Methodology Insights

Sustainable Investment | Climate Change

FTSE Russell

How to measure the temperature of sovereign assets

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Context

The Paris Agreement mitigation target aims to limit global warming to well below 2.0°C[1], which requires a net zero emissions level on a global scale by the second half of the century. Current trajectories and national plans (based on the nationally determined contributions, NDCs) appear to be insufficient to reach that target. For example, the achievement of the last NDCs submitted by the countries would result in a global warming of above 3°C.

A scientific and political consensus agreed to aim for a global warming of much lower than 2°C. However, to date, international climate negotiations have failed to determine how to allocate greenhouse gas (GHG) emissions reductions among countries.

In this context, Beyond Ratings has developed the unique CLAIM methodology (Climate Liabilities Assessment Integrated Methodology) to address this challenge and offer a consistent analytical framework at the country level.

Our approach is used in combination with an analysis of countries' policy commitments through NDCs to gauge the ambition level of countries' commitments and determine their temperatures.[2] We use a temperature equation that reflects the scientific consensus on the relationship between GHG emissions and temperature dynamics.

[1] And pursuing efforts to limit the increase to 1.5°C.

[2] "Temperatures" here refer to the effect of global warming in 2100 if all countries had the same ambition as the analyzed country.

Contents

Executive summary

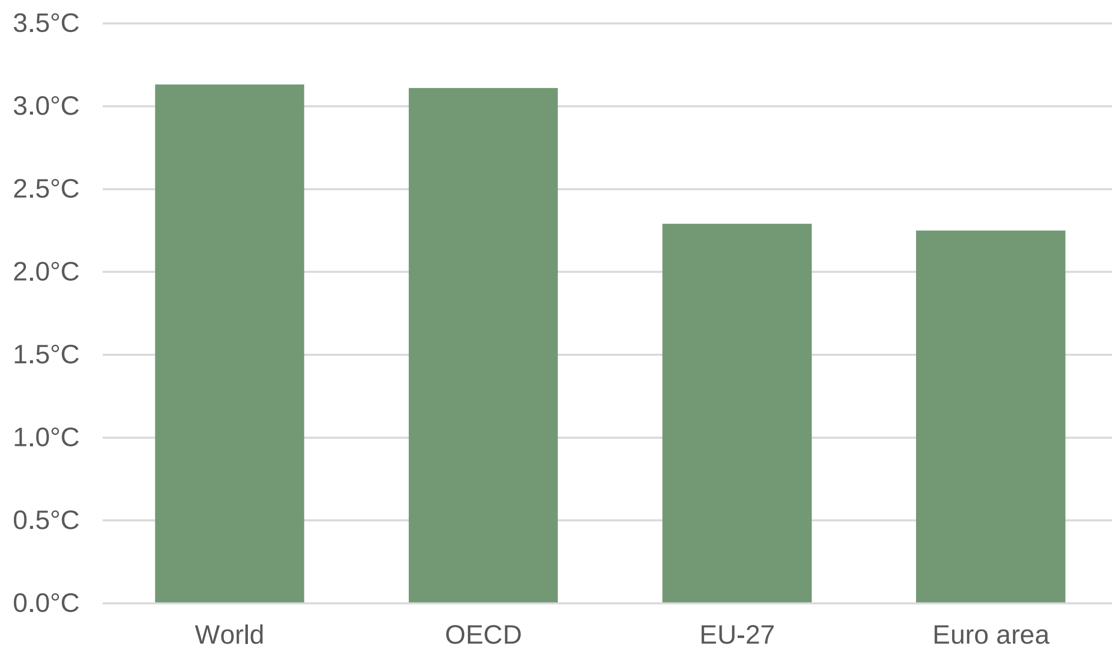
- FTSE Russell and Beyond Ratings offer a methodology to assess countries' implied global warming temperatures based on their national commitments concerning climate change mitigation, as per their NDCs ("*Nationally Determined Contributions*"), submitted to the UNFCCC.
- This approach is particularly relevant for investors who want to assess their alignment with climate targets (e.g. 2°C targets), and the underlying risks resulting from exposure to countries presenting a misalignment with these targets.
- Our methodology assesses that the warming temperature of NDCs remains above 3°C globally – far from the Paris Agreement target of well below 2°C. Moreover, the actual global warming by 2100 could reach a significantly higher level if measures are not implemented to reach NDC targets.
- The FTSE Russell's and Beyond Ratings' methodology is built on the proprietary CLAIM model (Climate Liabilities Assessment Integrated Methodology); it enables forward-looking assessments of countries alignment with long-term climate goals.
- In particular, this solution allows assessing country GHG emissions budgets consistent with a global 1.5°C or 2°C target (or any other target). In addition, it can compare these budgets with those derived from the political commitments of countries, and estimate a temperature equivalence by country.
- This methodological paper represents an introduction to:
    - the key principles of the CLAIM budget assessment model;
    - the variables used in the model and key outputs;
    - the approach applied to assess country temperatures beyond carbon budgets;
    - the climate equation used in this analysis.
- Our approach to measuring the temperature (implicit global warming trajectory) of sovereign investments consists of four simple key steps: (i) assessing 2°C carbon budgets by country; (ii) evaluating gaps between these budgets and the emissions level induced by countries' policy commitments; (iii) estimating countries' temperatures resulting from these gaps; and (iv) calculating aggregate results based on portfolios or benchmarks

