
Climate assessment of long-term emissions pathways: IPCC AR6 WGIII version

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Integrated assessment models (IAMs) produce emissions pathways as part of larger pathway output coming from the modelling of scenarios. These emissions pathways imply a certain temperature development. Some integrated assessment modelling teams can provide their own climate assessment based on these emissions outcomes, others just work on the level of emissions. Not all IAMs model all societal processes that cause emissions, meaning that they also generally do not report all emissions species required to run a climate model.

For the Working Group III (WGIII) contribution to the IPCC Sixth Assessment (AR6) report, a large set of scenarios with emissions pathways had to be assessed and classified based on their temperature implications. To do so, emission pathways need to be harmonized to the same historical emissions, need to report the same set of greenhouse gases, and need to be run with the same (simple) climate model(s).

This repository package allows for reproducing the AR6 results, as well as assessing your own full-century emissions pathways, given certain minimum requirements as described in the [Description of the workflow](#).

More information on how this package was used in AR6 can be found in the report itself, as well as the manuscript accompanying the release of this package.

GETTING STARTED

While this package aims to make it easier to run a climate model for a specific long-term scenario with emissions pathways, it is not quite “click and run”. Using this package requires some domain knowledge, understanding of certain research methods, and scientific computing skills.

- *Prerequisite knowledge & skills* gives an (incomplete, but hopefully helpful) list of these items for formal and self-guided learning.

After you have read the section above, you can get started with reading a more detailed description of the workflow (*Description of the workflow*), read about what ways there are to install this software (*Installation*), and go through a few examples for new users that demonstrate the basic features of the workflow (*How to use*).

1.1 Prerequisite knowledge & skills

Code knowledge. This package is implemented in the programming language Python. In order to use this properly, it is expected that you have a basic understanding of Python, using an Anaconda command prompt, as well as an environment manager like conda, or know how to install packages using pip. The workflow extensively uses the packages pyam, openscm, scmdata, and pandas for operations. Examples are implemented using Jupyter Notebooks.

Understanding emissions input files This workflow uses the IAMC format used also by pyam for emissions input. The input emissions must follow the AR6 scenario submission template. To see which emissions are accepted as input for the climate assessment workflow, see the file “data/emissions_variable_list_climateruns.xlsx”.

Computing power. Running one scenario for all configurations of one simple climate model can easily take up to one hour on a personal computer. For running scenario sets bigger than about 10-20 scenarios, you require more computing power. While MAGICC7 and CICERO-SCM mostly benefit from more cores, FaIR especially requires more RAM.

Tuning parallelisation settings for your specific setup currently requires delving into the code, editing joblib settings, and re-installing (e.g. with `pip install -e .`).

This workflow has been tested on Windows 10 and Linux (Ubuntu).

Questions. For questions, feel free to contact kikstra@iiasa.ac.at or raise an issue at <https://github.com/iiasa/climate-assessment/issues>

1.2 Description of the workflow

On this page, you will find a short summary of the main function of this package. The workflow is described in detail in the following manuscript:

Jarmo S. Kikstra, Zebedee R. J. Nicholls, Christopher J. Smith, Jared Lewis, Robin D. Lamboll, Edward Byers, Marit Sandstad, Malte Meinshausen, Matthew J. Gidden, Joeri Rogelj, Elmar Kriegler, Glen P. Peters, Jan S. Fuglestad, Ragnhild B. Skeie, Bjørn H. Samset, Laura Wienpahl, Detlef P. van Vuuren, Kaj-Ivar van der Wijst, Alaa Al Khourdajie, Piers M. Forster, Andy Reisinger, Roberto Schaeffer, and Keywan Riahi

“The IPCC Sixth Assessment Report WGIII climate assessment of mitigation pathways: from emissions to global temperatures”.

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2022

Integrated assessment models (IAMs) produce emissions pathways as part of larger pathway output coming from the modelling of scenarios. These emissions pathways imply a certain temperature development.

Some integrated assessment modelling teams can provide their own climate model runs based on these emissions outcomes, others just work on the level of emissions. Not all IAMs model all societal processes that cause emissions and therefore not all models report pathways for all emissions species for all scenarios. On top of that, for comparability, using the same climate model serves purposes of comparability. For a comprehensive assessment of all available long-term greenhouse gas emissions scenarios, like in the working group III (WGIII) contribution to the IPCC Sixth Assessment report (AR6), both consistency and calibration are required.

The workflow that ensures both this consistency and calibration is as follows (see also Figure 1):

0. Calibrating historical temperatures in climate emulators have to be harmonized to a historical temperature assessment and climate parameters across emulators have to be calibrated;
1. Preparing scenarios with emissions pathways;
2. “Harmonization”: Emissions pathways from IAM scenarios have to be harmonized against historical emissions observations in order to start from the same emissions levels (while still respecting the trends as described in the pathways);
3. “Infilling”: in order to assess each scenario based on a complete set of emissions, we need to infer missing (non-reported) emissions pathways (which can be more or less important depending on exactly what they are) for each scenario;
4. “Climate” – running earth system model emulators.

Step 0. was done in Chapter 7 of the working group I (WGI) contribution to AR6. The earth system model emulators (also called ‘climate emulator’, ‘emulator’, ‘reduced complexity model’, or ‘simple climate model’), also analyzed in the Reduced Complexity Model Intercomparison Project (RCMIP) Phase 1 and Phase 2, are run using the `openscm-runner` package.

Step 1. in AR6 was done by modelling teams across the world, with the scenarios submitted to and made available in the AR6 Scenario Database Explorer.

Step 2., *step 3.*, and *step 4.* are performed by this package.

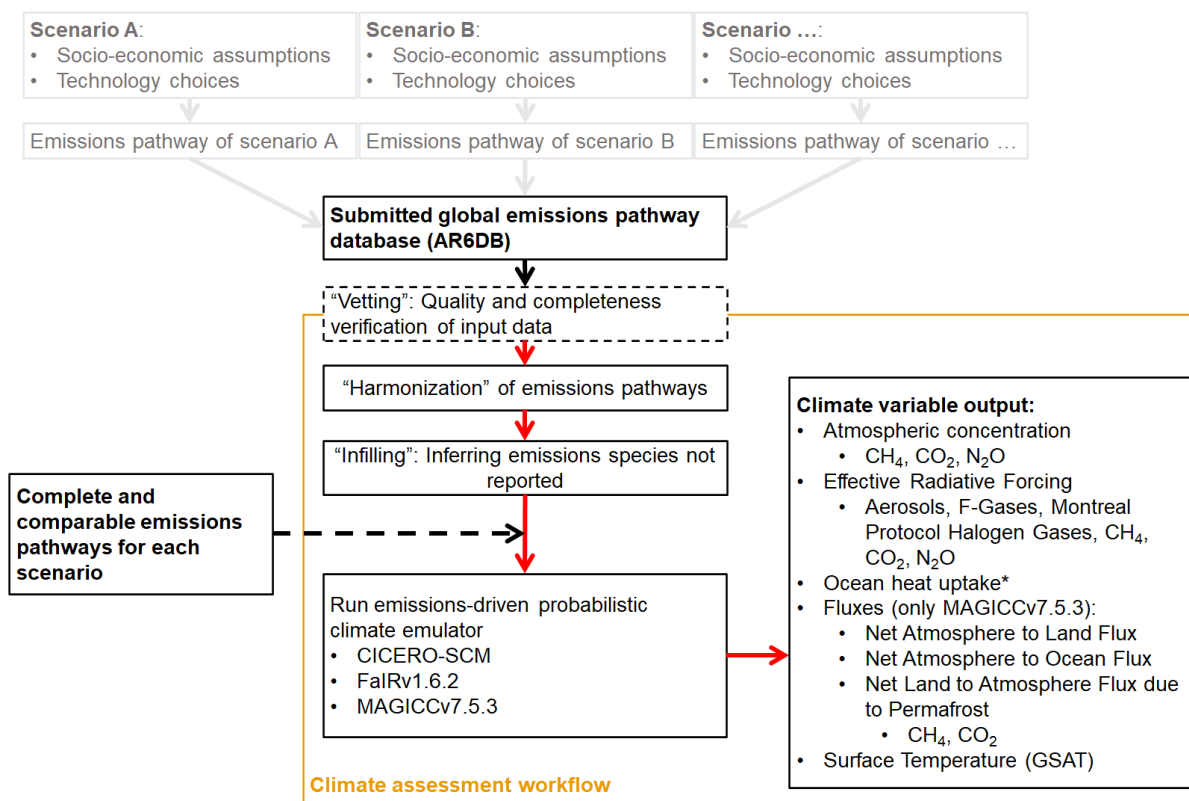


Fig. 1: **Figure 1:** Overview of the AR6 workflow.

