The significance of time horizon in determining the mitigation benefit of biomass and bioenergy

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Business from technology

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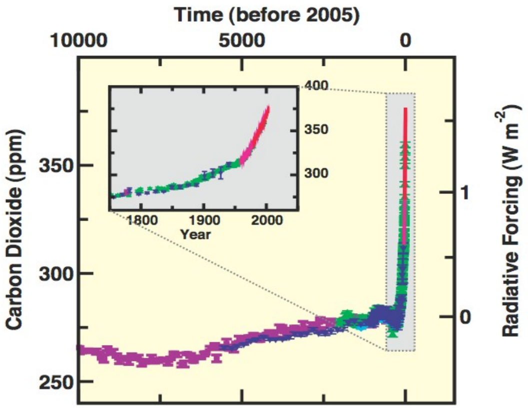
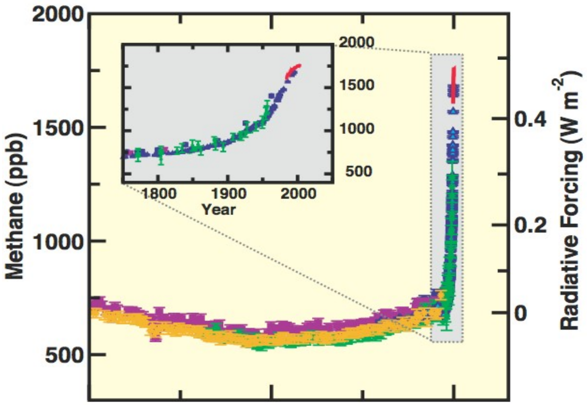
Observation: All GHG concentrations have increased making future warming unequivocal

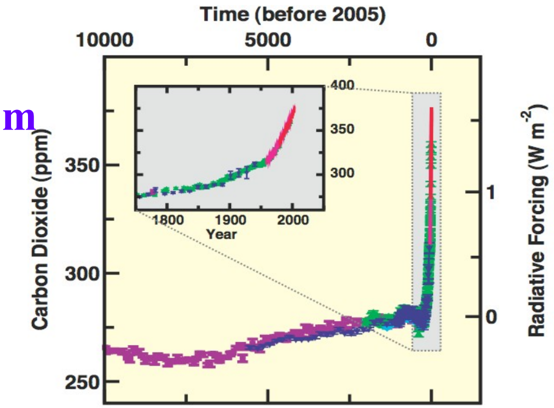
CO2 grew from 280 ppm in 1750 to 379 ppm in 2005



