The time aspect of bioenergy - Climate impacts of bioenergy due to how fast combustion related emissions are compensated by uptake of atmospheric CO_2

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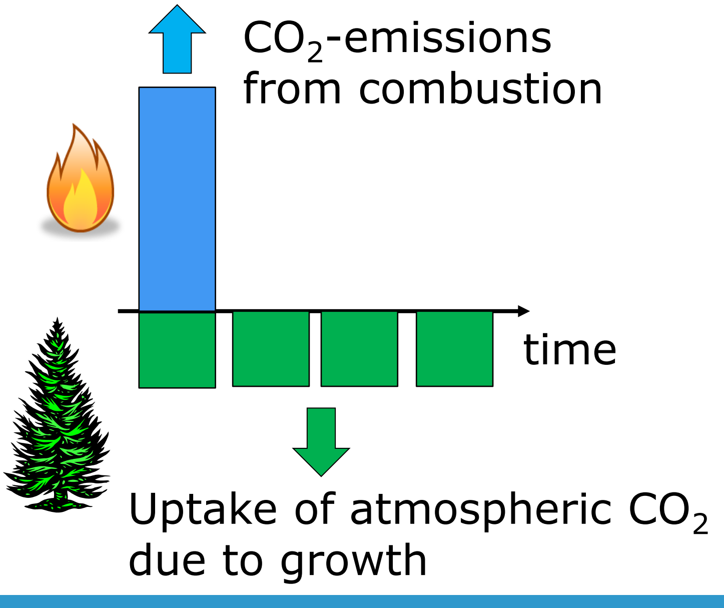
IEA Bioenergy Task38 Expert Working Meeting

Vienna, 16-17 November 2012

Bioenergy climate neutral?



Use of bioenergy affects the biogenic carbon stocks

Bioenergy production may influence biogenic carbon stocks and atmospheric CO_2 significantly in either a positive or negative way (IEA 2011)

Important time aspect

Assessments of the climate impacts of bioenergy need to consider the time perspective (Schlamadinger & Marland 1996).

Research question:

- Is there a climate impact due the time it takes for the combustion related emissions to be compensated?
- Is this effect significant compared to the climate impacts from fossils fuel alternatives?

Four fuels, representing different CO_2 compensation (neutralisation) rates have been analysed:

