PARIS
REINFORCE

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D2.6 I^2AM PARIS PLATFORM – UPDATE 2

WP2 – I^2AM PARIS

Version: 1.00

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Responsible Author	Georgios Xexakis		Email	gxexakis@holisticsa.gr	
	HOLISTIC		Phone	-	
Contributors	Alexandros Nikas (NTUA); Filippas Serepas (HOLISTIC)				
Reviewer(s)	Alessandro Chiodi (E4SMA), Alevgul Sorman (BC3)				
Keywords	I²AM PARIS; platform; modelling harmonisation; open access; data exchange; integrated assessment models				

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

EC Summary Requirements

1. Changes with respect to the DoA

No changes with respect to the work described in the DoA.

2. Dissemination and uptake

This deliverable is intended to accompany the I^{2}AM PARIS platform, as an update to the documentation report and reference point for all interested stakeholders, primarily aimed at scientists involved in integrated assessment and energy system modelling exercises in support of climate policymaking.

3. Short summary of results (<250 words)

This report provides the final documentation of the I^{2}AM PARIS platform, including an extensive description of available services (such as the Dynamic Model Documentation) as well as detailed instructions on how to take advantage of every available feature. The documentation also provides information on each of the six available workspaces that visualise and explain modelling results through interfaces aimed for advanced users but also for policymakers. It also contains an in-depth analysis of the I^{2}AM PARIS architecture, detailing the implemented core components of the platform: the I^{2}AM PARIS Backend, the Parsers, the Data Manager, and the Visualiser, describing the developed models, schemas, and entities that work as the backbone of the knowledge representation, illustrating the interaction between them and analysing several end-to-end scenarios as well as reporting and justifying the design and implementation choices made.

4. Evidence of accomplishment

This report and the final I^{2}AM PARIS platform: https://www.i2am-paris.eu.

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Preface

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

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

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Executive Summary

As the last version of the deliverable documenting the I²AM PARIS platform design and implementation, this report provides a documentation of the platform and its workspaces along with a description of its architecture (available core components) and implemented services.

The core components that constitute the I²AM PARIS architecture are: a) the Parsers, responsible for extracting, transforming, and storing data into the I²AM PARIS database; b) the I²AM PARIS Backend, a mediator component that aims at managing the interaction between components, renders the requested interfaces, and holds the main schemas of the developed entities; c) the Data Manager, a query execution and data transformation tool that prepares the data for the Visualiser; and d) the Visualiser, a visualisation generator that populates several interfaces with various meaningful charts.

Regarding the available services, the Detailed Model Documentation offers a detailed and extended presentation of the characteristics of every available model involved in the PARIS REINFORCE initiative as well as of models provided by teams outside the PARIS REINFORCE consortium. The Overview and Comparative Assessment is useful for comparing the models available in PARIS REINFORCE with one another, thus gaining significant insight into their coverage and fields of application. The Dynamic Model Documentation is a single-page application that allows going through all the important features of each model, utilising the visual aids of a map to define its geographical coverage, as well as several icons that correspond to specific characteristics (e.g., policy, socioeconomic, technology and SDG representation).

The workspaces are used to present the outcome of modelling analyses and other relevant project results, providing useful data exploration tools and insightful visualisations as well as facilitating the examination and comparison of different scenarios, models, and regions. The workspaces include several interfaces that have been commonly agreed among the involved partners, promoting co-creation and collaborative thinking, with a view to developing exploitable assets for both scientists and different types of stakeholder groups, like policymakers. The Variable Harmonisation Heatmap services provide information about how different variables are handled across different models along with other useful information.

The platform, as of November 11, 2022, counts 4,300 unique visitors corresponding to 8,400 sessions and with an average visiting time of 5.5 minutes per session (as reported by Google Analytics).

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1 The User Interface of the I²AM PARIS platform

In this section, the set of the available services of the final integrated version of the I²AM PARIS platform are presented. These services have largely been co-designed with stakeholders, given their inputs during the first stakeholder council dialogue of the PARIS REINFORCE project, which took place at Bruegel, in Brussels, Belgium on November 21, 2019.

To summarise this feedback, which is reported in detail in deliverables D2.2 ('Protocol for model use, scenarios and stakeholder engagement') and D3.3 ('Proceedings of the 1st regional EU workshop'), 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.

Aside from the evaluation of the platform, some of the topics raised included the potential for the platform to contribute to emissions ambition and inter-sectoral dependencies; the transparency of input variables, assumptions and datasets; and the need to go beyond quantitative tools and incorporate qualitative techniques and social aspects. Other topics raised during this workshop and included better representation of modelling capabilities outside the PARIS REINFORCE consortium; collaboration with past, present and future projects; rich output visualisation; separate interfaces for the public and the scientific community; and the organisation of webinars to engage stakeholders.

At the end of the dedicated session of the event, an online vote was given to the audience, regarding the selection of the design layout to be used in the dynamic documentation of the I²AM PARIS platform. Although the most favoured option of this vote pointed to a "single-page layout – less is better" direction, which can be partly attributed to the significant dominance of researchers among the audience, there was broad diversity in the results; as a result, a more inclusive approach was sought in the project, by incorporating alternative layouts and the capacity for the user to select among them.

1.1 Platform services and components

In Figure 1, an updated overview of the platform is presented including services and the respective components. The I²AM PARIS platform is available online[1], including a landing page that allows navigation throughout the platform, along with services mainly focused on the Model Documentation of the available models and the Modelling Results Presentation. It is a web application based on Django Framework 2.2.5, utilising AM-Charts 4 for the map and chart visualisations. The source code versioning and management is performed through Git version control system and the code is stored in a public GitHub repository[2].

[1] https://www.i2am-paris.eu/

[2] https://github.com/i2amparis/i2amparis_platform

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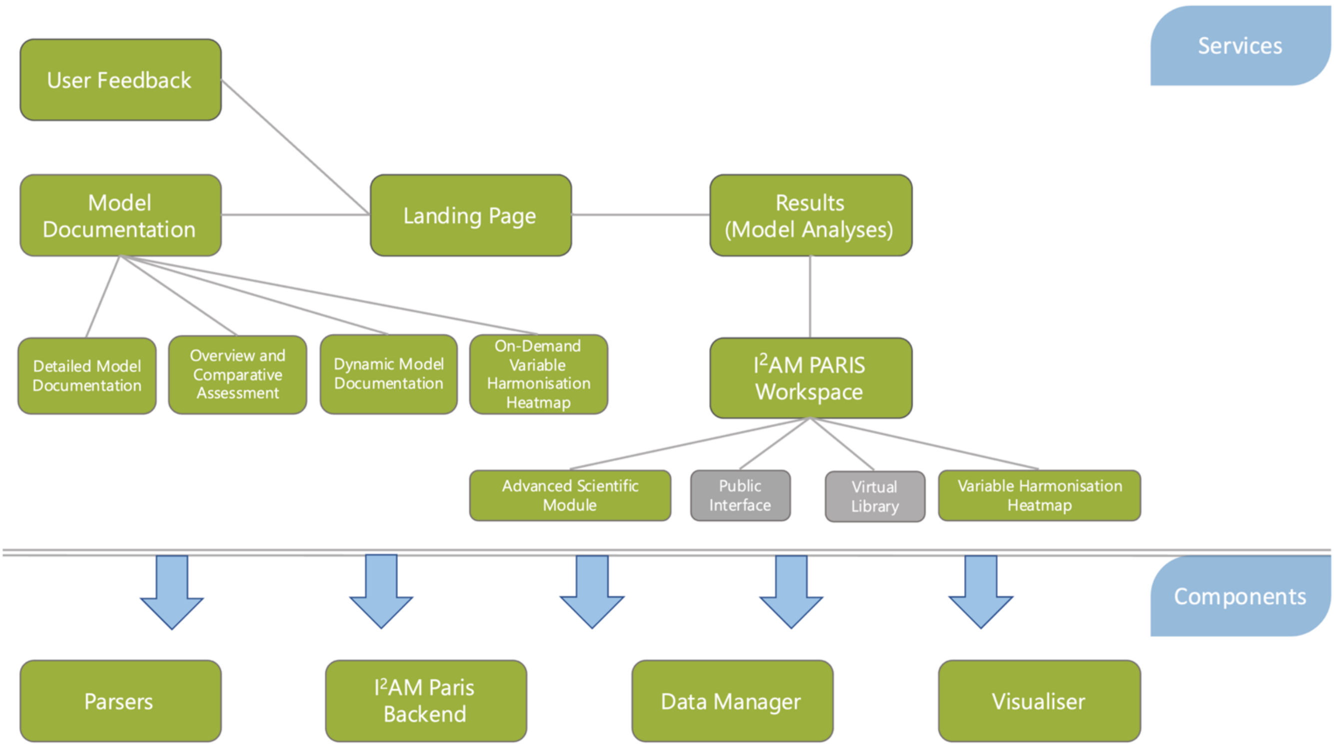

Figure 1: Platform overview

The interactive Dynamic Documentation component is an interactive library of the available models, in the form of a responsive "infographic", regarding their features, including geographical coverage as well as sector, emission, policy, SDG, socio-economic and mitigation/adaptation measure granularities. The descriptive Overview and Comparative Assessment consists of a collection of information included in Section 2 of PARIS REINFORCE deliverables D5.1, D6.1, D7.1 and aims at providing an overview of the suitability of each model for specific research needs, compared to one other. The Detailed Model Documentation, in essence, includes a detailed presentation of every model currently available on the platform and is composed of information retrieved from the corresponding deliverables. The documentation section is concluded with the On-Demand Variable Harmonisation Heatmap tool, an *on-demand comparison table* of harmonisable or extractable variables displayed across user-selected models of the consortium.

The Results section comprises different workspaces, which include the results of specific project studies. Each workspace has a similar structure, thus facilitating the creation of new workspaces and ensuring the sustainability of the specific platform service. It includes (a) a variable harmonisation heatmap , (b) an advanced scientific module focusing on a customisable tool generating scenarios, covering highlights of the inter-comparison project as well as those selected by the user, (c) a public "what does this mean?" interface telling select stories with a pre-set collection of visualisations, targeting a broader audience, in a user-friendly manner, and (d) a virtual library including relevant scientific publications, policy briefs, and databases.

The User Feedback or Contact Form is useful for collecting feedback from platform users, including requests for new services, bugs and errors on the platform, new ideas/suggestions, etc. The submitted form is forwarded to the developers and accordingly handled or further forwarded to the Project Coordinator to communicate to the consortium.

1.2 Landing Page

The landing page of the I²AM PARIS is composed of a carousel containing information about the project (Figure 2), a navigation bar that helps users easily navigate through each section, an entire section regarding the model documentation service (Figure 3) comprising links that lead to the Dynamic Documentation, the Overview and Comparative Assessment, and the Model Detailed Documentation, as well as a second section composed of a list of workspaces, each of which contains tools and interfaces that present the produced results of the modelling analyses for specific project studies. The screenshots below show the main parts of the Landing Page.

Figure 2: Landing page carousel

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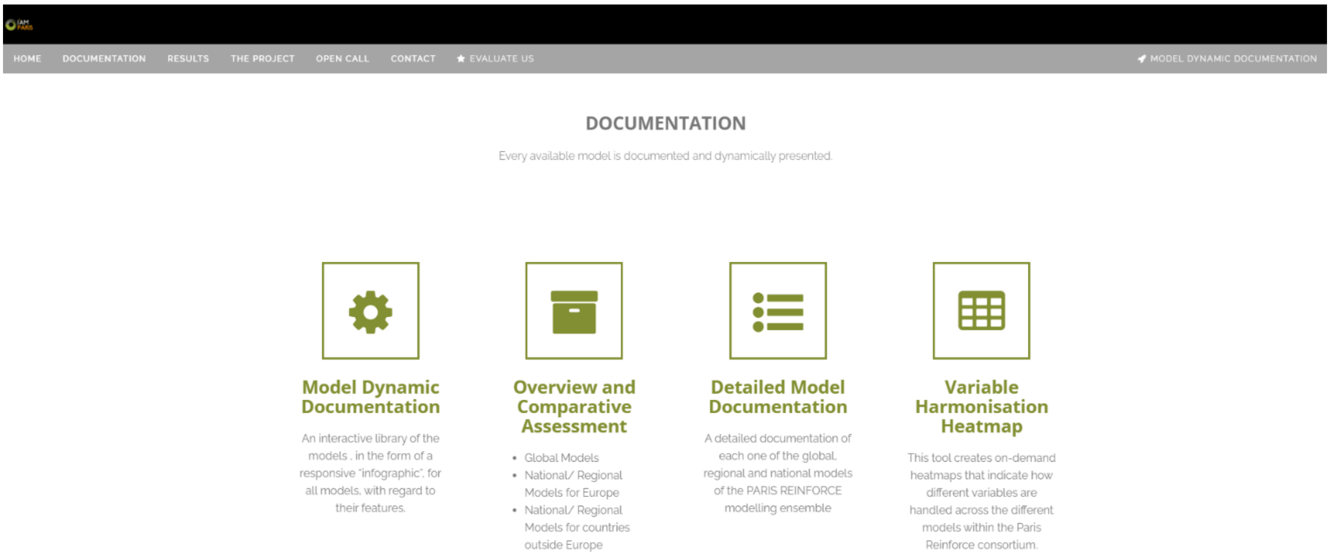

Figure 3: Landing Page – Documentation Section

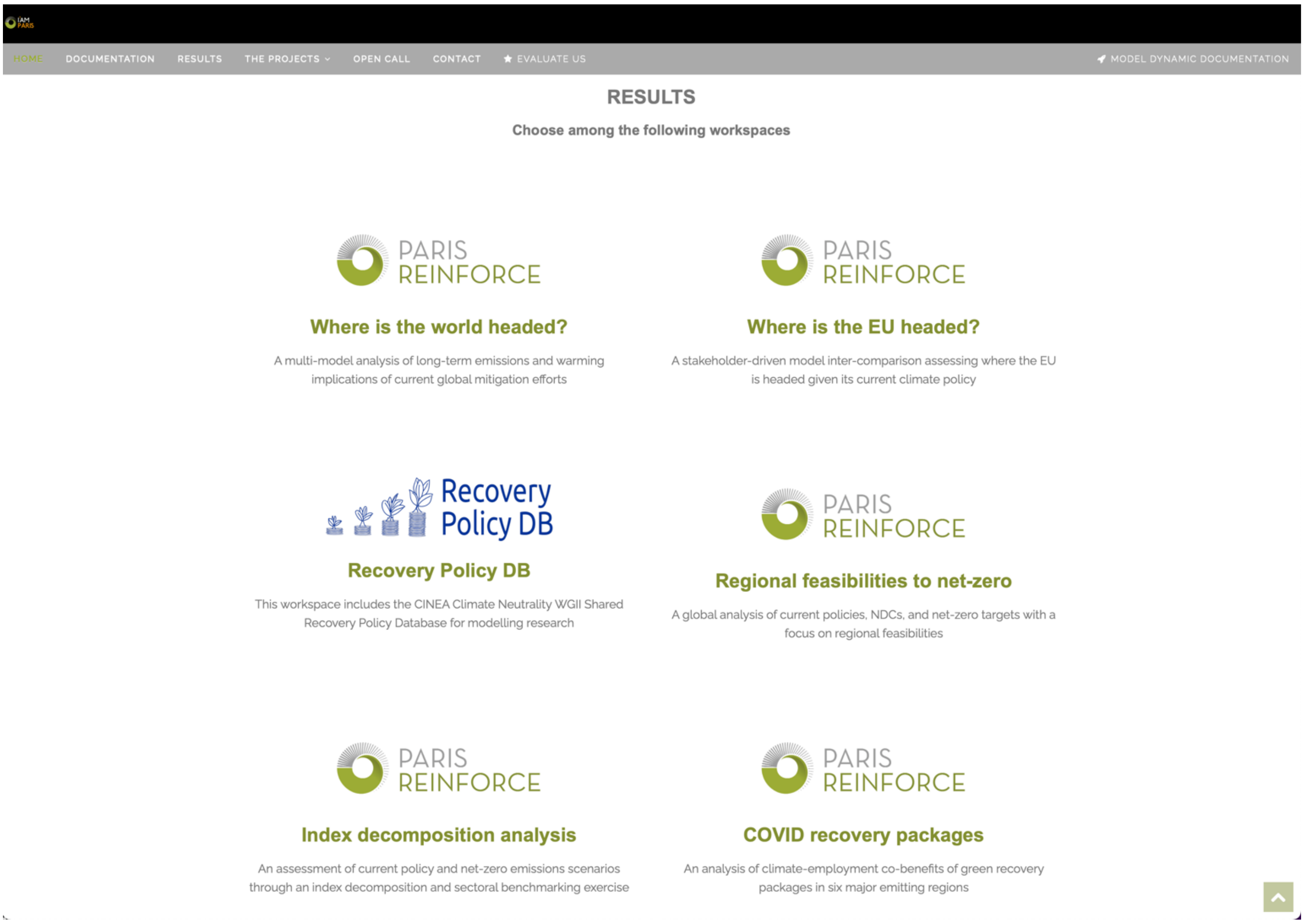

Figure 4: Landing Page – Results Section

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1.3 Model Documentation Services

This section of the platform includes the services responsible for the documentation of the available models on the platform. Each service covers a different aspect of the documentation and is utilised for different purposes. Since the previous version of this deliverable, more models (outside the PARIS REINFORCE project) have been integrated both in the Dynamic and the Detailed Model Documentation Section.

1.3.1 Dynamic Model Documentation

The Dynamic Model Documentation is a combination of a backend and a frontend infrastructure and is responsible for presenting the documentation of each model in a user-friendly manner, taking advantage of the information retrieved from the database as well as interactive maps, combined into an elegant user interface.

The Dynamic Documentation utilises "Django HTML Templates", "JQuery" and the "AMCharts4 Library" for its user interfaces. In the context of ***co-creation and collaborative thinking***, ideas were provided by several stakeholders and more than one different interfaces have been created for the Dynamic Documentation, with a view to receiving feedback on each of them and satisfying all the needs of every possible user. Some of them are more detailed and descriptive, others are minimal and compact. The user may choose any of the available options through a select/dropdown element positioned at the right top of the "Dynamic Documentation" webpage (Figure 5), in order to allow immediate interface alterations without much effort.

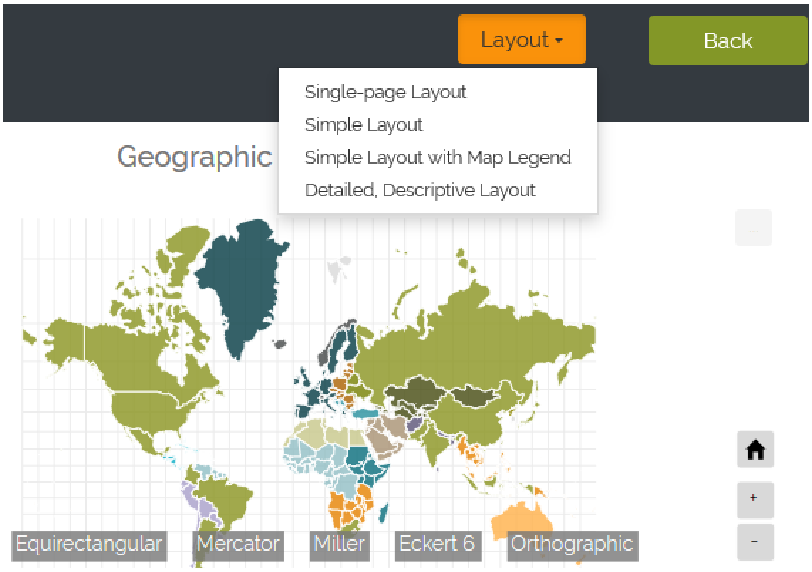

Figure 5: Choosing Different Dynamic Model Documentation Interface

The different interfaces are presented in the screenshots below:

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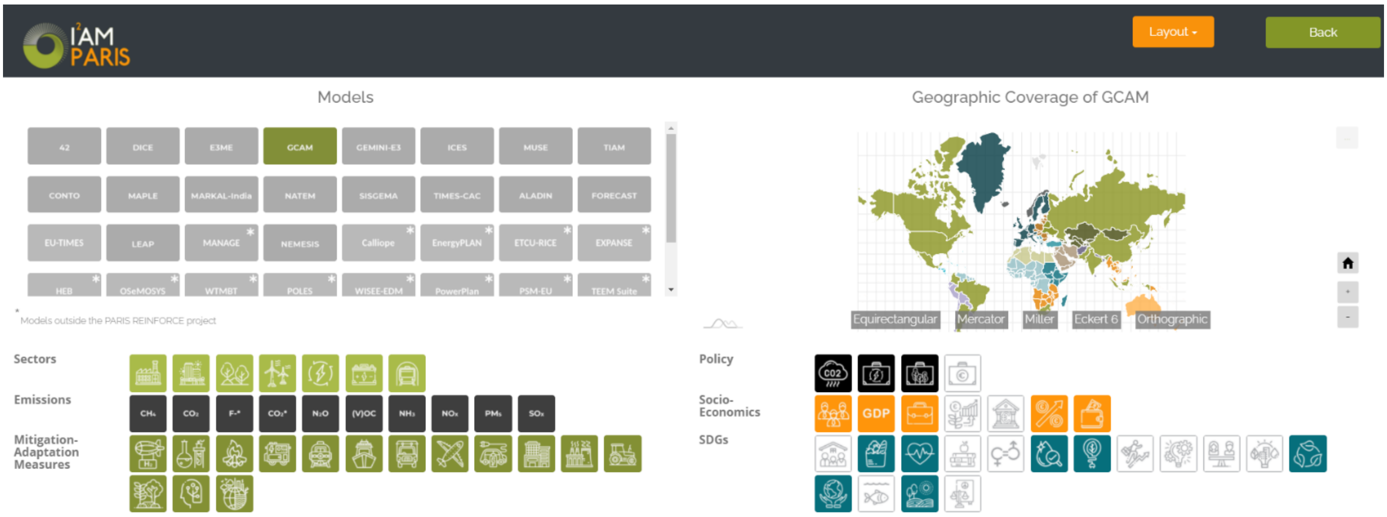

Figure 6: Single-Page layout

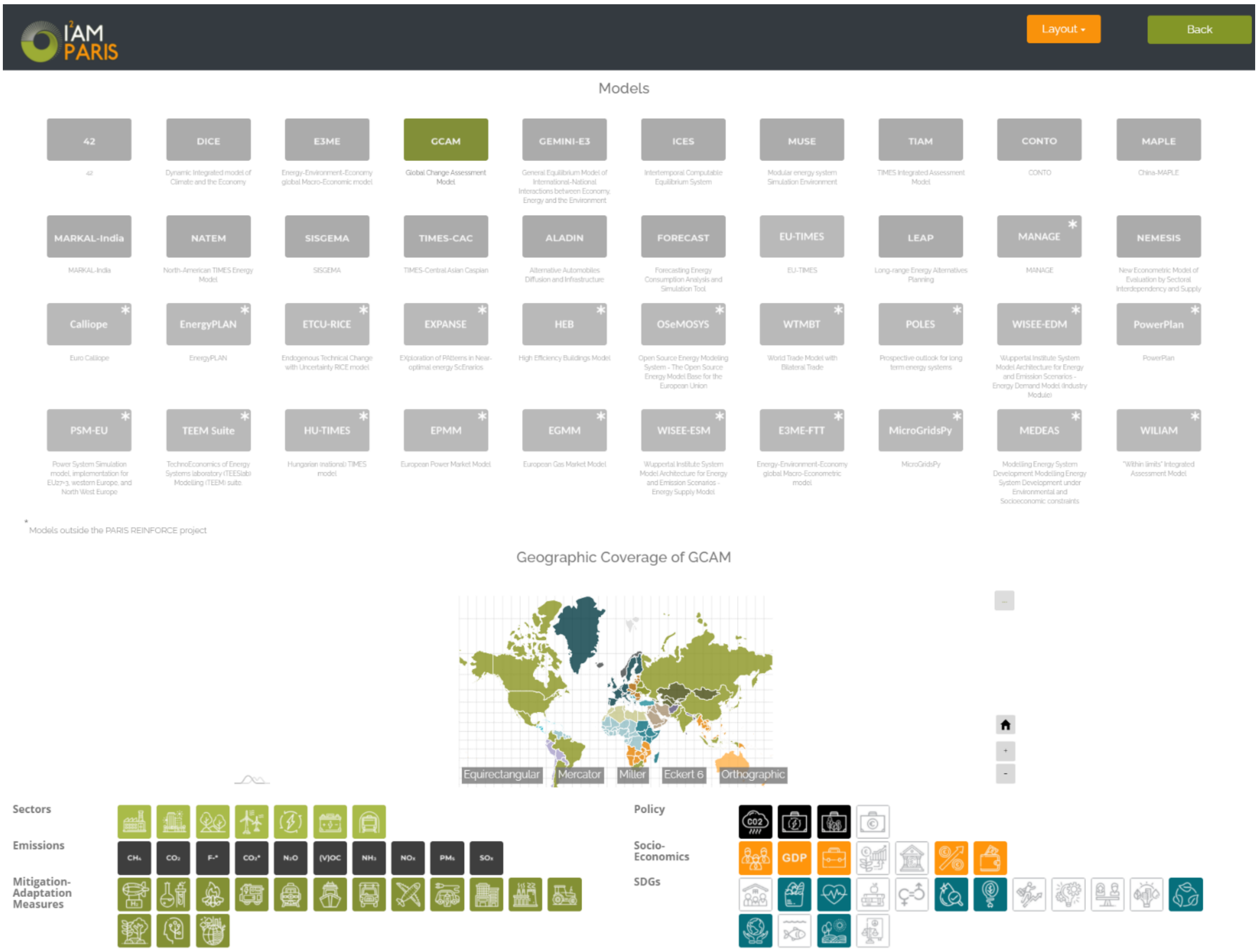

Figure 7: Simple layout

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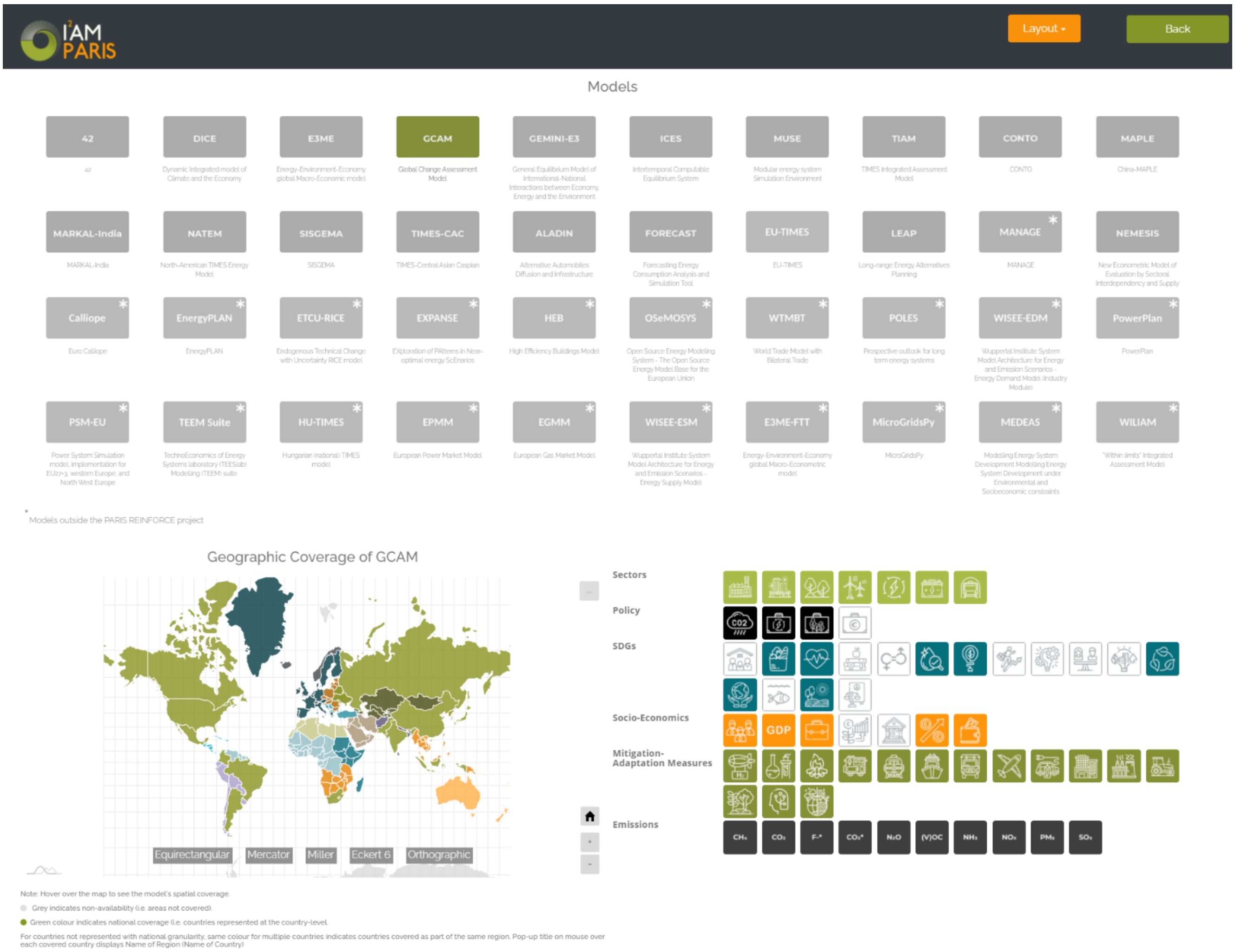

Figure 8: Simple layout with map legend

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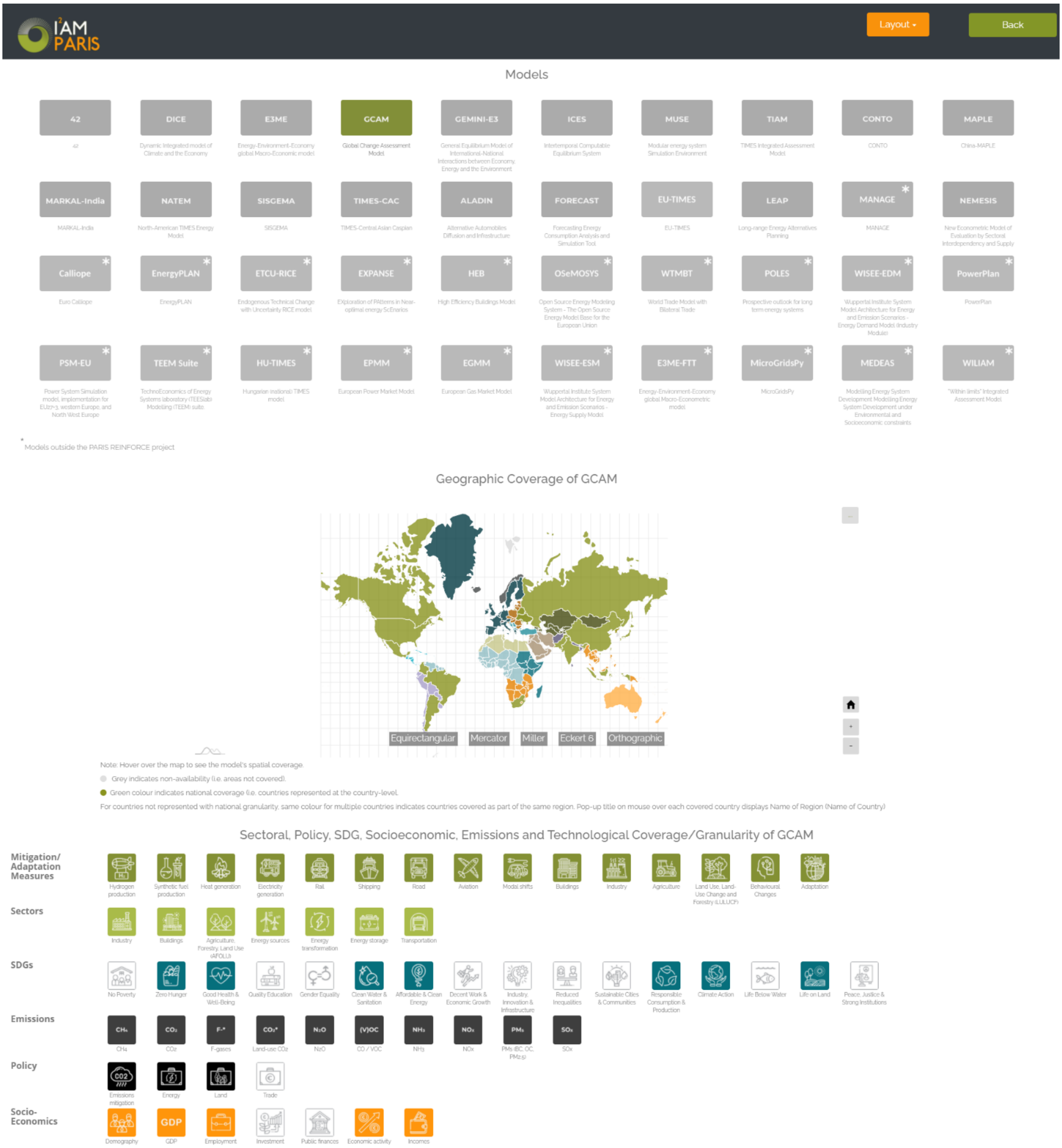

Figure 9: Detailed, descriptive layout

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In every interface the following rules apply:

- The currently selected model appears in green colour, while the remaining are greyed out.
- In the map: Grey colour indicates areas not covered by the model and (olive) green colour indicates national coverage (i.e., countries represented at the country-level). For countries not represented with national granularity, the same colour for multiple countries indicates countries covered as part of the same region. Pop-up title on mouse over each covered country displays the name of the region and the name of the country in the parentheses.
- The coloured icons in the granularity section are the categories (of each type) that are covered by the model (or at least a part of them). The greyed-out icons represent the categories that are not covered at all by the selected model.
- The user may select among different map projections according to their preference using the buttons positioned at the bottom of the map. The available options are: Equirectangular, Mercator, Miller, Eckert 6, Orthographic (Figure 10). Zooming in/out as well as dragging and dropping on the map behave according to the selected projection.