Methane grew from 715 ppb in 1750 to 1774 ppb 2005

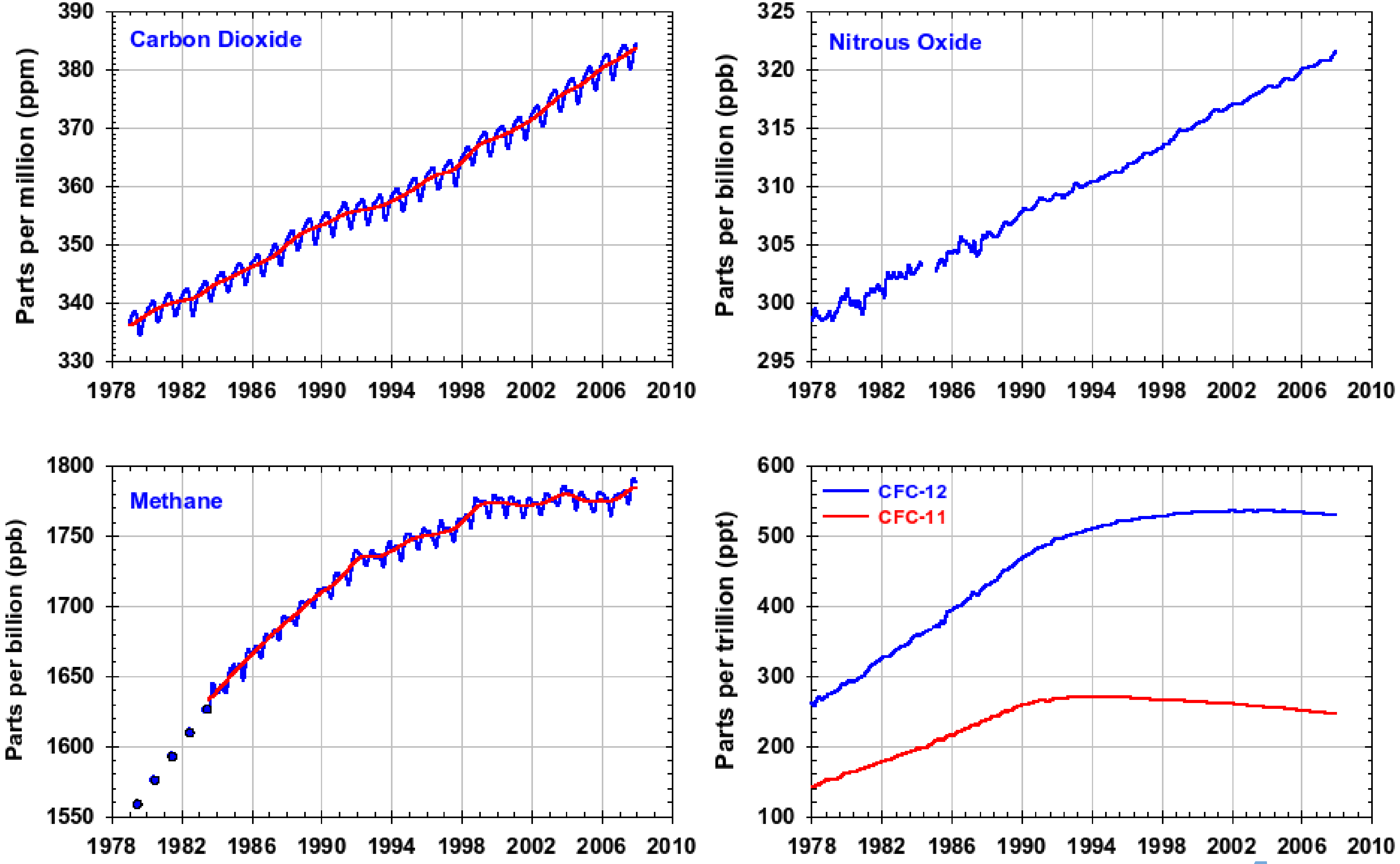


N20 grew from 270 ppb in 1750 to 319 ppb in 2005

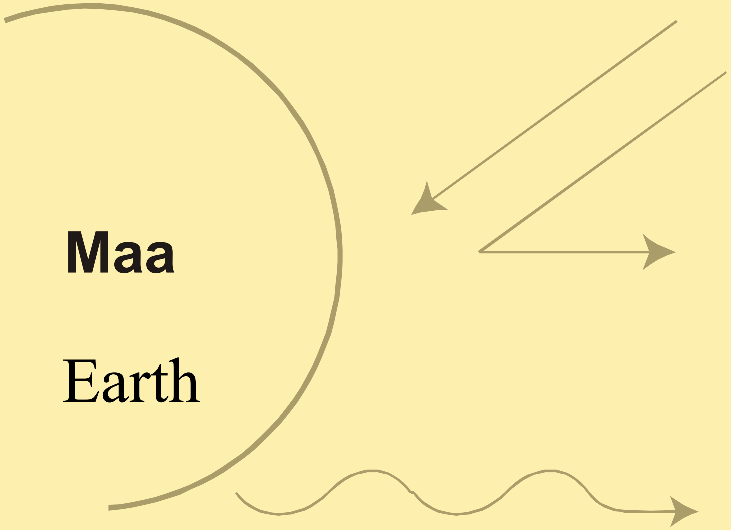


IPCC 2007

Greenhouse gas concentrations



Source: NOAA, 2008.



