

The XDC Model

1. About the X-Degree Compatibility (XDC) Model

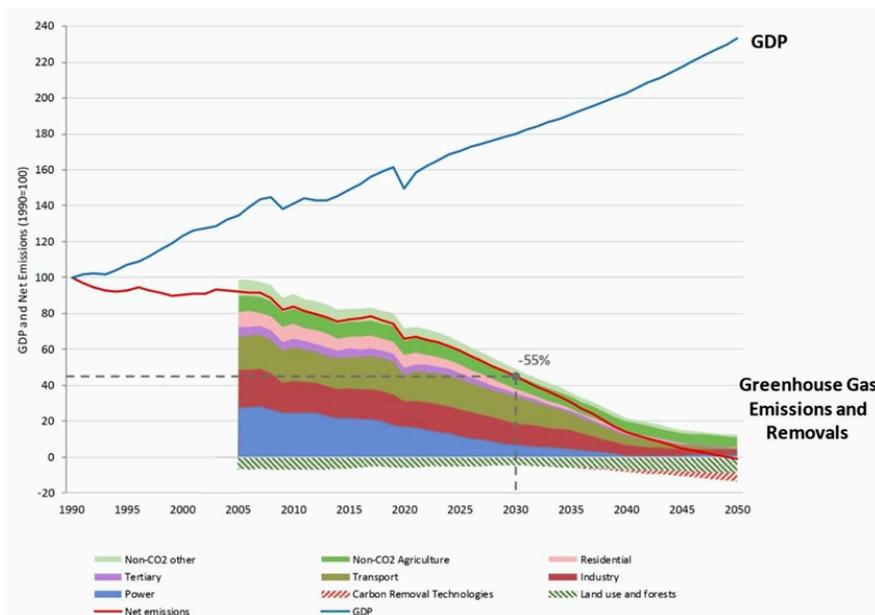
The X-Degree Compatibility (XDC) Model is an economic climate impact model, calculating the temperature alignment of an economic entity, such as a company, a building, a sovereign, or a portfolio. It analyses the degree of global warming that an economic entity is compatible with under various scenarios, answering the question: "How much warming could we expect if the entire world performed as well as this particular entity?", with performance measured with respect to a sector-specific economic emissions intensity (EEI) benchmarks. Results are expressed in a tangible degree Celsius (°C) number: **the XDC**.

To the best of our knowledge, the XDC Model is the only temperature alignment methodology to use an iterative climate model (Finite Amplitude Impulse Response, FaIR [1] [2]), i.e. one that updates the state of the climate system for each year of input emissions and considers multiple different gases explicitly. There are many advantages to this approach, one of which is the ability to quantify the different impacts of early mitigation of emissions versus later use of negative emission technologies. A further benefit is that the effect of climate uncertainties on the temperature calculation can be quantified.

The XDC Model was developed by *right. based on science* and is the 'engine' powering software products and services for companies, asset managers, banks, and others to conduct climate impact analysis, manage their Temperature Alignment / Paris Alignment, simplify sustainability reporting, set sound and science-based emission reduction targets, conduct forward-looking scenario analysis, guide climate-conscious investment and engagement decisions, and communicate with stakeholders. XDC Model is science-based, peer-reviewed, forward-looking, scenario-agnostic, and transparent temperature-alignment model and is available as an Open Source application.

2. The concept of XDC

XDC Model has a core logic which focuses on the decoupling of value creation from emissions. This is the same logic that underpins the European Green Deal as "a new growth strategy [...] where economic growth is decoupled from resource use" [3] (see Figure 1). As companies are the primary economic source of emissions, the application of the XDC Model's logic to companies describes the base version of the methodology, which is focused in this documentation. This core XDC Model is designed to analyze the Temperature Alignment of companies, focusing on Gross-Value Added (GVA) as the parameter for value creation.



1. Figure 1 - The EU's pathway to sustained economic prosperity and climate neutrality, 1990-2050

3. Core XDC Model: Companies

The following section describes the methodology behind the XDC calculations for companies. While some adjustments are necessary for the other applications of the XDC Model, the basic principles remain consistent throughout.

3.1. Data & Sources

The following data are used in the calculation of XDC Metrics for a company:

Company level data

- Gross value added in the base year: GVA_{by}

$$GVA_{by} = EBITDA + \text{Personnel Costs}$$

▼ GVA Definition

GVA is defined as EBITDA plus Personnel Costs.

