Forest residues for bioenergy: climate impacts and cumulative carbon budgets

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Aims

To present a set of results that illustrates the climate impacts of using forest residues for bioenergy.

<u>We describe:</u>

1. Global mean surface temperature impacts of using forest residues for bioenergy vs using fossil fuels.
2. Relationship between cumulative carbon emission and temperature change for carbon emissions from forest residues used for bioenergy.

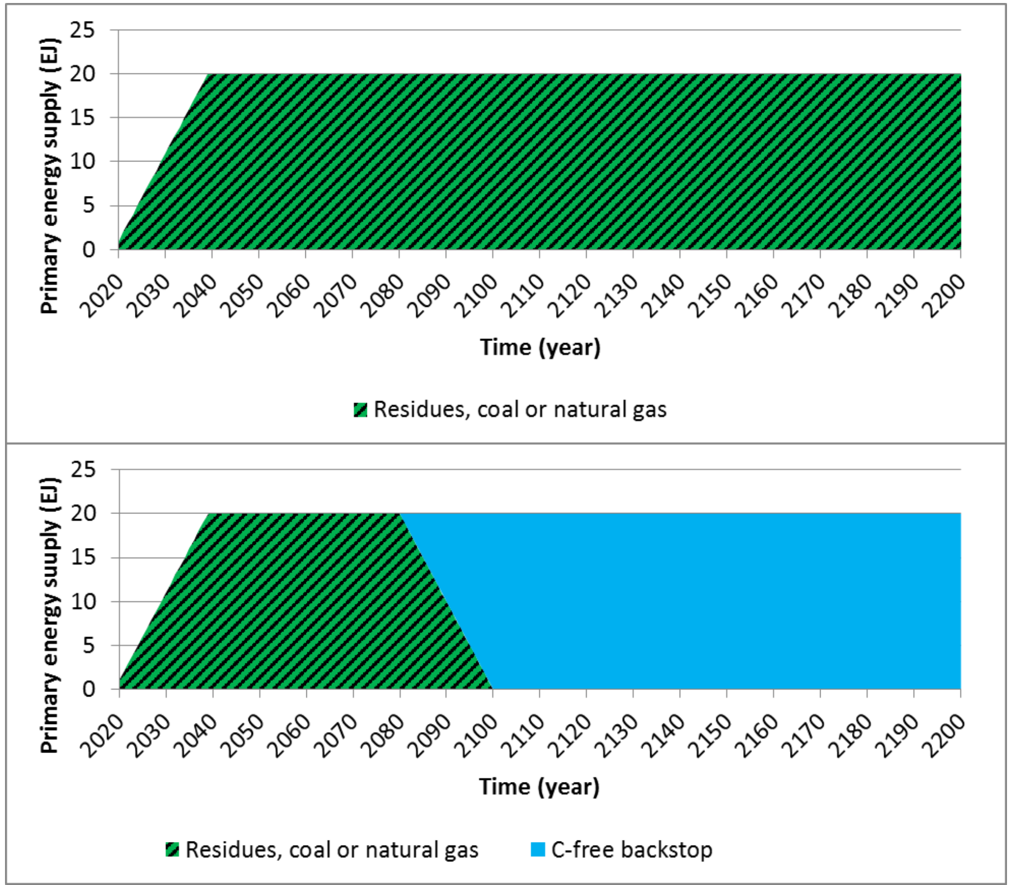
(We also illustrate possible influence of forest management in end of presentation)

Approach

Using a simple climate model (integrated global energy balance and carbon cycle model) to assess two scenarios added **on top of the RCP 2.6 scenario**.

Scenario 1:
Long-term carbon fuel scenario

Scenario 2:
Transition carbon fuel scenario



Residues, natural gas and coal are considered equal on a heating value basis

<u>Carbon content</u>

Coal – 25gC/MJ

Natural gas – 15gC/MJ

Residues – 28gC/MJ

Simple climate model

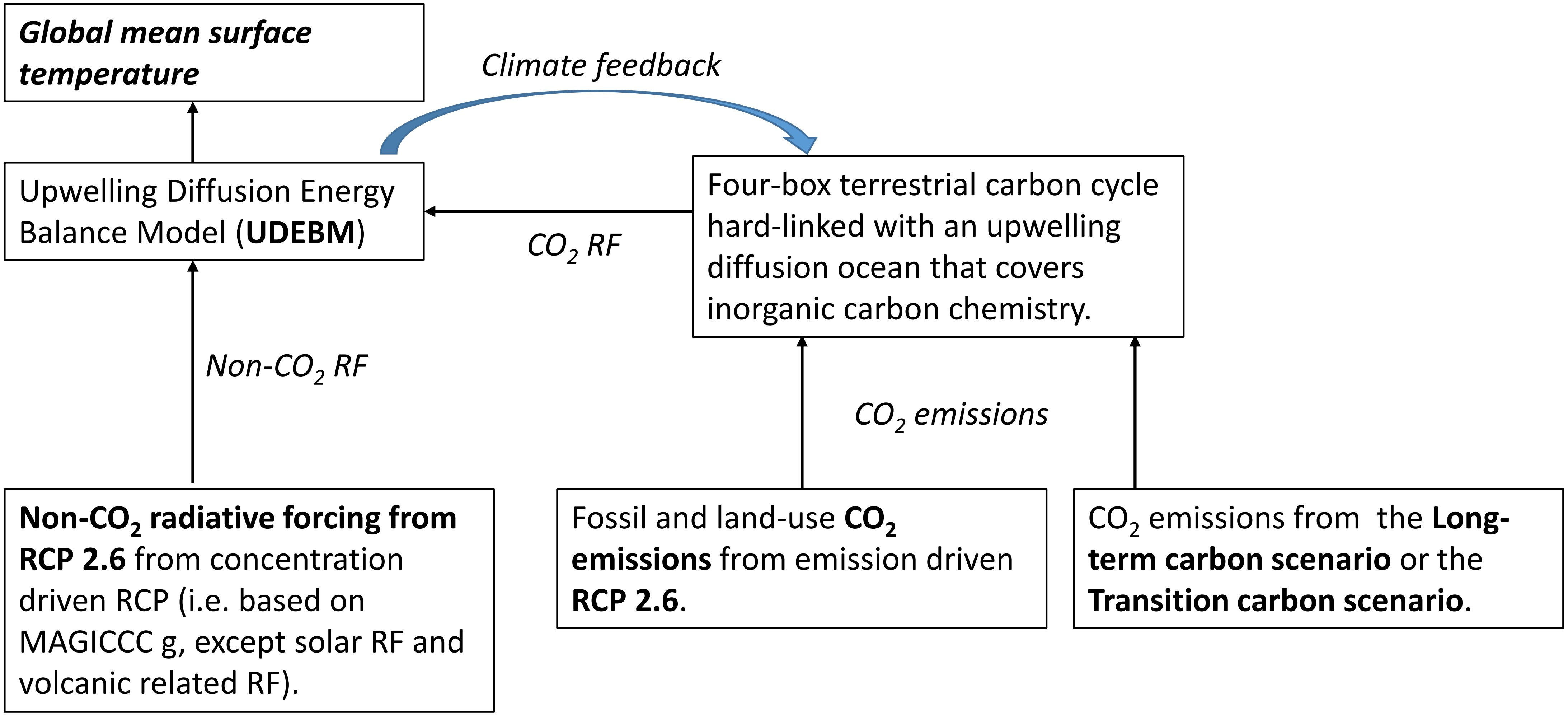
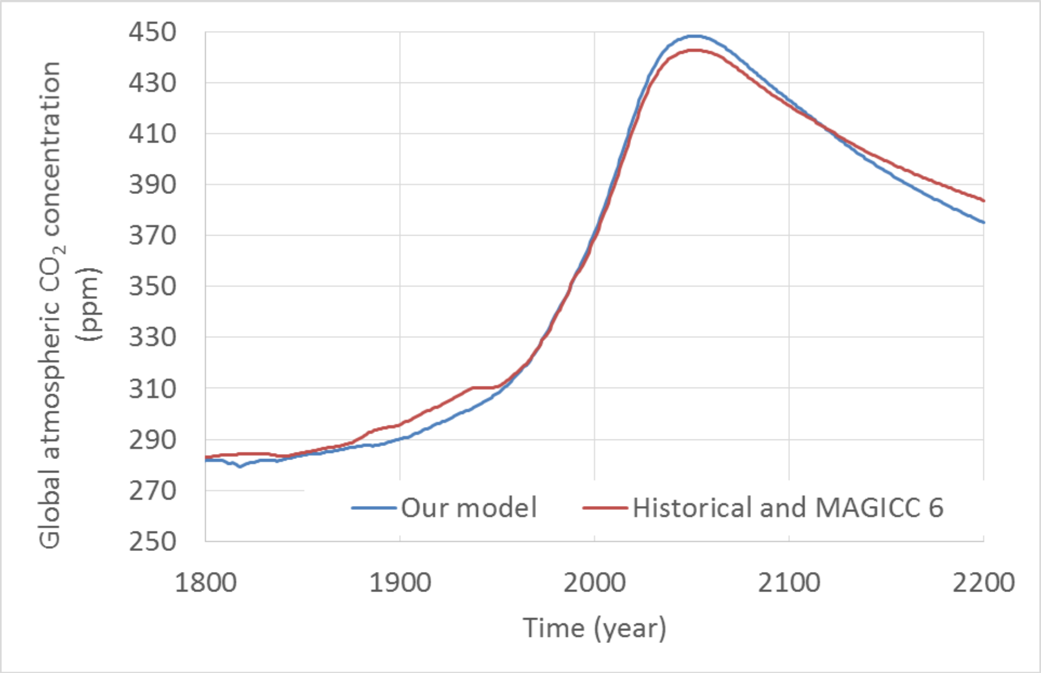
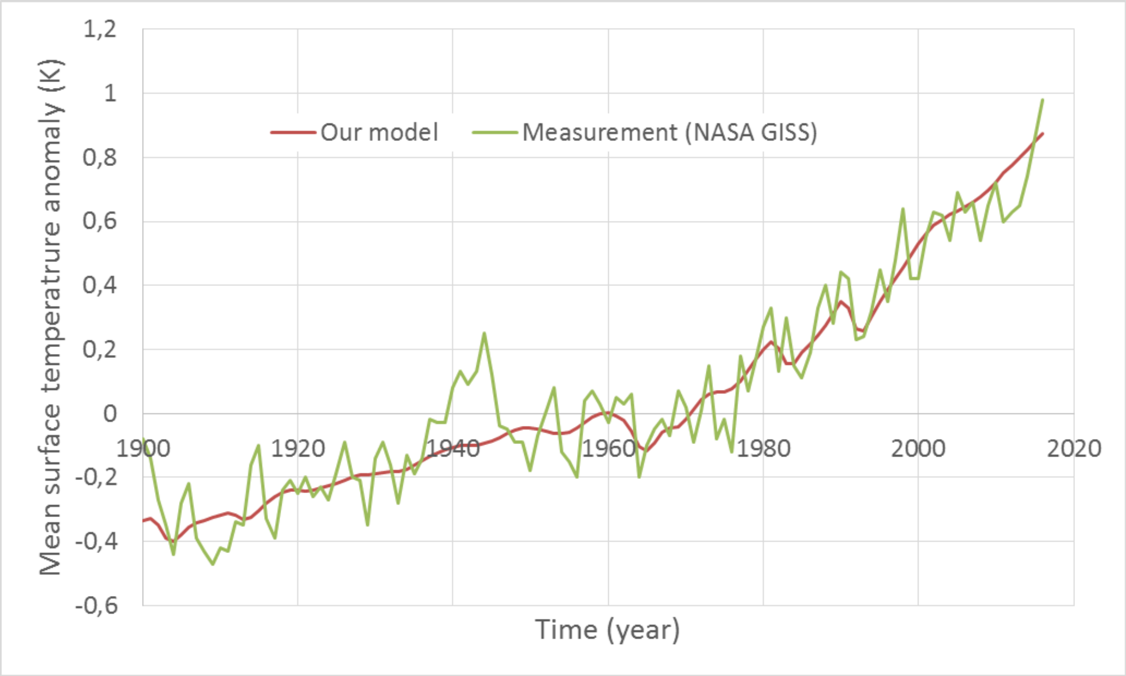


