EUCALC

Explore sustainable European futures

WP1 – Climate and emissions module documentation

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Short Description
This report describes - *the sources and hypotheses used to build the historical database;* - *The calculation logic and scope of the module;* - *The lever choices and ambition levels.*

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This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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List of abbreviations

AR5 – IPCC Fifth Assessment Report

FAO – Food and Agriculture Organization of the United Nations

GHG – Greenhouse gases

GWP – Global warming potential

IPCC – The Intergovernmental Panel on Climate Change

ISIMIP – The Inter-Sectoral Impact Model Intercomparison Project

NDC – Nationally Determined Contribution to GHG reductions

RCP – Representative Concentration Pathway

RoW – Rest of World (outside EUCalc countries)

Glossary

Pre-industrial: In alignment with AR5 (Field et al., 2014), this document uses the 51-year long period 1850-1900 as an approximation for pre-industrial temperature levels.

1 Introduction

To achieve the Paris agreement's target to keep global warming below 1.5°C, global Greenhouse Gas (GHG) emissions must be substantially reduced. In line with this agreement, the EU adopted a long-term strategy to reduce GHG emissions by 80-95% of the 1990 levels and achieve climate neutrality by 2050. In recent years, GHG emissions in the EU have declined, but reaching climate neutrality is challenging and requires further reductions in all sectors. A continuous increase in GHG emissions outside the EU also highlights the need for rapid action to avoid jeopardising the objectives of the Paris agreement.

The objective of this documentation is to provide a brief overview of recent climate trends and to describe how global climate change is addressed in EUCalc. This documentation further details how GHG emissions in the EU are projected until the end of the century and how EUCalc estimates a global temperature response.

2 Trends and evolution of climate and GHG emissions in the EU

This section provides a brief overview of context and recent climate and GHG emissions trends in the EU.

2.1 Climate

The world is getting warmer. Compared to pre-industrial, the mean temperature in 2006-2015 has increased by about 0.87°C (likely 0.75°C - 0.99°C, depending on climate data records; Allen et al, 2018). This does not mean each year is warmer than the next as the global temperature is still subject to natural variability (Fig. 1). Neither does it mean each region experiences the same rate of warming. On average, warming over land is higher than over water (Allen et al, 2018) and Europe experienced a warming by about 1.5°C in the same period (EEA 2016, Fig. 2).

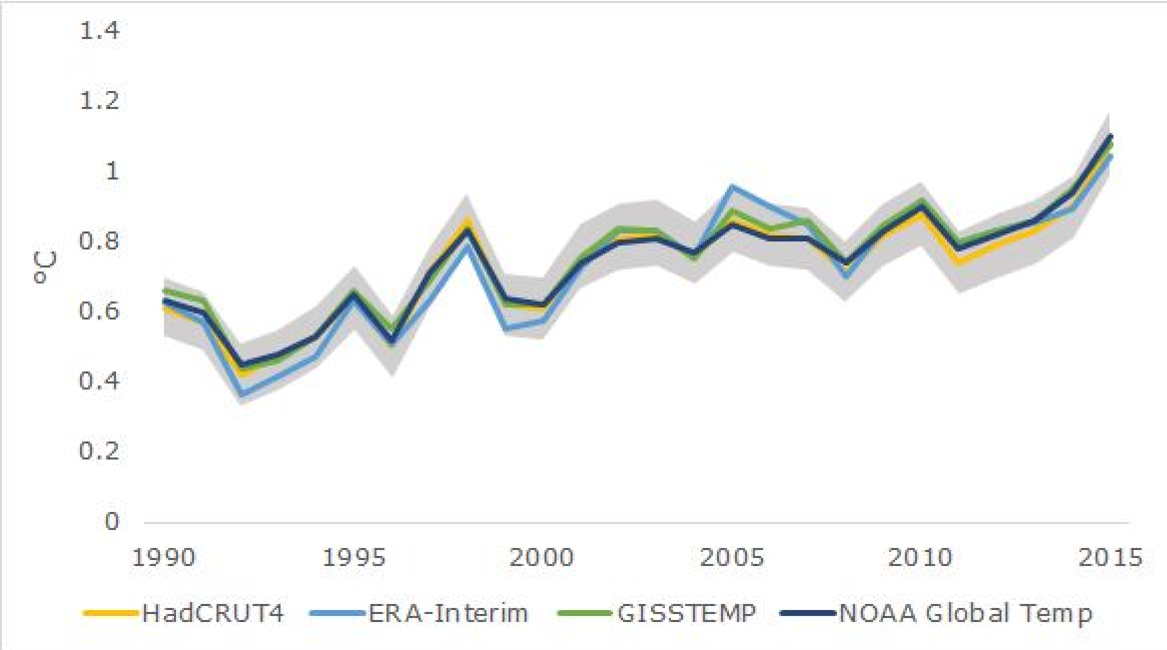

Figure 1 – Changes in global average near surface temperature relative to 1850-1900 based on four different climate data records (data from EEA, 2018) .