Säteily auringosta
340 W/m2

Solar radiation

Heijastunut säteily
100 W/m2

Reflected radiation

Infrapunasäteily
avaruuteen
236 W/m2

Infrared radiation to space

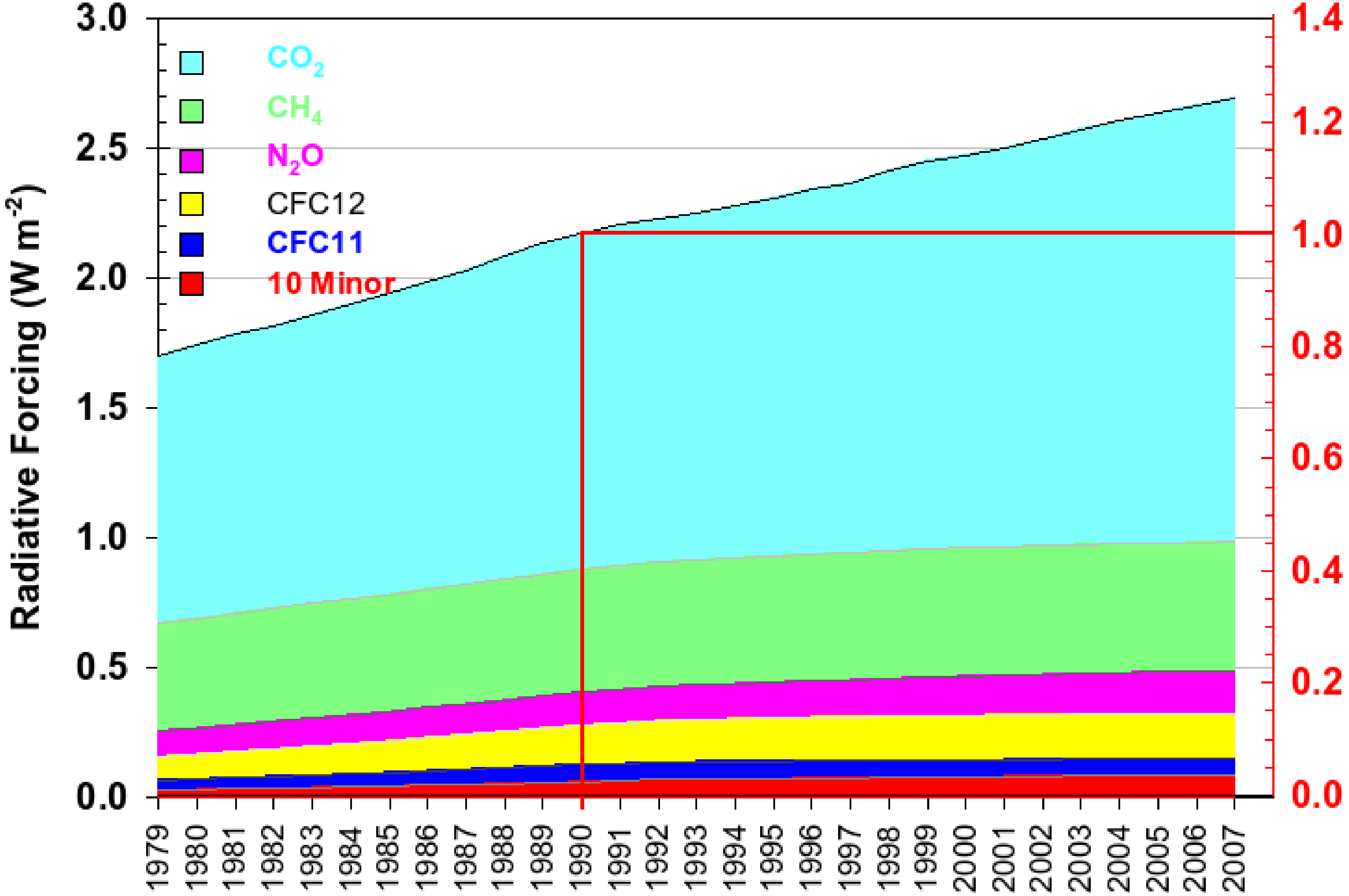
Concept of Radiative Forcing

Impact of a Doubled
CO2 Concentration

Poikkeama
CO2-pitoisuuden
kaksinkertaistumisesta
4 W/m2

Perturbation due to a doubled atmospheric CO2 concentration is 4 W/m2

Radiative forcing due to long-lived greenhouse gases



Source: NOAA, 2008.

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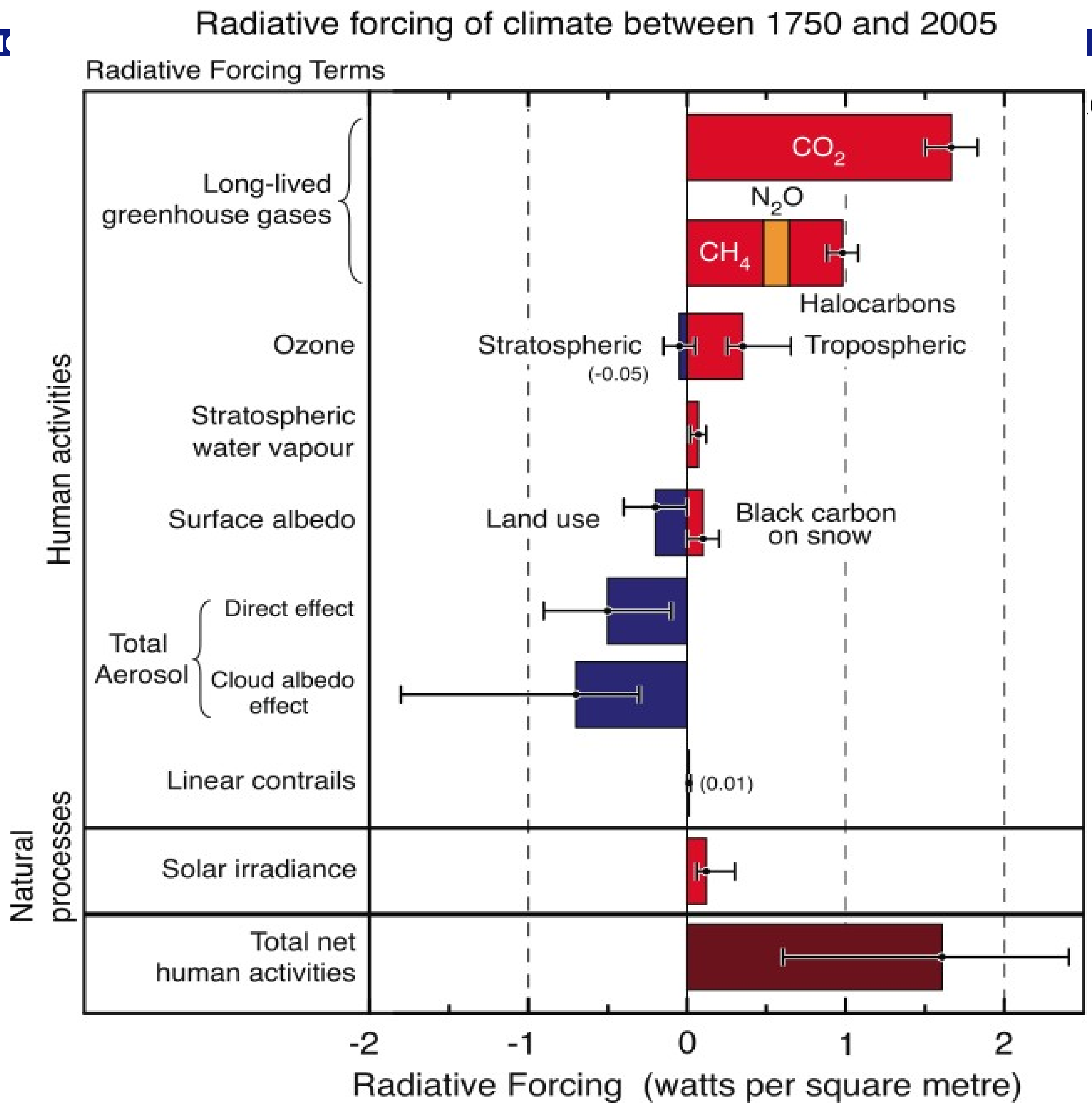


