%	17.3	10%	14.6	-16%	11.2
Czechia	41.6	-5%	39.6	-25%	31.2	-48%	21.5
Denmark	28.3	-52%	13.5	-70%	8.6	-91%	2.6
Germany	374.7	-40%	225.3	-60%	149.3	-82%	66.4
Estonia	4.4	-8%	4.0	-27%	3.2	-49%	2.2
Ireland	27.8	-62%	10.7	-73%	7.6	-91%	2.6
Greece	42.8	-5%	40.8	-26%	31.7	-50%	21.5
Spain	179.3	-28%	129.7	-47%	95.4	-68%	56.6
France	288.5	-44%	161.4	-63%	106.8	-85%	44.0
Croatia	11.2	3%	11.6	-16%	9.4	-39%	6.9
Italy	255.4	-36%	164.7	-55%	114.6	-77%	59.3
Cyprus	3.8	-37%	2.4	-53%	1.8	-72%	1.1
Latvia	5.1	5%	5.4	-13%	4.4	-36%	3.3
Lithuania	2.7	68%	4.5	45%	3.9	4%	2.8
Luxembourg	10.5	-44%	5.8	-63%	3.8	-83%	1.8
Hungary	31.8	9%	34.6	-13%	27.7	-36%	20.2
Malta	0.9	-13%	0.8	-34%	0.6	-56%	0.4
The Netherlands	97.4	-40%	58.7	-59%	39.6	-81%	18.3
Austria	45.3	-38%	28.0	-58%	19.0	-80%	9.2
Poland	102.1	6%	108.1	-13%	89.1	-36%	65.2
Portugal	33.7	-15%	28.5	-34%	22.2	-56%	14.8
Romania	31.2	39%	43.4	20%	37.4	-9%	28.5
Slovenia	8.3	-9%	7.6	-29%	5.9	-51%	4.0
Slovakia	13.9	-3%	13.6	-22%	10.8	-46%	7.6
Finland	22.8	-42%	13.3	-62%	8.6	-86%	3.2
Sweden	32.3	-47%	17.1	-66%	10.9	-88%	3.9
The United-Kingdom	327.1	-33%	218.7	-55%	147.1	-79%	70.2
EU-28	2 098.6	-31%	1 447.2	-51%	1 031.4	-73%	561.9

Source: authors' calculation

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