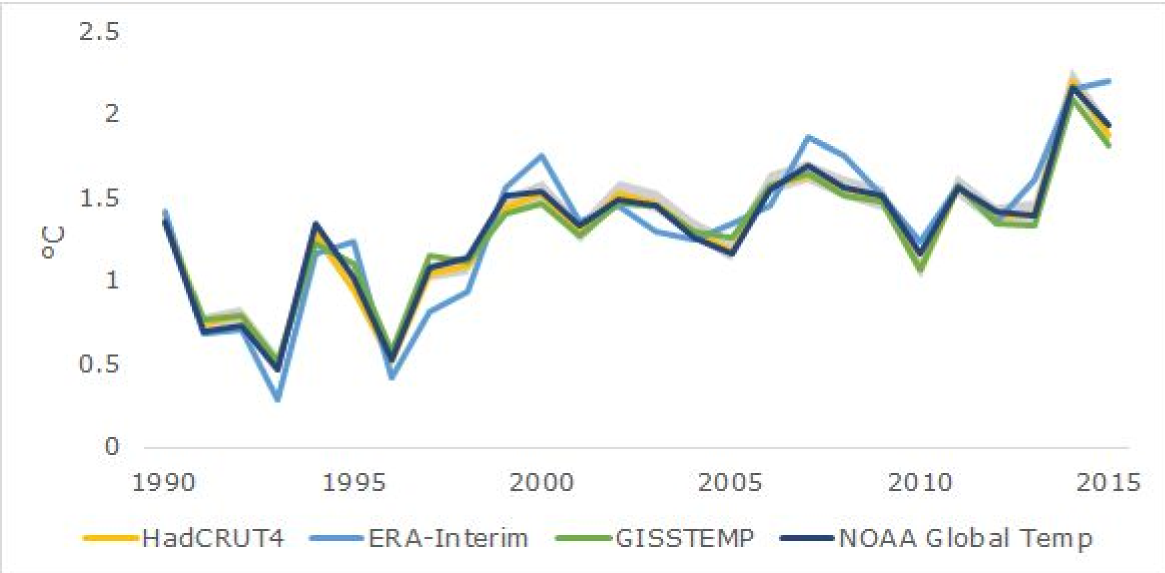

Figure 2 – Changes in European average temperature over land relative to 1850-1900 based on four different climate data records (data from EEA, 2018).

2.2 Greenhouse gas emissions

The trend of GHG emissions in the EU (EU28 + Switzerland) is in contrast to the trend in global GHG emissions . While global emissions in 2015 have increased by about 55% since 1990 (Olivier and Peters, 2018) territorial emissions in the EU were reduced by about 25% in the same period (UNFCCC, 2019; Fig. 3). The EU is the third largest emitter of GHGs, after China and USA, with a current share of about 9% (Oliver and Peters, 2018).

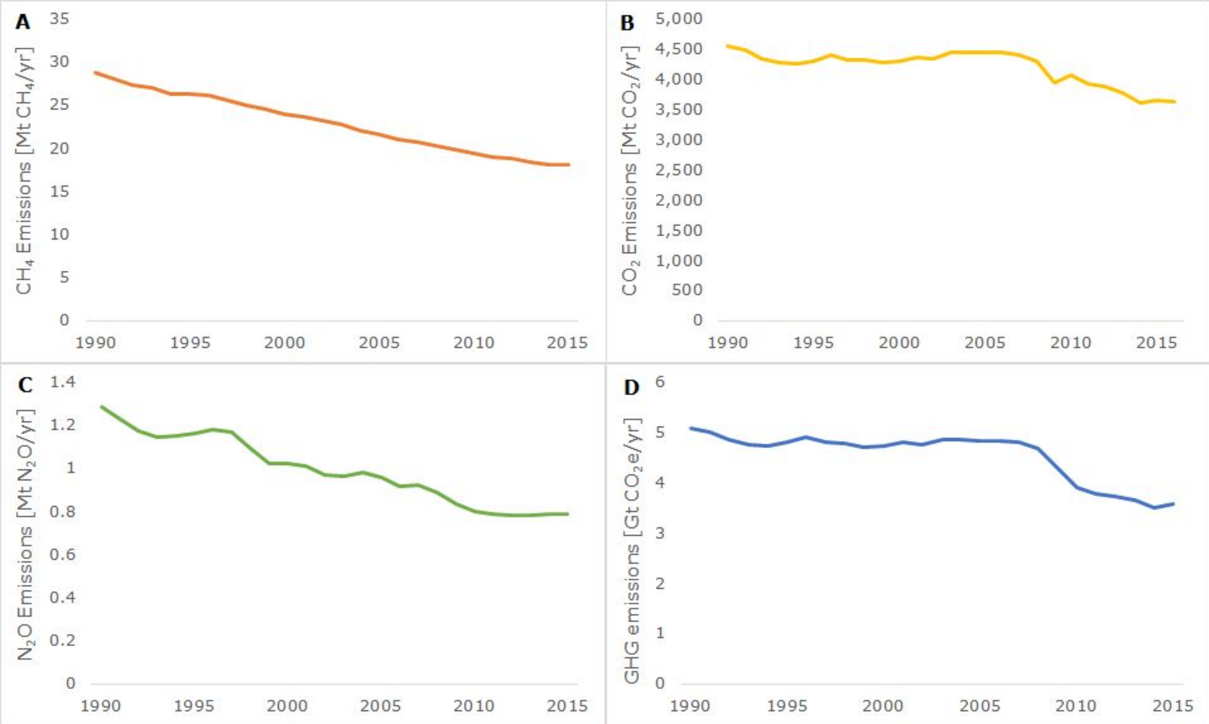

Figure 3 – Annual total emissions of EU28 and Switzerland. A: Megatonnes CH_4 per year B: Megatonnes CO_2 per year; C: Megatonnes N_2O per year; D: Megatonnes CO2e per year. (Data in A-C was obtained from Eurostat (2019). Data in D was calculated based on A-C using the method described in section 5.4.2.1 EU cumulative emissions).