More ambitious climate targets needed

The sovereign temperature methodology presented in this paper has been applied to evaluate the temperature of more than 100 countries. This allows us to quantify the implied global warming corresponding to NDCs.

Even if NDC goals were achieved worldwide, global warming would still remain above 3°C – far from the international target of sub-2°C. A similar result is also observed when considering OECD countries, even though the international commitments of the European Union and Euro area are closer to the Paris agreement objective (slightly below 2.5°C).

Figure 1. Regional temperatures (country averages weighted by 2019 territorial GHG)[3]



SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH.

These temperatures are based on an assessment of what each country's target would imply globally if all countries aimed to achieve a similar goal. To this end, the level of ambition for a country in its NDC is compared to the level of ambition that could be expected from this country based on our CLAIM assessment of national GHG budgets, for a given temperature target (*i.e.* 2°C or any other target). The gap between the two is then applied to a global budget to estimate the corresponding level of alignment to, or deviation from, the considered temperature target.

Beyond these aggregate results, it can be noted that sizeable differences of temperatures can exist between countries, as illustrated in Figure 2, based on the top 25 global economies.

[3] The assessments for the EU-27 and the Euro area are based on the 2016 European NDC. We will update our assessment when the breakdown by Member States of the updated NDC submitted by the European Union in December 2020 is available.

Figure 2. Categorization of the top 25 economies (2019 GDP) by alignment level[4]

Level of alignment with the Paris Agreement	Temperature range	Countries
Strong misalignment	Above 3°C	Saudi Arabia, Australia, Russia, United States, Canada, South Korea, China, Taiwan[5]
Intermediate misalignment	2.3 to 3.0°C	Thailand, Turkey, Japan, Netherlands, Poland, Belgium, Brazil, Germany
Alignment or close to alignment	Below 2.3°C	Indonesia, Mexico, United Kingdom, Spain, Italy, India, France, Switzerland, Sweden

SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

Note: These results are based on the achievement of NDC goals, which will generally require significant efforts.

It should be underlined that a significantly higher global warming could be reached if efforts were not made to meet NDC targets, particularly if the largest emitters do not achieve expected GHG cuts. Our methodology would result in higher temperatures under business-as-usual or current policy scenarios, as they imply higher levels of emissions than NDCs.

Among other uncertain factors, tipping points could also bring higher warming effects than expected, for example in relation to permafrost thawing and the resulting methane release. Such tipping point impacts are challenging to evaluate but could significantly intensify global warming. Lastly, temperature assessments as already described remain subject to possible changes, depending on evolutions of climate science parameters or country policy commitments, with 2021 a sensitive year in this regard. The sixth assessment report should be released by the Intergovernmental Panel on Climate Change (IPCC) and many countries may update their NDC targets prior to COP26, as indeed a number of countries have already started to do.

