

Markus Amann

International Institute for Applied Systems Analysis (IIASA)



Future scenarios of anthropogenic emissions

Atmospheric Chemistry, Climate, and Transboundary Air Pollution:
A Joint TF HTAP / NAS / AC&C Workshop
June 9-12, 2008, Washington DC, USA

Factors determining future emissions



- Development of driving forces of emissions
 - Economic development and population growth,
 - lifestyles,
 - energy use (influenced by energy prices, policy, etc.)
 - transport demand,
 - agriculture,
 - etc.
- Enforcement of existing and additional emission control legislation

Global emission projections of air pollutants from anthropogenic sources



Only few long-term projections available at the global scale.

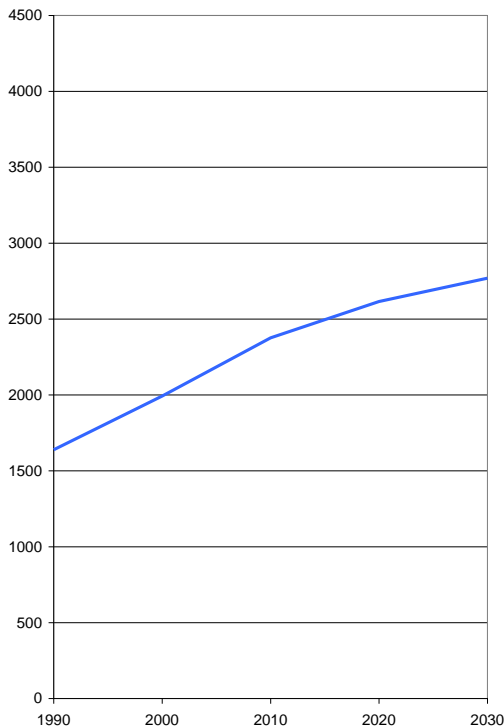
- IPCC SRES:
 - Developed in 1990s, up to 2100
 - Four storylines with endogenous activity projections
 - Constant 1990 technologies for air pollution controls
- Family of global RAINS/GAINS projections by IIASA
 - Activity projections exogenous, reflecting governmental policy targets for economic development, up to 2030
 - Taking into account changes in emission factors due to emission control legislation
 - Alternative set of long-term scenarios up to 2100 employing SRES activity projections, with current emission control legislation (for Royal Society)
- Blind spots for emissions from shipping and aviation (and biogenic sources)

GAINS emission projection of Cofala et al, 2007 (Atm. Env.)

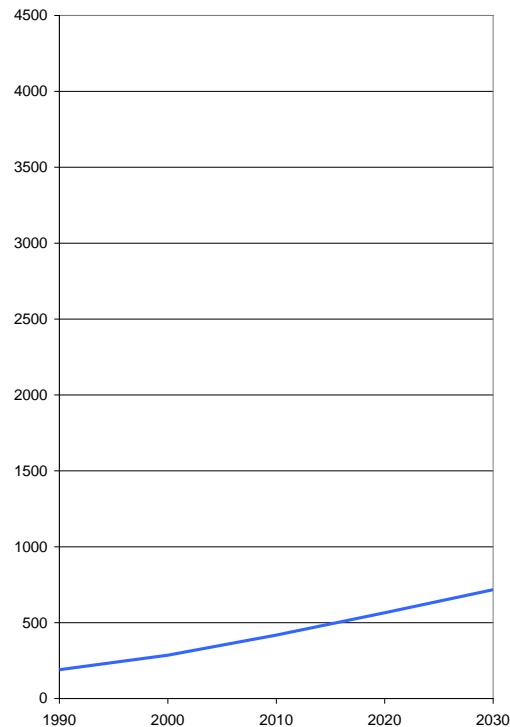


- Sources of activity projections:
 - Europe, China, India: GAINS model with national projections
 - North America, Russia: National sources
 - Other continents: IPCC SRES B2 scenario
- Local emission factors
- Implementation of current national emission control legislation, no additional measures assumed