1.2.1 Expected Input (Step 1)

The expected input is in the following format, as either an Excel (.xlsx) or CSV (.csv) file, covering 2015, and then at minimum decadal (up to yearly detail is accepted) timesteps from 2020 to 2100. Currently, no meta data from the input data is used or preserved in the workflow. At minimum, one needs to report *Emissions|CO2|Energy and Industrial Processes*. Emissions baskets or species not in the table below are not considered for the eventual climate assessment, but are automatically infilled. In this version, negative values are only allowed as input for CO₂.

Model	Scenario	Region	Variable	Unit	2015	2100
		World	Emissions BC	Mt BC/yr				
		World	Emissions CH4	Mt CH4/yr				
		World	Emissions CO	Mt CO/yr				
		World	Emissions CO2 AFOLU	Mt CO2/yr				
		World	Emissions CO2 Energy and Industrial Processes	Mt CO2/yr				
		World	Emissions HFC HFC125	kt HFC125/yr				
		World	Emissions HFC HFC134a	kt HFC134a/yr				
		World	Emissions HFC HFC143a	kt HFC143a/yr				
		World	Emissions HFC HFC23	kt HFC23/yr				
		World	Emissions HFC HFC32	kt HFC32/yr				
		World	Emissions HFC HFC43-10	kt HFC43-10/yr				
		World	Emissions N2O	kt N2O/yr				
		World	Emissions NH3	Mt NH3/yr				
		World	Emissions NOx	Mt NO2/yr				
		World	Emissions OC	Mt OC/yr				
		World	Emissions PFC C2F6	kt C2F6/yr				
		World	Emissions PFC C6F14	kt C6F14/yr				
		World	Emissions PFC CF4	kt CF4/yr				
		World	Emissions SF6	kt SF6/yr				
		World	Emissions Sulfur	Mt SO2/yr				
		World	Emissions VOC	Mt VOC/yr				

1.2.2 Workflow (Step 2-4)

Harmonization (Step 2)

Emissions harmonization refers to the process used to align modeled GHG and air pollutant pathways with a common source of historical emissions. This capability enables a common climate estimate across different models, increases transparency and robustness of results, and allows for easier participation in intercomparison exercises by using the same, openly available harmonization mechanism. We use the open-source Python software package called *aneris* to achieve this aim.

Infilling (Step 3)

Infilling ensures that all relevant anthropogenic emissions are included in each climate run for each scenario. This makes the climate assessment of alternative scenarios more comparable and reduces the risk of a biased climate assessment, because not all climatically active emission species are reported by all IAMs. The infilling methods used are from an open-source Python software package called *silicone*.

Climate (Step 4)

After model-reported emissions pathways have been both harmonized and infilled, they are ready as input for climate emulators. At the moment, three climate emulators are coupled to the workflow: FaIRv1.6.2, CICERO-SCM, and MAGICCv7.5.3. These climate emulators are run in probabilistic mode, based on a multi-member input set (coming from the calibration done in AR6 WGI). As this output is much too big to store (couple hundred MB per scenario per climate emulator), we do not write this out but rather calculate statistics over the variables, which are then reported as output of the workflow.

1.2.3 Expected Output

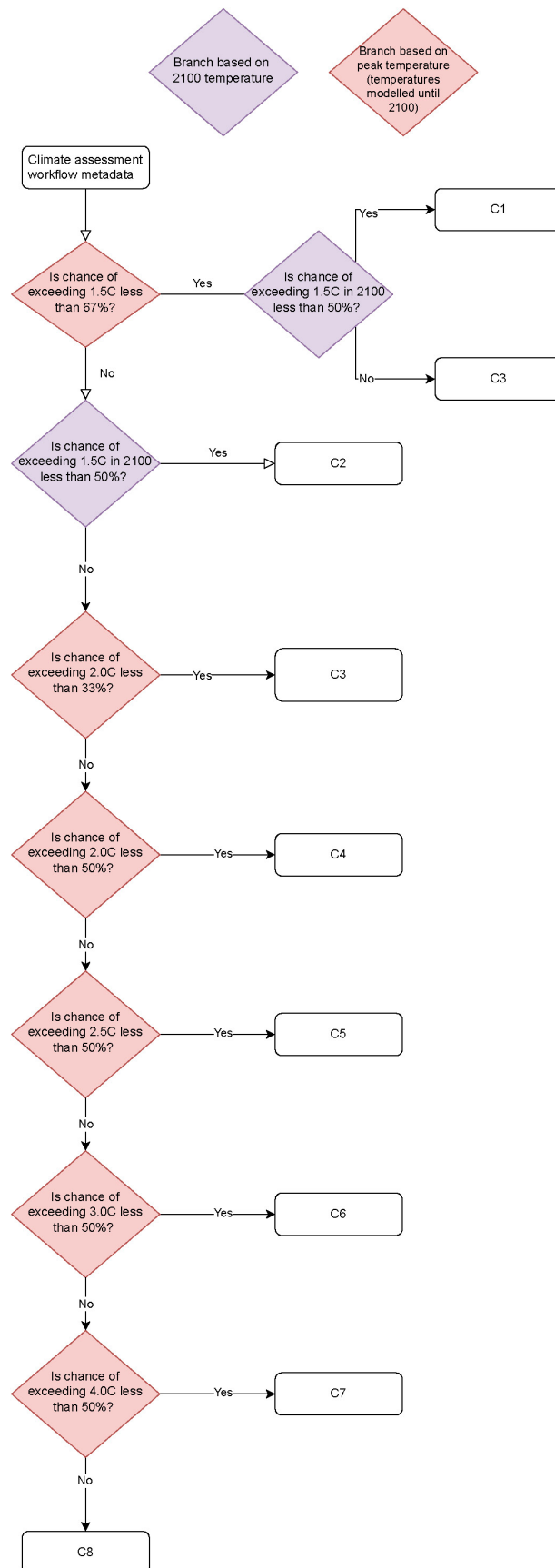
The output of the climate assessment workflow comes with both probabilistic scenario timeseries (data) and additional information per scenario (metadata).

Scenario metadata

Each scenario that can be assessed by the climate emulators receives extensive climate metadata at the end of the workflow. One key way that this metadata was used in the Sixth Assessment report was to classify scenarios in to temperature-based categories (from C1 to C8). In the figure below you can see an overview of the classification scheme that was applied.

Timeseries data

The expected output is in the following format (here emulator MAGICCv7.5.3 is used as example):



Model	Scenario	Region	Variable	Unit	1995	2100
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 10.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 16.7th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 33.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 5.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 50.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 67.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 83.3th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 90.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CH4 MAGICCv7.5.3 95.0th Percentile	ppb				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 10.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 16.7th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 33.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 5.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 50.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 67.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 83.3th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 90.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations CO2 MAGICCv7.5.3 95.0th Percentile	ppm				
		World	AR6 climate diagnostics Atmospheric Concentrations N2O MAGICCv7.5.3 10.0th Percentile	ppb				
		World				
		World	AR6 climate diagnostics Surface Temperature (GSAT) MAGICCv7.5.3 50.0th Percentile	K				
		World	AR6 climate diagnostics Surface Temperature (GSAT) MAGICCv7.5.3 67.0th Percentile	K				
		World	AR6 climate diagnostics Surface Temperature (GSAT) MAGICCv7.5.3 83.3th Percentile	K				
		World	AR6 climate diagnostics Surface Temperature (GSAT) MAGICCv7.5.3 90.0th Percentile	K				
		World	AR6 climate diagnostics Surface Temperature (GSAT) MAGICCv7.5.3 95.0th Percentile	K				

The full list of variables created as output is as follows:

- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CH4|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|67.0th Percentile
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- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|CO2|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|N2O|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Atmospheric Concentrations|N2O|MAGICCv7.5.3|16.7th Percentile
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- AR6 climate diagnostics|Effective Radiative Forcing|Aerosols|Direct Effect|BC|MAGICCv7.5.3|33.0th Percentile
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- AR6 climate diagnostics|Effective Radiative Forcing|Basket|Non-CO2 Greenhouse Gases|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Basket|Non-CO2 Greenhouse Gases|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Basket|Non-CO2 Greenhouse Gases|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C2F6|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|C6F14|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|90.0th Percentile

- AR6 climate diagnostics|Effective Radiative Forcing|CF4|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC11|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CFC12|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CH4|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|90.0th Percentile

- AR6 climate diagnostics|Effective Radiative Forcing|CO2|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|F-Gases|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HCFC22|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC125|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|90.0th Percentile