IPCC 2007

Recent forcing development

In 2007 the radiative forcing due to long-lived greenhouse gases was 2.7 W/m^2 which is equal to 460 ppmCO_2eq (NOAA 2008).

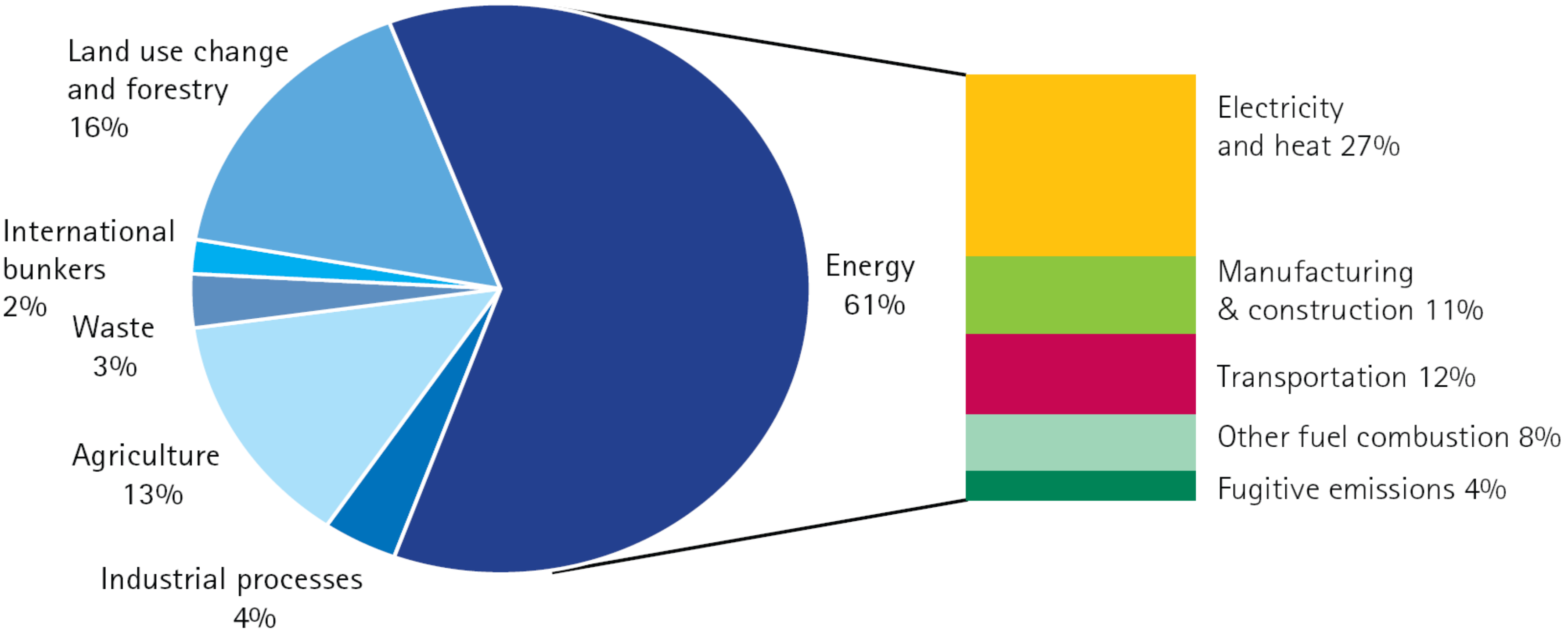
CO_2 concentration was 382 ppm in 2007 and it is rising about 2 ppm/year.

