The Climate Equity Reference Calculator core database

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10 October 2024, v7.4

The database for the *Climate Equity Reference Calculator*[1] includes 197 entities: 196 of the 197 state parties[2] to the UNFCCC, plus Taiwan. Data for China, Macao, and Hong Kong, which are typically reported separately in most income and emissions databases, are combined.[3] Likewise, we combine, where applicable, data for overseas dependencies of countries (e.g. we add Greenland and Faroe Island figures to Denmark). The *Climate Equity Reference Calculator* database is updated regularly with newly published data. The current calculator and published documentation are based primarily on data published up to September 2024 (see details below). For archival purposes it is database version 7.4.[4]

Income (GDP)

Recent historical income (GDP)[5] data comes primarily from the World Bank's *World Development Indicators Online* [4], as the highest priority data source, which contains data for national income from 1960 to 2020 for almost all of the countries in the database. For most of the missing countries, data comes from the *CIA World Factbook* [5], as a second-order priority source. For data prior to 1960 or other missing years, data comes from the Maddison data set [6]–[8]. Where data are available for a country for any year from a higher priority source, we use the slopes (rather than absolute values) from lower priority sources to extend, or fill in, the time series. Data are reported in 2010 US$, at market exchange rates (MER). For several of its calculations, the *Calculator* uses income adjusted for purchasing power parity (PPP). Conversion to PPP (2005) is based on converting "Current US Dollars" for 2005 to PPP (Current International Dollars). The PPP conversion rate is held constant at this value.

Income (GDP) projections from 2024-2029 are from the IMF's *World Economic Outlook* (WEO), April 2024 [9].[6] Each country's IMF-reported growth rate is applied to the most recent World Bank national GDP data (in most cases 2020); the IMF WEO growth rate for each country for 2029 is also applied to

[1] The Climate Equity Reference calculator [1] is available at https://calculator.climateequityreference.org. Its open source code can be inspected on Github at https://github.com/climateequityreferenceproject/cerc-web.

[2] The UNFCCC has 198 parties. However, one of those is the European Union, which in our database is represented by its member states and in the *Calculator* can also be examined as a single entity. The only state party to the UNFCCC that is not included in our *Calculator* is the Holy See, for which most of the indicators needed to construct the *Calculator* database are not readily available.

[3] Our methodology for combining the Gini Coefficients for these entities as a weighted sum of lognormal distributions is described in more detail in [2]. As of database version 7.4, we are not applying this methodology anymore and are instead using the Gini Coefficients for China. For all other metrics (emissions, GDP, population etc.), the figures for China include those of Hong Kong and Macao.

[4] Starting with version 7.0 from 2015, all main versions of the core database are available in the Harvard Dataverse [3].

[5] Conceptually, gross national income (GNI) would be the more appropriate principal measure to use in the *Calculator*'s effort sharing calculations as a measure of ability to pay, since GNI, unlike GDP, includes income earned by a country's residents from sources outside the country while it does not include income earned in the country by non-residents. Instead, however, we are using GDP here as a proxy for GNI. The main reason is that publicly available datasets for GNI have major data gaps and are therefore not suited for a calculator that includes all countries. Importantly, GNI and GDP are extremely closely correlated, so that GDP is a suitable proxy for GNI, despite the former's relative weakness as a measure of ability to pay.

[6] For a small number of countries, the IMF WEO does not provide a complete set of historical and projected GDP growth, typically owing to highly uncertain political and/or economic situations. For these countries (currently: Syria from 2011, Eritrea from 2020, Lebanon from 2022, Afghanistan and Sri Lanka from 2023, Palestine from 2024 and Venezuela from 2026), we use an arbitrary annual contraction rate of -10% until future IMF WEO updates resume projections. Additionally, due to the central role of GDP projections in our GHG baseline projections, for these countries, we hold GHG emissions constant from these same years onwards. Owing to this, results for these countries should be interpreted with a high degree of caution.

