Role of Black and Organic Carbon Emissions in Integrated Assessment

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Air Pollution as Climate Forcing Workshop
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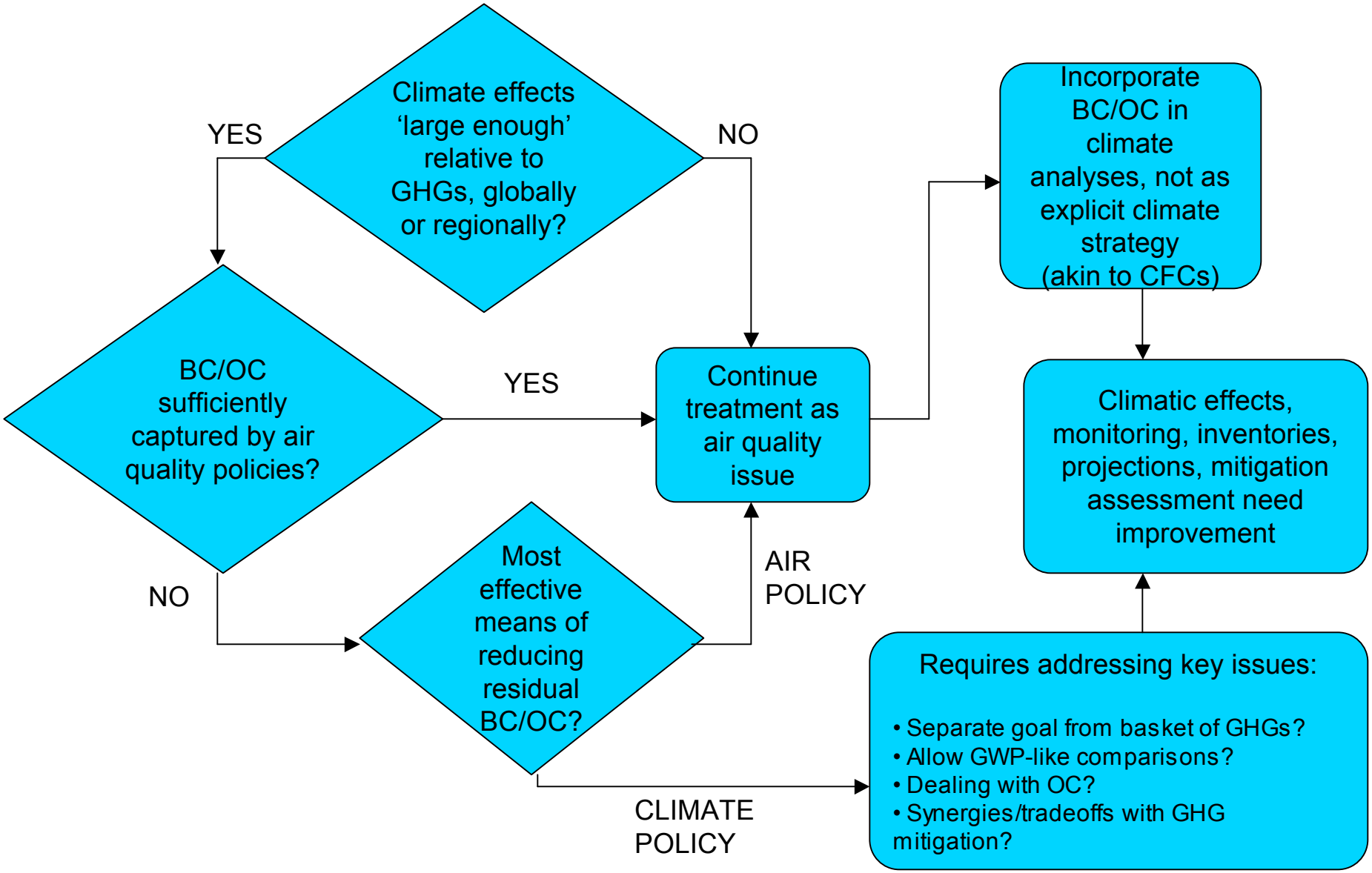
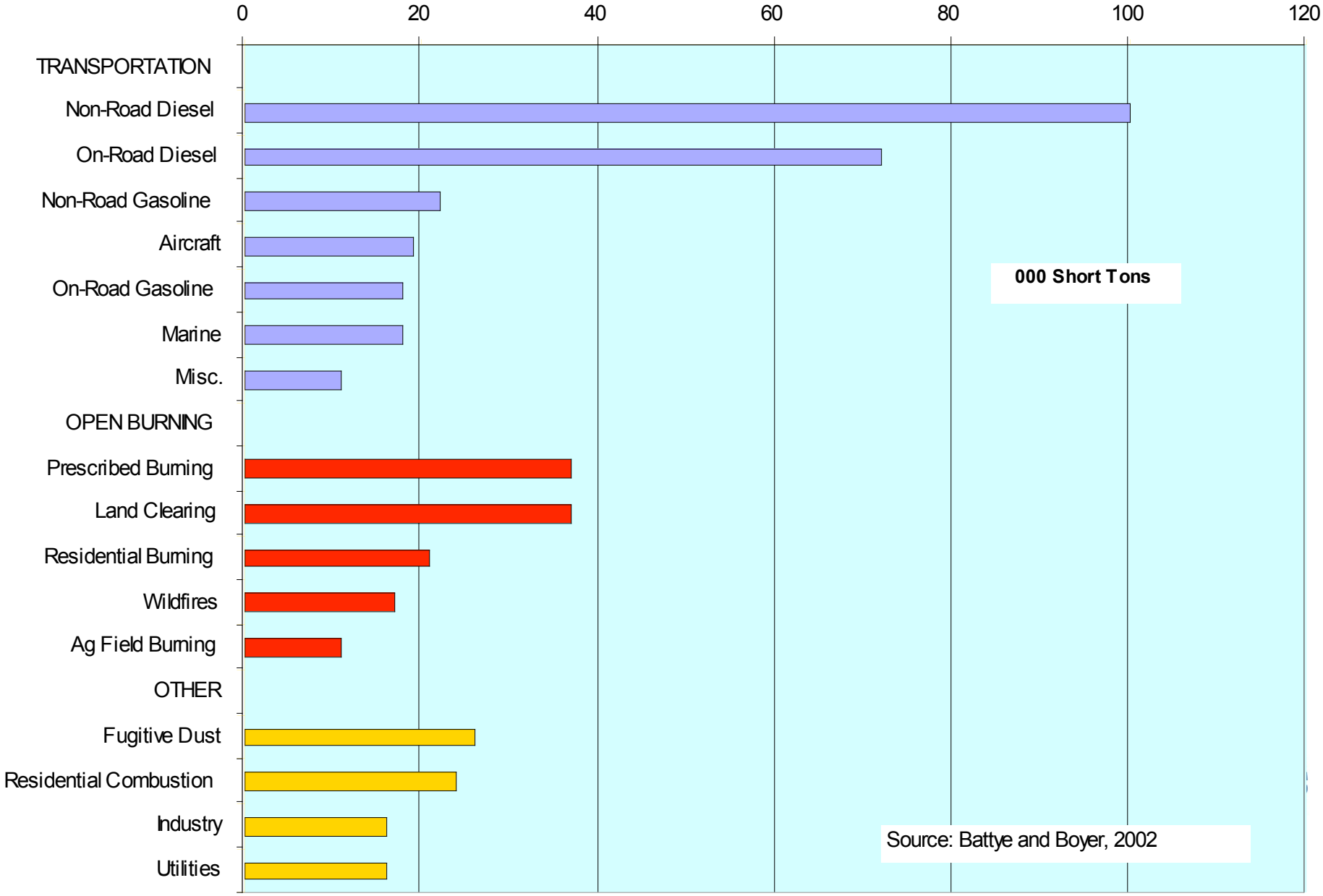
What is the appropriate role for BC/OC in climate change mitigation?