2.6 W/m^2 (450 ppmCO_2eq) corresponds to 2 ^{o}C warming in equilibrium (best estimate for climate sensitivity (IPCC 2007)).

The real radiative focing is lowered e.g. by particulate emissions. Particulate emissions will be decreased due to their health effects.

The warming has great inertia due to the heat capacity of oceans.

Global greenhouse gas emissions by sectors in 2005



The emissions sum up to approximately 46,000 MtCO_2eq.

*Data source: CAIT, cait.wri.org. *) The estimated effect of land use change & forestry, 8,000 MtCO_2, is for the year 2000.*

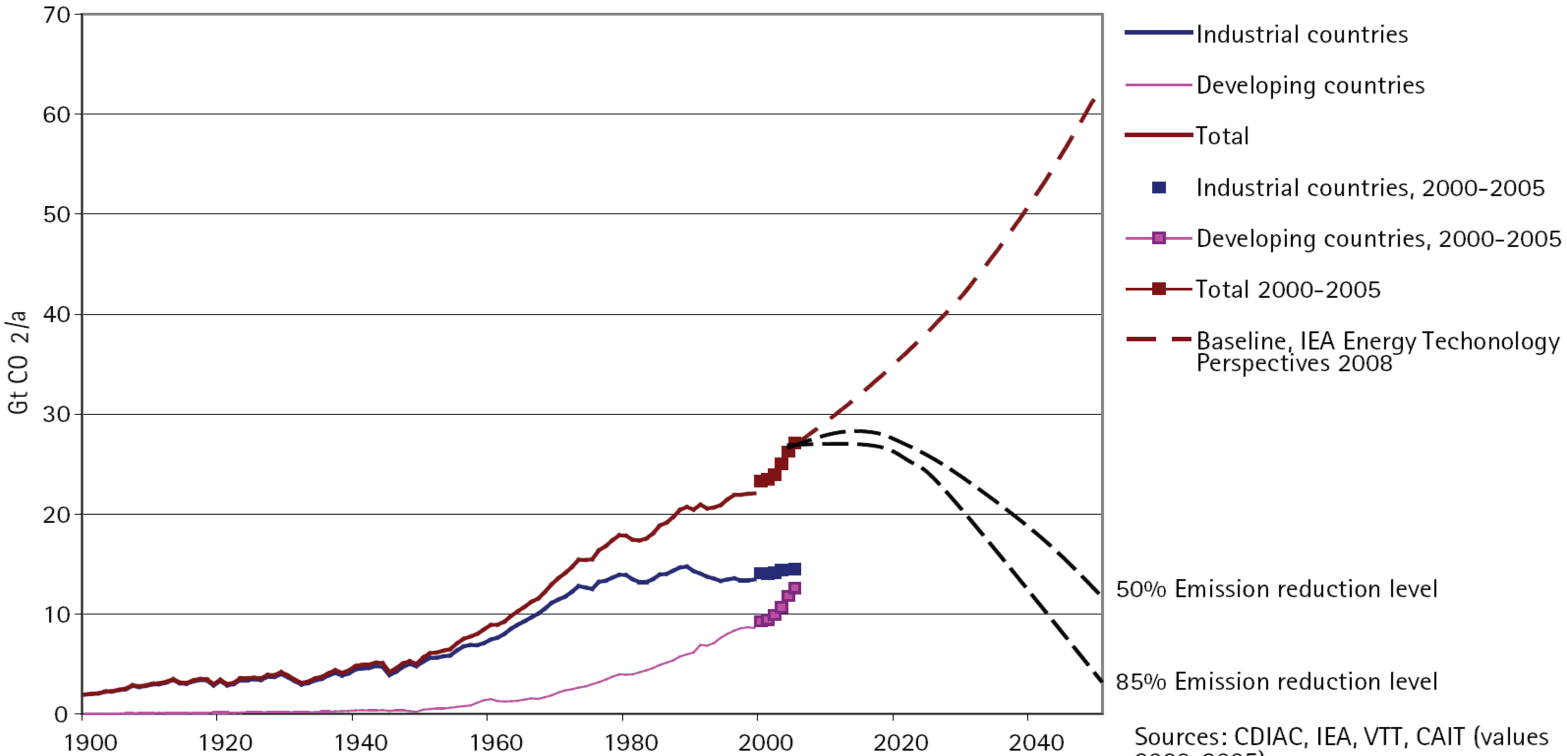
Reduction measures needed

Halting the rising CO_2 concentration and radiative forcing requires strict measures.

The 2 °C temperature rise limit requires deep global emission reduction (50-85%) by 2050, even much deeper in developed countries (IPCC 2007).

Food production causes about 20-30% of global emissions. Also these emissions should be lowered in order to reach the reduction targets. Without C sinks and BECCS (bioenergy CCS) the 2 C target requiring very low emissions in the long term seems to be impossible to obtain.

CO_2 emission from fossil energy use



Sources: CDIAC, IEA, VTT, CAIT (values 2000-2005)

Emission reduction scenarios for limiting the emission by 50% and by 85% corresponding the overlimit emissions and underlimit emission for a temperature rise level of 2 C.

