Regulation of climate gas emissions from air transport

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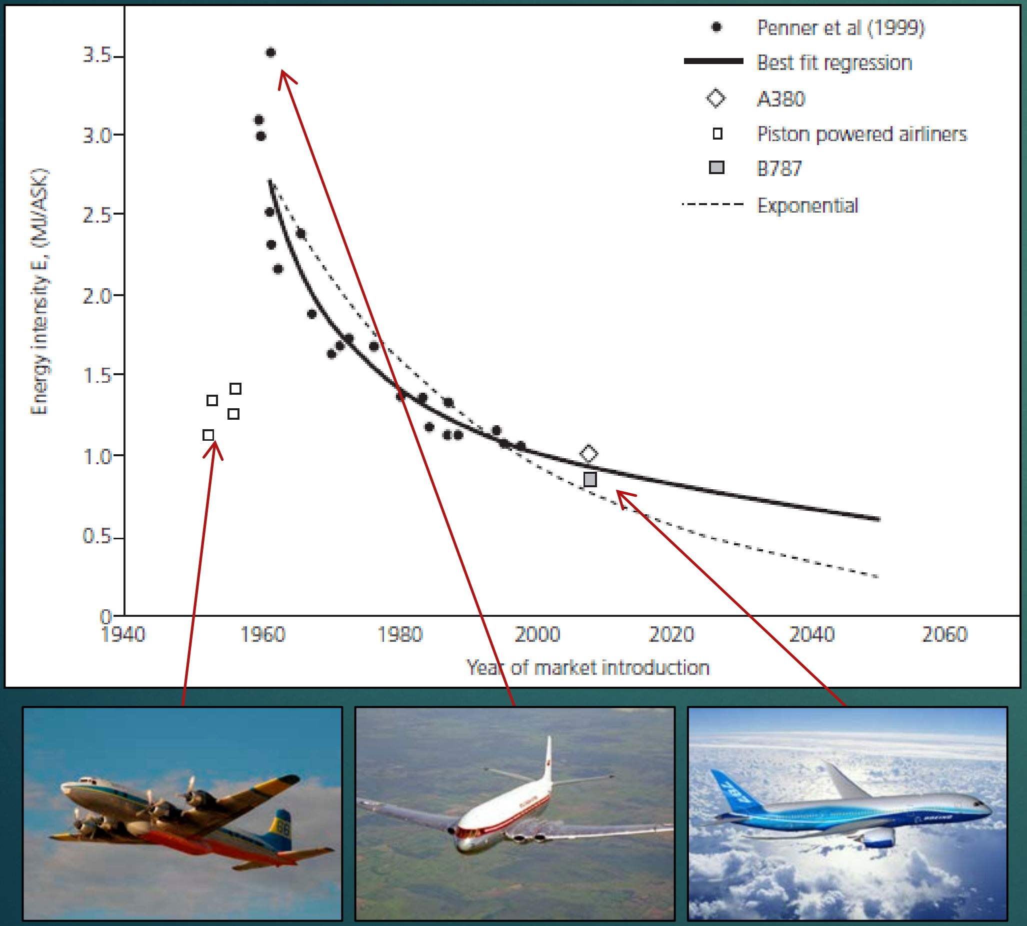
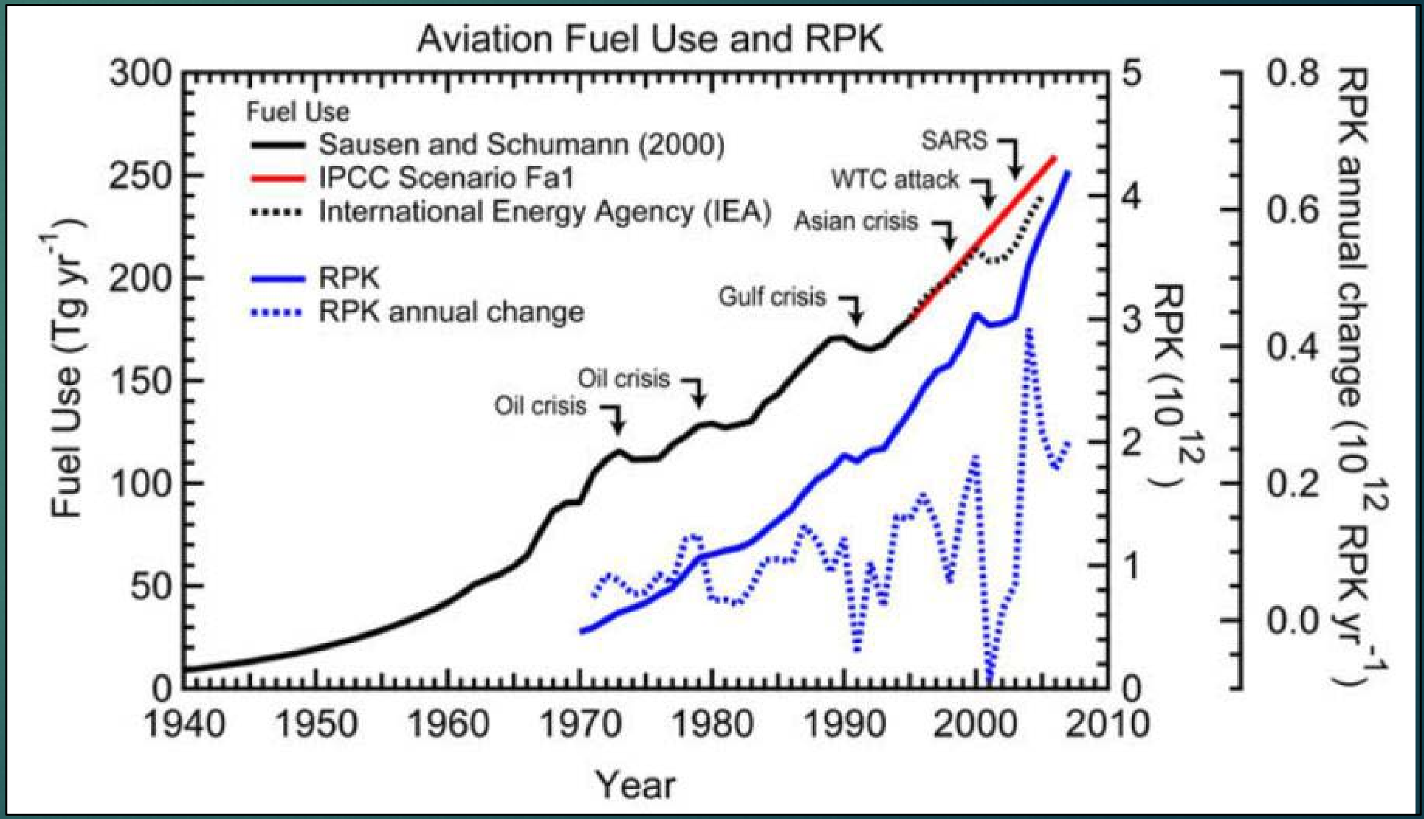
Aviation and CO_2-emissions