Key principles of the methodological approach

The temperature assessments are based on the comparison of two variables:

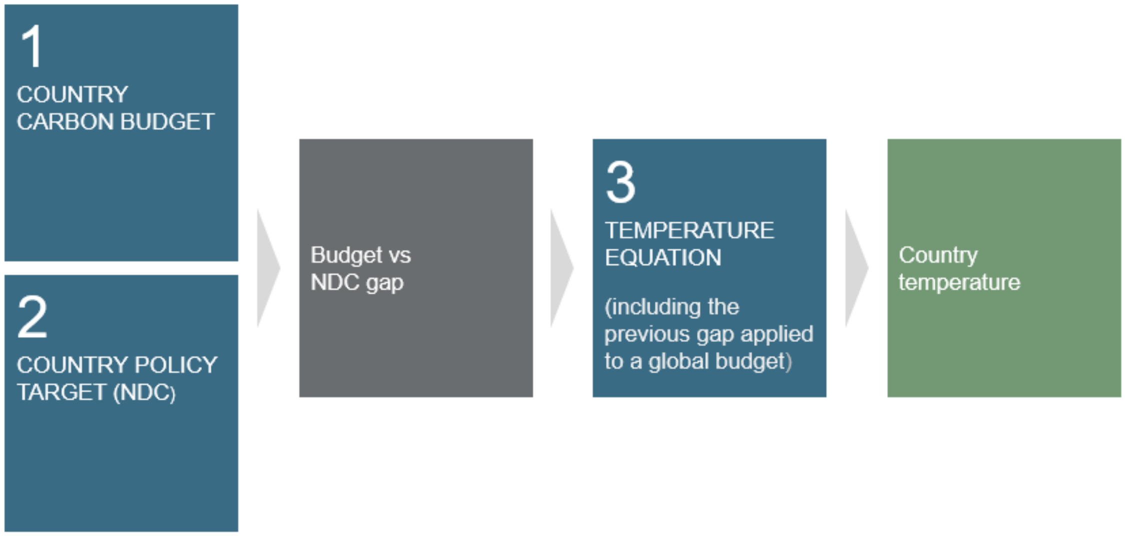
- The country's remaining GHG budget consistent with a given global warming limit (*e.g.,* 2°C) and depending on past and current emissions levels. The estimation of this budget is based on a statistical approach (*i.e.* the CLAIM model, see below).
- The projected GHG emissions deduced from the country's policy commitment to limit the level of its emissions (based on its NDC).

The comparison of these two variables allows the assessment of any gaps between a country's "share of the burden" to achieve global climate goals (level of effort to be expected, based on its climate profile) and its policy commitment (NDC goal). This gap can then be applied to the global budget in line with the selected objective (*e.g.,* 2°C). This allows the implicit global warming to be gauged if all countries have the same level of ambition (approximated through this gap between the remaining budget and the political target).

[4] We will accordingly update our assessment for European countries when the breakdown by Member States of the updated NDC submitted by the European Union in December 2020 is available.

[5] Taiwan is not formally part of the UNFCCC's process but our assessment is based on the official national target of this country

Figure 3. Overview of the calculation methodology (example based on 2°C GHG budgets)



SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

In this context, the next sections present the three dimensions of our methodology in more detail and outline how they are combined with each other.

Temperature assessment methodology

The global "implied" temperature of a country (implied 2100 global temperature warming based on the trajectory of the country's NDC) represents an expected global temperature assessment for 2100 if all countries had the same level of ambition as the country analyzed.

Country ambition is characterized by the difference between the GHG emissions of its NDC objective, and its GHG emissions budget compatible with a 2°C limit (or another warming limit). Applying the spread of this gap at a global level and translating it in terms of emissions make it possible to determine an implicit level of global warming in 2100.

Relation between temperature and carbon budget

Our approach involves a temperature equation adapted from IPCC (2018)[6] and Rogelj *et al.* (2019)[7], as described below. In this process, global variables are combined with country data.

Once the NDC-based budget is translated into a global budget equivalent, it can be used to determine a corresponding (or implied) global temperature variation. This step relies on a physical relation between emissions and temperature estimated in the scientific literature and consolidated in the IPCC reports. This relationship is mainly based on a coefficient called the "Transient Climate Response to cumulative carbon Emissions" (TCRE), in other words the global temperature change per unit of CO_2 emitted.[8]

[6] IPCC, 2018. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change.

[7] Rogelj, J., Forster, P.M., Kriegler, E. et al. (2019), Estimating and tracking the remaining carbon budget for stringent climate targets. *Nature.*

[8] It is important to note that this parameter can be adjusted in every new IPCC report in accordance with new scientific knowledge. There are still uncertainties in its calculation for instance around physical and carbon cycle feedbacks.