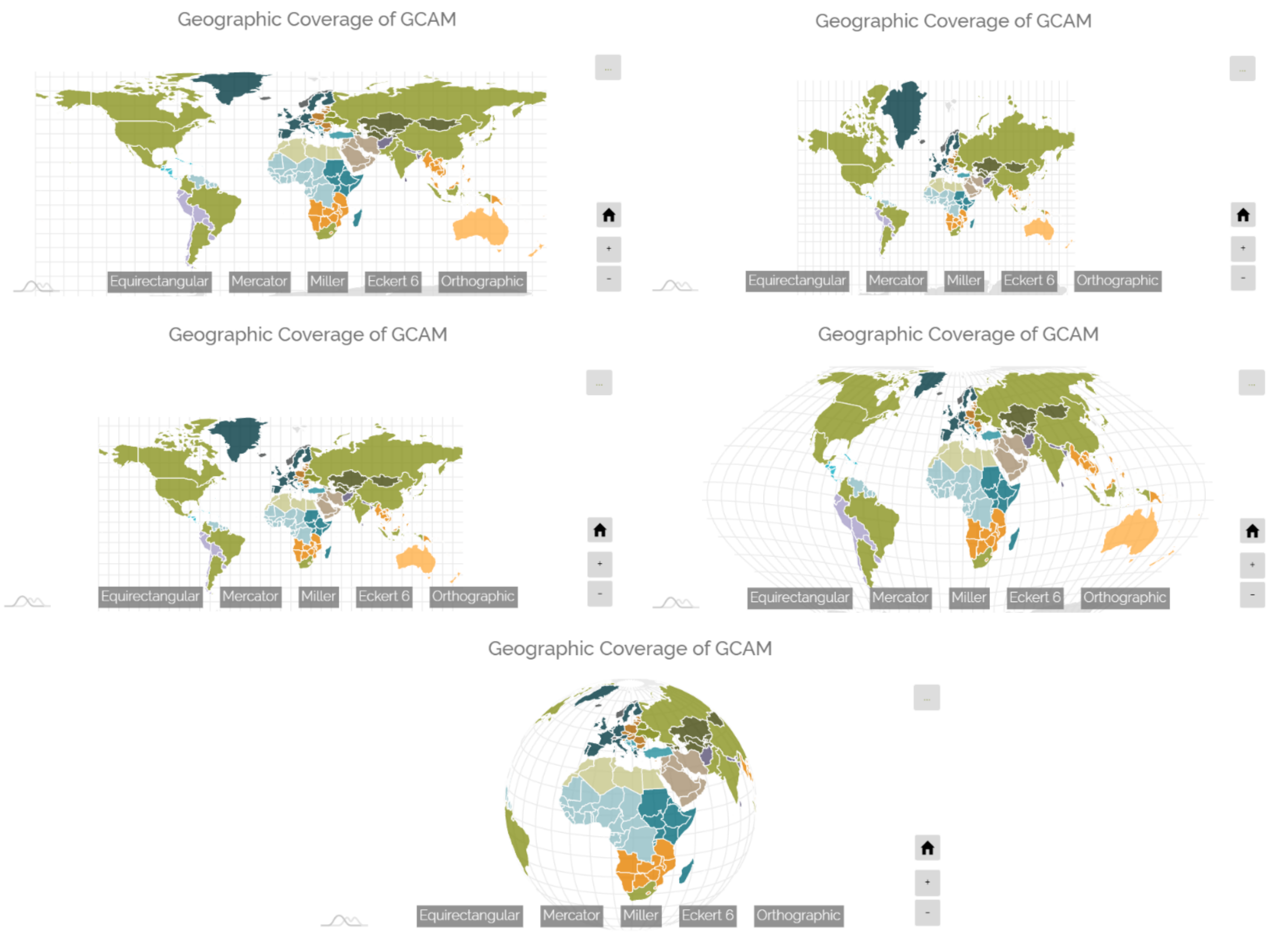

Figure 10: Different Projections (Equirectangular, Mercator, Miller, Eckert 6, Orthographical, placed in order from left to right)

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- By hovering over the granularity icons, a tooltip appears, showing the subcategories and specific quantities covered by the model in green. The rest are crossed out and shown in grey (Figures 11,12).

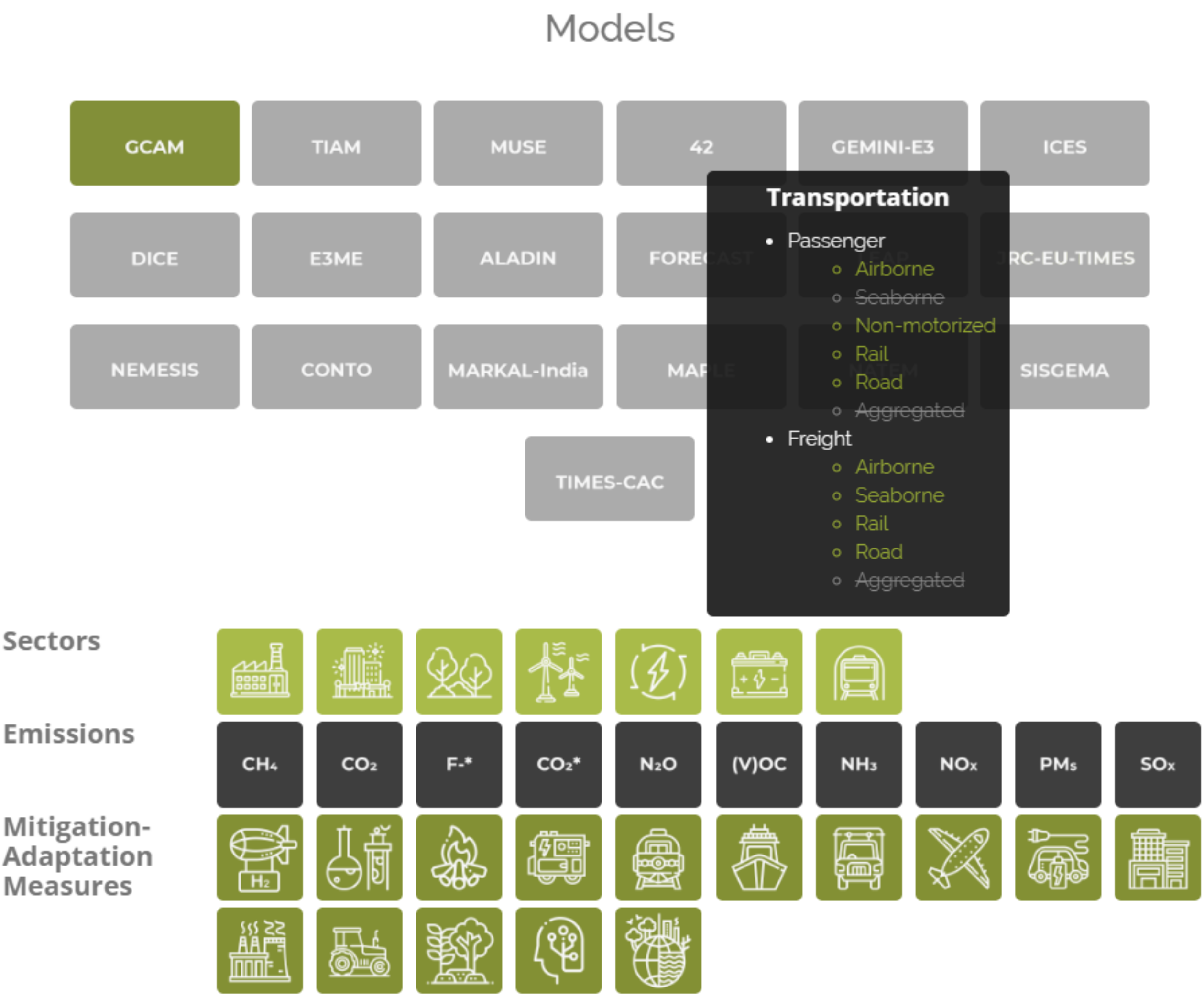

Figure 11: Hovering over the transportation sector

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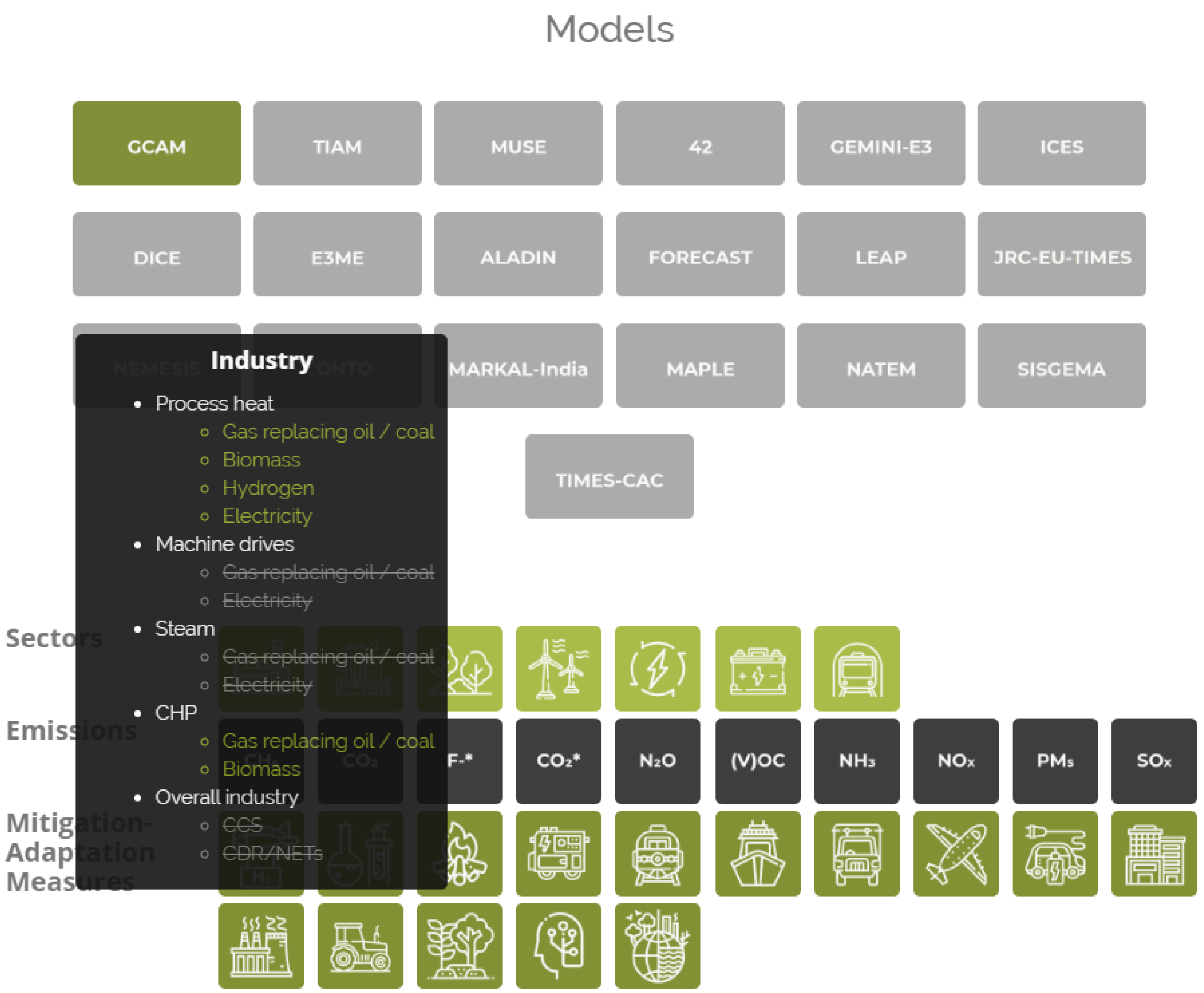

Figure 12: Hovering over the Industry Category of Mitigation and Adaptation Measures

- Hovering over a model button, an "i"-icon appears. Clicking on it, the user is redirected to the corresponding page of the detailed documentation for this specific model (Figure 13).

Figure 13: Information icon on the top-left on hover

1.3.2 Detailed Model Documentation

The Detailed Model Documentation interface contains detailed information regarding the models included in the I²AM PARIS platform, using a content menu for each model along with a navigation bar in order to seamlessly navigate throughout the entire documentation. The landing page of the Detailed Model Documentation consists of a model catalogue separated by geographical coverage (Global Models, National/ Regional Models for Europe, National/ Regional Models for Countries Outside Europe) as shown in the figure below.

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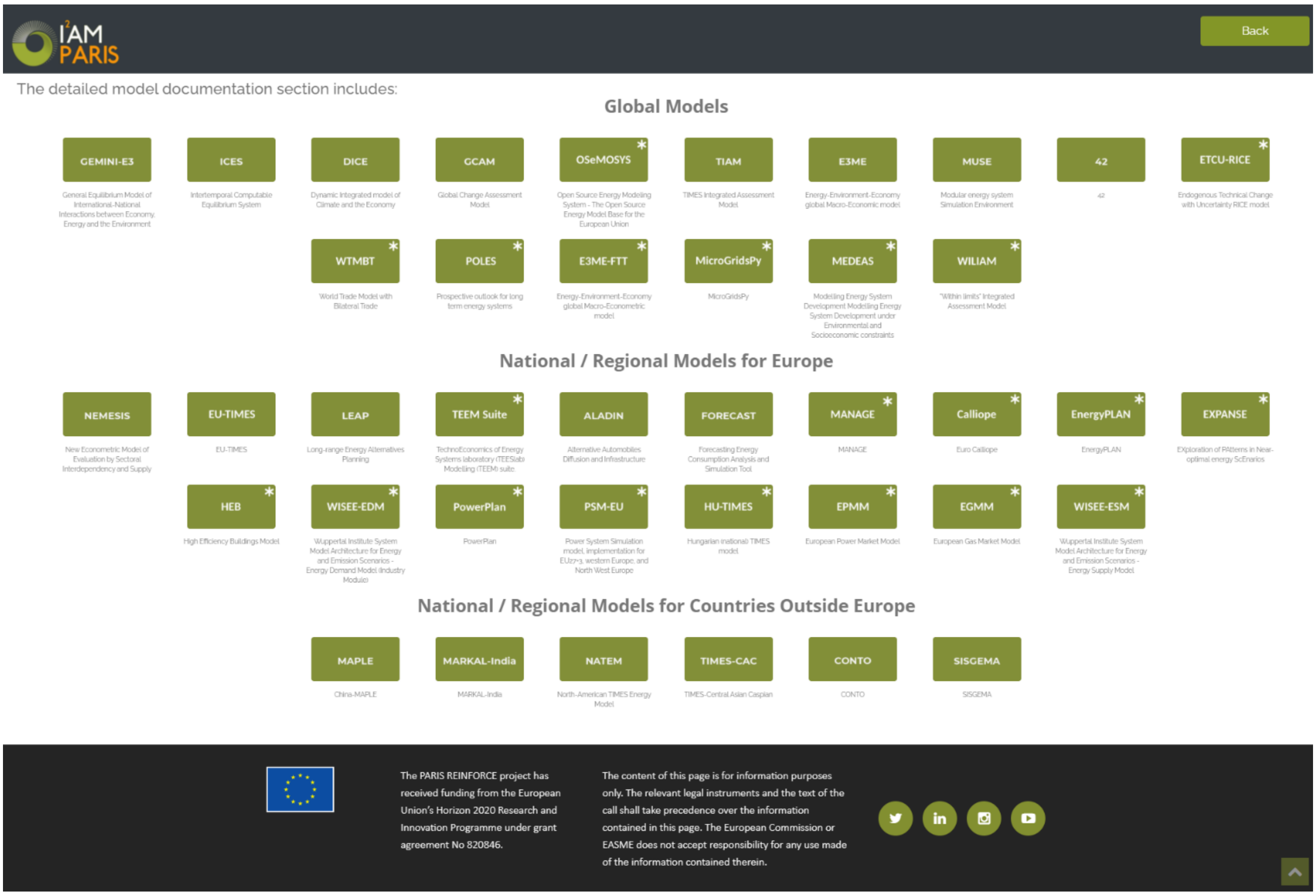

Figure 14: Detailed Documentation Landing Page

Once the user selects the desired model, they are led to the requested page. Each model has its own page, which provides a content menu (by pressing the content button on the top-right of the screen) that can be used to jump to a specific point in the text. Furthermore, a navigation bar is available on the top of each page, providing more flexibility and the ability to switch between models. The screenshots below present the above-mentioned features for the detailed documentation of the GCAM model.

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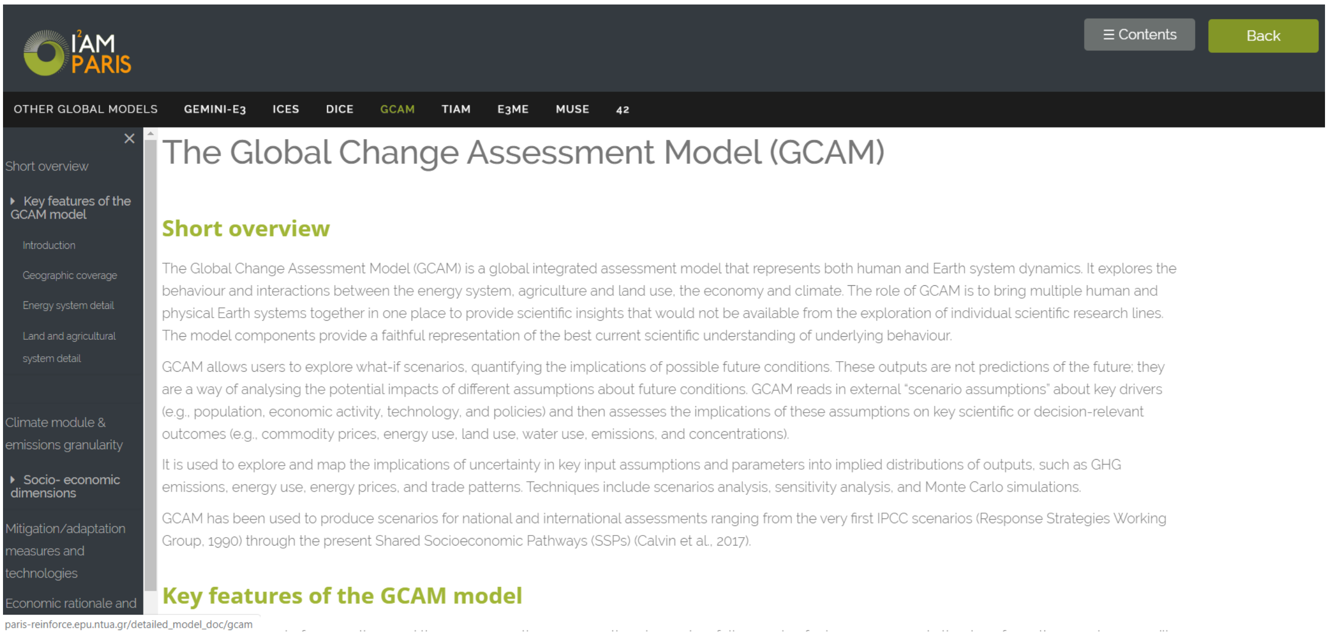

Figure 15: Detailed Documentation of GCAM

1.3.3 Overview and Comparative Assessment

The Overview and Comparative Assessment interface follows the same logic as the Detailed Model Documentation in terms of structure and available features, including the results of the comparison between models of the same coverage in the form of expanding headings. The following screenshots are taken from the global models' overview and comparative assessment.

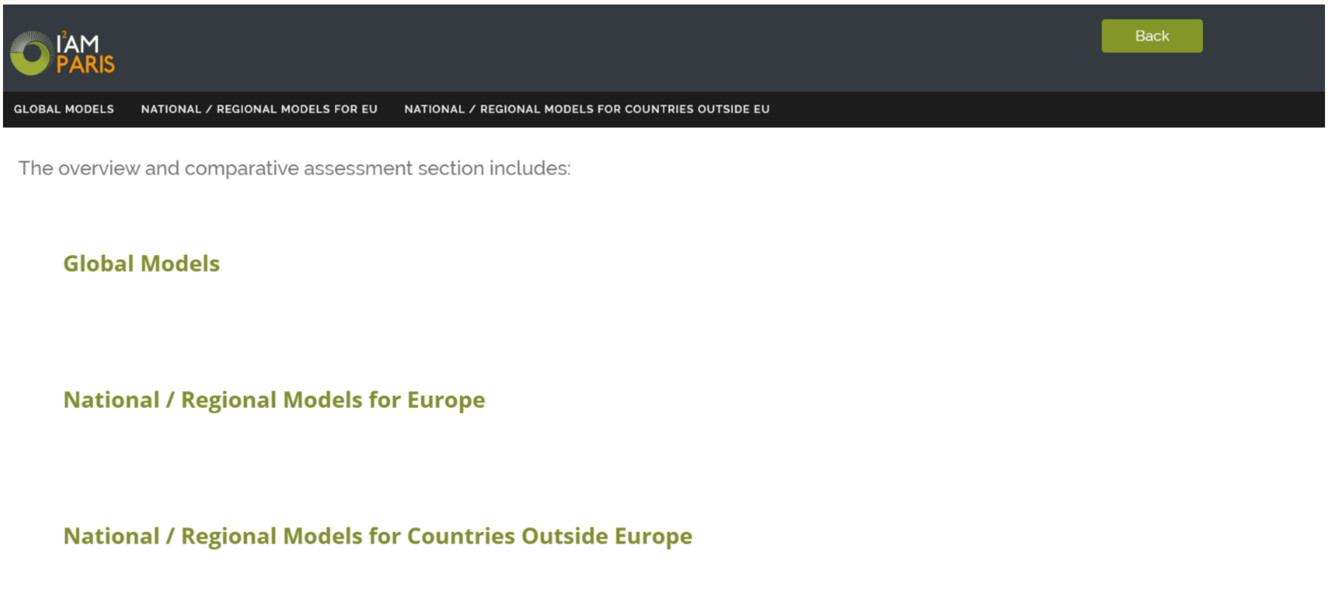

Figure 16: Overview and Comparative Assessment Landing Page

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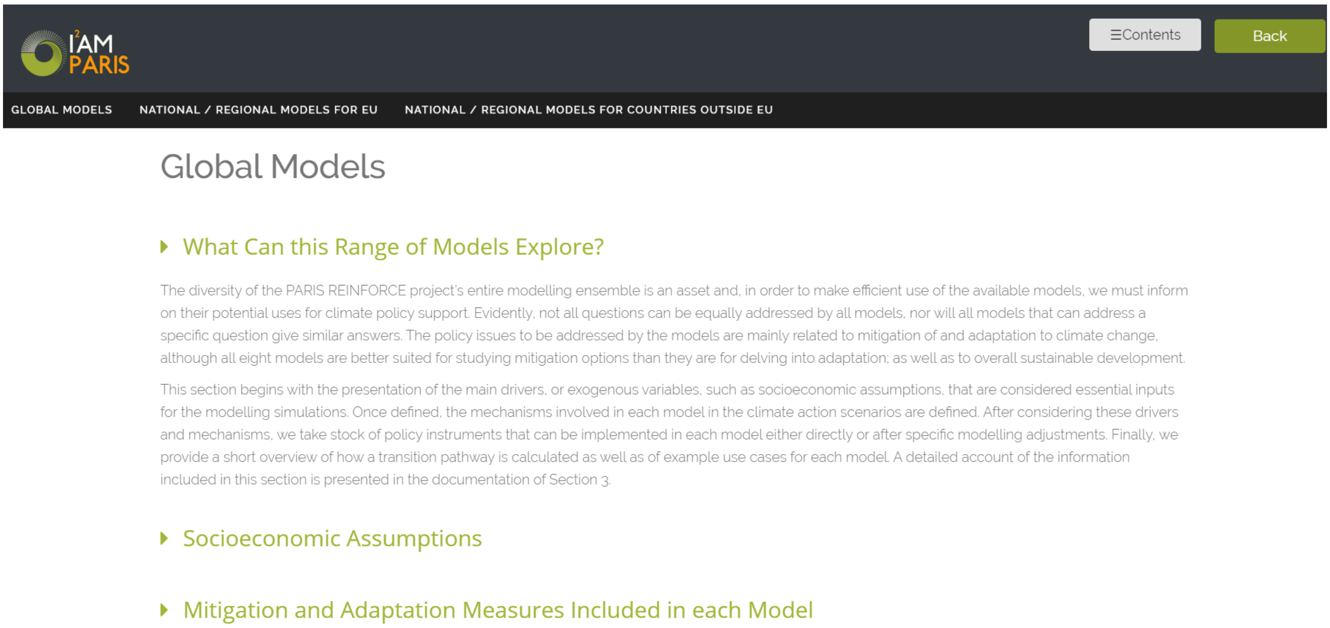

Figure 17: Overview and comparative assessment interface

1.3.4 On-Demand Variable Harmonisation Heatmap

The **On-Demand Variable Harmonisation Heatmap** presents an on-select, data comparison menu, where rows present the different socio- and techno-economic variables, and the columns can be selected to compare variables across the PARIS REINFORCE models.