"Controlling the growing influence of aviation on the climate is probably the largest challenge to be solved in the overall mitigation of climate change."

Houghton (2009: 346)

Growth in aviation -
fuel use and RPK (revenue passenger kms)

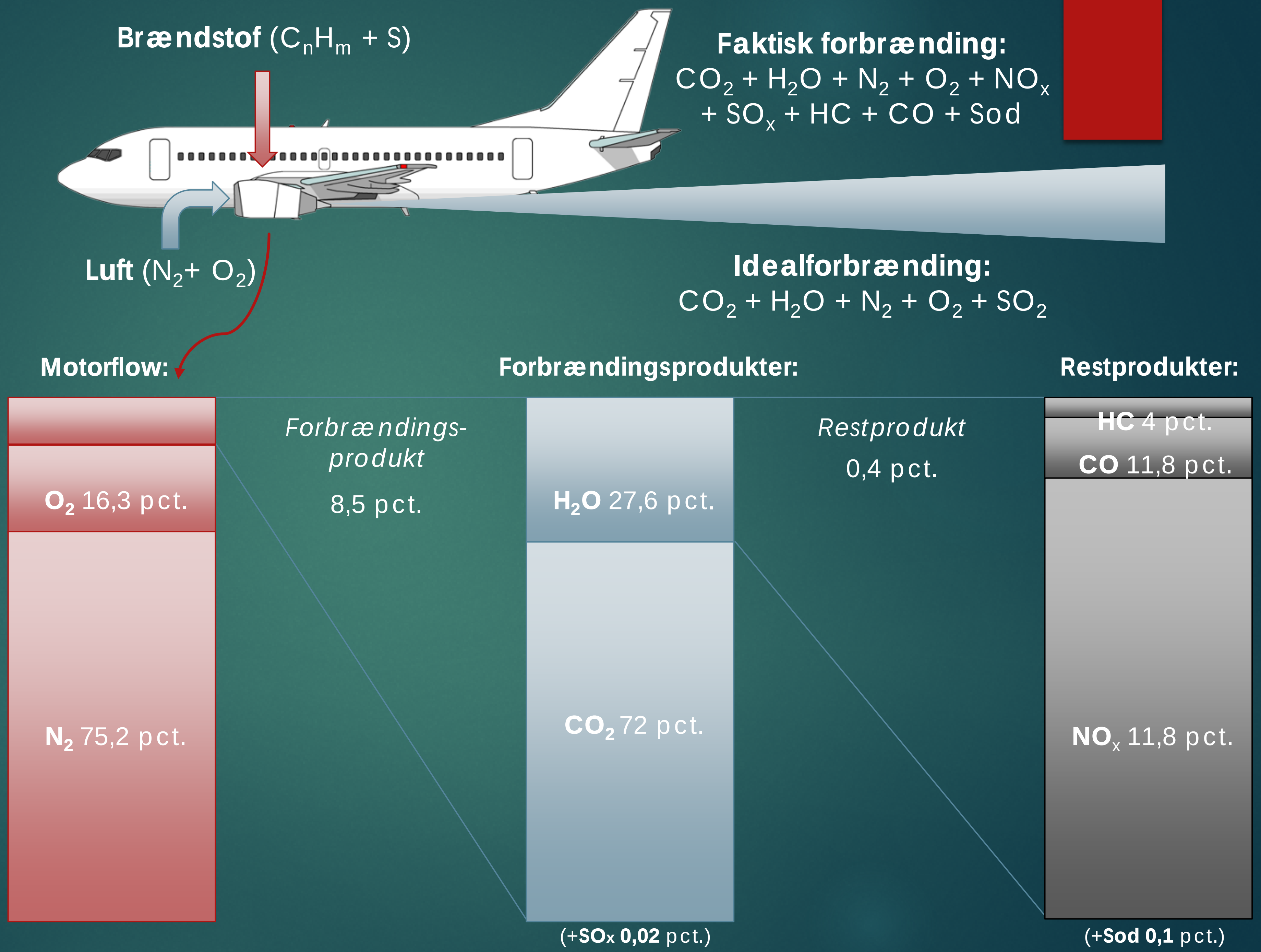




Aviation in the EU Emission Trading Scheme (ETS)

- CO2-emissions proportional to fuel consumption i.e. a fuel tax is an appropriate regulation
- Does not account for the non- CO_2 emissions (CO_2 accounts only for 60 pct. of the total atmospheric GHG-perturbation from aviation).

Emissions from aircraft



Own work:
Adjusted from IPCC (1999: 235) (Daley 2010: 22)