In order to calculate a global temperature variation $\mathbf{T_i}$ that would result from the carbon budget $\mathbf{B_i}$ (based on the NDC commitment of country **i**), the determination equation needs some adjustments in addition to the TCRE term. As a result, the following temperature equation is applied in our methodology.

$$T_i = TCRE * (B_i + B_{safe}) + T_{hist} + T_{non\text{-}CO2}$$

For more information, Figure 4 presents the definitions of considered variables.

Figure 4. Detailed variables of the applied temperature equation

Variable	Definition	Applied value[9]
TCRE	Transient Climate Response to cumulative carbon Emissions: coefficient of the physical relation between CO2 emissions and the global temperature	0.000544
$B_i = (GAP_i * B_{tot,2°})$	Application of a gap to the global carbon budget based on the characteristics of country i (implicitly assuming that all countries have the same gap as country i)	Country data
$GAP_i = (B_{i,NDC} / B_{i,2°})$	Gap between the NDC target of country *i* and its 2°C-aligned carbon budget (2030 values[10])	Country data
$B_{i,NDC}$	Level of carbon emissions calculated based on the NDC target of country *i*	Country data
$B_{i,2°}$	2°C-aligned carbon budget of country *i* calculated with the CLAIM methodology described below in this paper	Country data
$B_{tot,2°}$	The global carbon budget consistent with a 2° warming as assessed by the IPCC (in $GtCO_2$)	1333
B_{safe}	Safety budget (in $GtCO_2$) in anticipation of retroaction emissions not accounted in the TCRE estimation, for instance related to permafrost thawing and resulting methane release – Climate change can indeed be impacted by tipping points and significant feedback mechanisms	100
T_{hist}	The global warming induced by the GHG already emitted in the atmosphere due to human activities (in °C)	1.02
$T_{non\text{-}CO_2}$	Contribution of non-CO_2 gases to future warming (in °C)	0.2†

SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

†This value of Tnon-CO2 is relevant for a value of Ti around 2°. Afterwards, Tnon-CO2 increases by 0.1 for each 0.5 increase in Ti

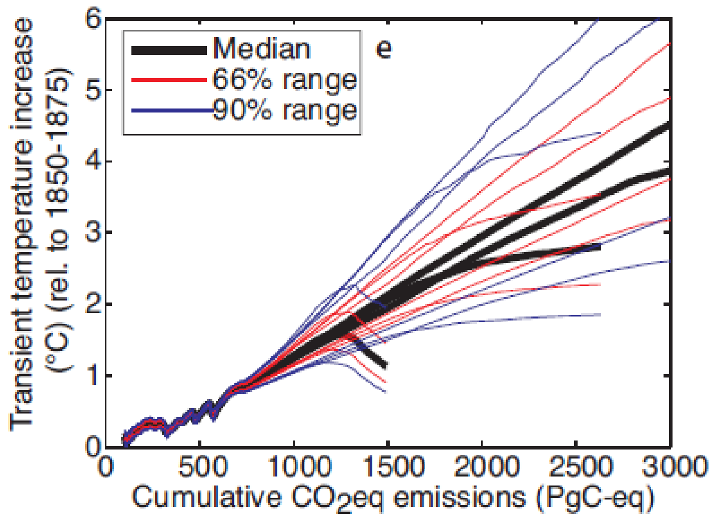
[9] As of the date of this report – These variables might evolve, for example in line with climate science developments.

[10] We estimate that the gap calculated with 2030 values is the best approximation of ambition gap between NDC and 2° trajectories. The NDCs provide precise information until 2030 but the extension of the trajectories after 2030 is necessarily dependant on weaker assumptions. This will most likely evolve in the future with the growing number of mid-century targets communicated by countries.

This equation is calibrated on the recommendations of Rogelj *et al.* (2019) based on IPCC (2018). We will assess the opportunity to update this calibration when the data from the next IPCC report become available.[11]

The TCRE plays a critical role in the analysis of the physical relation between emissions and temperature (see Figure 5 for an illustration). For instance, calibrating the global carbon budget consistent with a 2° warming relies on the median TCRE from IPCC (2018). With the 67th percentile of the TCRE, the 2°C remaining carbon budget would have been around 300GtCO_2eq lower.