3 Questions addressed by the module

Table 1 – Main questions addressed in the climate module

Theme	Information/Question		Ambition[1]	Progress
What happens to the rest of the modules in EUCalc if the Rest of the World follows differing pathways?	• Four ambition levels	• Business as Usual • Meet NDCs and no more • Aim for 2°C world • Aim for 1.5°C world	Yes	Done
What is the impact of existing solutions to decarbonise the sector?	Not applicable, this is a lever allowing the user to assume how the RoW decarbonises		No	Done
What is the impact of potential breakthrough (technologies or societal) ?	Breakthrough technologies are assumed implicitly to match RoW ambition levels		No	Done
What are the impacts of the sector on the others?	Many of the other modules (energy, buildings, agriculture, water, biodiversity) will be impacted by the setting of this lever as it determines how successful they may be in decarbonising their own sector (i.e., lower ambition levels in the RoW lead to higher levels of warming and more air conditioning use)		Yes	Done

[1] Does this module ambition to answer that question?

What are the impacts of other sectors on this one?	• What is the impact of other sectors' GHG emissions on the global temperature? • Possibly Transboundary, exports of emissions to other countries	Yes	Done

4 EU calculator logic

4.1 Definition of ambition levels

Lever settings are harmonised across the model and provide the user with up to 4 settings to explore the impact of different ambitions on the overall amount of GHG emissions.

4.1.1 GHG focused levels: 1-4

Ambition levels 1-4 represent increasing ambitions in terms of GHG emission reduction.

Table 2 – General definition of ambitions levels

Level	Definition
1	**Past trends of changes** This level contains projections that are aligned and coherent with the observed trends
2	**Ambitious change** This level is an intermediate scenario, more ambitious than level 1 but it is not reaching the full potential of the available solutions.
3	**Very ambitious change** This level is considered very ambitious but still realistic given the current technology evolutions and the best practices observed in some geographical areas.
4	**Transformational changes** This level is considered as transformational and requires large additional efforts such as strong changes in the way society is organized, a very fast market uptake of deep measures, an extended deployment of infrastructures, major technological advances and breakthroughs (but without relying on new fundamental research), etc.

4.1.2 Alternative ambition levels: A, B, C and D

It is not always possible to express the effects of a lever on GHG emission via a linear scale because some lever settings do not have a clear ranking. Although the mitigation associated with the lever intends to reduce GHG emissions, it might actually lead to an increase due to feedback loops in the system. For example, increasing the size of protected areas for biodiversity conservation could be positive or negative in terms of GHG emissions, depending on which type of land is converted and how levers within the agricultural sector are set.

5 Calculation logic and scope of module

5.1 Overall logic

The disparity between actions taken within the EU and what happens in the RoW have created potential difficulties for EUCalc. It has been unclear how to properly set the emission assumptions and temperature thresholds within EUCalc depending on how the RoW behaves and the policy decisions they make. Ultimately, even a completely decarbonised EU can only affect the global temperature by a small amount, unless others follow their lead. This module (lever settings) allows the user to make assumptions about how the RoW behaves and how this then feeds back on efforts to decarbonise in the other modules. By making the decision up front, the user is able to better see the relevant emission savings by decarbonising their own sector. For example, if the RoW is on a Business as Usual pathway (4.5°C warming) then buildings will require more cooling, and there may be constraints on power generation if they cannot cool the power station. Thus, overall emissions savings in these sectors, would be less as more emissions would need to be generated to achieve the same results.

Setting the RoW ambitions up-front also breaks the feedback loop between GHG emissions and resulting climate conditions in EUCalc. Reducing GHG emissions has a direct effect on global temperatures which in turn affect GHG reduction ambitions. The framework of EUCalc does not allow direct modelling of such a loop and it needs to be broken (see cross sectoral model documentation). Using climatic conditions based on RoW ambitions to drive the model removes the dependency between GHG emissions and temperature and allows the model to run. The calculation logic adopted here is straightforward but requires other modules to either have spreadsheets for emissions at 1.5, 2, 3.2 and 4.5° C above pre-industrial or to develop a damage function that equates levels of warming with emissions in their modules. However, not all modules fall into this category.

The climate and emissions module also collects the various emissions from the other modules and turns those into CO_2-warming-equivalent emissions and then to a global temperature response.

5.2 Scope definition

The climate and emissions module enables enables an assessment of how the EU is affected by how the rest of the world decarbonises. As mentioned above, the RoW will have a major impact on GHG emissions and thus global temperatures and changes in climatic conditions. These changes have a direct effect on multiple sectors and thus directly affect the EU's ambitions to reduce GHG emissions.