Illustration of model performance

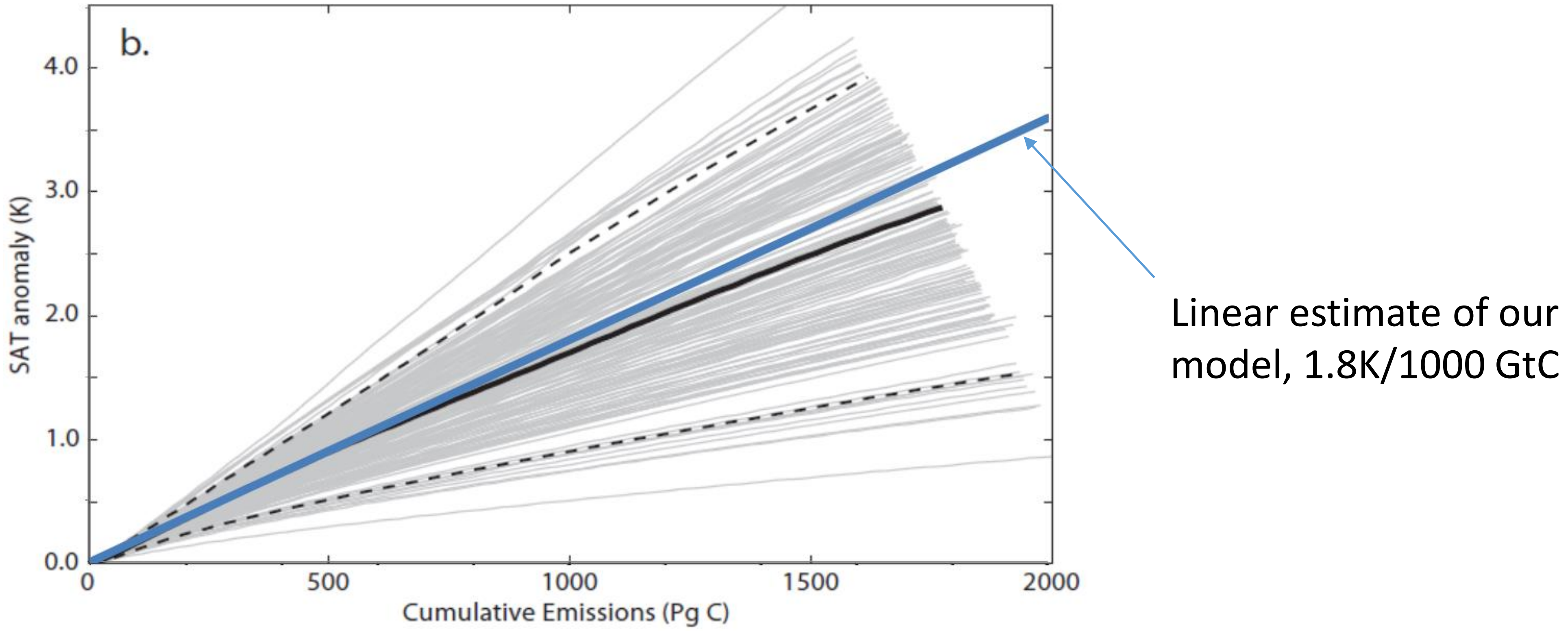
CO_2 concentration



Surface temperature anomaly



Cumulative (fossil) carbon emissions and Temperature change

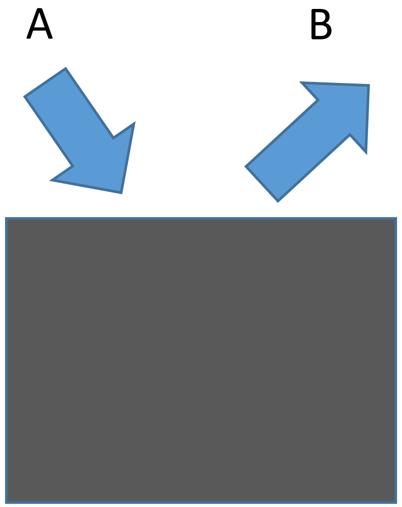


MacDougall et al, 2017, The uncertainty in the transient climate response to cumulative CO2 emissions arising from the uncertainty in physical climate parameters, *Journal of Climate.*

Principle of soil C balance for sustained level of residue removal

Residues left in forest

Input of C in residues = natural decomposition of C

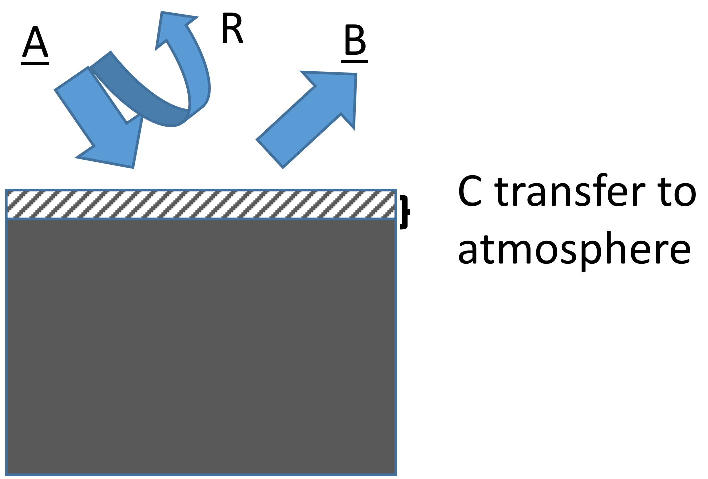


Equilibrium A=B

Residues harvested for bioenergy

Equilibrium – residues have a **short** soil C decay time scale

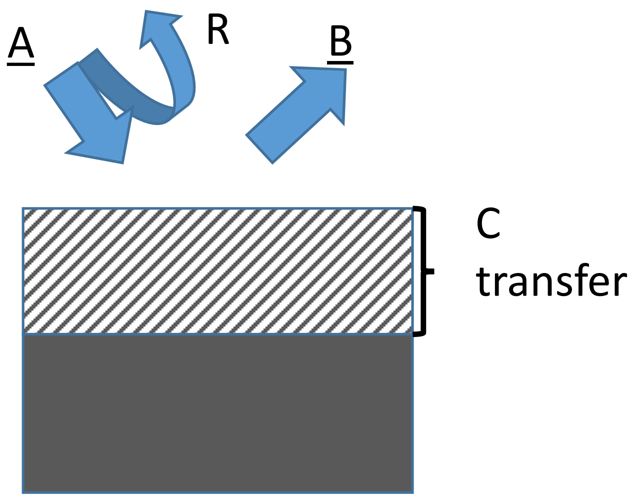
Residue removal



New equilibrium will be reached relatively **rapidly,** A=B, A+R=A, B+R=B.

Equilibrium – residues have a **long** soil C decay time scale

Residue removal



New equilibrium will be reached relatively **slowly ,** A=B, A+R=A, B+R=B.

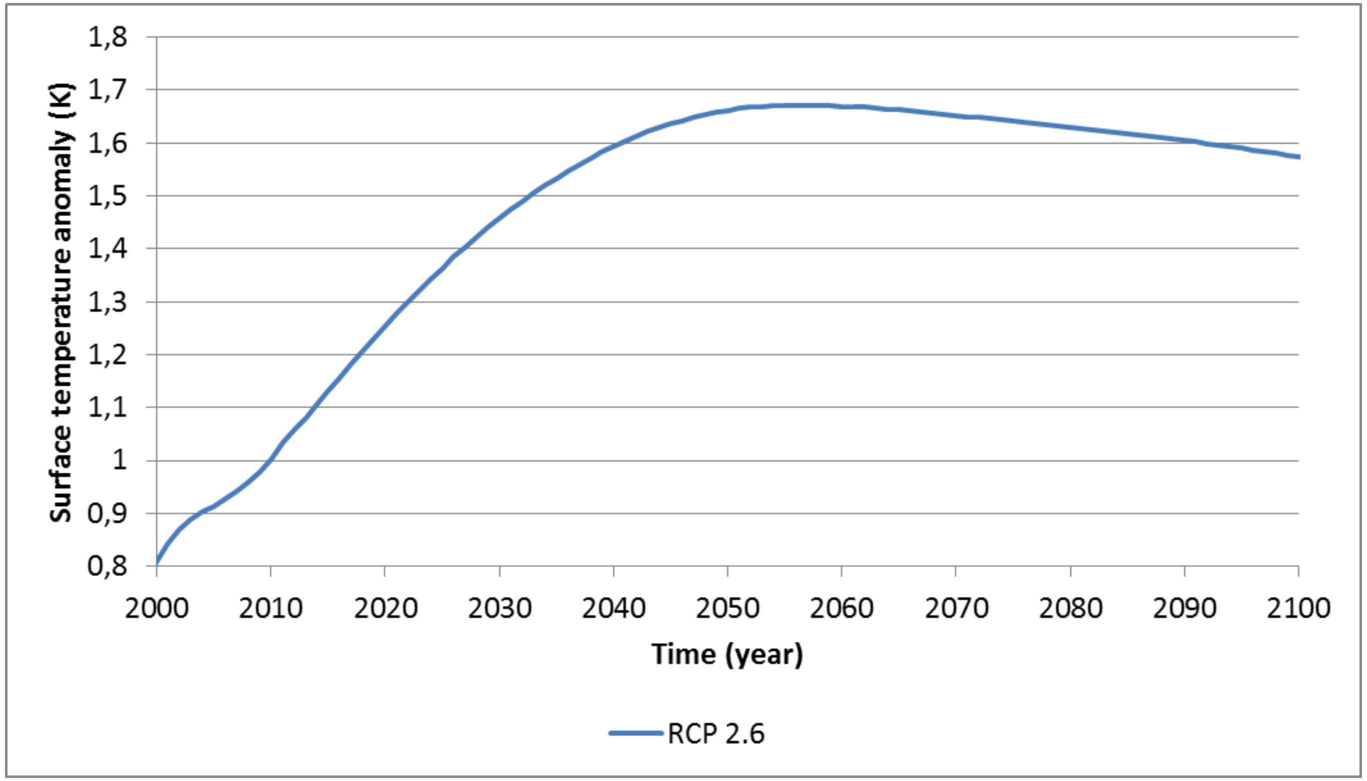
Carbon accounting approach and soil carbon decay time scale

