Aerosol and gas emissions: Dissecting future aerosol emissions

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Workshop on Air Pollution as Climate Forcing: Alternative Scenarios —Their Benefits and Costs

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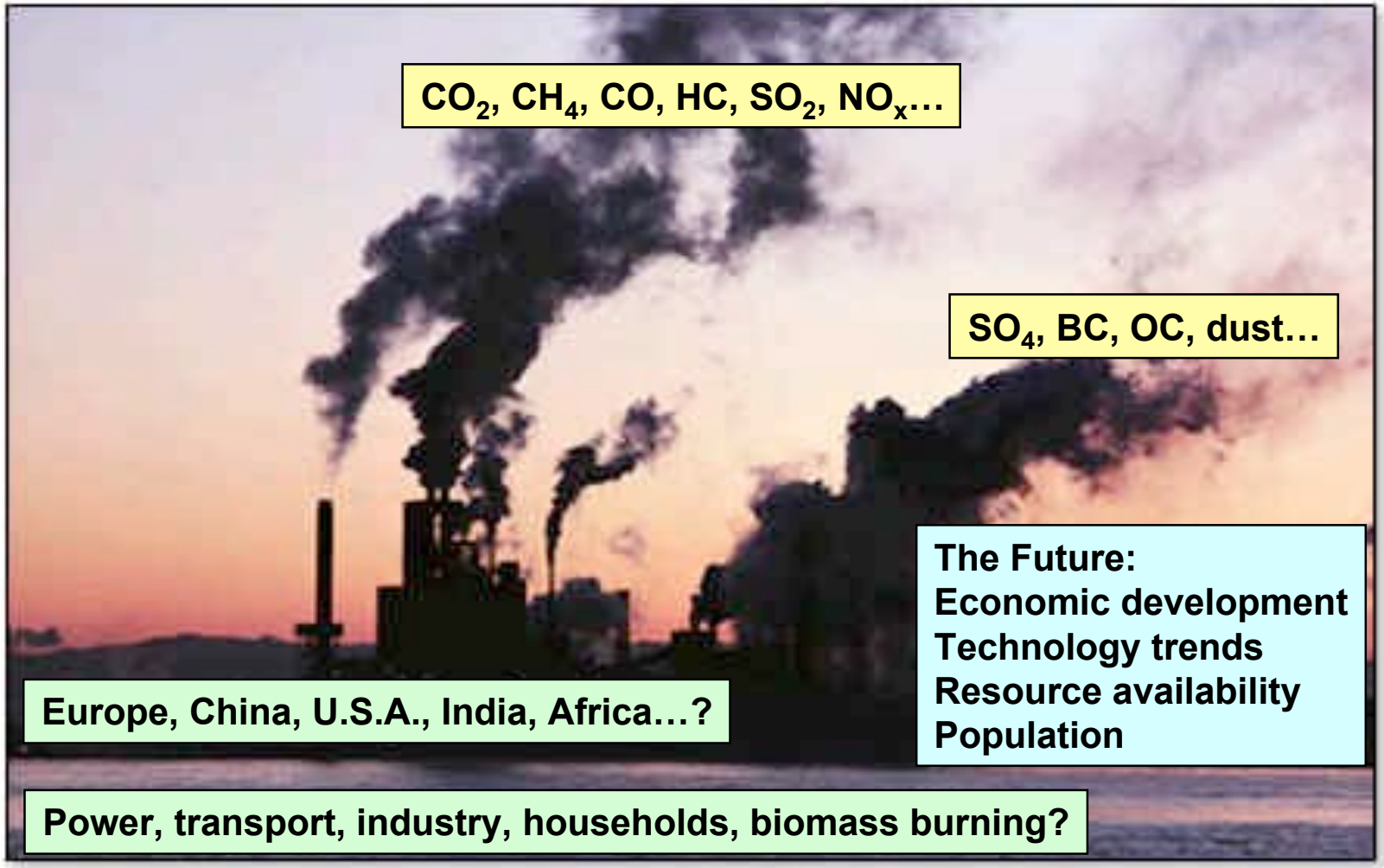
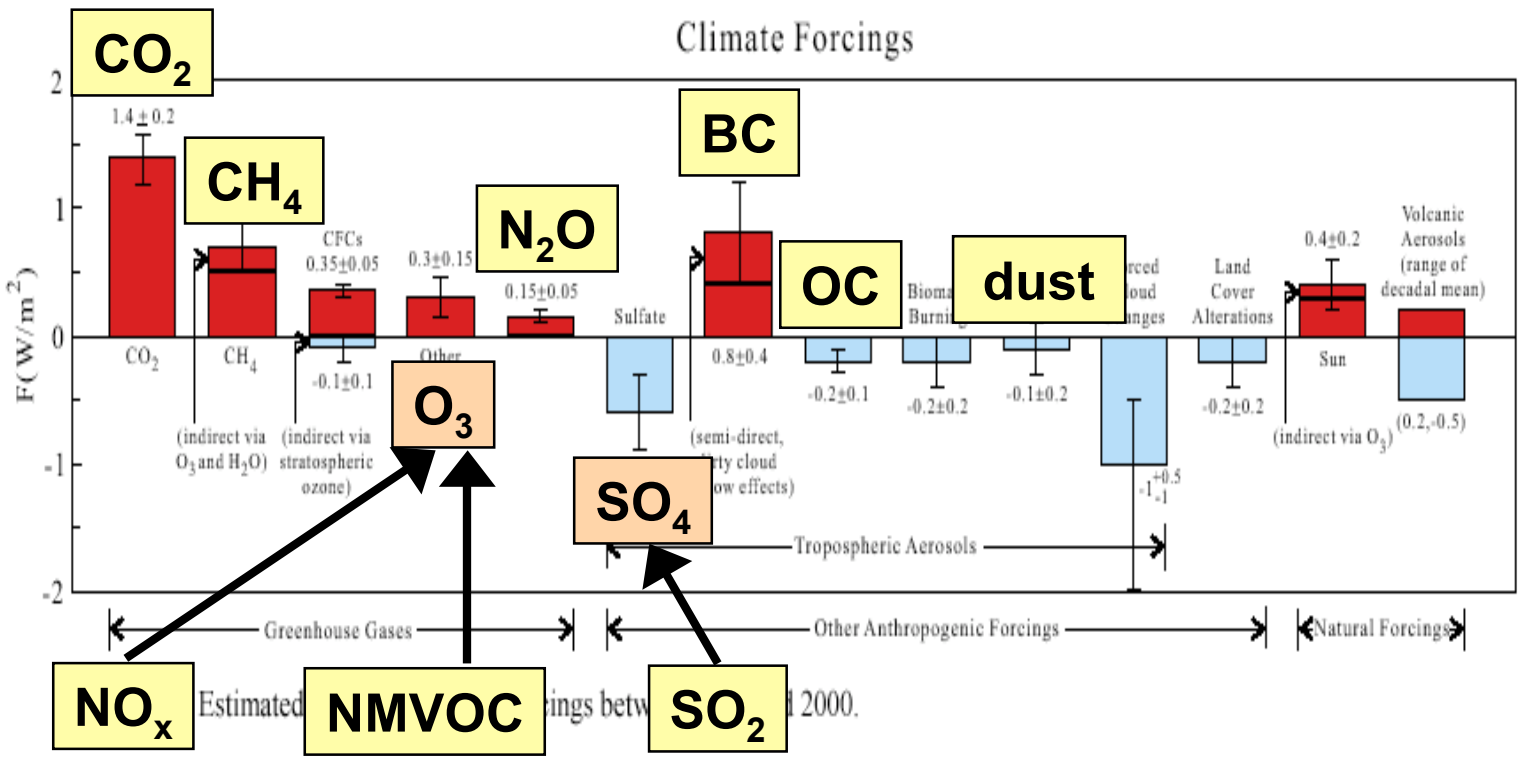
What actions can we take to alleviate climate change and air pollution in an integrated way?