Company's GVA is an equivalent metric to evaluate the contribution of a company to GDP, to be used in the construction of EEI pathways. GDP is an established metric to evaluate the economic growth in macroeconomic scale, i.e. global or national economies.

The equivalent measure of macro-level GVA in company-level can be calculated as: $GVA = \text{Employee costs} + \text{Taxes net of subsidies (excluding those applied to products)} + \text{Profit}$. This can equivalently be written as: $GVA = EBITDA + \text{all personnel costs}$, for EBITDA being earnings before interest, taxes, depreciation, and amortization (check page 38 in [4] and page 24 in [5] for further information).

Source: FactSet Research Systems (FactSet)[6], unless otherwise specified or agreed upon.

- Greenhouse gas (GHG) emissions for scopes 1, 2, and 3 in the base year: $E_{by, i}$ for $i=1,2,3$

Source: Intercontinental Exchange (ICE) [7], unless otherwise specified or agreed upon.

Alternatively, the Economic Emission Intensity (EEI) for the base year can be given directly as input, as described below in [Calculation](#).

Global data

- Emissions of 39 different gases including CO₂, CH₄, N₂O, etc (for further details check Table 1 in [1])

Source: SSP Database[8]

- Gross Domestic Product (current US\$)

Source: World Bank[9]

- Gross Domestic Product (constant 2010 US\$)

Source: World Bank

- Gross Domestic Product, PPP (current international \$)

Source: World Bank

Growth rates (depending on scenario assumptions)

- Annual growth rate of the entity's emissions: r_e
- Annual GVA growth rate of the entity (being company or sector): r_{gva}
- Annual global emissions growth rate of all FaIR gases

Growth rates are required inputs to the model. Depending on the chosen scenario, different assumptions about these growth rates are made.

3.2. Calculation

The core XDC calculation process is divided into the following steps:

1. Determining the Economic Emission Intensity (EEI) for the company in a given base year, that is: the quantity of GHG emissions the company needs to generate EUR 1 million in GVA adjusting for biases due to inflation and differences in purchasing power, and projecting the development of this EEI from the base year until the end year (along the assumptions derived from a chosen scenario).
2. Determining the Economic Emission Intensity (EEI) for the sector in a given base year, that is: the median EEI of the companies in the sector after adjusting for biases due to inflation and differences in purchasing power, and projecting the development of this EEI from the

base year until the end year along the assumptions derived from a baseline and decarbonization pathways of a chosen scenario provider.

3. Evaluate the performance of the company's EEI with respect to the sector-specific EEI benchmarks to calculate how the company is compared to its sector specific baseline and target decarbonization pathways.
4. Mapping the company EEI from base year to end year up in a global level, thus determining the GHG emissions that would reach the atmosphere if the entire world performed the same as the company under consideration.
5. Computing the degree of global warming resulting from the emissions determined in the previous step. To do so, the emissions of different gases need to be input into a climate model, namely the Finite Amplitude Impulse Response (FaIR) Model.

The following section provides the detailed calculations for each step.

Step 1: Determining Company's Economic Emission Intensity (EEI)

The Economic Emission Intensity (EEI) is defined as the quantity of GHG emissions (in tons CO₂e per EUR 1 million GVA).

The EEI of the company is then calculated for every year from the base year until the target year, and for each of the three scopes by applying growth rates according to growth assumptions under consideration (see paragraph "Growth Rates" in [Data & Sources](#)). For the purposes of the calculation, the following variables can be considered:

Let

- k span across the range from base year (e.g. 2022) to target year (2100),
- i be the GHG scope index (1,2,3),
- s be the internationalization shares (country, region, world)
- $E_{k,i}$ be the company's emissions for scope i in year k ,
- GVA_k be the GVA of the company in year k ,
- r_e , and r_{gva} be the coefficients which indicate respectively the growth rate of emissions and GVA of the company,
- p_s , be the PPP\$ conversion factor defined as quotient of the GDP in PPP\$ and the GDP US\$,
- and d_s , be the inflation adjustment based on corresponding deflators derived from the quotients of GDP in current US\$ and GDP in constant US\$.