Key assumption:

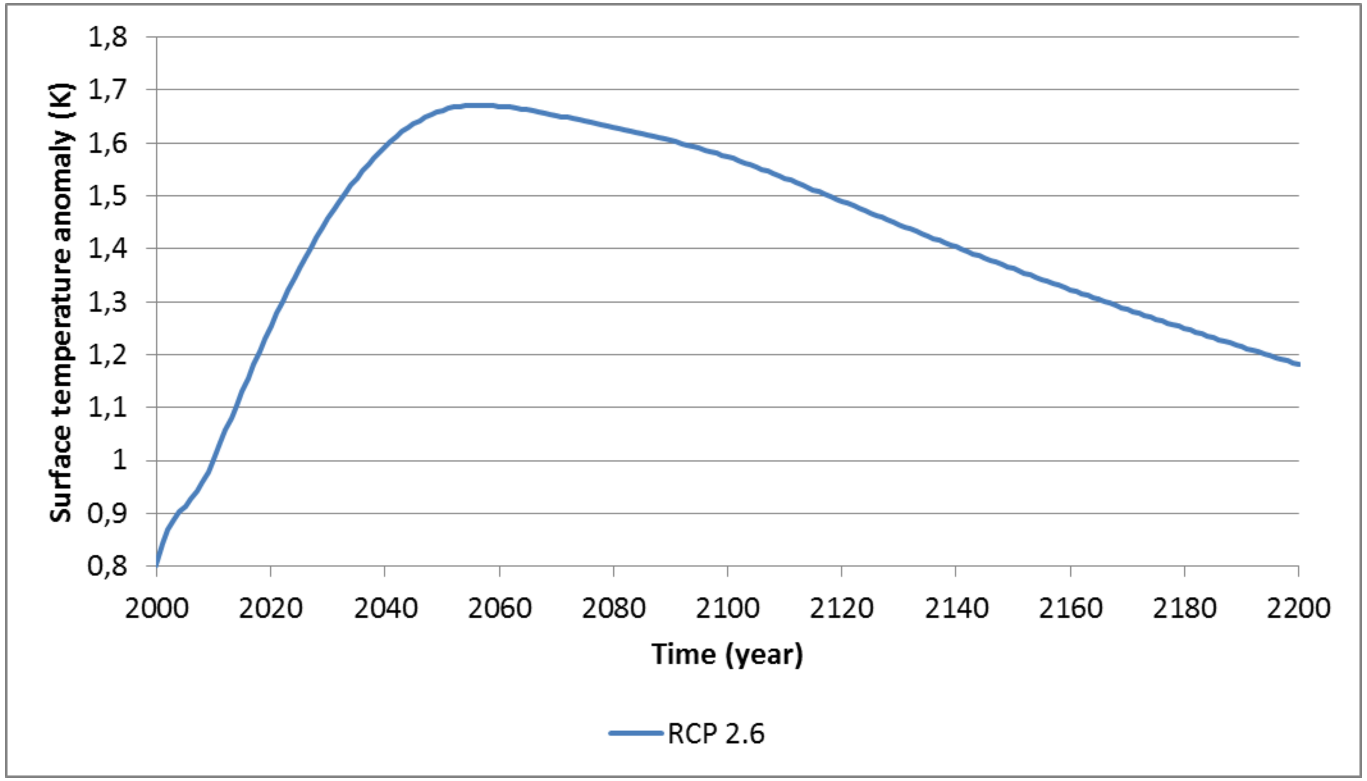
- BaU without residue extration, add-on scenario with residue extration. The carbon accounting is started when residues are harvested and used for bioenergy, i.e., least beneficial accounting window is used.
- Three soil C decay time constants are used:
  - 10 years
  - 20 years
  - 30 years

Model results

RCP 2.6 without add-on scenario – **until 2100**

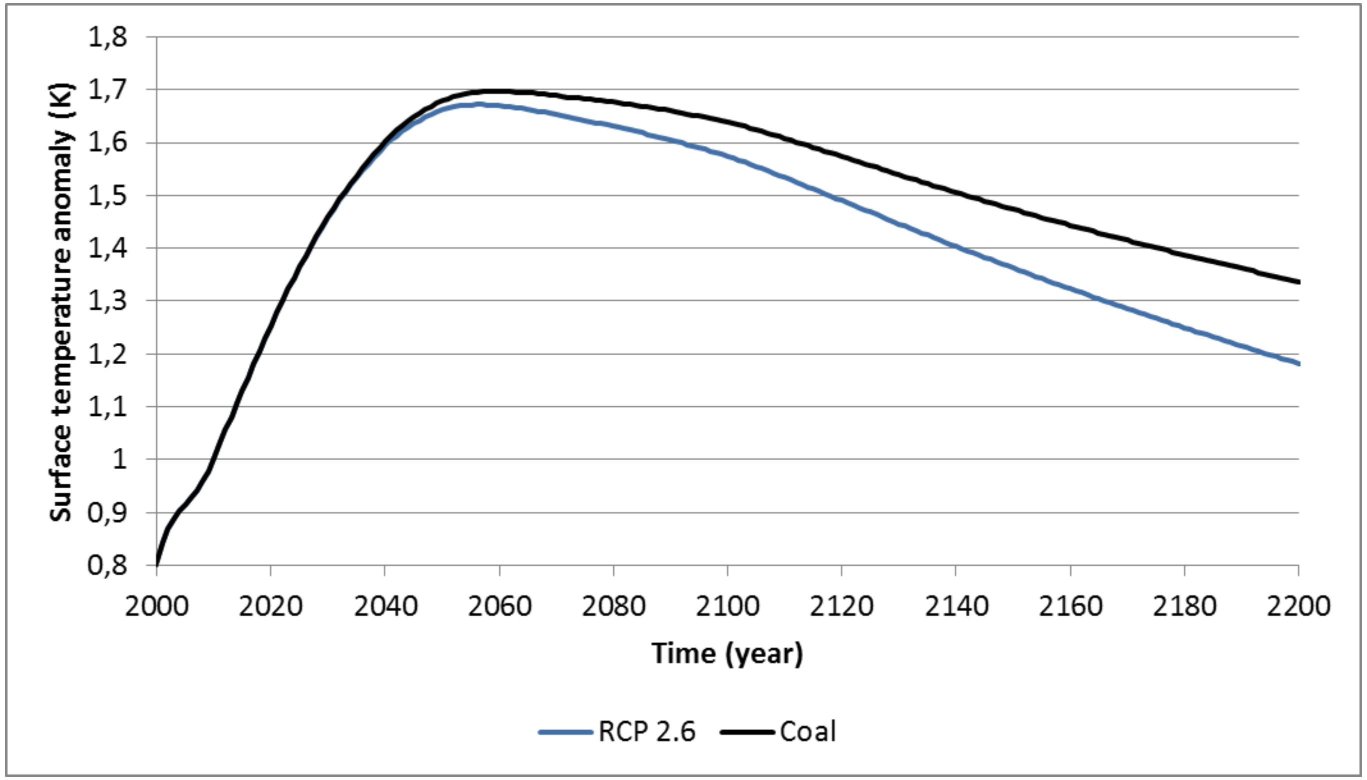


RCP 2.6 without add-on scenario – until **2200**

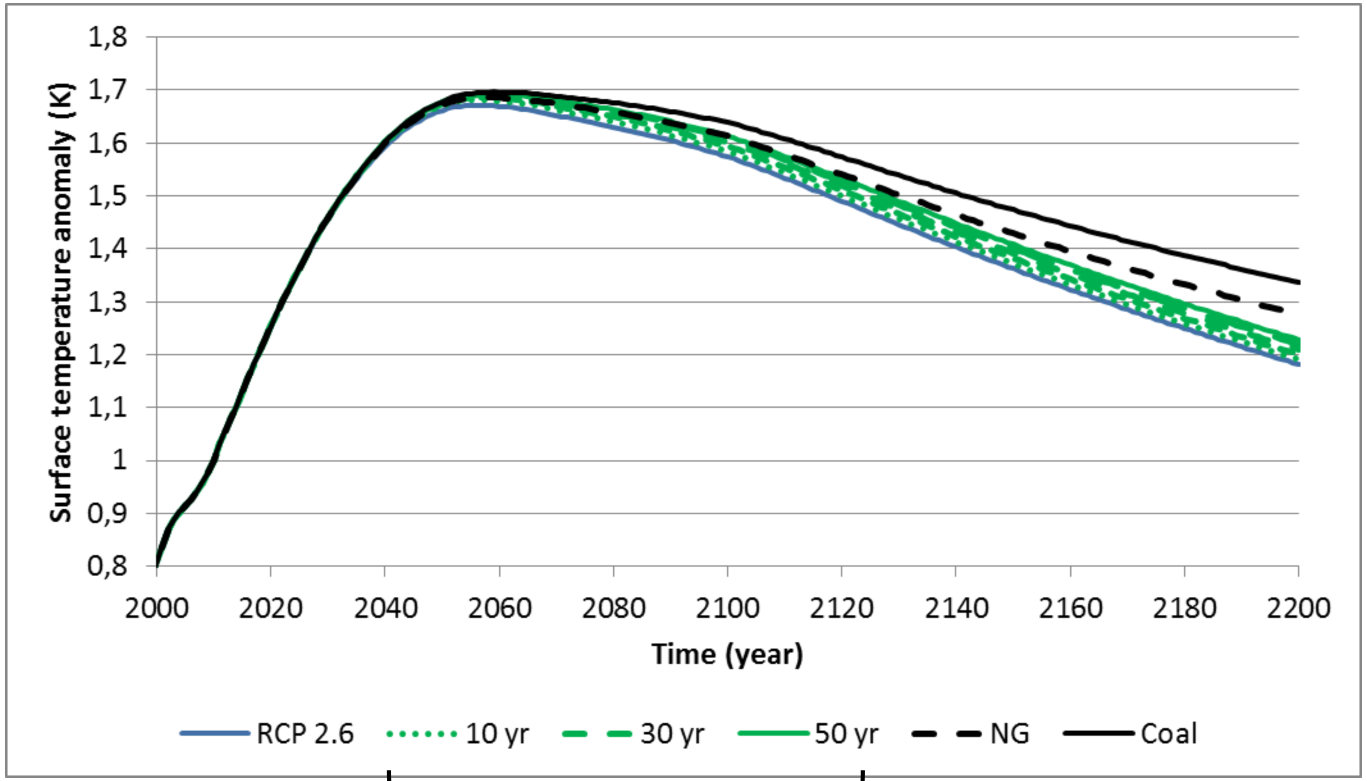


Long-run negative CO_2 emissions in the extended RCP 2.6 causes temperature to drop after a peak level.