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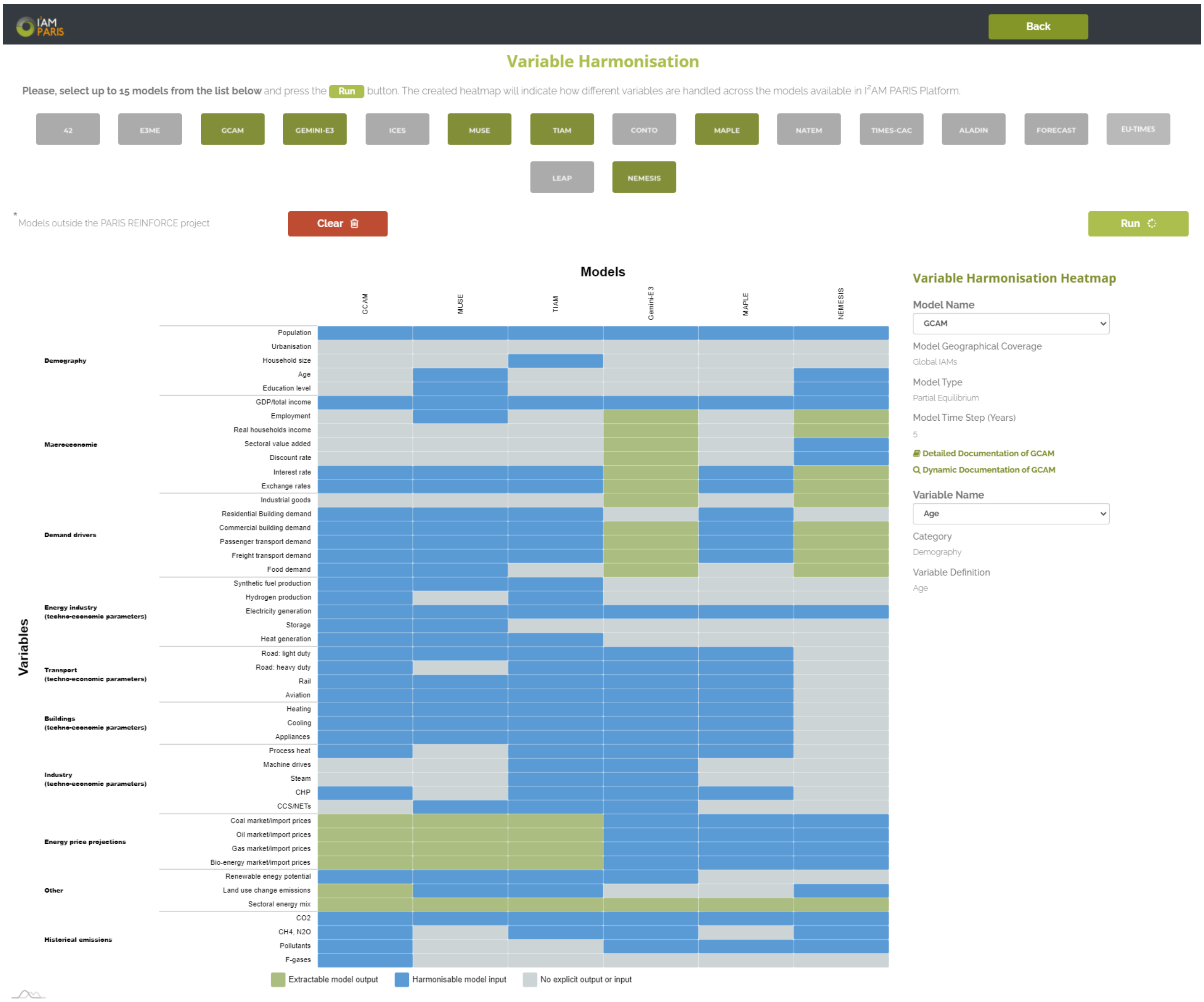

Figure 18: On-Demand Variable Harmonisation Heatmap Interface

The user selects the desired models to take part in the visualisation and clicks the "Run" button. The result includes a heatmap that indicates how different variables are handled across the selected models. Clicking on a specific heatmap cell displays a short description for the selected variable-model combination, as well as links to the corresponding sections of the Dynamic Documentation and the Detailed Documentation.

1.4 Modelling Analysis Results

The second main aspect of the I²AM PARIS platform is the demonstration of data deriving from modelling analyses. Since the examined scenarios and the types of the models differ in some respects, the outcomes are grouped and presented in different, independent workspaces for the sake of specificity and simplicity. These workspaces are composed of four sub-sections as decided among the PARIS REINFORCE partners and different stakeholders:

- "Advanced Scientific Module" – A scientific interface useful for researchers, modellers, and scientific experts, in order to go through the demonstrated results using the implemented tools to explore the available data.
- "Public Interface" – A broader-audience-oriented, self-explanatory interface that includes the main conclusions of the workspace's analysis, along with other insightful information, in a user-friendly manner.

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- "Variable Harmonisation Heatmap" – An enhanced version of the On-Demand Variable Harmonisation Heatmap tool, containing additional information and functionalities, focusing exclusively on the models and multi-model exercise of the workspace, being specifically customised for it.
- "Virtual Library" – A section that includes scientific publications, policy briefs, databases (direct download links, input data sources information, etc.) relevant to the specific workspace.

Figure 19 showcases the landing page of the WWH workspace ("Where is the world headed", i.e., the first global analysis of the project), providing access to all four sub-sections. The Advanced Scientific Module and the Public Interface have been renamed to match the content of the workspace and to become more attractive to platform visitors. The same structure is followed in almost all workspaces of the platform (see Chapter 2), with the exception of the Recovery Policy Database workspace (see Section 2.3).

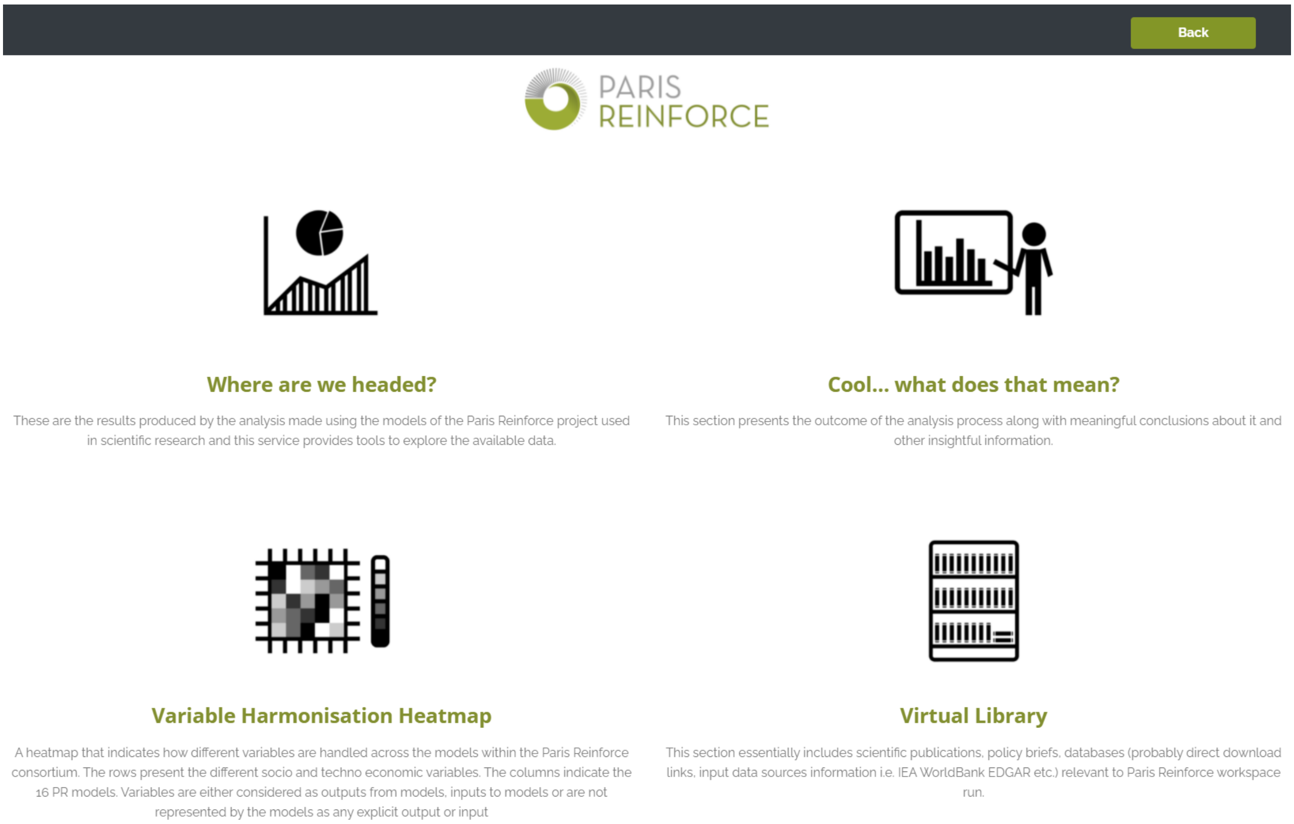

Figure 19: Example of a landing page (WWH workspace)

1.4.1 Advanced Scientific Module

This interface has two sub-sections. The first one is an introductory page that summarises in different tabs the main results of the analysis. The user can customise the generated visualisations by choosing from the available dropdown lists next to each visualisation, driving the end result based on specific objects (models, scenarios, variables, or regions), limiting the time frame using the slide bar on top of each chart, and activating/deactivating any of the demonstrated series.

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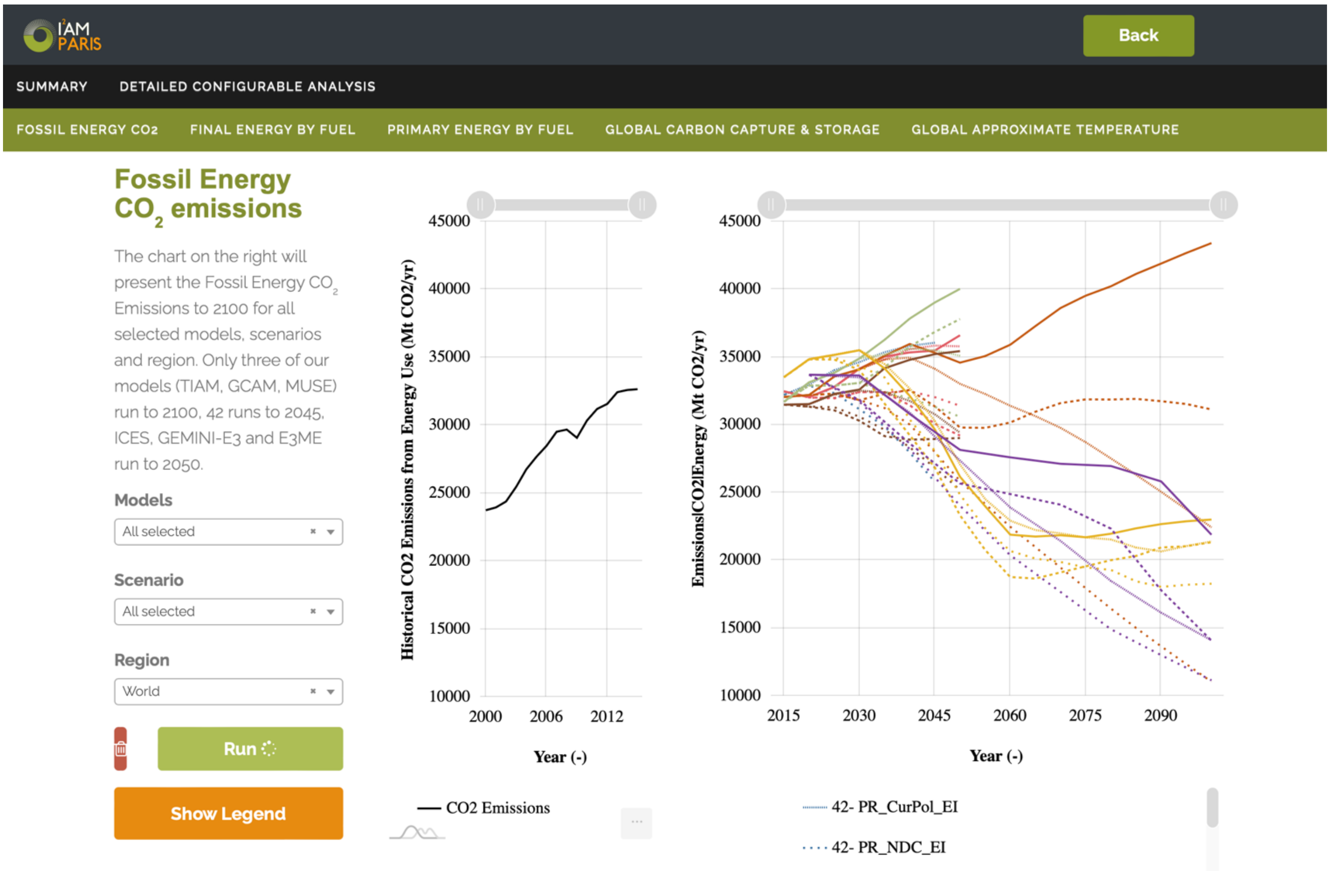

Figure 20: Example of Advanced Scientific Module – summary section (WWH workspace)

The second sub-section, called "Detailed Configurable Analysis", is a fully customisable data exploration and visualisation tool that can query data and produce results for any selected combination of variables, regions, scenarios, and models. In essence, this interface is a wizard-like assistant that includes a variety of filtering choices:

- Initially, the user can optionally filter the variables by selecting an SDG from a dropdown list. This limits the number of the available variables in the list only to the ones that are pertinent to the selected SDG. This feature is only visible in workspaces where SDG filtering is relevant.
- The next step includes the selection of one variable from the list. After pressing the "Next" button, the system automatically filters out all the unrelated regions to the selected variable.
- The same workflow applies for the selection of region(s), scenario(s), and model(s), each time filtering out the options from the list that do not match to any of the possible combinations of the previously selected fields. This tool also allows the multiple selection of values of one of the parameters region, scenario, and model, thus facilitating the creation of various complex queries with different scope.
- Finally, the user may select to visually represent the data either using a line-chart or a column chart.

The interface contains a collapsible legend explaining the scenario and region acronyms as well as a tabular representation of the queried data, offering keyword search and ordering-per-column functionalities, data exportation to CSV, JSON, and other formats, and download of the complete datasets. Moreover, the visualisation can also be exported in all popular formats (PNG, JPG, SVG, PDF), also supported by every chart produced by the visualisation engine.

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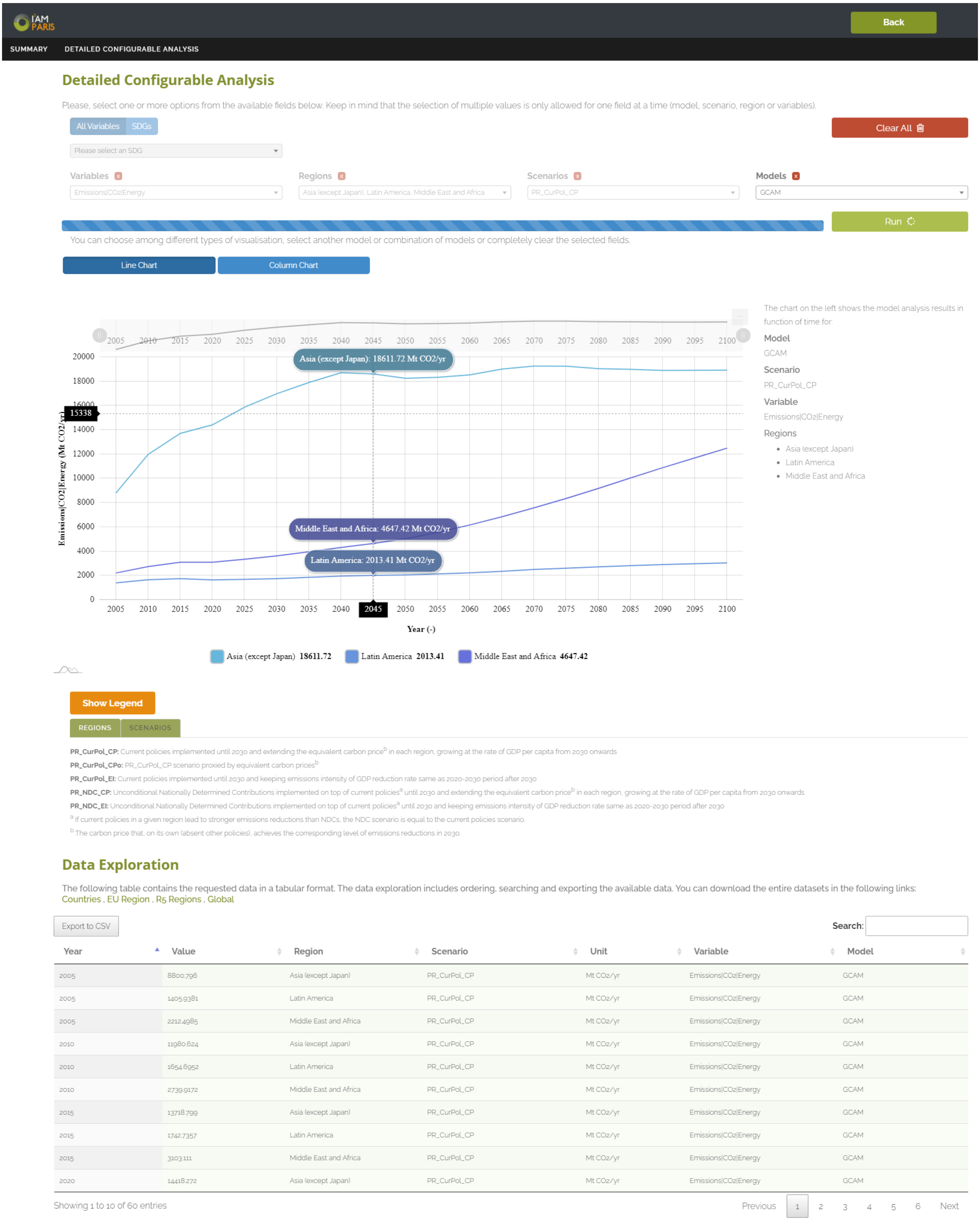

Figure 21: Example of Detailed Configurable Analysis Interface (WWH workspace)

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1.4.2 Public Interface

The public interface is based on a series of storylines and policy questions that make modelling results more accessible to a non-specialist audience. These storylines and questions are inspired from ideas and reflections obtained from a wide range of stakeholders in the workshops conducted worldwide as part of the co-creation process. Additional inspiration is drawn from the research questions of scientific articles that are relevant to the topics of the workspace (see the Virtual Library component in Section 1.4.4). The answers to these questions bring the key takeaways closer to a wide range of stakeholders and are presented in an understandable and user-friendly manner. At the same time, the graphs presented in this interface are designed so that users can understand the most important results without getting lost in complexity. An example of a public interface is shown in Figure 22.

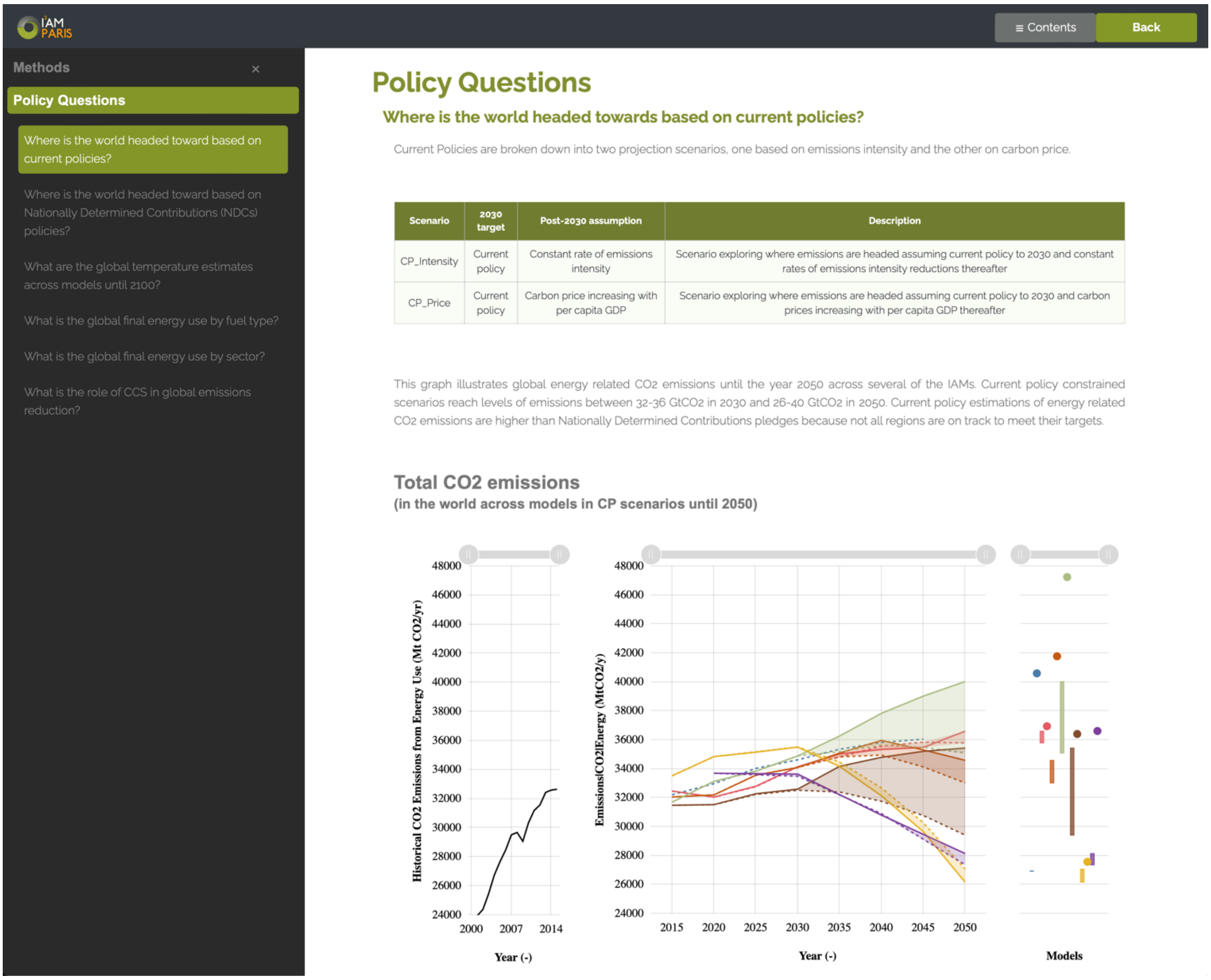

Figure 22: Example of Public Interface (WWH workspace)

1.4.3 Variable Harmonisation Heatmap

In the 'Variable Harmonisation Heatmap', different rows present the different socio- and techno-economic variables and different columns indicate the models. This interface has been customised to allow ordering and grouping of the available models and provides additional information such as unit, timespan, sources, etc. for each relation. The ordering/grouping options include alphabetically, by model type, by geographical coverage, and by

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timestep. Other than being a far more detailed and fixed-size version, this interface also supports the same functionalities and navigation options as the one generated by the module described in Section 1.3.4.

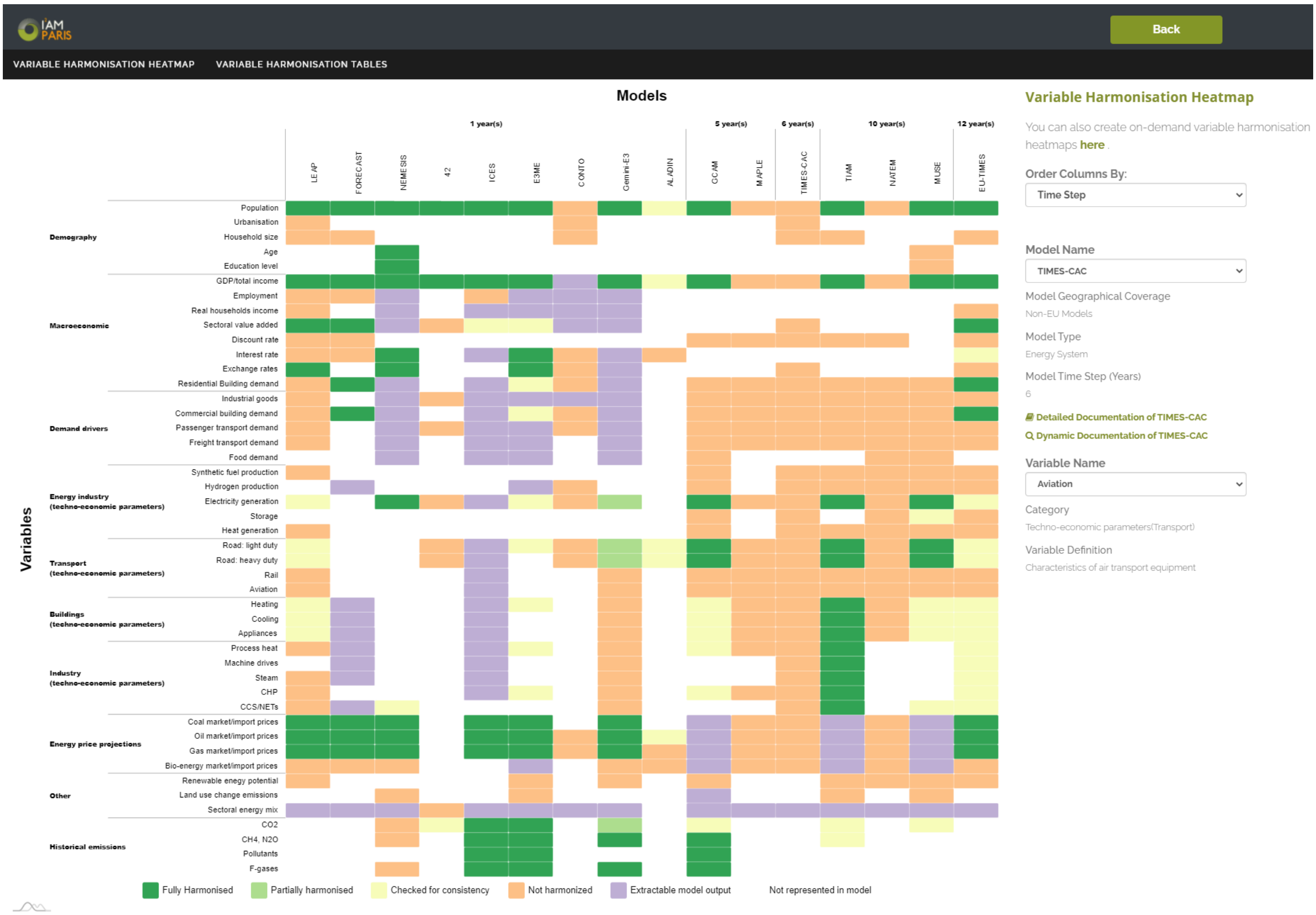

Figure 23: Example of Variable heatmap (WWH workspace)

1.4.4 Virtual Library

The Virtual Library contains different types of documents that are relevant to the workspace, including scientific publications, conference papers, policy briefs, data files, and deliverables. Documents are related to the co-creation process with stakeholders, as well as to the more modelling-focused part of the project. A screenshot of the Virtual Library of the WWH workspace is shown below.

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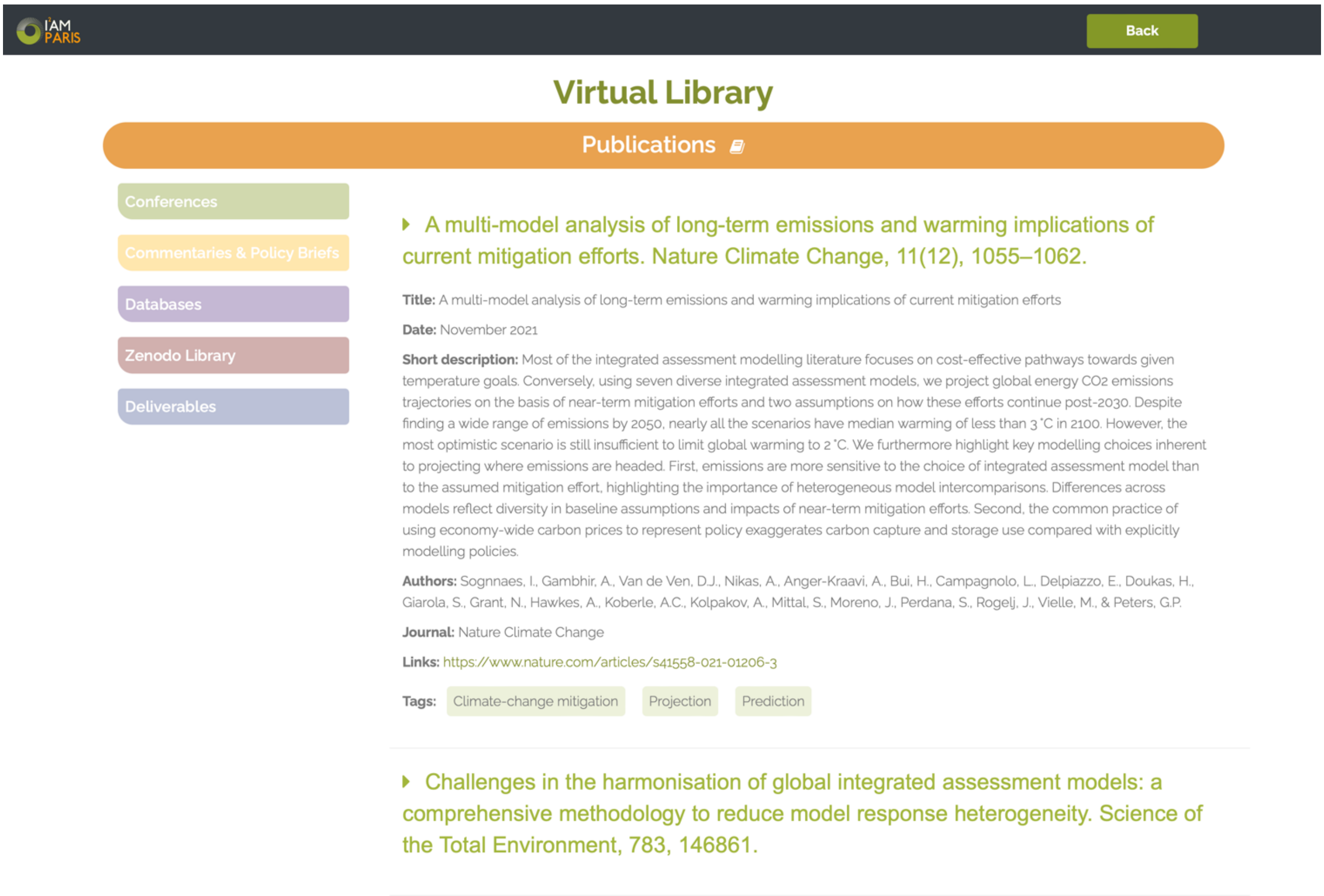

Figure 24: Example of Virtual Library (WWH workspace)

1.5 User Feedback Form

The User Feedback Form is placed at the bottom of the landing page of the I²AM PARIS platform (Figure 25) and aims at facilitating the feedback collection, in order to improve platform functionality, fix bugs and handle/respond to requests for new services. Once the form is filled in and submitted, its content is sent to the developers using Python's mail sending interface and Django's wrappers over it, specifying the SMTP host and port in the project settings. The Feedback form utilises Google's reCAPTCHA to protect the website against bots and spam.