Metrics for estimating climate impacts from bioenergy use

Carbon stock change, ΔS =>

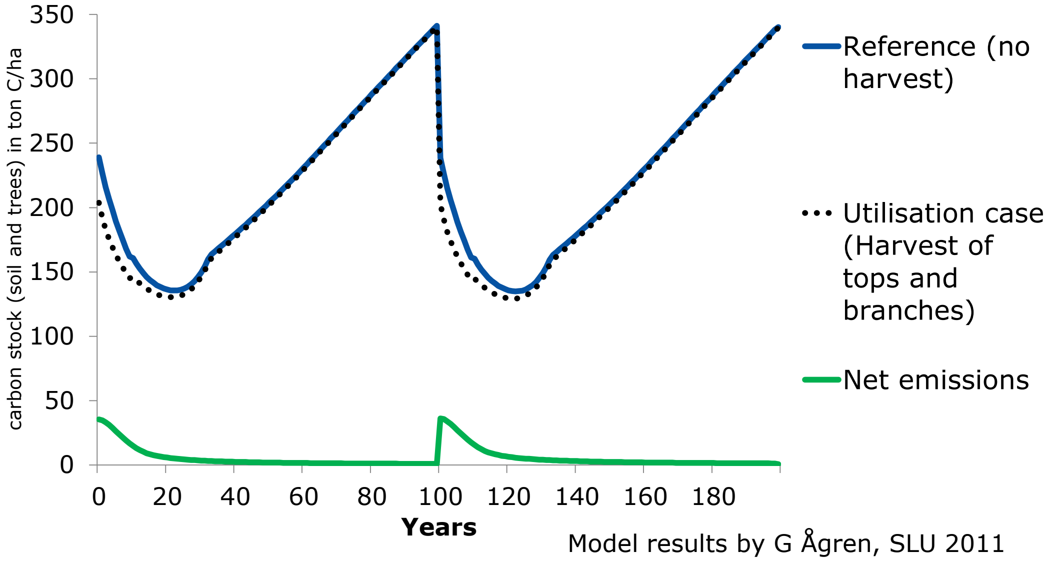
Emissions, E *=>*

Atmospheric concentration change, ΔC =>

Radiative Forcing, RF *=>*

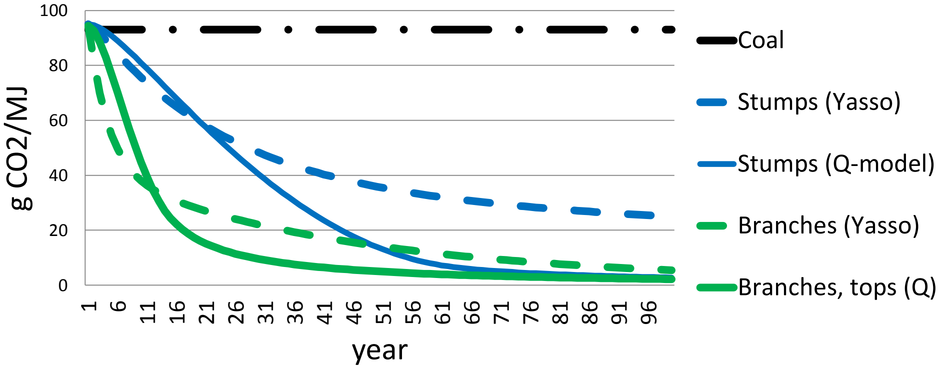
Global Average Temperature Change, ΔT

Forest residues: carbon stock changes from extracting branches and tops for energy