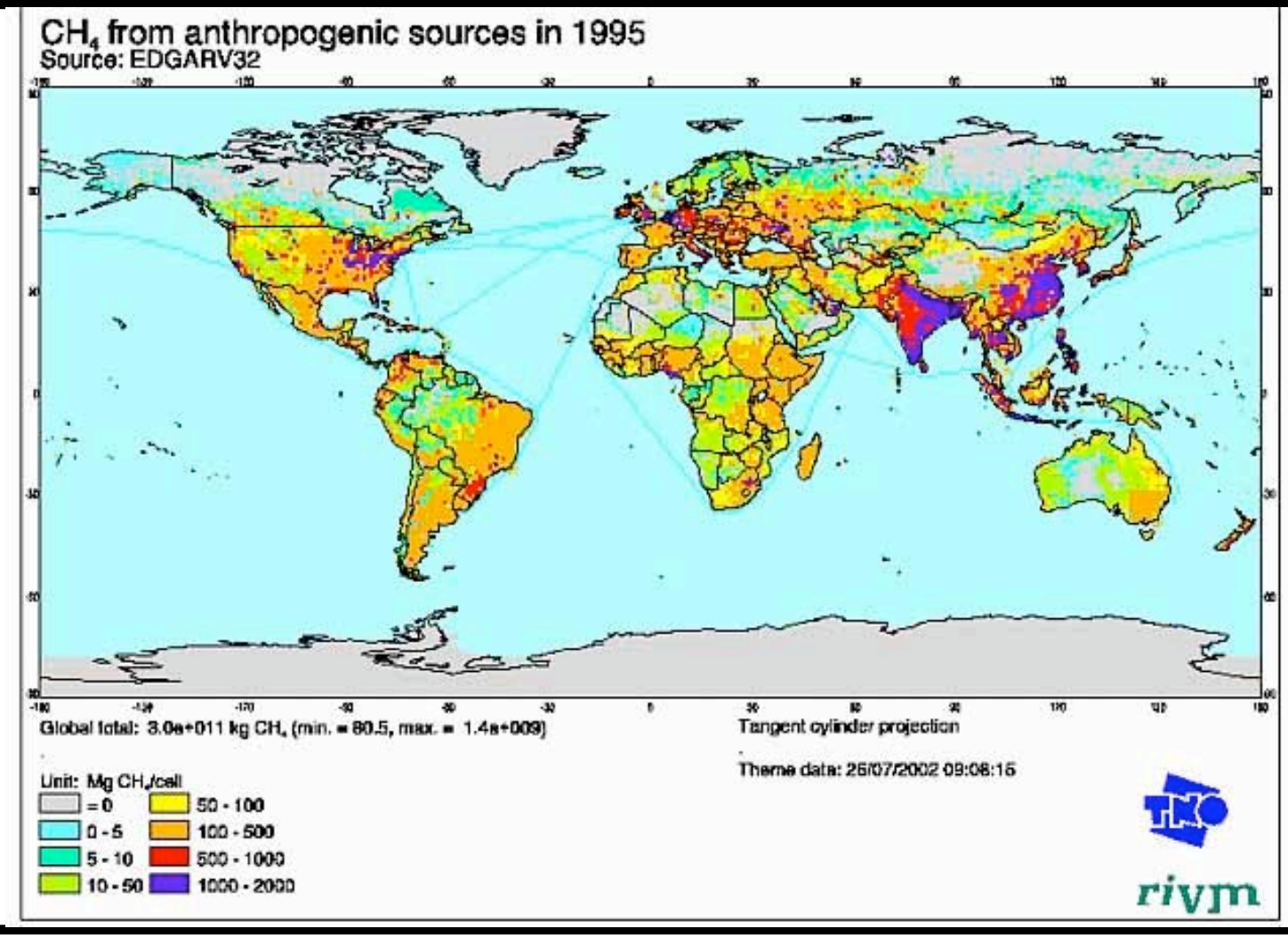


Which primary species are implicated in global climate change?