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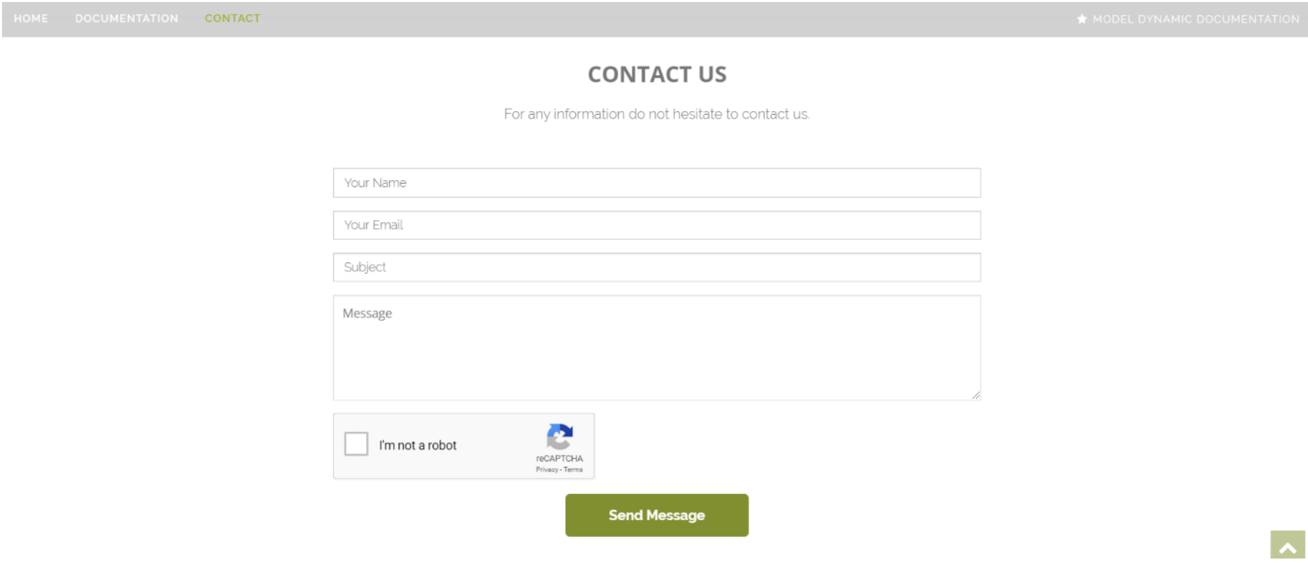

Figure 25: User Feedback Form

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2 Result workspaces

2.1 Where is the world headed? (WWH)

This workspace[3] focuses on global scenarios of climate change mitigation policies. Four different scenarios are used: two scenarios for up to 2030, corresponding to Current Policies and Nationally Determined Contributions, and two different ways of extrapolating after 2030 accordingly (to represent possible interpretations of continued ambition). NDC scenarios were modelled on top of Current Policies. The first post-2030 extension method takes the equivalent carbon price in 2030, increasing it with GDP per capita; the second method takes the rate of emissions intensity reductions implied between 2020 and 2030 and applies it after 2030. These scenarios are then modelled using numerous Integrated Assessment Models, with a specific focus on policy representation and harmonisation methods.

The Advanced Scientific Module summarizes the main results across different models and scenarios on the following global-level variables:

- fossil energy CO_2 emissions
- primary energy by fuel
- final energy by fuel
- carbon capture and storage
- approximate temperature

Visitors are also able to customise visualisations through the Detailed Configurable Analysis interface and request results for specific world regions when available. Additionally, the Public Interface explains the methodology of the analysis (Figure 26) and the aforementioned results of the global analysis based on the following questions:

- Where is the world headed toward based on current policies?
- Where is the world headed toward based on Nationally Determined Contributions (NDCs) policies?
- What are the global temperature estimates across models until 2100?
- What is the global final energy use by fuel type?
- What is the global final energy use by sector?
- What is the role of CCS in global emissions reduction?

Indicative screenshots of the summary section of the Advanced Scientific Module are shown in Figures 20, 27, and 28. For examples of the Public Interface, see Figures 22 and 29.

[3] https://www.i2am-paris.eu/pr_wwh/landing

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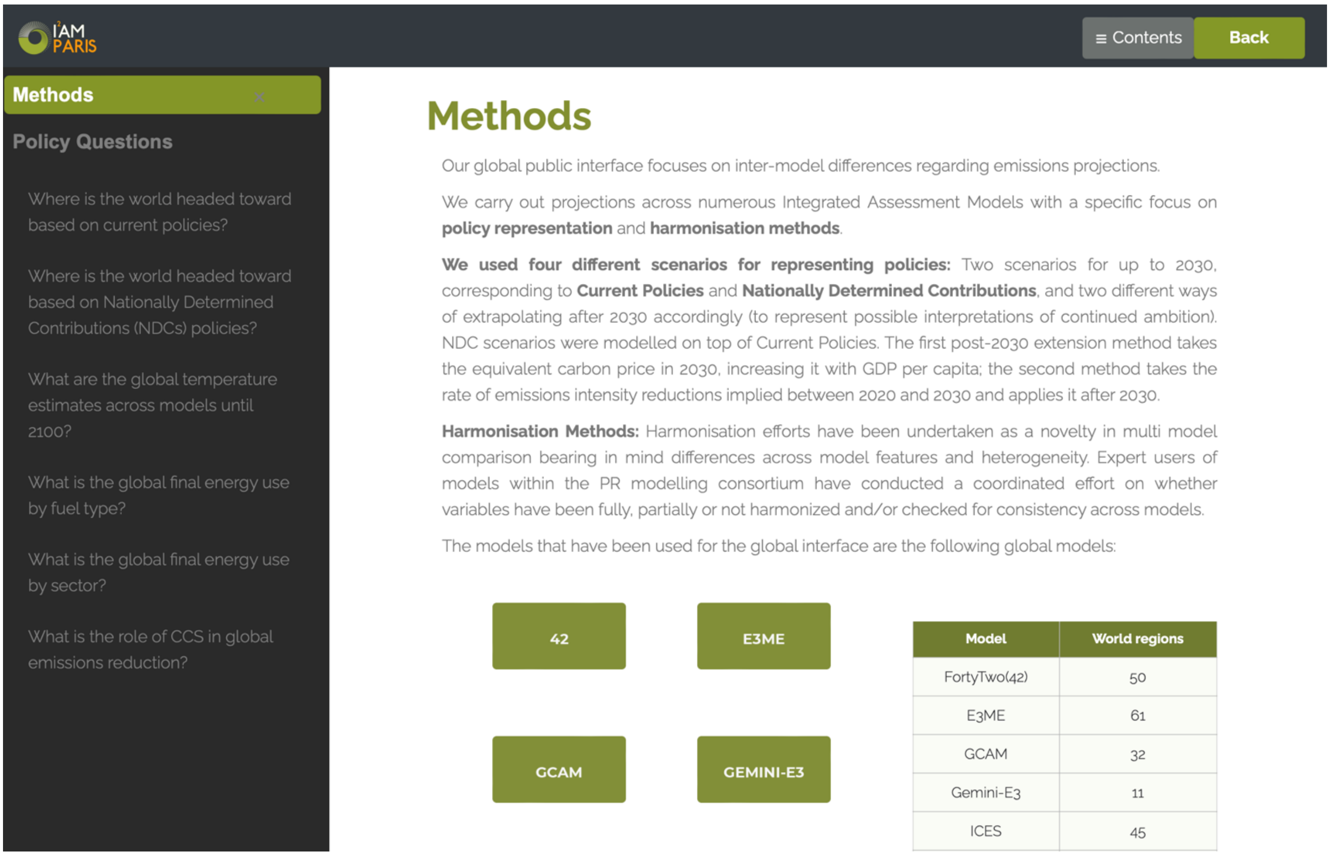

Figure 26: WWH workspace – Methods

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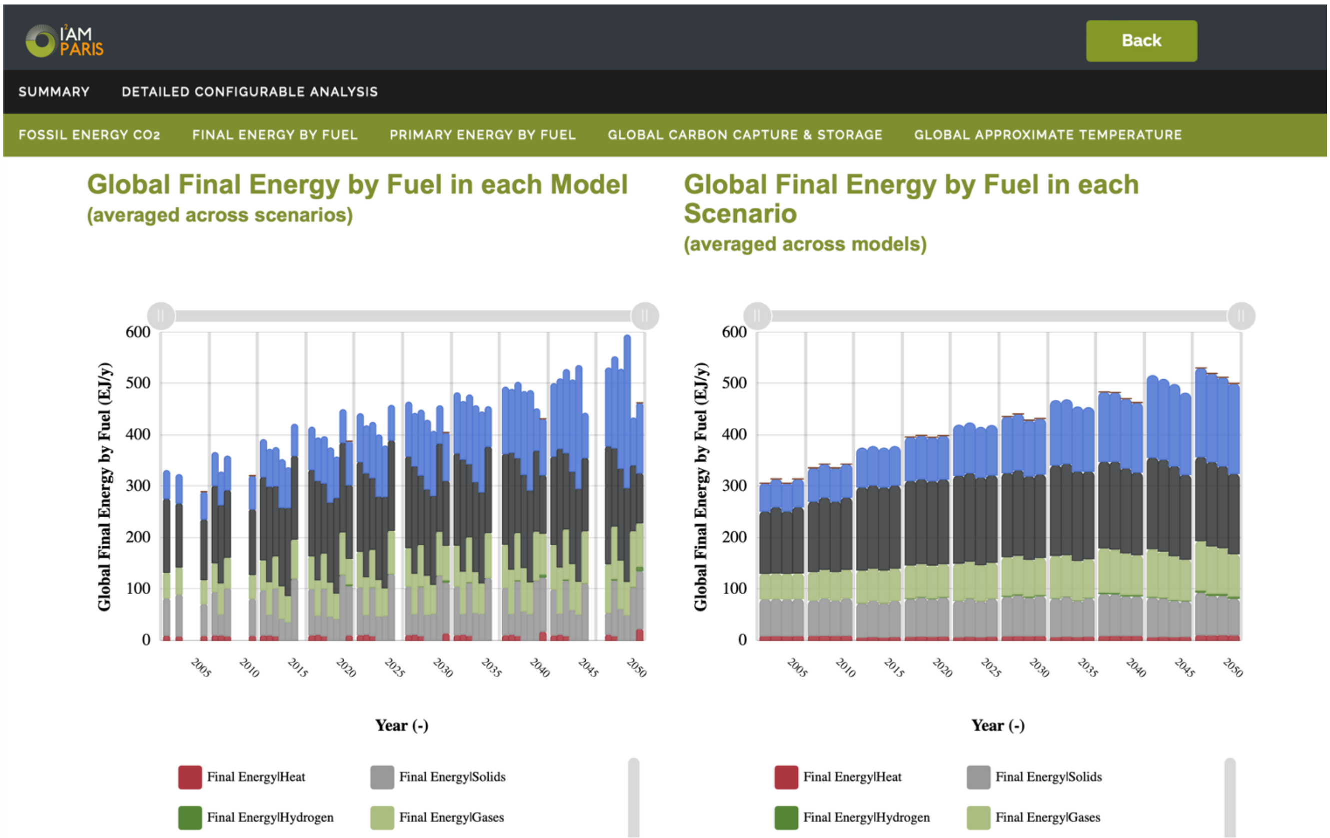

Figure 27: WWH workspace – Global primary energy by fuel

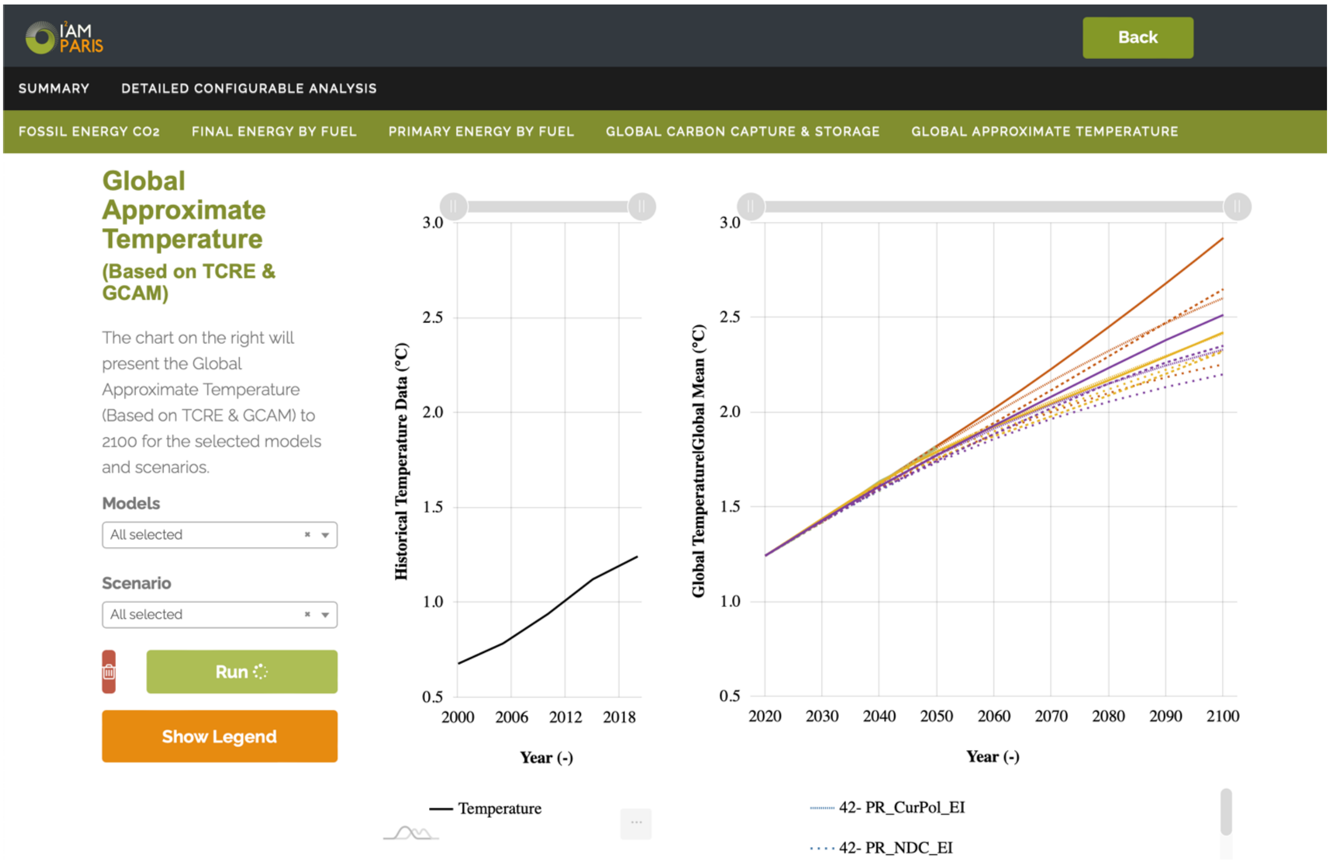

Figure 28: WWH workspace – Global approximate temperature

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Figure 29: WWH workspace – Policy question on where the world is headed based on NDC policies

2.2 Where is the EU headed? (EUWWH)

This workspace[4] presents the results of a multi-model analysis on the impacts of current mitigation efforts in Europe. The design of this analysis is based on an extensive co-creation process that took place in a regional workshop on November 21, 2019, in Brussels for the co-production of research underpinning new climate policy in Europe. Participants included high-level staff of the EC directorates-general (DGs) for energy, climate and research, ministries and climate-related governmental bodies from EU Member States, international organisations, business representatives, and scientists. The consultation resulted in a list of 22 research topics, which were then prioritised based on the preferences of stakeholders.

This co-creation process is described in the Policy Interface (Figure 30) and resulted in the following policy questions:

- Where is Europe headed towards in 2050?
- What is the role of Carbon Capture and Storage (CCS)?
- What is the role of import dependency in Europe?
- What will the role of electrification be in the transport sector?
- What is the future of hydrogen in the EU?
- What are the costs and gains of current policies?

[4] https://www.i2am-paris.eu/eu_wwh/landing

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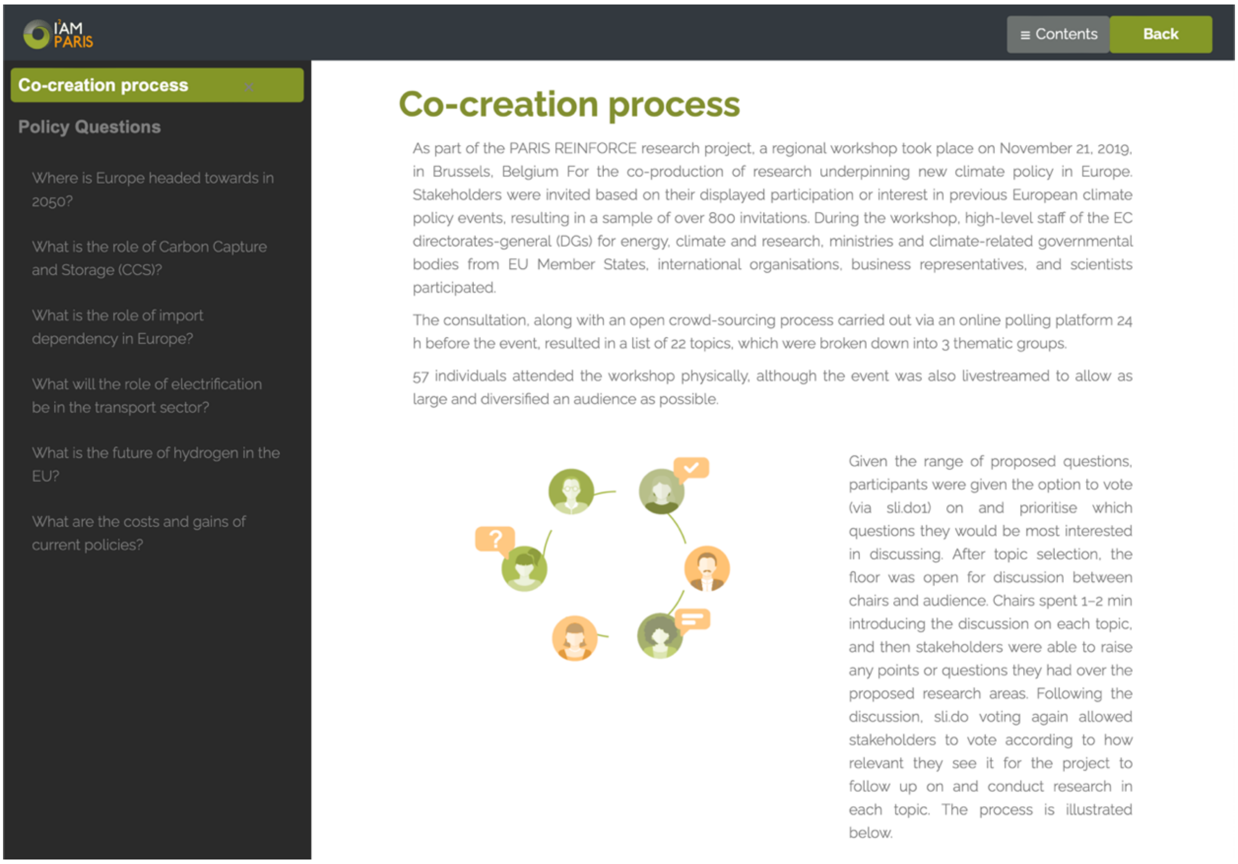

Figure 30: EUWWH – Co-creation process description

The policy questions were then answered in the Public Interface through a concise analysis of the main modelling results along with a combination of relevant visualisations. Indicative screenshots of these answers are given in Figures 31 and 32. It is noted that some of the visualisations included interactive elements to filter modelling results (such as buttons) in order to reduce their visual information load (see Figure 32).

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Figure 31: EUWWH – Policy question on where Europe is headed towards in 2050

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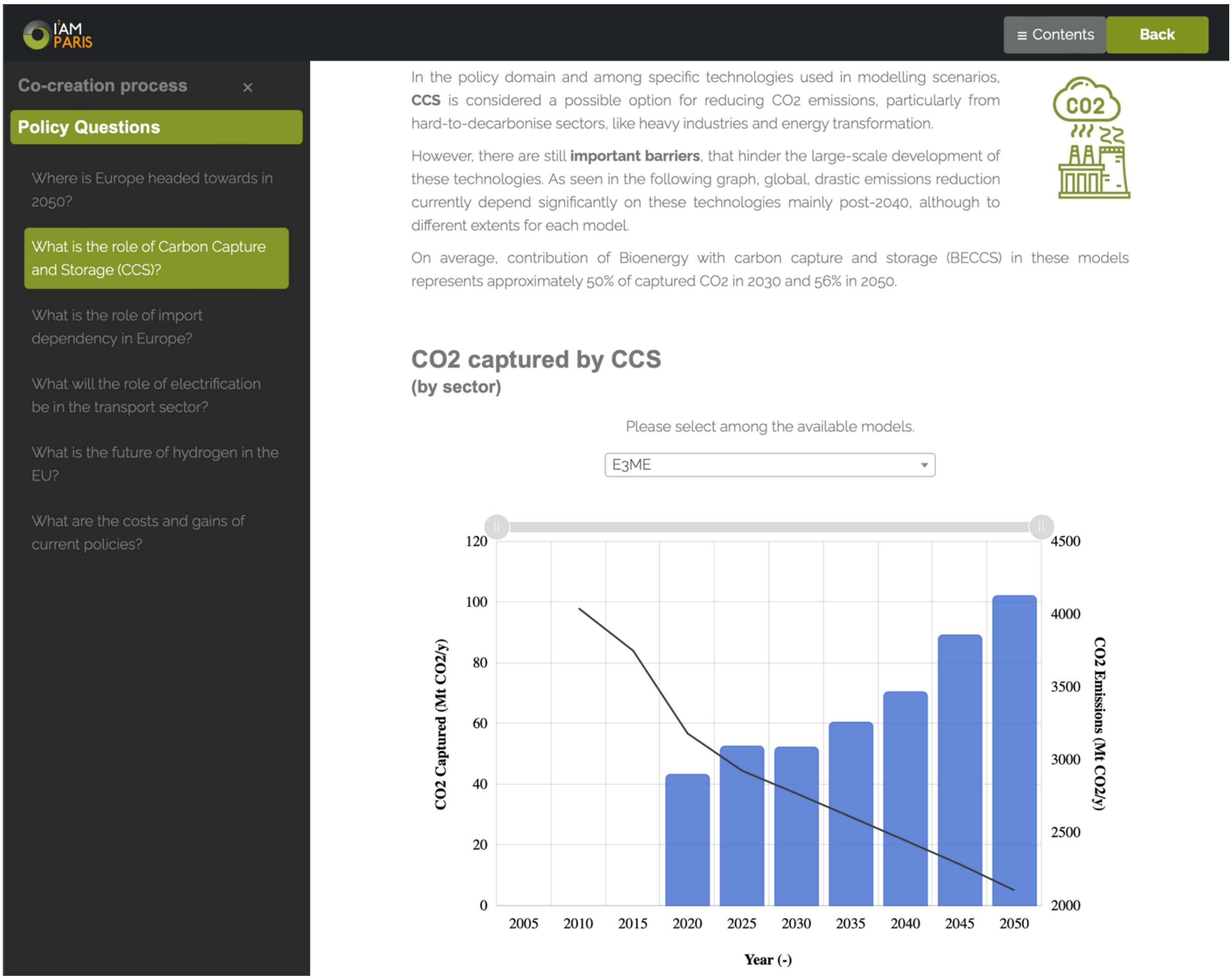

Figure 32: EUWWH – Policy question on the role of CCS

Users had access to all modelling results through the Detailed Configurable Analysis. Additionally, the Advanced Scientific Module included summary results on the following selected variables for Europe:

- CO_2 emissions
- Primary energy
- Final energy
- Carbon Capture & Storage
- Imports
- Transport electrification
- Hydrogen production
- Investments

Examples of these summary results are given in Figures 33 and 34.

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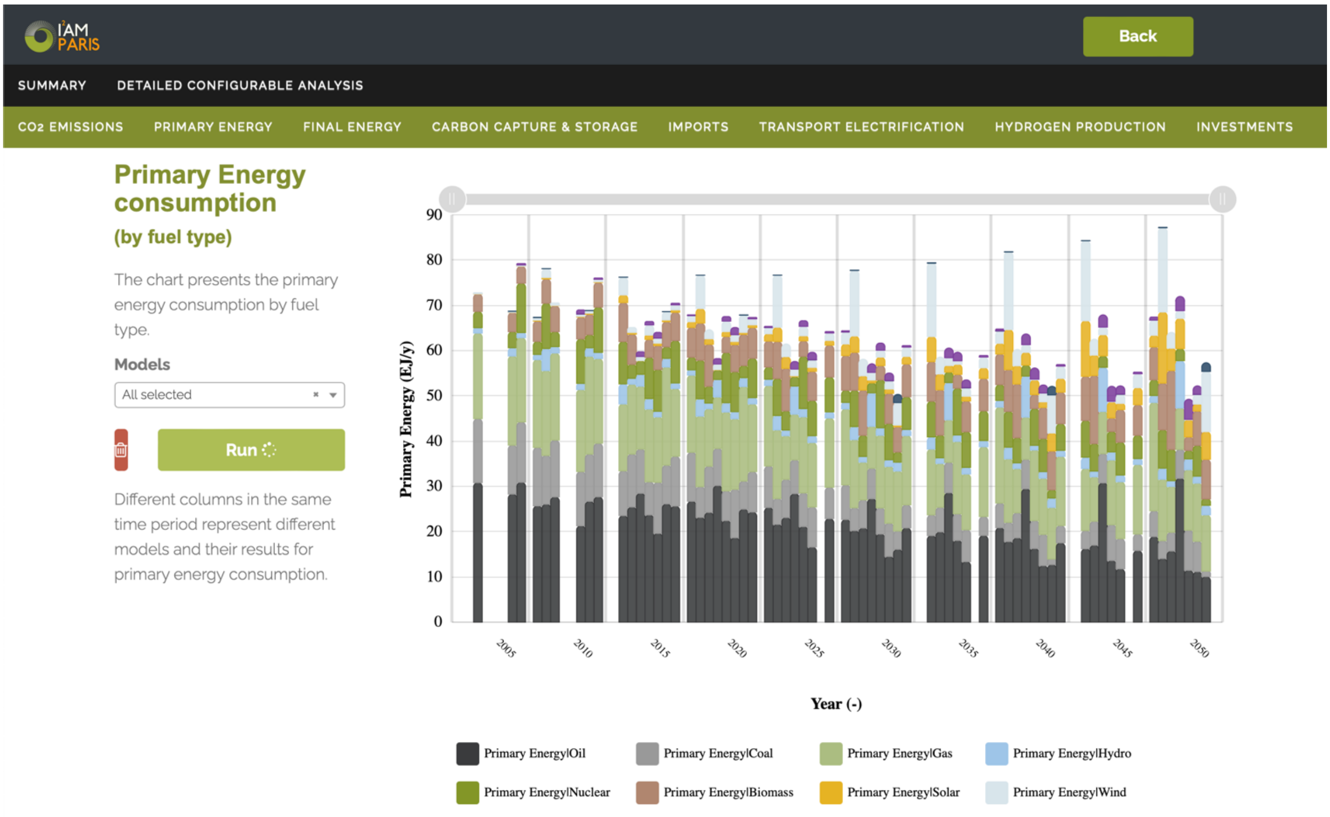

Figure 33: EUWWH – Primary energy consumption

Figure 34: EUWWH – Transport sector electrification

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2.3 Recovery policy database

The PARIS REINFORCE project coordinated a shared recovery policy database, in which different H2020 research and innovation projects for climate policy modelling took stock of intended/final recovery policies of selected Member States, as well as of other European countries. This shared policy database was intended to align with the ongoing efforts of the modelling community for enhanced transparency of model assumptions; save significant resources (avoiding duplicate work across research projects); enable cross-project comparison of relevant questions; and facilitate/encourage engagement in COVID- and recovery-related modelling work.

This workspace[5] differed from all other available workspaces as it featured only one webpage with an interactive table presenting information from the recovery policy database (Figure 35). The table allowed users to filter data based on specific search terms, to sort based on column titles, and to export all data in csv format.

