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What is the contribution to Global Warming of time-distributed biogenic CO_2 fluxes ?

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Biogenic CO_2 emissions in LCA

In LCA the same importance is given to emissions in the past, present and future (discount rate r = 0)

*"CO_2 emissions resulting from bioenergy consumption **should not** be included in a country's official emission inventory"*

(OECD, 1991)

CO_2 balance = + 1 CO_2 – 1 CO_2 = 0 → GWP = 0

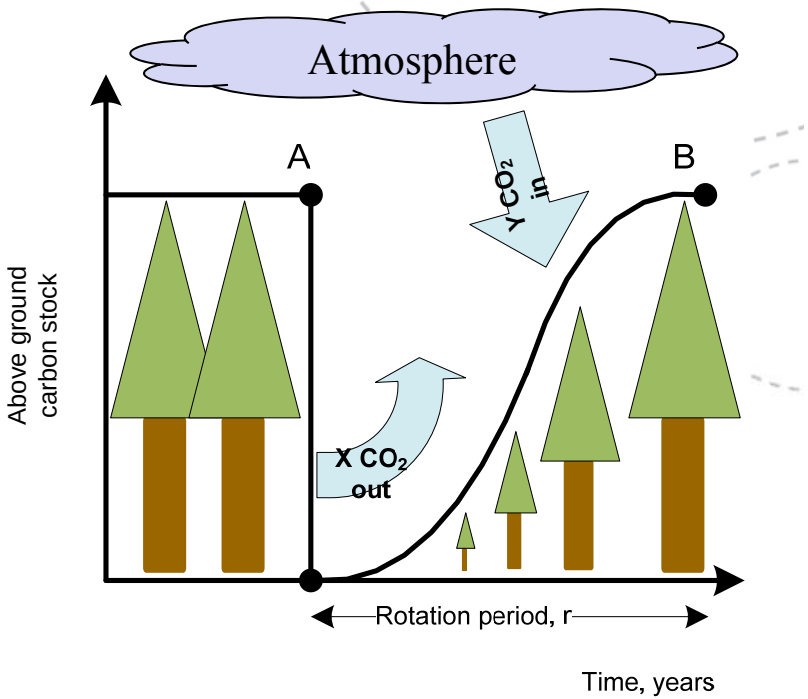
If bioenergy is carbon neutral it is also climate neutral

Only CO_2 from permanent C losses is considered

The appropriateness of this paradigm is questionable, especially when the analysis is constrained by a fixed timeframe

Time matters: all CO_2 is equal in the atmosphere and contributes to global warming

