A diagram illustrating Earth's radiative balance. The background is a dark blue gradient representing the sky, with a thin, horizontal band of light representing the Earth's atmosphere and surface. Two yellow arrows originate from the top of the frame. The arrow on the left, labeled 'Radiation IN', points downwards towards the Earth's surface. The arrow on the right, labeled 'Radiation OUT', points upwards away from the Earth's surface. The text below the diagram explains the concept of radiative forcing and its effect on Earth's temperature.

Radiation IN

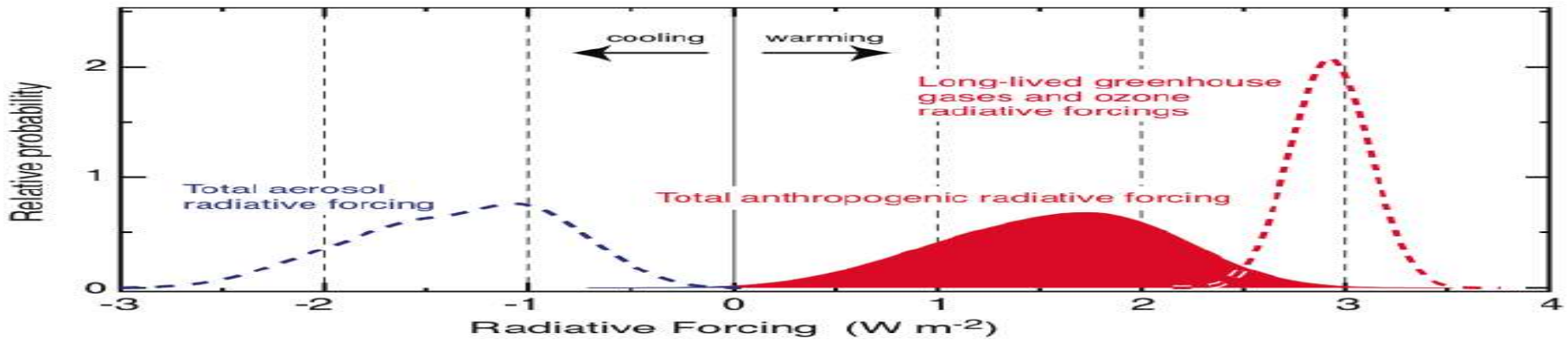
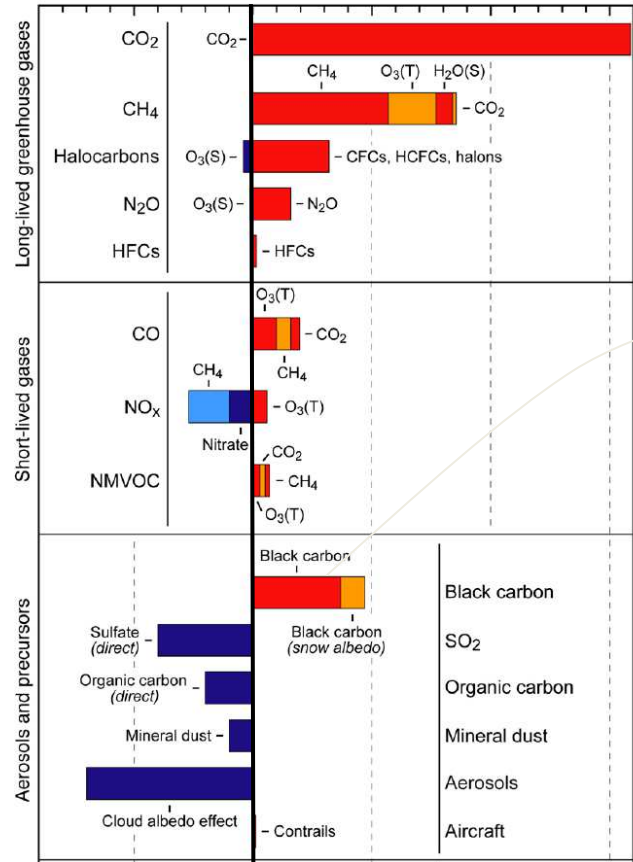
Radiation OUT

Radiative Forcing = **Radiation IN** - **Radiation OUT** (Watt/m²)

If Radiative Forcing > 0 then Temperature of the Earth increases

If Radiative Forcing < 0 then Temperature of the Earth decreases

Components of radiative forcing for principal emissions





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Opportunities to Limit Near-Term Climate Change

- 1. Introduction**
- 2. Emissions of BC and trop. O₃ ozone precursors: drivers, emissions, and trends**
- 3. Atmospheric processes, BC and trop. O₃ concentrations, deposition, and radiative forcing**
- 4. Impacts of BC and trop. O₃**
 - 4.1 on global and regional climatic system**
incl. extreme events, impacts in the Arctic, Himalayas, etc)
 - 4.2 on human health**
 - 4.3 on food security**
 - 4.5 on the carbon cycle**
 - 4.4 on ecosystems**
- 5. Mitigation Potential for BC and trop. O₃ precursors, and prospects for implementation**
- 6. Conclusions**