Calculation sequence & formulas

First, the EEI of the company is calculated by using the base year emissions and economic data from the company. Then the nominal gross value added of the company is converted to PPP\$ in 2017 constant prices. Finally, the development of the EEI pathway is calculated by applying the region-specific economic and emissions growth assumptions based on a chosen scenario. To avoid double counting, Scope 2 and Scope 3 emissions are currently considered with a factor of 50%.

Table 1

I.	Apply internationalization to each emission scope i in the base year	$E_{b_y,i} = E_{b_y,i,country} + E_{b_y,i,region} + E_{b_y,i,world}$
II.	Company emission regional shares s for year k and scope i	$E_{k,i,s} = E_{b_y,i,s} (1 + r_{e,s})^{k-b_y}$
III.	Company emissions for year k and scope i	$\sum_s^{shares} E_{k,i,s}$
IV.	Apply internationalization to the GVA in the base year	$GVA_{b_y} = GVA_{b_y,country} + GVA_{b_y,region} + GVA_{b_y,world}$
V.	Apply PPP\$ conversion p and inflation adjustment d to each share s	$GVA_{b_y,s} = p_s d_s GVA_{b_y,s}$
VI.	Company GVA shares s for year k	$GVA_{k,s} = GVA_{b_y,s} (1 + r_{gva,s})^{k-b_y}$
VII.	Company GVA for year k	$\sum_s^{shares} GVA_{k,s}$
VIII.	Company EEI for year k and scope i	$EEI_{k,i} = \frac{E_{k,i}}{GVA_k}$

Step 2: Determining Sector Benchmarks' Economic Emission Intensity (EEI)

Sector definition and constraints

The sector is defined by a NACE code; normally 4-digit NACE code, as the highest granularity available. The minimum data requirement to define the sector median EEI of a particular sector is 30 companies, which is commonly used in sampling in statistics [10]. If the sector does not have enough data, a lower granularity NACE code is used (e.g. the 3-, 2-, or 1-digit NACE code in lieu of the 4-digit NACE code).

Currently, the calculation is available on 4-digit NACE levels. Utilizing these data, the sector median EEI is determined as the median of the companies' EEI in a sector (Steps I-V in [Table 2](#)).

▼ NACE

“Nomenclature statistique des Activités économiques dans la Communauté Européenne” = Statistical Classification of Economic Activities in the European Community. European standard system for classifying industries.

Sector baseline EEI pathway

Sector baseline EEI pathway is the emission intensity (EEI) trajectory of the particular company's sector. For the purpose of calculating XDCs, the XDC Model treats each sector like an economic entity. The baseline assumptions for the sector baseline EEI pathways are derived from a chosen SSP scenario data.

Table 2

I.	Apply internationalization to the companies GVA in the base year	$GVA_{b_y} = GVA_{b_y, country} + GVA_{b_y, region} + GVA_{b_y, world}$
II.	Apply PPP\$ conversion p and inflation adjustment d to each share s	$GVA_{b_y, s} = p_s d_s GVA_{b_y, s}$
III.	Company GVA for base year	$\sum_s^{shares} GVA_{k, s}$
IV.	Companies EEI for base year and scope i	$EEI_{b_y, company, i} = \frac{E_{b_y, i}}{GVA_{b_y}}$
V.	The EEI representative of the sector for each scope i in the base year is computed	$EEI_{b_y, NACE, i} = med(EEI_{b_y, company, i})$
VII.	Sector Baseline EEI for year k	$EEI_{k, NACE, i} = EEI_{b_y, NACE, i} (1 + r_{EEI, world})^{k-b_y}$ Let r_{EEI} be the coefficients which indicate the growth rate of the sector

Sector target EEI pathway

Sector target EEI pathway is a sector-specific EEI pathway in line with a global warming target (e.g., 1.5°C or 2°C). The sector target EEI benchmarks are given by applying the sector-specific decarbonization assumptions of a specific scenario. The sector-specific scenarios, which are currently integrated in the XDC Model, are provided by the International Energy Agency (IEA) [11][12], the Network for Greening the Financial System (NGFS)[13], and One Earth Climate Model (OECM) [14]. These scenarios consider mitigation capacities for different sectors, countries, and regions, and lay out contributions to emission reductions in line with the overall achievement of the 2°C or 1.5°C target for various industry groups and regions at various points of time in the future (for further information check Section [Model Characteristics](#)). Except NGFS sector-specific decarbonization pathways, all other scenario providers have data only until around mid-century. Thus, an extension of these decarbonization scenarios is necessary to be able to calculate temperature in 2100.