Figure 5. Illustration of the TCRE (slope of the curves)



SOURCE: IPCC (2013)[12]

Note: The four black curves represent the cumulative emissions from the four IPCC's emissions scenarios (RCP). The TCRE can be interpreted as the slope of the curves.

Despite inherent uncertainties, the TCRE coefficient is considered to be robust within a large range of carbon budgets, approximatively corresponding to a global warming between 1°C and 5°C. The level of uncertainty is higher beyond this range, but the temperature results still remain useful to compare countries' levels of ambition.

Country carbon budget assessment (CLAIM model)

Applying the temperature equation described above to determine a country's temperature requires to evaluate a relevant gap between its position, or policy commitment, and the carbon budget that could adequately be attributed to it. This section provides more details on how we estimate carbon budgets by country through the CLAIM model (Climate Liabilities Assessment Integrated Methodology).

The methodology is based on several key principles. It does not assign a national budget following a unique criterion – such as "capacity" or "responsibility." It offers, for analytical purposes, a statistical

[11] The sixth assessment report of the IPCC is supposed to be published by the end of 2021.

[12] Figure 12.45 in IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

and non-normative approach to allocate a global carbon budget among countries in a consensual manner.

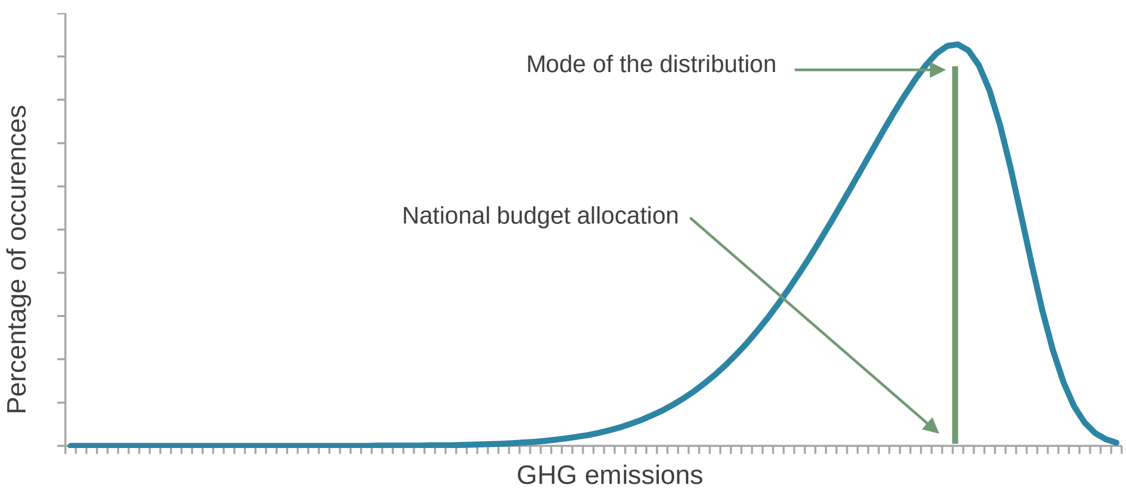
- The starting point of the methodology is the Kaya equation, which is a formula that illustrates the main drivers of carbon emissions.

Figure 6. Kaya equation

$$\frac{GHG\ Emissions}{Population} = \frac{GDP}{Population} * \frac{Energy}{GDP} * \frac{GHG\ Emissions}{Energy}$$

- The components of the Kaya equation are broken down into 15 variables that take into the current situation of emissions drivers, their recent evolution and historical emissions.
- Based on these 15 criteria, a probabilistic approach of allocations, which consist of two million simulations that test multiple ways of combining criteria, is then applied.
- These tests give a number of potential carbon budgets for each country, taking into account the ways in which criteria can be combined. The result provides a distribution of potential budgets by country with associated probabilities.
- We can then estimate the most likely carbon budget for each country with the mode of the distribution. The mode can be interpreted as the broadest scope of potential negotiation outcomes.
- As a result, a national budget is attributed to each country.
- Finally, to ensure consistency between the sum of these budgets and a given global target (2° or 1.5°C for instance), an adjustment coefficient is uniformly applied to each national budget. This reconciles the country distribution of budgets assessed based on our simulations, with global carbon budgets corresponding to specific alignment levels. The IPCC database provides the global carbon budgets associated to specific global warming levels used for this calibration.