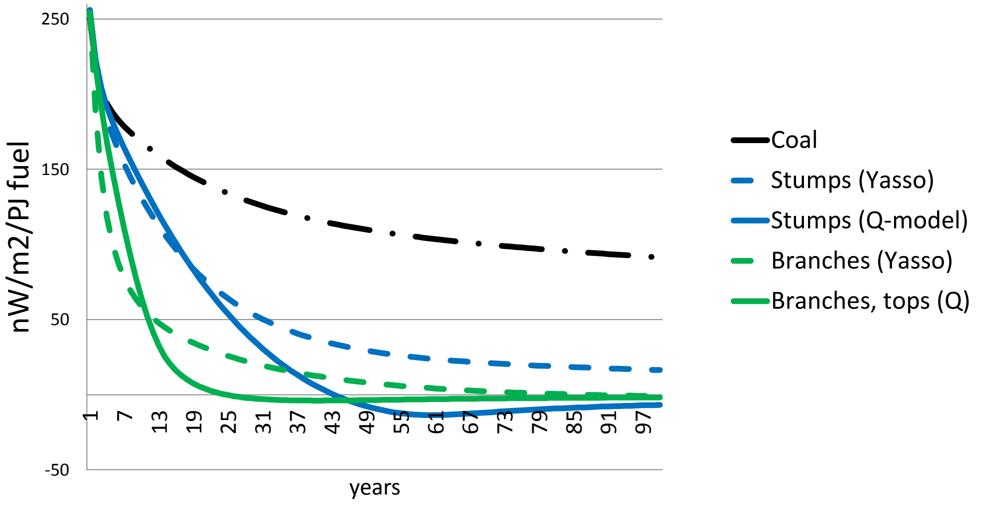
Model results by G Ågren, SLU 2011

Carbon emissions from using forest residues for energy

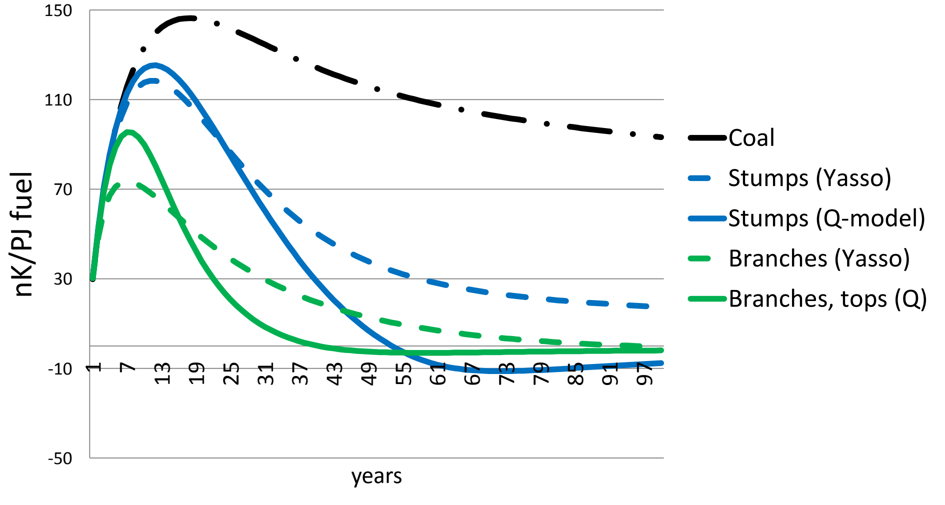


[g CO_2/MJ fuel]	**20 years**	**100 years**
Coal	93	93
Fossil gas	56	56
Branches and tops	**15-27**	**2-5**
Stumps	**57-58**	**3-25**