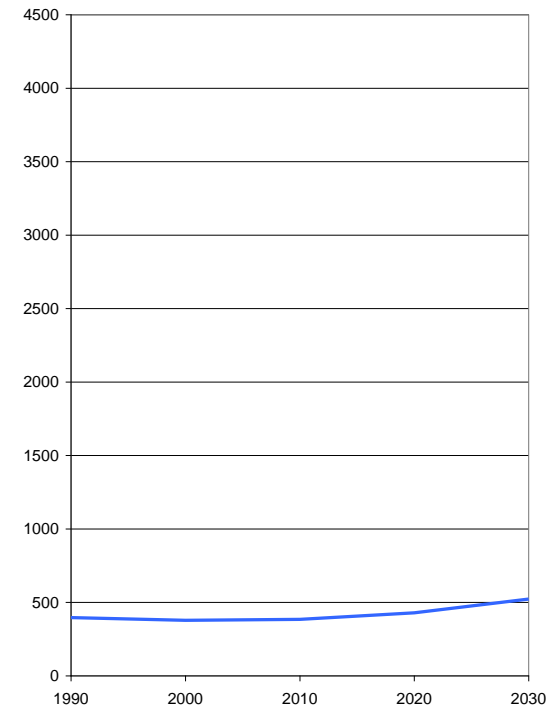
Driving forces for global emissions 1990-2030: Economic wealth (GDP/capita) (Governmental and UN projections)



OECD



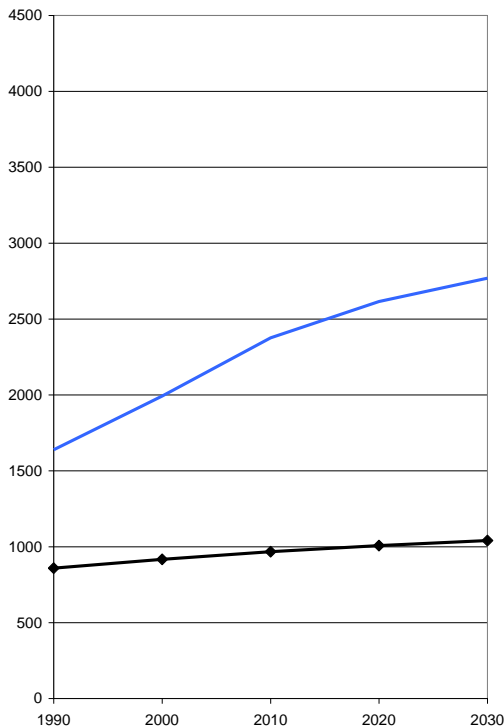
Asia



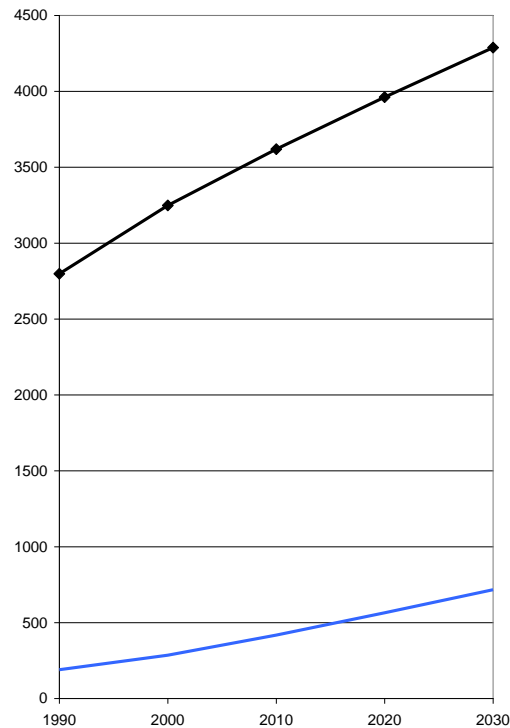
Rest of world

□ GDP (PPP) ◆ Population — GDP/cap (/10)