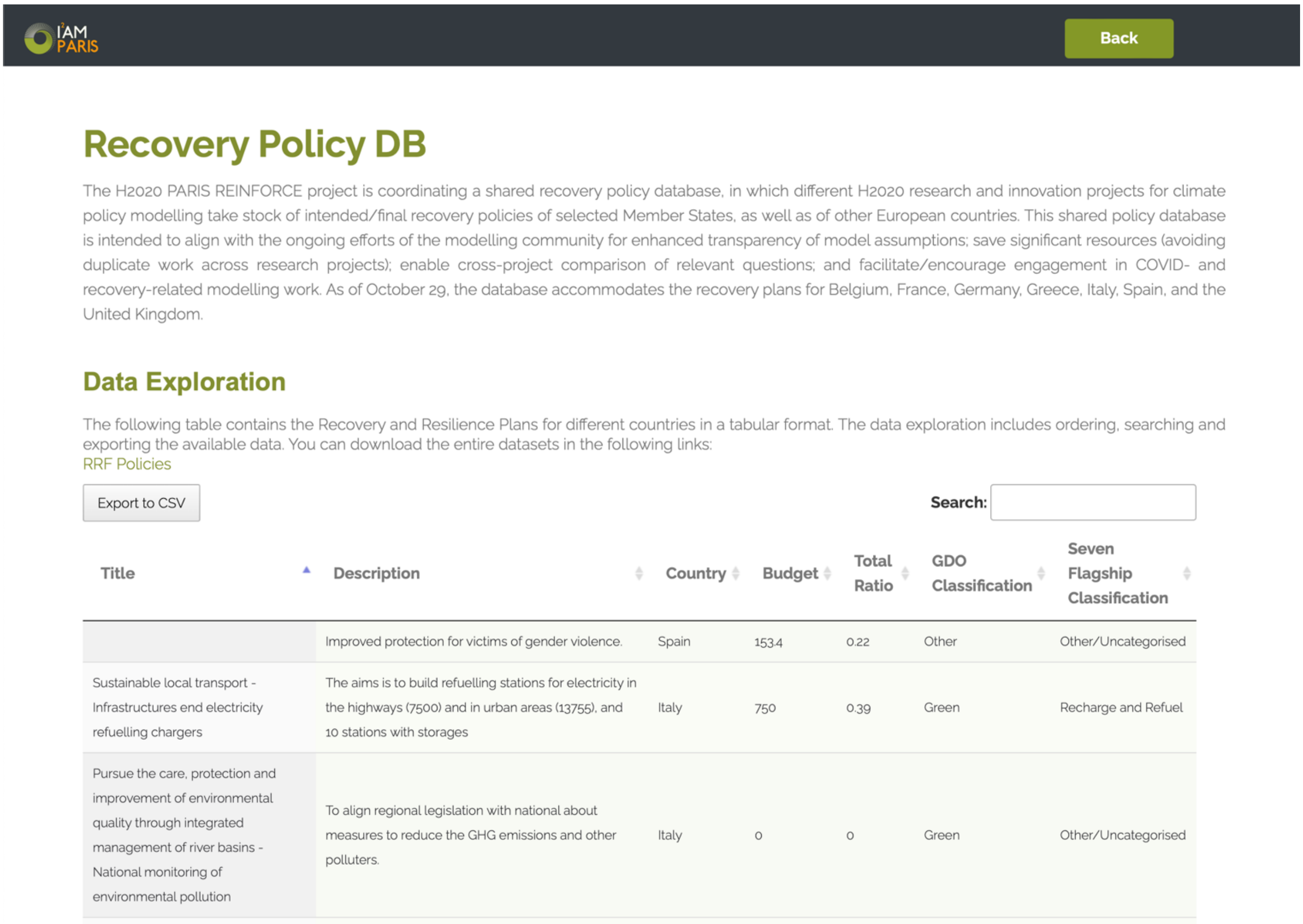

Figure 35: Recovery policy database

[5] https://www.i2am-paris.eu/rrf_policy_intro

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2.4 Index decomposition analysis (IDA)

This workspace[6] describes a meta-analysis on the results of the EUWWH workspace (see Section 2.2) in order to identify key driving forces and levers of emission changes over time. In this analysis, a variable changing over the time period 2020-2050 is decomposed into its factors of influence. For instance, in the case of sectoral CO_2 emissions, these factors include the sectoral activity, its energy efficiency, and its CO_2 intensity. The IDA allows identifying the chosen emission reduction levers for different scenarios within one model as well as between models. Overall, the IDA aims to improve the link between climate science and policy by increasing the transparency on the range of levers of CO_2 reduction.

In addition to the IDA analysis, this workspace includes a comparison of the results from various energy-system models and IAMs of the EUWWH analysis with two sectoral models, FORECAST and ALADIN. This comparison is based on extracting specific indicators from the analysis of the sectoral models such as electrification rate and CO_2 intensity. These indicators are then used as sectoral benchmarks to assess the result ranges of the EUWWH models over time. The sectors that are examined include industry, buildings, and transport sectors.

This methodology is described in the Policy Interface of the workspace (see Figure 36). Selected screenshots from the results included in the workspace are given in Figures 37 and 38.

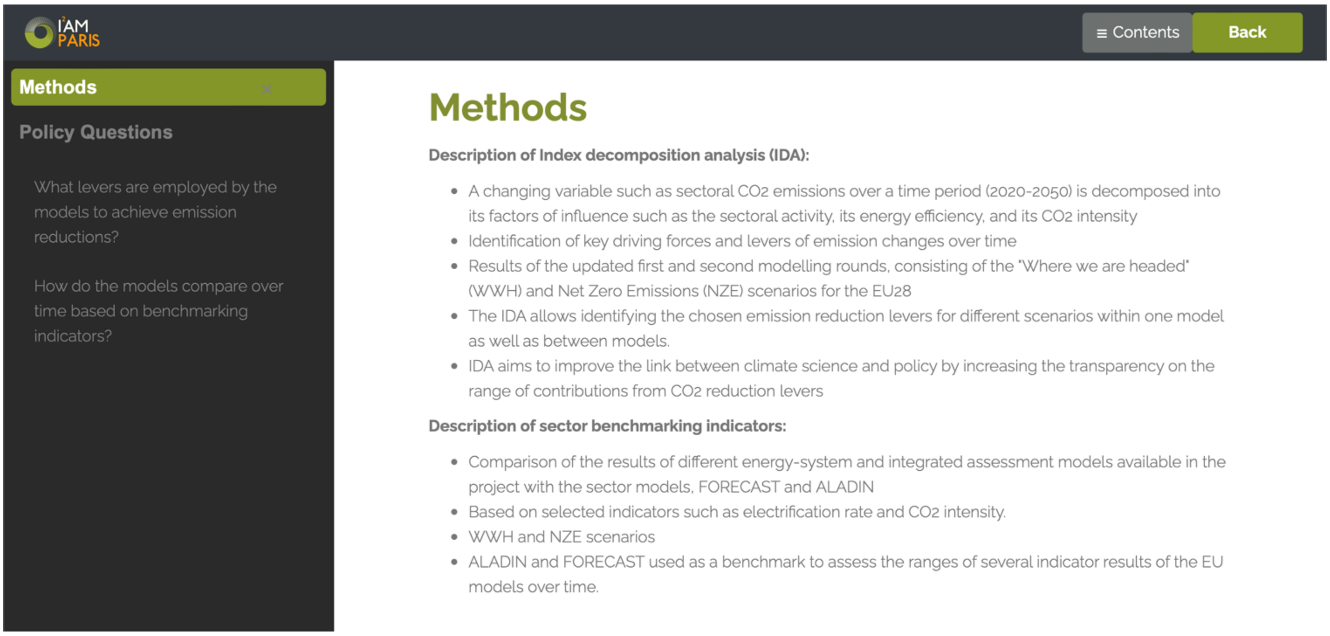

Figure 36: IDA workspace – Methods

[6] https://www.i2am-paris.eu/ida/public_module#methods

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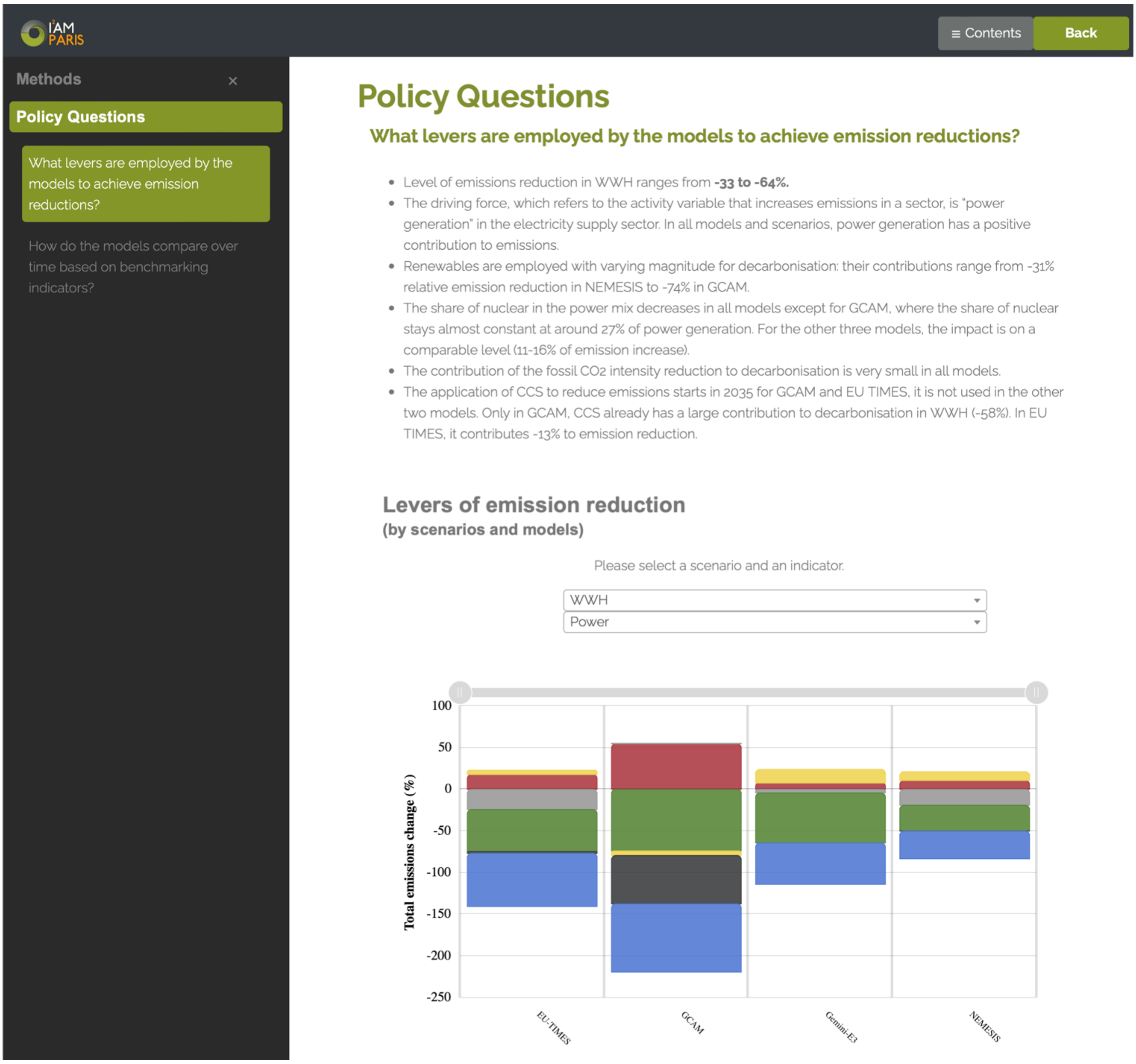

Figure 37: IDA workspace – Policy question on modelling levers behind emission reductions

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

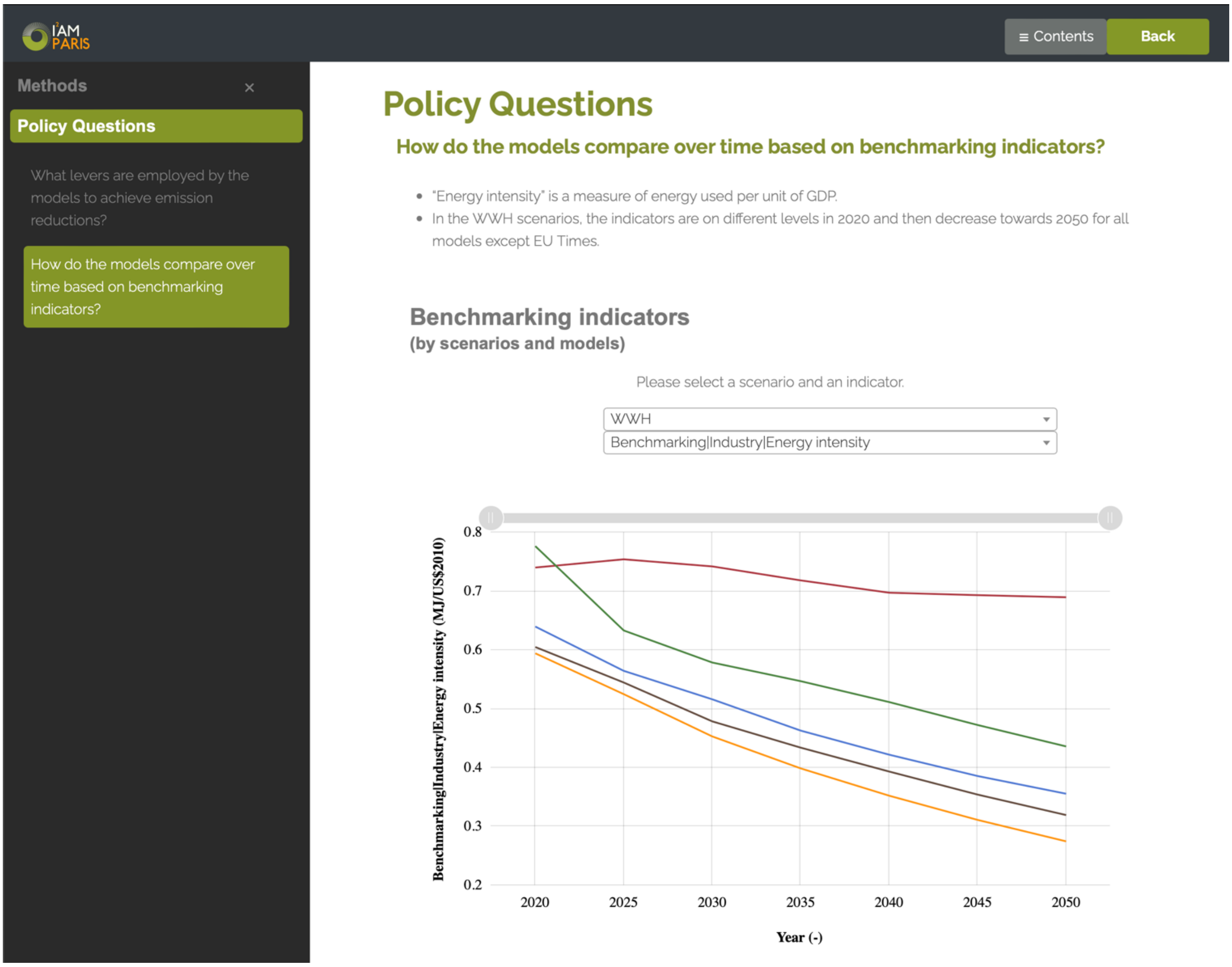

Figure 38: IDA workspace – Policy question on sectoral benchmarks

2.5 COVID recovery packages

This workspace[7] presents the results of an analysis of investment portfolios of green recovery packages from major countries around the world in order find portfolios that optimise both climate mitigation and employment benefits. The study used three energy-economic models, combined with a portfolio analysis approach, to find optimal low-carbon technology subsidy combinations in six major emitting regions: Canada, China, the EU, India, Japan, and the United States. Overall, the workspace presents results answering the following questions:

- What are the impacts of the optimal allocation of COVID-19 recovery packages over power-sector technologies?
- Which technology portfolios maximise greenhouse gas emissions cuts and jobs?

Methods are detailed in the Policy Interface (Figure 39) while examples of the results are shown in Figures 40-41.

[7] https://www.i2am-paris.eu/covid/landing

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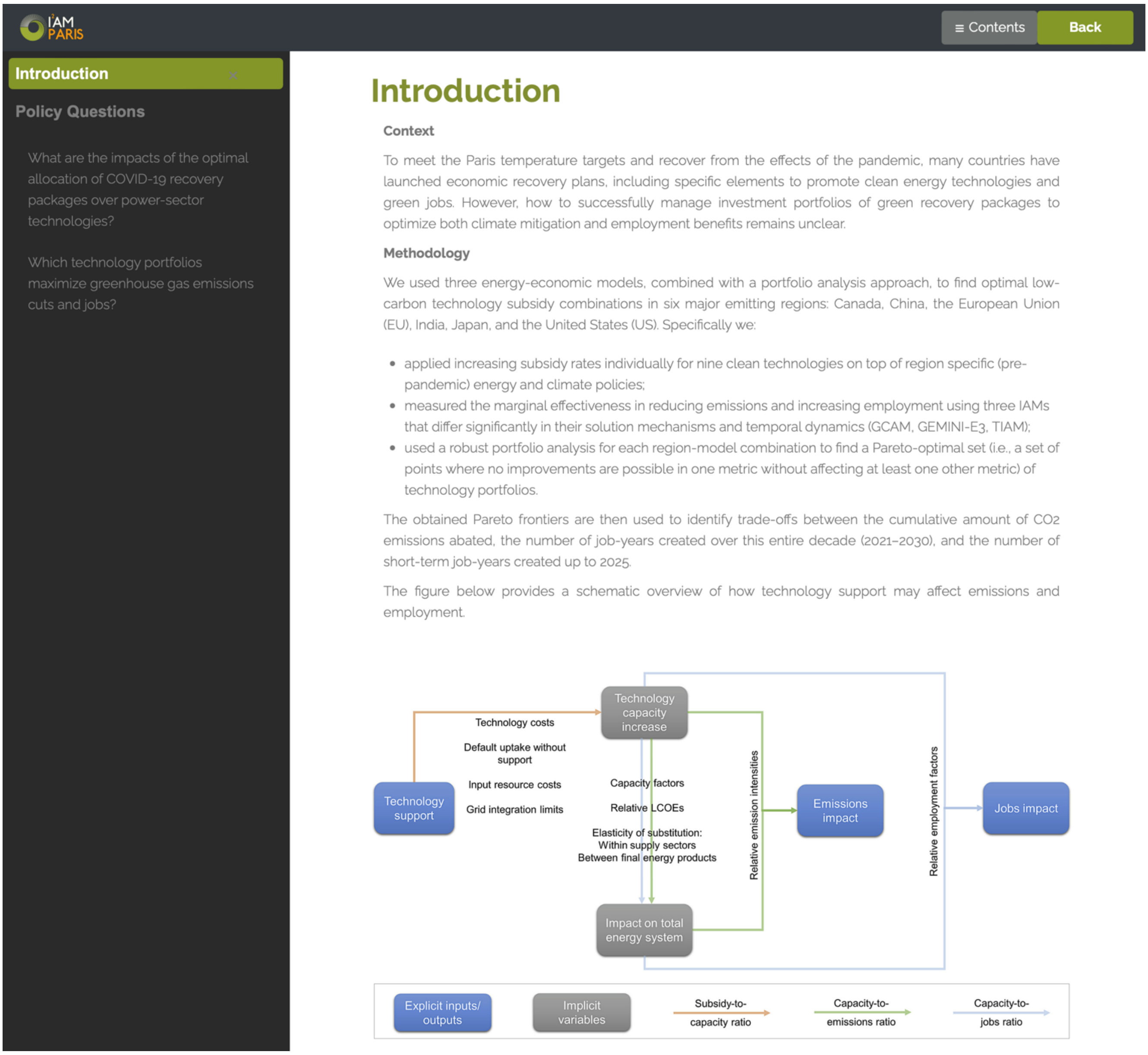

Figure 39: COVID workspace – Introduction

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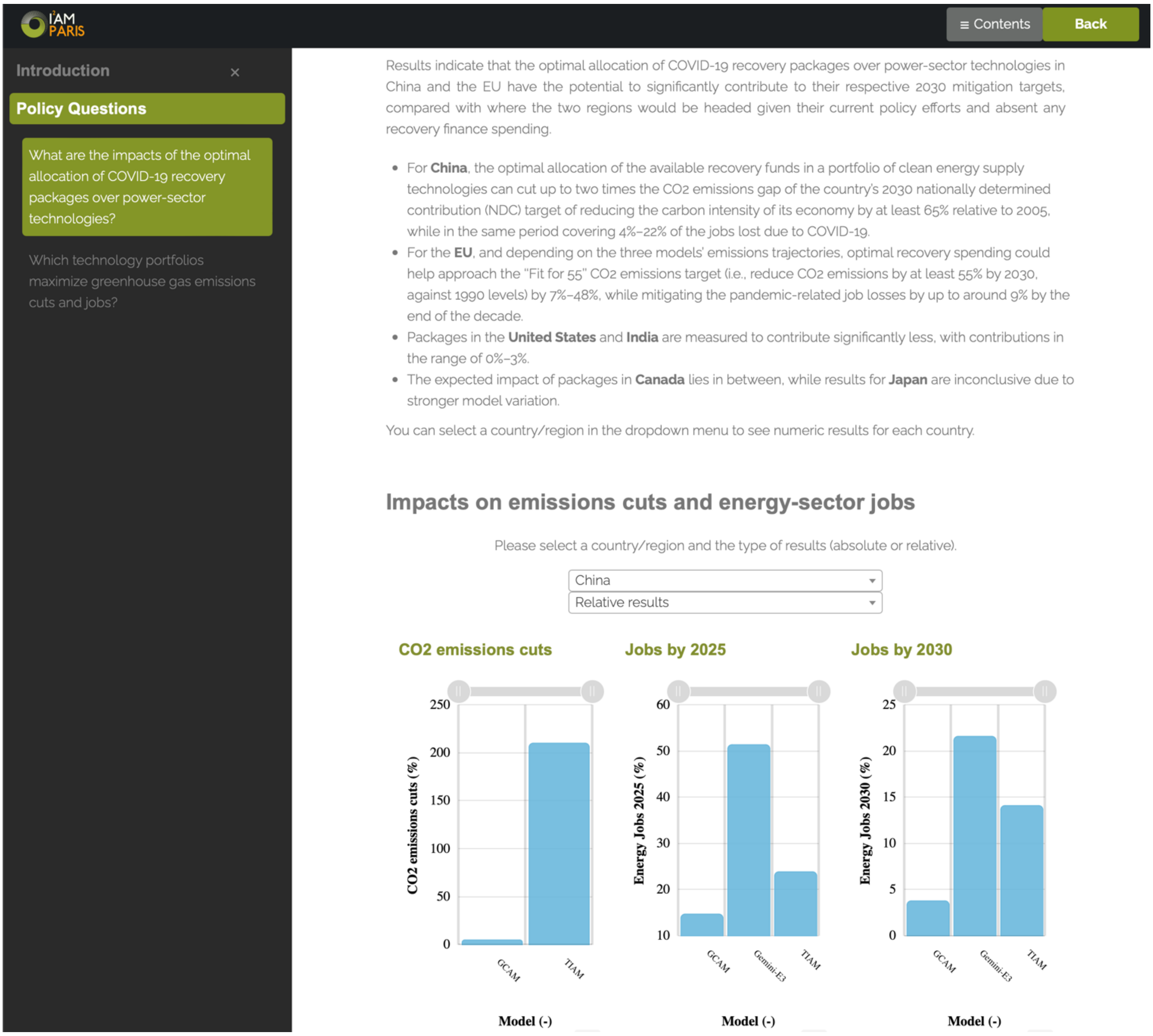

Figure 40: COVID workspace – Policy question on impacts of optimal COVID recovery packages

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Figure 41: COVID workspace – Policy question on optimal technology portfolios

2.6 Regional feasibilities to net-zero

This workspace[8] presents the results from the updated global analysis shown in Section 2.1. Specifically, this includes a global analysis of current policies, NDCs, and net-zero targets with a focus on regional feasibilities. As this workspace is mostly an update to the previous one, it will not be described here in detail. Examples of results showcased in the workspace are given in Figures 42-44.

[8] https://www.i2am-paris.eu/feasibility/scientific_module

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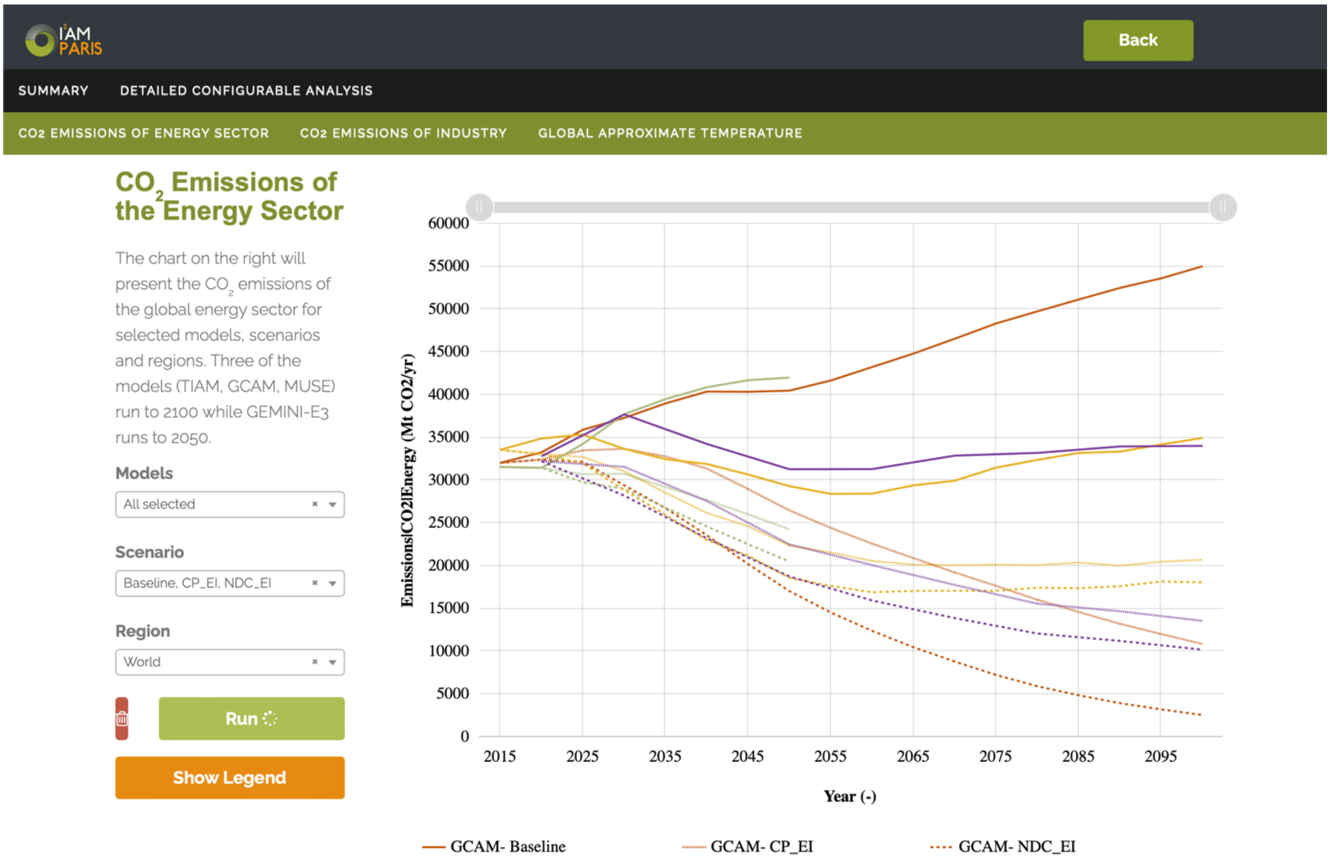

Figure 42: WWH update – CO_2 emissions of the energy sector

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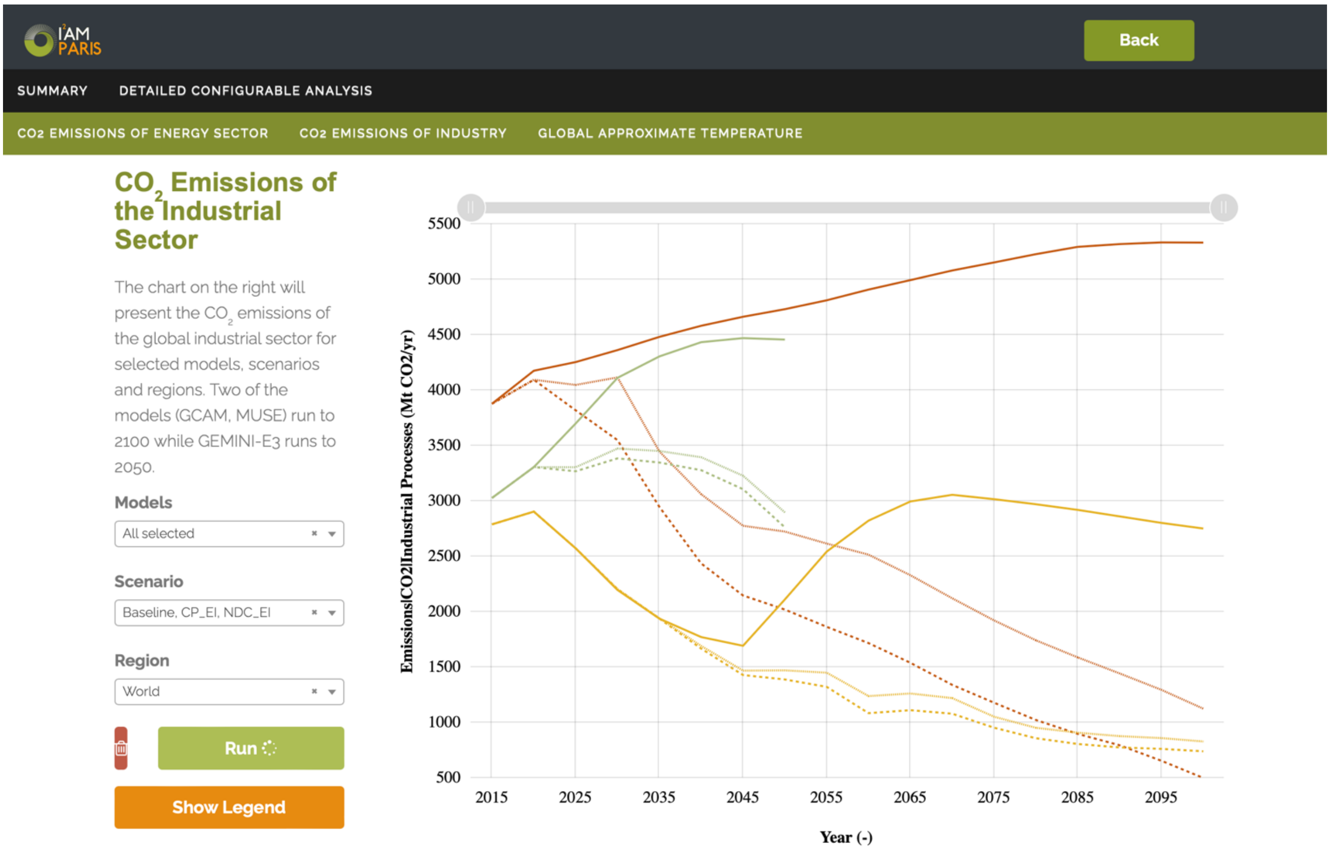