- AR6 climate diagnostics|Effective Radiative Forcing|HFC134a|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC143a|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC227ea|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC23|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|90.0th Percentile

- AR6 climate diagnostics|Effective Radiative Forcing|HFC245fa|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC32|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|HFC4310mee|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|50.0th Percentile

- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Montreal Protocol Halogen Gases|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|N2O|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|Ozone|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Effective Radiative Forcing|SF6|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Exceedance Probability 1.5C|MAGICCv7.5.3
- AR6 climate diagnostics|Exceedance Probability 2.0C|MAGICCv7.5.3

- AR6 climate diagnostics|Exceedance Probability 2.5C|MAGICCv7.5.3
- AR6 climate diagnostics|Exceedance Probability 3.0C|MAGICCv7.5.3
- AR6 climate diagnostics|Harmonized|Emissions|BC
- AR6 climate diagnostics|Harmonized|Emissions|CH4
- AR6 climate diagnostics|Harmonized|Emissions|CO
- AR6 climate diagnostics|Harmonized|Emissions|CO2|AFOLU
- AR6 climate diagnostics|Harmonized|Emissions|CO2|Energy and Industrial Processes
- AR6 climate diagnostics|Harmonized|Emissions|F-Gases
- AR6 climate diagnostics|Harmonized|Emissions|HFC
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC125
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC134a
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC143a
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC227ea
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC23
- AR6 climate diagnostics|Harmonized|Emissions|HFC|HFC32
- AR6 climate diagnostics|Harmonized|Emissions|Kyoto Gases (AR5-GWP100)
- AR6 climate diagnostics|Harmonized|Emissions|Kyoto Gases (AR6-GWP100)
- AR6 climate diagnostics|Harmonized|Emissions|N2O
- AR6 climate diagnostics|Harmonized|Emissions|NH3
- AR6 climate diagnostics|Harmonized|Emissions|NOx
- AR6 climate diagnostics|Harmonized|Emissions|OC
- AR6 climate diagnostics|Harmonized|Emissions|PFC
- AR6 climate diagnostics|Harmonized|Emissions|SF6
- AR6 climate diagnostics|Harmonized|Emissions|Sulfur
- AR6 climate diagnostics|Harmonized|Emissions|VOC
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Heat Uptake|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Infilled|Emissions|BC
- AR6 climate diagnostics|Infilled|Emissions|CCl4

- AR6 climate diagnostics|Infilled|Emissions|CFC11
- AR6 climate diagnostics|Infilled|Emissions|CFC113
- AR6 climate diagnostics|Infilled|Emissions|CFC114
- AR6 climate diagnostics|Infilled|Emissions|CFC115
- AR6 climate diagnostics|Infilled|Emissions|CFC12
- AR6 climate diagnostics|Infilled|Emissions|CH2Cl2
- AR6 climate diagnostics|Infilled|Emissions|CH3Br
- AR6 climate diagnostics|Infilled|Emissions|CH3CCl3
- AR6 climate diagnostics|Infilled|Emissions|CH3Cl
- AR6 climate diagnostics|Infilled|Emissions|CH4
- AR6 climate diagnostics|Infilled|Emissions|CHCl3
- AR6 climate diagnostics|Infilled|Emissions|CO
- AR6 climate diagnostics|Infilled|Emissions|CO2|AFOLU
- AR6 climate diagnostics|Infilled|Emissions|CO2|Energy and Industrial Processes
- AR6 climate diagnostics|Infilled|Emissions|HCFC141b
- AR6 climate diagnostics|Infilled|Emissions|HCFC142b
- AR6 climate diagnostics|Infilled|Emissions|HCFC22
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC125
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC134a
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC143a
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC152a
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC227ea
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC23
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC236fa
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC245ca
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC32
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC365mfc
- AR6 climate diagnostics|Infilled|Emissions|HFC|HFC43-10
- AR6 climate diagnostics|Infilled|Emissions|Halon1202
- AR6 climate diagnostics|Infilled|Emissions|Halon1211
- AR6 climate diagnostics|Infilled|Emissions|Halon1301
- AR6 climate diagnostics|Infilled|Emissions|Halon2402
- AR6 climate diagnostics|Infilled|Emissions|Kyoto Gases (AR5-GWP100)
- AR6 climate diagnostics|Infilled|Emissions|Kyoto Gases (AR6-GWP100)
- AR6 climate diagnostics|Infilled|Emissions|N2O
- AR6 climate diagnostics|Infilled|Emissions|NF3

- AR6 climate diagnostics|Infilled|Emissions|NH3
- AR6 climate diagnostics|Infilled|Emissions|NOx
- AR6 climate diagnostics|Infilled|Emissions|OC
- AR6 climate diagnostics|Infilled|Emissions|PFC|C2F6
- AR6 climate diagnostics|Infilled|Emissions|PFC|C3F8
- AR6 climate diagnostics|Infilled|Emissions|PFC|C4F10
- AR6 climate diagnostics|Infilled|Emissions|PFC|C5F12
- AR6 climate diagnostics|Infilled|Emissions|PFC|C6F14
- AR6 climate diagnostics|Infilled|Emissions|PFC|C7F16
- AR6 climate diagnostics|Infilled|Emissions|PFC|C8F18
- AR6 climate diagnostics|Infilled|Emissions|PFC|CF4
- AR6 climate diagnostics|Infilled|Emissions|PFC|cC4F8
- AR6 climate diagnostics|Infilled|Emissions|SF6
- AR6 climate diagnostics|Infilled|Emissions|SO2F2
- AR6 climate diagnostics|Infilled|Emissions|Sulfur
- AR6 climate diagnostics|Infilled|Emissions|VOC
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Land Flux|CO2|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Net Atmosphere to Ocean Flux|CO2|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|16.7th Percentile

- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CH4|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Net Land to Atmosphere Flux due to Permafrost|CO2|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GMST)|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|16.7th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Raw Surface Temperature (GSAT)|MAGICCv7.5.3|95.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|10.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|16.7th Percentile

- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|33.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|5.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|50.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|67.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|83.3th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|90.0th Percentile
- AR6 climate diagnostics|Surface Temperature (GSAT)|MAGICCv7.5.3|95.0th Percentile

1.3 Installation

- *Using pip*
- *From source*
- *Infiller database*
- *Climate emulator configuration files*

This package is tested using python 3.9, and has also been used with python 3.7, though continuous integration tests are not run for 3.7.

Attention: Due to the better dependency resolution installing with `pip>=22` is recommended.

1.3.1 Using pip

`pip` is Python's default package management system. If you install Anaconda, then `pip` is also usable. `pip` can also be used when Python is installed directly, *without* using Anaconda.

1. Ensure `pip` is installed—with Anaconda, or according to the `pip` documentation.
2. Open a command prompt and run:

```
$ pip install climate-assessment
```

1.3.2 From source

1. (Optional) If you intend to contribute changes to `climate-assessment`, first register a Github account, and fork the `climate-assessment`-repository. This will create a new repository `<user>/climate-assessment`.
2. Clone either the main repository, or your fork; using the `Github Desktop` client, or the command line:

```
$ git clone git@github.com:iiasa/climate-assessment.git  
  
# or:  
$ git clone git@github.com:USER/climate-assessment.git
```

3. Open a command prompt in the `climate-assessment` directory and type:

```
$ pip install --editable .[docs,tests,deploy,linter,notebooks]
```

The `--editable` flag ensures that changes to the source code are picked up every time `import climate-assessment` is used in Python code. The `[docs,tests,deploy,linter,notebooks]` extra requirements ensure additional dependencies are installed.

4. (Optional) If installed from source, run the built-in test suite to check that `climate-assessment` functions correctly on your system:

```
$ pytest tests/integration -m "not nightly and not wg3"
```

Credits

The `message_ix` [documentation](#) was the main source of the text in this *installation guide*.

1.3.3 Infiller database

To reproduce the results from the Sixth Assessment Report Working Group III, one must download the AR6 infiller database from the AR6 Scenario Explorer. Go to <https://data.ene.iiasa.ac.at/ar6/>, log in, and under “Downloads” you will find “Infiller database for silicone: IPCC AR6 WGIII version (DOI: 10.5281/zenodo.6390768)”. Download that file, and place it in your folder of choice (we suggest `climate-assessment/data`). After that, you can use the following option `--infilling-database data/1652361598937-ar6_emissions_vetted_infillerdatabase_10.5281-zenodo.6390768.csv` when using the command-line interface.

1.3.4 Climate emulator configuration files

To reproduce the results from the Sixth Assessment Report Working Group III, one must download the relevant specific configuration files for the climate emulator you want to use. See (see [Climate emulators](#)) for more information.