Non-CO_2 Greenhouse Gas (GHG) emissions

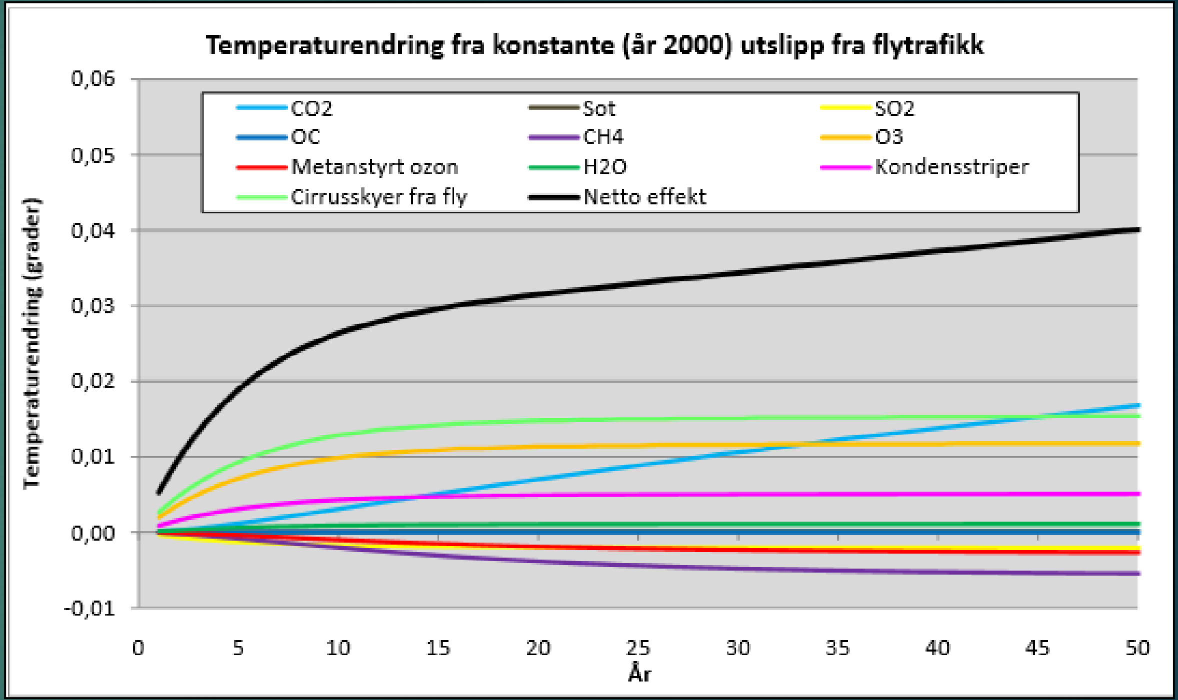
- **Water H_2O**
  - Greenhouse gas (absorbs infrared radiation)
  - Proportional to fuel consumption
  - At low altitudes
    - a very small part of the water cycle (evaporation from the sea, rainfall etc.) an insignificant net-contribution to the GHG-effect
  - At higher altitudes (upper troposphere, tropopause, stratosphere)
    - A much longer residence time of vapor
    - A significant contribution to GHG-effect

Non-CO_2 Greenhouse Gas (GHG) emissions

- **Nitrogen oxides NO_x**
  - Emissions consist mainly of NO but is quickly oxidized to NO_2 and other nitrogen oxides
  - Interacts with atmospheric ozone O_3 + CH_4
  - Greenhouse gases (absorb infrared radiation)
  - Emissions depend on engine and operational conditions of engine