Figure 43: WWH update – CO_2 emissions of the industrial sector

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

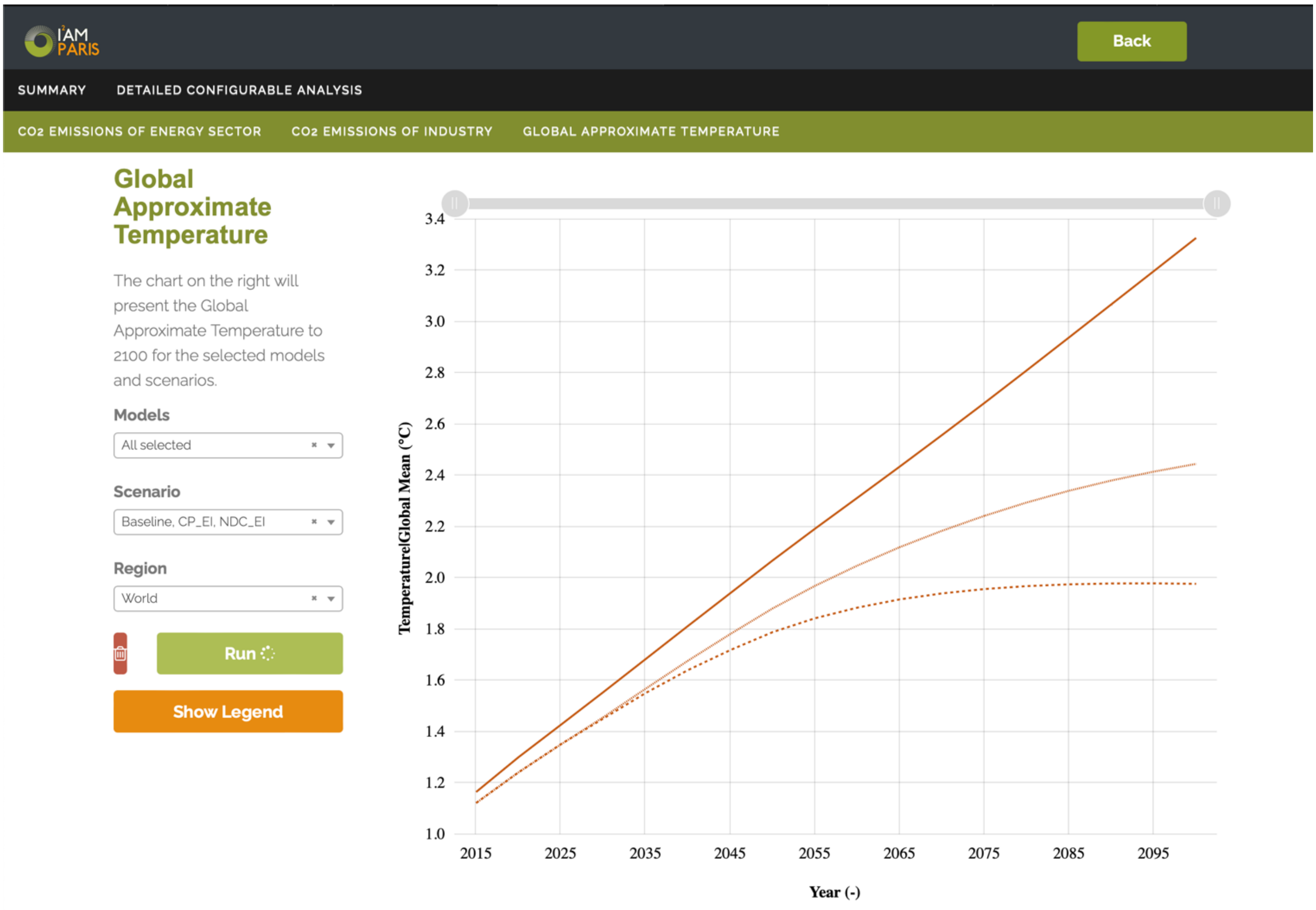

Figure 44: WWH update – Global approximate temperature

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3 The architecture of the I²AM PARIS platform

All the aforementioned services of the I²AM PARIS platform are implemented utilising the four main components of the I²AM PARIS platform architecture (see Figure 1), which are thoroughly described in the following chapters:

- **The Parsers**, responsible for automatically extracting data from files that follow given templates, processing and storing the information into the I²AM PARIS Database.
- **The I²AM PARIS Backend**, a mediator component that orchestrates all the operations executed for all end-to-end scenarios, which contains the main Database Models/Entities/Schemas, providing APIs that give access to specific data sources and functionalities, and facilitates the integration of the other components, rendering the suitable interfaces for each use-case scenario.
- **The Data Manager**, a dual-role component that is responsible for the following tasks:
    - The creation, storage, and execution of queries in a pre-defined JSON format aiming at retrieving the requested data from the available datasets of the project.
    - The processing of the data returned by an executed query, in order to be converted into an appropriate format for the visualiser.
- **The Visualiser**, a standalone chart and map visualisation generator, mainly fed by data deriving from the model analyses and pre-processed by the Data Manager. This component is utilised to populate several interfaces with various visual representations of the available information, such as line charts, column charts, heatmaps, map visualisations, etc.

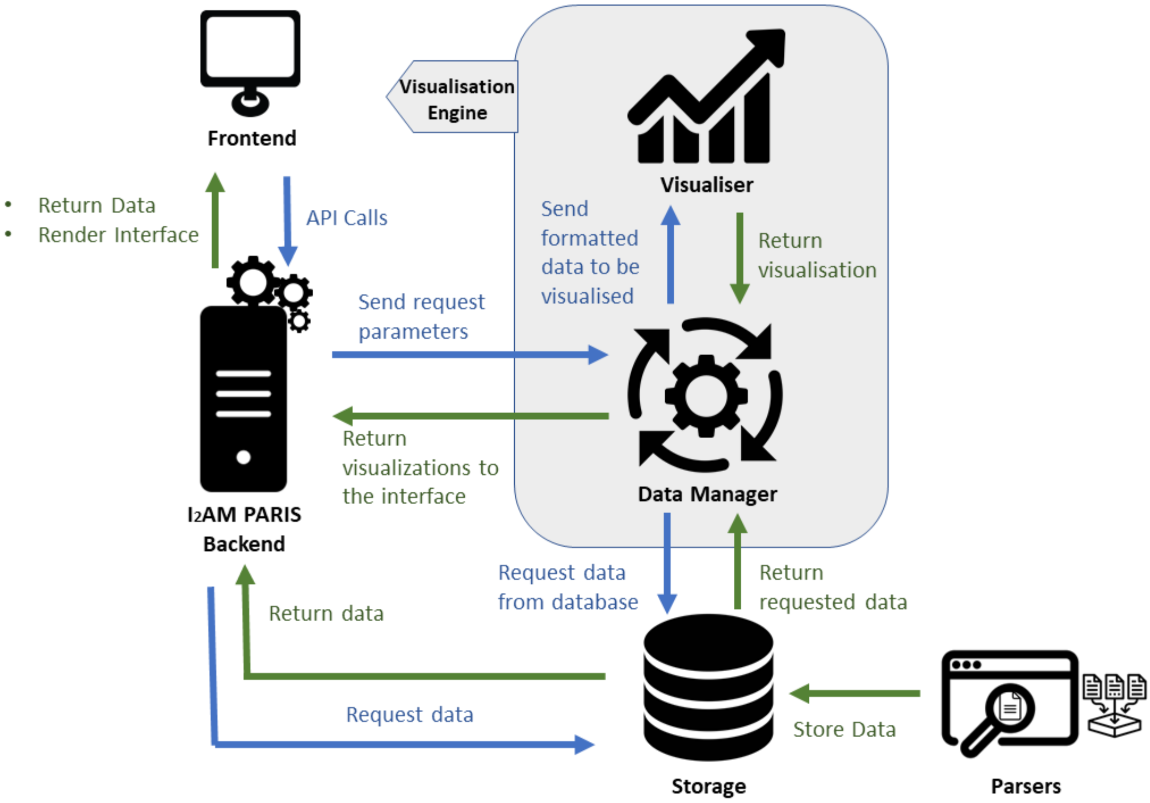

Figure 45: High-level I2AM PARIS Architecture

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3.1 Parsers

The information available in the I²AM PARIS database has been acquired through different Extract-Transform-Load (ETL) procedures that took place after the development of three different data parsers:

- The first one is responsible for extracting information about new models from a template, provided by the technical team to ensure homogeneity, and storing it in the appropriate format into the database so as to allow seamless functionality of the Dynamic Model Documentation.
- The second one aims at parsing relatively large files that contain data from model analyses, according to the IPCC AR6 template, commonly agreed among all modelling teams so that they are completely aligned.
- The last parser was developed specifically for loading and storing data pertinent to the variable harmonisation heatmap applications. This information is vital for enabling several custom features in the corresponding interfaces.

All three parsers are working seamlessly on the defined templates, thus facilitating the continuous update of the I²AM PARIS database when new datasets are available. As long as no changes are applied to the commonly decided templates, the automated data integration can contribute to the long-term sustainability of platform.

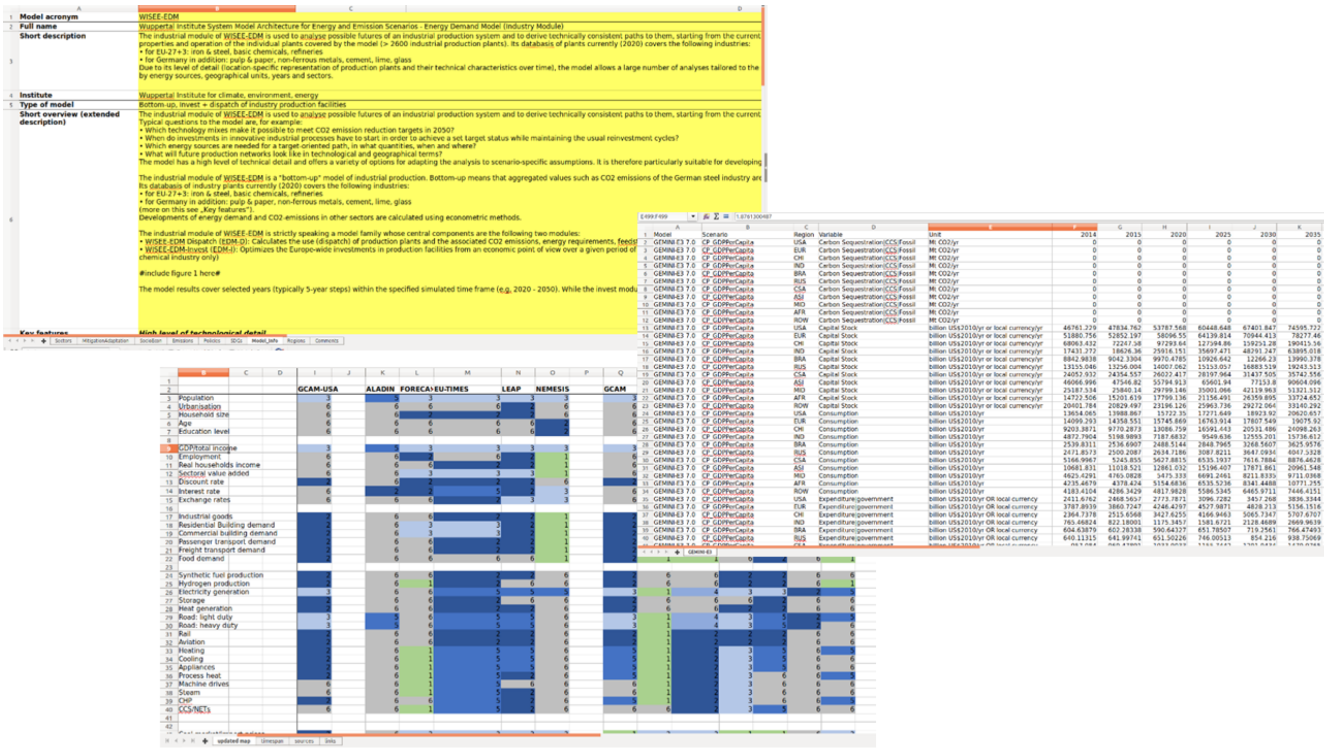

Figure 46: The three CSV parser templates

It should be noted that the modelling results parsers orient on the global/sectoral and national/regional data preparation templates used by all contributors to IPCC AR6, as provided by IIASA[9]. This enables smooth harmonisation of all modelling outputs and interlinkage with the platform, as well as minimise the effort required by non-consortium parties upon submitting their analyses.

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

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3.2 I²AM PARIS Backend

The I²AM PARIS Backend contains the main data schemas and APIs for the afore-mentioned services and is responsible for rendering the requested interfaces by combining the functionalities of the rest of the components. The next chapters highlight its main features.

3.2.1 Backend Services of Dynamic Documentation

3.2.1.1 Django Models

The functionality of the backend services of the Dynamic Model Documentation is based on retrieving and filtering data from the I²AM PARIS database. This database mainly consists of the following entities and its structure is presented in the Entity Relationship (ER) Diagram below:

- Models
- Regions
- Countries
- Sustainable Development Goal (SDG) Categories
- SDG Descriptions
- Mitigation/Adaptation Measure Categories
- Mitigation/Adaptation Measure Subcategories
- Mitigation/Adaptation Measures
- Sector Categories
- Sector Subcategories
- Sectors
- Emissions
- Emission- Model States
- Socio-Economics Categories
- Socio-Economics
- Socio-Economics - Model States
- Policy Categories
- Policies
- Policy- Model States

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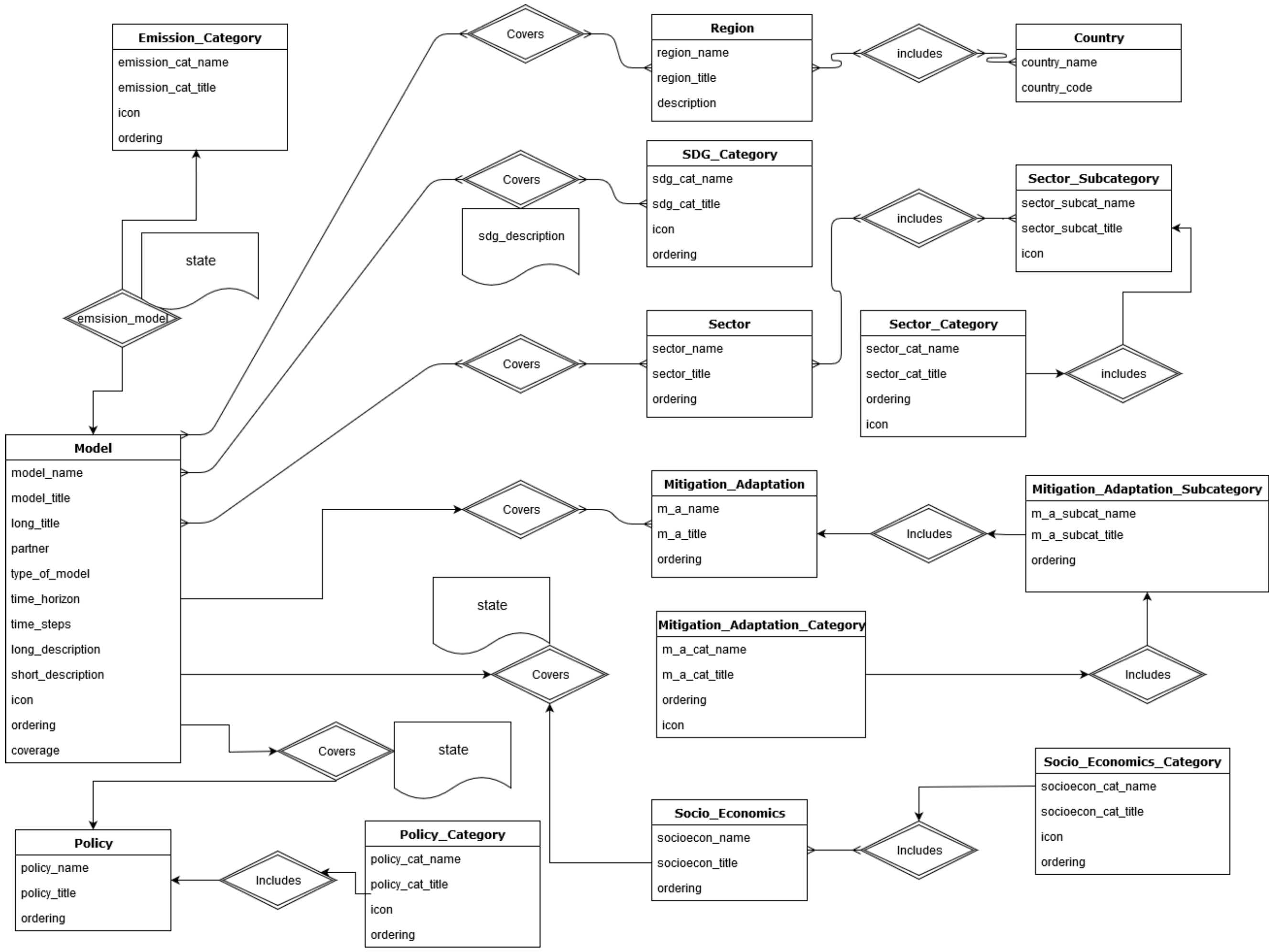

Figure 47: ER Diagram of the I2AM Paris Database

The database has been automatically created utilising Django models and migrations, according to the aforementioned entities. The tables below contain the main information of each Django model:

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Table 1: Model

Field	Description
model_name	The unique name of each model used inside the code
model_title	The title of each model used on the interfaces
long_title	A more descriptive title of each model
partner	The name of the partner that developed the model
type_of_model	The type of the model according to the domain it focuses on
time_horizon	The time horizon of each model
time_steps	The time step that each model uses to produce results
long_description	An extensive description of the model
short_description	A short description of each model used in popovers, popups etc.
icon	It is the path to an image file (icon) used for each model on the interfaces
ordering	The ordering in the list of models as presented on the interfaces
coverage	A field that describes the geographical coverage of each model and takes one of the following values: a) global b) national_EU (for countries inside Europe) c) national_OEU (for countries outside Europe)

Table 2: Region

Field	Description
region_name	The unique name of each region used inside the code
region_title	The title of each region used on the interfaces
description	A list of the countries included in this specific region
model_name	A many-to-many field used for matching models to regions

Table 3: Country

Field	Description
country_name	The unique name (and title) of each country
country_code	A two-letter abbreviation of each country
region_name	A many-to-many field used for matching countries to regions

Table 4: SDG_Category

Field	Description
sdg_cat_name	The unique name of each SDG category used inside the code
sdg_cat_title	The title of each SDG category used on the interfaces
icon	The path to an image file (icon) used for each SDG category on the interfaces
ordering	The ordering in the list of SDG categories as presented on the interfaces
model_id	A many-to-many field that is used for matching models to SDGs

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Table 5: SDG_Description

Field	Description
sdg_cat_id	A foreign key to the SDG category entity
model_id	A foreign key to the model entity
sdg_description	The description of the relationship between an SDG and a model
ordering	The ordering in the list of SDGs as presented on the interfaces

Table 6: Sector_Category

Field	Description
sector_cat_name	The unique name of each sector category used inside the code
sector_cat_title	The title of each sector category used on the interfaces
ordering	The ordering in the list of sector categories as presented on the interfaces
icon	The path to an image file (icon) used for each sector category on the interfaces

Table 7: Sector_Subcategory

Field	Description
sector_subcat_name	The unique name of each sector subcategory used inside the code
sector_subcat_title	The title of each sector subcategory used on the interfaces
sector_cat_id	A foreign key to the Sector category each sector subcategory belongs to
ordering	The ordering in the list of sector subcategories as presented on the interfaces

Table 8: Sector

Field	Description
sector_subcat_id	A foreign key to the Sector subcategory each sector belongs to
sector_name	The unique name of each sector used inside the code
sector_title	The title of each sector used on the interfaces
ordering	The ordering in the list of sectors as presented on the interfaces
model_id	A many-to-many field that is used for matching models to sectors

Table 9: Mitigation_Adaptation_Category

Field	Description
m_a_cat_name	The unique name of each mitigation/adaptation category used inside the code
m_a_cat_title	The title of each mitigation/adaptation category used on the interfaces
ordering	The ordering in the list of mitigation/adaptation categories as presented on the interfaces
icon	The path to an image file (icon) used for each mitigation/adaptation category on the interfaces

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Table 10: Mitigation_Adaptation_Subcategory

Field	Description
m_a_subcat_name	The unique name of each mitigation/adaptation subcategory used inside the code
m_a_subcat_title	The title of each mitigation/adaptation category used on the interfaces
ordering	The ordering in the list of mitigation/adaptation subcategories as presented on the interfaces
m_a_cat_id	A foreign key to the mitigation/adaptation category each mitigation/adaptation subcategory belongs to

Table 11: Mitigation_Adaptation

Field	Description
m_a_name	The unique name of each mitigation/adaptation measure used inside the code
m_a_title	The title of each mitigation/adaptation measure used on the interfaces
ordering	The ordering in the list of mitigation/adaptation measures as presented on the interfaces
m_a_subcat_id	A foreign key to the mitigation/adaptation subcategory each mitigation/adaptation measure belongs to
model_id	A many-to-many field that is used for matching models to mitigation/adaptation measures

Table 12: Emission_Category

Field	Description
emission_cat_name	The unique name of each emission category used inside the code
emission_cat_title	The title of each emission category used on the interfaces
icon	The path to an image file (icon) used for each emission category on the interfaces
ordering	The ordering in the list of emission categories as presented on the interfaces

Table 13: Emission_Model_State

Field	Description
emission_id	A foreign key to the emission entity
model_id	A foreign key to the model entity
state	A field that describes the relationship between a model and a specific emission and takes one of the following values: a) endogenous b) exogenous c) not represented

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Table 14: Socio_Economics_Category

Field	Description
socioecon_cat_name	The unique name of each socio-economics category used inside the code
socioecon _cat_title	The title of each socio-economics category used on the interfaces
icon	The path to an image file (icon) used for each socio-economics category on the interfaces
ordering	The ordering in the list of socio-economics categories as presented on the interfaces

Table 15: Socio_Economics

Field	Description
socioecon _cat_id	A foreign key to the socio-economics category each socio-economics parameter belongs to
socioecon _name	The unique name of each socio-economics parameter used inside the code
socioecon _title	The title of each socio-economics parameter used on the interfaces
ordering	The ordering in the list of socio-economics parameters as presented on the interfaces
model_id	A many-to-many field that is used for matching models to socio-economics parameters

Table 16: Socio_Economics _Model_State

Field	Description
socioecon_id	A foreign key to the socio-economics entity
model_id	A foreign key to the model entity
state	A field describing the relationship between a model and a specific socio-economics parameter and takes one of the following values: a) endogenous b) exogenous c) not represented

Table 17: Policy_Category

Field	Description
policy_cat_name	The unique name of each policy category used inside the code
policy _cat_title	The title of each policy category used on the interfaces
icon	The path to an image file (icon) used for each policy category on the interfaces
ordering	The ordering in the list of policy categories as presented on the interfaces

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Table 18: Policy

Field	Description
policy _cat_id	A foreign key to the policy category each socio-economics parameter belongs to
policy _name	The unique name of each policy used inside the code
policy _title	The title of each policy used on the interfaces
ordering	The ordering in the list of policies as presented on the interfaces
model_id	A many-to-many field that is used for matching models to policies

Table 19: Policy_Model_State

Field	Description
policy_id	A foreign key to the policy entity
model_id	A foreign key to the model entity
state	A field that describes the relationship between a model and a specific policy and takes one of the following values: a) feasible b) feasible with modifications c) not feasible

3.2.1.2 Methods and Functionality

The main functionality in the backend services is based on two classes and their constructor methods:

- **RetrieveDB:**

  It creates an object of a specific model, whose name is provided by the user (if not, a default model is selected). The class utilises its methods, requesting data from the database, to determine the geographical coverage of the selected model, in specific, the regions it covers and the countries that belong to every region. A JSON file is then created containing the necessary information for the creation of an interactive map, using the AMCharts Library. The format of this JSON file is described below:

```
[
    {
        "name": the name of the region,
        "colour": the colour of each region,
        "data": [
            {"title": the name of the country,
            "id": the two-letter abbreviation of the country,
            "descr": a short description for each country that is displayed on the map
            }, …
            ]
    },
… ,
]
```

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When a model works on national level, the green colour is used on the map for each country. When a model works on a regional level, the colour of each region on the map is determined by the "generate_colour" method, choosing among different colours included in the palette. Last but not least, the "RetrieveGranularities" method is called.

- **RetrieveGranularities:**

The input of the "RetrieveGranularities" method is the id of the selected model. In turn, this method calls a different method for each granularity describing the selected model, and the retrieved information is returned in the following JSON format:

```
{
        'MitigationAdaptationMeasures': {..} ,
        'Sectors': {..},
        'SDGs': {..},
        'Emissions': {..},
        'Policy': {..},
        'SocioEconomics': {..}
}
```

Mitigation and Adaptation Measures and **Sector** granularities are formatted as shown below:

```
{'category_name':{
        'subcategories':[
                'subcategory_name':{
                        'names': list of names (of Mitigation and Adaptation Measures or Sectors)
                }, ...
        ],
        'icon': a path to an image file (icon) used on the interfaces,
        'is_enabled': True or False,
        'html': the HTML code that will be used in the bootstrap tooltips
        }
}
```

The 'is_enabled' parameter is True if the model covers at least one of the Mitigation and Adaptation Measures or Sectors of a category.

Emissions are formatted as shown below:

```
{'emission_name':
        {'icon': a path to an image file (icon) used on the interfaces,
        'html': the HTML code that will be used in the bootstrap tooltips,
        'is_enabled': True or False
```

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}, …

}

The 'is_enabled' parameter is True if a gas is calculated Endogenously or used Exogenously.

SDGs are formatted as shown below:

{'**sdg_category**':{

'**name**': **the name of the SDG**,

'**title**': **a detailed description of the SDG**,

'**icon**': **a path to an image file (icon) used on the interfaces**,

'**is_enabled**': **True or False**,

'**html**': **the HTML code that will be used in the bootstrap tooltips**

}

}

The 'is_enabled' parameter is True if an SDG name exists for the selected model.

Socio-economics and **Policy** granularities are formatted as shown below:

{'**category**':{

'**names**': [{"**quantity_name**":"**quantity_state**"}, ….],

'**icon**': **a path to an image file (icon) used on the interfaces**,

'**is_enabled**': **True or False**,

'**html**': **the HTML code that will be used in the bootstrap tooltips**

}

}

For socio-economics, the 'is_enabled' parameter is True if at least one socio-economics quantity in a category is covered Endogenously or Exogenously. For policies, the 'is_enabled' parameter is True if at least one policy in a category is Feasible or Feasible with modifications.

Essentially, the "names" parameter is a list of JSON objects, whose key is a granularity quantity and value a Boolean value that shows if the specific quantity is covered by the model.

3.2.2 Backend of modelling results

3.2.2.1 Django Models

The relational model used for the implementation of the modelling results demonstration is displayed in the tables and figures below. The two main entities of the implementation are the Dataset and the Variable Django models.

Table 20: Dataset

Field	Description
dataset_name	The unique name of the dataset used inside the code
dataset_title	The title of the dataset

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dataset_description	A description about what kind of information this dataset contains
dataset_provider	The name of the provider of the dataset as shown in the UI
creation_date	The date the dataset was imported in the database
update_date	The date the dataset was last updated
django_model	The name of the Django Model (table name) that contains the data of this dataset.

Table 21: Variable

Field	Description
variable_name	The unique name of the variable used inside the code
variable_title	The title of the variable as shown in the UI
variable_definition	A definition small description of the variable
variable_category	The category of the variable
variable_type	The type of the variable (i.e., int, dec, char, date)
table_name	This field is nullable. If it exists, it displays the name of the Django model that this specific variable object is taking its values from. If not, it means that this variable is just a simple numerical or string value.
dataset_relation	The id of the dataset the variable belongs to

The Dataset Model carries a list of all the datasets currently available on the platform along with important information about them. Each dataset record has a corresponding dataset Django model that contains the data of the dataset. Its name is stored in the "django_model" field and behaves as a separate model, having its own fields. These fields are called variables and are listed in the second main entity of the Modelling Results Backend infrastructure, the "Variable" model. This means that every record of the "Variable" model is not only related to the dataset objects through a foreign key ("dataset_relation"), but also the name of a column in the respective dataset object. If a Variable record has a "table_name", its value in the corresponding dataset object points to a "Variable Object" that is a separate Django model having its own fields (following the same logic as the datasets). If not, the value is a number or a string. To sum this up, a Dataset Object Model is composed of columns whose names derive from the Variable Model and the value of each cell can be either a foreign key to a Variable Object Model or a simple value.

This implementation decision was made in order to be able to take advantage of the Django ORM that is utilised by the Data Manager Component and create an expandable infrastructure that has the potential to support more complex data in the future.