1.4 How to use

1.4.1 Preparation steps before running from Command Line Interface (CLI)

1. Put input emissions csv files in desired folder (suggested: “data”)
2. Download the required configuration files for the climate emulator you want to use (see [Climate emulators](#))
3. (optional, but recommended) Download an infiller database like the one used for AR6 (see [Infiller database](#))
4. Open up an anaconda prompt, load the right environment, go to the `climate-assessment` folder
5. Run `python scripts/run_workflow.py` with appropriate arguments

Example usage: `python scripts/run_workflow.py tests/test-data/ex2.csv output --model "fair" --model-version "1.6.2" --num-cfgs 2237 --probabilistic-file data/emulator/fair/fair-1.6.2-wg3-params-slim.json --fair-extra-config data/emulator/fair/fair-1.6.2-wg3-params-common.json --infilling-database src/climate_assessment/infilling/cmip6-ssps-workflow-emissions.csv`

Warning: The above example uses the very simple and small infiller database “cmip6-ssps-workflow-emissions.csv”, which will yield a warning. For most applications, it is strongly advised to use a larger infiller database, like the one based on AR6 scenarios.

Please make sure you have followed the download instructions under *Infiller database* on how to use the full AR6 setup.

1.4.2 Further examples

We also provide one worked example as a Jupyter Notebook, namely under `notebooks/run-example-fair.ipynb`

CODE DESCRIPTION

To better understand what is going on, or to use more advanced options of this workflow, we provide more detailed documentation on specific parts of the workflow, as well as describe the functionality of the functions in the code base.

The page [Core configuration](#) provides detailed description of the command line interface (CLI), that can be used from e.g. an Anaconda prompt, and descriptions of specific functions for infilling, harmonization, climate emulator runs, and post-processing.

The page [Climate emulators](#) provides more detail and instructions on how the climate emulators FaIR, CICERO-SCM, and MAGICC are coupled to this workflow, where to download additional files, and how to set up emulators for running.

The page [Utility functions](#) lists a couple of utility functions that serve some specific functions including calculating a GHG basket to estimate CO₂eq Kyoto Gases.

Lastly, if you would like to contribute to the code of this package, please check out the [Notes for developers](#).

2.1 Core configuration

Table of Contents

- *CLI*
 - *Infilling database*
 - *Infilling*
 - *Harmonisation*
 - *Harmonisation and infilling*
 - *Workflow*
 - *Climate*
 - *Postprocess*
- *Infilling*
- *Harmonization*
- *Harmonisation and infilling*
- *Climate*
 - *Postprocess*
- *Postprocess*

- *Checks on input and output scenario data*

2.1.1 CLI

Infilling database

`climate_assessment.cli.create_infiller_database(*args: Any, **kwargs: Any) → Any`

Creates infiller database by harmonizing data in `input_emissions_file` which is followed by some common-sense vetting and then saved in `outdir`

`input_emissions_file` should be a path to a file of emissions

`outdir` should be a path a directory which already exists

Infilling

`climate_assessment.cli.infill(*args: Any, **kwargs: Any) → Any`

Infill harmonized data in `input_emissions_file`, saving output in `outdir`

`input_emissions_file` should be a path to a file of harmonized emissions

`outdir` should be a path a directory which already exists

Harmonisation

`climate_assessment.cli.harmonize(*args: Any, **kwargs: Any) → Any`

Harmonise data in `input_emissions_file`, saving output in `outdir`

`input_emissions_file` should be a path to a file of emissions

`outdir` should be a path a directory which already exists

Harmonisation and infilling

`climate_assessment.cli._harmonize_and_infill(input_df, inputcheck, key_string, outdir, infilling_database, harmonize, prefix, harmonization_instance)`

Thin wrapper function for running both harmonization and infilling.

Returns True if there are scenarios that can be run by a climate emulator. Those scenarios are not returned by this function, but rather written to the `outdir`. Returns False if there are no complete scenarios to be run.

For more information, see the code description under `climate_assessment.harmonization_and_infilling.harmonization_and_infilling()`.

`climate_assessment.cli.harmonize_and_infill(*args: Any, **kwargs: Any) → Any`

Harmonise and infill data in `input_emissions_file`, saving output in `outdir`

`input_emissions_file` should be a path to a file of emissions

`outdir` should be a path a directory which already exists


```
climate_assessment.cli.harmonization_and_infilling(df, key_string, infilling_database, prefix='AR6
climate_diagnostics', instance='ar6',
outdir='output', do_harmonization=True)
```

Parameters

- **input_df** (pyam.IamDataFrame) – Input native emissions to harmonize and infill.
- **inputcheck** (bool) – Perform checks to remove unsuitable emissions pathways. [Default: True]
- **key_string** (str) – Identifier string for writing out results. By default derived from the input_emissions_file string in a CLI command.
- **outdir** (str) – Path to output folder.
- **infilling_database** (str) – Path to the infiller database emissions file.
- **harmonize** (bool) – Perform harmonization (with False, only infilling is run). [Default: True]
- **prefix** (str) – Prefix used to identify the new variable names of results produced by the workflow.
- **harmonization_instance** (str) – Config string required by anemis.

Returns

Returns True if there are scenarios that can be run by a climate emulator. Those scenarios are not returned by this function, but rather written to the outdir. Returns False if there are no complete scenarios to be run.

Return type

bool

Workflow

```
climate_assessment.cli.workflow(*args: Any, **kwargs: Any) → Any
```

Run the full IPCC AR6 climate assessment workflow.

Example usage: `python scripts/run_workflow.py tests/test-data/ex2.csv output --model "FaIR" --model-version "1.6.2" --num-cfgs 2237 --probabilistic-file tests/test-data/fair-1.6.2-wg3-params-slim.json --fair-extra-config tests/test-data/fair-1.6.2-wg3-params-common.json --infilling-database src/climate_assessment/infilling/cmip6-ssps-workflow-emissions.csv`

See further documentation at [Description of the workflow](#).

Climate

```
climate_assessment.cli.clim_cli(*args: Any, **kwargs: Any) → Any
```

Run the climate emulator step of the IPCC AR6 climate assessment workflow.

Example usage: `python scripts/run_clim.py tests/test-data/workflow-fair/ex2_harmonized_infilled.csv output --model "fair" --model-version "1.6.2" --num-cfgs 2237 --probabilistic-file tests/test-data/fair-1.6.2-wg3-params-slim.json --fair-extra-config tests/test-data/fair-1.6.2-wg3-params-common.json --scenario-batch-size 4`

For more information, see the code description under `climate_assessment.climate.climate_assessment()`.

Postprocess

`climate_assessment.cli._postprocess_worker(fname, outdir, **kwargs)`

Helper function which takes a file that ends with “_rawoutput.xlsx” and the output location, and then calls the function `do_postprocess(output, outdir, key_string, prefix)`.

`climate_assessment.cli.postprocess(*args: Any, **kwargs: Any) → Any`

Merge and postprocess a collection of rawoutput into a single set of output files

This script should be run after `run_workflow.py` if `--no-postprocess` was supplied. This is particularly useful for a clustered run where a `run_workflow` is run multiple times with batches of scenario data.

Each file is processed individually, but the metadata from all the runs is merged into a single output file.

2.1.2 Infilling

`climate_assessment.infilling.run_infilling(harmonised_df, prefix, database_filepath=None, start_year=2015, end_year=2100)`

Run infilling

Parameters

- **harmonised_df** (`pyam.IamDataFrame`) – Input harmonised emissions to infill
- **prefix** (`str`) – Prefix used for the variable names
- **database_filepath** (`str`) – Path to the file which contains the infilling database
- **start_year** (`int`) – First year which should be reported in output
- **end_year** (`int`) – Last year which should be reported in output

Returns

Infilled emissions. Output also includes the input emissions. The output is interpolated onto an annual timestep.

Return type

`pyam.IamDataFrame`

`climate_assessment.infilling._infill_variables(cruncher, variables, to_infill, db, lead, output_timesteps, old_prefix)`

Start core infilling run, using `silicone.multiple_infillers.infill_all_required_variables`

Parameters

- **cruncher** (`str`) – Infilling method
- **variables** (`list`) – List of required variables to infill
- **to_infill** (`pyam.IamDataFrame`) – Emissions data to be infilled
- **db** (`pyam.IamDataFrame`) – The infilling database
- **lead** (`str`) – Lead infiller variable
- **output_timesteps** (`list`) – List of required output timesteps

- **old_prefix** (*str*) – The prefix of harmonized emissions, which will be replaced by a prefix for the infilled emissions variables.

Returns

Infilled emissions.