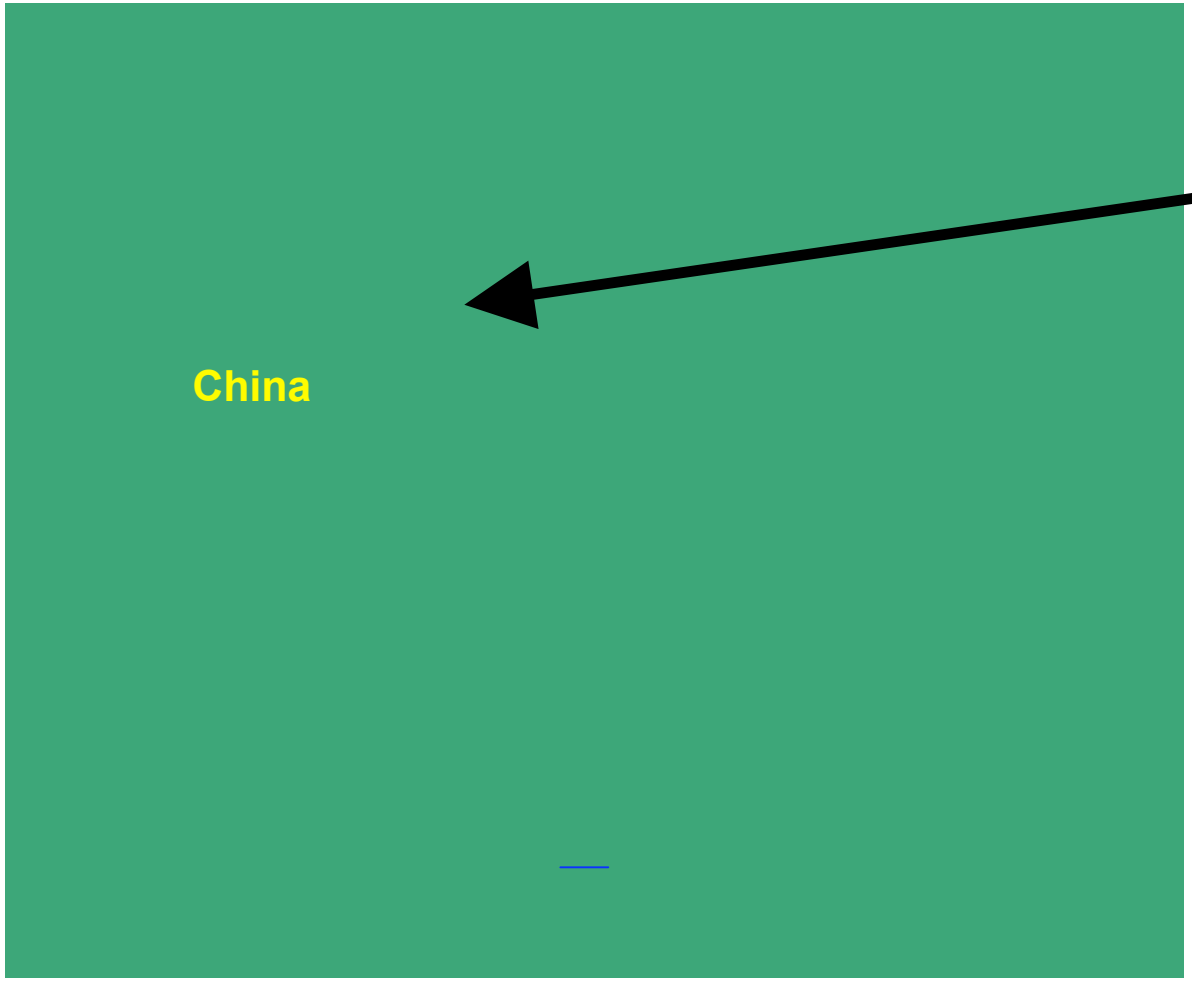


(Hansen et al., Senate testimony, May 1, 2001; Hansen and Sato, PNAS)

Finding emission inventories is not a problem. Knowing how good they are is another matter…



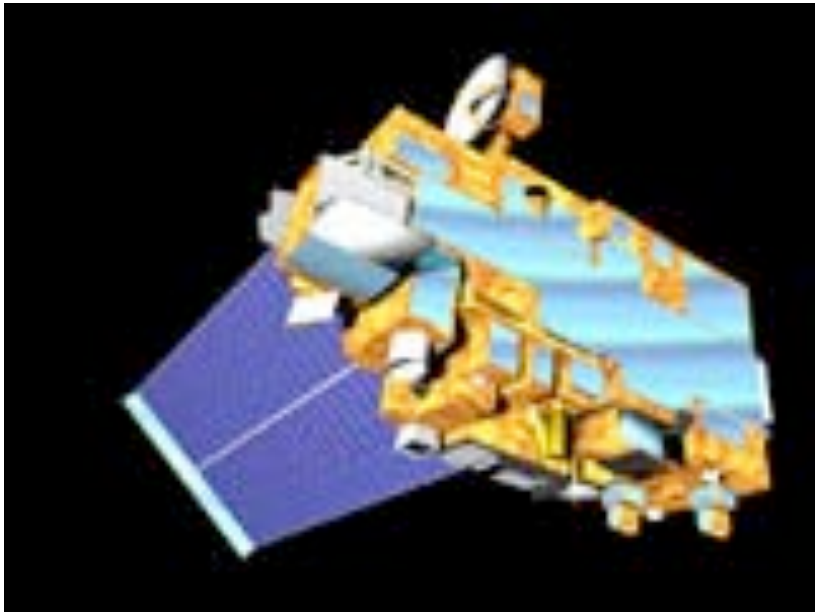
Experiments such as TRACE-P, ACE-Asia, and ITCT employ mobile "super-sites" and provide ways to characterize emissions



Surprisingly high values of some species, particularly CO and BC, observed close to the coast of China.
We now suspect that all CO inventory values for China are about 50% too low.

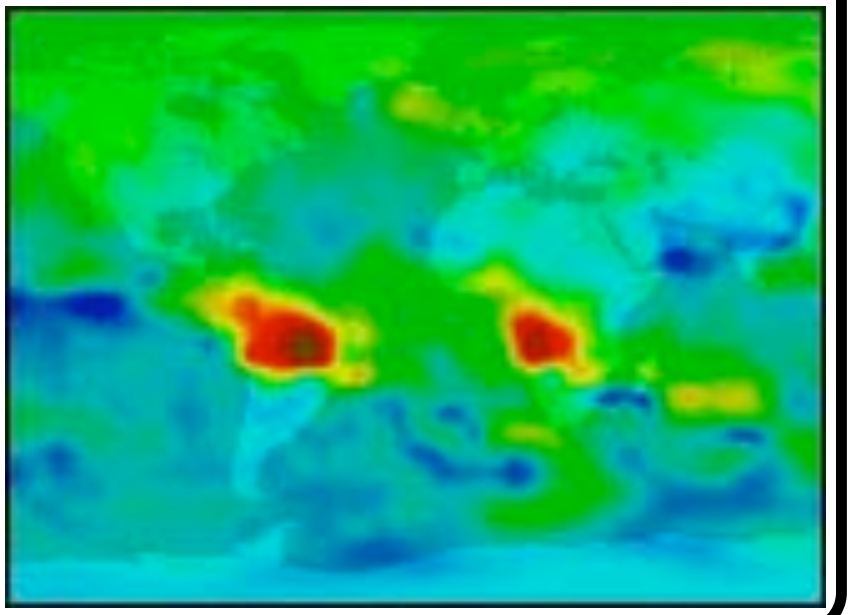
Spring 2001

Increasingly, satellite observations from space are giving information about ground-level emissions



The Terra satellite has a variety of instruments pointed back at the earth

This is an image of CO emissions from forest fires in Africa and Brazil seen by the MOPITT instrument



Typical emission factors (Gg/PJ) for power generation and residential fuel combustion

	SO_2	SO_2*	NO_x	CO	BC**	CO_2
coal	0.61	0.06	0.30	0.02	0.00001	96
oil	0.26	0.07	0.20	0.02	0.008	77
gas	0.01	0.01	0.15	0.03	~ 0	56
[coal]	0.51	0.07	0.08	3.5	0.18	96
[biofuel]	0.06	0.06	0.05	5.1	0.07	110

*with controls, such as FGD for coal, low-sulfur oil, briquettes, etc.