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Opportunities to Limit Near-Term Climate Change

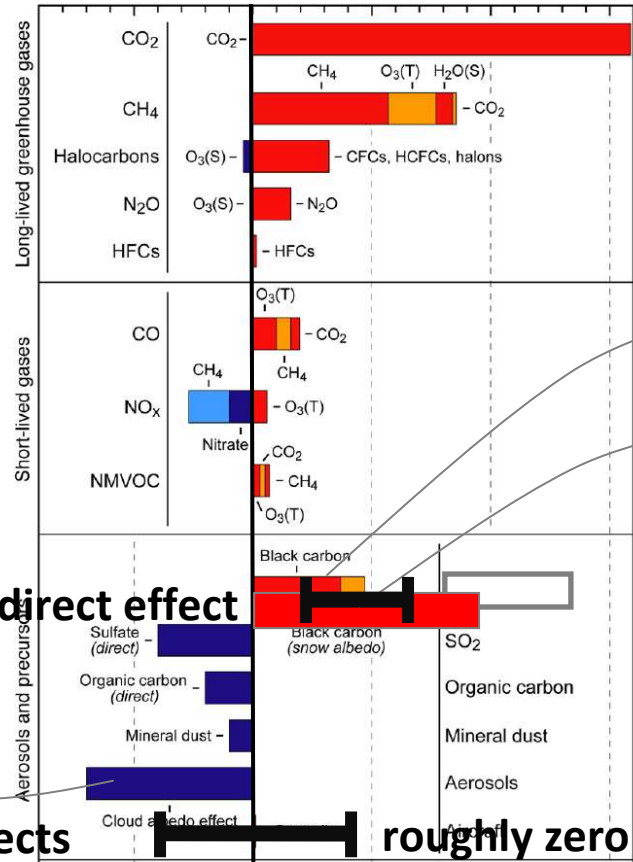
Literature review alla IPCC

+

Dedicated studies following DPSIR framework

- Identification of promising (=cooling!) measures (IIASA/GAINS)
- Globale Emission inventories for 2000, 2030 (CLE), 2030 (with measures)
- Calculation of the effect of measures on BC and O3 fields and radiative forcing
 - GISS GCM (NASA, Goddard)
 - ECHAM GCM (JRC)
 - JRC/FASST tool (JRC)
- Calculation of effect of measures on Temperature, Health (PM), Ecosystems
 - off-line models (US-EPA, JRC, SEI, ...)

Components of radiative forcing for principal emissions

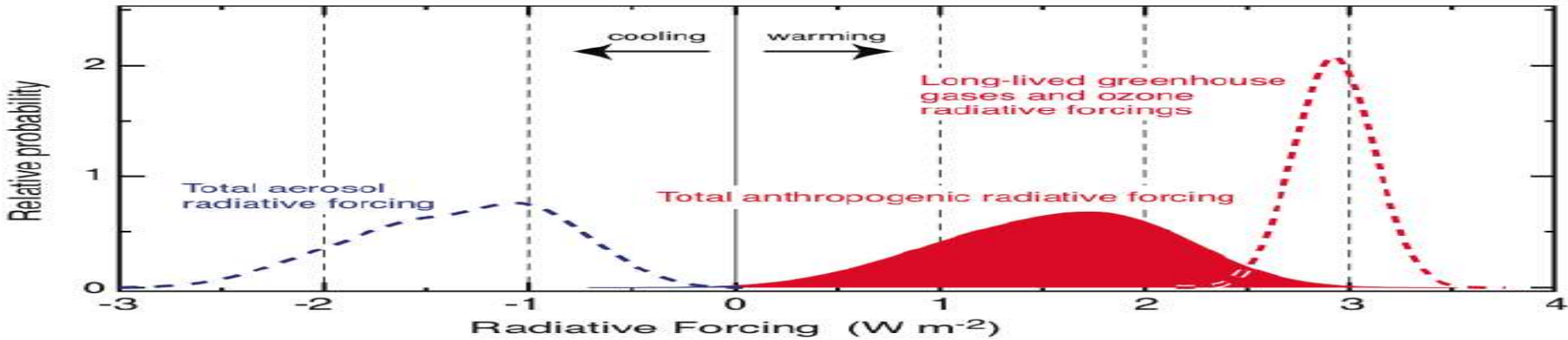


based on EC emission inventories and subsequent calculations (IPCC 4AR)

based on extrapolating absorption measurements in the atmosphere (Ramanathan et al. 2008)

how much does "BC" contribute to cooling through cloud effects??