Long-term carbon fuel scenario with Coal

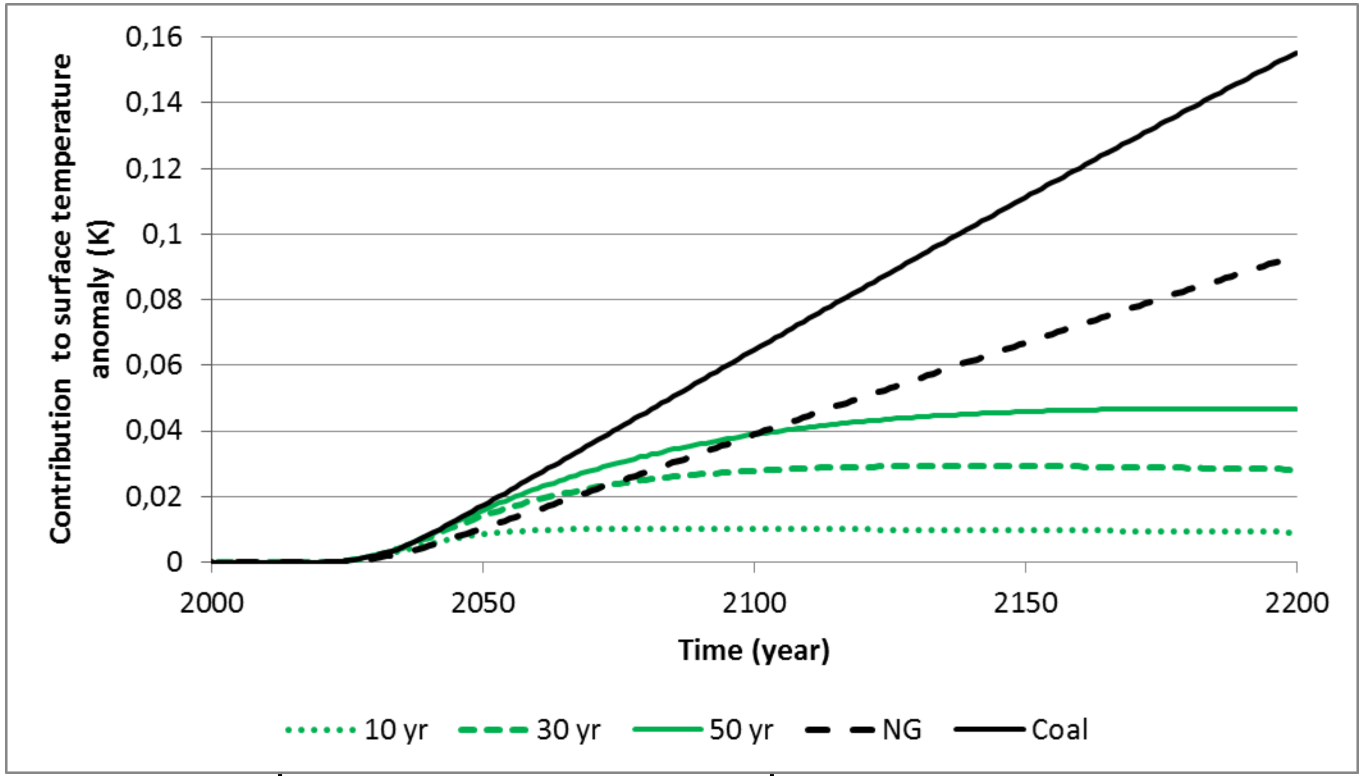


Long-term carbon fuel scenario – different fuels



Residues – decay time

Long-term carbon fuel scenario – ΔT until 2200



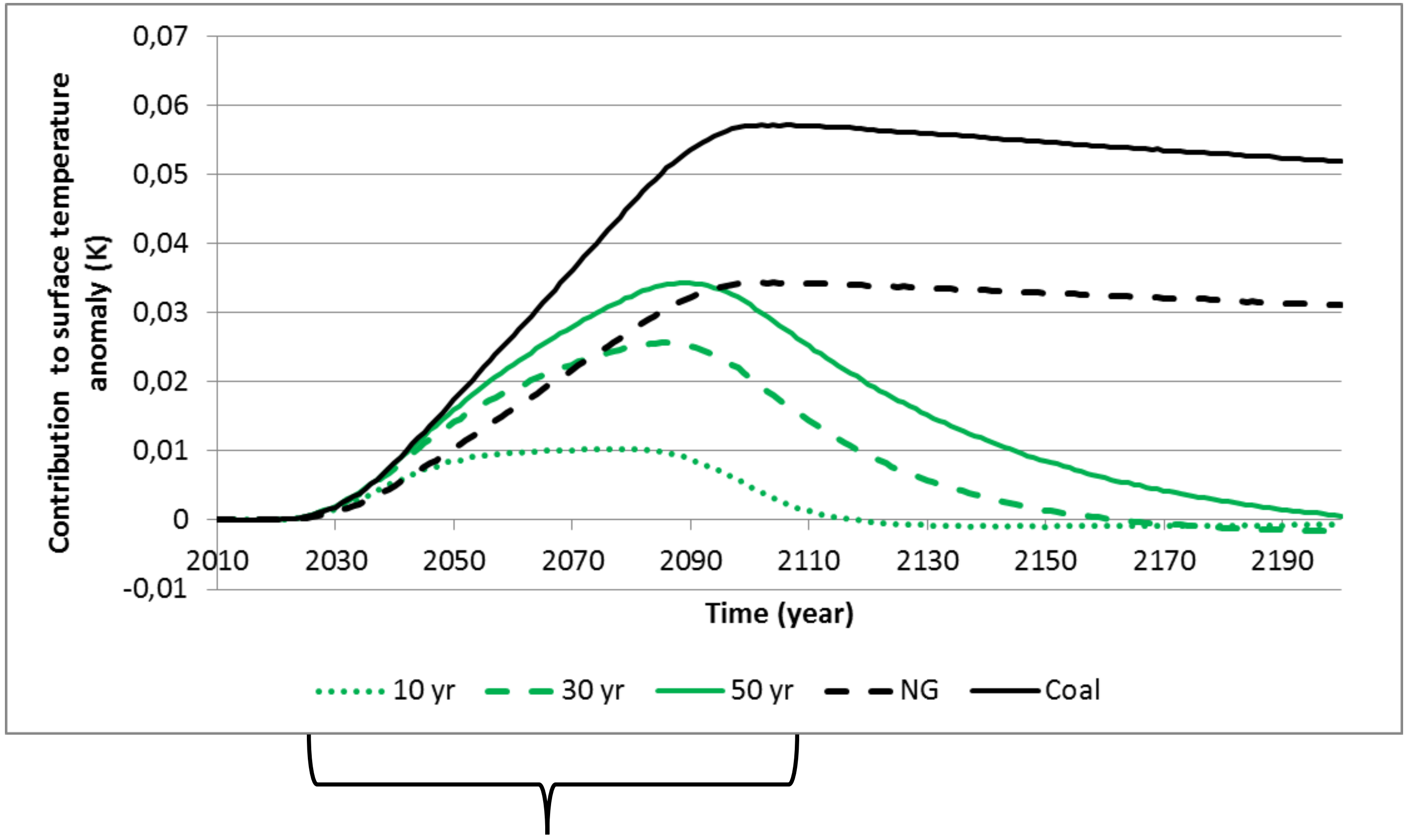
Residues – decay time

For the fossil fuels the temperature contribution grows approximately linearly with cumulative C emissions.

This does not hold for residues used as bioenergy

Temperature contribution from residue combustion stabilizes at a specific level depending on the soil decomposition time scale.

Transition carbon fuel scenario – ΔT until **2200**

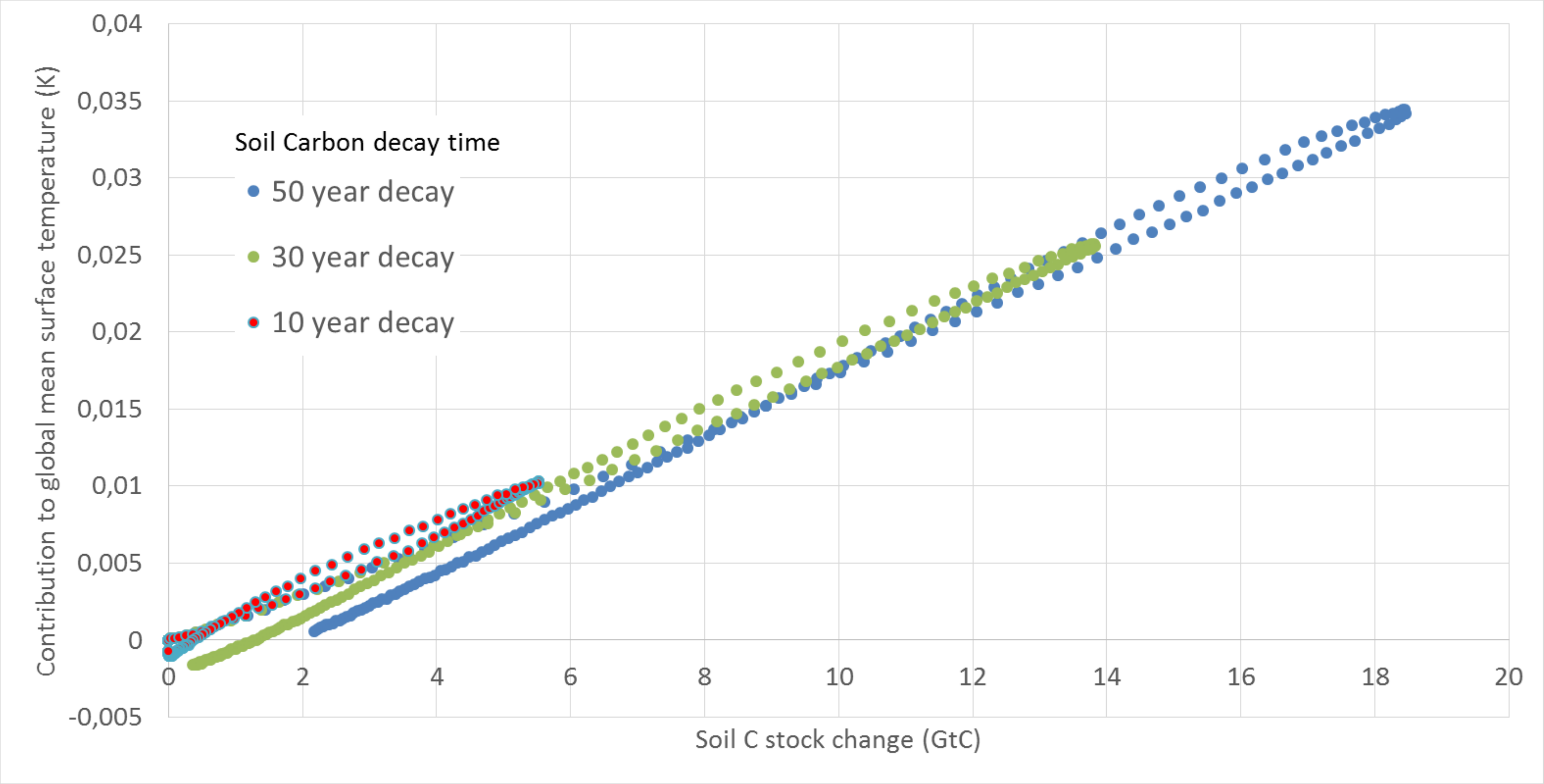


If carbon based fuels are **phased out between 2080 and 2100** the long-term climate consequences of fossil fuels and forest residues are very different

The temperature impact of fossil fuel use are virtually constant for 100 years after they were phased out. (The consequences are much more long-term, but are not shown here).