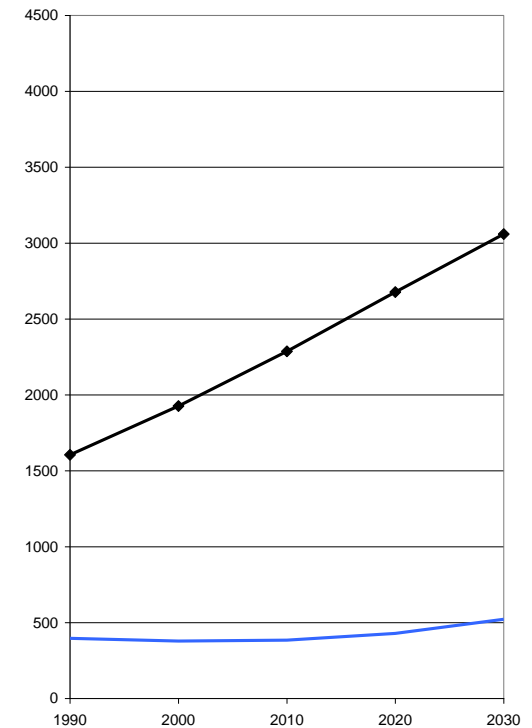
Driving forces for global emissions 1990-2030: Population and per-capita income



OECD



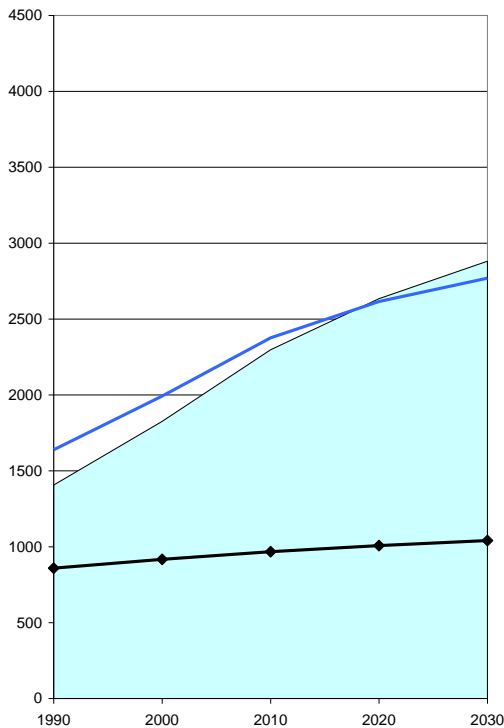
Asia



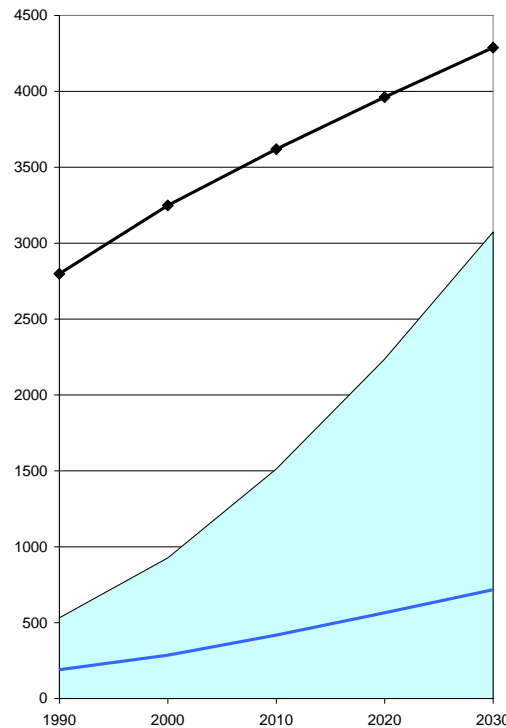
Rest of world

□ GDP (PPP) ◆ Population — GDP/cap (/10)