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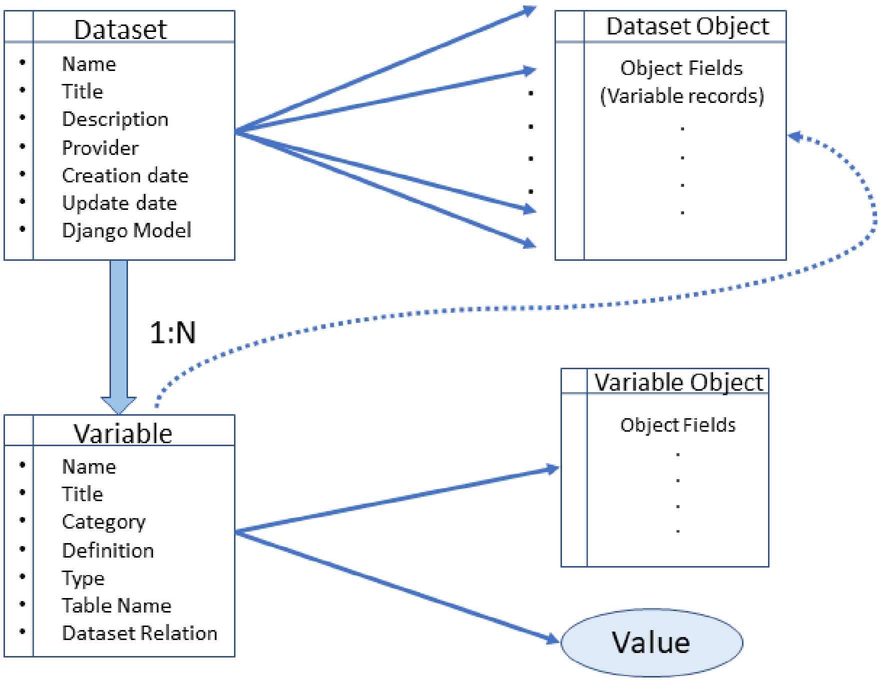

Figure 48: Modelling Results Schemas

3.2.2.2 Methods and Functionality

The main functionality of the component in this case is to coordinate the calls to the Data Manager and the Visualiser with a view to populating the interfaces with the requested information. For static interfaces, this is a straightforward one-way workflow. For dynamic interfaces, where the user interacts moving knobs, filling in empty fields, selecting values from dropdown lists, etc., this component is responsible for retrieving information about the interface and the executed queries, managing the user's interactions, making multiple requests to the rest of the components that produce the content, gathering and rendering the results. AJAX calls are executed for each change, updating only the parts of the interface that are affected by the changes, thus avoiding reloading the entire page from scratch and allowing the user to keep on with the navigation through the page (since this is an asynchronous process). In some cases, the change requires making new requests to acquire new data, while in others the data is already cached (or even processed).

3.3 Data Manager

As already mentioned, the Data Manager in essence aims at decoding queries from a JSON pre-defined format and executing them, utilising the Django ORM, along with transforming the returned data to an appropriate format for the Visualiser.

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3.3.1 Query Format

```
{	"dataset": "dataset_1",
	"query_configuration": {
		"select": ["variable_1", "variable_2"],
		"filter": {"and": [
					{"operand_1": "variable_3",
					"operand_2": 5,
					"operation": ">"},

					{"operand_1": "variable_5",
					"operand_2": ['value1', 'value2', 'value3'],
					"operation": "in"}
					],
			"or": [
					{"operand_1": "variable_3",
					"operand_2": 500.
					"operation": "<"},

					{"operand_1": "variable_4",
					"operand_2": 100.
					"operation": "<"},
					]
			} ,
		"ordering": [
				{"parameter": "variable_8",
				"ascending": true},
				{"parameter": "variable_9",
				 "ascending": true}
				] ,
		"grouping": {
			"params": ["variable_1", "variable_2"],
			"aggregated_params": [
					{"name": "variable_3",
					 "agg_func": "Sum"},
					{"name": "variable_4",
					 "agg_func": "Avg"}
					 ]
			}
		},
	"additional_app_parameters": {}
}
```

Figure 49: Query in JSON Format

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The format of the JSON-query displayed above was decided after considering all the possible required queries for the demonstration of the available modelling results. As in a usual SQL query, the JSON object contains a SELECT, a FILTER, an ORDER-BY, and a GROUP-BY clause. In this case:

- The SELECT-clause (“select”) is a list of the names of the variables that the query is focused on (only these columns are returned from the database).
- The FILTER-clause (“filter”) contains AND and OR lists of operations that are applied in order to filter the results. All the conditions in the AND-list and at least one (if the list is not empty) of the conditions in the OR-list will have to be satisfied in order for the corresponding data to be returned. In any other case, the data are filtered out. Each condition is expressed by two operands and one operation. The first operand is the name of the examined variable, the second one is a value, and the third one is the condition that needs to be satisfied and can be one of the following:
  - >, >=, =, <=, <: as in mathematics
  - Between: the condition is true if the operand’s value is between a given range
  - In: the condition is true if the value exists in a list of values
- The ORDER-BY-clause (“ordering”) is a list of JSON objects (allowing ordering by multiple fields) that include the ordering parameter and whether the ordering that takes place is ascending or descending.
- In the GROUP-BY-clause (“grouping”) the “params” field is a list of the variables that are used for grouping the data. The “aggregated_params” field is a list of json objects that include the aggregated variables along with the aggregation function used for each one. The currently available aggregation functions are: Sum, Avg. (Average), Min. (Minimum), and Max. (Maximum).
- In some applications further information needs to be provided in order to fetch additional data from the database. This can be declared in the “additional_app_parameters” object.

3.3.2 Decoding and executing the query

Every interface that requires data to be retrieved, using jQuery, creates a JSON query that follows the aforementioned rules and sends it to the Data Manager in order to be either stored or decoded and executed. There is a dedicated part of the Data Manager responsible for converting step-by-step the created Query to a complex Django ORM Query and executing it, thus retrieving the requested data. This facilitates possible future changes, in case more sophisticated filtering is required by the users for example. These changes will only affect the decoding of the filtering part and will not affect the rest of the query. This is very useful since more requirements come to light by the stakeholders, as they get familiar with the platform.

The Data Manager has an API that can receive the id of a stored query, retrieve it, decode it and execute it, returning the results to the user. However, in most cases in the I²AM PARIS platform, these data are demonstrated in charts and map visualisations, utilising the Visualiser, since batches of raw data are usually illegible and not very insightful. For that reason, the Visualiser calls the Data Manager by providing the id of a query. The data returned from the execution of the query usually need further reformatting to be compatible with the Visualiser, depending on the type of the requested chart. This is achieved by several implemented methods that utilise Pandas Dataframes for efficient data conversion. In the cases that the data require even more processing before being considered ready for visual representation, aggregation functions are applied on the data, additional sorting according to a field (i.e., time), etc.

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Afterwards, the final data are sent to the visualiser that proceeds with the creation of the visualisation.

It is clear that the Data Manager and the Visualiser, although technically completely independent components, in the scope of the I²AM PARIS platform work as one and constitute the Visualisation Engine as shown in Figure 50.

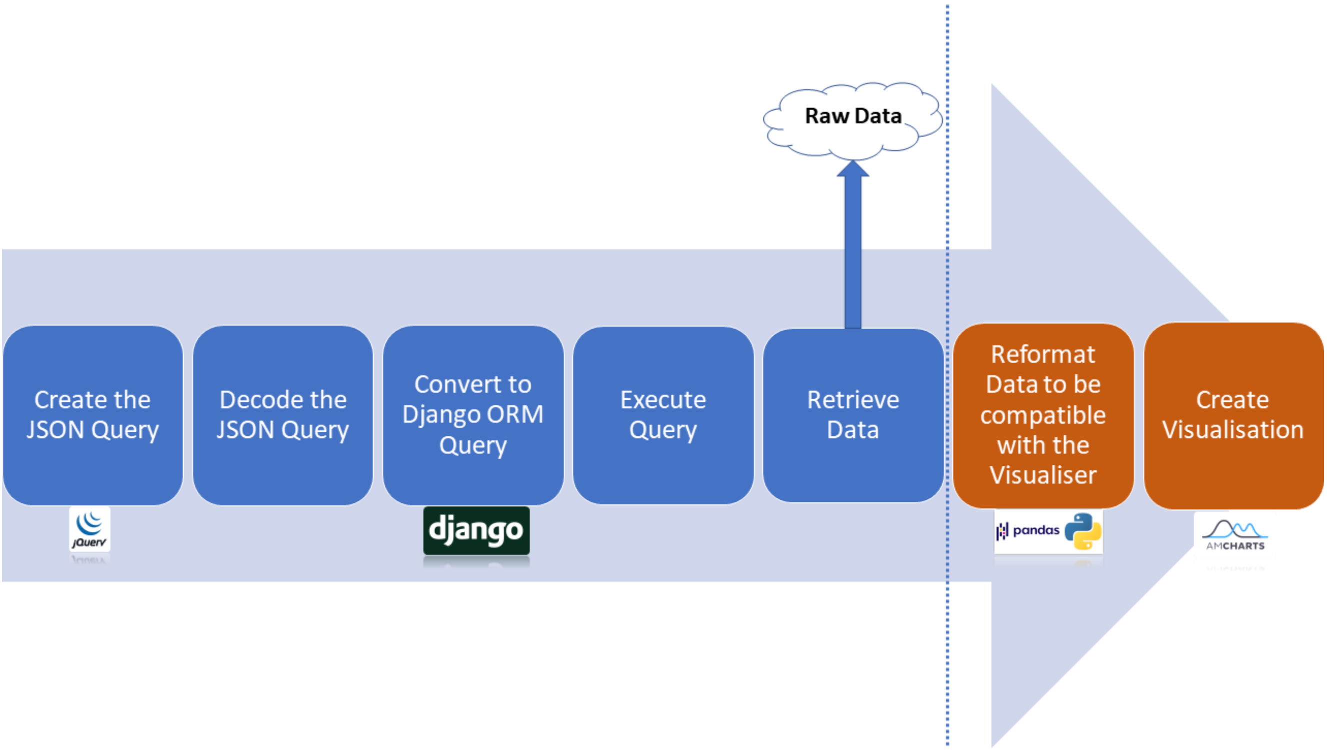

Figure 50: Visualisation Engine Workflow

3.4 Visualiser

One important service of the I²AM PARIS platform is the generation of different visualisations, based on the available data derived from the model analyses. The visualisations are generated from a standalone component called *Visualiser* and are viewed at multiple developed static and interactive interfaces within the platform. The visualisations are divided into two groups:

- Chart visualisations: several types of line charts and column charts, pie charts, radar charts, 2d histograms, Sankey diagrams, chord diagrams, Gantt charts, parallel coordinates charts.
- Map visualisations.

3.4.1 Visualisation Backend Services

Two software libraries are used at the moment, namely AmCharts 4 and D3-charts. Depending on the requirements for new types of visualisations, more libraries will be used.
Instead of implementing different classes for every visualisation, we have opted for creating super-classes for visualisations with common attributes. These classes encompass all arguments and parameters necessary for this particular type of visualisation. The classes are described below, in Table 20-23.

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Table 22: XY_chart Class

Field	Description	Type
x_axis_name	The unique name of the selected variable of the X-Axis as used in the code	String
x_axis_title	The title of the selected variable of the X-Axis as displayed in the user interfaces	String
x_axis_unit	The unit of the selected variable of the X-Axis	String
y_var_names	A list of names of the selected variables presented on the Y-Axis as used in the code. In several visualisations that do not support multiple series on the Y-Axis this list contains only one element.	List of Strings
y_var_titles	A list of titles of the selected variables presented on the Y-Axis as displayed in the user interfaces. The order of the elements in the list as well as its length should correspond to the "y_var_names" list.	List of Strings
y_var_units	A list of units of the selected variables presented on the Y-Axis as displayed in the user interfaces. The order of the elements in the list as well as its length should correspond to the "y_var_names" list. This makes sense in multi-axial charts, where different types of variables are presented on different Y-Axes.	List of Strings
chart_data	A JSON object in the appropriate format (depending on the visualisation) that contains the data to be displayed.	JSON Object
chart_type	The type of chart that will be created. It could be one of the following: • line_chart • column_chart • range_chart • bar_range_chart • stacked_column_chart • column_heatmap_chart • pie_chart • radar_chart	String
x_axis_type	The type of the X-Axis, as several visualisations support more than one type. Options: "Time", "Text", "Number". The first option is used when the X-Axis includes dates or time. The second option is used when distinct categories are displayed on the X-Axis. The third option is used for continuous values.	String
use_default_colors	If "true", the default colours are used for the chosen visualisation	Boolean
color_list	• A list of colours used for each series of the chosen visualisation in case use_default_colors = "false". Options include "light_blue, blue, violet, purple, fuchsia, red, ceramic, light_brown, mustard, gold, light_green, green, cyan, black, gray, white" • A list of two colours that are used for minimum and maximum values in heatmap charts (i.e. bar_heatmap_chart; if one colour is given in a bar heatmap, then the white colour is selected by	List of Strings

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	default as the other colour) and for creating the gradient legend.	
chart_3d	If "true", the chart is displayed in three dimensions. (not all visualisations support 3D)	Boolean
min_max_y_value	A two-element list that contains the minimum and maximum value of the variable presented on the Y-Axis.	List of Numbers

Table 23: XYZ_chart Class

Field	Description	Type
x_axis_name	The unique name of the selected variable of the X-Axis as used in the code	String
x_axis_title	The title of the selected variable of the X-Axis as displayed in the user interfaces	String
x_axis_unit	The unit of the selected variable of the X-Axis	String
y_var_name	The name of the selected variable presented on the Y-Axis as used in the code.	String
y_var_title	The title of the selected variable presented on the Y-Axis as displayed in the user interfaces.	String
y_var_unit	The unit of the selected variable presented on the Y-Axis as displayed in the user interfaces.	String
z_axis_name	The unique name of the selected variable of the Z-Axis as used in the code	String
z_axis_title	The title of the selected variable of the Z-Axis as displayed in the user interfaces	String
z_axis_unit	The unit of the selected variable of the Z-Axis	String
chart_data	A JSON object in the appropriate format (depending on the visualisation) that contains the data to be displayed.	JSON Object
chart_type	The type of chart that will be created. it could be one of the following: • heat_map_chart	String
use_default_colors	If "true", the default colours are used for the chosen visualisation	Boolean
color_list	• A list of colours used for each series of the chosen visualisation in case use_default_colors = "false". Options include "light_blue, blue, violet, purple, fuchsia, red, ceramic, light_brown, mustard, gold, light_green, green, cyan, black, gray, white" • A list of two colours that are used for minimum and maximum values in heatmap charts (i.e. heat_map_chart; if one colour is given in a bar heatmap, then the white colour is selected by default as the other colour) and for creating the gradient legend.	List of Strings
min_max_z_value	A two-element list that contains the minimum and maximum value of the variable presented on the Z-Axis.	List of Numbers

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Table 24: FlowChart Class

Field	Description	Type
chart_data	A JSON object in the appropriate format (depending on the visualisation) that contains the data to be displayed.	JSON Object
chart_type	The type of chart that will be created. It could be one of the following: • sankey_diagram • chord_diagram	String
use_default_colors	If "true", the default colours are used for the chosen visualisation	Boolean
color_node_list	• A list of colours used for each node in the chosen visualisation in case use_default_colors = "false". Options include "light_blue, blue, violet, purple, fuchsia, red, ceramic, light_brown, mustard, gold, light_green, green, cyan, black, gray, white"	List of Strings
node_list	A list of names/titles of the existing nodes in the charts.	List of Strings
chart_title	The title used for the whole chart that is displayed.	String

Table 25: MapChart Class

Field	Description	Type
map_data	A JSON object in the appropriate format (depending on the visualisation) that contains the data to be displayed on the map.	JSON Object
map_var_name	The name of the selected variable presented on the map as used in the code.	String
map_var_title	The title of the selected variable presented on the map as displayed in the user interfaces.	String
map_var_unit	The unit of the selected variable presented on the map as displayed in the user interfaces.	String
min_max_value	A two-element list that contains the minimum and maximum value of the variable presented on the map.	List of Numbers
chart_type	The type of chart that will be created. it could be one of the following: • heatmap_on_map	String
color_list	• A list of colours used for different elements on the map (future implementation). Options include "light_blue, blue, violet, purple, fuchsia, red, ceramic, light_brown, mustard, gold, light_green, green, cyan, black, gray, white" • A list of two colours that are used for minimum and maximum values in heatmap charts (i.e. heat_map_on_map) and for creating the gradient legend.	List of Strings
Projection	The type of projection that will be used for the map. Options include "eckert6, equirectangular, naturalearth, miller, orthographic, mercator"	List of Strings
chart_title	The title used for the whole chart that is displayed.	String

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The visualisation generation service is triggered by an HTTP request (either POST or GET) that contains information like the type of visualisation that must be created, all parameters necessary for the configuration of the visualisation (which can vary in number and depends on the type of each visualisation) and information about the data that will be used, either from a dataset stored in the database or from an external file.

- In the first case, the data are retrieved from the Data Manager by executing the corresponding query using the parameters provided in the request.
- In the second case, the data are acquired from a CSV file of a predefined format that will be commonly agreed among the related consortium partners.

In any case, the data are loaded and processed properly, in order to be in the form required by each visualisation type. The processing that takes place is based on the format of the provided data, the data volume, the user requirements, and the choices that are made when interacting with the interfaces, and is done by the Data Manager.

The final data are sent to the respective libraries that create and render the visualisation, which is finally returned as a response to the initial request.

The different visualisation types currently implemented on the platform (to be finalised as the Data Manager is developed) are described below:

- ***Line chart***, with multiple variables displayed at the same visualisation. The X-Axis and Y-Axis variables along with their type, titles and units as well as the dataset or the file name are obtained from the parameters of the request.
- ***Range line chart***, with multiple variables displayed at the same visualisation. Follows the same logic as the simple line chart but also displays the minimum and maximum values of the examined variables.
- ***Column chart***, again with multiple variables displayed side-by-side, in columns. Follows the same logic as the line chart.
- ***Column heatmap chart***, which examines the value of one variable and displays it in columns of different colour depending on its value (according to a heatmap legend).
- ***Bar range chart***, mainly (but not exclusively) used as a Gantt chart, that is a variation of a column chart with (usually) time-based horizontal axis and bars starting at arbitrary values rather than on the axis. This can be used, inter alia, to capture the exact timeline of the PARIS REINFORCE modelling runs; or, for future assessment cycles.
- ***Pie chart***. The examined variable and the key variable for slicing the pie are obtained from the parameters of the request.
- ***Radar chart***, which is used to display directional or circular visual representation of a 2-dimensional data.
- ***2D-Histogram*** (heatmap chart) of one variable that shows the intensity of a variable in function of two other variables acquired from the request parameters.
- ***Chord diagram***, which is used to indicate one-level quantitative relations between multiple items, organised in a circular diagram.
- ***Sankey diagram***, which can be used to depict branched, multi-level flows of values.
- ***Parallel coordinates chart***, for plotting multivariate, numerical data. This chart is ideal for comparing many variables together and seeing the relationships between them.
- ***Heatmap (on map)*** that shows the intensity of a variable or the frequency of events on a map. The examined variable is retrieved from the request.

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In most of the aforementioned visualisation alternatives, the option of choosing specific colours for the diagrams is also provided, while some can also be displayed in three dimensions. These two functionalities (colouring and 3D display) are also configured by passing the necessary parameters in the requests.

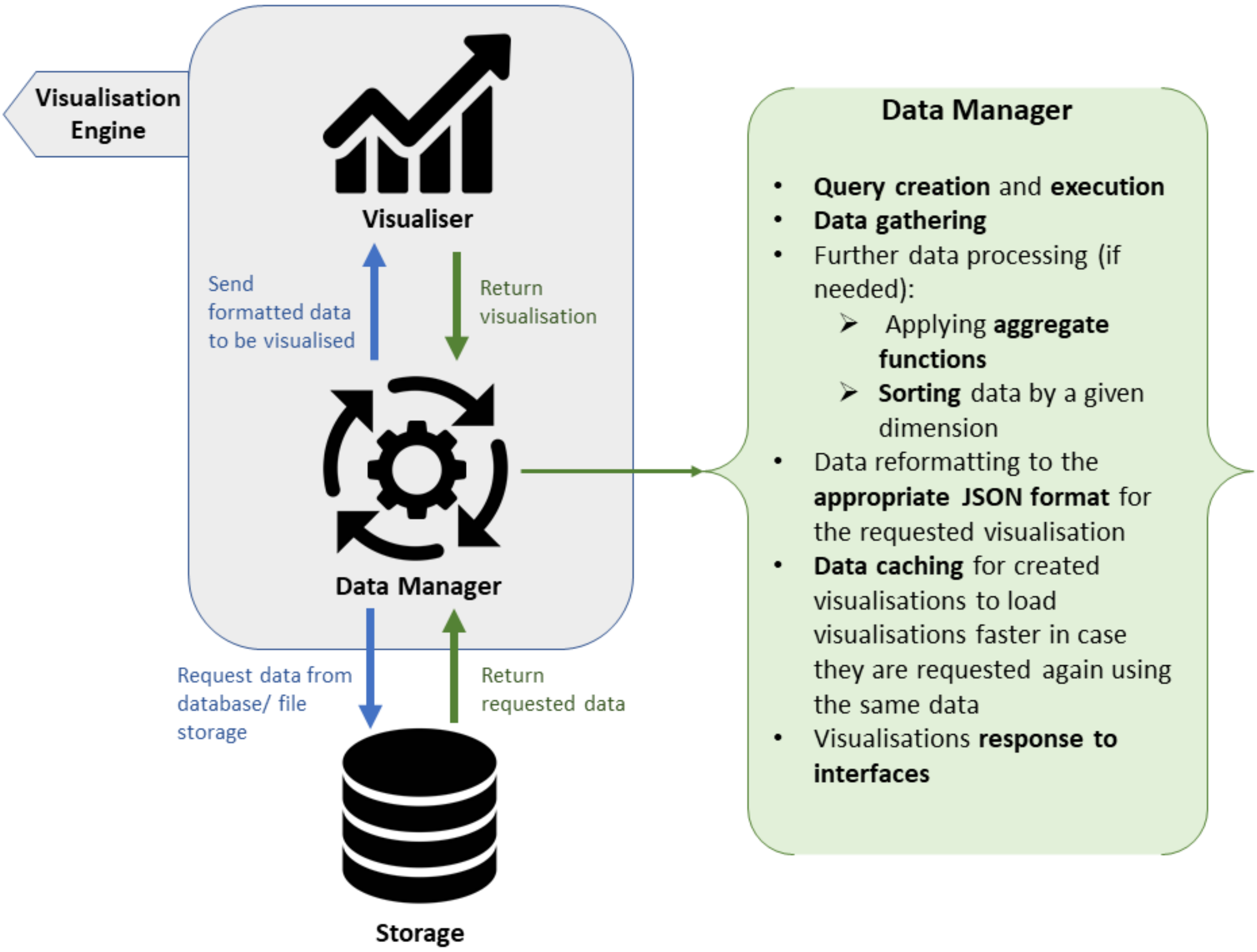

Figure 51: Visualisation Engine Design

3.4.2 Visualiser API and Request Examples

The Visualiser API receives both GET and POST requests in a specific format (passing the necessary parameters according to the Class the requested visualisation belongs to; see section 1.6.1) and returns an HTML page that contains the requested visualisation. For example, the following requests creates and returns a line chart:

GET Request:

http:// http://paris-reinforce.epu.ntua.gr/ visualiser/ show_line_chart? y_var_names[]=myVariable1 & y_var_names[]=myVariable2 & y_var_titles[]=Variable1 & y_var_titles[]=Variable2 & y_var_units[]=v1_unit & y_var_units[]=v2_unit & x_axis_type=time & x_axis_name=time & x_axis_title=Time & x_axis_unit=-& y_axis_title=YAxisVariable & color_list_request[]=blue & color_list_request[]=red & use_default_colors=false & min_max_y_value[]=0 & min_max_y_value[]=2000

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POST Request:

http://localhost:8000/visualiser/show_line_chart

Body: {

"**y_var_names**": **["myVariable1", "myVariable2"]**,

"**y_var_titles**": **["Variable1", "Variable2"]**,

"**y_var_units**": **["v1_unit", "v2_unit"]**,

"**x_axis_type**": **"time"**,

"**x_axis_name**": **"time"**,

"**x_axis_title**": **"Time"**,

"**x_axis_unit**": **"-"**,

"**y_axis_title**": **"YAxisVariable"**,

"**color_list_request**": **["blue", "red"]**,

"**use_default_colors**": **"false"**,

"**min_max_y_value**": **[0, 2000]**,

"**dataset**": **"my_dataset"**

}

There are three points regarding both types of requests that should be clarified:

- The names of the variables must be the same with those used in the JSON object that contains the data to be visualised as shown below.
- The values of specific parameters should follow the available options provided by the four main visualisation classes**: XY_Chart, XYZ_Chart, FlowChart, MapChart**.
- The "dataset" is used for defining the dataset (either table from a database, or file) that is going to be used as data source for the requested visualisation. Currently, the data used for demonstrating each visualisation are synthesised.

The data used by the visualiser for this specific example are in the following format:

[{"time": 1577743200000, "myVariable1": 269.5},

{"time": **1577829600000**, **"myVariable1"**: **129.25}**,

....

{"time": **1577743200000**, **"myVariable2"**: **163.2}**,

{"time": **1577829600000**, **"myVariable2"**: **222.15}]**

The list of available visualiser URLs is presented below (examples):

- paris-reinforce.epu.ntua.gr/visualiser/show_line_chart

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- paris-reinforce.epu.ntua.gr/visualiser/show_column_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_pie_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_radar_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_range_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_bar_range_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_stacked_column_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_heat_map_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_bar_heat_map_chart
- paris-reinforce.epu.ntua.gr/visualiser/show_sankey_diagram
- paris-reinforce.epu.ntua.gr/visualiser/show_chord_diagram
- paris-reinforce.epu.ntua.gr/visualiser/show_heat_map
- paris-reinforce.epu.ntua.gr/visualiser/parallel_coordinates_chart

3.4.3 Visualisation Frontend Services

The Visualisation Engine utilises AmChart4 and D3 Charts, as mentioned above, in order to produce the requested visualisations. The screenshots below show the visualisations that are currently available using the visualiser, presenting synthesised data for the sake of demonstration.

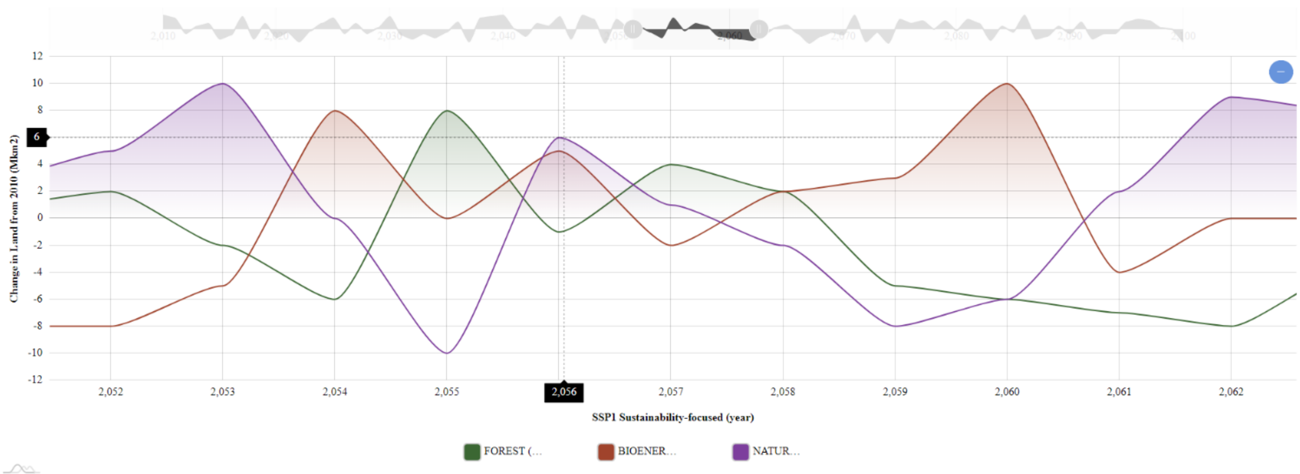

Figure 52: Line Chart

A Line chart displays series of data points connected by straight line segments. Line graphs are often used to display time series chronologically with the x-axis serving as an evenly spaced date-time scale (Figure 52).

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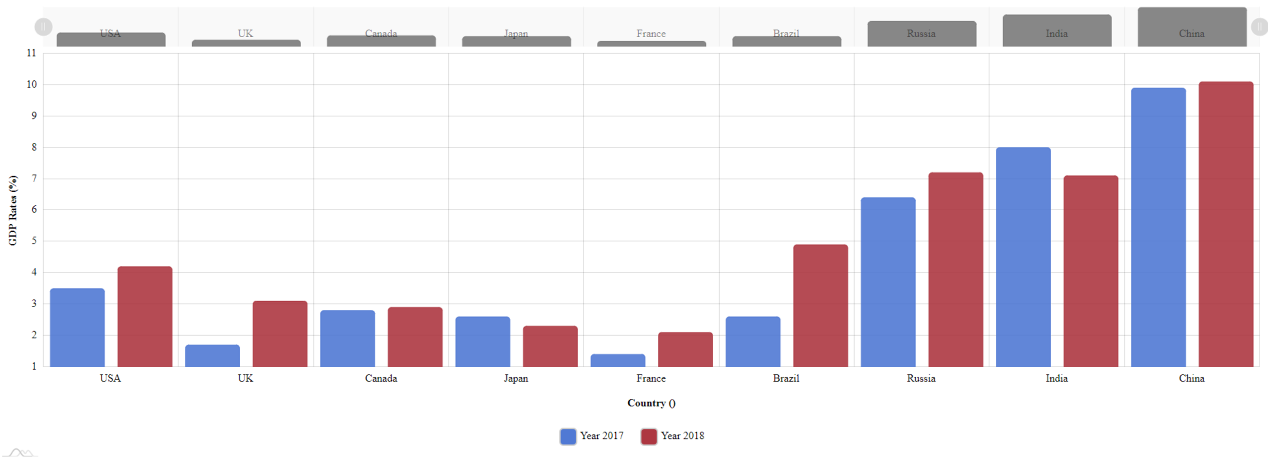

Figure 53: Column Chart

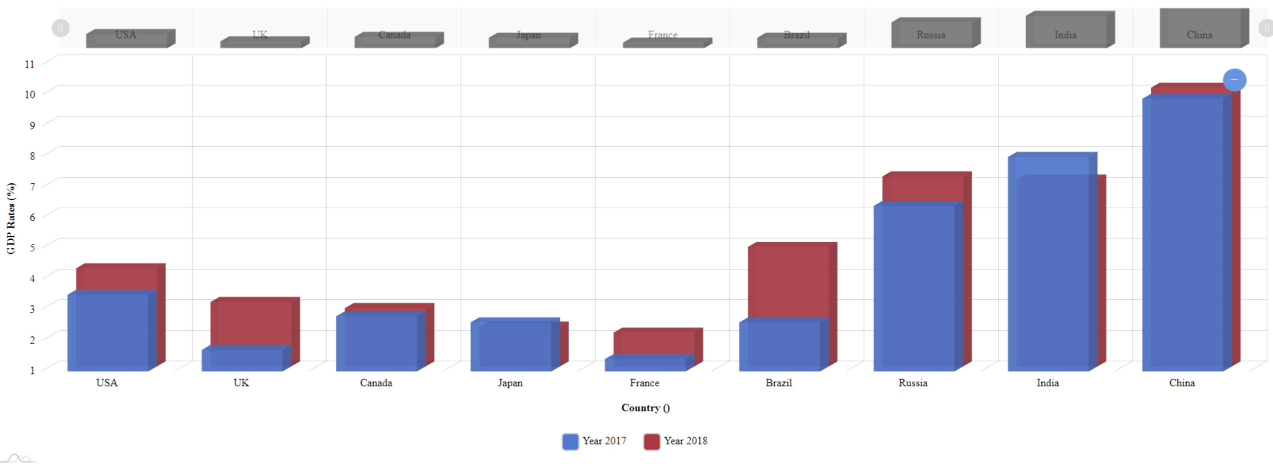

Figure 54: Column Chart 3D

A Column Chart (Figure 53) is one of the most common and, arguably, easiest charts to read when it comes to visualising category-based values. Rectangular bars are placed along the category axis with the bar length representing the value for a specific category. The visualisation engine can also produce three-dimensional column charts (Figure 54).