- Energy demand for heating and cooling of buildings depends on near surface temperature, wind speed and near surface downwelling radiation.
- Capacity factors of wind turbines and sun collectors for energy production are affected by temperature.
- Water availability is mainly driven by precipitation.
- Agricultural food production (crops) depends on temperature, precipitation and CO_2 concentration levels.

In addition, the module enables a coherent conversion of GHG emissions into a warming-equivalent quantity of CO_2 emissions and the projection of European and global emissions until 2100. The module uses the projected emissions to estimate the resulting global temperature change and thus allows assessing the impact of rising temperatures for a variety of sectors beyond 2050. By estimating the global temperature response, it is further possible to project potential physical impacts (e.g. flooding) at the end of the 21st century

5.3 Interactions with other modules

Specific modules (energy, buildings, water, agriculture) worked with UEA to feed appropriate lever settings equating to which years equal a given level of warming from this module to their modules. In the case of buildings, the basic climate data was provided to them to pre-calculate the emissions related to heating and cooling based on climate variables.

5.3.1 Inputs for the climate and emissions module

Any other emission producing module provides the climate and emissions module with GHG emissions emitted in the corresponding sector.

Table 3 – List of inputs to emissions module

Module	Variable
2.1 Buildings	bld_emissions-CH4[Mt] bld_emissions-N2O[Mt] bld_emissions-CO2[Mt] bld_emissions-CO2e[Mt]
2.2 Transport	tra_emissions-CH4[Mt] tra_emissions-N2O[Mt] tra_emissions-CO2[Mt] tra_emissions-CO2e[Mt]
2.3 District Heating	dhg_emissions-CH4[Mt] dhg_emissions-N2O[Mt] dhg_emissions-CO2[Mt] dhg_emissions-CO2e[Mt]

3.1a Industry	ind_emissions-CH4[Mt] ind_emissions-N2O[Mt] ind_emissions-CO2[Mt]
3.1b Industry Ammonia	amm_emissions-CH4_ammonia[Mt] amm_emissions-N2O_ammonia[Mt] amm_emissions-CO2_ammonia[Mt]
4.1 Land-use	lus_land_emissions-CO2_total[Mt]
4.3 Agriculture	agr_emissions-CH4[Mt] agr_emissions-N2O[Mt]
4.5 Biodiversity	bdy_emissions-CH4[Mt] bdy_emissions-N2O[Mt] bdy_emissions-CO2[Mt]
5.1 Electricity	elc_emissions-CO2e[Mt]
5.2 Oil Refinery	fos_emissions-CO2e[Mt]

5.3.2 Outputs from the climate and emissions module

5.3.2.1 Buildings (WP2)

The interface between the climate and buildings modules currently consists of the RoW ambition level, which is directly tied to global temperature. The buildings module uses this information to select the appropriate levels of wind-speed, near surface temperature and surface downwelling longwave radiation from the ISIMIP database (see 8.1 Databases for climate module).

5.3.2.2 Agriculture (WP4)

The agriculture module enables the assessment of climate smart cropping systems for which it needs to estimate crop yields. Crop production is directly affected by precipitation, temperature and CO_2. The climate and emissions module thus provides the agriculture module with a crop production change factor based on the selected RoW ambitions level. The change factors were derived from pathways created by FAO (2018). These pathways are based on RCP scenarios and the resulting change factors can thus be directly linked to the RoW ambitions level.

5.3.2.3 Water (WP4)

The water module estimates water stress as a warning sign for water scarcity as a ratio between water availability and water consumption. Water availability is mainly driven by precipitation which itself is driven by climatic conditions. The climate and emissions module thus provides the amount of water available based on which RoW ambition level is selected. These availability values were derived from a spatially explicit water model creating projections for water resources based on RCP 4.5 and RCP 8.5 climate scenarios (Bisselink et al., 2018). The

RoW ambition lever was then matched to appropriate time points in those models runs.

Table 4 – Description of data used to describe future water availability based on RoW ambition lever

RoW ambition level	Description of water resources data used
1	Annual output for period 2016-2050 from model runs based on RCP 8.5
2	Annual output for period 2016-2050 from model runs based on RCP 4.5
3	Annual output for period 2016-2048 from model runs based on RCP 4.5. Recourse levels in years 2049-2050 are kept at level available in 2048.
4	Annual output for period 2016-2030 from model runs based on RCP 4.5. Resource levels in years 2031-2050 are kept at level available in 2030.

5.3.2.4 Electricity (WP5)

The interface between the climate and electricity modules work similar to the interface between climate and buildings (WP2). The climate module provides the RoW ambition level which allows the selection of temperature dependent capacity factors.

5.3.2.5 Transition Pathway Explorer (TPE)

The Pathway explorer displays the output associated with selected lever settings. In case of the climate and emissions module TPE displays the estimated global temperature response and global physical impacts in 2100. The module also provides TPE with cumulative GHG emissions which are used by the TPE interface to represent and adjust the budget to stay below the temperature target.