Radiative forcing from using forest residues for energy

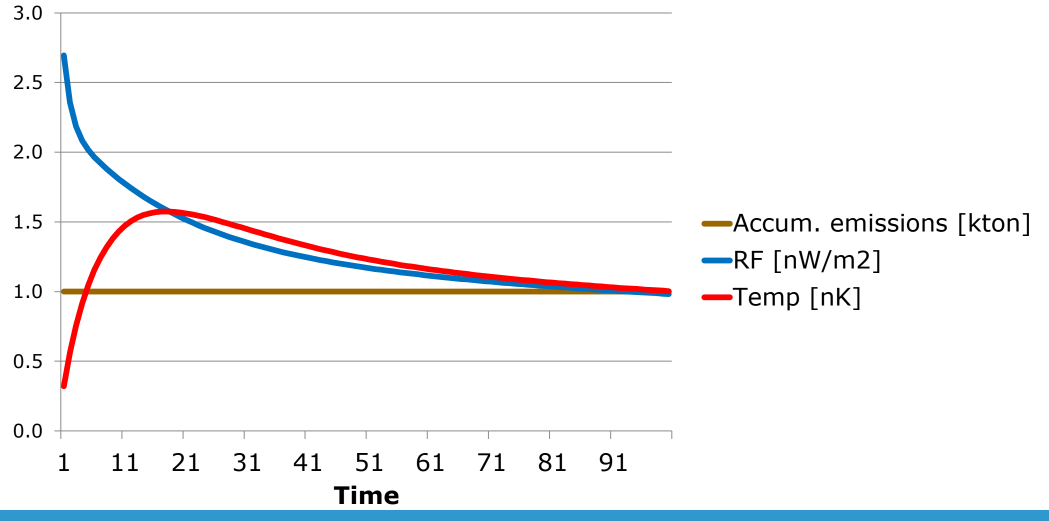


Global surface temperature change from using forest residues for energy



Comparison of metrics for assessing climate impacts

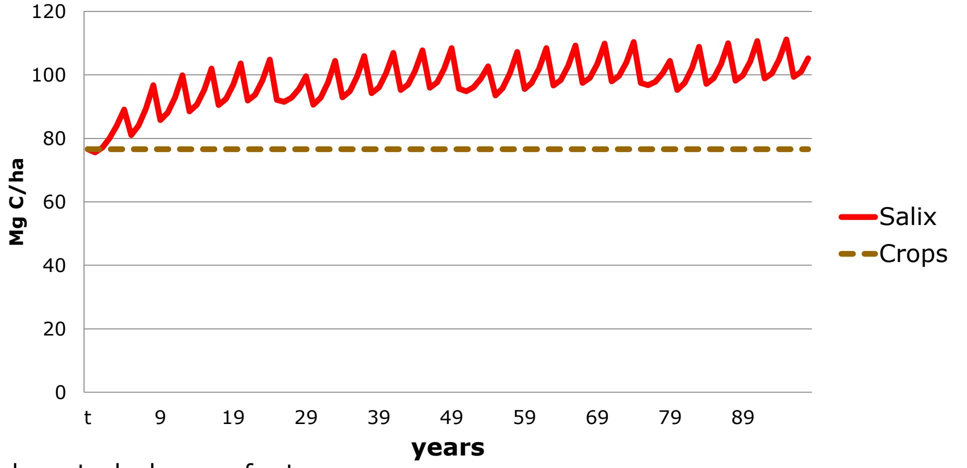
Accumulated emissions, concentration change, Radiative forcing and Temperature change due to a 1 kton CO_2 pulse emission



Conclusions forest residues

- **Bioenergy use has a climate impact** which is due to how biogenic carbon stocks are affected over time.
- **There is an important time aspect**. The faster the combustion related emissions are compensated by growth or avoided emissions, they lower the climate impacts.
- **The time frame** over which the analysis is done **is crucial for the results**. Over 100 years, forest residues are significantly better than stumps, which in turn are significantly better than coal. Over 20 a year perspective, this conclusion holds but the relative difference between these fuels are smaller.
- These conclusions hold **regardless of choice of metrics**, be it *Emissions*, *Radiative forcing* or *Temperature change*

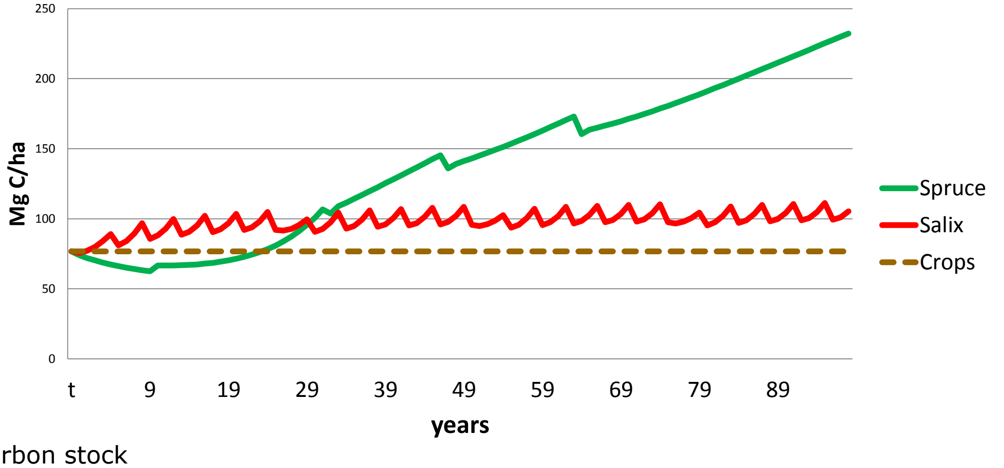
Establishing energy crops on agricultural land



Carbon stock changes for two different options of land use. Data from Ågren et al (2010).

Conclusion: Establishing willow on earlier crop land may reduce atmospheric carbon, provided new land is available.

The importance of the reference case



Carbon stock changes for three different options of land use. Data from Ågren et al (2010).

Conclusion: The choice of reference scenario is critical for the calculated net emissions from using biofuels and for the consequent climate impacts.