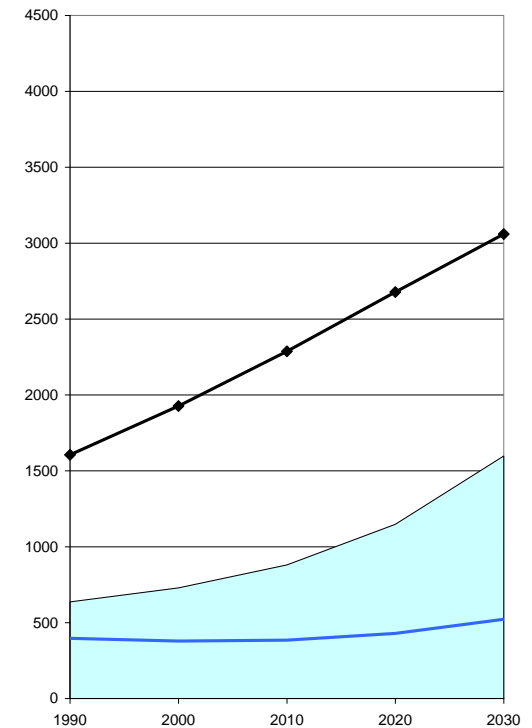
Driving forces for global emissions 1990-2030: GDP (PPP) (Governmental and UN projections)