Biomass and bioenergy in mitigation of climate change

1. Biomass can be used to replace fossil fuels and emission intensive materials (e.g. steel, cement) **(Substitution management)**

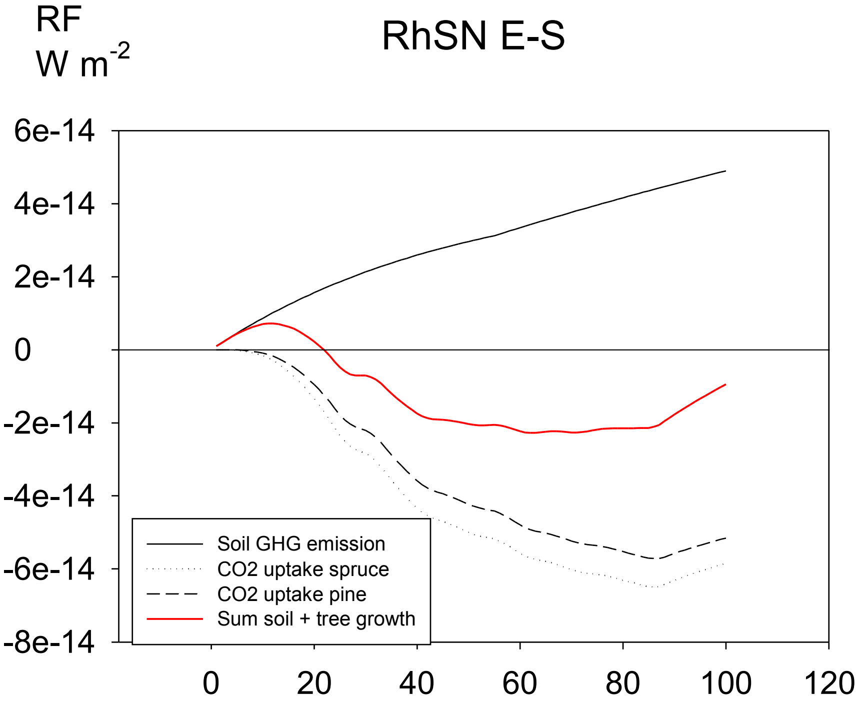
2. Increase of carbon stocks in ecosystems can be used to lower the atmospheric CO_2 concentration **(Sequestration management)**

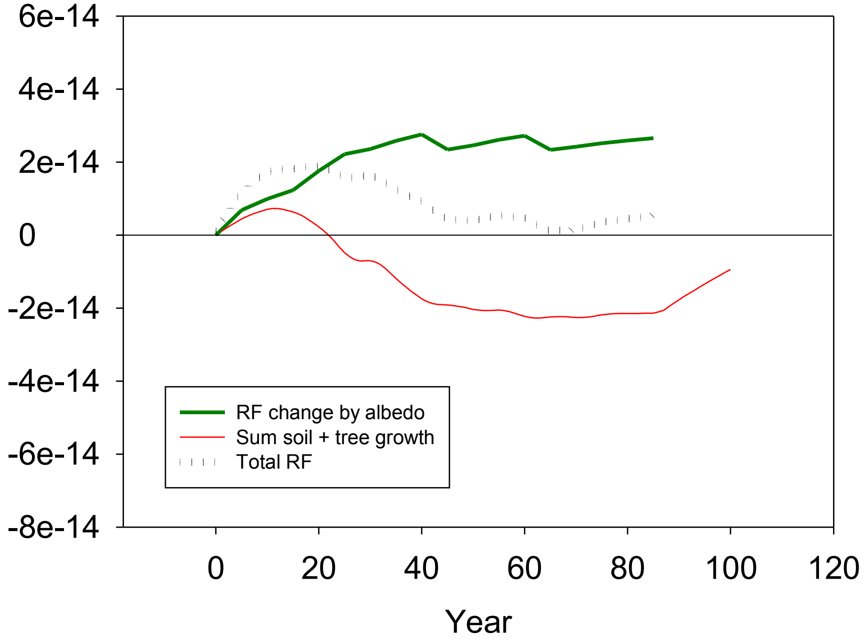
3. Conservation of large terrestrial carbon stocks (natural forests, peatlands) **(Conservation management)**

4. Carbon capture and storage applied to bioenergy (BECCS) can help to lower CO_2 concentration (expensive, possible after 2050 when the carbon price is over 100-200 $ /tCO_2 ?)

Land use change and biomass related activities can change also radiative forcing through **albedo changes**. When emissions decrease the changes in albedo will have more relative importance.

RhSN E-S





Drying of peatland and forestation can lead to a net positive global average radiative forcing RF_n (watts per square meter of the surface area of the earth). Results are calculated per square meter of drying peatland area. Wood is only a temporary storage of carbon. At the end of the rotation, wood is cut and carbon is released relatively soon.