Quantifying climate impacts of bioenergy in LCA and carbon footprints

a) Carbon neutral or not (as in the EU Emissions trading system, Kyoto protocol)

	[g CO_2/MJ fuel]
Bioenergy	**0**
Peat	**103**

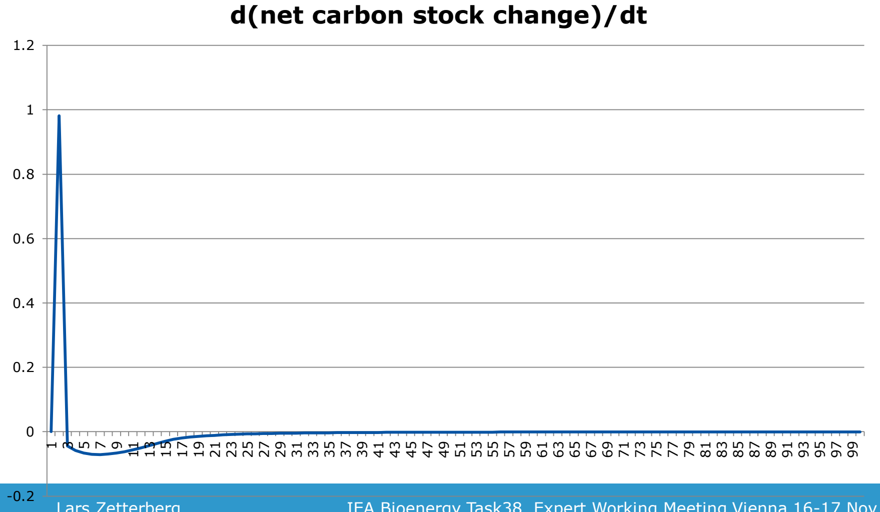
Quantifying time aspect of bioenergy in LCA and carbon footprints

b) Time integrated emissions

g CO_2/MJ fuel	**20 yrs**	**100 yrs**
Coal	93	93
Fossil gas	56	56
Branches/tops	**15-27**	**2-5**
Stumps	**57-58**	**3-25**

Quantifying time aspect of bioenergy in LCA and carbon footprints

c) Time dependent emission factor:



Summary - Quantifying time aspect of bioenergy in LCA and carbon footprints

Metric	Time dependant	Time integrated
Emissions	Emissions/year	Accumulated emissions, Carbon stock change
Radiative forcing	Instant RF	AGWP, GWP
Temperature change	ΔT	ΔT · time

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Thanks for your attention!

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PhD thesis is available from:
gupea.ub.gu.se/handle/2077/26672

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Extra slides if needed

The carbon neutrality of bioenergy in question

New York Times, 14 Sept 2011:

'Serious' Error Found in Carbon Savings for Biofuels

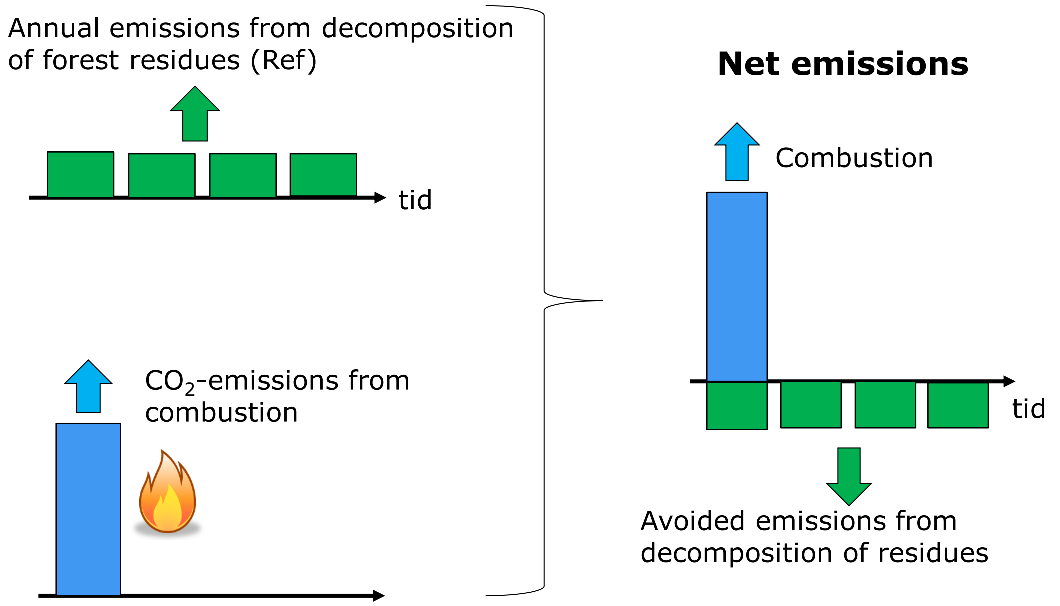
The European Union is overestimating the reductions in greenhouse gas emissions achieved through reliance on biofuels as a result of a "serious accounting error," according to a draft opinion by an influential committee of 19 scientists and academics