BC indirect effects roughly zero?



control measures (IIASA)

Group 1: Technical measures for CH₄

1. Extended recovery of **coal mine gas**
2. Extended recovery and flaring (instead of venting) of associated gas from **production of crude oil and natural gas**
3. Reduced **gas leakage** at compressor stations in long-distance gas transmission pipelines
4. Separation and treatment of biodegradable **municipal waste** through recycling, composting and anaerobic digestion
5. Upgrading primary **wastewater treatment** to secondary/tertiary treatment with gas recovery and overflow control
6. Control of methane emissions from **livestock**, mainly through farm-scale **anaerobic digestion** of manure from cattle and pigs with liquid manure management
7. Intermittent aeration of continuously flooded **rice paddies**

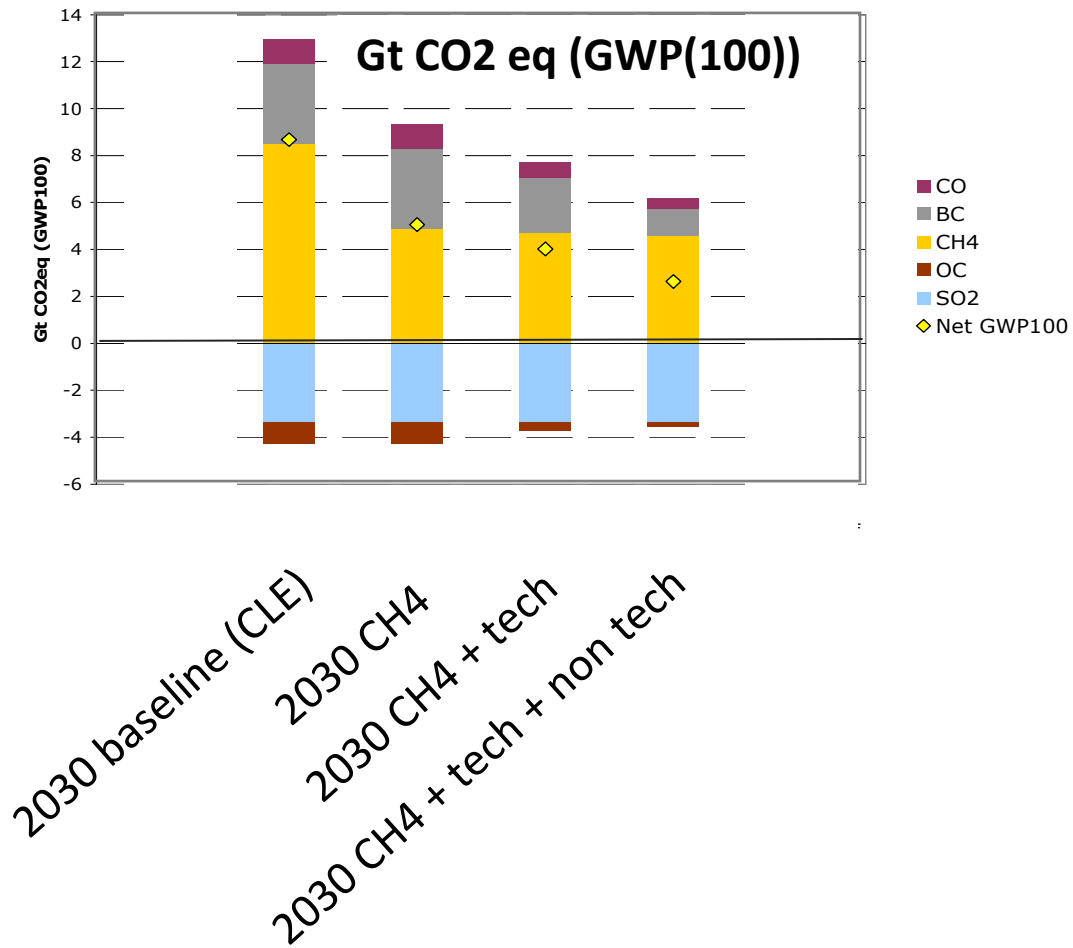
Group 2: Technical measures for BC

1. Replacing **traditional coke ovens** with modern recovery ovens, including the improvement of end-of-pipe abatement measures (in developing countries)
2. Replacing **traditional brick kilns** with vertical shaft kilns and Hoffman kilns where considered feasible (in developing countries)
3. Wide-scale introduction of **pellets stoves and boilers** in the residential sector (in industrialized countries)
4. **Diesel particle filters** for road vehicles and off-road mobile sources (excluding shipping)
5. Particle control at **stationary engines**

Group 3: Non-technical measures for BC

1. Elimination of **high-emitting vehicles** in road and off-road transport (excluding shipping)
2. Ban of **open burning of agricultural waste**
3. Elimination of **biomass cook stoves** in developing countries