Annual U.S. BC Emissions, 1999

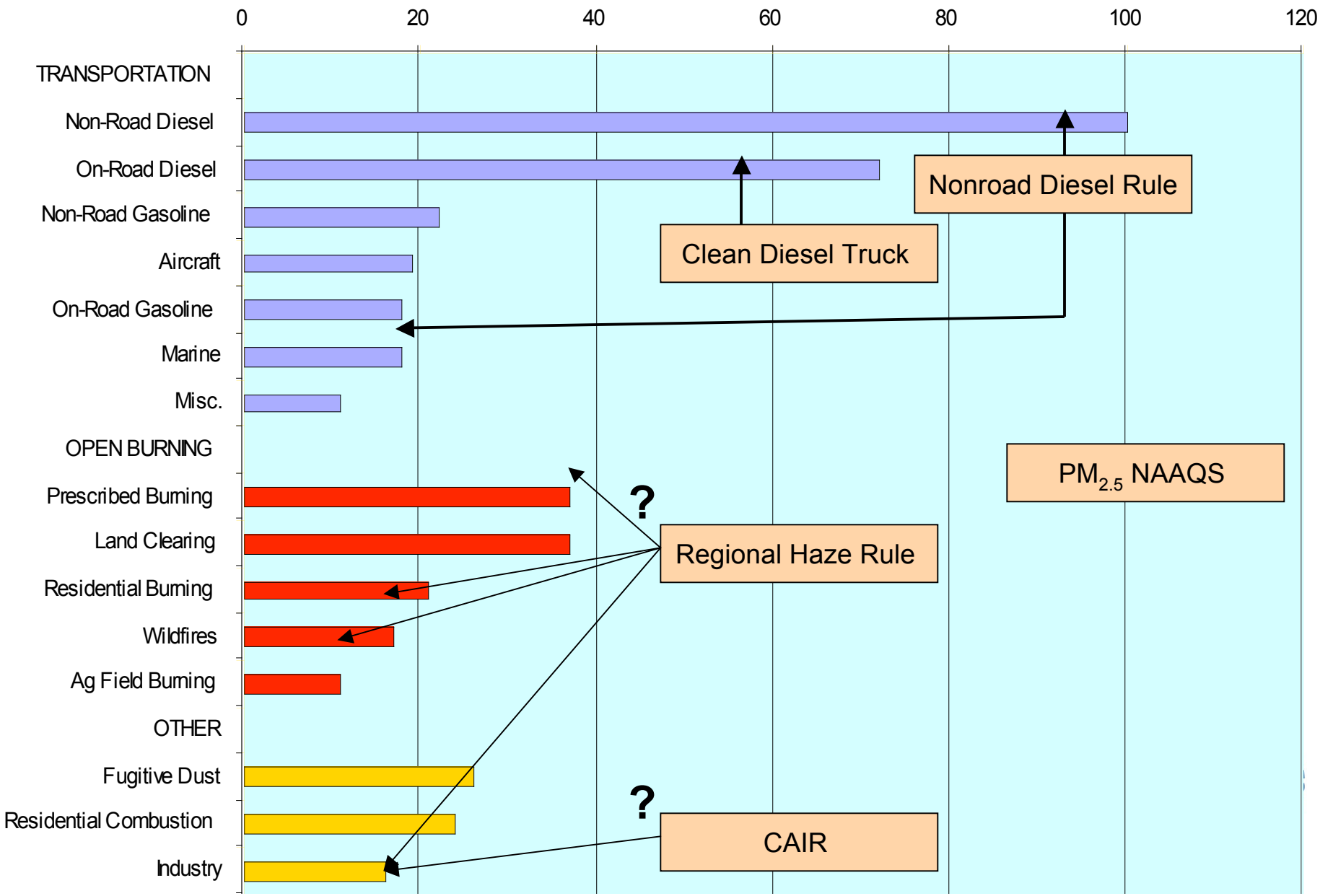
Derived from EPA 1999 National Emissions Inventory for PM2.5