(Source: Lohila et al. manuscript under preparation)

$$RF_n = (A_{for}/A_{glob})\, RF_{\Delta alb} + RF_{\Delta ghg}$$

$A_{glob} = 5{,}1 \times 10^{14}\ m^2$

The heating power can be up to order of about 10 W /m² (10 MW / km²) if assessed for drying peatland area.

Importance of time horizon

Time horizon is important due to:

- Halting rapidly the increase in concentration and radiative forcing is in line with the 2 °C warming limit.
- Biomass utilization strategies having an impact on large terrestial C stocks. In halting the concentration growth there are trade-offs between:

  a) biomass use for displacement of emission generating activities, and

  b) increasing or just conserving biomass C stocks.

  The weight between a and b depends on rotation length and yield of the biomass resource vs. the efficiency by which biomass displaces fossil C emissions. In the short run bioenergy can cause higher emissions than its fossil reference. Long rotation times and low displacement efficiency emphasize alternative b in rapid mitigation strategies.

  Possible rough criterion?: (turn-over time of carbon storage including displacement benefits of biomass use) / (time horizon of climate policy (50-100 years). If less than 1, emphasize alternative a)

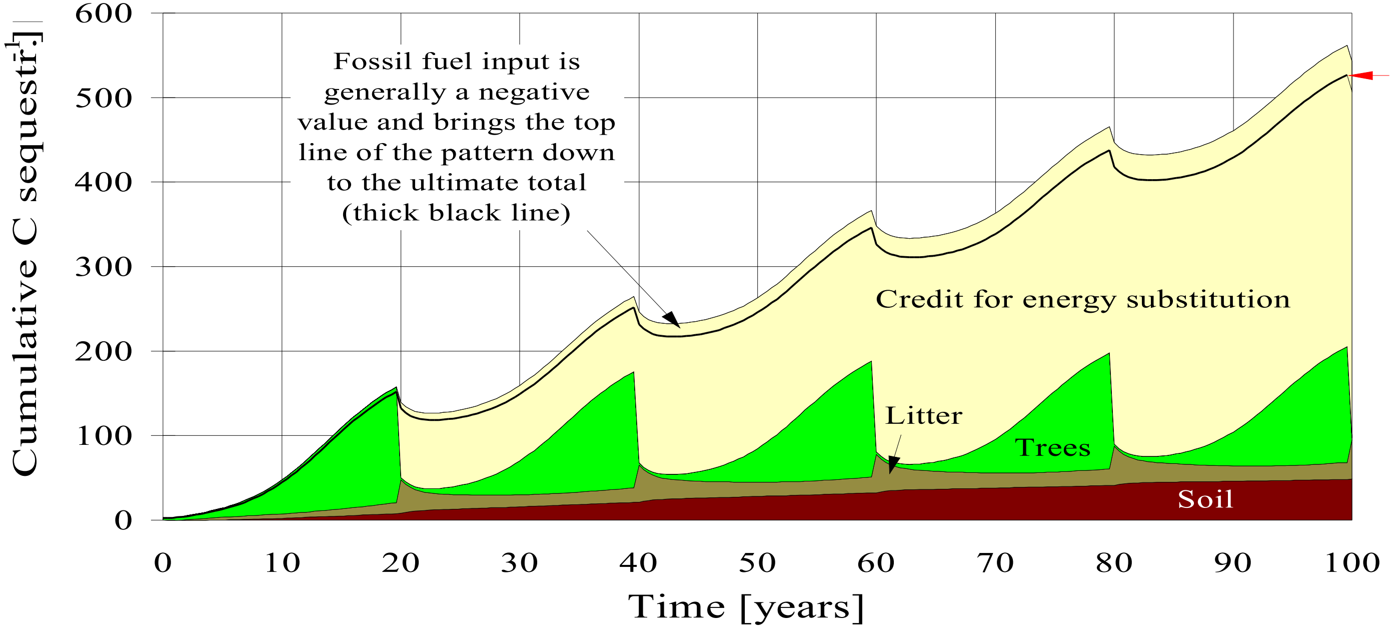
References cases needed

Two reference cases:

In substitution management: the activities to be replaced

Both in substitution and sequestration management: the development of land use and carbon storage if not utilized.

Examples (1)



Model results: fuelwood plantation on agricultural land (generic ideal case)

Fossil fuel input is generally a negative value and brings the top line of the pattern down to the ultimate total (thick black line)