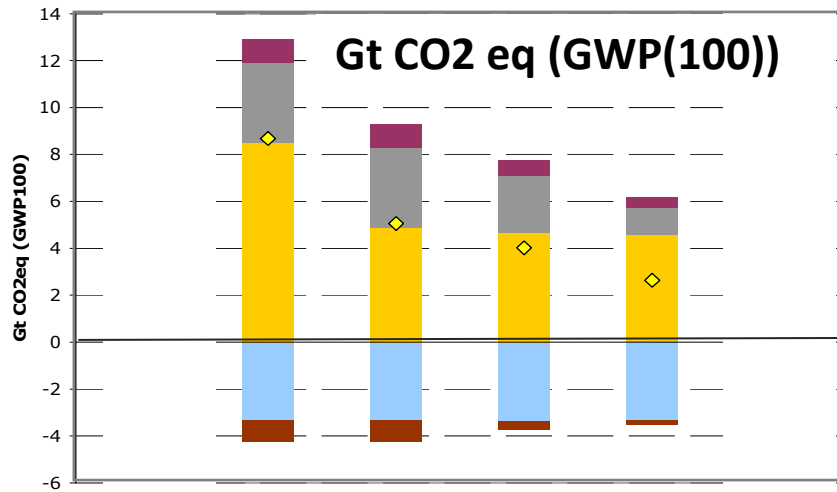
r1



IIASA

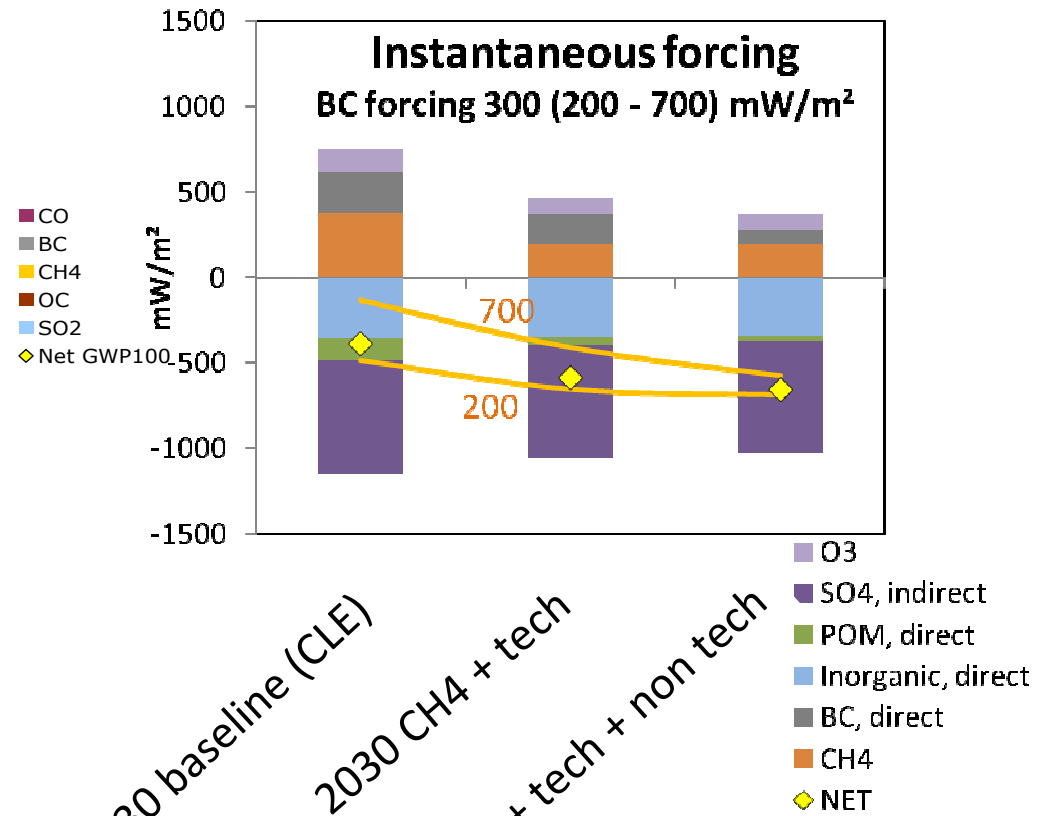
WORK IN PROGRESS

r1



2030 baseline (CLE)
2030 CH4
2030 CH4 + tech
2030 CH4 + tech + non tech

IIASA

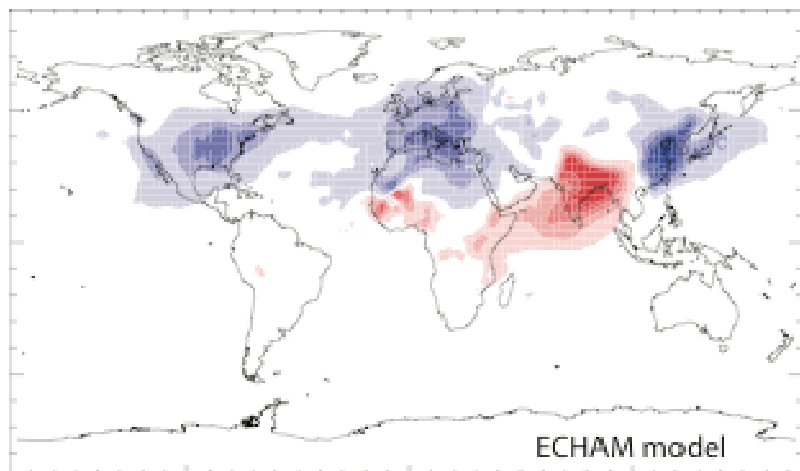
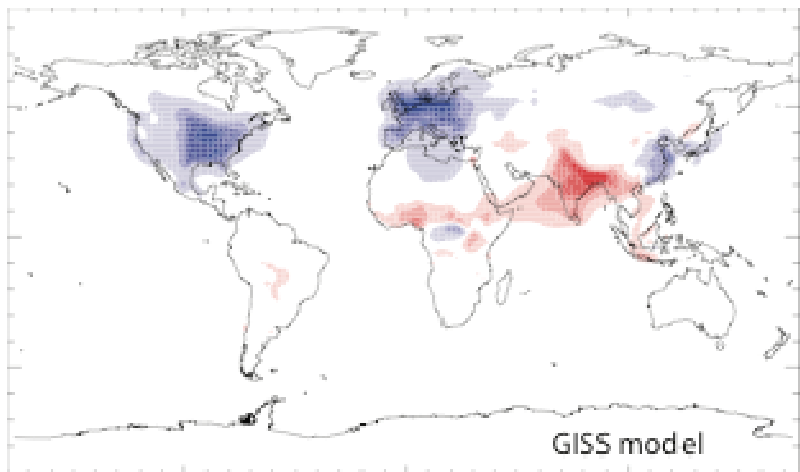


2030 baseline (CLE)
2030 CH4 + tech
2030 CH4 + tech + non tech

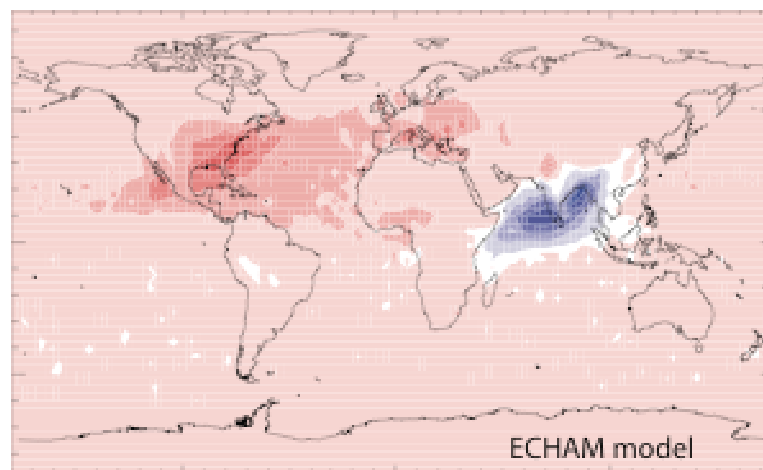
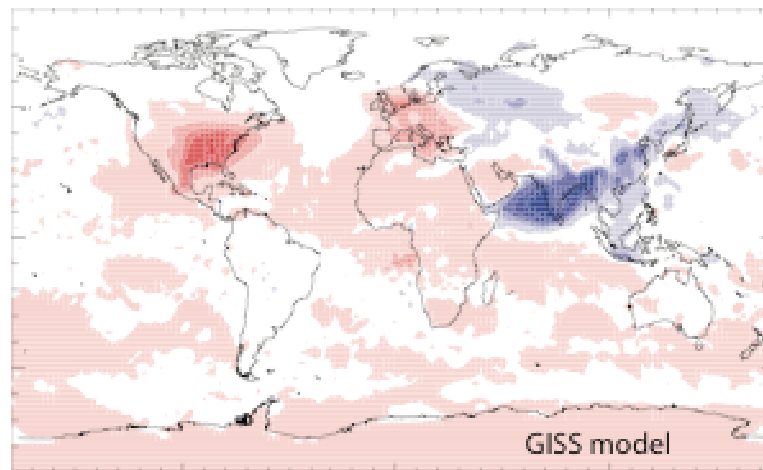
JRC/FASST

WORK IN PROGRESS

PM2.5 ($\mu\text{g}/\text{m}^3$) 2030 - 2005



TOA RadFor (W/m^2) 2030 - 2005



WORK IN PROGRESS

Radiative forcing (W/m^2)

Figure 3.5.1. Change in annual average PM2.5 ($\mu\text{g}/\text{m}^3$), 2030 baseline change relative to 2005.

Figure 3.5.2. Radiative forcing (W/m^2) due to methane, ozone, and the direct effects of aerosols, 2030 baseline change relative to 2005. Values are instantaneous at the tropopause.