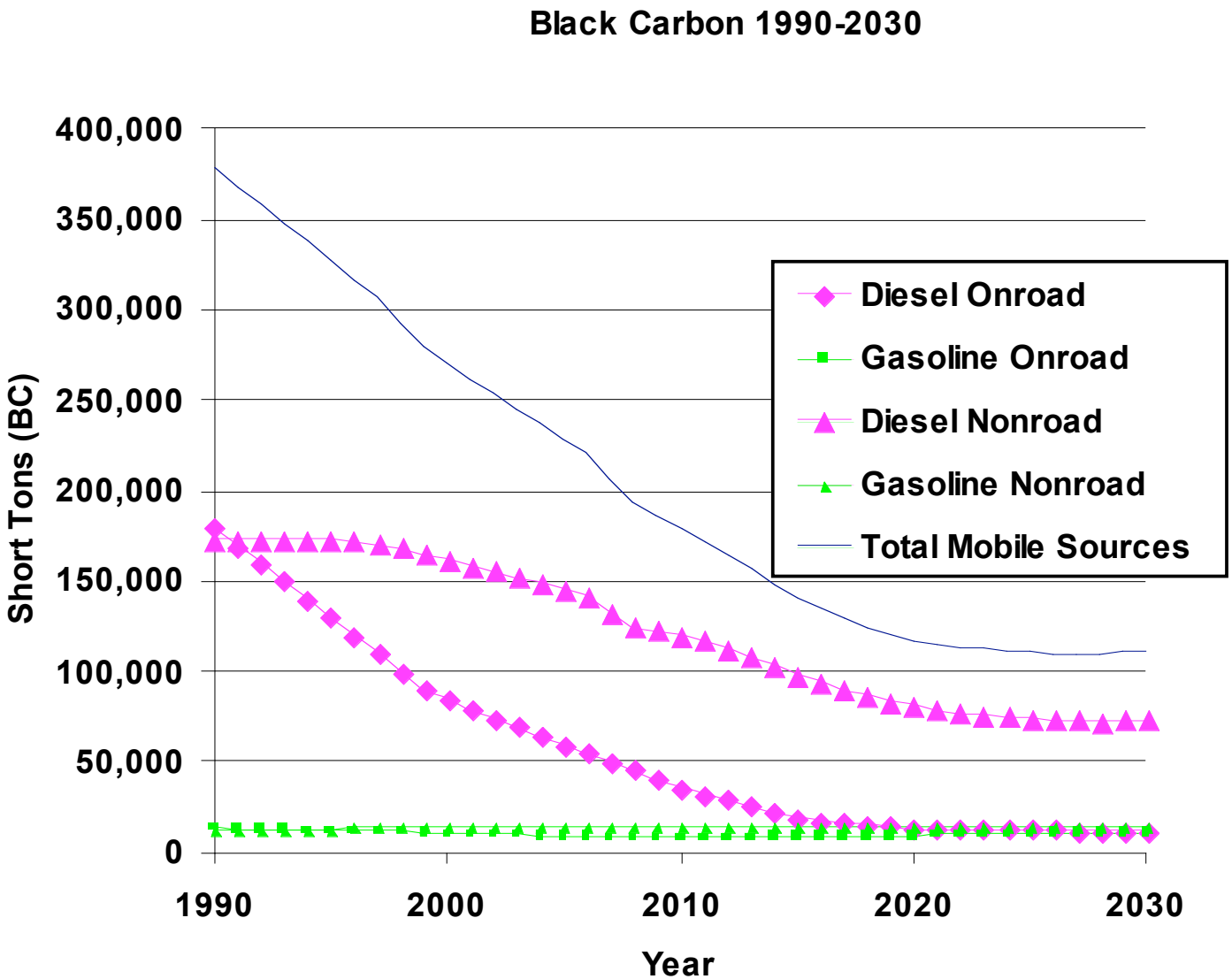
Key U.S. criteria pollutant control programs can influence BC/OC…to varying degrees

- National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$
  - At or below 65 μg/m^3 over 24-hr, and at or below 15 μg/m^3 on an average annual basis
  - 35% nation's population potentially in nonattainment areas
  - States required to reach attainment by 2010, with possible extensions
- Clean Air Nonroad Diesel Rule
  - PM & NOx standards for new nonroad engines + low sulfur diesel fuel for nonroad, locomotives and marine engines
  - Phase in beginning 2008; most engines must meet PM and NOx standards by 2014
- Clean Diesel Truck and Bus Rule
  - PM & NOx standards + low highway diesel sulfur fuel phased in 2006 – 2010 estimated to result in trucks/buses 90% cleaner than today's
- Regional Haze Rule
  - States submit and EPA approves implementation plans 2007-09
- NOx SIP Call
  - Requires 21 eastern states + District of Columbia to revise 'State Implementation Plans' to prohibit sources from emitting NOx in amounts that lead to non-attainment of national ambient O_3 standards; most states had to comply beginning 2004
- Clean Air Interstate Rule
  - Targets SO_2 and NOx in power sector
  - Full implementation expected to lead to 70% reduction
- Acid Rain Cap and Trade Program
  - SO_2 trading with phased reductions in power sector; phase I began 1995; phase II began 2000; affects existing units with greater than 25 megawatt capacity and all new units

Effects of Air Quality Policies on BC Inventory: Some expected effects readily quantifiable, others less clear



New PM & sulfur fuel standards expected to reduce BC emissions from largest sources: diesel vehicles