2030. Beyond 2030, long term estimates are based on the median GDP growth rates across the models in the EMF27-Base-FullTech baseline scenario ensemble as reported in the IPCC AR5 scenario database that are available for the five IPCC world regions [10].

The short term projections directly take the economic impact of the COVID-19 pandemic into account, both in terms of the economic shock in 2020/21 as well as typically lower growth rate projections through 2029. Long-term projections indirectly account for this impact by extending the same GDP projection time series beyond 2030.

CO_2 emissions (excluding LULUCF)

CO_2 data come from the *PRIMAP-hist* database [11], [12] for the period from 1850[7] through to 2022. *PRIMAP-hist* is a well-documented, well-constructed, and well-maintained composite dataset compiled at the Potsdam Institute for Climate Impact Research (PIK). *PRIMAP-hist*, in turn, is based on various authoritative data sources including the UNFCCC, the *Carbon Dioxide Information and Analysis Center (CDIAC)*, the *EDGAR* database and others. For Palestine, we use data from the *Global Carbon Budget* dataset [13], [14] directly, and subtract those figures from Israel's value as *PRIMAP-hist* reports those countries together.

Since one of the main purposes of the *Climate Equity Reference Calculator* is the assessment of national climate action pledges (for example, as expressed in countries' Nationally Determined Contributions (NDCs) under the Paris Agreement), we project national baseline emissions starting after 2015, the year the Paris Agreement was adopted. For CO_2 emissions, exclusive of emissions from Land Use, Land Use Change, and Forestry (LULUCF), these projections after 2015 are based on the median carbon intensity changes modelled in the EMF27-Base-FullTech scenario from the IPCC AR5 scenario database for each of the five IPCC regions [10], combined with national GDP projections as described above.[8] The EMF27-Base-FullTech scenario ensemble has been chosen since it represents a very conventional baseline scenario that does not intentionally embed preferences for any particular technologies. Another reason for choosing this scenario ensemble over more recent baseline scenarios is that contemporary baseline scenarios are typically conceptualized as "current policy" or "current effort" scenarios, whereas, conceptually, the *Climate Equity Reference Calculator* requires "no effort" baselines. Using "current policy" baselines in the *Calculator* database would disadvantage countries that are already undertaking meaningful mitigation efforts by disregarding those efforts in the effort-sharing calculations.

Non-CO_2 Greenhouse Gases

Values for non-CO_2 GHGs are also taken directly from the *PRIMAP-hist* database [11], [12]. All non-CO_2 greenhouse gases are converted into CO_2 equivalents (CO_2eq) using the 100-year Global Warming Potential (GWP-100) values from the IPCC's Fourth Assessment Report (AR4).

Baseline projections for 2016 to 2035 for all countries are based on the median annual absolute rates of change reported in the IPCC AR5 scenario database for the models of the EMF27-Base-FullTech scenario ensemble by region [10].

CO_2 from Land Use, Land Use Change and Forestry (LULUCF)

This database update, like every version since 7.2, does not support *Climate Equity Reference Calculator* calculations that include CO_2 emissions from Land Use, Land Use Change, and Forestry (LULUCF). This decision has been taken for several reasons. First, LULUCF emissions data are subject to very large uncertainties and fluctuations, which in some cases are so large that for the same year and country one

[7] Emissions before 1850 are ignored because most of the other variables required for our calculations have no reliable, country-level data sources for prior to 1850, and since pre-1850 emissions only represent about 0.3% of global cumulative CO_2 emissions from fossil fuels, flaring and cement over the 1750-2020 period [13].

[8] For the seven countries for which the IMF WEO does not offer GDP projections (see above), and for which, therefore, our standard projection approach is unsuitable, we simply keep baseline emissions constant at the level of the last year for which the IMF WEO has data (see footnote above).

data source reports a land use sink while another reports a source. For example, for Annex I countries the UNFCCC data interface [15] reports removals three times as large in 2015 as the values of the *PRIMAP-hist* database, which are in turn based on *FAOSTAT* [16].