Return type

`pyam.IamDataFrame`

`climate_assessment.infilling._add_to_infilled(infilled, infilled_variables)`

Helper function which takes two dataframes, and binds them together.

Parameters

- **infilled** (`pyam.IamDataFrame`) – An `IamDataFrame`.
- **infilled_variables** (*str*, *None*) – An `IamDataFrame`.

Returns

An `IamDataFrame`.

Return type

`pyam.IamDataFrame`

`climate_assessment.infilling.load_csv_or_xlsx_for_one_region(file, sheet)`

This loads data from either a csv or an xls(x) file and checks that it has only a single region.

Parameters

- **file** (*str*, *None*) – The (relative or absolute) file address of the file to load
- **sheet** (*str*, *None*) – If file is a csv, use *None*. Otherwise, the sheet name to read from the file.

Returns

The information in the file.

Return type

`pyam.IamDataFrame`

`climate_assessment.infilling.postprocess_infilled_for_climate(df_infilled, prefix, start_year=2015)`

Helper function that takes a set of infilled emissions data, adds a provided prefix, and filters out the scenarios that are appropriately infilled by checking both for a minimum set of years of data and checking that there are no non-co2 negative emissions caused by the infilling method.

Parameters

- **df_infilled** (`pyam.IamDataFrame`) – Infilled data.
- **prefix** (*str*) – Prefix used for the variable names

Returns

Checked and reformatted infilled data.

Return type

`pyam.IamDataFrame`

2.1.3 Harmonization

`climate_assessment.harmonization.postprocessing(harmonized_results, prefix)`

Helper function that makes sure that the harmonization prefix is added.

`climate_assessment.harmonization.add_year_historical_percentage_offset(df, dfhist, yr=2015, low_yr=2010)`

In the case that the chosen harmonization year (yr, default=2015) is not reported, this function uses an earlier year (low_yr, default=2010) to derive the historical offset for harmonization. It takes the relative difference in low_yr, and assumes that this relative difference stays the same until yr.

`climate_assessment.harmonization.run_harmonization(df, instance, prefix)`

Run harmonization. Harmonization method overrides by specific species are set within this function too.

Parameters

- **df** (`pyam.IamDataFrame`) – Input native emissions in IAMC format.
- **instance** (`str`) – String used to choose what historical data to use.
- **prefix** (`str`) – Prefix used for the variable names

Returns

Harmonized scenarios.

Return type

`pyam.IamDataFrame`

2.1.4 Harmonisation and infilling

`climate_assessment.harmonization_and_infilling.harmonization_and_infilling(df, key_string, infilling_database, prefix='AR6 climate diagnostics', instance='ar6', outdir='output', do_harmonization=True)`

Parameters

- **input_df** (`pyam.IamDataFrame`) – Input native emissions to harmonize and infill.
- **inputcheck** (`bool`) – Perform checks to remove unsuitable emissions pathways. [Default: True]
- **key_string** (`str`) – Identifier string for writing out results. By default derived from the input_emissions_file string in a CLI command.
- **outdir** (`str`) – Path to output folder.
- **infilling_database** (`str`) – Path to the infiller database emissions file.
- **harmonize** (`bool`) – Perform harmonization (with False, only infilling is run). [Default: True]
- **prefix** (`str`) – Prefix used to identify the new variable names of results produced by the workflow.
- **harmonization_instance** (`str`) – Config string required by anemis.

Returns

Returns True if there are scenarios that can be run by a climate emulator. Those scenarios are not returned by this function, but rather written to the outdir. Returns False if there are no complete scenarios to be run.

Return type

bool

2.1.5 Climate

```
climate_assessment.climate.climate_assessment(df, key_string, outdir, model='magicc',
                                              model_version=None, num_cfgs=600,
                                              historical_warming=0.85,
                                              historical_warming_reference_period='1850-1900',
                                              historical_warming_evaluation_period='1995-2014',
                                              test_run=False, scenario_batch_size=20,
                                              save_raw_output=False,
                                              probabilistic_file='data/magicc/0fd0f62-derived-
metrics-id-f023edb-drawnset.json',
                                              magicc_extra_config=None, fair_extra_config=None,
                                              co2_and_non_co2_warming=False, prefix='AR6 climate
diagnostics')
```

Run the climate assessment

Parameters

- **df** (pyam.IamDataFrame) – pyam.IamDataFrame with data to assess
- **key_string** (str) – String to use to identify output files and find input files
- **outdir** (str) – Directory in which to save the output
- **model** (str) – Reduced-complexity climate model to run assessment with
- **model_version** (str, None) – Version of the climate model. If None, use default
- **num_cfgs** (int) – Number of model configs to run. Multiply this number by the number of scenarios to get total runs. The full drawnset is 600 so if you're just testing it's probably worth using a smaller number unless you want to wait for 58 000 runs (of course by using a smaller subset the temperature numbers won't make sense but if all you're checking is that things run you also don't really care).
- **historical_warming** (float) – Historical warming to match the climate model output to
- **historical_warming_reference_period** (str) – Reference period to use for the historical warming (e.g. "1850-1900")
- **historical_warming_evaluation_period** (str) – Evaluation period to use for the historical warming (e.g. "1995-2014")
- **test_run** (bool) – Is this a test run? If it is, we won't raise an error if the historical temperatures don't match the assessment perfectly.
- **scenario_batch_size** (int) – How many scenarios do you want to run at once? This should be adjusted to balance the amount of RAM and number of cores available on your system. The limit depends mostly on the RAM available.
- **save_raw_output** (bool) – Should we also save the raw climate output (i.e. every ensemble member) to disk?

- **probabilistic_file** (*str*) –

Path to file containing parameters to run climate model with (will be passed to *openscm-runner*). Currently, only json files are supported.

- **co2_and_non_co2_warming** (*bool*) – Include assessment of CO2 and non-CO2 warming (requires 3x as many runs)?
- **prefix** (*str*) – Prefix for all variable names

Returns

`pyam.IamDataFrame` containing climate assessment

Return type

`pyam.IamDataFrame`

```
climate_assessment.climate.run_and_post_process(scenarios, climate_models_cfgs,
                                                climate_models_out_config, historical_warming,
                                                historical_warming_reference_period,
                                                historical_warming_evaluation_period, outdir,
                                                test_run, save_raw_output,
                                                co2_and_non_co2_warming)
```

Run the climate models probabilistically

Uses *openscm-runner* to parallise the model runs. The results are then post processed to calculate exceedence probabilities

Parameters

- **scenarios** (`[scmdata.ScmRun, pyam.IamDataFrame]`) – Emissions for the scenarios of interest
- **climate_models_cfgs** (*dict*) – Configuration as expected by *openscm-runner*
- **climate_models_out_config** (*dict*) – Climate models output config as expected by *OpenSCM-Runner*
- **historical_warming** (*float*) – Historical warming to match the climate model output to
- **historical_warming_reference_period** (*str*) – Reference period to use for the historical warming (e.g. “1850-1900”)
- **historical_warming_evaluation_period** (*str*) – Evaluation period to use for the historical warming (e.g. “1995-2014”)
- **outdir** (*str*) – Output directory for the raw output
- **test_run** (*bool*) – If true, check model output
- **save_raw_output** (*bool*) – If True, save all the raw climate model output for later analysis.
- **co2_and_non_co2_warming** (*bool*) – Include assessment of CO2 and non-CO2 warming?

```
climate_assessment.climate._get_model_configs_and_out_configs(model, model_version,
                                                             probabilistic_file,
                                                             magicc_extra_config,
                                                             fair_extra_config, num_cfgs,
                                                             co2_and_non_co2_warming)
```

Postprocess

`climate_assessment.climate.post_process.check_hist_warming_period(period)`

Check period for historical warming calculations

Parameters

period (*str*) – Input period, must be formatted as “YYYY-YYYY” where the first year is less than or equal to the last year. The last year is included in the period.

Returns

All years in the period

Return type

range

Raises

ValueError – period is formatted incorrectly

`climate_assessment.climate.post_process.calculate_exceedance_probability_timeseries(res, exceedance_probability_cal_test_run=False, historical_warming_evaluation_period='1850-1900', historical_warming_evaluation_period='1995-2014')`

Calculate the timeseries with which we should determine exceedance probabilities.

Please note that calculating the statistical properties like the exceedance probability is done on the count of the raw, full ensemble data. It cannot be derived from the time series of the final statistical indicator afterwards.

`climate_assessment.climate.post_process.calculate_co2_and_nonco2_warming_and_remove_extras(res)`

Calculate non-CO2 warming. Currently only implemented for MAGICC, which can be run twice to allow for this calculation, using (the CLI option) `co2_and_non_co2_warming`.