  - Not proportional to fuel consumption
  - Complex GHG-effect dependent of altitude
- **Contrails**
  - Condensates (droplets and ice crystals)
  - Formed mainly from external moisture under certain conditions
  - 'Positive' GHG-effect
- **Soot & aerosols**
  - 'Negative' – but small – GHG-effect

Metrics of GHG-emission

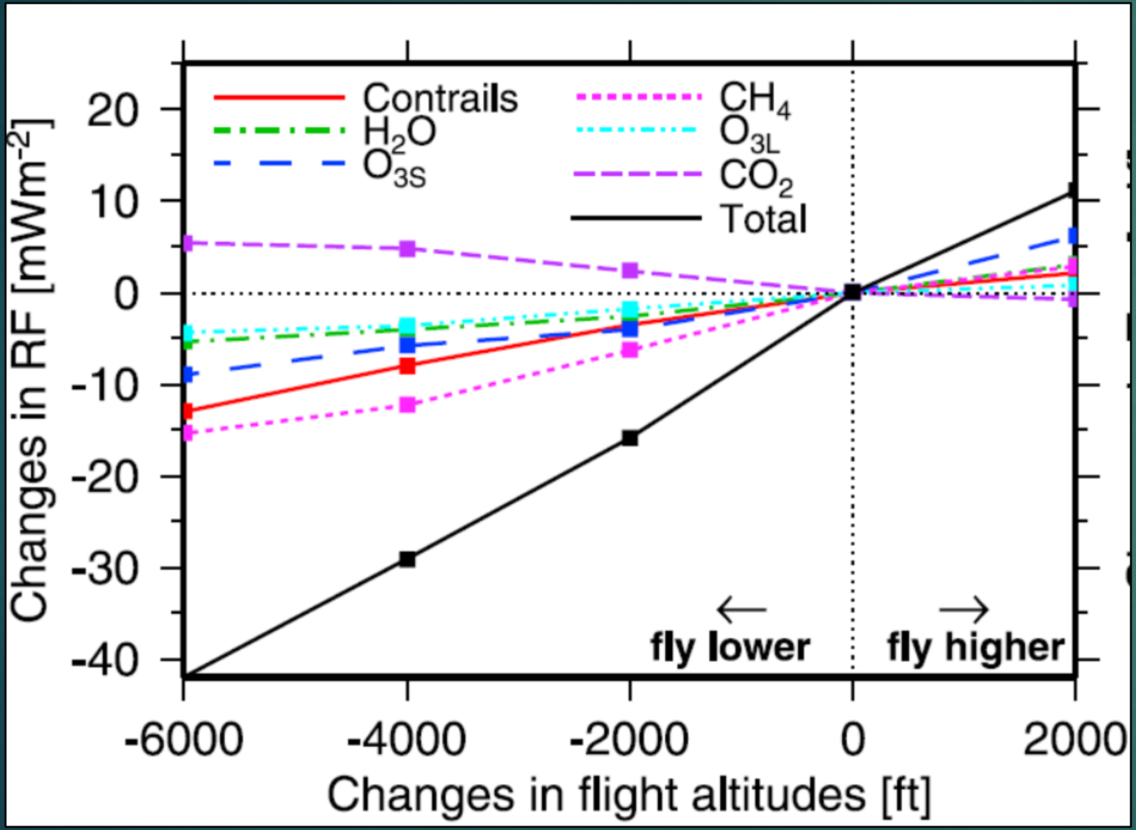
- **Radiative forcing** – the most accurate way to measure the impacts of greenhouse gases!
  - Radiative forcing index
  - Does not account for future
  - A progress report on the previously emitted emissions
- **GWP** – account for the future impact of current released CO_2-emissions.
  - Not suitable for short lived non CO_2 GHG-emissions.
- **AGWP and EWF** – the ratio of sustaining the current RF-impact aviations emissions divided by GWP CO_2