The temperature impact of residue combustion drops towards zero at a rate depending on the soil decay time constant.

Soil stock changes due to residue removal and temperature implications

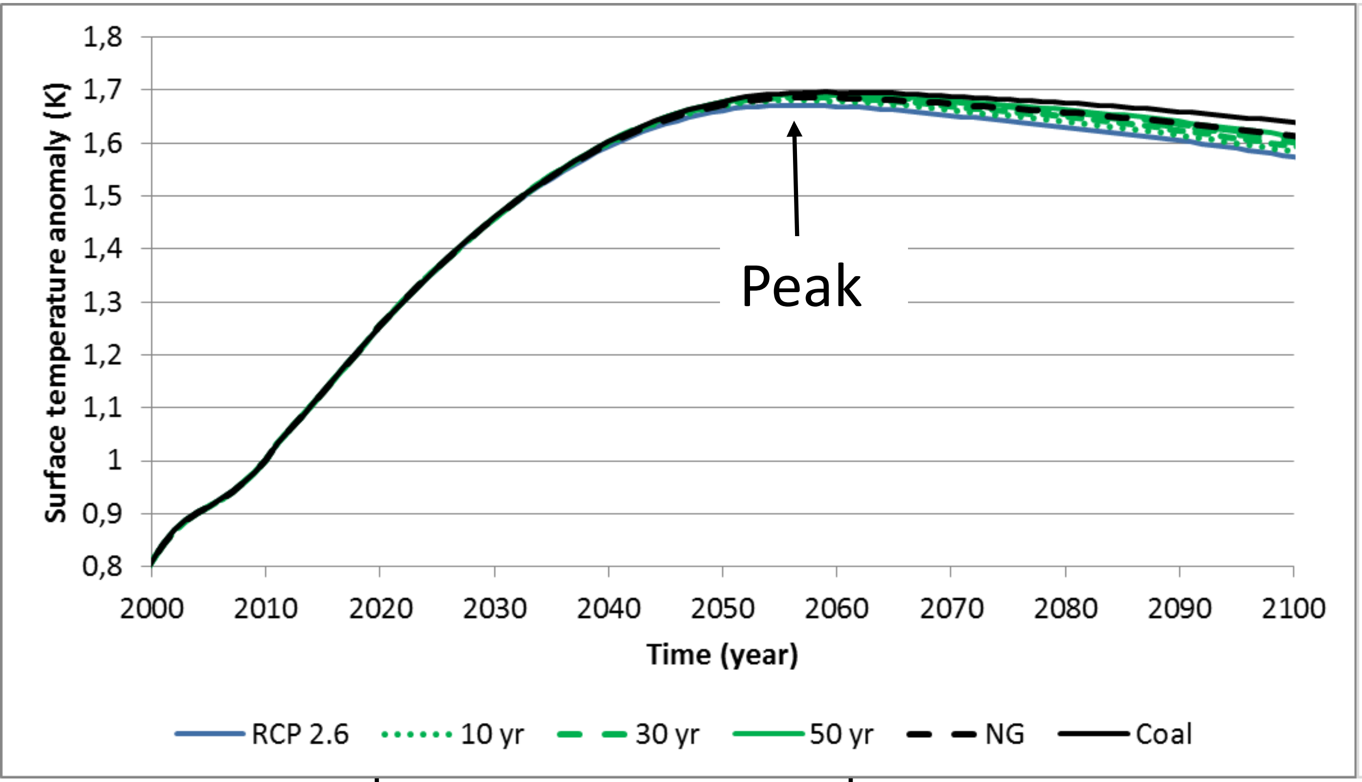


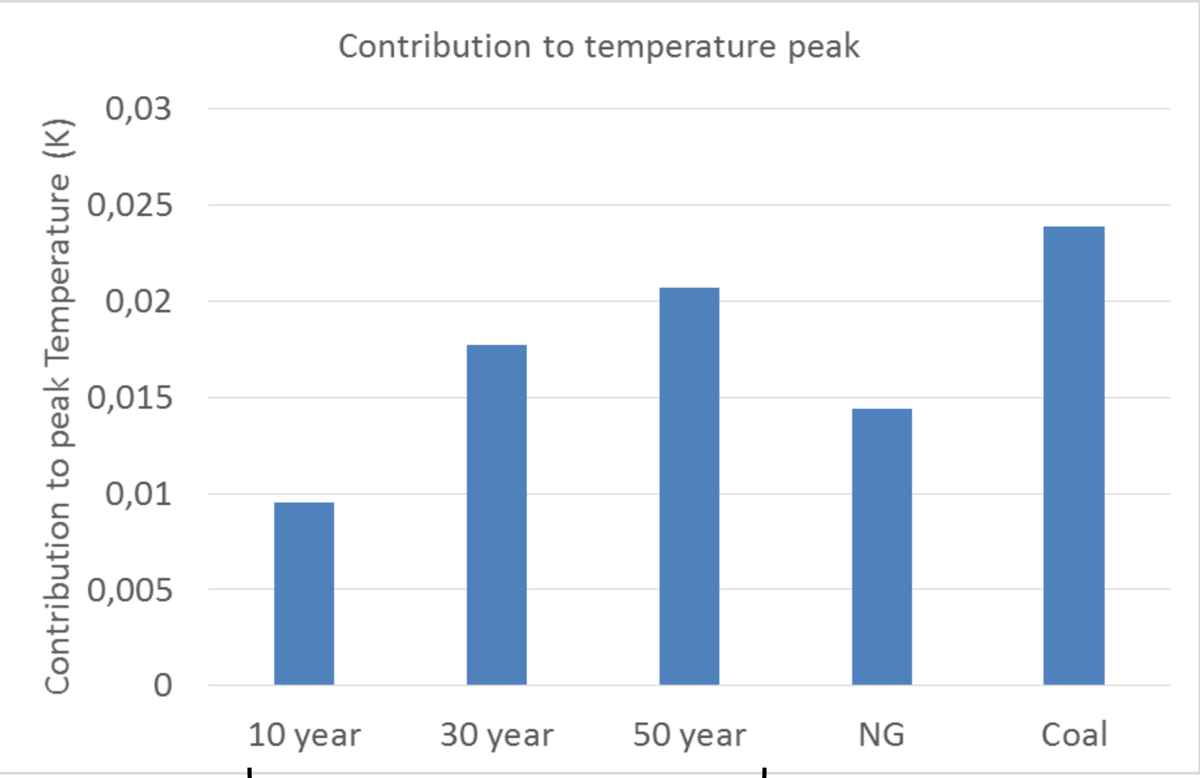
Equal amount of energy (and carbon) is extracted in the three cases.

Large differences in soil C stock changes and consequently impacts on temperature.

Near linear and reversible relationship between soil C stock changes and temperature impact (about 1.8 K/1000 GtC).