`climate_assessment.climate.post_process.post_process(res, outdir, test_run=False, save_raw_output=False, co2_and_non_co2_warming=False, temp_thresholds=(1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0), peak_percentiles=(5, 10, 17, 25, 33, 50, 66, 67, 75, 83, 90, 95), percentiles=(5, 10, 16.666666666666664, 17, 25, 33, 50, 66, 67, 75, 83, 83.33333333333334, 90, 95), historical_warming=0.85, historical_warming_reference_period='1850-1900', historical_warming_evaluation_period='1995-2014')`

2.1.6 Postprocess

```
climate_assessment.postprocess.do_postprocess(output, outdir, key_string, prefix,  
                                              model_version='v7.5.3', categorisation=True,  
                                              reporting_completeness_categorisation=True,  
                                              gwp=True, model='magicc')
```

Runs any required postprocessing steps

Namely:

- Categorisation
- Completeness checks
- Add GWP100 Kyoto Gases sums
- Adding additional metadata
- Plots

2.1.7 Checks on input and output scenario data

```
climate_assessment.checks.add_completeness_category(df, filename, delete_no_confidence=False,  
                                                    output_csv=False, outdir='output', prefix='AR6  
climate_diagnostics\Harmonized\')
```

Add a meta column that specified the reporting completeness based on qualitative categories.

```
climate_assessment.checks.check_against_historical(df, filename, instance, output_csv=False,  
                                                  outdir='output')
```

Check against historical data. Currently requires 2015 to already be in the dataframe.

```
climate_assessment.checks.check_negatives(df, filename=None, negativethreshold=-0.1, outdir='output',  
                                          prefix='')
```

Check for negative emissions and remove any timeseries which has negative non-CO2 values.

```
climate_assessment.checks.check_reported_co2(df, filename, output_csv=False, outdir='output')
```

Check CO2 reporting.

```
climate_assessment.checks.co2_energyandindustrialprocesses(df)
```

Auxiliary function for `climate_assessment.checks.check_reported_co2()`. Check if either CO2|Energy and Industrial are reported. Add the aggregate Energy and Industrial, if only subcomponents reported

```
climate_assessment.checks.count_variables_very_high(df, vars, num=9, prefix='AR6 climate  
diagnostics\Harmonized\')
```

Auxiliary function for `climate_assessment.checks.add_completeness_category()`. Performs check of variables + number of variables

```
climate_assessment.checks.infill_vetting(df, prefix='AR6 climate_diagnostics')
```

Filters out a set of harmonized emissions pathways df to then return an infiller_database that does not have emissions pathways that might skew infilling due to what is likely a model reporting error.

```
climate_assessment.checks.perform_input_checks(df, output_csv_files=True, output_filename='checks',  
                                              lead_variable_check=False, historical_check=False,  
                                              reporting_completeness_check=False, outdir='output')
```

Perform several selected checks on the native emissions input to the climate assessment workflow.

Parameters

- **input_df** (`pyam.IamDataFrame`) – Input native emissions before checks.
- **inputcheck** (`bool`) – Perform checks to remove unsuitable emissions pathways. [Default: True]
- **key_string** (`str`) – Identifier string for writing out results. By default derived from the `input_emissions_file` string in a CLI command.
- **outdir** (`str`) – Path to output folder.

Returns

IAM dataframe with only model-scenario that will be without emissions. Output also includes the input emissions. The output is interpolated onto an annual timestep.

Return type

`pyam.IamDataFrame`

`climate_assessment.checks.reclassify_waste_and_other_co2_ar6(df)`

Reclassify waste and other CO2 into the energy and industrial processes category

Reclassify CO2 emissions reported under Emissions|CO2|Other and Emissions|CO2|Waste, instead putting them under Emissions|CO2|Energy and Industrial Processes.

Parameters

df (`pyam.IamDataFrame`) – The original set of reported emissions

Returns

Reclassified set of emissions.

Return type

`pyam.IamDataFrame`

`climate_assessment.checks.remove_rows_with_only_zero(df, filename=None, outdir='output')`

Check and remove rows with zero emissions.

`climate_assessment.checks.remove_rows_with_zero_in_harmonization_year(df, filename=None, harmonization_year=2015, outdir='output')`

Check for zeros in harmonization year emissions and remove rows.

`climate_assessment.checks.require_allyears(df, filename='test', output_csv=False, outdir='output', required_years=[2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100], base_yr=2015, low_yr=2010)`

Check if some variables are reported for the required years (drops per variable)

`climate_assessment.checks.require_allyears_and_drop_scenarios(df, filename='test', output_csv=False, outdir='output', required_years=[2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100])`

Filters out full scenarios if some year is not reported (using pyam)

`climate_assessment.checks.sanity_check_bounds_kyoto_emissions(output_postprocess, out_kyoto_infilled)`

Check that the calculated Kyoto gases of the infilled emissions data are within certain bounds

`climate_assessment.checks.sanity_check_comparison_kyoto_gases(output_postprocess, out_kyoto_harmonized, out_kyoto_infilled)`

Check that the calculated Kyoto gases of the infilled emissions data is in every year smaller than the calculated Kyoto gases of the harmonized emission data

```
climate_assessment.checks.sanity_check_hierarchy(co2_inf_db, harmonized, infilled, out_afolu,
                                                out_fossil)
```

Check that hierarchy of variables is internally consistent (in this case check that Emissions|CO2 is the sum of AFOLU and Energy and Industrial Processes emissions)

2.2 Climate emulators

In this section, we provide more information specifically on how the climate emulators used in IPCC AR6 WGIII can be used with this package, and where to find more information.

When you have a scenario with sufficient information on its emissions pathways (see {link-to-input-requirements-page}), you can run the climate assessment process with an emulator of choice, producing probabilistic output. Three emulators are available: MAGICCv7.5.3, FaIRv1.6.2, and CICERO-SCM.

Emulators are run using the functionality in the `openscm-runner` package (see [documentation](#)), which is a wrapper that allows for running simple climate models with a unified interface.

In general, if you have a working setup on your computer and this package installed, you need two things to make everything work:

1. The climate emulator itself: for CICERO and FaIR this is provided through the package, for MAGICC the binary file should be downloaded.
2. Configuration file(s) for the climate emulator: this data is provided externally as much as possible to keep code and data separate (e.g. for MAGICC and FaIR), though for CICERO the data is for now made available through this package.

In the example notebook, `notebooks/run-example-fair.ipynb`, we provide an example of how the configuration files can be downloaded for FaIR using `pooch`.

Warning: In the examples below, the commands use the very simple and small infiller database “`cmip6-ssps-workflow-emissions.csv`”, which will yield a warning. For most applications, it is strongly advised to use a larger infiller database, like the one based on AR6 WG3 scenarios.

Please make sure you have followed the download instructions under [Infiller database](#) on how to use the full AR6 setup.

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2.2.1 FaIR

Download instructions

FaIR itself does not need to be downloaded. Upon installing this package, it is ready to go on any computer platform.

However, the configuration files for FaIR do need to be downloaded. This can be done either manually from <https://doi.org/10.5281/zenodo.5513022>, or interactively using a tool such as [pooch](#). In the example notebook, `notebooks/run-example-fair.ipynb`, we provide an example of how this can be done.

Setup instructions

FaIR is implemented in Python, and nothing has to be done to run it after you have installed this package; it is provided through `openscm-runner`. The only thing that is required, is running with the correct location for the FaIR probabilistic input files (after you have downloaded these). FaIR uses two input files in this implementation, that need to be called as follows: `--probabilistic-file path/to/fair-1.6.2-wg3-params-slim.json` and `--fair-extra-config path/to/fair-1.6.2-wg3-params-common.json`

Example run command

```
python scripts/run_workflow.py data/input_scenarios.csv output --model "FaIR" -  
→ -model-version "1.6.2" --num-cfgs 2237 --probabilistic-file data/fair/fair-1.  
→ 6.2-wg3-params-slim.json --fair-extra-config data/fair/fair-1.6.2-wg3-params-  
→ common.json --infilling-database src/climate_assessment/infilling/cmip6-ssps-  
→ workflow-emissions.csv
```

Emulator-specific functions

```
climate_assessment.climate.get_fair_configurations(fair_version, fair_probabilistic_file,  
                                                    fair_extra_config, num_cfgs)
```

Get configuration for FaIR

References

Please refer to this paper for more detailed use: Smith, C. J., Forster, P. M., Allen, M., Leach, N., Millar, R. J., Passerello, G. A., and Regayre, L. A.: FAIR v1.3: a simple emissions-based impulse response and carbon cycle model, 11, 2273–2297, <https://doi.org/10.5194/gmd-11-2273-2018>, 2018.