Regulation objectives

- CO_2 emissions during flight are minimized by choosing high cruising altitudes
- H_2O- and NO_x-emissions have much higher GHG-effect at high altitudes
- A fuel based economic regulation such as ETS is not an optimal GHG-reduction scheme
- Questions
  - Can we improve the regulation scheme to minimize GHG-effects of aviation and further climate friendly technological development in the aviation industry?
  - Does sufficient scientific knowledge exist to make a more precise regulation?
  - Can a simple and fool proof regulation be established?

Radiative forcing and flight altitude



Source: Frömming et al, 2012

- Figure is a prospect for the year 2100
- Average RF 158 mWm^{-2}
- If all flight altitudes were reduced by 6000 feet
  - Radiative forcing from CO_2 would increase ~6 mWm^{-2} due to increased fuel use
  - Radiative forcing from non-CO_2 emissions would reduce ~48 mWm^{-2}
  - Net effect would be a reduction of 42 mWm^{-2} corresponding to a ~25% reduction of total radiative forcing
- The negative non-CO_2 effects of increased flight altitude outweigh the positive CO_2 effects by a factor of ~8
- There is an almost linear relationship between flight altitude and the total change in radiative forcing

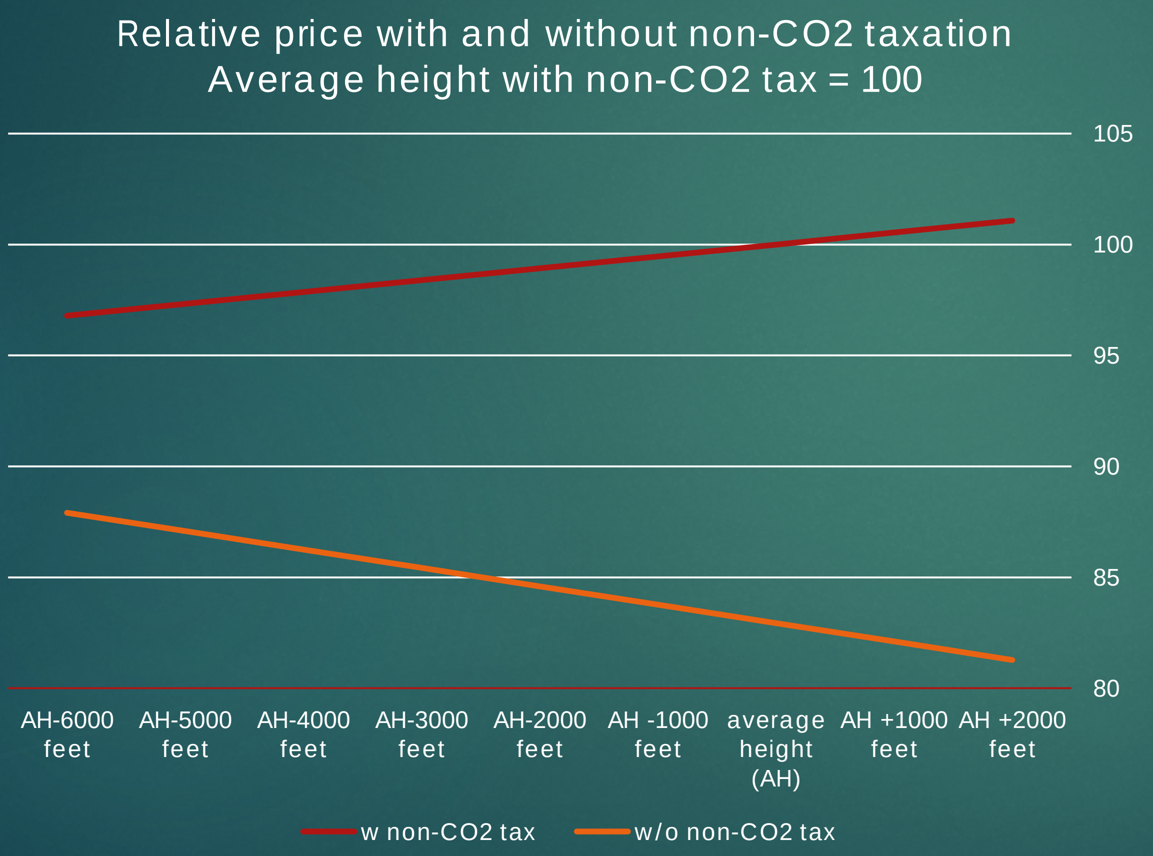
Regulation philosophy

- Fuel tax is an efficient way of regulating CO_2-emissions
- CO_2 accounts for ~60% of GHG-emissions
- Non-CO_2 externalities should be taxed with ~2/3 of CO_2-emission taxes
- It will not be feasible to tax non-CO_2 externalities based on concrete meteorological conditions
- However, non-CO_2 externalities would be reduced if flight altitudes were to be reduced
- A tax scheme based on aircraft type, flight altitude and kilometers flown - added to the carbon tax – would be based on data already known and recorded
- The tax scheme could both be a regular tax or the revenue could be sent back to the industry e.g. proportional to km flown, passenger kilometers or other parameters – as long as the marginal costs of CO_2 and non-CO_2 emissions are maintained.