OECD



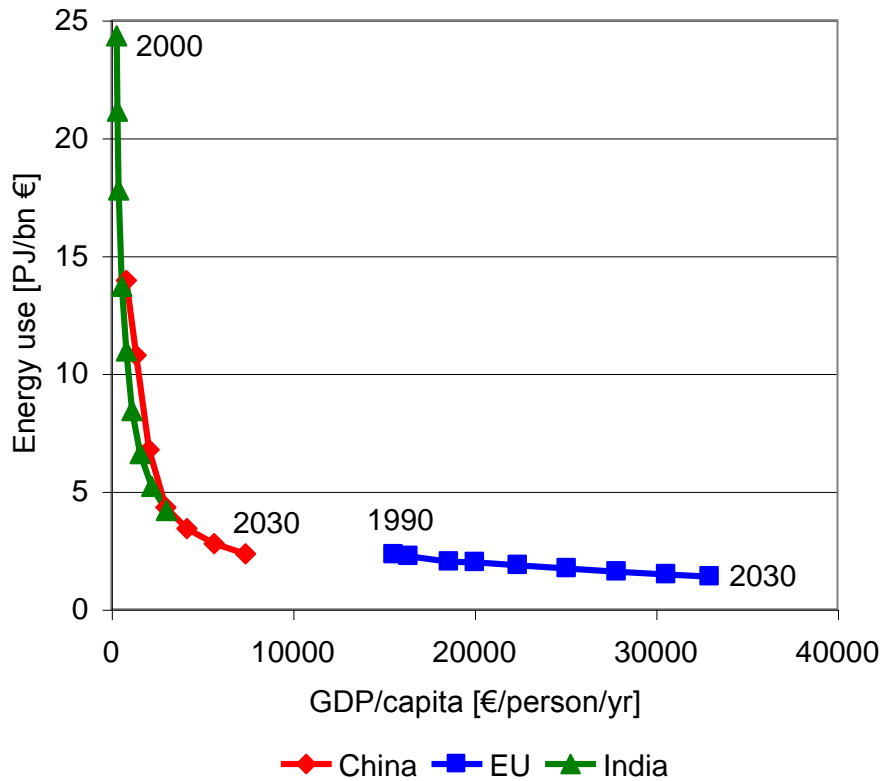
Asia



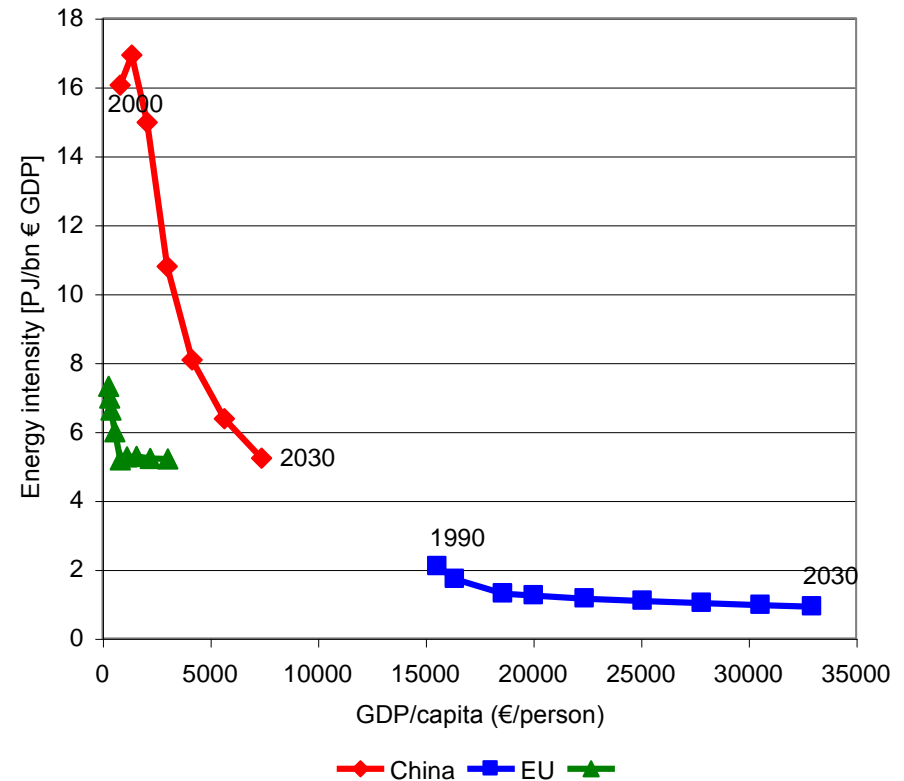
Rest of world

GDP (PPP)
 Population
 GDP/cap (/10)

Energy intensity vs. economic wealth of the household and industrial sectors, 1990-2030