- Super emitters not accounted for
- BC % of $PM_{2.5}$ assumed constant over time
  - 60% for diesel
  - 40% for gasoline

Derived from $PM_{2.5}$ projections by EPA OTAQ using MOBILE6.2 and NONROAD

Tightening of vehicle emission controls will affect BC in other countries…*but car population/VMT may be a different story*

Country		95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10
European Union	Euro 1		Euro 2					Euro 3				Euro 4			Euro 5		
Bangladesh										Euro 2 (under discussion)							
Hong Kong, China		Euro 1		Euro 2				Euro 3					Euro 4				
India[a]								Euro 1				Euro 2					E3
India[b]						E1	Euro 2					Euro 3					
Indonesia												Euro 2					
Malaysia				Euro 1			Euro 2										
Nepal							Euro 1										
Philippines										Euro 1							
PRC[a]								Euro 1				Euro 2					
PRC[c]								Euro 1		Euro 2		Euro 3					
Singapore[e]	Euro 1							Euro 2									
Singapore[g]	Euro 1							Euro 2					Euro 4				
Sri Lanka										Euro 1							
Taipei,China						US Tier 1								US Tier 2 for diesel[d]			
Thailand	Euro 1							Euro 2			Euro 3					Euro4	
Viet Nam[e]					Euro 1												
Viet Nam[f]												Euro 1					

[a] Entire country
[b] Delhi and other cities; Euro 2 introduced in Mumbai, Kolkata and Chennai in 2001; Euro 2 in Bangalore, Hyderabad, Khampur, Pune and Ahmedabad in 2003, Euro 3 to be introduced in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad in 2005
[c] Beijing and Shanghai
[d] Gasoline vehicles under consideration
[e] for gasoline vehicles
[f] for diesel vehicles
[g] for all types of diesel vehicles

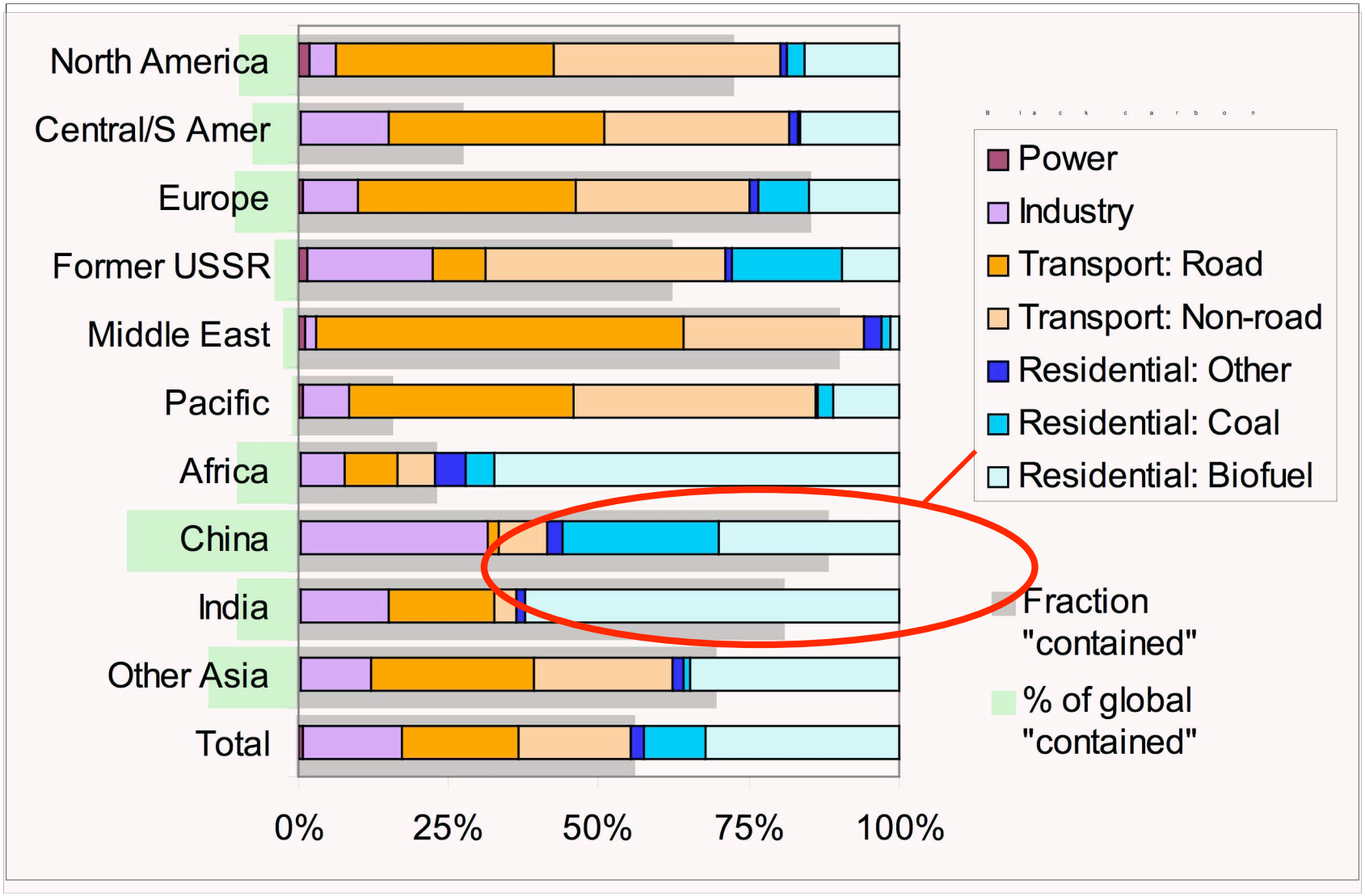
Source: Huizenga 2004

Example of PM_{10} projections for Transport for OECD Europe

Year	Road Diesel Exhaust		Road Gasoline Exhaust		Total Road Exhaust	
	Emissions (Gg)	% Change from 1995	Emissions (Gg)	% Change from 1995	Emissions (Gg)	% Change from 1995
1995	250	0	70	0	320	0
2000	180	-28	40	-43	220	-31
2005	120	-52	30	-57	150	-53
2010	70	-72	35	-50	105	-67
2015	50	-80	40	-42	90	-72