Figure 7. Distribution function analysis in CLAIM assessments of budget allocations



Note: This chart is only illustrative and does not rely on real data.

SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

To conclude, the CLAIM simulations enable the breakdown of a global carbon budget into national budgets, in a manner that corresponds to a given warming target and which could be seen to be as consensual as possible. The table below describes the 15 factors tested in the statistical simulations applied to estimate national carbon budgets.

Figure 8. Variables included in CLAIM simulation tests

Variables
GDP/capita in constant US$ (Last Available Data: LAD)
GDP/capita evolution since 2000
Energy intensity of GDP at US$ constant (without biomass) (LAD)
Energy intensity of GDP at US$ constant (without biomass) evolution since 2000
CO_2 intensity of energy (kg per kg of oil equivalent energy use) (LAD)
CO_2 intensity (kg per kg of oil equivalent energy use) evolution since 2000
GHG including LULUCF (land use, land-use change, and forestry) per capita (LAD)
GHG including LULUCF per capita evolution since 2000
CO_2 emissions from the energy sector (LAD)
CO_2 emissions from the energy sector evolution since 2000
GHG emissions excluding CO_2 from the energy sector (LAD)
GHG emissions excluding CO_2 from the energy sector evolution since 2000
Primary energy consumption per capita (LAD)
Primary energy consumption per capita evolution since 2000
Total CO_2 emissions since 1950

SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

Country policy target assessment

Assessing countries' commitments to limit their GHG emissions is a cornerstone of the global temperature methodology, with the "Gap" variable being an indicator of the level of ambition of these commitments. This variable relies on (i) the carbon budget computed by the CLAIM model and (ii) the countries' official mitigation commitment, taken from the Nationally Determined Contributions. However, the information embedded in the countries' NDCs is extremely heterogenous. Countries' commitments can vary in different ways:

- their mathematical nature: *e.g.* emissions reduction compared to an historical level (with various possible reference dates such as 1990, 2005 or 2010), emissions reduction compared to a «business as usual» scenario (projected level), emissions intensity reduction (emissions per capita or per GDP), emissions peak, etc.
- their sectoral coverage: the sensitive issue with regards to sectoral aspects is mainly the inclusion (or not) of the LULUCF sector (land use, land-use change and forestry). Globally, countries expect that this sector will provide around 25% of the mitigation outcomes by 2030. However, there are very high uncertainties around the accounting of emissions and

removals[13] of the LULUCF sector, potentially leading to strong biases in the assessment of countries' ambition levels (for more details see for instance Forsell et al. 2016[14]). We rely on Grassi et al. (2017)[15] to coherently include the LULUCF sector in our analyses.

More generally, the different data sources used by countries in their NDCs is a significant challenge from the perspective of constructing an homogenous database of countries' NDC targets. Therefore, we use the "PRIMAP-hist" GHG emissions database developed by the PIK Institute (Potsdam Institute for Climate Impact Research)[16] to which we apply the emissions evolution rates deduced from the information found in NDCs. In the end, we find a global volume of emissions from NDCs' targets in 2030 that is very close[17] to the one computed by UNEP in its pledge pipeline[18] calculations.

Finally, it is important to note that long-term commitments (usually on a 2050 horizon) are not taken into account in our analytical framework. Despite recent announcements, the submission of long-term strategies to the UNFCCC[19] is not mandatory in the Paris Agreement and very few countries have done it. Net zero objectives are very important signals to economic actors, but targets with such a far horizon should be integrated in the evaluation of a country's ambition only if this country provides intermediate objectives consistent with the long-term target. With more specific commitments from countries and further modelling developments, long-term strategies are expected to become a more important component of our assessments in the future.

[13] Absorptions of CO_2 by the different categories of land, especially forests

[14] Forsell *et al.* (2016). Assessing the INDCs' land use, land use change, and forest emission projections. *Carbon Balance Manage*

[15] Grassi *et al.* (2017), The key role of forests in meeting climate targets requires science for credible mitigation, *Nature Climate Change.*

[16] Gütschow et al. (2019): The PRIMAP-hist national historical emissions time series (1850-2017)

[17] The difference is less than 2%.

[18] https://www.unenvironment.org/explore-topics/climate-change/what-we-do/mitigation/pledge-pipeline.