**black carbon, i.e., sub-micron elemental carbon

[…] = residential fuel use

Emissions are determined to a large extent by fuel use in particular sectors

Residential coal use has very high emissions

China photo courtesy of Bob Finkelman

Residential electricity use from nuclear power has close to zero emissions

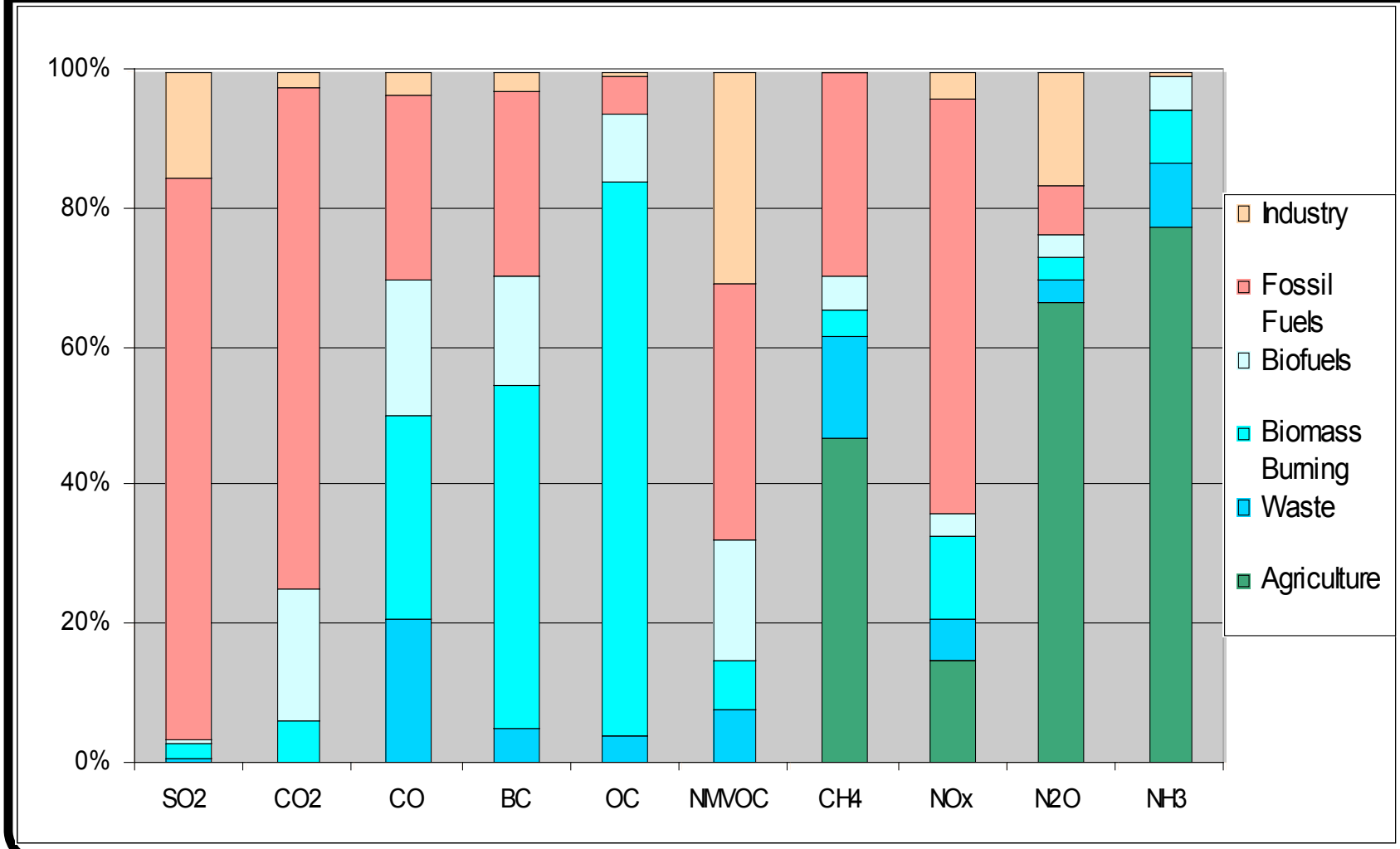
But the technology used to meet a specific energy service is critically important for particle emissions

Direct coal-fired stove, high emissions

Electricity from coal-fired power plant, low emissions

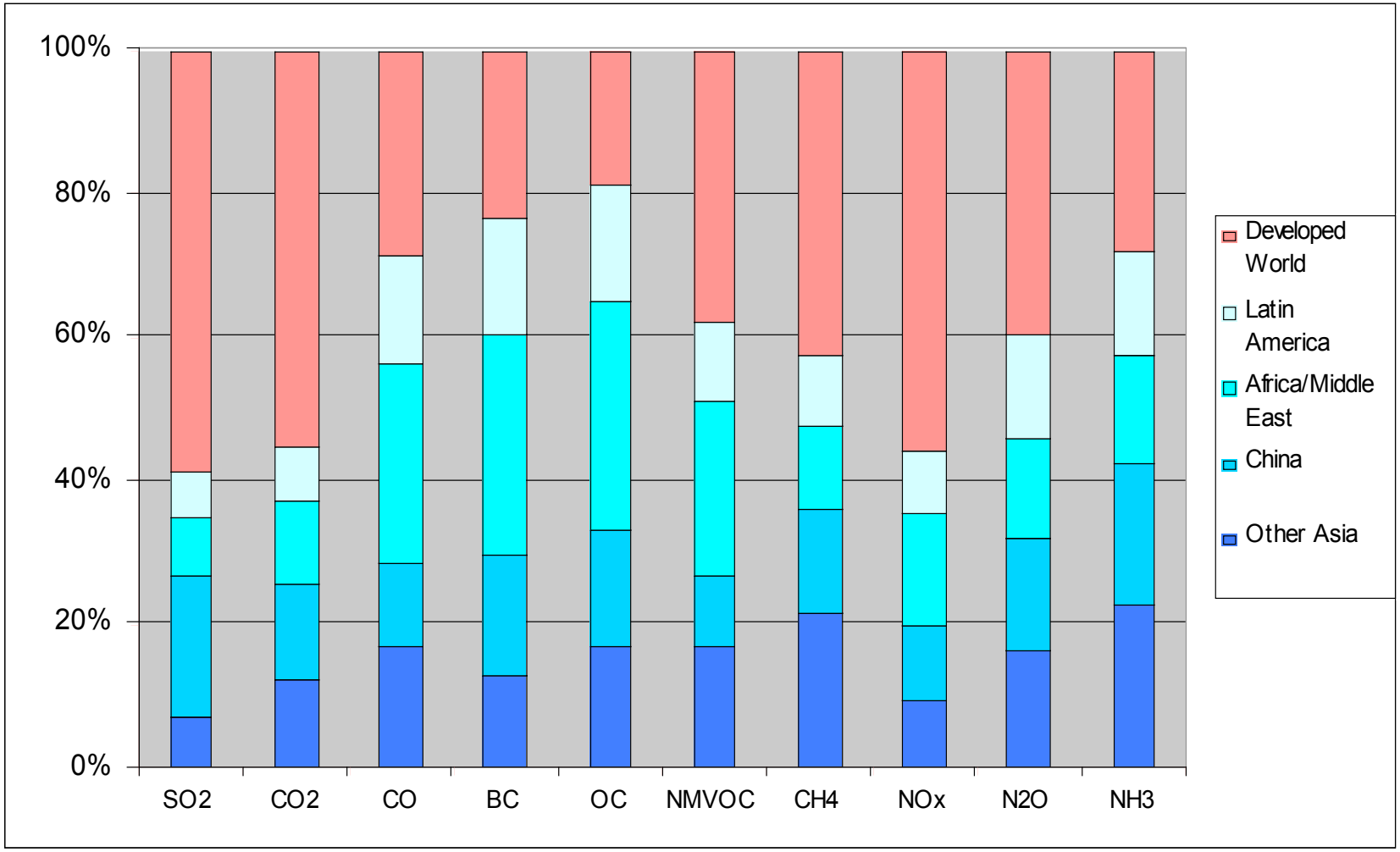
Composition of global emissions by source type

(van Aardenne et al., *GBC*, *15*, 909, 2001; Bond et al., *JGR*, *109*, D14203, 2004)



Composition of global emissions by world region

(EDGAR inventory; Bond et al., *JGR*, *109*, D14203, 2004)



An integrated view of future aerosol emissions

Technically, we are most concerned about:

black carbon (BC), fine aerosol particles generally smaller than 1 micrometer in diameter and mostly elemental carbon,

organic carbon (OC), similar particles in which the carbon is bonded to other atoms, and

sulfate (SO_4), formed by oxidation of primary sulfur dioxide (SO_2) .