The challenge is to estimate this contribution in LCA studies

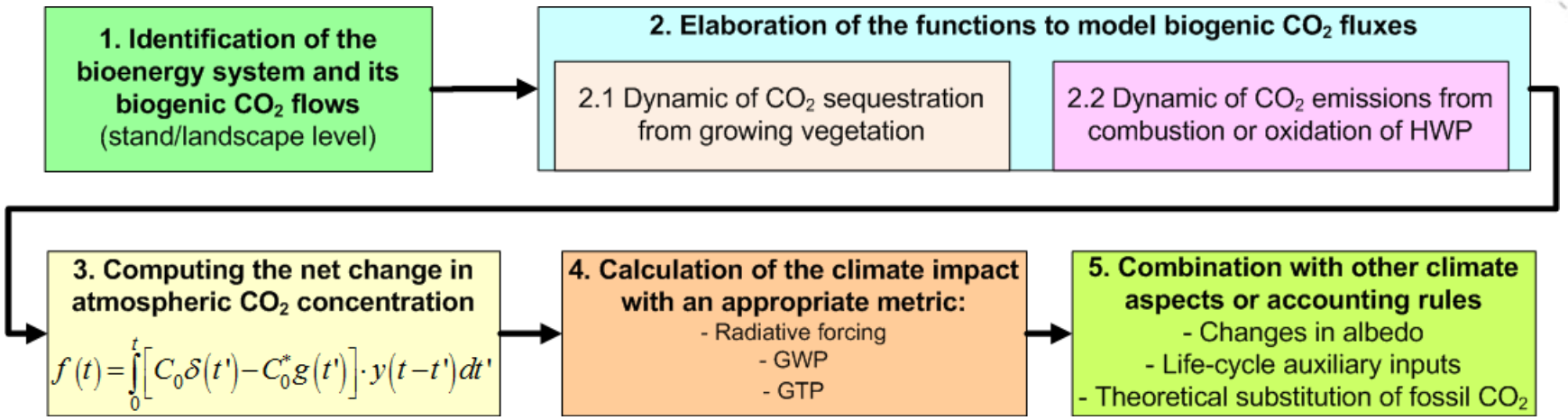


An increasing number of scientists proposes to assign to tailpipe CO_2 emissions from biomass the same climate impact of CO_2 from fossils

$GWP_{bioCO2} = 1$

Integrated approach for GWP of biogenic CO_2

1. Biogenic CO_2 emissions cause a perturbation in atmospheric CO_2 concentration, but their GWP ≤ 1
2. We account for the *time profile* of biogenic CO_2 fluxes in LCA
3. The biomass system is not isolated but it is integrated with the global C cycle
4. The perturbation is modeled with an Impulse Response Function (IRF) to simulate interactions among the atmosphere, the oceans and the terrestrial biosphere



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GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2011), doi: 10.1111/j.1757-1707.2011.01102.x

CO_2 emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming

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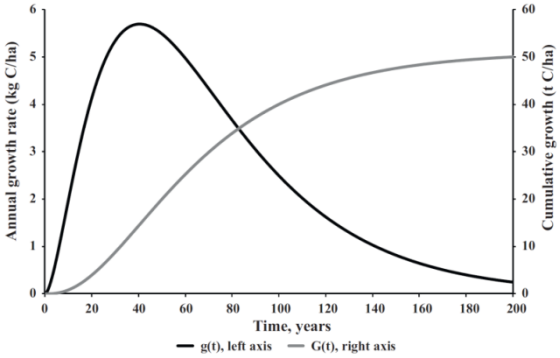
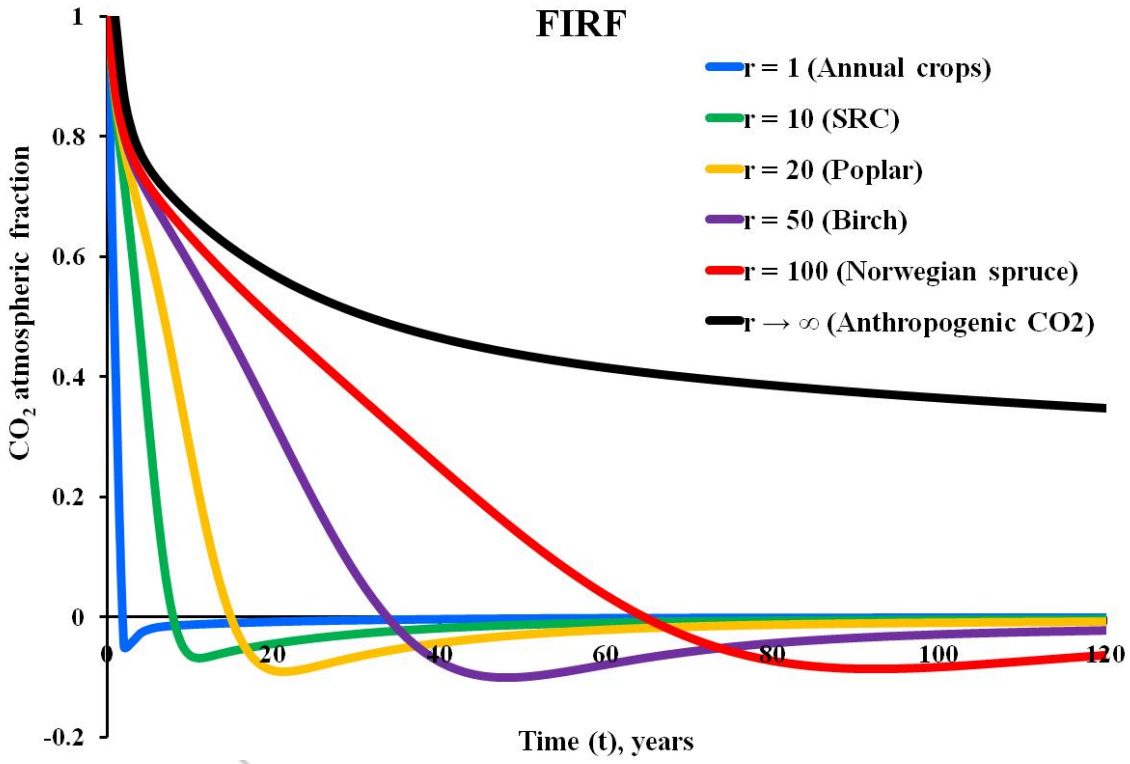