Contribution to peak temperature





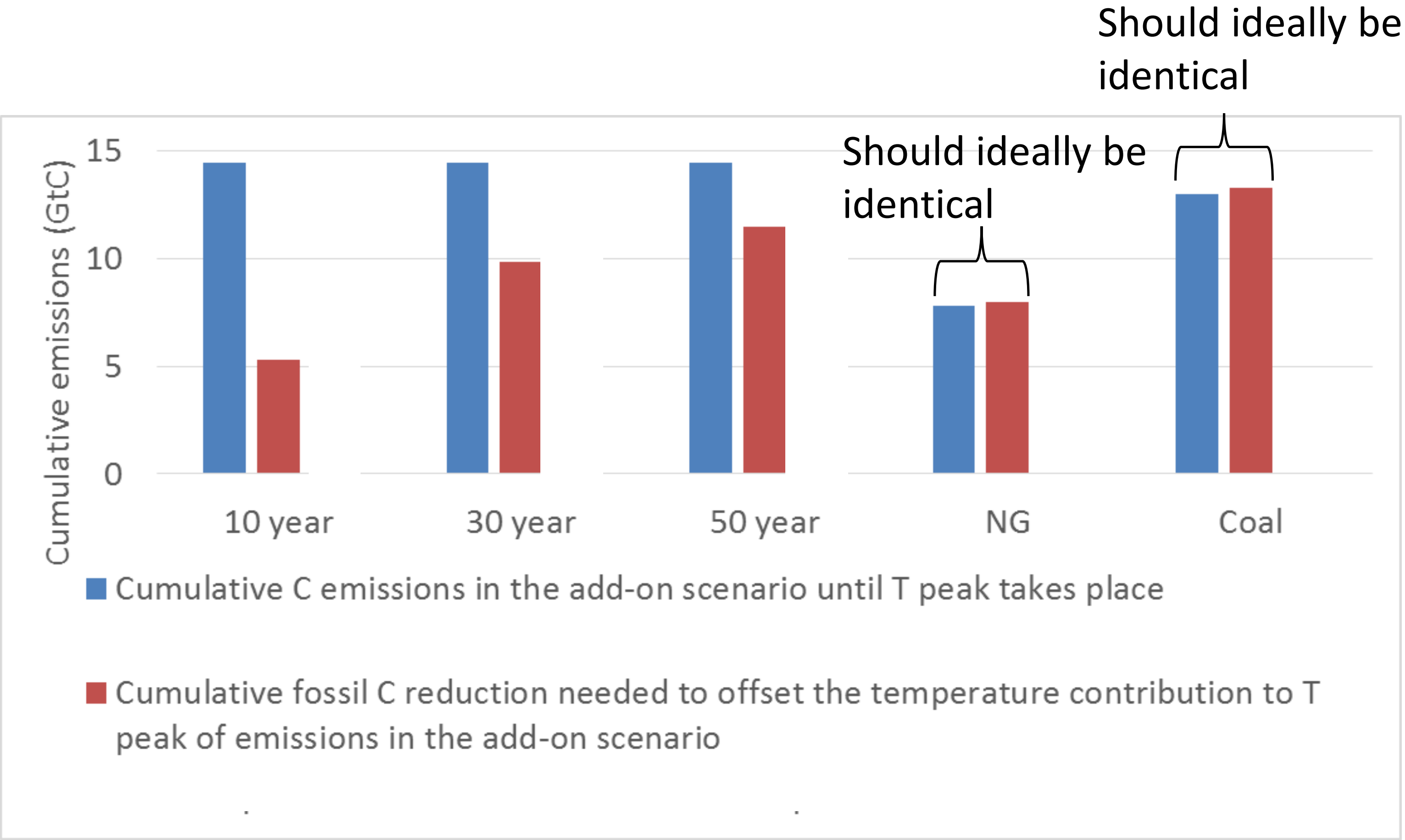
Residues – decay time

Residues – decay time

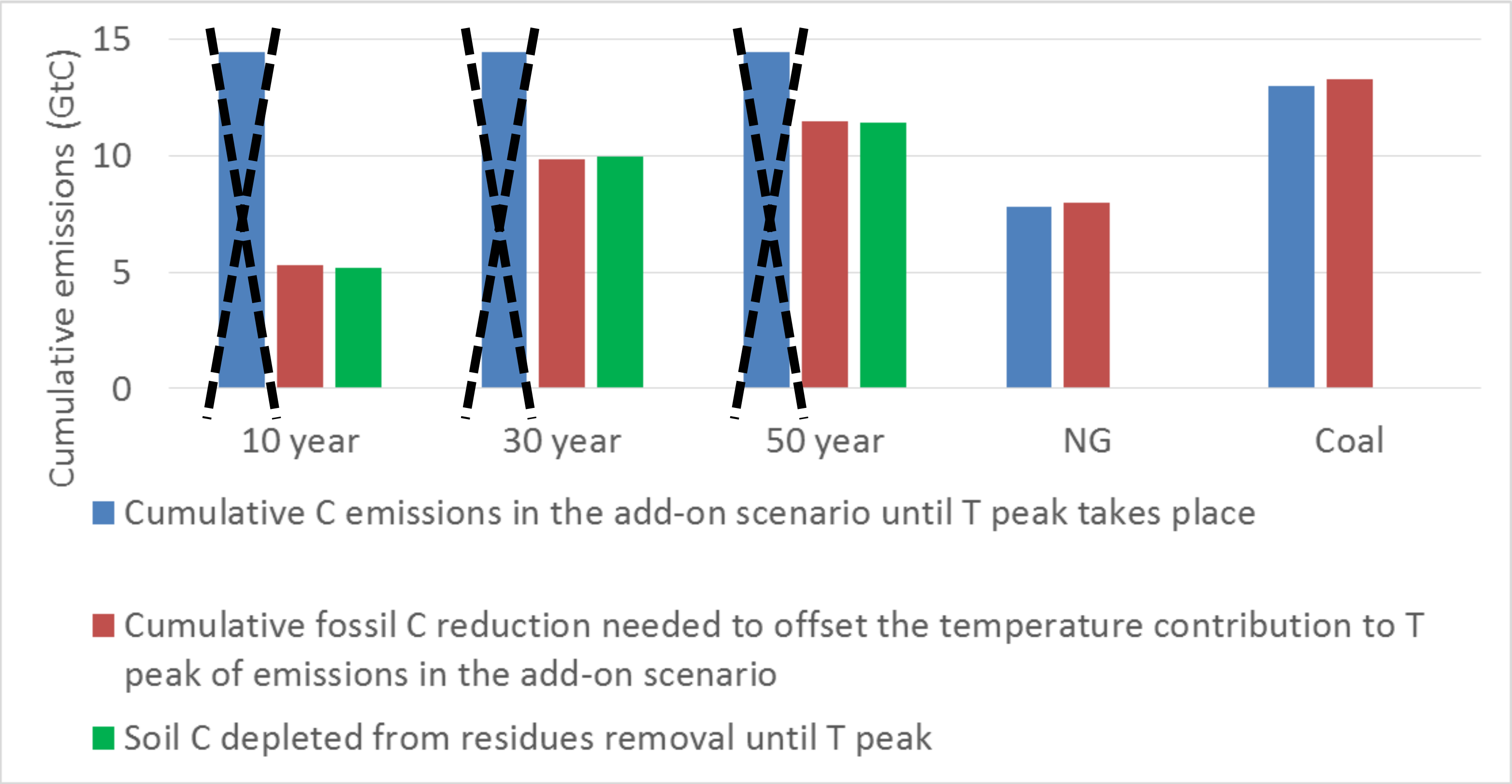
Reduction in cumulative C needed to offset contribution to T peak

The close to linear relationship between cumulative fossil C emissions and temperature is used here (1.8K/GtC) to estimate the needed reduction in cumulative C emissions within the RCP 2.6 scenario, in order to keep the temperature peak constant at the ”original RCP 2.6 level”.

No clear relatioship between residue C emissions and fossil C emissions needed to offset those.

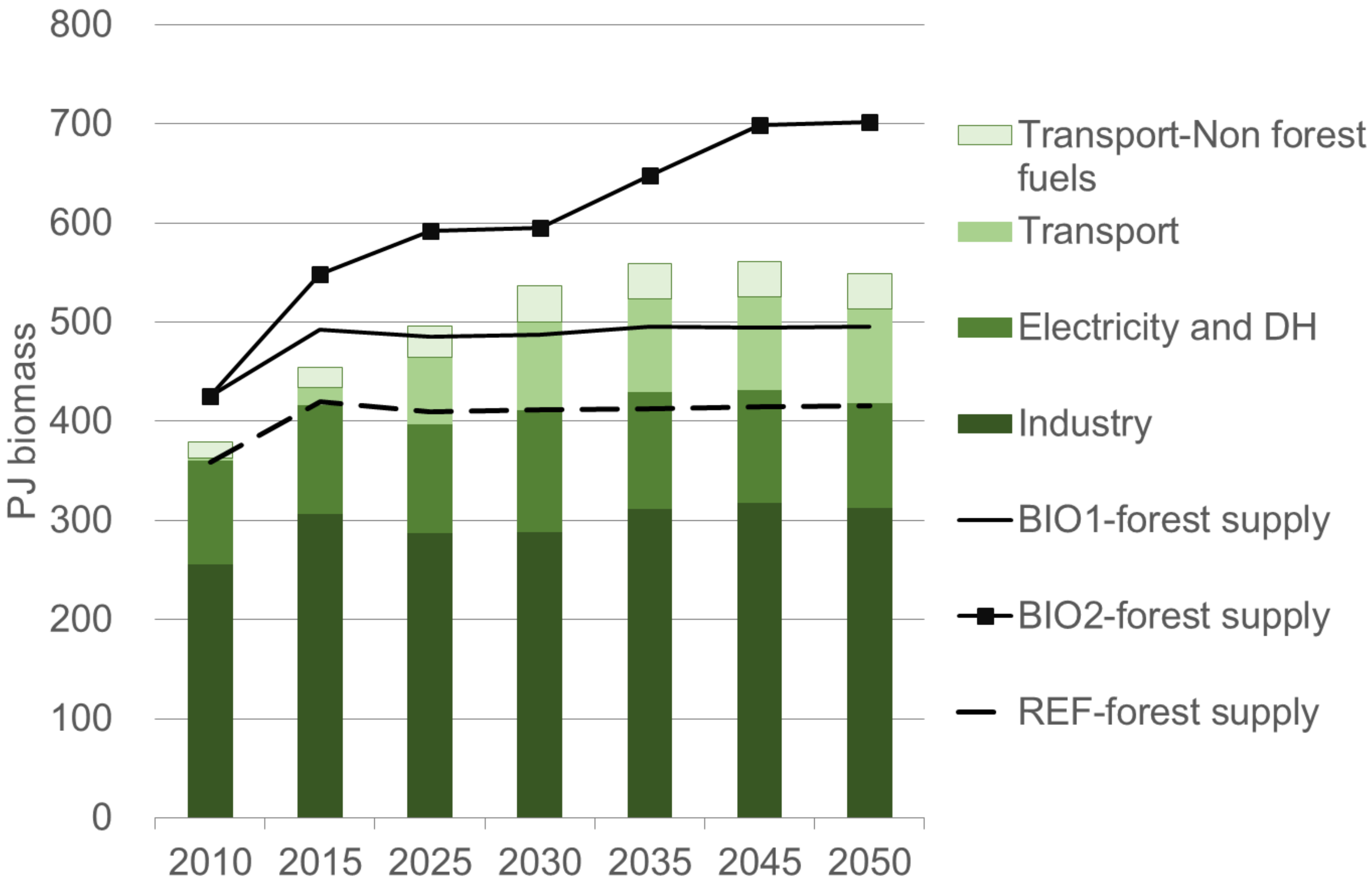


Reduction in cumulative C needed to offset contribution to T peak



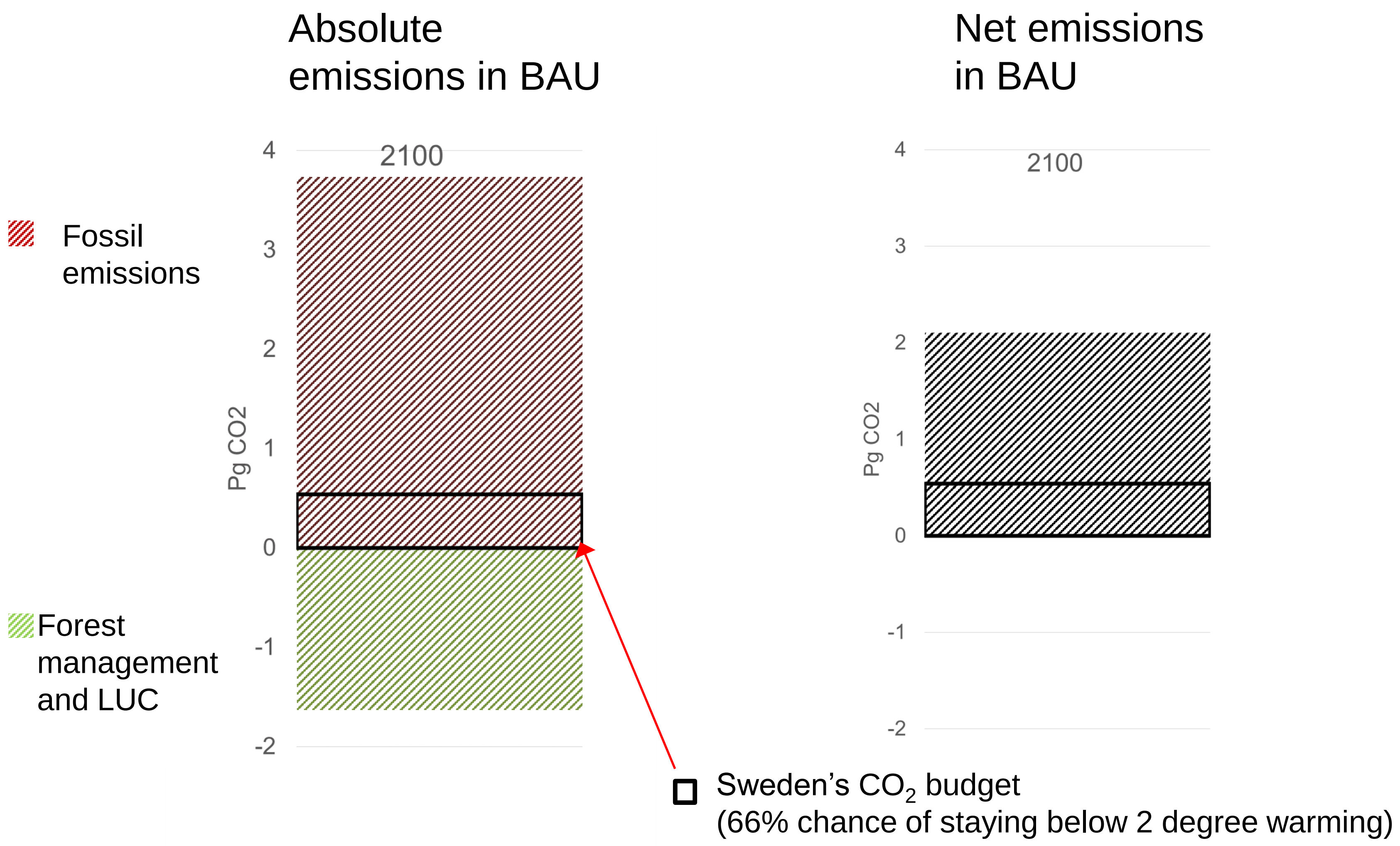
For fossil emissions: Close to linear relationship between cumulative emisions and temperature impact.
For forest residue removal: Close to linear relationship between soil C stock changes and temperature impact.