OECM scenarios only rely on nature based negative emissions, and reach zero emissions for all sectors by mid-century. For all sectors, emissions are kept constant to zero level from 2050 to 2100. IEA decarbonization pathways have integrated negative emission technologies within their modeling structure. To extend the sector-specific projection data, the XDC Model treats negative and gross emissions of the scenarios separately. In most scenarios, the gross emissions are decreasing over time while there is an increase in negative emissions especially in the second half of the century. So these two processes are asynchronous. Thus, in the XDC Model, gross emissions are reduced following a linearly reduction based on the last five-year average of the sector-specific gross emissions data. Negative emissions, on the other hand, are assumed to remain at the 2050 level for all sectors and subsectors until the end of the century. This documentation describes the XDC calculation utilizing the IEA decarbonization pathways. Nonetheless, similar methodology is used when applying NGFS and OECM decarbonization pathways.

Feasibility of cutting CO₂ emissions differs from sector to sector. From a comprehensive perspective, the excess of emissions caused by those industries with limited reduction potential needs to be compensated for by additional reductions in other sectors to achieve an overall temperature goal. Consequently, sector-specific benchmarks needs to be defined based on the sector's emission reduction potential in the context of the other sectors' reduction potential.

For the purpose of calculating XDCs, the XDC Model treats each sector like an economic entity with GVA growth derived from SSP2 data and emission reduction rate values obtained from the underlying scenarios. The sectors are defined using NACE codes as described in [Sector definition and constraints](#), but the IEA sectors are broader than these. XDC calculations therefore require a NACE-IEA sector mapping, as described in [Table 4](#) below. The IEA sectors are used to calculate the sector decarbonization emissions trajectory starting from the base year, but not the base year emissions themselves. Base year emissions are calculated from the NACE sector EEI as described above.

Since indirect (Scope 2 & 3) emissions can usually not be attributed to the same sector as the Scope 1 emissions, integrating them into the

sector median EEI requires an adjusted approach. Scope 2 emissions can be attributed to the power sector, thus scenario-specific emissions reduction goals of the power sector (or similar) are applied here. Scope 3 emissions mostly stem from a wide variety of sources, which can again be attributed to a wide variety of sectors. Thus, for Scope 3 an emission reduction rate is used that is aggregated from all sector-specific emission reduction rates as set out by the chosen temperature target scenario. To avoid double counting, Scope 2 and Scope 3 emissions are currently considered with a factor of 50%.

Calculation sequence & formulas

Table 3

I.	A linear interpolation to the IEA sector emissions trajectory of world is applied to provide annual values, where ks is the first year of the time step, kf is the final year of the time step, and k is any year in in the time step	$E_{IEA,k} = E_{IEA,ks} + \frac{E_{IEA,kf} - E_{IEA,ks}}{kf - ks} (k - ks)$
II.	The IEA sector emissions trajectory of world is normalized such that it is equal to 1 in the base year	$\frac{E_{IEA,k}}{E_{IEA,0}}$
III.	The GVA pathway (based on SSP2 scenario) is normalized for region 'World' such that it equals 1 in the base year	$\frac{GVA_{scenario,k}}{GVA_{scenario,0}}$
IV.	The normalized IEA pathway is divided by the normalized GVA pathway to get the sector EEI reduction curve	$\frac{E_{IEA,k}}{E_{IEA,0}} \left(\frac{GVA_{scenario,k}}{GVA_{scenario,0}} \right)^{-1}$
V.	Base year sector EEI is multiplied by the EEI growth pathway to get the NACE sector target EEI pathway	$EEI_{NACE,k} = \frac{E_{IEA,k}}{E_{IEA,0}} \left(\frac{GVA_{scenario,k}}{GVA_{scenario,0}} \right)^{-1} EEI_{NACE,0}$

NACE to IEA sector conversion

Because the target pathways are calculated using the emission trajectories from the IEA and the IEA sectors are different to the NACE sectors used for the sector definition, a mapping between the two is required. Table 4 includes a mapping between NACE 1- and 2-digit sectors to IEA sectors. A similar approach is used for NACE 3- and 4-digit.