Table 5 – List of outputs from climate and emissions module to other modules

Module	Variable
2.1 Buildings	ClimateLeverLevel[num]
4.3 Agriculture	clm_tmp-annual_cop_yield[%]
4.4 Water	ClimateLeverLevel[num]
5.1 Electricity	ClimateLeverLevel[num]
0.2 Pathway Explorer	clt_emissions-CO2[Mt] clt_global-temp[degC] clt_cum-emissions-CO2e[Mt] clt_drought-max[people] clt_drought-mean[people] clt_drought-min[people]

clt_flvflooding-max[people]
clt_flvflooding-mean[people]
clt_flvflooding-min[people]
clt_cstlflooding-max[people]
clt_cstlflooding-mean[people]
clt_cstlflooding-min[people]
clt_vertebrates-max[people]
clt_vertebrates-mean[people]
clt_vertebrates-min[people]
clt_mammals-max[%]
clt_mammals-mean[%]
clt_mammals-min[%]
clt_birds-max[%]
clt_birds-mean[%]
clt_birds-min[%]
clt_invertebrates-max[%]
clt_invertebrates-mean[%]
clt_invertebrates-min[%]
clt_plants-max[%]
clt_plants-mean[%]
clt_plants-min[%]

5.4 Detailed calculation trees

5.4.1 Climate

Based on the RoW temperature lever setting, the climate module loads all necessary data from the database and passes the appropriate data on to other modules.

5.4.2 Emissions

5.4.2.1 EU cumulative emissions

Building, industry, transport, land-use and energy modules generate GHG emissions (Table 2). Emissions are summed into EU totals for each of CO_2, CH_4, N_2O and SO_2. These annual time series between 1990-2016 are calibrated to match the EuroStat emissions inventories for each gas over this period. The 2016 scaling factor is used for all future times. This accounts for missing emissions from the sector output of EUCalc.

To find the global temperature response, the module combines the separate gases into a physically realistic CO_2-warming-equivalent quantity. By warming-equivalence we mean the CO_2 emissions profile which produces the same warming response as the separate gas emissions. Long-lived gases (lifetime > 100 yrs; CO_2, N_2O), are converted to their CO_2-warming-equivalent using the GWP metric with a 100-year horizon (GWP_{100}), while short-lived gases (lifetime < 100 yrs; CH_4, SO_2) are converted using an updated GWP* metric (Allen et al. 2018, Cain et al. 2019). Short-lived and long-lived gases are treated differently because the GWP_{100} metric does not adequately represent the relationship between the emissions of short-lived pollutants and their corresponding temperature response (Cain et al. 2019).

For SO_2, the module uses GWP* following Allen et al. (2018) (Eq. 1), while it uses GWP* following Cain et al. (2019) for CH_4 (Eq. 2).

$$E_{SO2,CO2e*} = \frac{\Delta E_{SO2}}{\Delta t} \times GWP_{H,SO2} \times H \quad (1)$$

$$E_{CH4,CO2e*} = 0.75 \times \left[\frac{\Delta E_{CH4}}{\Delta t} \times GWP_{H,CH4} \times H \right] + 0.25 \times \left[E_{CH4} \times GWP_{H,CH4} \right] \quad (2)$$

Here E_x is the emissions of gas x, $\frac{\Delta E_x}{\Delta t}$ is the 20 year averaged emissions rate of gas x, $GWP_{H,x}$ is the GWP value for gas x over time horizon H.

5.4.2.2 Emissions after 2050

EUCalc is not set to directly calculate the emissions after 2050 but a sensible assessment of EU mitigation efforts requires an estimation of GHG emissions for the second part of the century as well. The emissions module thus projects the average GHG gradients between 2035 and 2050 forward to 2100. This projection is limited to a minimum CO_2-warming-equivalent emissions quantity of -1GtCO_2/yr. The limitation is added because for particularly ambitious mitigation efforts the 2035-2050 gradient in emissions could otherwise result substantial and unfeasible levels of negative emissions by 2100. To restrict the negative emissions over the second half of the 21st century in these ambitious scenarios to feasible rates, consistent with global emissions projections, a minimum CO_2-warming-equivalent emissions quantity is set. This value is taken as the EU percentage share of average 2100 annual CO_2 emissions in the IIASA database of 1.5°C-compatible scenarios used in the IPCC SR15 report (where the EU percentage share is found in the same way as for the RoW/EU emissions splitting discussed in section 4.4.2.3).

5.4.2.3 RoW emissions

Calculating the temperature response requires total GHG emissions both for the EU and the RoW. By setting the RoW GHG emission reduction ambitions, the user automatically sets an estimate of the global temperature in 2100 (see section 3.2.1) and its associated GHG emissions. The module thus has to estimate the fraction of emissions originating from the EU and thus of the RoW.

In order to obtain this fraction, the module uses the ratio of GHG emissions between EU and RoW in 2012 as its baseline and assumes this ratio to remain constant until the end of the century. Once the fraction for the RoW is known, the CO_2-warming-equivalent emissions for the RoW are obtained as outlined in section 2.4.2.1.