Residue extraction in wider context of forest management planning

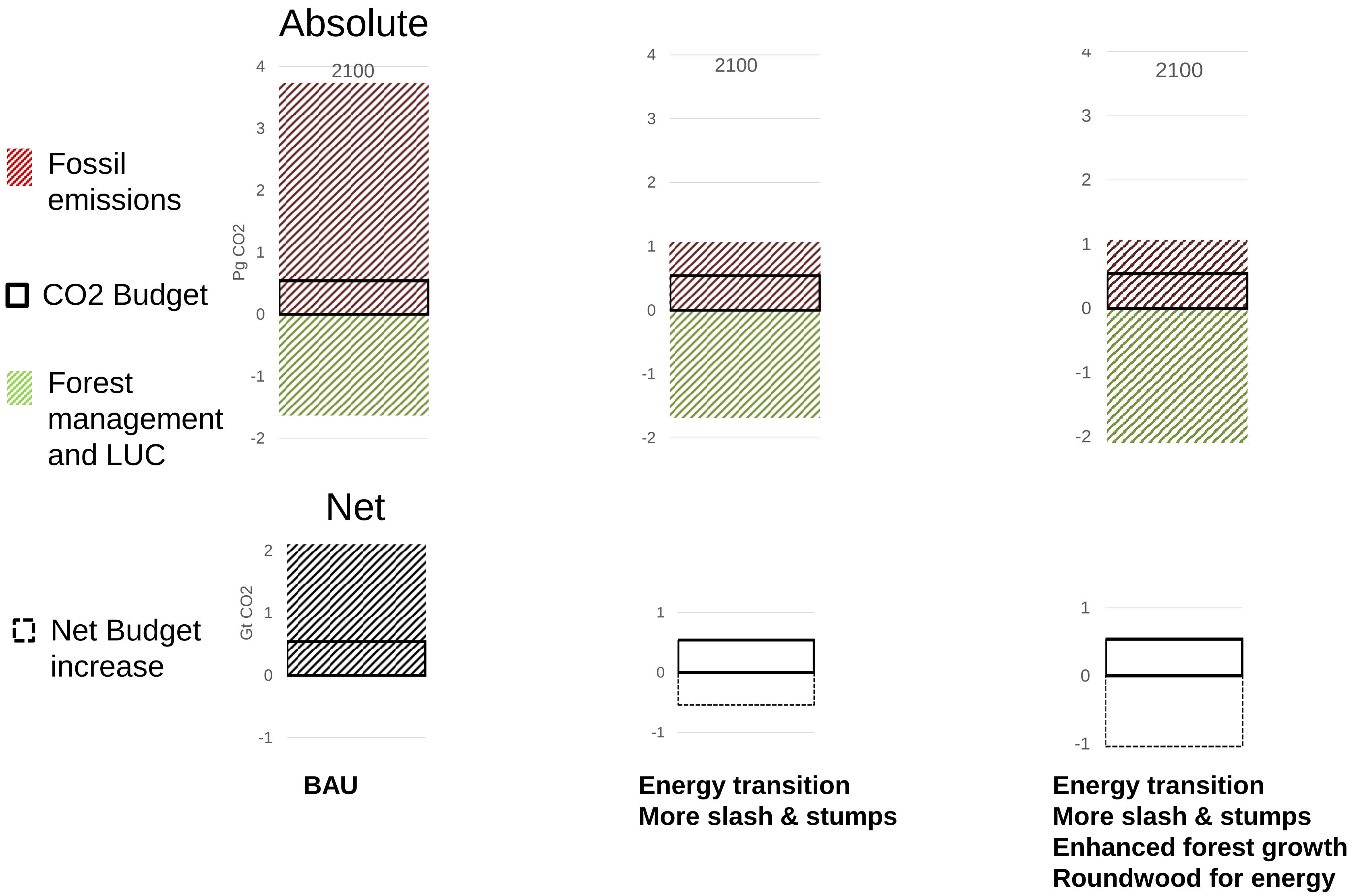


Cintas O, Berndes G, Hansson J, Poudel B, Bergh J, Börjesson P, Egnell G, Lundmark T, Nordin A. *The potential role of forest management in Swedish scenarios towards climate neutrality by mid-century*. Forest Ecology and Management 383 (2017) 73–84

Sweden: climate neutrality and fossil independent transport sector



Sweden: climate neutrality and fossil independent transport sector



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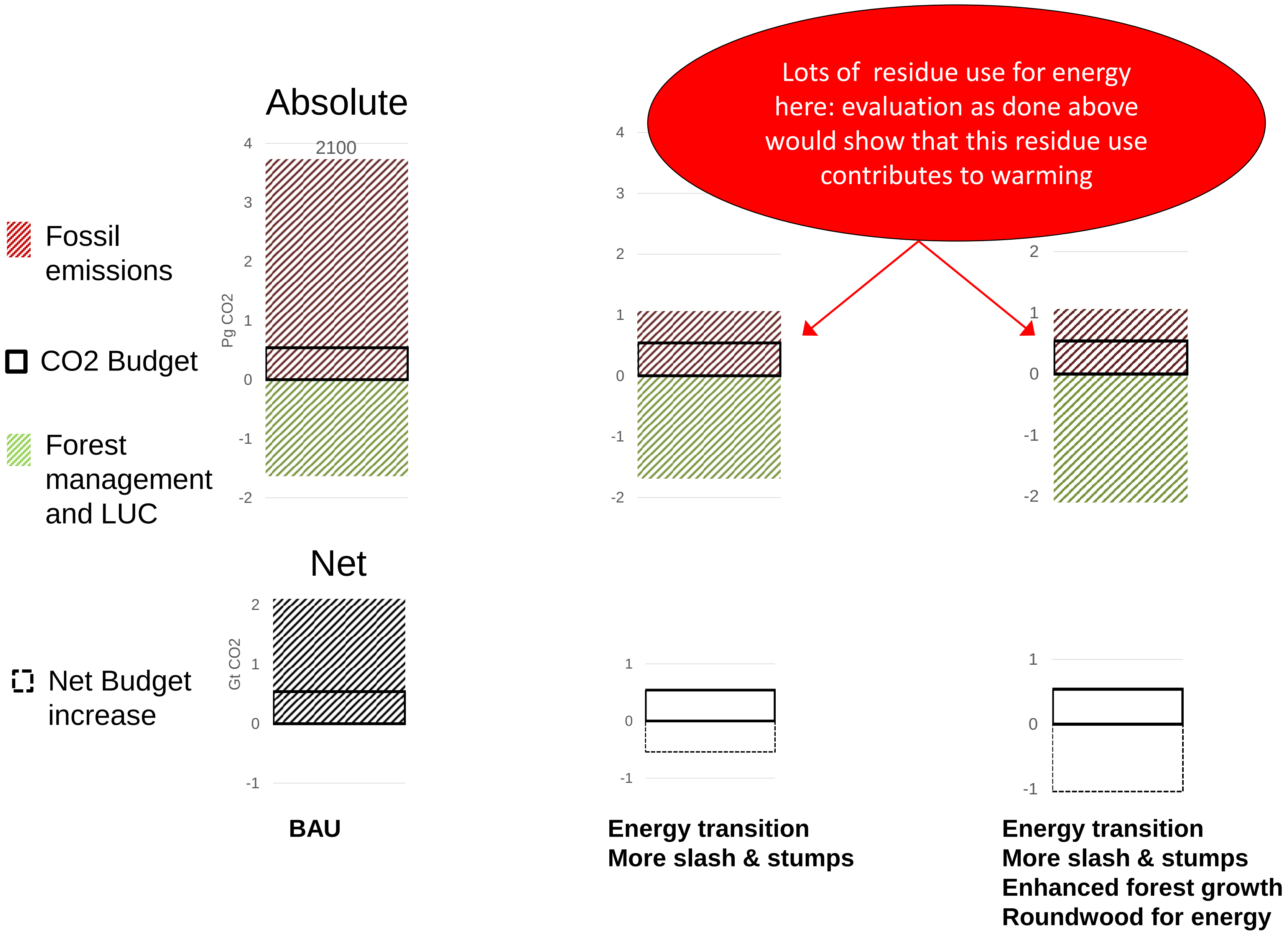