"The potential consequences of this bioenergy accounting error are immense since it assumes that all burning of biomass does not add carbon to the air,"

Controversy between EU Environmental Agency (EEA) and the Commission:

- EEA: EU policy on the use of bioenergy for electricity and transport is based on a serious carbon accounting error
- European commission disputes opinion on biofuels emissions

Net emissions from using forest residues for energy



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Forest residues

- *Using forest residues for energy instead of leaving them on the ground to decompose, will lead to a lower carbon storage in litter and soils (i.e. Eriksson and Hallsby 1992)….*
- *…but this effect is of transient character. If forest residues are left, the major part will decompose over time and release carbon to the atmosphere.*
- *The use of forest residues can be seen as shifting the emissions earlier in time compare to leaving them on the ground to decompose (Lindholm et al 2010)*

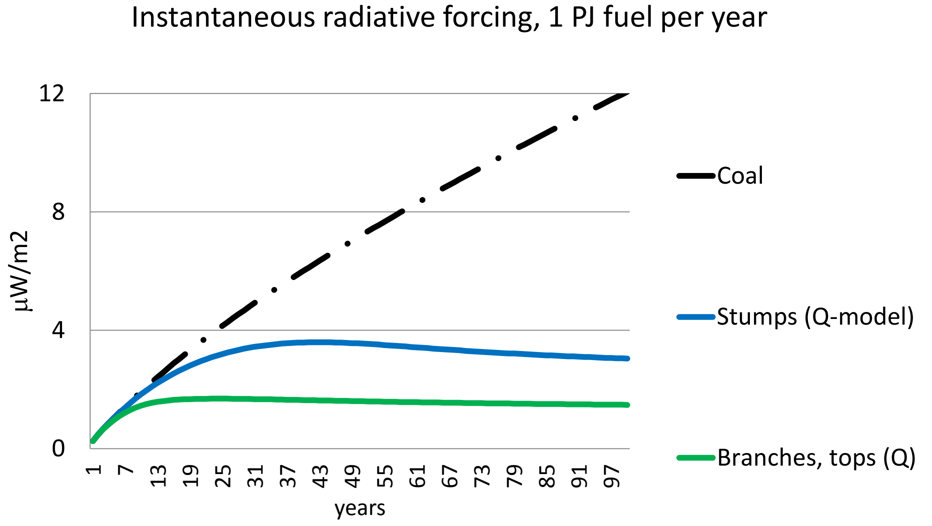
In addition to impacts on biogenic carbon stocks, the use of bioenergy also affects climate due to:

- Use of fossil oil for harvest, collection, transport, drying, refining, storage
- Emissions of other GHG, like methane, nitrous oxide, particles and formation of tropospheric ozone
- Changes in albedo

Indirect effects:

- **Substitution of fossil fuels may reduce net emissions of GHG**
- Relocation of food production if bioenergy crops are established on agricultural land.

Multiple generations – radiative forcing due to the use of 1 PJ fuel per year



Points for discussion

- What metrics are best for assessing climate impacts?
- What time perspective is most appropriate for assessing the climate impacts of bioenergy?
- What comes first, emissions or uptake?