These particles are small enough to travel in the air for a week or more, forming regional air pollution and ultimately being deposited far from the source.

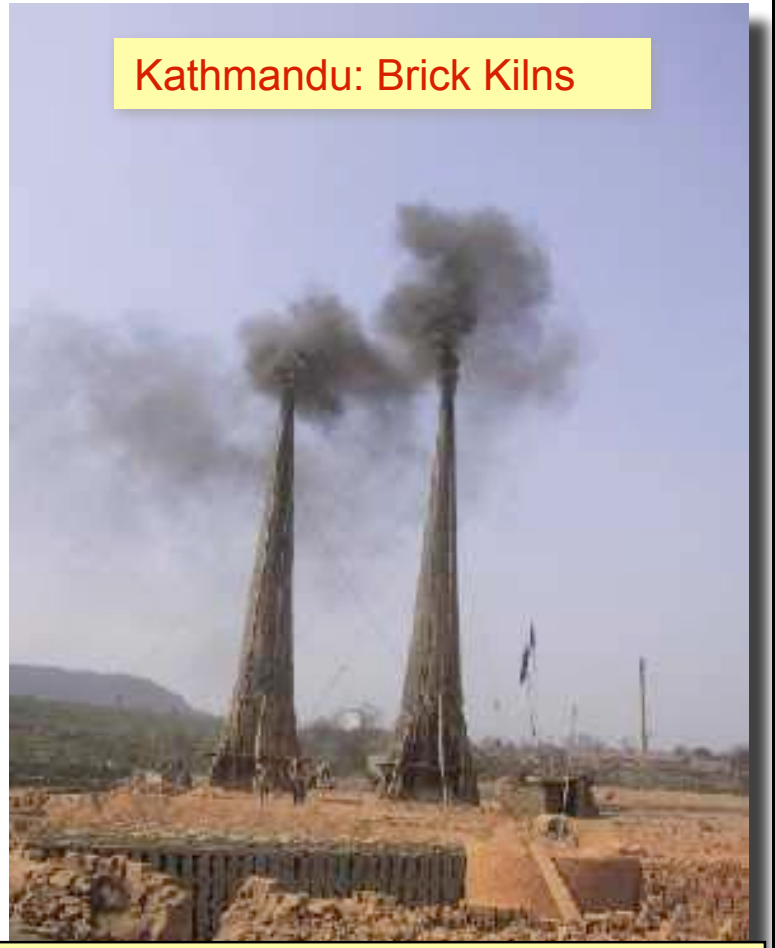


Photo courtesy of Anil Raut, Clean Energy Nepal

Dissection of future primary aerosol emissions

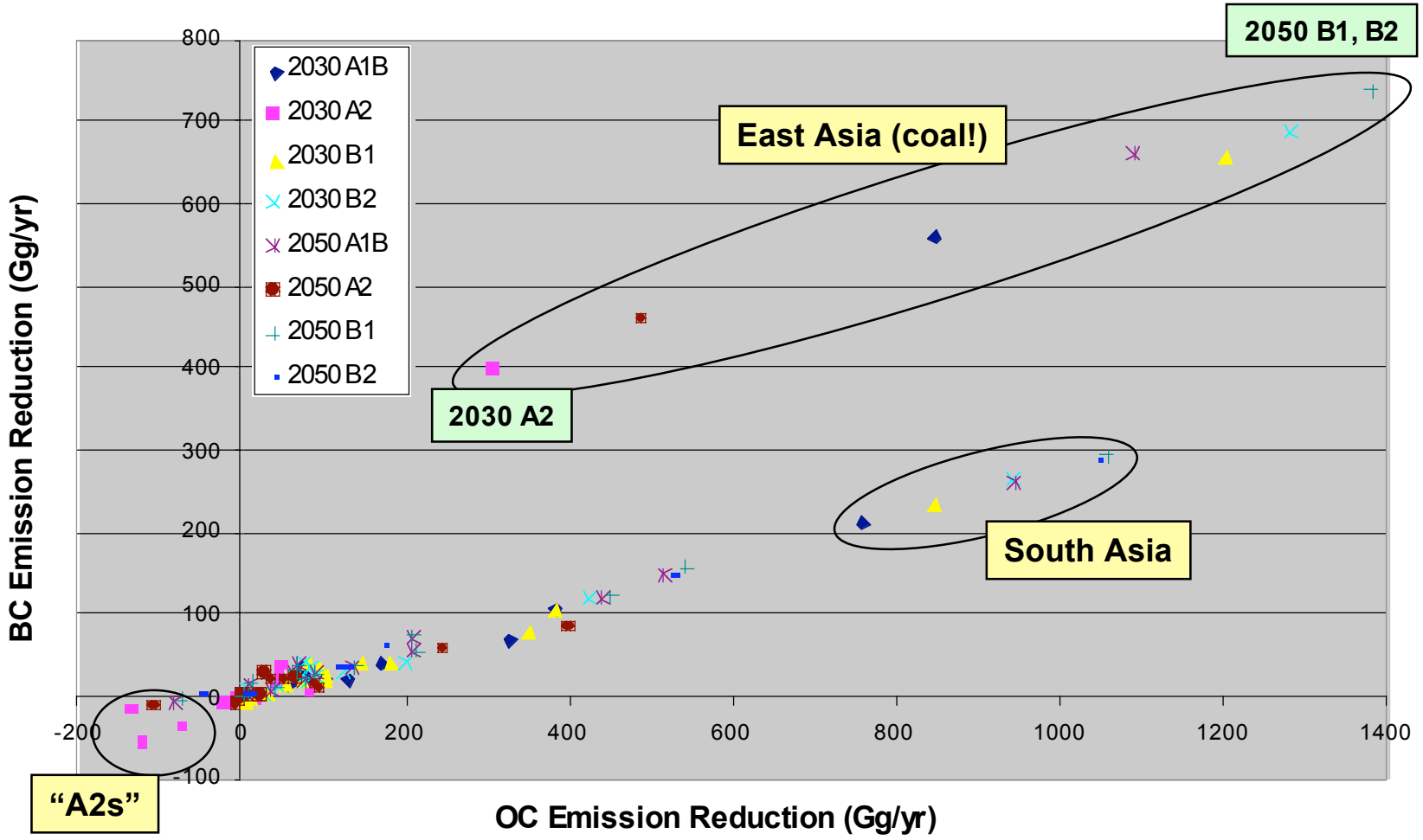
(Streets et al., *JGR*, *109*, D24212, 2004; IPCC, 2001)