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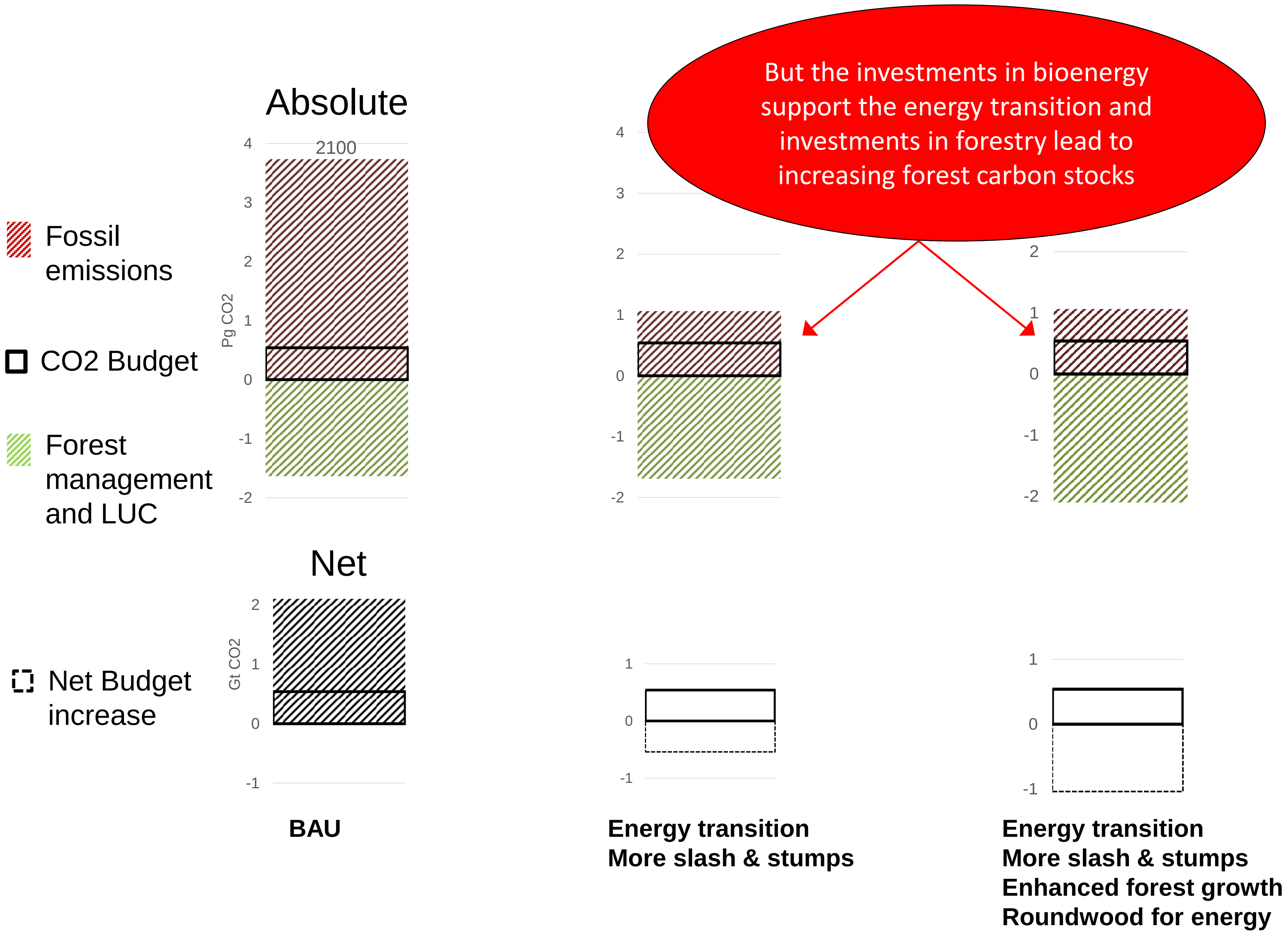
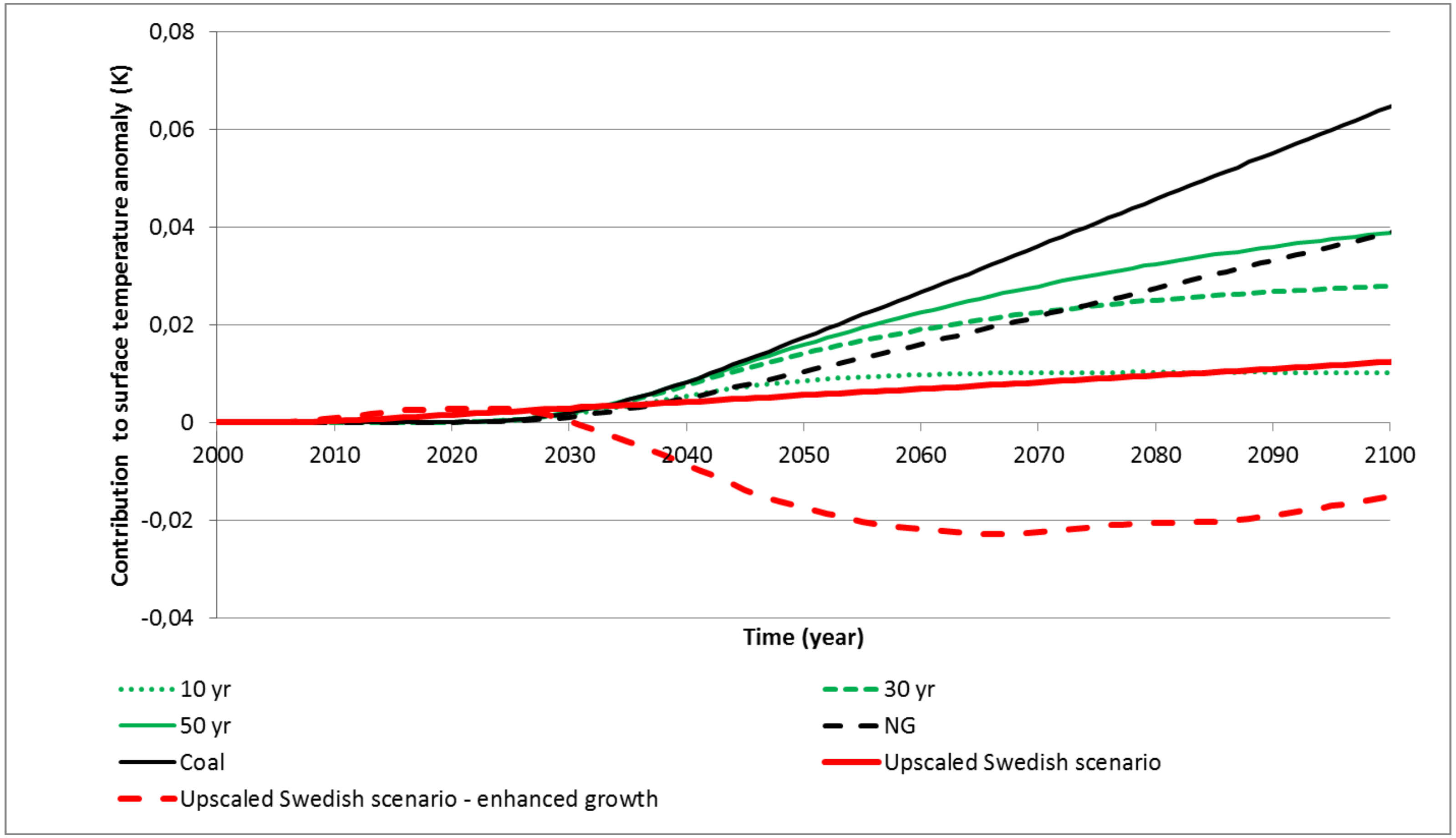


Swedish scenarios, scaled up* to facilitate comparison with carbon fuel scenarios



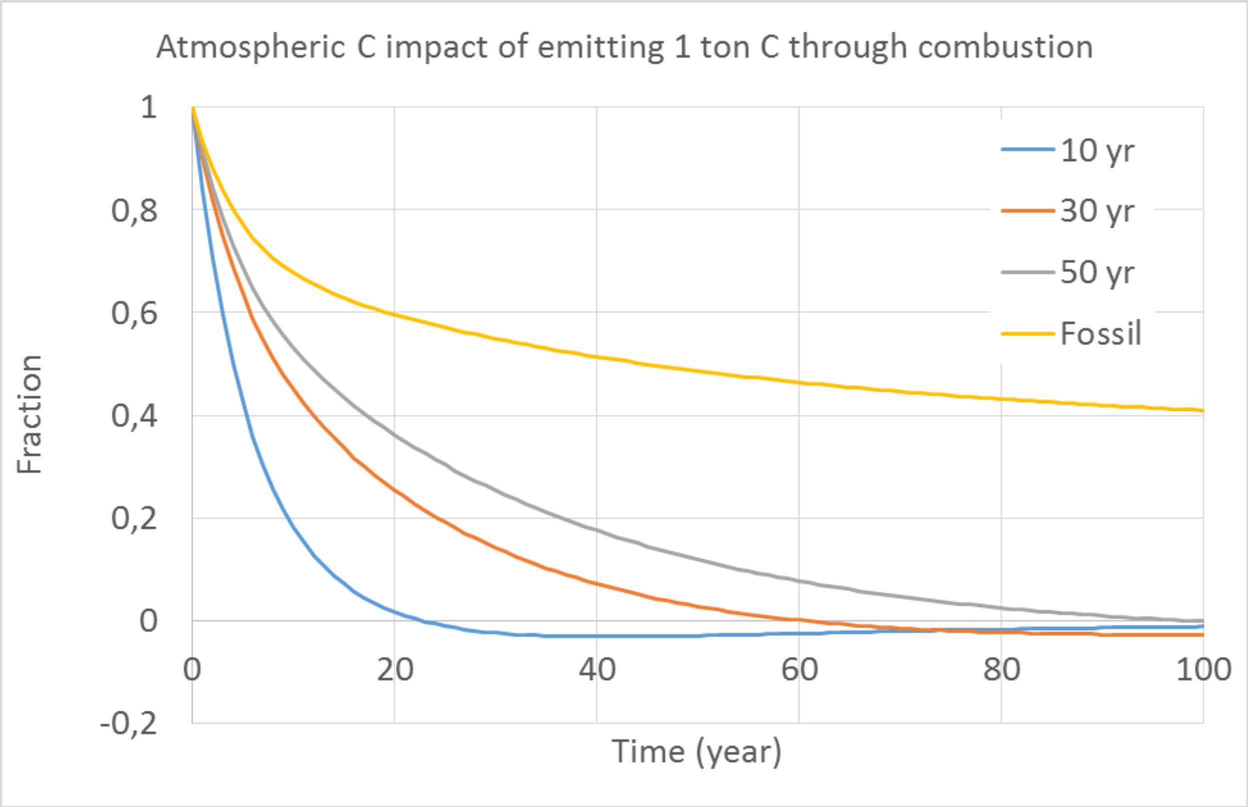
*Scaled to generate equal amount of cumulative use of residues for bioenergy (above baseline) over the 21st century.

Conclusions

- Temperature impacts are linearly related to cumulative fossil CO_2 emissions. This does not hold for cumulative CO_2 emissions from forest residue burning.
- Fossil CO_2 emissions have an irreversible climate impact. CO_2 emissions from the burning of forest residues have not.
- If the use of forest residues reduces soil C stocks, temperature impacts are linearly related to the soil C stock changes.
- The longer the residue decay time, the larger climate impacts of using residues for bioenergy (ceteris paribus).
- Forest management influences wood production and forest carbon stocks – and hence influences the climate. This influence can outweigh the specific influence of residue harvest for bioenergy.

Extra slides

Emission pulse perspective



Rate of temperature change impacts