Reference: IEA Bioenergy Task 38

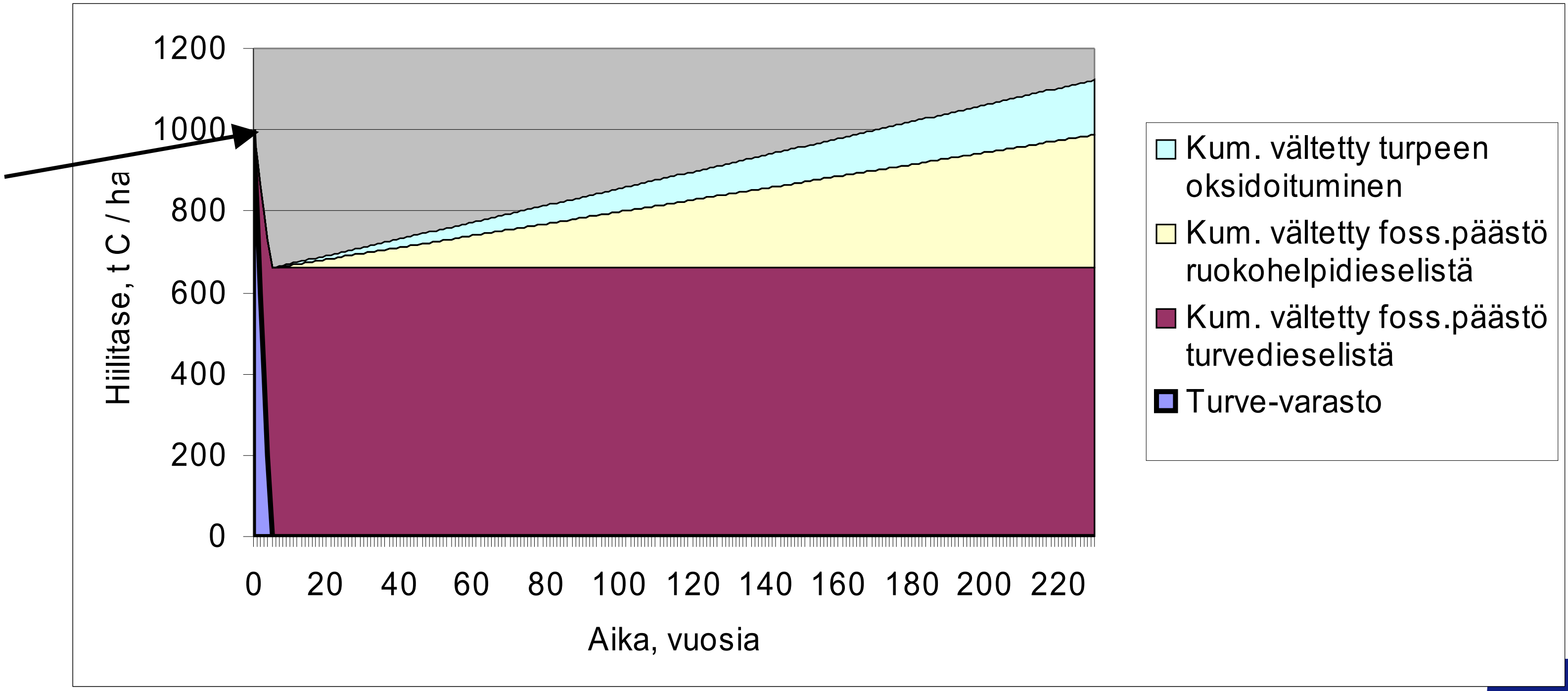
Sequestration vs. substitution

- C sequestration potential *saturates* in the long run
- Substitution leads to *cumulative emission reductions* of fossil C emissions from permanent stocks, being proportional to the harvested biomass
- The GHG benefits from substitution dominate in long time frame when biomass is utilised in sustainable way (=regrowth)

Examples (2)

Peat diesel from <u>forestry drained peatland</u> substituting for fossil diesel:

- Calculations based on the numbers adapted from Kirkinen et al. (2007). Assumptions:
  - Original 2 m peat layer (incl 1000 t C/ha) used as raw material for F-T diesel fuel
  - Peat F-T from integrate, estimated fossil C displacement factor D = 0.66 when average electricity mix used in integrate (for marginal electricity D = 0.32).
  - After treatment of harvested peatland: Cultivation of reed canary grass to produce F-T biodiesel, biomass yield 2.75 t biomass C/ha/yr, displacement factor D = 0.53 assuming average electricity mix in FT integrate.
  - The emissions from peat oxidisation 0.6 t C/ha/yr in the reference scenario (=no utilisation of peat)
- Achieving GHG credits in proportion to fossil diesel takes about 170 years!



= Cum. avoided peat oxidisation

= Cum. avoided fossil C emissions by biodiesel

=Cum. avoided fossil C emissions by peat

= C stock of peat

Indicators of mitigation impact

Greenhouse gas balance compared with the reference system

Radiative forcing impact compared with the reference system (includes the dynamics of ghgs and it is easy to include the albedo changes)

Cumulative radiative forcing impact compared with the reference system

Conclusions

Challenges and trade-offs:

- Competing land use: food, energy, materials, settlements and infrastructure, biodiversity
- Impact of albedo changes can lower the mitigation impact

Time horizon

5. Rapid measures needed to halt the increase in concentarions and radiative forcing
6. Time horizon has impacts on the climate benefits of the utilisation of large terrestrial C stocks: short-term climate targets (sinks) vs. sustainable use for substitution and displacement of fossil emissions