Further, including LULUCF emissions in a single framework together with CO_2 emissions from fossil fuel and industry and non-CO_2 gases, presupposes the, in our view problematic, assumption that emissions from LULUCF and other sources are essentially fungible, and that emissions reductions in either space are perfectly equivalent. This has with profound implications, for example, with regard to the speed of the decarbonization of the energy system and the treatment of nature primarily as a carbon sink.

We are exploring the possibility of including LULUCF emissions again in future releases, albeit only in the context of the calculation of historical responsibility. However, users with specific projects where inclusion of LULUCF emissions is vital, should contact the authors to explore how this might best be facilitated.[9] Furthermore, even though the *Climate Equity Reference Calculator* does not support LULUCF anymore, the calculator database still contains up-to-date values for LULUCF emissions (for most countries, using the *BLUE* time series [18] as reported by the *Global Carbon Project* [13], [14], for Brazil using [19]). As a result, the LULUCF emissions time series will still be included in the files generated by the calculator's "download complete Excel table" functionality, but these data should be used with appropriate caution.

Gini Coefficients

This version 7.4 includes a major update to the sourcing of Gini Coefficients for the *Climate Equity Reference Calculator* database.[10] Recently, the *World Inequality Database* (*WID.world*) has established itself as a high-quality data source for inequality data with excellent temporal and spatial coverage [21]–[23]. *WID.world* now covers 173 of the 197 countries in our database for the period from 1980-2022 and provides Gini Coefficients for a number of different wealth and income inequality concepts. From among those, for the *Climate Equity Reference Calculator* database, we consider the inequality in post-tax incomes the most suitable metric, as it measures the distribution of income after redistribution, that is, it reflects the distributional effects of each country's tax and social welfare systems (including in-kind welfare provision, such as government-provided health care).[24]

For the missing 24 countries,[11] we turn to the *World Income Inequality Database* (*WIID*) [25] as a second-tier data source.[12] The *WIID* utilizes different approaches, concepts, and underlying data sources for measuring income inequality than *WID.world*, and Gini coefficients from *WIID* are thus generally lower than those from *WID.world*. To compensate for this structural difference, we adjust the *WIID*-sourced values by multiplying with a constant (for each year) that is obtained by dividing the simple average across all Gini Coefficients in *WID.world* for that year by the average of the Gini Coefficients in *WIID* for the same countries for the same year.

It is important to note that this change of Gini Coefficients, relative to prior versions of the *Calculator* database, has substantial impact on the results of the effort sharing calculations for individual countries. For most countries, *WID.world* reports higher Gini Coefficients than the data source for Gini Coefficients that had been used in *Calculator* databases prior to the present version 7.4 (namely version 2 of the *WIID* dataset [20]). Specifically, out of the 173 countries in the *WID.world* database, the *WID.world* Gini Coefficients are lower than those in our previous database versions for 27 countries (with an average decrease in Gini Coefficients in 2020 across these countries of 9.8%), whereas the remaining 147 countries have a higher Gini Coefficient (with an average increase of 34%). Perhaps the most notable examples of the 27 countries with decreased Gini Coefficients are the United States, China, and the United Kingdom.[13]

[9]For example, we contributed to Observatorio do Clima's proposal for Brazil's Second Nationally Determined Contribution (NDC) under the Paris Agreement (2030-2035) [17], which included LULUCF emissions in the mitigation fair shares calculations.

[10]Prior versions of the database have been using gini coefficients for income inequality from the *World Income Inequality Database*, maintained at the United Nations University's World Institute for Development Economics Research (UNU-WIDER) [20].

[11]The missing countries are small island states and four European microstates.

[12]Only the Cook Islands and Niue are missing from both the WIID and WID.world datasets. For these two countries, we simply use the average across all Pacific Small Island Developing States for each year.