5.4.2.4 Temperature response

The emission module uses equations originating from the FaIR simple climate module updated based on Millar et al. (2017) and Smith et al. (2018). GHG emissions are split into 4 carbon pools which decay into the biosphere, land, upper ocean and lower ocean respectively, from which the total atmospheric carbon concentration can be found. Subsequently, the module calculates the associated radiative forcing assuming a logarithmic relationship (Eq. 3) between concentration changes and forcing. Here C(t) is the CO_2 concentration at time t, C_0 is the preindustrial CO_2 concentration, F_{2x} is the forcing response to a doubling of CO_2 concentrations, and F_{ext} is any other externally applied climate forcing. The overall temperature response is then found using a two-box model (Millar et al., 2017) with the calculated radiative forcing as input.

$$F(t) = F_{2\times}\, ln\left(\frac{C(t)}{C_0}\right)\frac{1}{ln(2)} + F_{ext} \quad (3)$$

5.4.3 Physical impacts at the end of the century

To provide the user with an outlook to the consequences of a chosen combination of lever settings, the climate emissions module uses damage functions to quantify the physical impacts associated with the resulting global temperature change at the end of the 21st century. In the most recent version, the model estimates the global number of people at risk from severe droughts, fluvial flooding and coastal flooding as well as the global percentage of species losing more than half of their climatic range. The damage functions are based on projections of people at risk from Warren, Andrews et al. (2018), and projections for impact on species derived from a global assessment performed by the Wallace Initiative[2] (Warren, Price et al., 2018). These functions were created by fitting linear or second-degree curves to available impact data associated with global temperature changes between 1.5°C and 4.5°C.

A selection of possible impacts on biodiversity in 2100 is depicted in Fig. 4. With growing global temperature, increasing numbers of species are projected to lose more than half of their climatic range. The same relationship applies for impacts to the human system (Figs. 5 and 6). However, while growing global temperatures increase the risk in all three sectors, far more people are projected to be at risk from drought than from flooding. The model will not present projections for the full range of possible temperatures but select only those associated with the estimated global temperature response.

EUCalc deliberately uses damage functions to estimate climate change impacts for the end of the century. Running separate and spatially explicit[3] impact models for each sector is computational intensive and not feasible to perform in real time. An emulation of spatially explicit impact models using damage functions based on these models' outputs was thus considered to be a good alternative. By projecting impacts for 2100 rather than 2050, EUCalc allows for a better display of mitigation benefits. Although the model displays positive effects immediately after mitigation starts, it will take time until the full benefits become truly visible because some mitigation efforts have a delayed effect. A timescale of 30 years until 2050 was thus considered too short and a longer period until the end of the century was adopted instead.

[2] http://wallaceinitiative.org
[3] Spatially explicit means that processes are directly related to geographic locations.

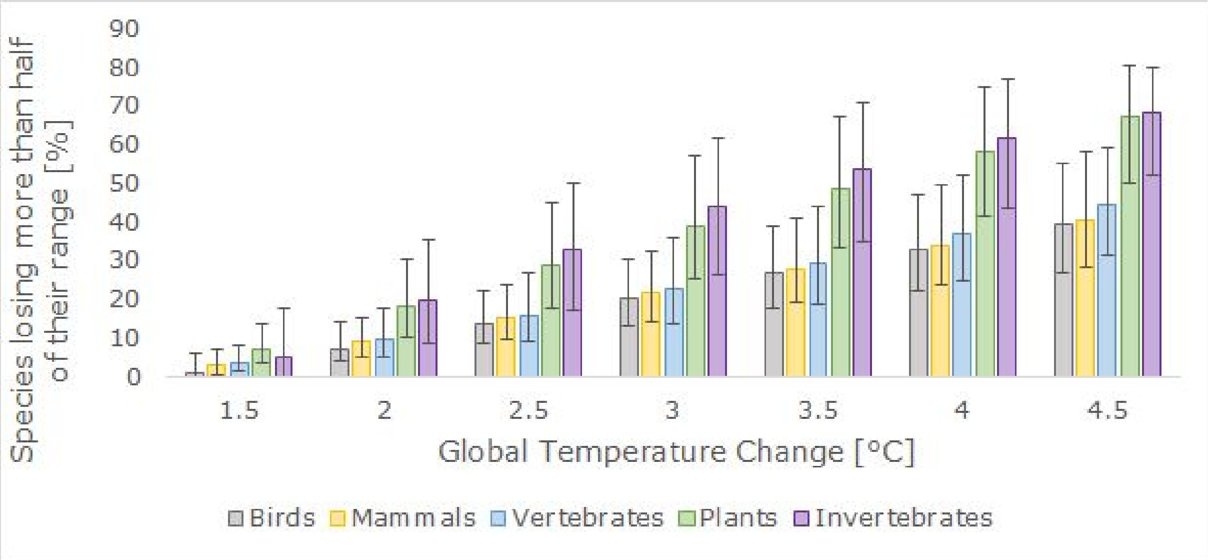

Figure 4 – Projected proportion of species losing more than half of their climatically determined range by 2100. Presented are the mean projections across 21 alternative climate model patterns with error bars representing the 10th and 90th percentile (data from Warren, Price et al. 2018).