Source: as Predicted by CONCAWE in Umweltbundesamt, 2004

Black Carbon Estimates by Country & Region

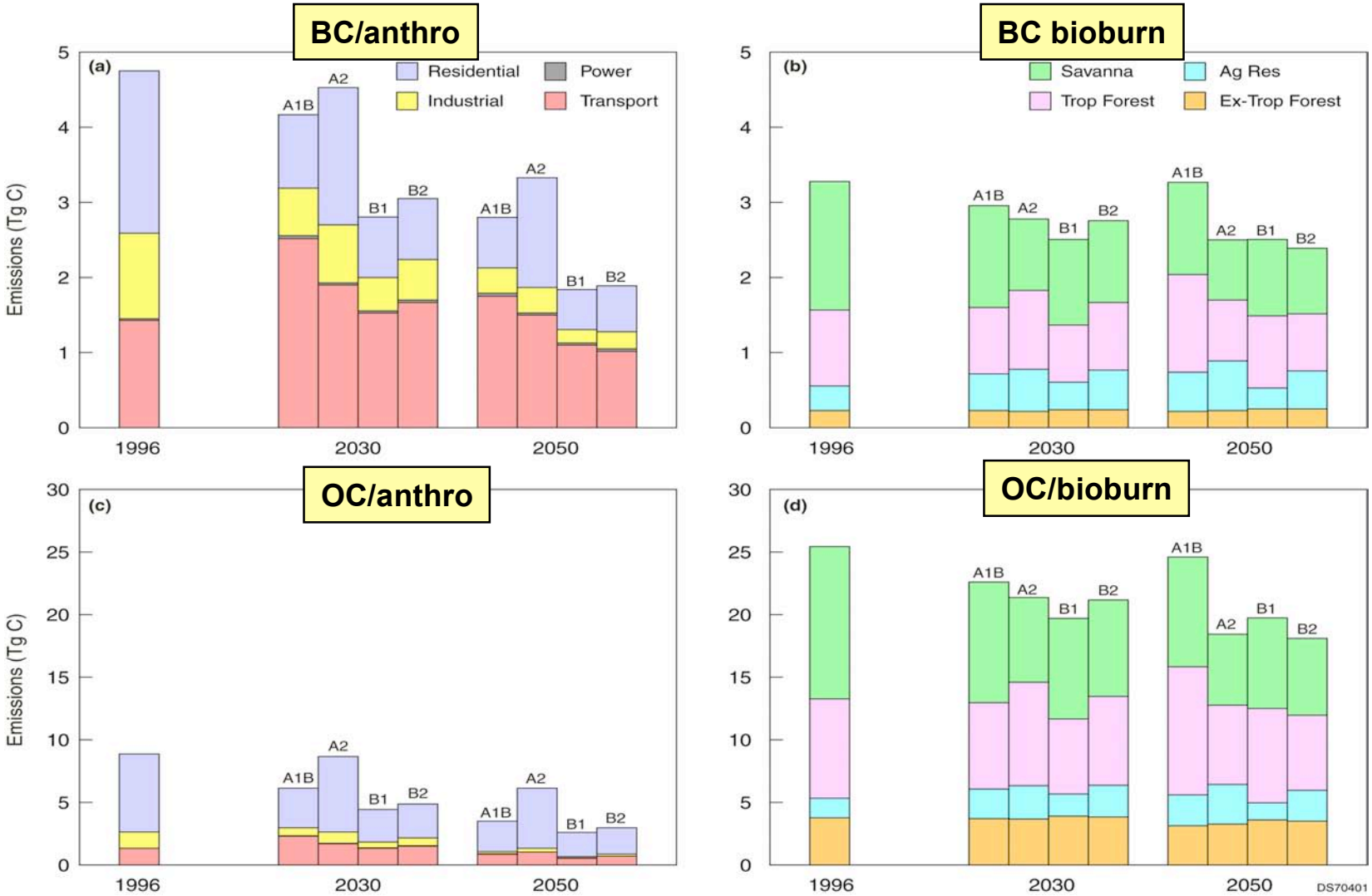


Source: Bond et al. (2004) "A technology-based global inventory of black and organic carbon emissions from combustion," *J. Geophys. Res.*

