Summary

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Climate impact model

The model is based on the IPCC bibliography and uses the impulse response function (IRF) approach to calculate the radiative forcing RF and the global mean temperature change GMTC. The constants used for all GHGs are taken from the last updates (IPCC, 2013).

The GHG present in ecoinvent LCA data base are included in the software.

The atmospheric burden of substance s, B_s , is calculated as the convolution product (symbol *) between the temporal emissions of the substance s, g_s (kg.year⁻¹) and the concentration - impulse response function of that substance, IRF_s :

$$B_{s}(t) = g_{s} * IRF_{s} = \int_{0}^{t} g_{s}(t') IRF_{s}(t-t')dt'$$
(1)

The RF is calculated as the product between the radiative efficiency, A_s , and the atmospheric burden, B_s . The radiative efficiency A_s (W.m⁻².kg⁻¹) can be considered as time-invariant for small emissions. In the followings, the convolution symbol will be used for simplicity and clarity. We call the RF of direct GHG 'direct RF' RFd:

$$RFd_{s}(t) = A_{s}(t) B_{s}(t) = A_{s}(t)(g_{s} * IRF_{s})$$
(1)

The global mean temperature change generated by the forcer s is defined as the convolution product between its radiative forcing and the temperature impulse response function IRFT. For direct GHG substances, we call this parameter 'direct GMTC' GMTCd:

$$GMTCd_s(t) = RFd_s * IRFT$$
 (2)

IRFT is independent of the type of GHG. However, it may be different if for specific forcers IRFT is determined by specific pathways, e.g. not including a "burden – RF – GMTC" modelling pathway.

According to the IPCC AR6 report, the carbon-climate feedback effect on the radiative forcing, RF_CCF , is added to the direct radiative forcing (and the other cascade indicators), for all climate forcer except CO_2 , as follows:

 $RF_{CCF_s}(t) = A_{CO2}(GMTCd_s * IRFCCF * IRF_{CO2})$

 $RF_{s}(t) = RFd_{s}(t) + RF_{CCF_{s}}(t)$

The same holds for the temperature :

$$GMTC_CCF_s(t) = RF_CCF_s * IRFT$$
(3)

$$GMTC_{s}(t) = GMTCd_{s} + GMTC_{c}CCF_{s}$$
(4)

Where IRFCCF is the impulse response function (CO₂ flux perturbation following a unit temperature pulse), in kg CO₂ yr⁻¹ K⁻¹.

IRFCCF (t) = $\gamma \ \delta(t) - \gamma \sum_{i=1}^{3} \frac{\alpha_i}{\tau_i} e^{\frac{t}{\tau_i}}$ See Gasser et al, 2017; and IPCC AR7, 7.SM.5.

The dynamic global RF (W.m⁻²) for all gases taken together is then:

$$RF(t) = \sum_{s} RF_{s}(t)$$
(5)

Cumulated radiative forcing, iRF (W.m⁻².year), over a given time span TH is:

$$iRF(TH) = \int_{t=t_0}^{TH} RF(t)dt$$
(6)

The global mean temperature change at a given time t, GMTC (K), is obtained by aggregating values for all the concerned forcers:

$$GMTC(t) = \sum_{s} GMTC_{s}(t)$$
(6)

Cumulated temperature change, iGMTC (K.year), is calculated as:

$$iGMTC(TH) = \int_{t=t_0}^{TH} GMTC(t)dt$$
(7)

References

IPCC, 2013, Climate Change. The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2013.

IPCC, 2021, Climate Change. The Physical Science Basis: Contribution of Working Group I to the 6th assessment report of the IPCC. 7 : The earth's Energy Budget, Climate Feedbacks and climate sensitivity. Cambridge University Press, Cambridge, 2021.

Thomas Gasser, Glen P. Peters, Jan S. Fuglestvedt, William J. Collins, Drew T. Shindell, Philippe Ciais, Accounting for the climate-carbon feedback in emission metrics, Earth Syst. Dynam., 8, 235–253, 2017, doi:10.5194/esd-8-235-2017

An example of application

A factory operating 30 years, from 2020 to 2050. GHG emissions take place until 2050.

Does this system respect the European requirements to reduce impacts from 2030 and to be climate-neutral in 2050 ?

European Climate Law <u>https://ec.europa.eu/info/sites/default/files/commission-proposal-regulation-european-climate-law-march-2020_en.pdf</u>



No, the factory does not meet these targets: the figure shows global mean temperature change (K) relative to the production of one unit of product (e.g. 1kg product) (functional unit in LCA; the result can be multiplied by the total production amount to see the absolute value of the impact).

Mitigation action is proposed starting from 2020, through afforestation. Two tree species are proposed: Pinus (50 years to maturity) and Fagus (140 years to maturity). According to the simulation results, Factory and Pinus scenario performs better based on the peak temperature and the neutrality time.