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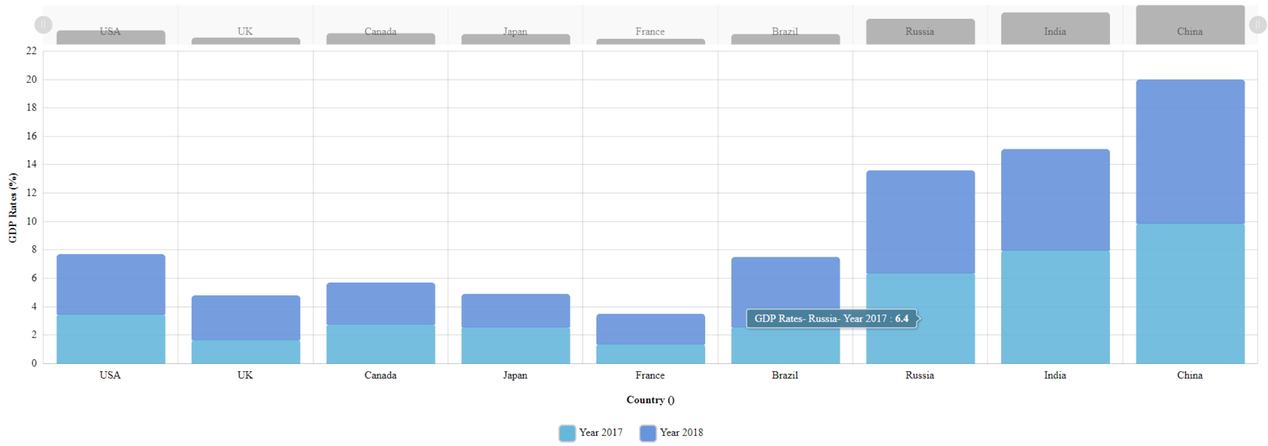

Figure 55: Stacked Column Chart

Stacked Bar Charts (Figure 55) are useful to demonstrate how a larger data category is comprised of smaller categories, and what part each of the smaller categories plays in the total of a larger one.

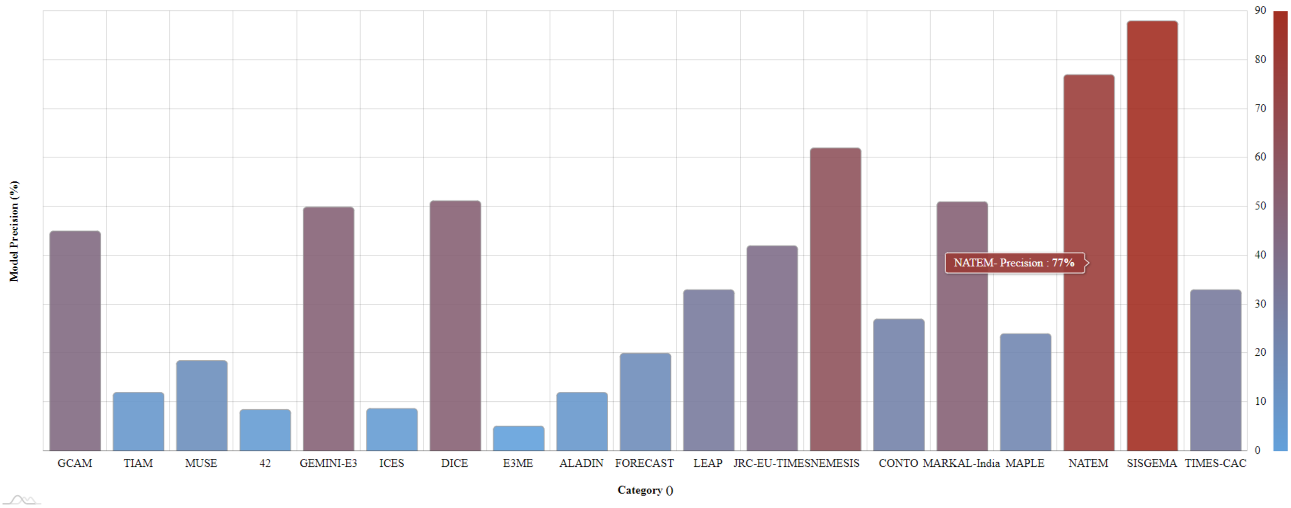

Figure 56: Heatmap Bar Chart

A Heatmap Bar Chart (Figure 56) is used the same way as a simple column chart, but each bar is coloured according to a heatmap legend, showing the value for specific categories using the proper colour (thereby adding an additional data dimension).

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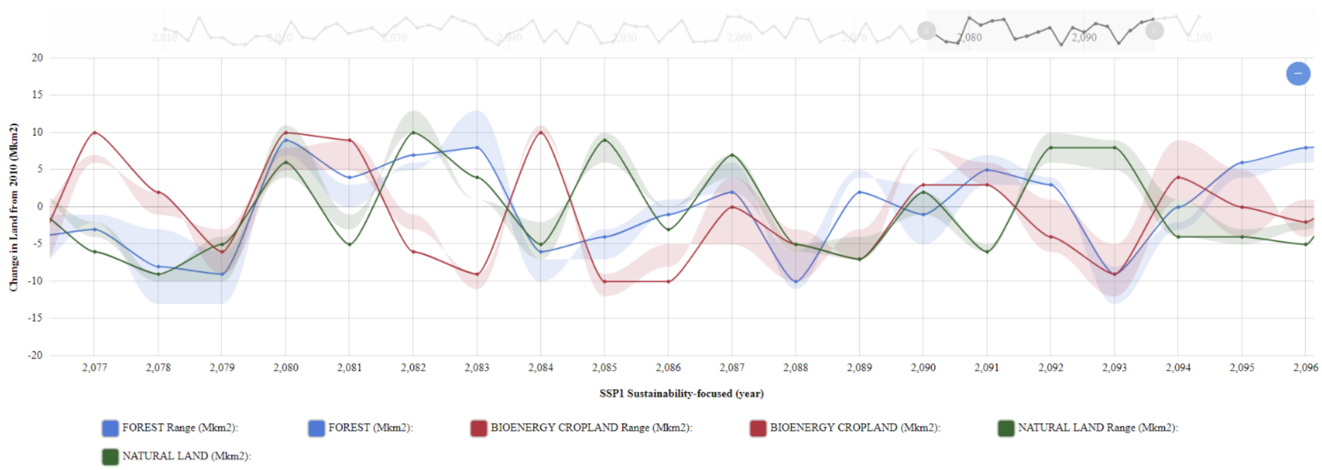

Figure 57: Range Chart

A Range Chart (Figure 57) is a type of area chart where, rather than starting on the axis, the area is represented by the space between two values. These charts are useful for displaying ranges of values, such as between minimum and maximum values over a timespan, or projected values for the future when the projection is represented by a range instead of a specific value.

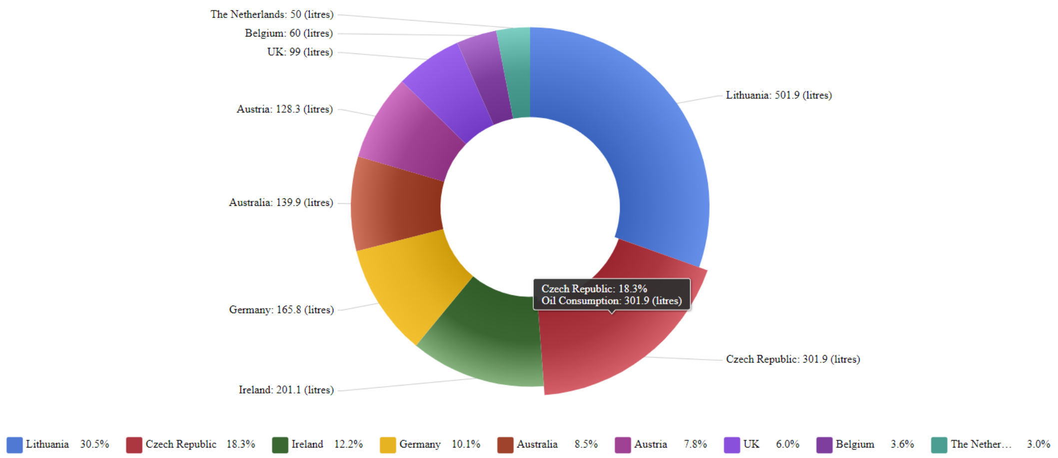

Figure 58: Pie Chart

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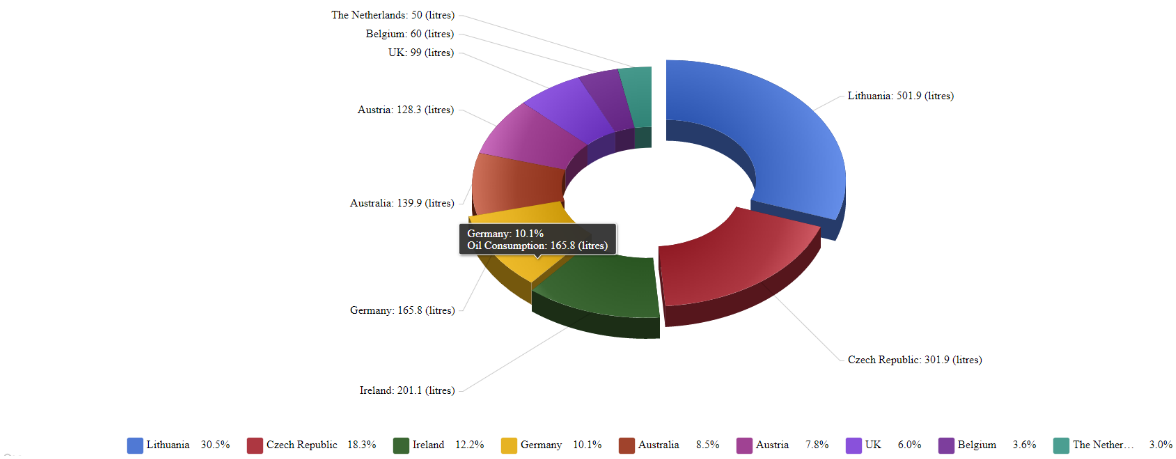

Figure 59: Pie Chart 3D

A Pie Chart (Figures 58-59, for 2D and 3D respectively) is used to represent data series as part of the whole. Each slice in a pie chart represents a data item proportionally to the sum of all the items in the series.

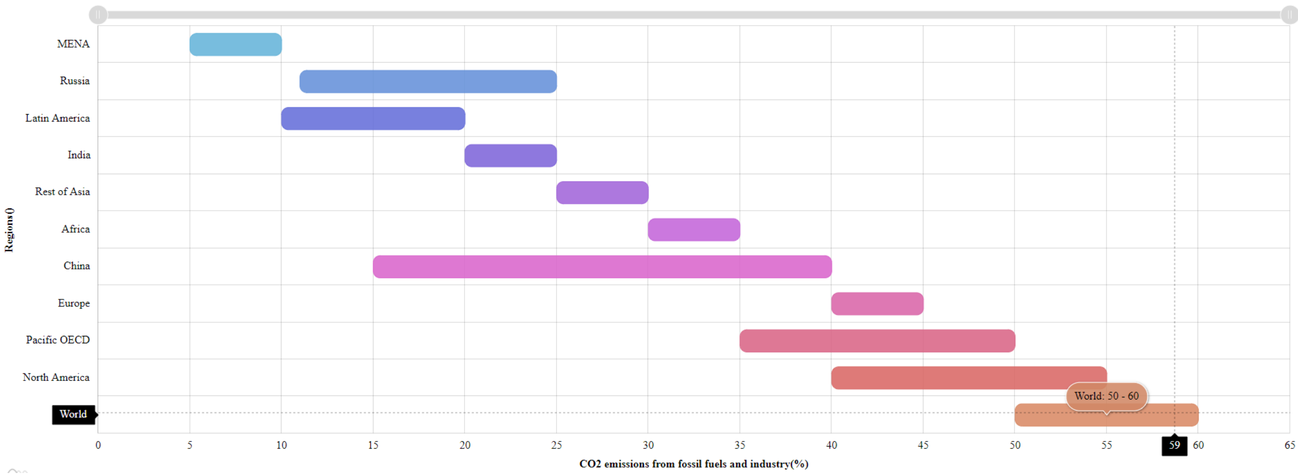

Figure 60: Bar Range Chart

A Bar Range Chart (Figure 60) is a variation of a column chart with a horizontal (time-based when it implements a Gantt diagram) axis and bars starting at arbitrary values rather than on the axis.

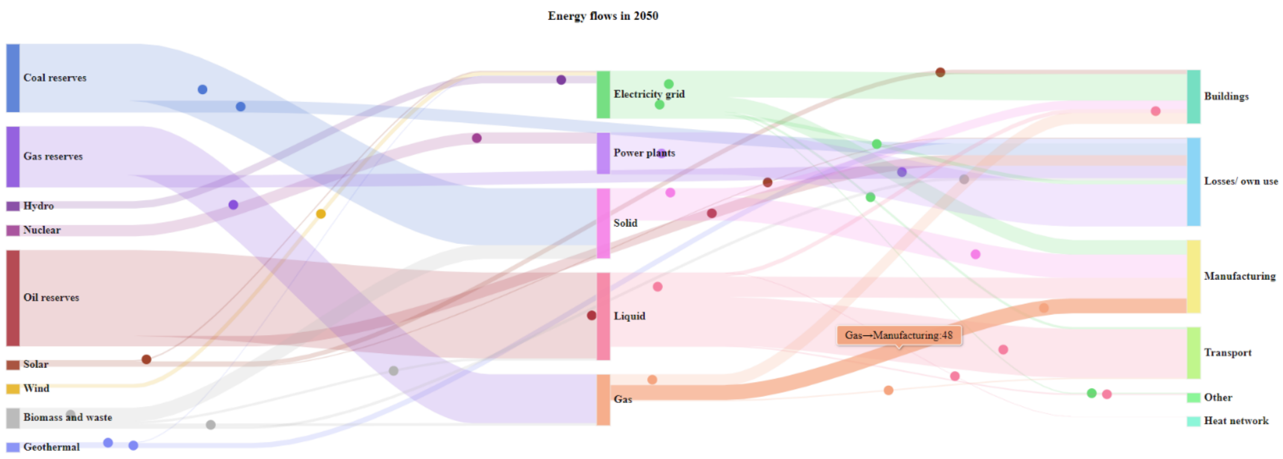

Figure 61: Sankey Diagram

A Sankey Diagram (Figure 61) is an ideal chart to show the flow and relation between stages of a process. It can

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be used for building pathways and roadmaps.

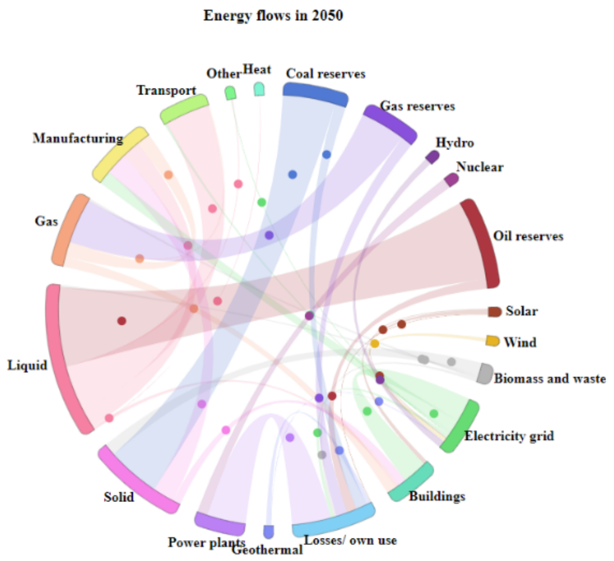

Figure 62: Chord Diagram

Chord Diagrams (also known as Radial network diagram, Chord layout, Dependency wheel) facilitate the visualised representation of relationships between data arranged beautifully in a circle (Figure 62).

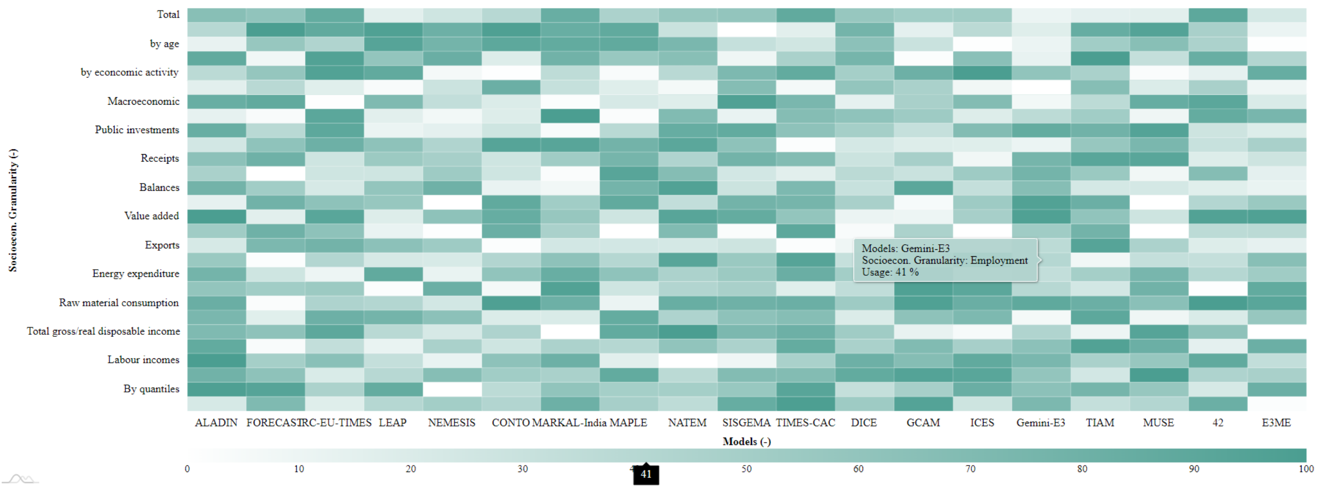

Figure 63: Heatmap Chart (2D Histogram)

Heatmaps (also known as 2D Histograms, Heat tables, Shading matrices) represent data in a rectangular matrix where individual values are differentiated by colour according to a heatmap legend (Figure 63).

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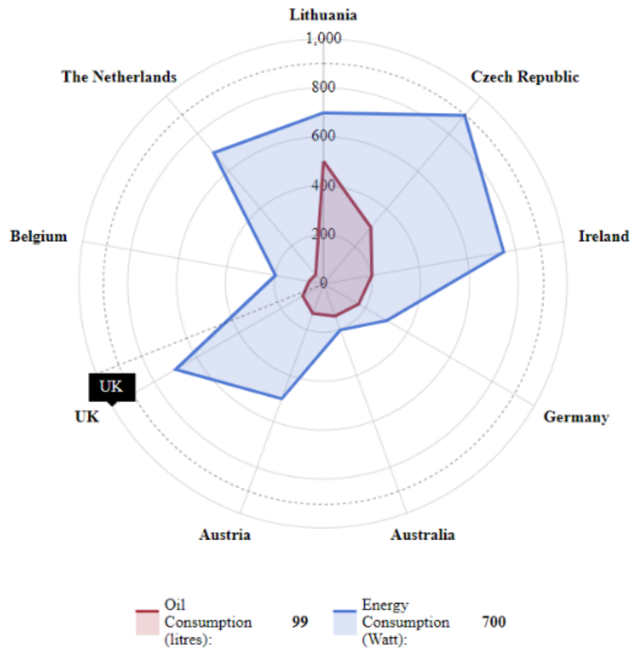

Figure 64: Radar Chart

A Radar Chart (Figure 64) is used to display directional or circular visual representation of a 2-dimensional data and is useful for either comparing and contrasting different instances of one physical quantity or as a visual aid for describing different aspects of a chosen unit.

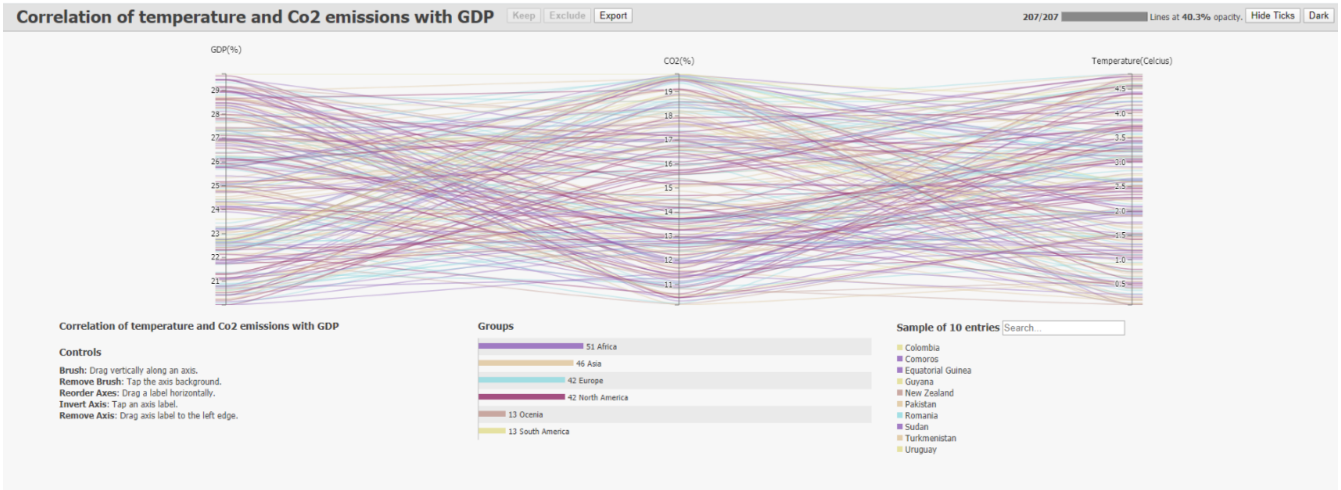

Figure 65: Parallel Coordinates Chart

Parallel Coordinates (Figure 65) are a common way of visualising high-dimensional geometry and analysing multivariate data, and facilitate the comparison among the features of several individual observations on a set of numeric variables. Each vertical axis represents a variable and often has its own scale; the units can even be different. Values are then plotted as series of lines connected across each axis. Showing all data can be confusing sometimes, and that is why the user can choose specific values to be visualised as well as limit output of the visualisation according to a selected range for each axis.

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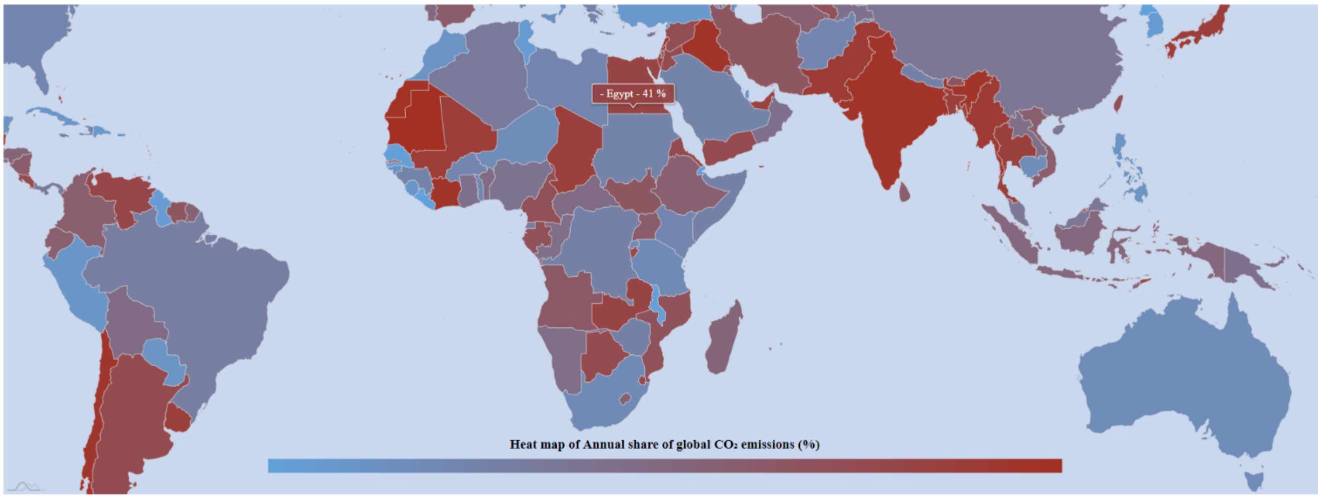

Figure 66: Heatmap

Heatmaps (on an actual map) are used for presenting the value of a selected variable on the map using colours that correspond to specific values according to a given heatmap legend (Figure 66).

All of the presented visualisations are interactive diagrams that allow seeing the desired information by utilising tooltips that pop up when the user hovers over specific elements of a chart, offering zoom-in and zoom-out functionality as well as the ability to enable or disable selected categories on a diagram or temporarily remove selected values or entire series from it, in order to clear up the results of the visualisation. In some cases, there is also animated movement in the diagrams to showcase the data flow or the exchange of information between nodes.

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4 Conclusion and Sustainability of the Platform

As the last version of the deliverable documenting the I2AM PARIS platform design and implementation, this report provides a documentation of the platform along with a description of its available workspaces and services, including the Dynamic Model Documentation, the Detailed Model Documentation, the Overview and Comparative Assessment, the Modelling Results Demonstration, and the Variable Harmonisation Heatmap services. A thorough description of the I2AM PARIS architecture is also included, comprising the implemented core components of the platform: the I2AM PARIS Backend, the Parsers, the Data Manager, and the Visualiser.

As far as the documentation section of the platform is concerned, the Detailed Model Documentation offers a detailed and extended presentation of the characteristics of every available model involved in the PARIS REINFORCE initiative and is currently being enriched with models from modelling teams outside the PARIS REINFORCE consortium. The Overview and Comparative Assessment is useful for comparing and contrasting the models available in PARIS REINFORCE, thus gaining significant insight into their coverage and fields of application. The Dynamic Model Documentation is a single-page application that allows going through all the important features of each model utilising the visual aids of a map to define its geographical coverage as well as several icons that correspond to specific characteristics (e.g. policy, socioeconomic, technology and SDG coverage). Last but not least, the On-Demand Variable Harmonisation Heatmap service allows the creation of a two-dimensional histogram that indicates how variables are handled across a list of selected models.

The modelling results are demonstrated in six different workspaces. Most of them are divided in four subsections: "Advanced scientific module" – a scientific interface consisting of tools that facilitate data exploring and visualisation; "Policy interface" – a user-friendly not strictly scientific interface that presents the conclusions drawn by the analysis; "Variable Harmonisation Heatmap" – a workspace-oriented effort to showcase the management of different variables across the models of the workspace; and "Virtual Library" – a content-based section containing documents like publications, policy briefs, data files and sources, etc. pertinent to the workspace.

Architecture-wise, these services require data that are extracted from files (following defined templates) shared by partners and external contributors, utilising three different implemented data parsers, and are stored in the I2AM PARIS database. The I2AM PARIS Backend holds the data models used for the representation of the data in a structured and machine-friendly way and manages the interaction among all components. The Data Manager, responsible for query execution and data transformation, and the Visualiser, a chart generator, constitute the Visualisation Engine that aims at producing all the necessary visualisations for the I2AM PARIS platform, including both static and interactive interfaces commonly agreed among the involved partners and stakeholders, promoting co-creation and collaborative thinking, with a view to developing exploitable tools for both scientists and different types of stakeholder groups, like policymakers, citizens, etc.

Compared to the version of I2AM PARIS that was described in the previous deliverable (2.5), the following features have been implemented:

- Five new workspaces, introducing modelling results in the database and producing the respective interfaces.
- An additional table interface to present the results of Recovery Policy Database.
- Performance improvements, data curation, and bug fixing.

The platform, as of November 11, 2022, counts 4,300 unique visitors corresponding to 8,400 sessions and with an average visiting time of 5.5 minutes per session (as reported by Google Analytics).

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The platform will be supported for at least 5 years through the work of the H2020 projects **NDC ASPECTS**[10] and **ENCLUDE**[11], and the Horizon Europe projects **IAM COMPACT**[12] and **DIAMOND**[13]. During the course of these projects, the platform will be enhanced with new features such as automated data checks and user interfaces for the automatic creation of workspaces through data input fields. Additionally, the target group of the workspaces will be expanded, and new interfaces will be developed for other users of climate information such as industry representatives and citizens. On the latter, significant efforts will be taken from the new projects to develop pathways based on the feedback of a large variety of stakeholders, including citizens. Further work in these projects will ensure the sustainability of I²AM PARIS, further promoting and cementing the platform as a vessel of information on climate and energy research.

[10] https://www.ndc-aspects.eu/
[11] https://encludeproject.eu/
[12] https://www.iam-compact.eu
[13] https://www.climate-diamond.eu

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