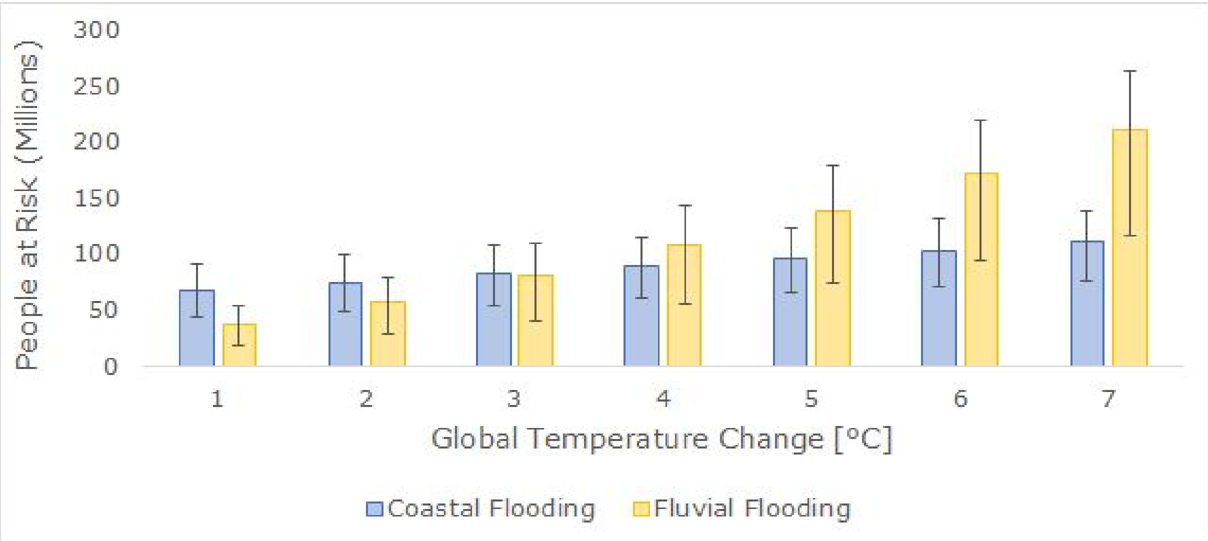

Figure 5 – Projected number of people at risk from coastal flooding and fluvial flooding in 2100. Presented are mean projections across 5 (3 in case of fluvial flooding) alternative climate model patterns with error bars representing the minimum and maximum values (data from Warren, Andrews et al., 2018).

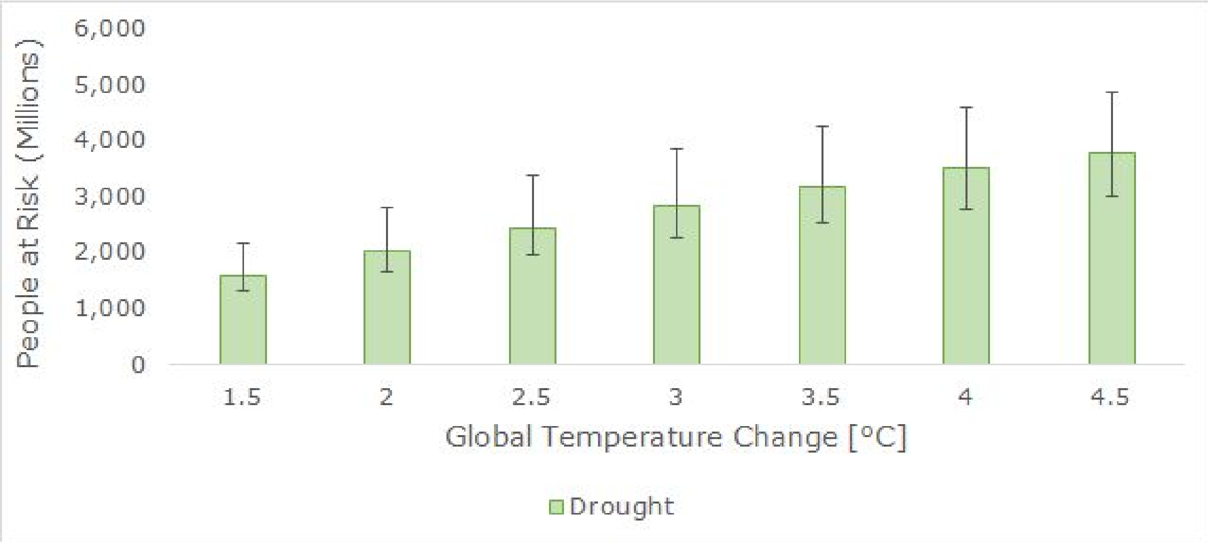

Figure 6 – Projected number of people at risk from drought in 2100. Presented are mean projections across 5 alternative climate model patterns with error bars representing the minimum and maximum values (data from Warren, Andrews et al., 2018).

5.5 Calibration

The calibration process is introduced in the cross sectoral model documentation.

5.5.1 Sources

In the climate emissions module we only calibrate GHG emissions for the EU28 and Switzerland as a whole. The calibration is performed against the official GHG emission database of the UNFCCC (UNFCCC, 2019) for each gas inputted.