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Opportunities to Limit Near-Term Climate Change

Timing

UNEP assessment

first draft for review: end of sept 2010

printed: february 2011

HTAP assessment

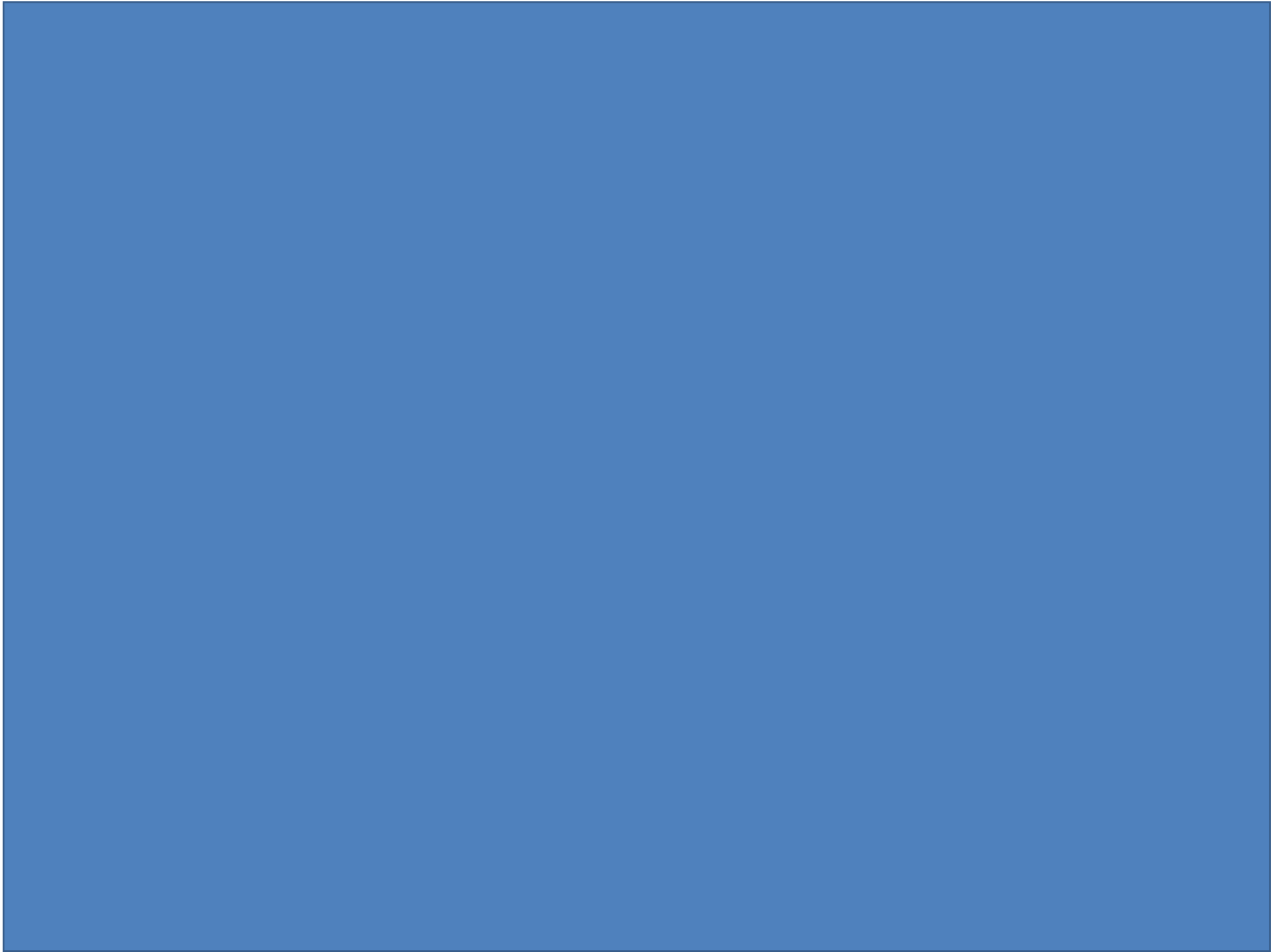
presentation EMEP SB, sept. 2010

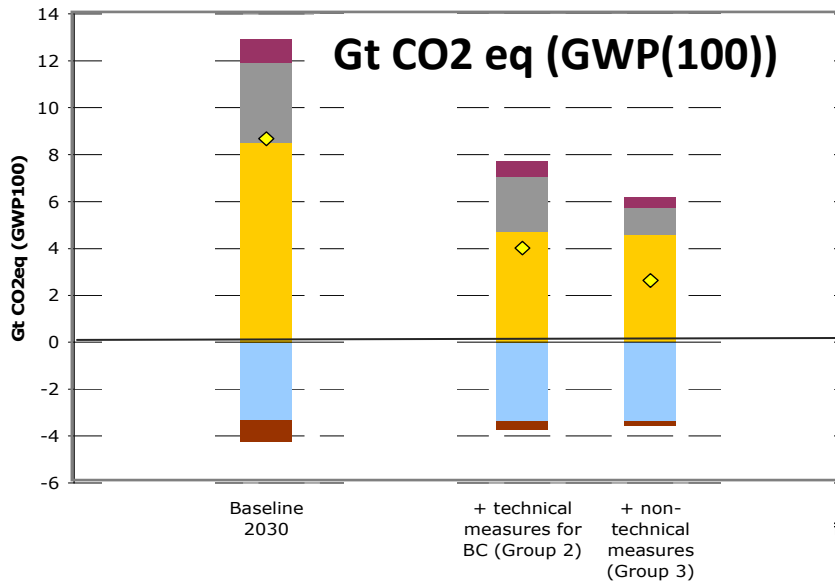
Expert Group BC (UN CLRTAP)