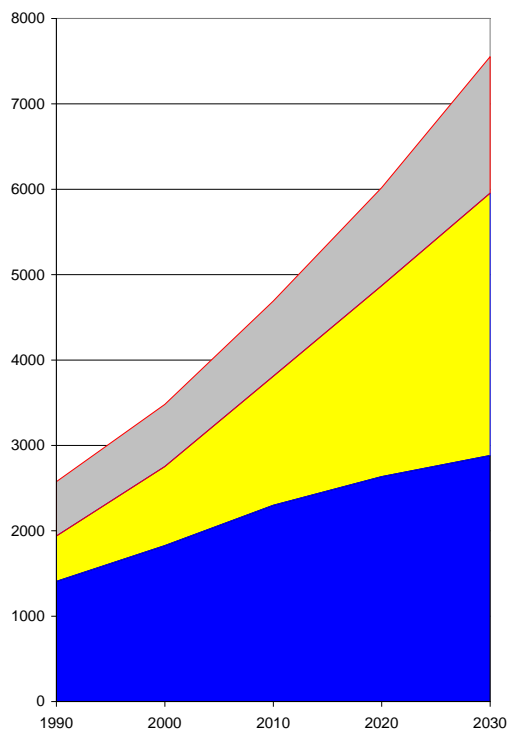
Domestic sector



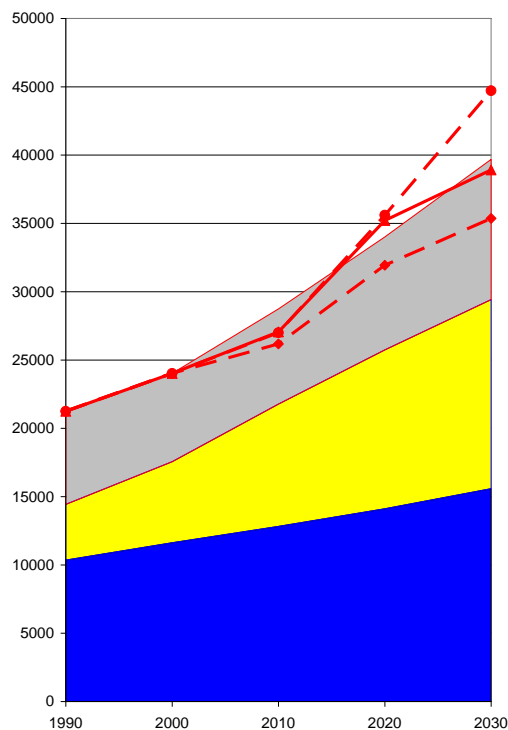
Industry

Projections of global GHG emissions

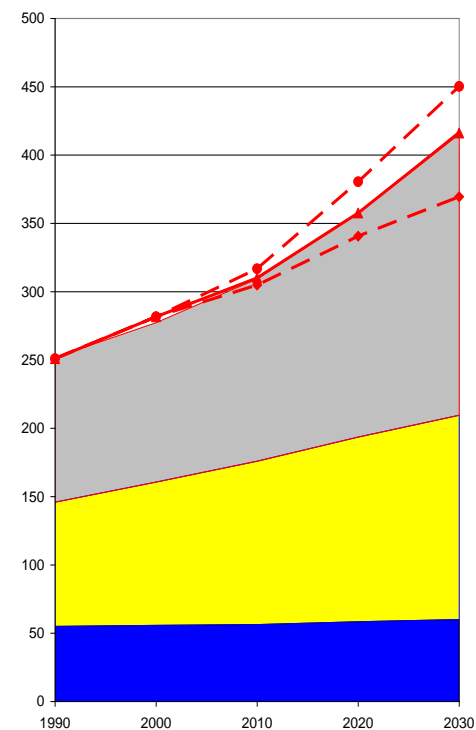
GAINS vs SRES estimates



GDP



CO₂



CH₄

■ OECD ■ Asia ■ Rest of world —◆— SRES B1 —▲— SRES B2 —●— SRES A2

Emission control legislation for vehicles

Source: Clean Air Initiative Asia



| Country | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 |
|-------------------------|----|--------|----|----|----|--------|----|----|----|--------|----|----|----|--------|----|----|----|----|----|----|
| European Union | E1 | Euro 2 | | | | Euro 3 | | | | Euro 4 | | | | Euro 5 | | | | E6 | | |
| Bangladesh ^a | | | | | | | | | | | | | | | | | | | | |
| Bangladesh ^b | | | | | | | | | | | | | | | | | | | | |
| Hong Kong, China | | | | | | | | | | | | | | | | | | | | |
| India ^c | | | | | | | | | | | | | | | | | | | | |
| India ^d | | | | | | | | | | | | | | | | | | | | |
| Indonesia | | | | | | | | | | | | | | | | | | | | |
| Malaysia | | | | | | | | | | | | | | | | | | | | |
| Nepal | | | | | | | | | | | | | | | | | | | | |
| Pakistan | | | | | | | | | | | | | | | | | | | | |
| Philippines | | | | | | | | | | | | | | | | | | | | |
| PRC ^a | | | | | | | | | | | | | | | | | | | | |
| PRC ^e | | | | | | | | | | | | | | | | | | | | |
| Singapore ^a | | | | | | | | | | | | | | | | | | | | |
| Singapore ^b | | | | | | | | | | | | | | | | | | | | |
| Sri Lanka | | | | | | | | | | | | | | | | | | | | |
| Taipei, China | | | | | | | | | | | | | | | | | | | | |
| Thailand | | | | | | | | | | | | | | | | | | | | |
| Viet Nam | | | | | | | | | | | | | | | | | | | | |

Notes:

Italics – under discussion

a – gasoline

b – diesel

c – Entire country

d – Delhi, Chennai, Mumbai, Kolkata, Bangalore, Hyderabad, Agra, Surat, Pune, Kanpur, Ahmedabad, Sholapur, Lucknow; Other cities in India are in Euro 2