5.5.2 Module improvement through calibration

Calibrating a module generally refers to the process of adjusting the module parameters in such a way that predefined criteria are met. Here, we do not adjust any parameters but correct the systematic errors introduced by incomplete modelling of GHG emitting procedures within the other modules. This process is necessary because estimating the global temperature change depends on the availability of accurate GHG concentrations in the atmosphere. Since modules within EUCalc currently only estimate emissions of CO_2, N_2O and CH_4, we neglect other emissions and thus change the ratio of GHGs in the atmosphere which will affect the global temperature. If we would not perform the correction, we would also mis-calculate the budgets available to stay below 1.5°C or 2.0°C.

5.5.3 Current calibration rate

In its current state, the model achieves a mean calibration rate of 82%. We expect to see an increase of this rate in future versions while development of the model continues. It must be stressed that any improvements to raise the rate have to happen in other modules. The climate and emissions module directly calibrates the emissions it receives from other modules and has no direct influence on their calculations.

6 Description of levers and ambition levels

6.1 Lever list and description

Table 6 – Lever list of the climate module

#	Levers	Description	Level	Status
1	RoW GHG emission reduction ambitions	The efforts the Rest of the World makes in reducing their GHG emissions. This effort is the overall total, not differentiated by country or sector.	1-4	Implemented
2	Emissions after 2050	How will emissions develop after 2050?		In progress

6.2 Lever specification

6.2.1 RoW GHG emission reduction ambitions

The Row GHG emissions reduction ambitions lever works by assuming other countries follow, or fail to follow policy choices and treaty obligations.

Table 7 –Ambitions levels for RoW GHG emissions reduction

Level	Definition
1	Make no real changes to emissions and fail to follow published emission reduction ambitions. This also takes into account the possibility that some emission reductions are achieved, but climate sensitivity is such that these ambitions make no real difference to the amount of warming in 2100. While this may not seem to be much of an ambition it follows from the increasing levels of CO_2 in the atmosphere and lack of sustained reductions in rates of increase.
2	Each country meets their NDC pledges within the timeframe specified and goes no farther. This is estimated to lead a climate changes associated with 2.7°C – 3.5°C of warming, and we are proposing to use 3.2°C as the resulting global mean temperature in terms of data fed through to other modules.
3	Each country meets and further strengthens their NDC targets so as to achieve an overall level of warming of 2°C. While this does not meet the targets of the Paris Accords, it does meet previous ambition levels and is a significant improvement on Level 3 in terms of sectoral impacts.

4	Highest ambition, equalling meeting a goal of a warming no greater than 1.5°C – the ultimate goal of the Paris Accords (well below 2°C). This does not include the possibility of a significant overshoot in temperature that then is reduced through negative emissions.

6.2.2 Emissions after 2050

[not yet fully implemented in the KNIME framework]

To estimate a temperature response and associated physical impacts at the end of the century, emissions have to be projected until 2100. EuCalc only directly calculates emissions up to 2050 and it thus becomes necessary to estimate potential trajectories for the time period beyond. At the present, the module only considers a pathway in which the gradient of emissions reduction between 2035 and 2050 continues in the future. As module development and refinement continues we plan to integrate additional pathways in which the ambition levels is linked to a factor between 0 and 1 by which the 2035-2050 trend is multiplied. An ambition level of 1 (factor 0) will correspond to keeping emissions at the level achieved in 2050, while ambition level 4 (factor 1) will correspond to a continuation of the trend in 2035-2050.

7 Description of constant or static parameters

7.1 Constants list

Constants refer to parameters that are independent of year and country.

- $GWP_{100,\ SO2}$ = -40
- $GWP_{100,CO2}$ = 1
- $GWP_{100,CH4}$ = 28.0
- $GWP_{100,N20}$ = 265.0

7.2 Static parameters

Static parameters are parameters which vary by year but are not linked to a lever. There are no parameters within the climate and emissions module that fall into this category.

8 Historical database

Both historic and projected data collected for the climate module are described in Table 7.

8.1 Databases for climate module

Table 8 – Database for climate

Dataset	Description	Main sources	Quality check	Hypothesis to fill the gaps
Observed climate	Observed monthly, seasonal and annual climate	CRU TS 3.24.01 Harris et al. (2014)	Commonly used data source; considered very reliable	no gaps
Projected climate	Projected and bias-corrected monthly near surface downwelling longwave radiation, wind speed and mean temperature	ISIMIP Frieler et al. (2017)	ISIMIP data source; considered very reliable	no gaps
Projected emissions	Projected global GHG emissions	RCP Database (2009)	Official RCP data source; considered very reliable	no gaps
EU historical emissions (calibration)	EU inventory emissions 1990-2016 for calibration of EUCalc	UNFCCC (2019)	Official data source; considered very reliable	no gaps
Historical temperature change [K]	anthropogenic temperature anomaly over historical period	Allen et al. (2018)	Peer reviewed study; considered very reliable	no gaps
Physical impacts	Projected impacts on human system and biodiversity	Warren, Andrews et al. (2018) Warren Price et al. (2018)	Peer reviewed studies; considered reliable	no gaps
Water resources	Historic and projected water availability	Bisselink et al. (2018)	Official data source; considered reliable	no gaps
Agriculture	Historic and projected crop yield changes	FAO (2018)	Official data source; considered reliable	no gaps

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