Table 4

IEA Sector	NACE Code
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1-digit NACE Codes	
Industry	B, C, E, F
Power	D
Non-residential Buildings	G, I, J, K, L, M, N, O, P, Q, R, S, U
Transport	H
Residential Buildings	T
2-digit NACE Codes	
Industry	B05, B06, B07, B08, C10, C11, C12, C13, C14, C15, C16, C18, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, E36, E37, E38, E39, F41, F42, F43
Non-residential Buildings	B09, G45, G46, G47, H52, I55, I56, J58, J59, J60, J61, J62, J63, K64, K65, K66, L68, M69, M70, M71, M72, M73, M74, M75, N77, N78, N79, N80, N81, N82, O84, P85, Q86, Q88, R90, R91, R92, R93, S94, S95, S96, U99
Pulp and Paper	C17
Chemicals and Petrochemicals	C19, C20, C21
Power	D35
Transport	H49, H53
Residential Buildings	Q87, T97, T98
Shipping	H50
Aviation	H51

Step 3: GHG Performance

The XDC metric introduces the concept of performance, which compares the entity with the sector benchmarks. It can be treated as a universal criterion which maps the sector-specific data to the global scale through a normalization process, allowing the comparison to the sector specific benchmarks. The performance is the position of the entity's EEI compared to the sector benchmarks. It is calculated for each year up to the end of century. The XDC model applies the same performance of a particular entity to the world, assuming the world GHG contributors perform the same relative to their equivalent global benchmarks. Thus, the metric enables the comparability of XDC values among different sectors.

Moreover, in addition to CO₂, global emissions of other greenhouse gases (GHG, such as CH₄ and N₂O) can also be accounted for calculating the temperature level assuming same performance for all gases. By using global emission pathways for different GHGs and applying the XDC methodology, we can directly compare the XDC of an entity with the global temperature target (e.g., 1.5°C or 2°C). This feature provides the users of the XDC Model with XDC results which are easy to understand, communicate, and further use. For instance, a media company can claim their alignment with Paris Agreement when they have a XDC value of 1.4°C, while a car manufacturer with its XDC of 2.6°C needs more effort on emission reduction to reach the alignment with the Paris Agreement.