[13]For transparency, the other countries where this is the case are Azerbaijan, Belgium, Denmark, France, Gabon, Iceland,

This means inequality within countries is higher for most countries with the current *Calculator* database than with previous database versions, which in turn means higher Capacity even without any changes to GDP, because an increase in the Gini Coefficient (signifying higher inequality) shifts income upward in the income distribution, and hence a larger fraction of a country's income could be shifted above the development threshold and/or upper threshold, depending on where these thresholds are set.[14] However, since it is a country's share of global Capacity that determines its fair share, it is the *relative* shift of countries' Capacity that matters (relative to the shift of all other countries). In other words, an increase (or decrease) in Gini Coefficient does not automatically result in an increase (or decrease) in fair share. For the definitions of Capacity that were adopted by a number of studies that used the *Climate Equity Reference Calculator* (e.g. [27]–[31]), developing countries as a group (and most of them individually – though note the exceptions listed in the footnote) are assigned larger fair shares with the Gini Coefficients from the *WID.world* database than they would have with previous database versions, while the reverse is generally true for developed countries. However, for definitions of Capacity that were significantly more progressive (i.e., a higher development threshold and/or uppper threshold), this may not be the case.

Population

Current, historical and projected population for most countries are taken from the 2022 edition of the *United Nations Population Division*'s *World Population Prospects* (medium variant) [32].

Calculating the RCI from the Equity Calculator dataset

The *Climate Equity Reference Calculator* sets a country's fair share of the global climate effort in proportion to its Responsibility and Capacity Index, or *RCI*, which in turn is calculated from a country's capacity and responsibility. Capacity for a given year is defined as the sum of the income of all individuals in the country, excluding the total income of everyone under a user-specified income level referred to as the development threshold. Central to the calculation is the commonly-used assumption that national income distributions can be modeled as lognormal distributions.[15] The lognormal distribution has been shown to provide a reasonable approximation of measured income distributions [34]. With this assumption, any national income distribution can be estimated with just a Gini Coefficient and the per-capita income.

The *Calculator*'s initial setting for the development threshold is $7,500 per capita, in PPP-adjusted 2005 USD; so we will use that number in the following example. For people receiving more than $7,500 annually, only their income above that threshold counts towards the national measure of capacity (as a result, two countries with the same population and with the same per capita GDP will not have equal capacity if they have different Gini Coefficients. Rather, the country with the higher Gini Coefficient, i.e. the country with the less equal income distribution, will have more income above the development threshold, and thus will have greater capacity[16]).

Responsibility is calculated in a similar manner. Emissions are calculated from income based on a user-specified elasticity, which is initially set to one (i.e., all individuals in a country have emissions proportional to income); thus, all emissions are excluded for those whose incomes are under the development threshold, and emissions equivalent to $7,500 of consumption at the national average carbon intensity of income are excluded for those with income over the threshold. Unlike the calculation of capacity, however, responsibility is calculated on a cumulative basis, starting at a user-specified initial year, so that responsibility in (say) 2035 is the sum of responsibility calculated in this way for each year from the specified start year to 2035.

Capacity and responsibility are then expressed as a percentage of the global total, and combined into a single "Responsibility and Capacity Index," or *RCI*, by taking a weighted average. In other words, a

Ireland, Kenya, Lebanon, Lesotho, Luxembourg, Moldova, Namibia, Norway, Portugal, Sao Tome and Principe, Singapore, Slovakia, Slovenia, Spain, Switzerland, Ukraine, and Zimbabwe.

[14] For a more thorough discussion of the link between Gini Coefficients and Capacity, see Supplementary Text 3 in the supplementary materials to [26].

[15] Wikipedia [33] offers a good technical description of the lognormal distribution

[16] Again, a more thorough discussion of the effects of income inequality on the RCI, see Supplementary Text 3 in the supplementary materials to [26].

country's *RCI* measures the country's share of the combined global Capacity and Responsibility. In the *Calculator*, the Responsibility and Capacity weightings are initially set to be equal, but the calculator allows this to be user-specified, all the way from 100% Responsibility to 100% Capacity, to allow users to reflect their views that determining equitable shares of the global effort based on one of these factors alone is the appropriate ethical position to take.

A more detailed technical description of the algorithms and equations involved in these calculations is available elsewhere [2].

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