Rotation (years)	GWP_{bio} TH = 20	GWP_{bio} TH = 100	GWP_{bio} TH = 500
1	0.02	0.00	0.00
10	0.22	0.04	0.01
20	0.47	0.08	0.02
30	0.68	0.12	0.02
40	0.80	0.16	0.03
50	0.87	0.21	0.04
60	0.90	0.25	0.05
70	0.93	0.30	0.05
80	0.94	0.34	0.06
90	0.95	0.39	0.07
100	0.96	0.43	0.08

GWP of time-distributed emissions (HWP and LUC)

1. Example: wood from forest plantation (*r = 100 years*) used as particle board (mean lifetime τ = 15 years)

2.1 CO_2 sequestration from forest re-growth **(Gaussian distribution)**

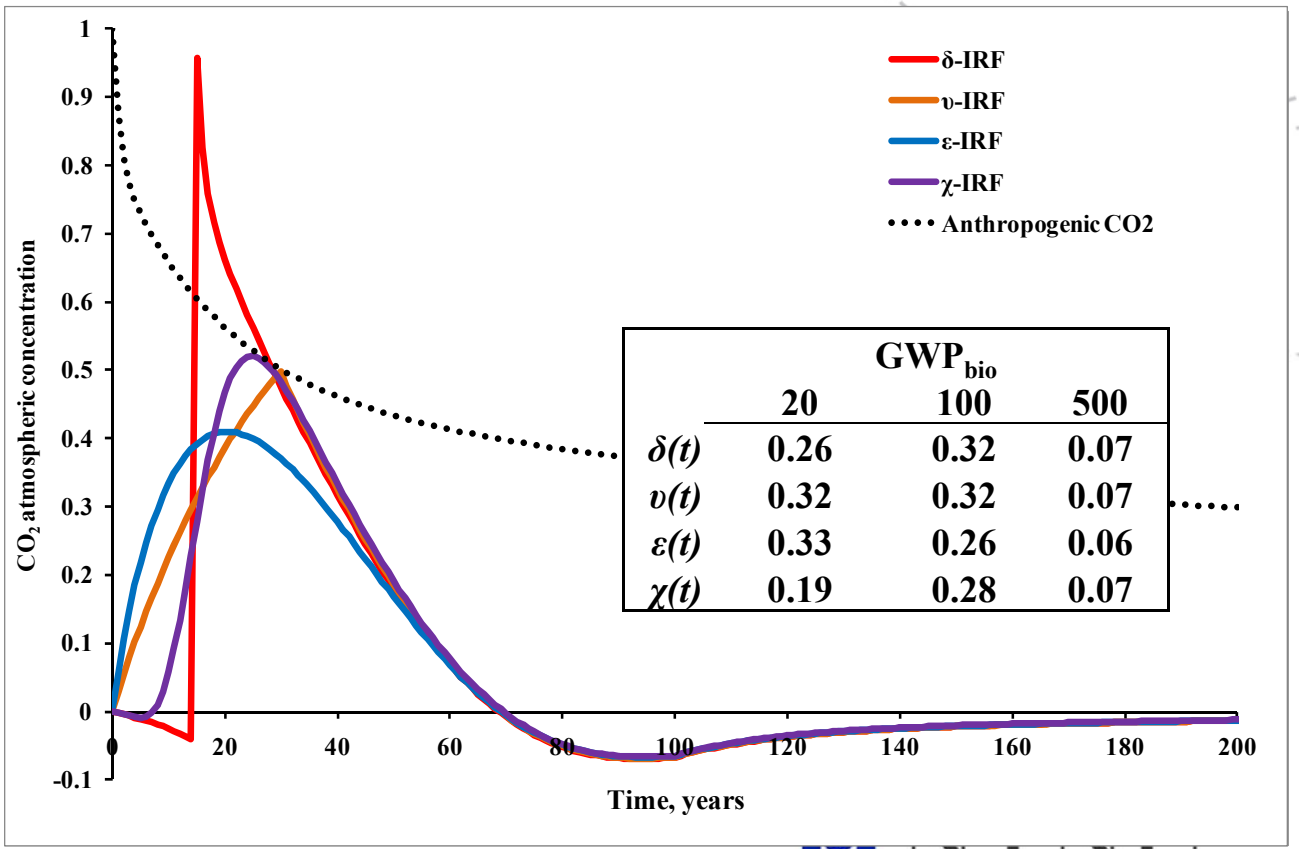
2.2 Comparison of different probability distributions to model CO_2 emission rate:

1) **Delta function *δ(t)*** (all C oxidized at t = 15)

2) **Uniform distribution *υ(t)*** (C oxidation equally distributed)

3) **Exponential distribution *ε(t)*** (1st order decay, IPCC)

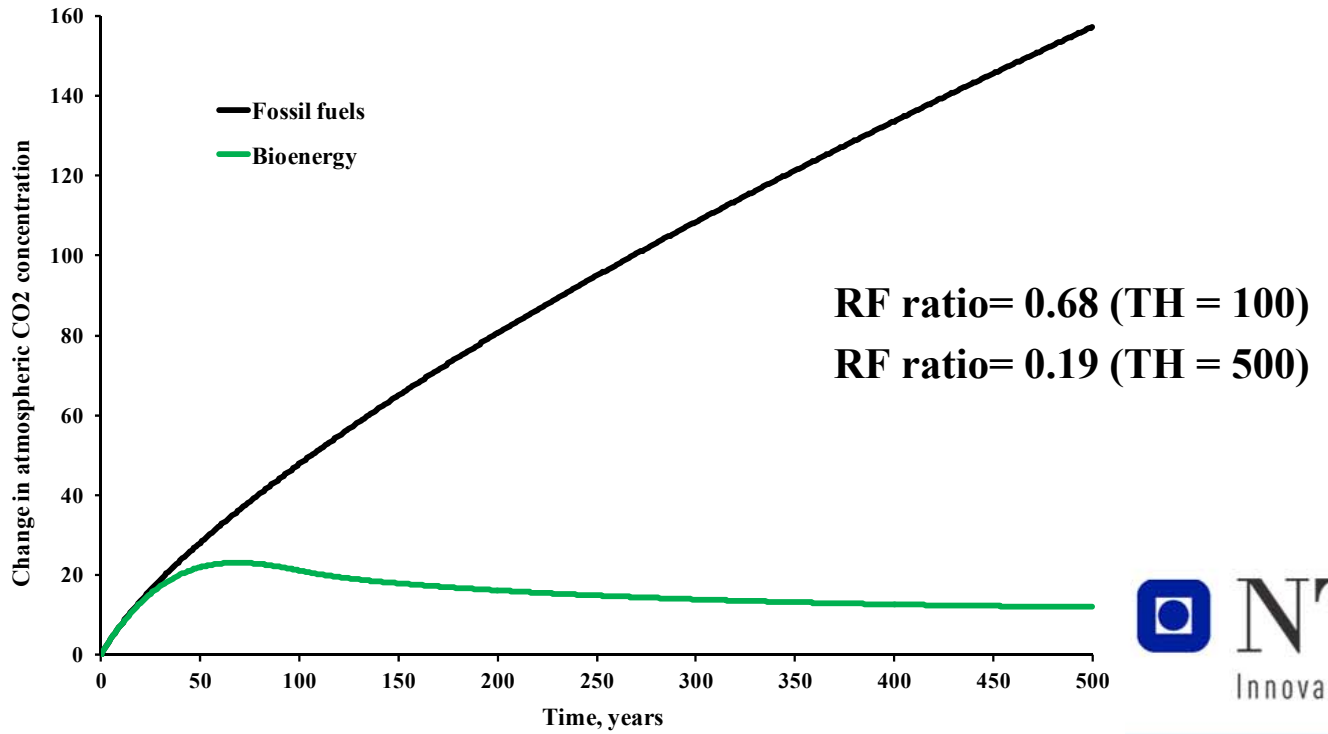
4) **χ^2 distribution *χ(t)*** (emissions are distributed around the mean lifetime)