With the recent availability of future projections of primary carbonaceous aerosol emissions, we can begin to examine the relationships between emissions of different species in an integrated way across different visions of the future over time, space, and source types:

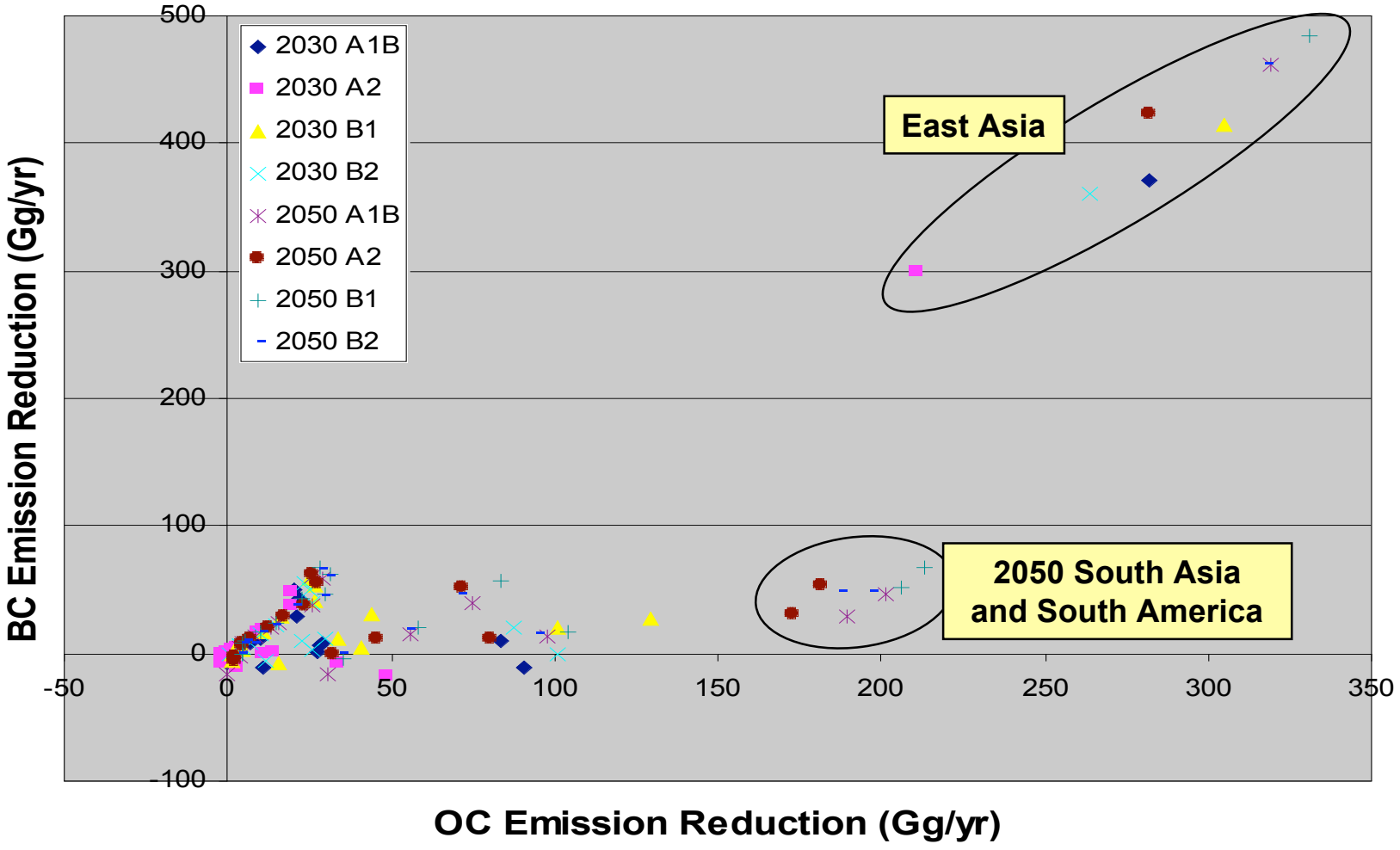
- 17 world regions
- Two future years (2030 and 2050)
- Four IPCC SRES scenarios (A1B, A2, B1, B2)
- Five emitting sectors (household, industry, power, transport, biomass burning)
- Three emitted species (BC, OC, SO_2 as surrogate for SO_4)

Dissection of the various contributions to emission reductions relative to the present day can guide the development of realistic control measures that will optimize environmental benefits.