[19] United Nations Framework Convention on Climate Change

Key output and indicators

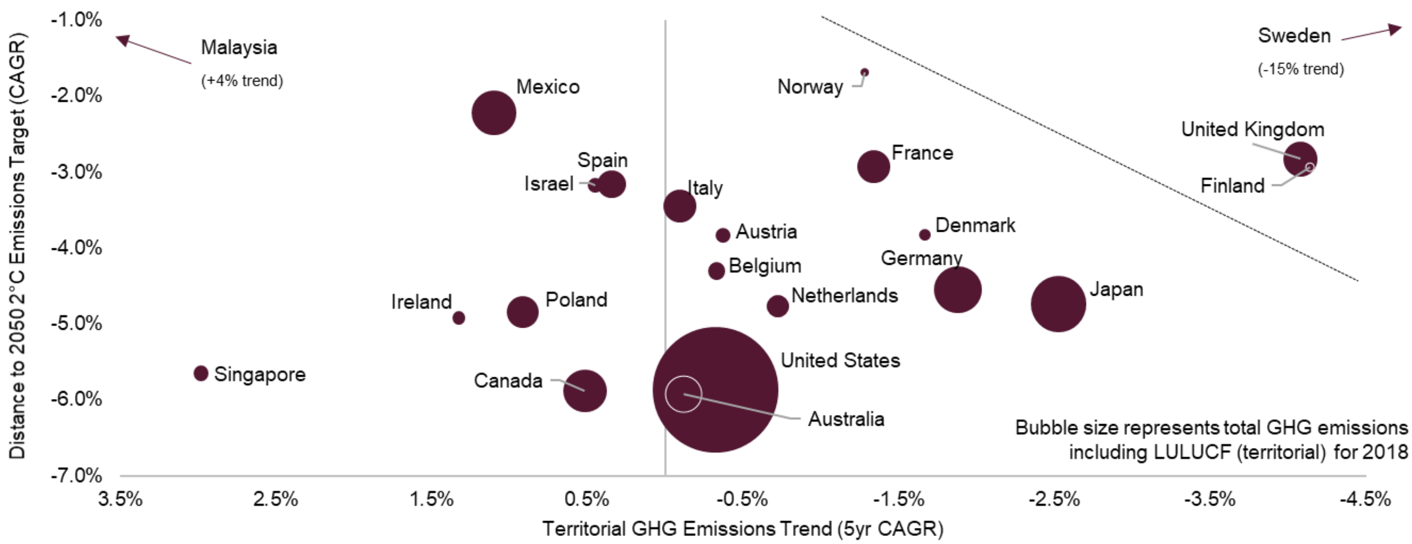
The CLAIM methodology can be leveraged to calculate several types of indicators. This includes of course temperatures as has been described, but also various other KPIs using carbon budgets derived from CLAIM simulations.

The list below describes several examples of indicators that can be produced, based on our approach.

- **NDC temperature equivalent:** Implied 2100 global temperature increase based on the trajectory of countries' NDCs. Intended country CO_2 emissions in the future – as explicitly or implicitly targeted in the National Determined Contribution (NDC) – are translated into an equivalent climate trajectory (temperature evolution) by comparing them with carbon budgets.
- **Territorial distance to target**: Required annual reduction of total territorial GHG emissions, including LULUCF (land use, land-use change and forestry) to reach 2°C-compliant territorial GHG budgets in a given future year. This indicator is expressed as CAGR (compounded annual growth rate).
- **GHG emissions gap between trend and distance to target:** Gap between the 5-year historical trend of total territorial GHG emissions, including LULUCF, and the required annual reduction of these emissions to reach 2°C-compliant territorial GHG budgets in a given future year (based on CAGRs).

Beyond temperatures, the figure below shows for instance the territorial GHG distance to target by 2050 and 2012-2017 GHG trend values for the countries of the FTSE World Government Bond Index (WGBI), used in our 2020 assessment. Such indicators help to highlight the additional efforts required in most countries to achieve a 2°C alignment, in comparison with historical trends.

Figure 9. Annualized distance to 2 Degrees Emission Target vs Recent 5 Year Trend – WGBI countries (2018 data)



SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

Notes: The variable represented on the Y-axis (distance to target) is the annual emissions reduction necessary to reach the 2050 emissions level consistent with a 2°C world. WGBI countries as of July 2020.