Open Biomass Burning Emissions of BC/OC

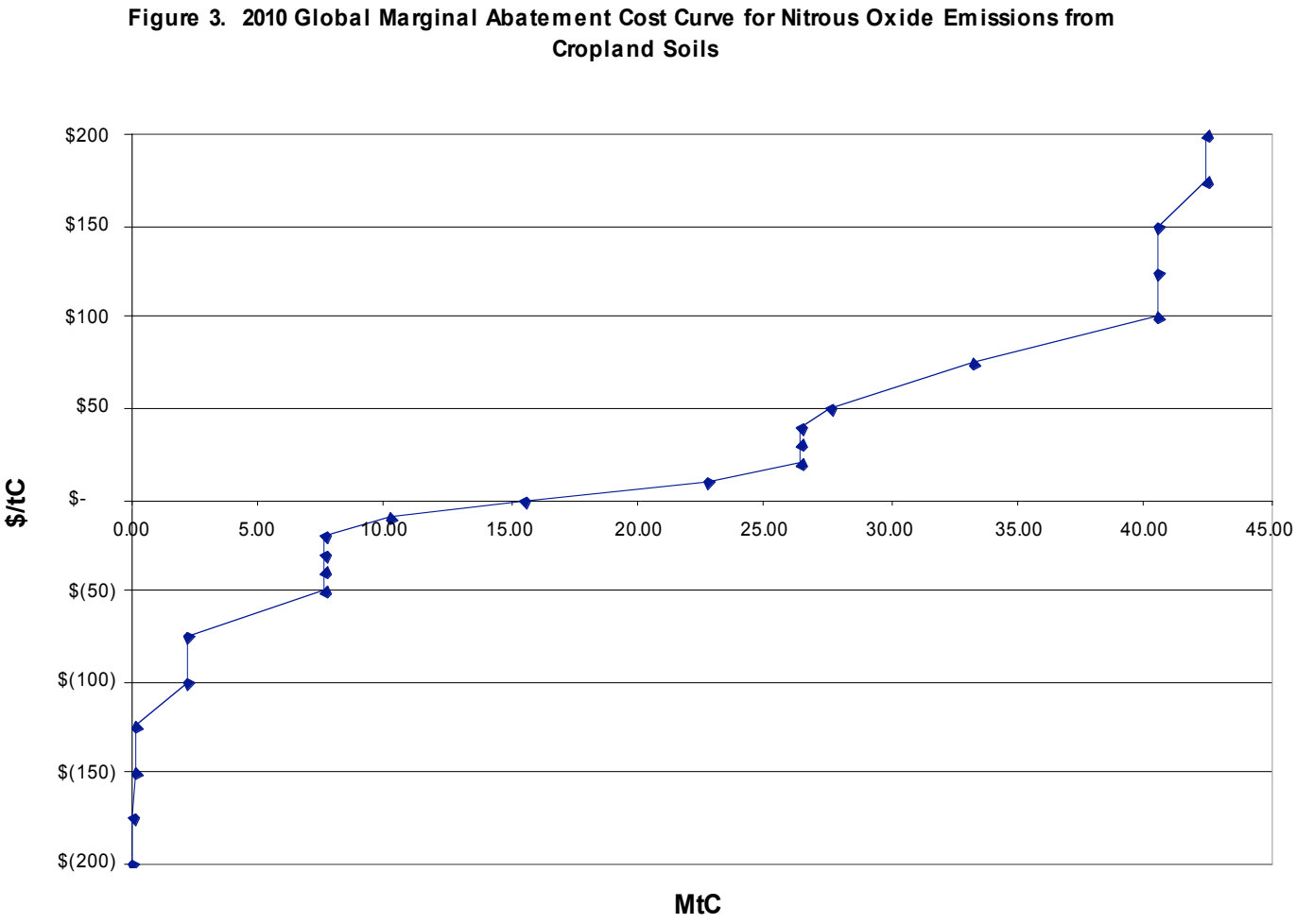
- Less controlled, no single policy lever
- In U.S., if diesel emissions decline as expected, open burning likely to become largest source
- Significant source in other regions (e.g., savannah burning in Africa, forest fires in Latin America)

Projecting Forward for All Sectors…general decline appears likely



Source: Streets, D. et al. 2004; Presented by D. Streets, Workshop on Global Air Pollution Trends, January, 2005

Mitigation Beyond BAU: Developing Cost Curves for BC/OC… only preliminary work to date



Estimating BC/OC mitigation from open biomass burning with associated costs…proving difficult

Barriers to mitigating BC/OC from practice of prescribed burning in the US:

Technical	• Lack of equipment, and appropriately sized equipment • Access to project areas due to terrain, lack of roads
Environmental	• Water quality degradation due to increased runoff from soil compaction, heavy equipment • Removal of nutrients on-site which burning would replenish
Economic	• Lack of markets for small diameter biomass • Equipment and labor costs • Transportation costs moving material to market
Socio-political	• Long history of using prescribed burns; difficult to change

Source: Jones & Stokes (2004) Nonburning Alternatives to Prescribed Fire on Wildlands in the Western United States

…Now gathering preliminary, first-order estimates of BC/OC mitigation for open biomass in Latin America

Mitigation Target	Mitigation Activity	Applicability/ Biomass Type	Mean Cumulative Emission Reduction (Ton BC)	Mean Marginal Mitigation Cost ($1996/Ton BC)
Land-clearing burn	Hay harvesting	Savannah	34,700	-688,000
	Grazing	Savannah	44,400	-157,000
	Timber harvesting	Forest	153,000	-7,450
	Use of biomass for energy production	Forest	260,000	-3,170
Prescribed burn	Burn before large fuels cure	Forest	263,000	193
	Burn before precipitation	Forest	267,000	198
	Burn when there is high moisture in large woody fuels	Forest	270,000	198
	Backing fires	Forest	275,000	127
	Burn when litter and/or duff are moist	Forest	277,000	327
	Burn before litter fall	Forest	279,000	327
	Burn in pile	Forest	280,000	654
Land clearing burn	Conservation	Forest	354,000	3580
Prescribed burn	Backing fires	Savannah	371,000	7770
	Mosaic burning	Savannah	384,000	10,400
	Thinning and cutting leaving biomass on the floor	Forest	388,000	29,200
Land clearing burn	Conservation	Savannah	454,000	241,000