- Documentation: [FaIR ReadTheDocs](#)
- Open-source code: [FaIR GitHub](#)
- Calibrated and constrained parameter set (as one single file): <https://doi.org/10.5281/zenodo.5513022>

2.2.2 CICERO-SCM

Download instructions

CICERO-SCM does not need to be downloaded. Upon installing this package, it works on Linux. It is not yet possible to run this version of CICERO-SCM on Windows or on MacOS. For now, the configuration file for CICERO-SCM is also available with this package directly, under *data/cicero/subset_cscm_configfile.json*.

Setup instructions for a Linux computer

CICERO-SCM is provided through `openscm-runner`. The only thing that is required, is running with the correct location for the CICERO-SCM probabilistic input file, which needs to be called as follows: `--probabilistic-file path/to/subset_cscm_configfile.json`

Setup instructions for a Windows or MacOS computer

Not yet available.

Example run command

```
python scripts/run_workflow.py data/input_scenarios.csv output --model
↪ "ciceroscsm" --model-version "v2019vCH4" --num-cfgs 600 --probabilistic-file_
↪ data/cicero/subset_cscm_configfile.json --infilling-database src/climate_
↪ assessment/infilling/cmip6-ssps-workflow-emissions.csv
```

Emulator-specific functions

```
climate_assessment.climate.get_ciceroscsm_configurations(ciceroscsm_version,
                                                         ciceroscsm_probabilistic_file, num_cfgs)
```

Get configuration for CICERO-SCM

References

Please refer to this paper for more detailed use: Skeie, R. B., Fuglestad, J., Berntsen, T., Peters, G. P., Andrew, R., Allen, M., and Kallbekken, S.: Perspective has a strong effect on the calculation of historical contributions to global warming, Environ. Res. Lett., 12, 024022, <https://doi.org/10.1088/1748-9326/aa5b0a>, 2017.

- Calibrated and constrained parameter set (as one single file): see data/cicero/subset_cscm_configfile.json

2.2.3 MAGICC

Download instructions

The MAGICC model is available at magicc.org, where you can also download the parameter set used in AR6. Please read the license and expectations carefully, we rely on users to act in a way which brings both new scientific outcomes but also acknowledges the work put into the MAGICC AR6 setup.

After you have downloaded the tar files, please extract it (we typically extract MAGICC and the probabilistic distribution into magicc-files). You then need to copy all the default files into the run folder (i.e. run a command like `cp -r magicc-files/magicc-v7.5.3/run/defaults/* magicc-files/magicc-v7.5.3/run/`).

In one set of commands on Linux (PRs to add the Windows equivalent are welcome), this can be summarised as:

```
# MAGICC binary
mkdir -p magicc-files/magicc-v7.5.3
wget -O magicc-files/magicc-v7.5.3.tar.gz [magicc-link-from-magicc-dot-org]
tar -xf magicc-files/magicc-v7.5.3.tar.gz -C magicc-files/magicc-v7.5.3
cp -r magicc-files/magicc-v7.5.3/run/defaults/* magicc-files/magicc-v7.5.3/run/

# Probabilistic distribution
mkdir -p magicc-files/magicc-ar6-0fd0f62-f023edb-drawnset
wget -O magicc-files/magicc-ar6-0fd0f62-f023edb-drawnset.tar.gz [magicc-prob-
↪ distribution-link-from-magicc-dot-org]
tar -xf magicc-files/magicc-ar6-0fd0f62-f023edb-drawnset.tar.gz -C magicc-files/magicc-
↪ ar6-0fd0f62-f023edb-drawnset
```

Setup instructions for a Linux computer

For a Linux computer, these environment variables can be provided either via a `.env` file (see `.env.sample` in the root directory of this repository) or from the command line.

Setup instructions for a macOS computer

We don't currently have a compiled macOS binary in our distribution (we are working on it but mac runners have only recently become widely available). If you need this for your use case, please email zebedee.nicholls@climate-energy-college.org.

Setup instructions for a Windows computer

On Windows, environment variables cannot be set using an input file. Rather, one must set the following system-wide environment variables, with the paths depending on where you put your MAGICC7 emulator files. Below, we provide some examples with their functions. Note that these are the same as in the `.env.sample` file.

```
# MAGICC executable.
MAGICC_EXECUTABLE_7 = /path/to/climate-assessment/data/emulator/magicc/magicc-v7.5.3/bin/
↳ magicc.exe
# MAGICC probabilistic input setup file.
MAGICC_PROBABILISTIC_FILE = /path/to/climate-assessment/data/emulator/magicc/0fd0f62-
↳ derived-metrics-id-f023edb-drawnset.json
# Number of (hyperthreaded) cores to run on.
MAGICC_WORKER_NUMBER = 4
# Folder for MAGICC parallel workers (make sure that this folder exists!):
MAGICC_WORKER_ROOT_DIR = /path/to/climate-assessment/data/emulator/magicc/magicc-v7.5.3/
↳ workers
```

Example run command

```
python scripts/run_workflow.py data/input_scenarios.csv output --model "magicc
↳ " --model-version "v7.5.3" --num-cfgs 600 --probabilistic-file data/emulator/
↳ magicc/0fd0f62-derived-metrics-id-f023edb-drawnset.json --infilling-database_
↳ src/climate_assessment/infilling/cmip6-ssps-workflow-emissions.csv --co2-and-
↳ non-co2-warming
```

Emulator-specific functions

```
climate_assessment.climate.get_magicc7_configurations(magicc_version, magicc_probabilistic_file,
magicc_extra_config, num_cfgs,
co2_and_non_co2_warming)
```

Get configuration for MAGICC7

References

Please refer to the following for more detailed use:

Nicholls, Z. R. J., Meinshausen, M., Lewis, J., Smith, C. J., Forster, P. M., Fuglestvedt, J. S., Rogelj, J., Kikstra, J. S., Riahi, K., and Byers, E.

“Changes in IPCC Scenario Assessment Emulators Between SR1.5 and AR6 Unraveled”.

Geophysical Research Letters

<https://doi.org/10.1029/2022GL099788>

2022

- More information, multiple references, and an interactive online tool: magicc.org

2.2.4 Advanced functionality

When running from the command line with CLI option `--save-raw-climate-output`, an additional output folder will be created which writes out one large (~300-1000MB) file per scenario.

2.2.5 Notes for developers

If you would like to get the MAGICC SR15 tests running, you will first need to run the command `MAGICC_RUN_DIR=bin/magicc/magicc-v7.5.3/run/ python scripts/generate-magicc-sr15-input-files.py` from your Anaconda prompt. N.B. note that this way of running a command, with the environment variable provided before the python call, only works on Linux. On Windows, you need to set `MAGICC_RUN_DIR` as a system-wide environment variable and then only run `python scripts/generate-magicc-sr15-input-files.py`.

2.3 Utility functions

`climate_assessment.utils.columns_to_basic(df)`

Takes a `pyam.IamDataFrame` and only keeps the basic columns [“model”, “scenario”, “region”, “variable”, “unit”, “year”, “value”], discarding potential other input columns ([“exclude”, “meta”, “subannual”, “version”]).

Parameters

df (`pyam.IamDataFrame`) – The input data to be formatted.

Returns

The input data with only the remaining basic columns.

Return type

`pyam.IamDataFrame`

`climate_assessment.utils.require_var_allyears(df, vars)`

Filter out the scenarios that, for a set of variables, do not report all required years. This is currently hard-coded to be decadal from 2020 to 2100.

Parameters

df (`pyam.IamDataFrame`) – The input data to be checked and filtered.

Returns

The output data with only scenarios that have full-century information for all necessary variables.

Return type

`pyam.IamDataFrame`

`climate_assessment.utils.convert_units_to_co2_equiv(df, metric)`

Converts the units of gases reported in kt into Mt CO2 equivalent per year

Uses GWP100 values from either (by default) AR5 or AR4 IPCC reports.

Parameters

- **df** (`pyam.IamDataFrame`) – The input dataframe whose units need to be converted.
- **metric** (`str`) – The name of the conversion metric to use. This will usually be AR<4/5/6>GWP100.

Returns

The input data with units converted.

Return type

`pyam.IamDataFrame`

`climate_assessment.utils.convert_co2_equiv_to_kt_gas(df, var_filter, metric='AR6GWP100')`

Convert units from CO2 equivalent to kt of gas.

Parameters

- **df** (`pyam.IamDataFrame`) – The input data to be converted.
- **var_filter** (`list[str]`, `str`) – Filter to use to pick the variables to convert
- **metric** (`str`) – The name of the conversion metric to use. This will usually be AR<4/5/6>GWP100.