	GWP_{bio}		
	20	100	500
δ(t)	0.26	0.32	0.07
υ(t)	0.32	0.32	0.07
ε(t)	0.33	0.26	0.06
χ(t)	0.19	0.28	0.07

Landscape level (1)

- Pulse emission each year
  - Fossil fuels
  - Forest biomass with r = 100 years (100 forest parcels, at steady state before harvest, then managed re-growth thereafter)



RF ratio= 0.68 (TH = 100)
RF ratio= 0.19 (TH = 500)

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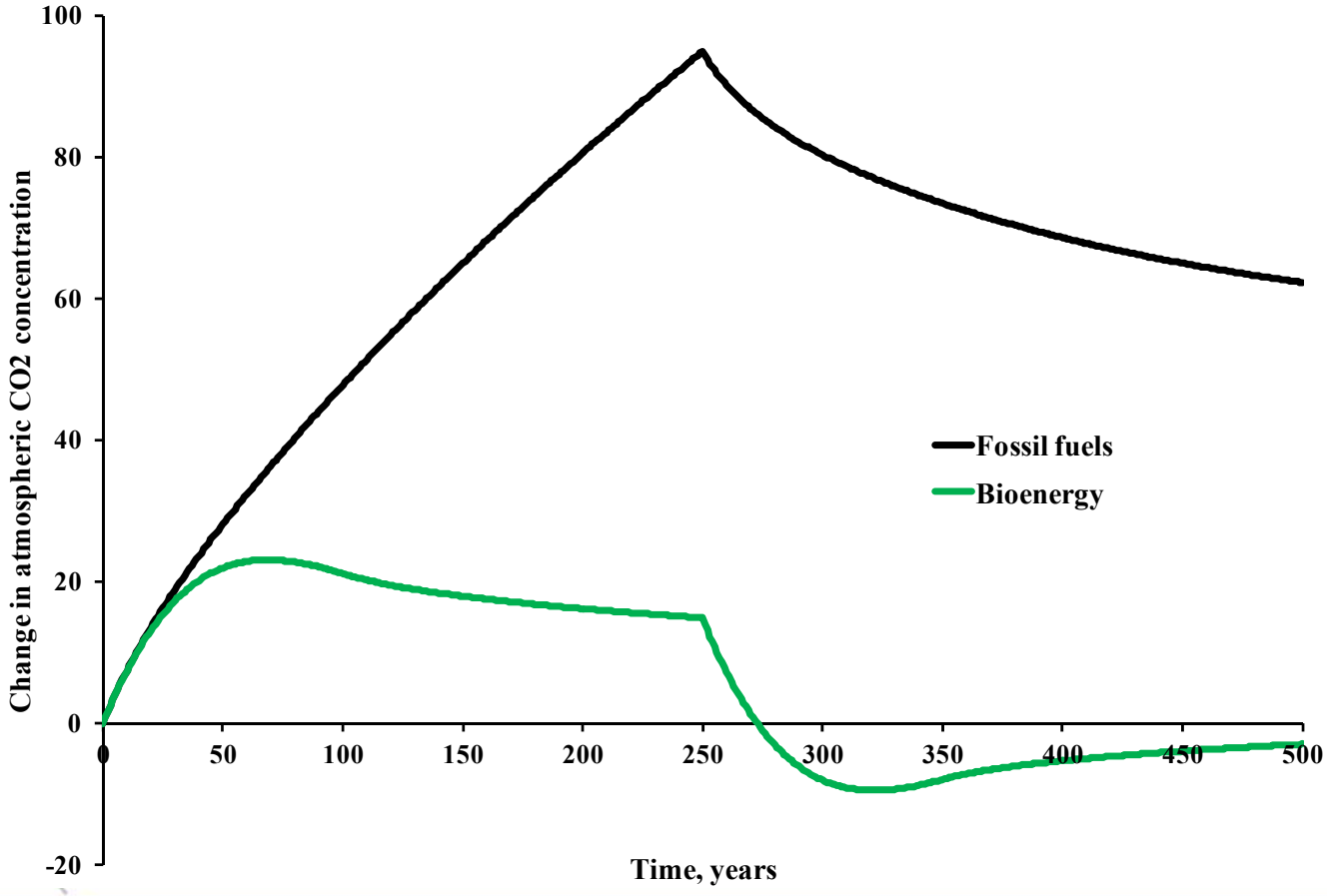
Landscape level (2)