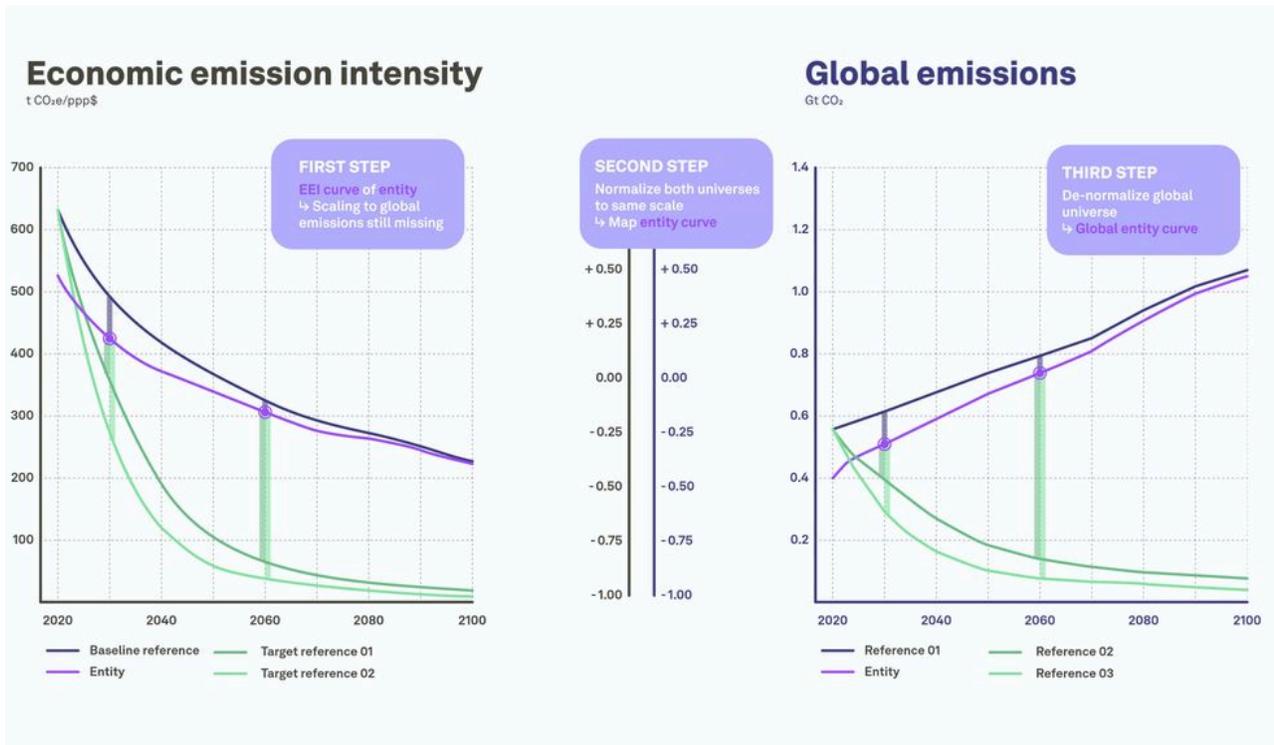


Figure 2 - The sector-world mapping, base year to 2100

Step 4: The XDC calculation

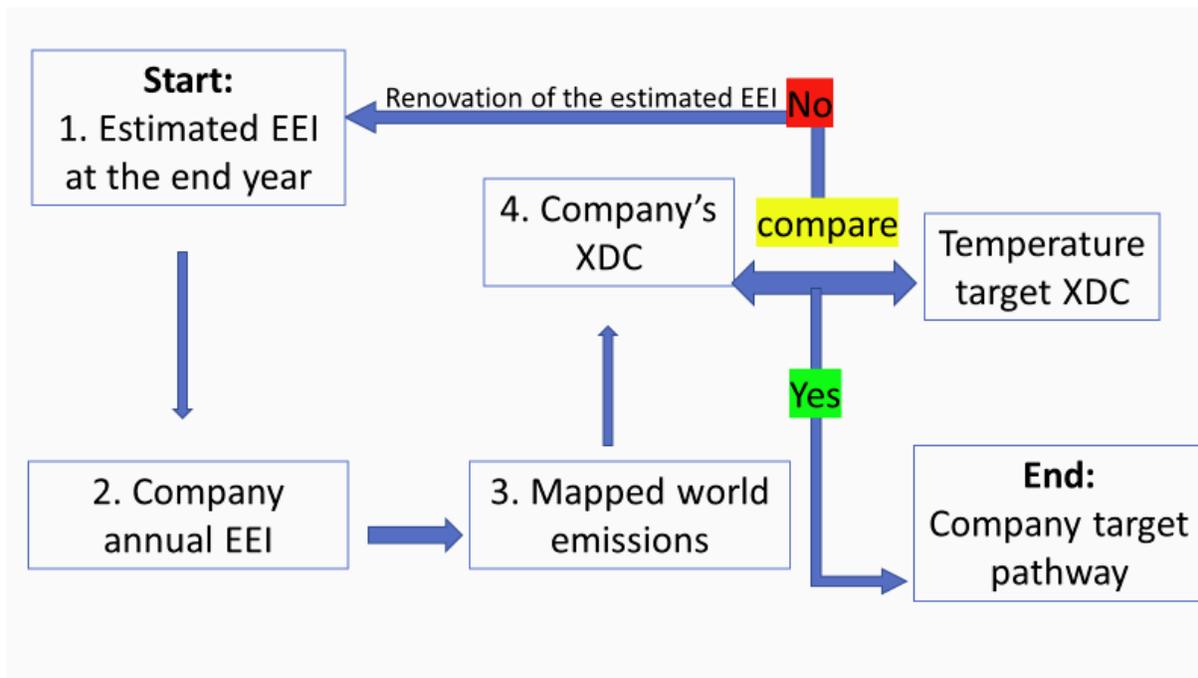
XDC is calculated by assuming that the whole world's GHG performance is identical to the company's GHG performance. The annual globally mapped emission data from previous step will be passed to the FaIR climate model. The FaIR model calculates the global temperature resulting from the emissions from base year to the end year (i.e. 2100). Accordingly, the XDC value is the global mean temperature change in 2100 relative to the pre-industrial level.

4. Company Target Pathway

The company target pathway is a pathway, which would lead a company to reach a specific temperature (e.g. 1.5°C in 2100). By following the target pathway from the base year, a company will achieve the compliance with a particular mitigation scenario.