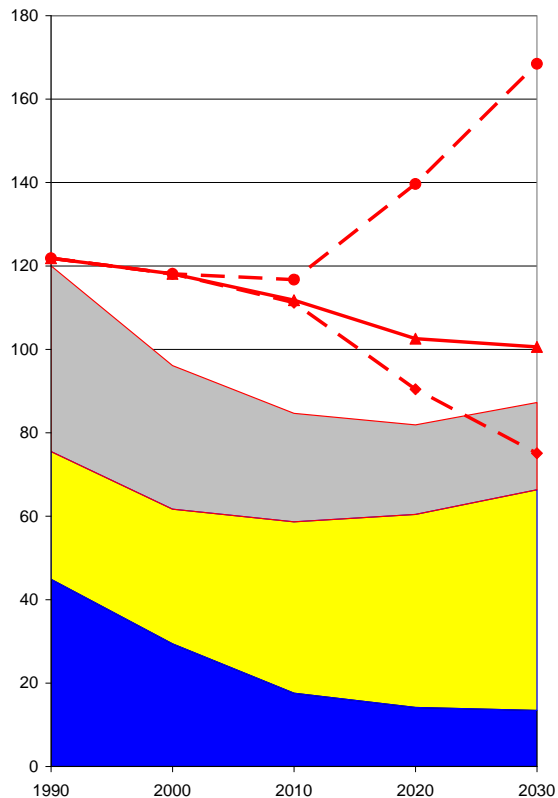
e – Beijing and Guangzhou (as of 01 September 2006) have adopted Euro 3 standards; Shanghai has requested the approval of the State Council for implementation of Euro 3

f – Euro 4 for gasoline vehicles and California ULEV standards for diesel vehicles

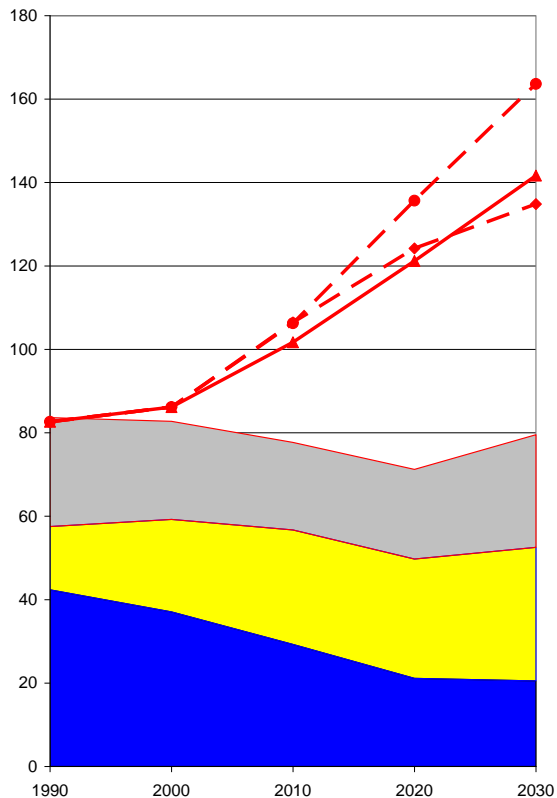
g – Gasoline vehicles under consideration