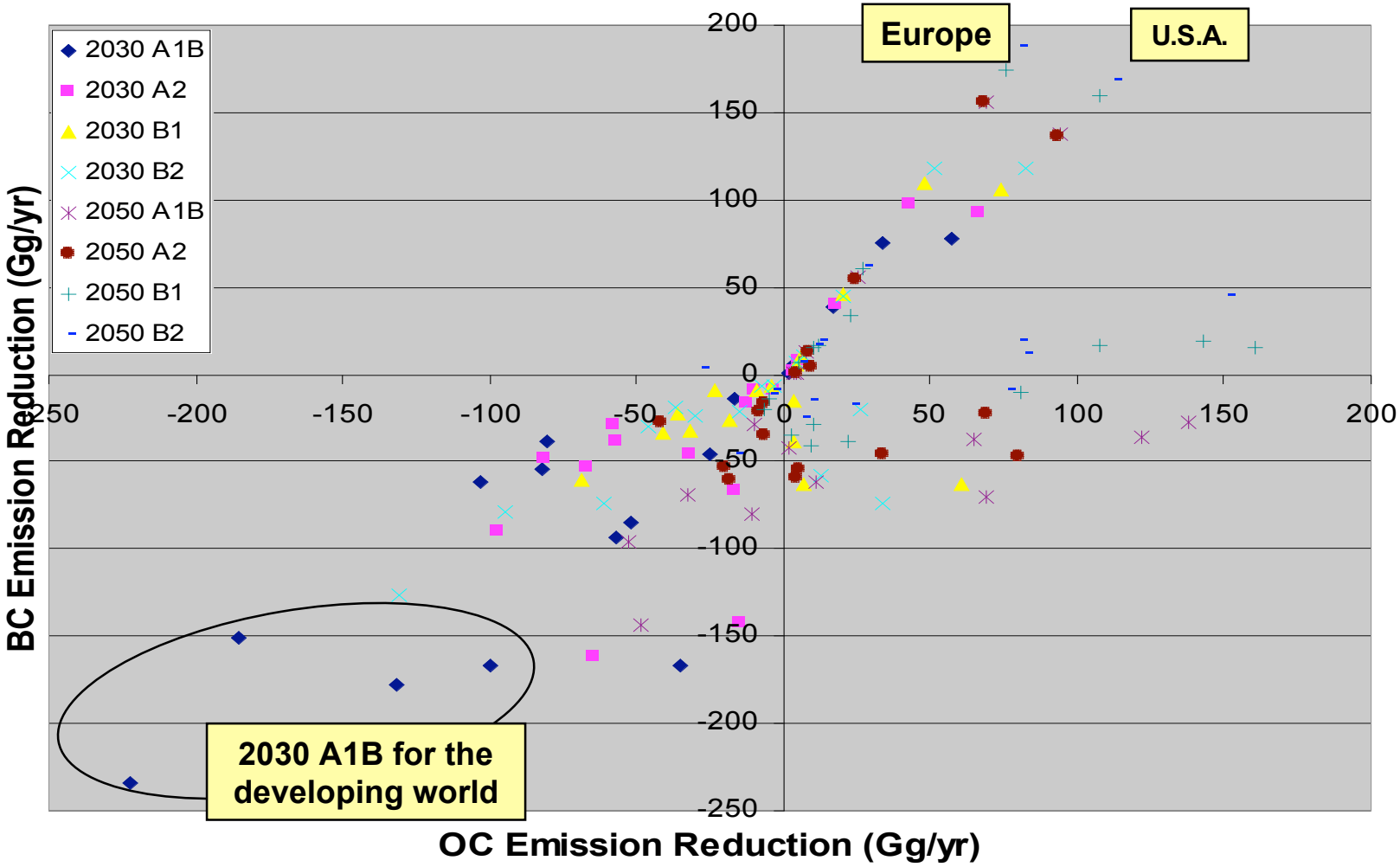
Future household BC/OC emission changes



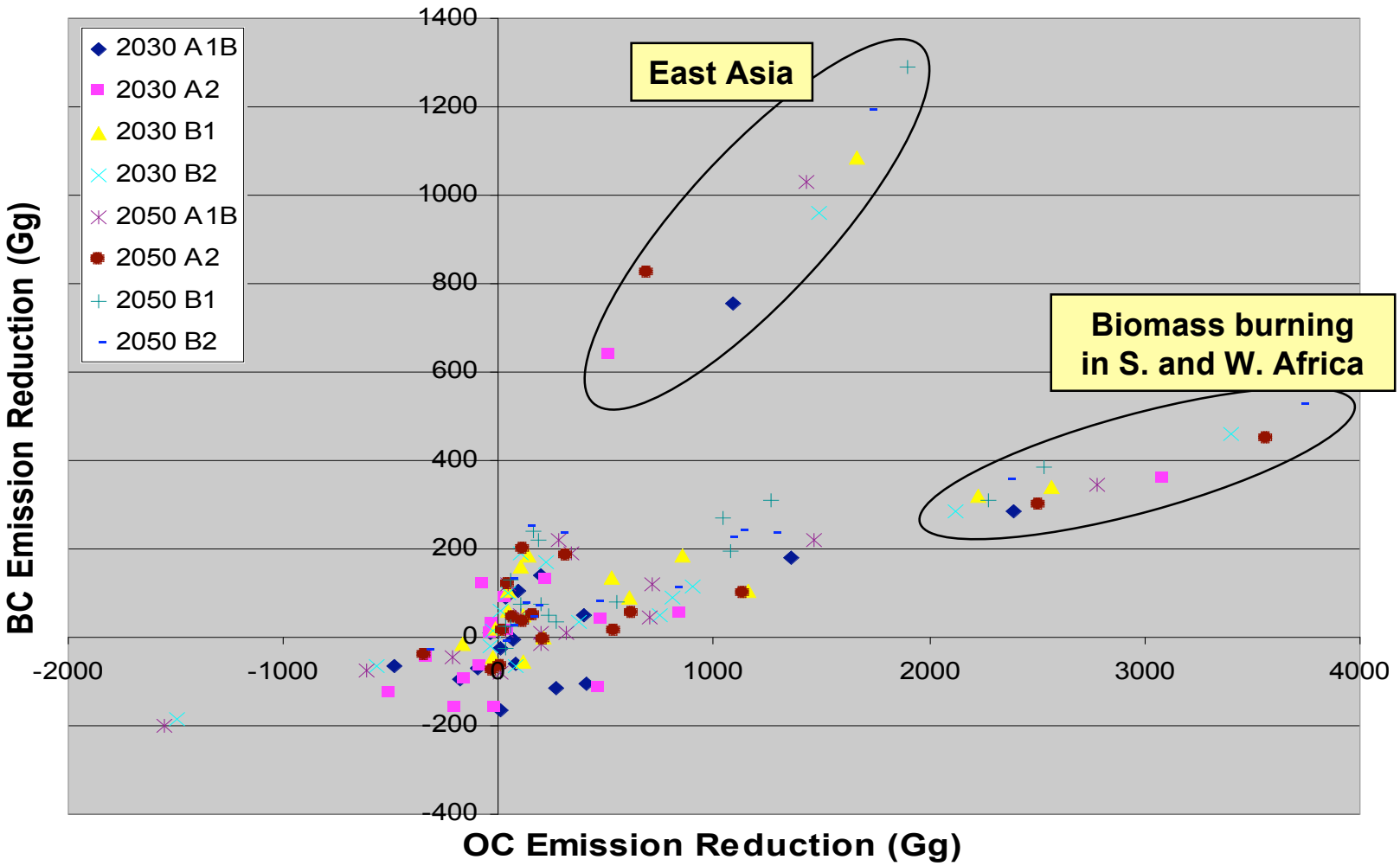
Future industrial BC/OC emission changes