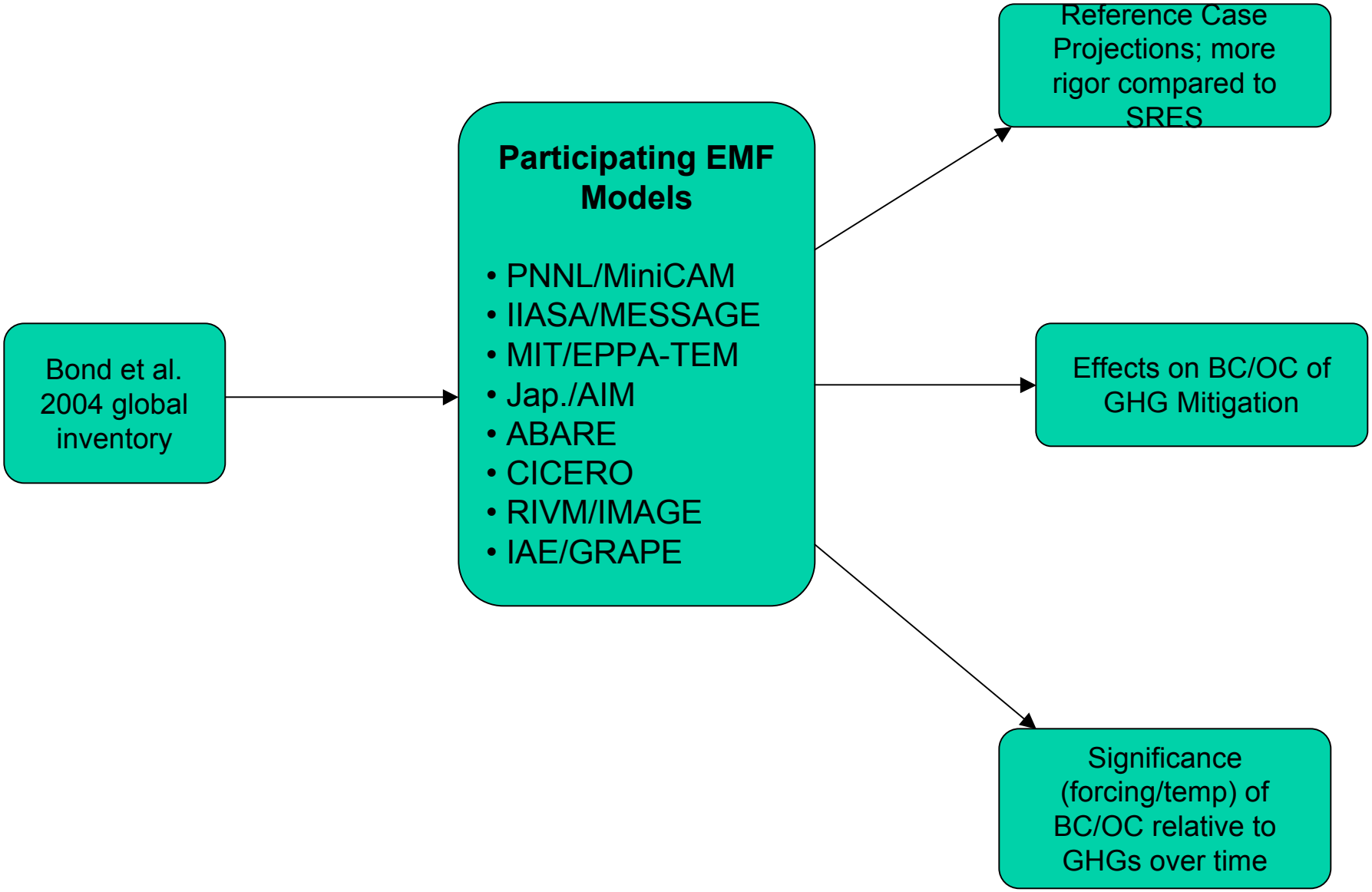
Stanford Energy Modeling Forum, EMF-22 Black Carbon Subgroup

§ Improve emission projections
- IPCC SRES did not include BC/OC
- IPCC TAR used simplified scaling with CO/SO_2 emissions
- Will unlikely be included in IPCC AR4

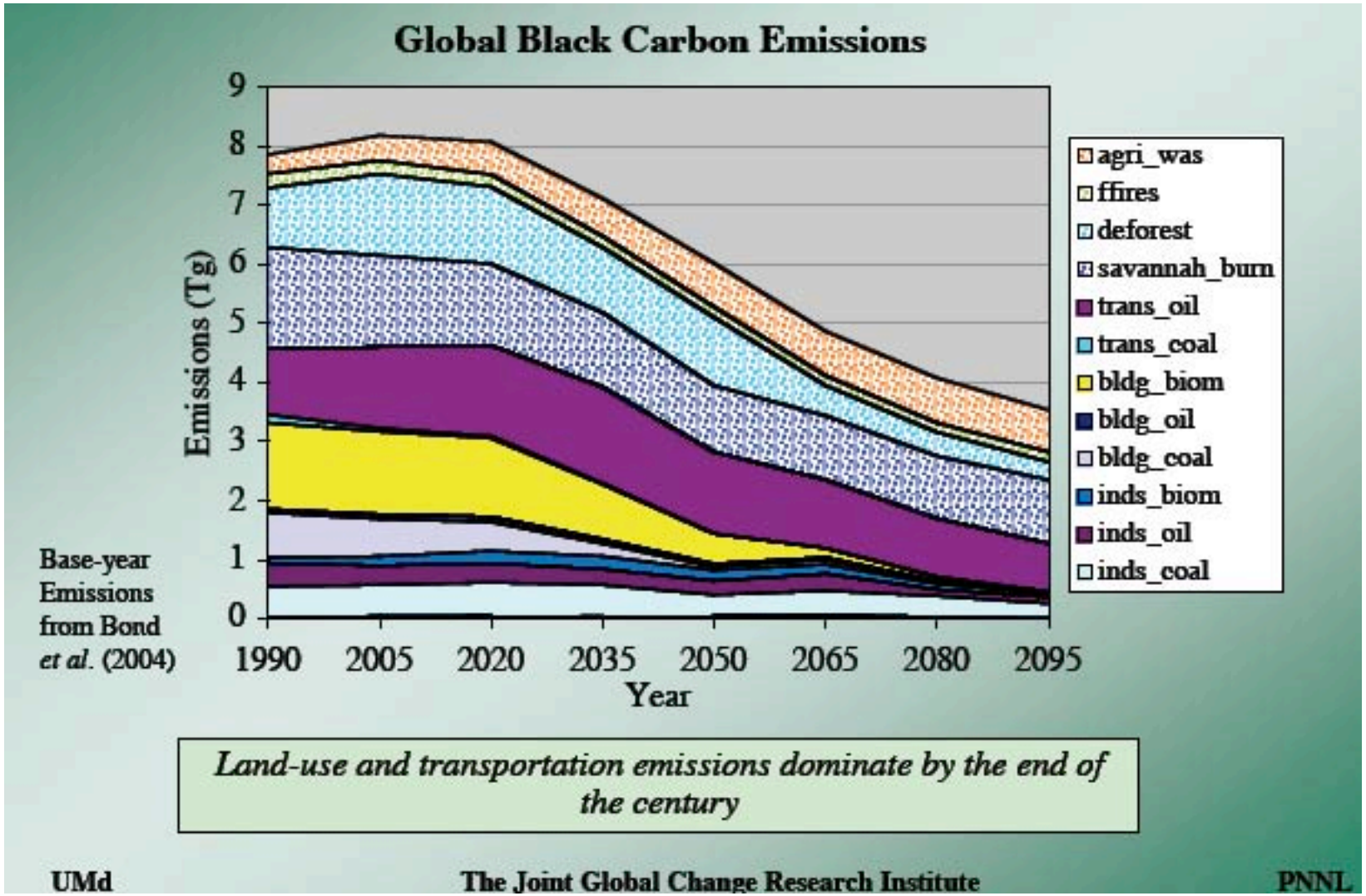
§ Improve understanding of synergies/tradeoffs of GHG mitigation w/ BC/OC
- Models participating in EMF can capture multiple interactions across gases/sectors, over long term