- Pulse emissions stopped at year 250



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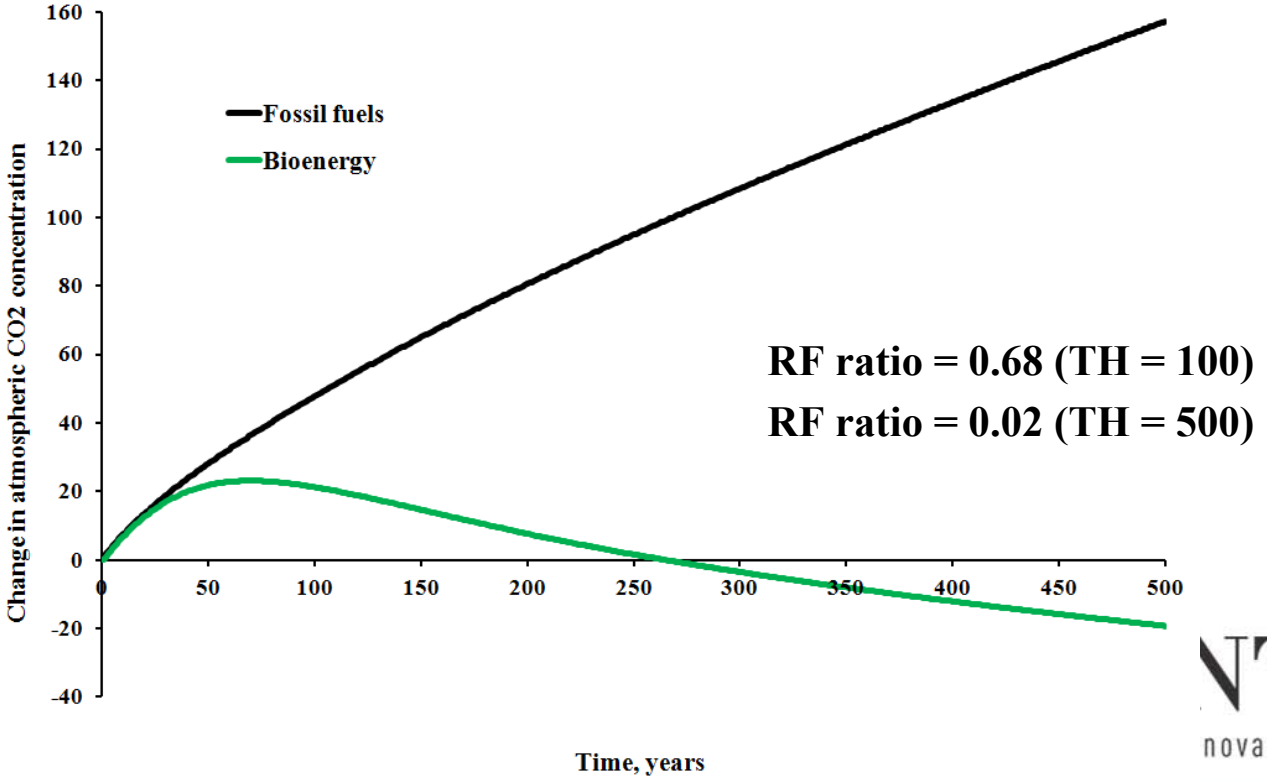
Landscape level (3)