To do this, the company's emissions intensity pathway is constrained to the most ambitious shape of target pathway of the company's sector. This constraint provides the emissions intensity of the company in any year as a function of the shape of the sector's target emission intensity pathway and the company's emissions intensity in the base and target year.

However, in this case, the company's emissions intensity in the target year are not specified and cannot easily be calculated using analytical techniques. Therefore, an iterative method is used to produce a numerical solution for the target year emission intensity which will result an XDC equal to the temperature target. Once found, the company's annual emissions from the base year to the target year can be calculated accordingly. In this approach, the company can build a strategy such that its XDC is compatible with a specific global warming mitigation target (e.g. 1.5°C).



Workflow of the iterative procedure

5. Functionalities

The XDC value represents the global warming of a plausible scenario, and the value is easy to communicate and understand. Comparisons between companies from different sectors or portfolios would be facilitated, helping our clients gain clarity regarding their own climate impact and helping them make climate friendly investment decisions. The XDC can be calculated for a multi-asset portfolio including different asset classes such as listed equity, corporate bonds, sovereign bonds, private equity, and real estate. Methodologically, same logic is applied to different economic entities through different modules, each following a defined narrative. The narratives mainly differ in the denominator for the emission intensity that is the starting point for the XDC calculation.

6. Attachments

6.1. Model Characteristics

	OECM [14][15] [16]	NGFS [13] [17] [18] [19] [20]	IEA NZE [12]
Model	OECM (One Earth Climate Model)	REMIND-MAgPIE	GEC (Global Energy and Climate) Model
Scenario Type	<ul style="list-style-type: none"> Target temperature <u>1.5°C no overshoot</u>. The assumptions for the OECM 1.5°C pathway are consistent with the 1.5°C (66% likelihood) carbon budget of 400 GtCO₂(2020–2050) identified by the IPCC 	<ul style="list-style-type: none"> Target temperature <u>1.5°C with overshoot</u>. Considering 2018 budget, 1.5°C limited CDR scenario has a budget of 455 GtCO₂, which is roughly close to the 66% budget of the IPCC (~420GtCO₂). 	<ul style="list-style-type: none"> Target temperature <u>1.5°C with limited overshoot</u>. IEA budget is consistent with 50% chance of limiting warming to 1.5°C based on the IPCC budget.
Calculation of Reduction Pathways	<ul style="list-style-type: none"> OECM is an integrated Climate-Energy model: OECM merges the energy system model EM, the transport model 	<ul style="list-style-type: none"> REMIND model: is a modular multi-regional model with a detailed representation of the energy sector in the context of 	<ul style="list-style-type: none"> Combination of ETP and WEM models.

	<p>TRAEM, and the power system model [R]E 24/7.</p> <ul style="list-style-type: none"> Climate metrics such as global mean temperature are examined with the reduced complexity model MAGICC. No economic module/model is integrated. 	<p>long-term macro-economic developments.</p> <ul style="list-style-type: none"> REMIND model is a fully integrated Climate-Energy-Economy model. The macro-economic core of REMIND is a Ramsey-type optimal growth model in which intertemporal global welfare is optimized subject to equilibrium constraints. Can be coupled with <ul style="list-style-type: none"> MAGPIE: (Model of Agricultural Production and its Impacts on the Environment). MAGICC: Climate model. 	<ul style="list-style-type: none"> NZE scenario reaches net zero CO₂ emissions by 2050 by deploying a portfolio of clean energy technologies, without offsets from land-use measures.
Assumptions of the Scenario	<ul style="list-style-type: none"> Considering widespread and accepted technologies. The main drivers of the energy demand are population and GDP. OECD relies on rapid fossil-fuel phase-out and transition to 100% renewable energy by 2050. OECD achieves net zero emissions by negative emission through nature-based solutions. 	<ul style="list-style-type: none"> Ramsey growth model, cost-effective dynamic optimization Using a range of exogenous data as an input to ensure consistency of scenarios with historic developments and realistic future projections Time horizon: 2005-2150 12 regions Detailed energy sector Production function inputs include labour, capital, and energy services Technology parameters are projected into the future, in general assuming a certain level of convergence across regions in the very long term. Endogenous technological change 	<ul style="list-style-type: none"> Reduction pathways based on: <ul style="list-style-type: none"> costs technology maturity policies market conditions available infrastructure and policy preferences Net zero is a common goal Average global economic growth 2.6%

7. References

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