presentation at EMEP EB, december 2010

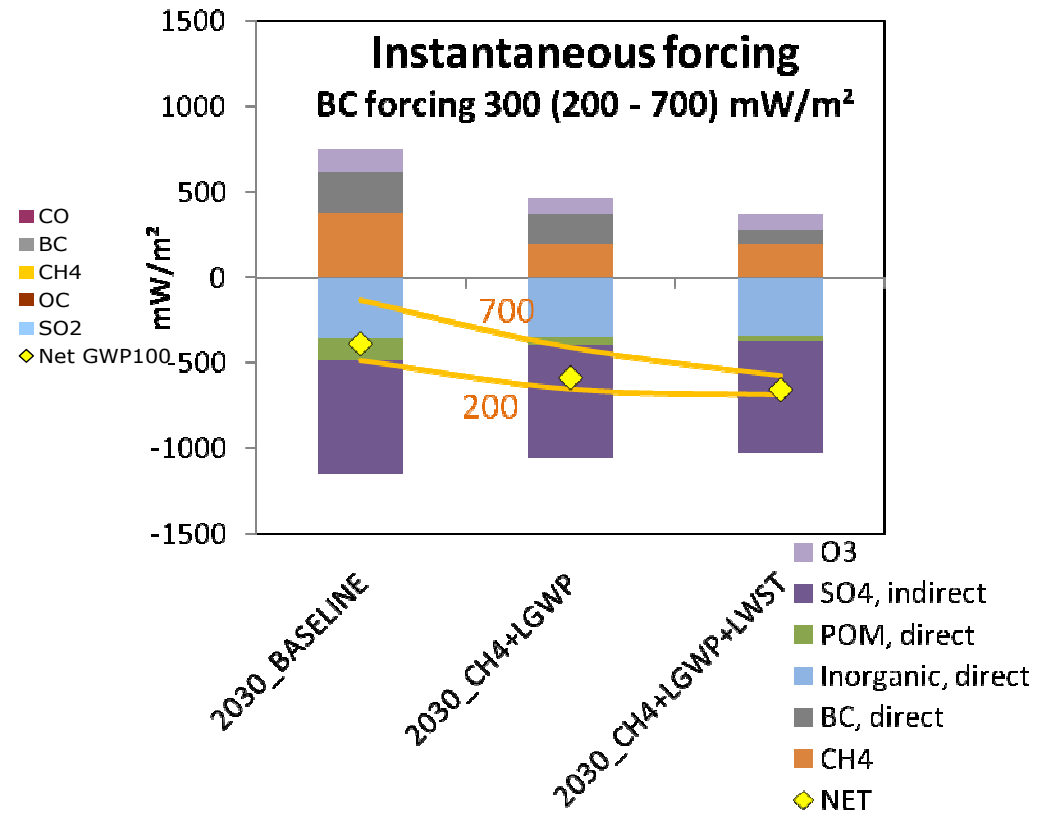
Bounding BC (IGAC)

"soon"





IIASA approach



JRC/FASST approach

WORK IN PROGRESS

3 groups of measures to reduce BC and trop. O3 (IIASA/GAINS)

- Measures that affect emissions of methane
 - to be implemented centrally by large multi-national and national energy companies, municipalities and through modified agricultural practices;
- Technical measures that reduce emissions of black carbon
 - mainly at small stationary and mobile sources;
- Non-technical measures to eliminate the most polluting activities
 - e.g., through improved enforcement of legislation or through economic and technical assistance to the poorest population

Group 1:

Technical measures for methane emissions

1. Extended recovery of **coal mine** gas
2. Extended recovery and flaring (instead of venting) of associated gas from **production of crude oil and natural gas**
3. Reduced **gas leakage** at compressor stations in long-distance gas transmission pipelines
4. Separation and treatment of biodegradable **municipal waste** through recycling, composting and anaerobic digestion
5. Upgrading primary **wastewater treatment** to secondary/tertiary treatment with gas recovery and overflow control
6. Control of methane emissions from **livestock**, mainly through farm-scale **anaerobic digestion** of manure from cattle and pigs with liquid manure management
7. Intermittent aeration of continuously flooded **rice paddies**

Group 2:

Technical measures for black carbon

1. Replacing **traditional coke ovens** with modern recovery ovens, including the improvement of end-of-pipe abatement measures (in developing countries)
2. Replacing **traditional brick kilns** with vertical shaft kilns and Hoffman kilns where considered feasible (in developing countries)
3. Introduction of **improved biomass cook stoves** in developing countries
4. Wide-scale introduction of **pellets stoves and boilers** in the residential sector (in industrialized countries)
5. **Diesel particle filters** for road vehicles and off-road mobile sources (excluding shipping)
6. Particle control at **stationary engines**