- Pulse emission each year
  - Fossil fuels
  - Forest biomass (at steady state before harvest, which occurs each year in a new forest parcel, then natural re-growth thereafter)



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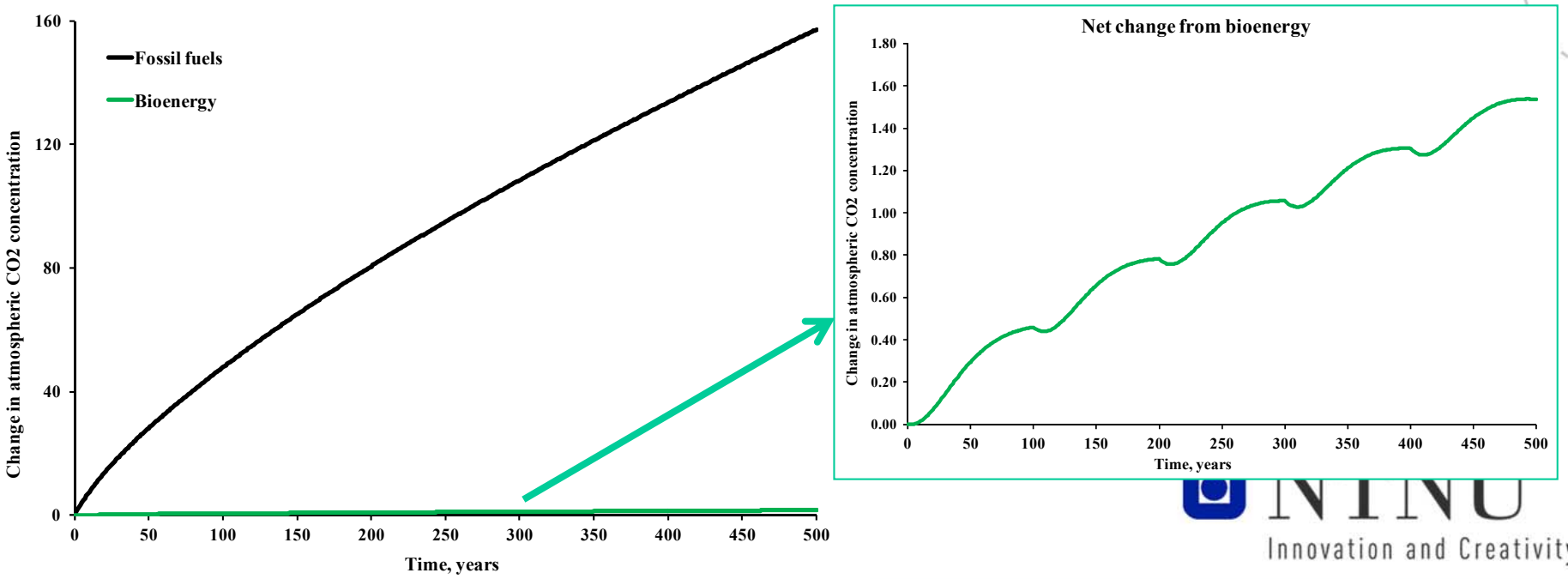
Landscape level (4)

- Pulse emission each year
  - Fossil fuels
  - Forest biomass (r = 100 years), full dynamics of each forest parcel under rotation (uneven age forest)



Conclusions

- The existing CO_2 accounting frameworks in LCA are shaky and potentially inappropriate
- It is time to distinguish between "carbon neutral" and "climate neutral"
- The adoption of a GWP = 1 (like anthropogenic CO_2) overestimates the climate impact
- We propose a methodology based on physical aspects (net change in CO_2 atmospheric concentration)
- Climate impact of biogenic CO_2: $GWP_{bio} \leq 1$
- Large mitigation of GW with long time frames
- Issue of scale: applicability both at single stand and landscape level
- Results are suitable for being routinely applied in LCA studies and incorporated in methodological standards (e.g. accounting of emissions from HWP, emission inventories, etc.)
- N.B. General conclusions can be derived after a comprehensive climate assessment only, which includes life-cycle auxiliary inputs, changes in terrestrial C pools, albedo, evapotranspiration, etc.

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