3 Introduction of validity checks

The validity and credibility of modelling methods, inputs, and outputs are quintessential for providing stakeholders of climate action with the confidence to use modelling information in strategic decision-making, investment planning and policy design. Data quality is even more significant in large modelling exercises, where the volume of modelling and scenario data increases to a level that it becomes difficult to visually keep track, requiring automatic algorithmic checks. While a wide range of validation methods and protocols have been developed in the last decade, the growing modelling community and the wide production of studies require user-friendly and transparent methods for helping modellers to ensure data quality in their results.

During PARIS REINFORCE, an initial level of quality check was achieved by means of a common template for formatting modelling results from the Integrated Assessment Modelling Consortium (IAMC)[16]. The template is prevalent in the community of climate mitigation modelling and was recently used for data input in the scenario database of the Sixth Assessment Report (AR6) of the Intergovernmental Panel for Climate Change (IPCC). The template has index fields for models, scenarios, regions, variables, and units, and then shows data values for specific years following a timeseries format (see Table 1). While the template helped standardise the format of scenario results of the PARIS REINFORCE project, many parsing errors were observed due to mistakes in variable names or model names as well as due to duplicate data.

Table 1. Example of the IAMC template[17] for modelling results of climate change mitigation

Model	Scenario	Region	Variable	Unit	2005	2010	...
GCAM	Baseline	World	Temperature|Global Mean	°C	0.89	1.01	...

Based on a meeting with modelling partners within IAM COMPACT in December 2022 as well as drawing from the experience of PARIS REINORCE and other modelling projects, the following validation checks were suggested:

- **Model name consistency**: Model names in results will be kept consistent with the ones used in the documentation components. In that way, the different platform sections can cross-reference one another, allowing visitors to directly access details of models that were used to create specific results—and vice versa. Model names in the results will include the exact model version used for a specific modelling run, providing a link to version-specific documentation in the platform or in other locations such as code repositories (for instance, the repository of the GCAM model in GitHub[18]).
- **Variable name consistency**: Variable entries will be checked against the typical list of variables used in the IPCC reports. In case that a new variable is added, it will be flagged so that the user can confirm whether it is truly a new variable or a misspelt version of an existing one.
- **Region name consistency**: Like variables, regions will be checked against the typical list of regions used in the IPCC as well as in other major modelling projects, such as the ECEMF or NAVIGATE projects.
- **Unit consistency**: Typical units will be coupled with specific variables to avoid the case that models use different units for the same variable, allowing for easier comparison. Deviations will be reported, and users will be recommended to use the standard unit type. For many standard unit conversions, such as between joule, watt hour, and tonne oil equivalent, a unit converter routine will be developed and automatically apply when new modelling results are added to the platform (subject to confirmation from the user that uploads these results).
- **Duplication checks:** The check will search for entries with the same indices and flag potential

[16] https://www.iamconsortium.org/scientific-working-groups/data-protocols-and-management/iamc-time-series-data-template/
[17] https://pyam-iamc.readthedocs.io/en/stable/
[18] https://github.com/JGCRI/gcam-core

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duplicates.

- **Value format**: Entries under the value columns will be checked as to whether they contain numerical data. Empty entries will be assumed to indicate a N/A value. This will be communicated to all consortium modellers, as some models may indicate zero values as an empty entry. In that case, these cells will need to be changed to a zero numeral before adding data to the platform.
- **Basic sums across variables**: When variables are provided both in a disaggregated and an aggregated form (for instance, total emissions and emissions per sector), the sum of the disaggregated variables will be checked against the aggregated one and flagged when the deviation is larger than ±1-2%.

It is noted that some of these checks may be already present in the nomenclature software package provided by the IAMC[19]. In that case, the code repository of this software will be forked and extended accordingly. Apart from validation checks, data consistency and feasibility checks will be also implemented, based on different benchmarks. Among other metrics, we will evaluate our modelling results against the 'vetting' criteria used at the IPCC AR6 scenario database. This vetting process required key indicators of modelled scenarios to be within reasonable ranges for a historical year (commonly 2019 or 2015); other vetting criteria assessed the feasibility of future scenario projections, indicating, for instance, whether models assumed very high or unrealistic ramp-up rates for specific technologies. The IPCC AR6 vetting criteria mostly relate to emissions and energy sector characteristics and can be seen in Table 1 below.

Table 2. Vetting criteria from the IPCC AR6 scenario database (Annex 3[20], Section 3.1)

Indicators	Reference value	Vetting range for all global scenarios	Vetting range for illustrative pathways
Historical emissions (sources EDGAR v6 IPCC and CEDS, 2019 values)			
CO_2 total emissions (EIP + AFOLU)	44,251 $MtCO_2$/yr	±40%	±20%
CO_2 EIP emissions	37,646 $MtCO_2$/yr	±20%	±10%
CH_4 emissions	379 $MtCH_4$/yr	±20%	±20%
CO_2 emissions EIP 2010-2020 - % change	-	0 to +50%	0 to +50%
CCS from Energy 2020	-	0-250 $MtCO_2$/yr	0-100 $MtCO_2$/yr
Historical energy production (sources IEA 2019; IRENA; BP; EMBERS; trends extrapolated to 2020)			
Primary Energy (2020, IEA)	578 EJ	±20%	±10%
Electricity Nuclear (2020, IEA)	9.77 EJ	±30%	±20%
Electricity Solar & Wind (2020, IEA, IRENA, BP, EMBERS)	8.51 EJ	±50%	±25%
Future criteria (not used for exclusion, only flagged as potentially problematic)			
No net negative CO_2 emissions before 2030	CO_2 total in 2030 > 0	-	-
CCS from Energy in 2030	< 2000 $MtCO_2$/yr	-	-
Electricity from Nuclear in 2030	< 20 EJ/yr	-	-
CH_4 emissions in 2040	100-1000 $MtCH_4$/yr	-	-

Note: EIP stands for energy and industrial process emissions; AFOLU stands for Agriculture, Forestry and Other Land Use.

Apart from the vetting criteria of IPCC AR6, additional data consistency and feasibility checks will be established to evaluate more variables or regional results (e.g., individual values for the EU or China). All data checks will be scripted using the Python programming language. The script will take scenario results from a modelling exercise as an input, using an Excel or CSV format based on the IAMC template. As an output, the script will flag the

[19] https://github.com/IAMconsortium/nomenclature
[20] https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_Annex-III.pdf

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scenarios that do not pass the data consistency and validation process and explicitly show the indicators that fail. The script will then be deployed in the platform and integrated in an interface that will be developed in the future, allowing modellers to insert scenario results to the platform directly (see Chapter 4 for more details). The interface will be interactive, showing first validation results to modellers before submitting their data to the platform and allowing them to upload a corrected version of the results if needed. A version control system will also be developed, to allow modellers to track the versions of results that are within the platform.

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