The territorial distance to target and GHG emissions gap between trend and distance to target are two of the main indicators used in the FTSE Climate GBI Series (Climate Risk-Adjusted Government Bond Index). More details can be found on this methodology in our Research on the Climate GBI index family.[20]

Temperature at portfolio level

There are several ways to aggregate temperatures at portfolio level. A simple and standard approach consists in calculating the weighted average of the temperatures associated with each portfolio holding.

Such averages are typically weighted by market values. In some cases, weightings by contributions to total GHG emissions or carbon footprints (such as GHG/GDP) may also be considered.

If using a standard weighted average (weighted by market value), the portfolio temperature would be calculated as follows.

Figure 10. Illustrative calculation of a portfolio average weighted by market values

Country	Market value weight	Temperature	Contribution
Country A	40%	3.5°C	40% x 3.5 = 1.4
Country B	35%	3.0°C	35% x 3.0 = 1.1
Country C	25%	4.0°C	25% x 4.0 = 1.0
Total	**100%**	**1.4 + 1.1 + 1.0 = 3.5°C**	

SOURCE: FTSE RUSSELL & BEYOND RATINGS RESEARCH

At world level, it can be observed that the temperature assessment weighted by territorial GHG emissions and by general government debt are very similar, respectively 3.1°C and 3.0°C (with about 95% of government debts globally being covered).

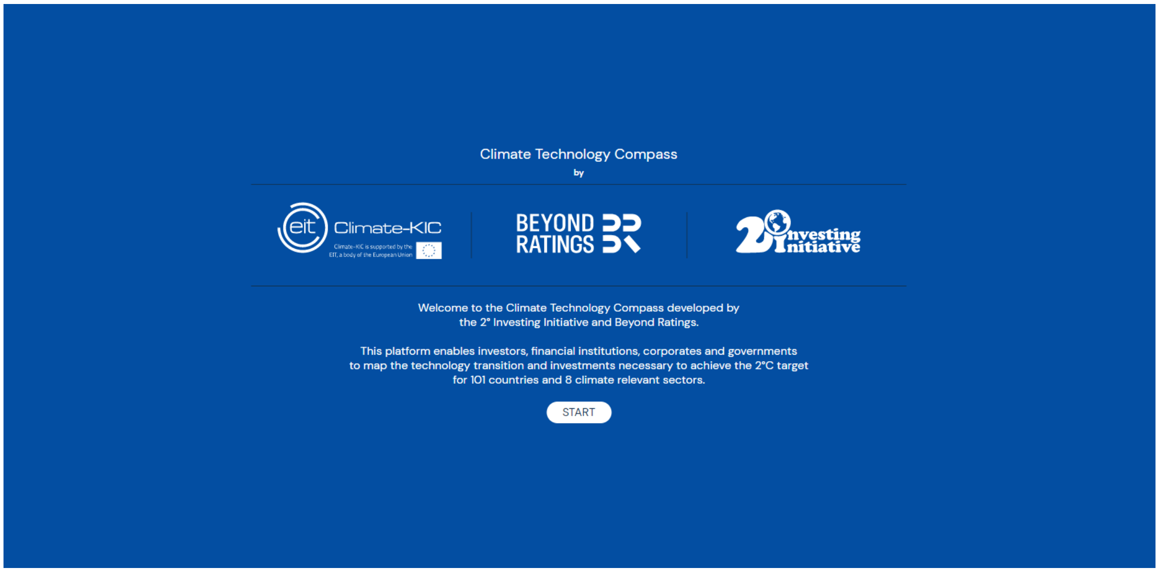
[20] FTSE Russell (2020). How to build a climate-adjusted government bond index.

Appendix

The Climate Technology Compass

The CLAIM model has led to further methodological developments. On this basis, we have also developed the Climate Technology Compass available online:

https://compass.transitionmonitor.org



This open-access platform combines our national climate alignment assessments with sector analyses. It enables investors, financial institutions, corporates and governments to map the technology transition and investments necessary to achieve the 2°C target for 101 countries and eight climate-relevant sectors (e.g. power, automotive, steel, cement etc.).

Outputs include a range of sector-specific metrics (such as production, capacity, emissions or investment needs data) under 2°C or NDC scenarios, and based on relevant technologies in analyzed sectors. It was supported by EIT Climate-KIC, a European Union-financed body.

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