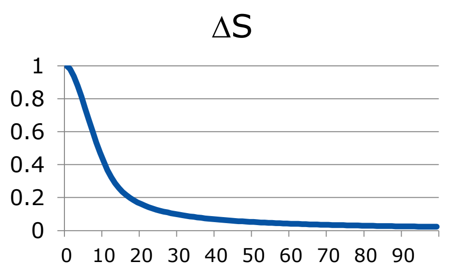
Confirmed by other scholars

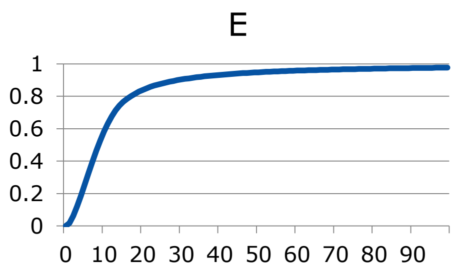
- Repo et al (2010): The emission of using forest residues for energy depend critically on the **decomposition rates** of the residues if they were left at the site
- Melin et al (2010), using accumulated emissions: over long term stumps are better than coal; over short term coal is slightly better than stumps
- Sathre and Gustavsson (2011), using radiative forcing: Over the first 10-25 years, oil and fossil gas have a lower climate impact than forest residues and stumps, but thereafter forest residues and stumps are increasingly superior to fossil alternative

Step 1. Calculating emissions, *E*, due to carbon stock changes, ΔS

Assume that a carbon stock change leads to an instant release of CO_2 to the atmosphere. Then:

$$E = -\Delta S$$





Net emissions, E_{net}, due carbon stock changes:

$$E_{net} = E_U - E_{Ref}$$

where:

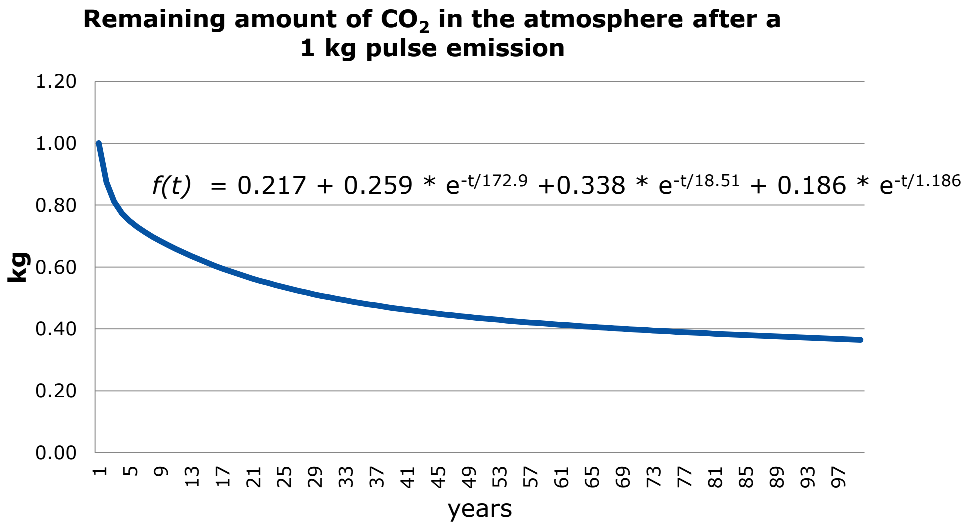
$$E_{Ref} = -\Delta S_{Ref}$$

$$E_U = -\Delta S_U$$

so:

$$E_{net} = S_{Ref} - S_U$$

Other metrics
Step 2. Calculating concentration changes, due to emissions



Step 3. Calculating Radiative Forcing, *RF*, due to increased atmospheric CO_2

$$RF(CO_2) = 5.35 \ln (CO_2/CO_{2,0})$$

Step 4. Calculating Global Surface Temperature Change, *ΔT*, due to Radiative Forcing, *RF*

ΔT(RF):

Calculated by different Models

Important political dimension

EU:s sustainability criteria for liquid biofuels:

- Calculated over a **20 year period**
  - At least 35% better than fossil alternatives
  - 2017: at least 50% better than fossil
- Next step (2012) corresponding criteria for solid biofuels

If criteria for solid biofuels are calculated over 20 years:

	rel. coal [years]	rel. fossil gas [years]
Branches, tops:		
Same or better	**1**	**4-7**
35% better	**4-7**	**10-11**
50% better	**6-9**	**13-19**
Stumps		
Same or better	**2-3**	**21-22**
35% better	**19**	**31-47**
50% better	**25-30**	**37-75**

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