An example

- An average commercial aircraft would have an average CO_2-emission of x ton per 100 kilometer flown (take-off and landing included). With a price of C €/ton CO_2, the average fuel tax for 100 kilometers would be C*x €
- For flying 100 kilometers in a corridor of average height, an additional tax of 2/3 of C*x € should be levied
- Reducing the flight height 300 feet to the next corridor level would reduce non-CO_2 externalities by around 1%, and the tax should be reduced accordingly

An example – cruising part of a medium haul flight



- The non-CO_2 tax 'compensates' for the cost advantage of flying at higher altitudes
- This means that flight corridors will be filled up from below also to save fuel for climbing
- A potential of up to 25% GHG saving

Background data

- Haul ~1000 kms, A320-200 (168 seats), passengers 72% (SAS-data)
- 75% of fuel for cruising
- Carbon tax 8% of fuel price (~130 kr./ton CO2)
- Total non-CO_2 tax 2/3 of total carbon tax
- Fuel consumption - 1% per 1000 feet (Frömming et al. 2012)
- Non-CO_2 GHG-emissions + 8% per 1000 feet (Frömming et al. 2012)

Conclusions

- A global regulatory regime for the aviation industry is crucial for meeting GHG reduction goals
- Proposed GHG reduction schemes like the inclusion of aviation in the emission trading scheme (ETS) focus on CO_2 emissions
- No emission tax or taxes only based on CO_2 emissions will discourage flight at high altitudes where fuel consumption is lower
- Flight at high altitudes have the highest non-CO_2 GHG emissions. The non-CO_2 emissions have a negative climate effect that much outweighs the obtained CO_2-reduction
- A taxation of non-CO_2 emission can be based on data already available: aircraft type, flight altitude and kilometers flown. This should be added to the carbon tax.
- It is shown that such a tax could greatly reduce climate effect by giving incentives to fill up the flight corridors from below instead o as now from above