Returns

The input data with units converted.

Return type

`pyam.IamDataFrame`

`climate_assessment.utils.add_gwp100_kyoto_wrapper(df, prefixes=["", 'AR6 climate diagnostics|Harmonized|', 'AR6 climate diagnostics|Infilled|'], gwps=['AR5GWP100', 'AR6GWP100'])`

Add Kyoto GWP100 emissions

Parameters

- **df** (`pyam.IamDataFrame`) – `pyam.IamDataFrame` containing emissions from which the GWP sum should be created
- **prefixes** (`list[str]`) – List of prefixes to use for the aggregation
- **gwps** (`list[str]`) – GWPs to use for aggregation

Returns

Input emissions plus the Kyoto GWP100 equivalents

Return type

`pyam.IamDataFrame`

`climate_assessment.utils.parallel_progress_bar(tqdm_bar)`

Context manage to patch joblib so it shows a progress bar with tqdm

Shoutout to <https://stackoverflow.com/a/58936697> for the original implementation of this code

`climate_assessment.utils.split_df(df, **filter_options)`

This function splits the dataframe into model/scenario sets that fulfill the filter condition and those that don't.

Parameters

df (`pyam.IamDataFrame`) – Input scenario data

Returns

- **to_return_1** (`pyam.IamDataFrame`) – Scenarios that fulfill the condition.
- **to_return_2** (`pyam.IamDataFrame`) – Scenarios that do not fulfill the condition.

`climate_assessment.utils._perform_operation(df, var_1, var_2, out_variable, op, raise_if_mismatch=True)`

Helper function that is called in `_diff_variables()` and `_add_variables()`, instead of `silicone.multiple_infillers.infill_composite_values`, because `silicone.multiple_infillers.infill_composite_values` does not check whether all components are included.

`climate_assessment.utils._diff_variables(df, var_1, var_2, out_variable, raise_if_mismatch=True)`

Calculates the difference between two variables, and adds this new variable to the dataframe.

Parameters

- **df** (`pyam.IamDataFrame`) – Input scenario data
- **var_1** (`str`) – First variable in operation
- **var_2** (`str`) – Second variable in operation
- **out_variable** (`str`) – What to call the new variable

Returns

Dataframe with added difference variable

Return type

`pyam.IamDataFrame`

`climate_assessment.utils._add_variables(df, var_1, var_2, out_variable, raise_if_mismatch=True)`

Calculates the sum of two variables, and adds this as a new variable to the dataframe.

Parameters

- **df** (`pyam.IamDataFrame`) – Input scenario data
- **var_1** (`str`) – First variable in operation
- **var_2** (`str`) – Second variable in operation
- **out_variable** (`str`) – What to call the new variable

Returns

Dataframe with added sum variable

Return type

`pyam.IamDataFrame`

2.4 Notes for developers

2.4.1 Installation

For developers, we recommend using the following command for installation, which needs to be run from the root of the folder after cloning the GitHub repository:

```
pip install --editable .[docs,tests,deploy,linter,notebooks]
```

2.4.2 Formatting code

Before committing or merging code, the following lines should be run to ensure that the formatting is consistent with what is expected by the continuous integration setup (for users with `make` installed, `make checks` will run these for you):

```
black --check src scripts tests setup.py
isort --check-only --quiet src scripts tests setup.py
flake8 src scripts tests setup.py
```

2.4.3 Tips and tricks

Looking at changes in output

`git diff --word-diff-regex="[^\s,]+"` will show you differences in csv files on the output level (quote and delimiter) (see <https://resonantecho.net/software/git/2018/03/29/git-word-diff.html#:~:text=It%20does%20this%20by%20having,word%2Ddiff%2Dregex%3D.>) for more details)

LICENSE

This package is licensed under an MIT License. You may obtain a copy of the License at <https://github.com/iiasa/climate-assessment/blob/main/LICENSE>.

ACKNOWLEDGEMENTS

Per good scientific practice, you **must** cite the following publication when you use this package in scientific work.

Jarmo S. Kikstra, Zebedee R. J. Nicholls, Christopher J. Smith, Jared Lewis, Robin D. Lamboll, Edward Byers, Marit Sandstad, Malte Meinshausen, Matthew J. Gidden, Joeri Rogelj, Elmar Kriegler, Glen P. Peters, Jan S. Fuglestad, Ragnhild B. Skeie, Bjørn H. Samset, Laura Wienpahl, Detlef P. van Vuuren, Kaj-Ivar van der Wijst, Alaa Al Khourdajie, Piers M. Forster, Andy Reisinger, Roberto Schaeffer, and Keywan Riahi

“The IPCC Sixth Assessment Report WGIII climate assessment of mitigation pathways: from emissions to global temperatures”.

Geosci. Model Dev., 15, 9075–9109

<https://doi.org/10.5194/gmd-15-9075-2022>

2022

You may additionally also cite the package itself:

Kikstra, J. S., Nicholls, Z. R. J., Lewis, J., Smith, C. J., Lamboll, R. D., Byers, E., Sandstad, M., Wienpahl, L., and Hackstock, P.:

Climate assessment of long-term emissions pathways: IPCC AR6 WGIII version,
Zenodo, 10.5281/zenodo.6624519, 2022.

For more detail, see *How to cite*.

4.1 How to cite

We ask that you take the following two actions whenever you:

- **use** the `climate-assessment` workflow, or any model(s) you have built using these tools
- **produce** any scientific publication, technical report, website, or other **publicly-available material**.

The aim of this request is to ensure good scientific practice and collaborative development of the platform.

4.1.1 1. Understand the code license

Use the most recent version of `climate-assessment` from the Github repository. Specify clearly which version (e.g. release tag, such as `v0.1.0`, or commit hash, such as `26cc08f`) you have used, and whether you have made any modifications to the code.

Read and understand the file `LICENSE`; in particular, clause 7 (“Disclaimer of Warranty”), which states:

Unless required by applicable law or agreed to in writing, Licensor provides the Work (and each Contributor provides its Contributions) on an “AS IS” BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied, including, without limitation, any warranties or conditions of TITLE, NON-INFRINGEMENT, MERCHANTABILITY, or FITNESS FOR A PARTICULAR PURPOSE. You are solely responsible for determining the appropriateness of using or redistributing the Work and assume any risks associated with Your exercise of permissions under this License.

4.1.2 2. Cite the scientific publication

Cite, at minimum, the following manuscript:

Jarmo S. Kikstra, Zebedee R. J. Nicholls, Christopher J. Smith, Jared Lewis, Robin D. Lamboll, Edward Byers, Marit Sandstad, Malte Meinshausen, Matthew J. Gidden, Joeri Rogelj, Elmar Kriegler, Glen P. Peters, Jan S. Fuglestvedt, Ragnhild B. Skeie, Bjørn H. Samset, Laura Wienpahl, Detlef P. van Vuuren, Kaj-Ivar van der Wijst, Alaa Al Khourdajie, Piers M. Forster, Andy Reisinger, Roberto Schaeffer, and Keywan Riahi

“The IPCC Sixth Assessment Report WGIII climate assessment of mitigation pathways: from emissions to global temperatures”.

Geosci. Model Dev., 15, 9075–9109

<https://doi.org/10.5194/gmd-15-9075-2022>

2022

Additionally, you may cite the source code using the Zenodo reference (DOI: <https://doi.org/10.5281/zenodo.6624519>).

If you are using the AR6 scenario data (DOI: <https://doi.org/10.5281/zenodo.5886911>) and the AR6 infiller database (DOI: <https://doi.org/10.5281/zenodo.6390767>), you should in addition cite those respective sources.

In addition, to provide credit to the climate emulator modelers, please cite literature describing the climate emulator(s) that you use.

Lastly, you may cite the tools that enabled the development of this climate assessment workflow, including `aneris`, `silicone`, and `openscm-runner`.

All these citations are also provided in full in the manuscript mentioned above, if further guidance is required on how to cite specific tools and data.

- **Cite the code via Zenodo.** The DOI [10.5281/zenodo.6624519](https://doi.org/10.5281/zenodo.6624519) represents *all* versions of the `climate-assessment` code, and will always resolve to the latest version. Zenodo also provides citation export in BibTeX and other formats. If you would like to cite a specific release version, that is possible too and requires using the dedicate URLs, such as DOI [10.5281/zenodo.6782457](https://doi.org/10.5281/zenodo.6782457) <<https://doi.org/10.5281/zenodo.6782457>> for version `v0.1.1`.
- Include a link, e.g. in a footnote, to the online documentation at <https://climate-assessment.readthedocs.io>.

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