§ Aiming for initial scenario comparison by Fall '05

Plan for BC/OC Subgroup in EMF-22



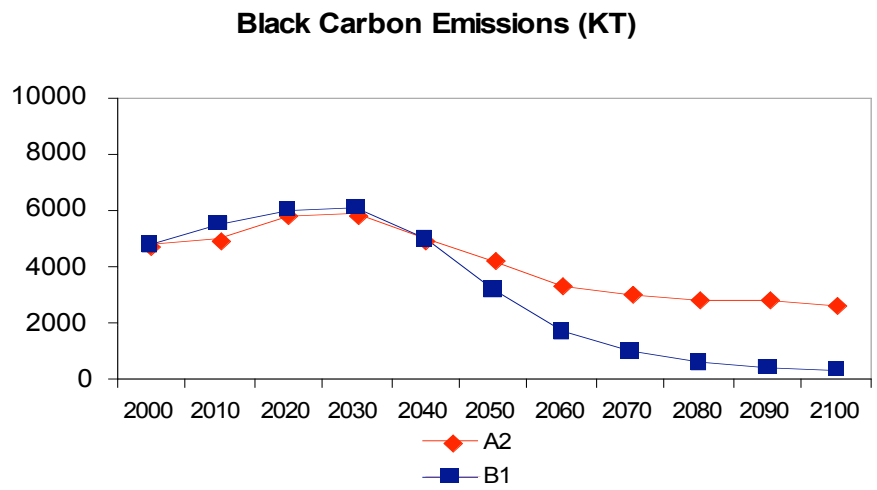
Example of MiniCAM projections

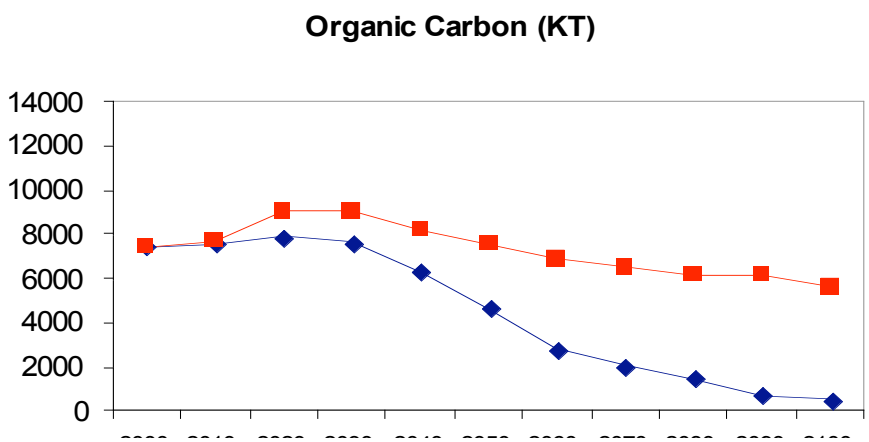


Source: S. Smith, PNNL, draft manuscript

Example of MESSAGE projections

(Fossil fuel and Biomass*)





Presented by Rao et al, IIASA, 28 Jan 05

**Does not include emissions from open vegetative burning*

Considerations on Including BC/OC into Climate Mitigation Strategies

- Metrics comparing long-lived GHGs w/ BC/OC
  - Who needs them, for what purpose?
    - For analysis: OK
      - We need to continue to improve our understanding of relative climatic importance
      - GWPs not necessary for comparative climate modeling
    - For emissions trading/offsets w/ GHGs: Let's Be Very Careful!!
      - Complexities of net BC effects captured in single number?
      - Localized health & climatic effects
      - Separate goal (outside trading basket of GHGs) would not require GWP-like metric (e.g., vehicle standards)
      - OC?

Considerations on Including BC/OC into Climate Mitigation Strategies

- Feasibility
  - Additional complexity
  - Emission reduction verification; inventory guidance
  - ‘Burden shifting’