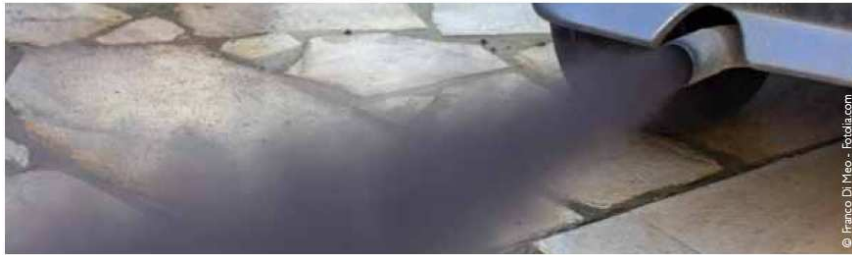
Group 3:
Non-technical measures

1. Elimination of **high-emitting vehicles** in road and off-road transport (excluding shipping)
2. Ban of **open burning of agricultural waste**
3. Elimination of **biomass cook stoves** in developing countries

(This analysis explores only the theoretical potential from such measures,
but not the feasibility of their implementation)

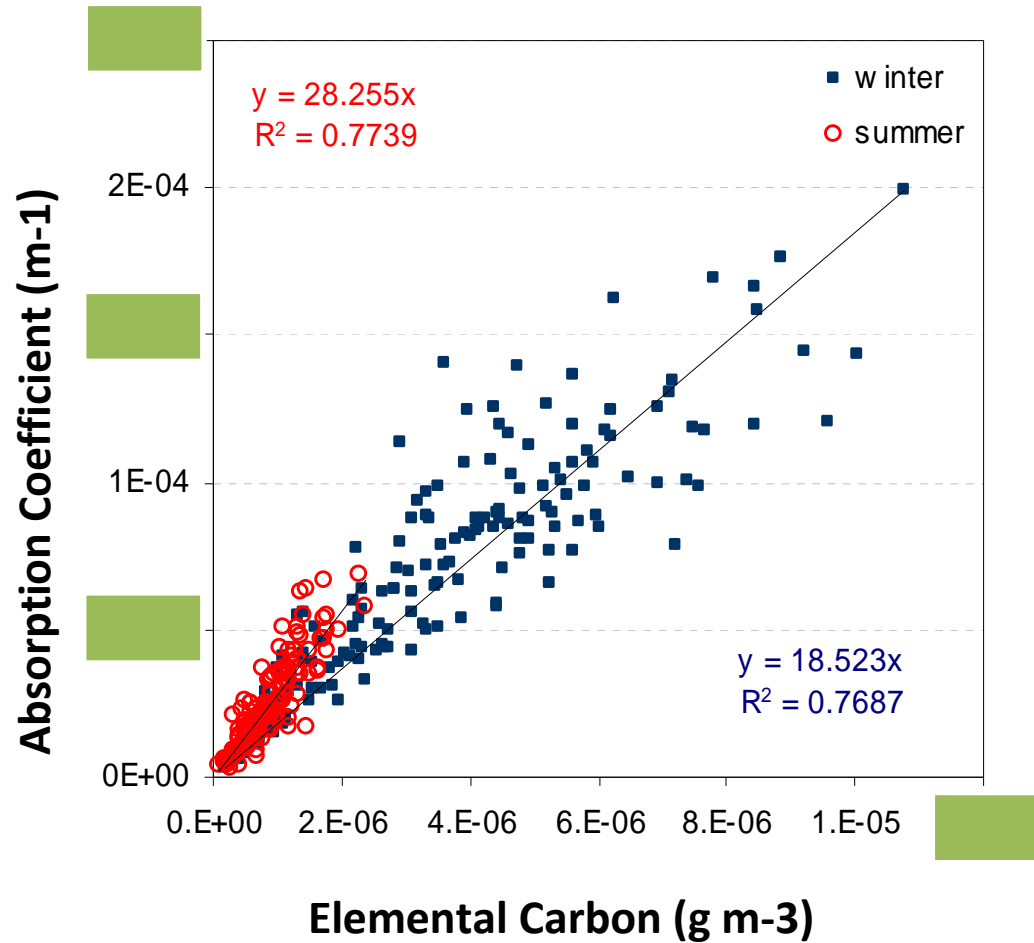
“Black Carbon”:

- carbon-containing particulate matter, resulting from burning
 - it withstands high temperatures
 - it is black, hence absorbs light



not all burning produces light absorbing particles !

Measuring “BC” through measuring EC and absorption



There is no one-to-one relationship between EC and absorption !

Source: JRC, Cavalli et Putaud et al., 2010, EML

Instantaneous forcing BC forcing 300 (200 - 700) mW/m²