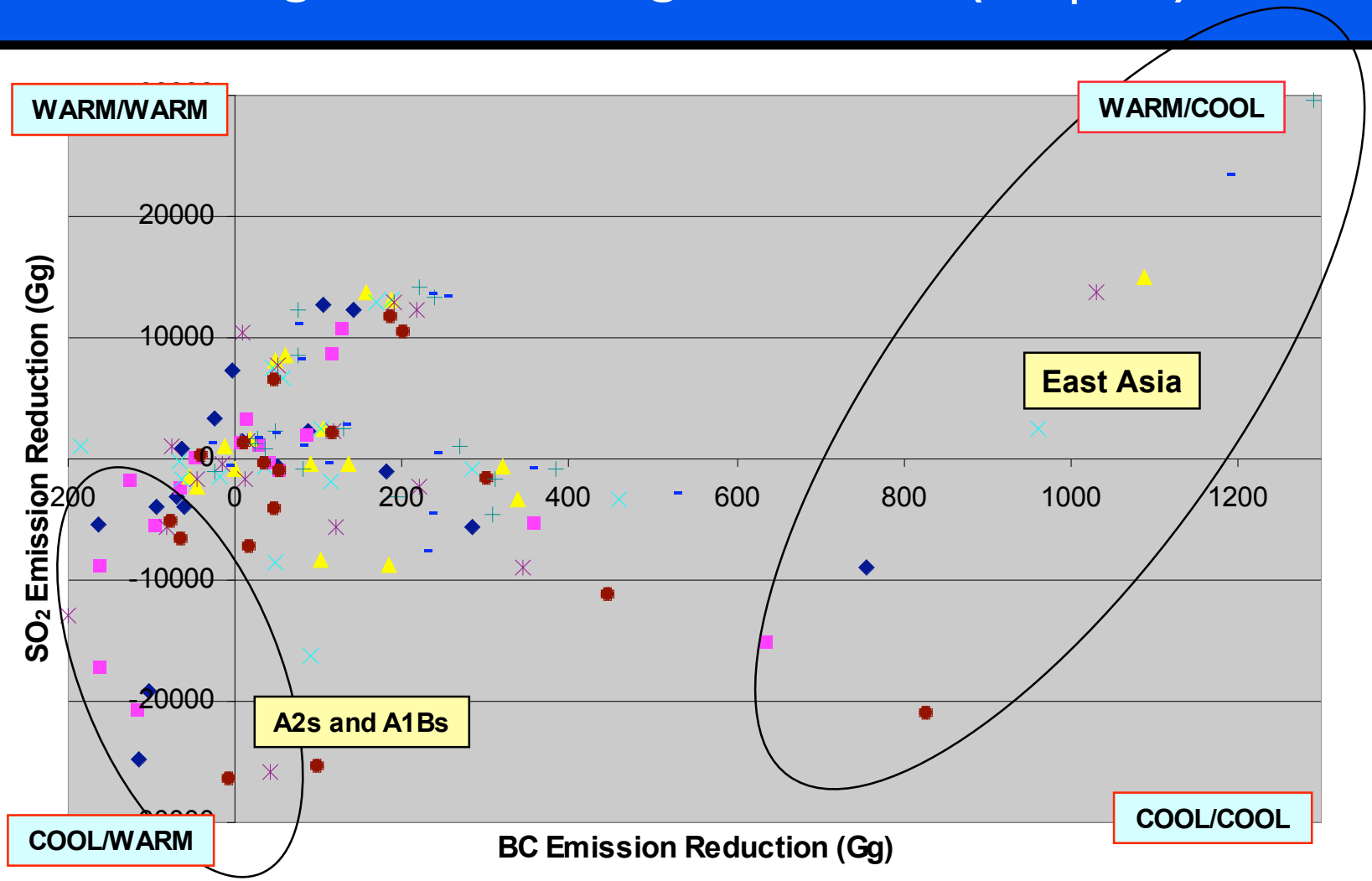
Future transportation BC/OC emission changes



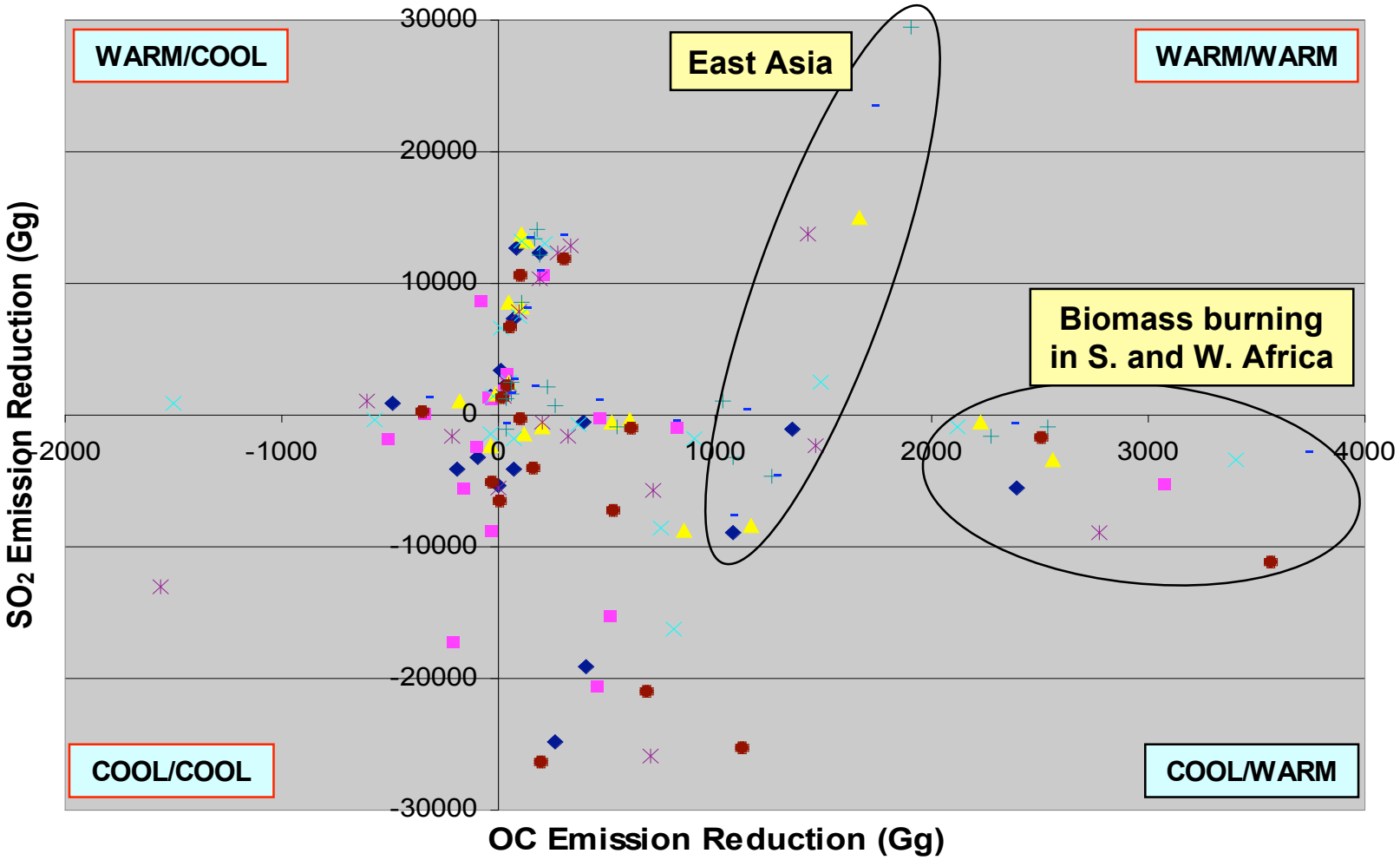
Future BC/OC emission changes from all sectors



Relationship between future SO_2 and BC emission changes and forcing directions (SO_4/BC)



Relationship between future SO_2 and OC emission changes and forcing directions (SO_4/OC)



Conclusions

What happens in China and India will largely determine household sector emissions of aerosols, but reductions in BC and OC are likely unless we enter an "A2 world"

Industrial emission reductions in BC and OC are highly likely, with the magnitude largely determined by coal consumption in China

For the transportation sector, reductions in BC and OC are expected in Europe and North America, but in many situations BC and OC will increase, especially in developing regions under the high near-term growth scenario (2030 A1B)

Reduced biomass burning in S. and W. Africa could yield substantial reductions in OC emissions

Developments in China dominate the BC/SO_2 picture, with most cases showing reduced BC with high/low SO_4; high economic growth scenarios (A1B and A2) tend to yield joint increases in BC and SO_4 emissions in many regions

Dominant trends for OC and SO_4 are many cases of high SO_4 reduction/small OC reduction; and a few cases of high SO_4 increase/moderate OC reduction