Projections of global air pollution emissions

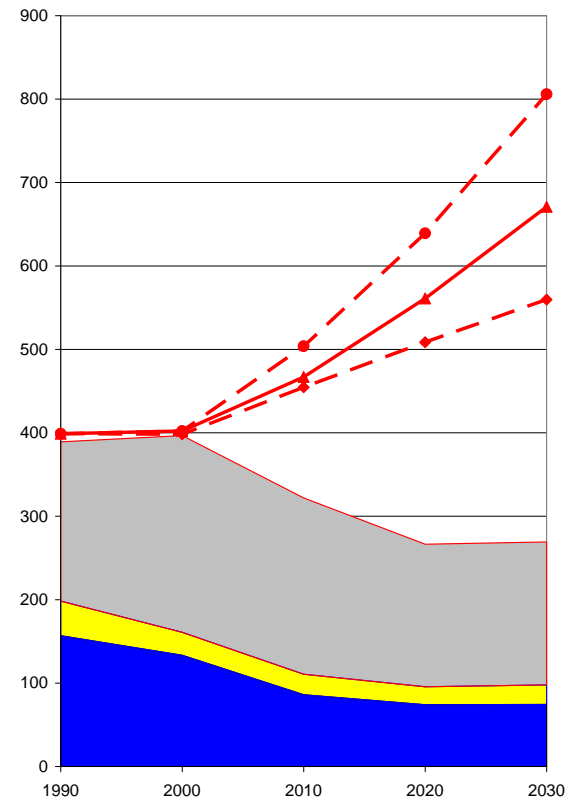
GAINS vs SRES estimates



SO₂



NO_x

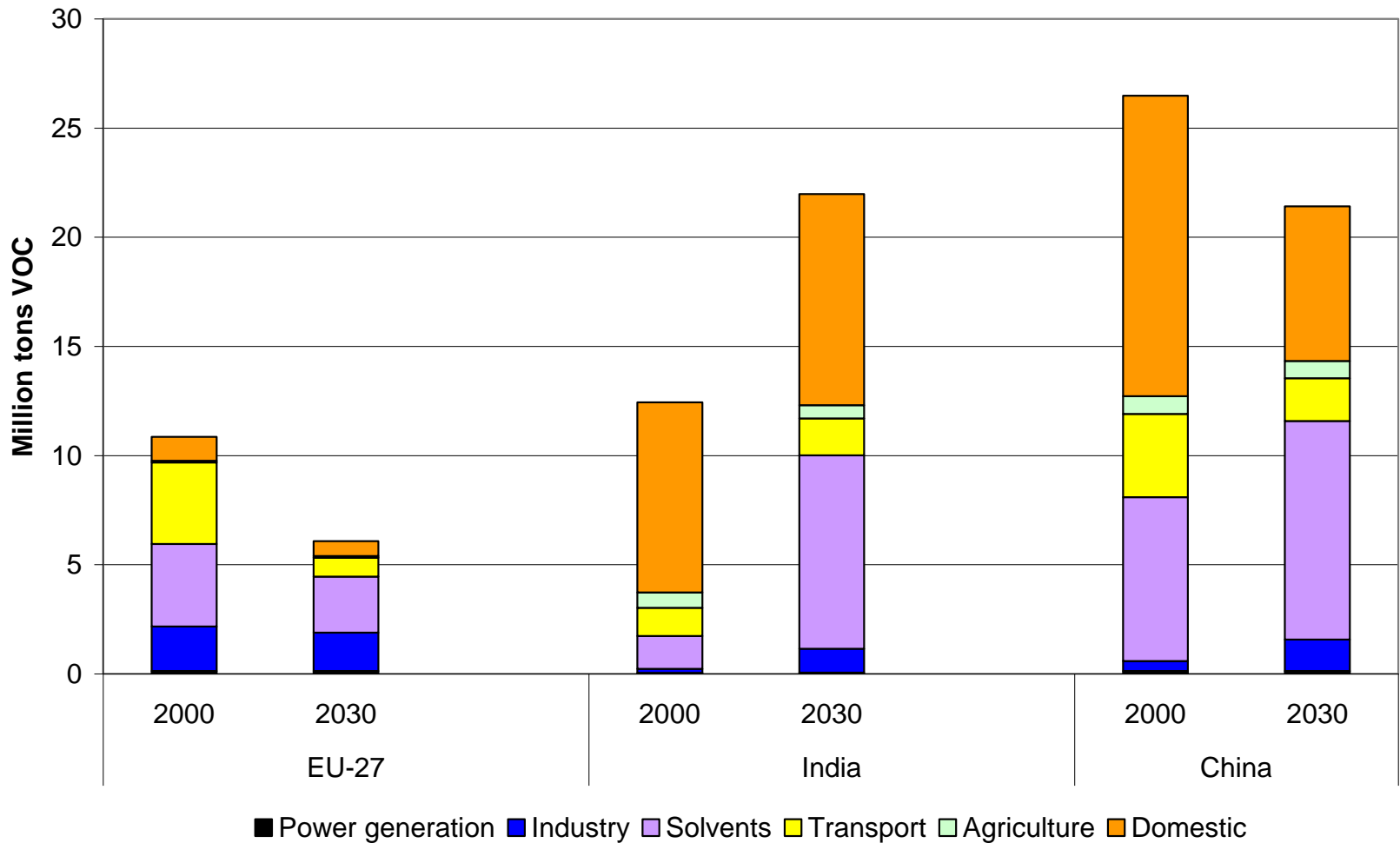


CO

■ OECD ■ Asia ■ Rest of world —◆— SRES B1 —▲— SRES B2 —●— SRES A2

Sources of anthropogenic VOC emissions

EU-27 - India - China, 2000 and 2030

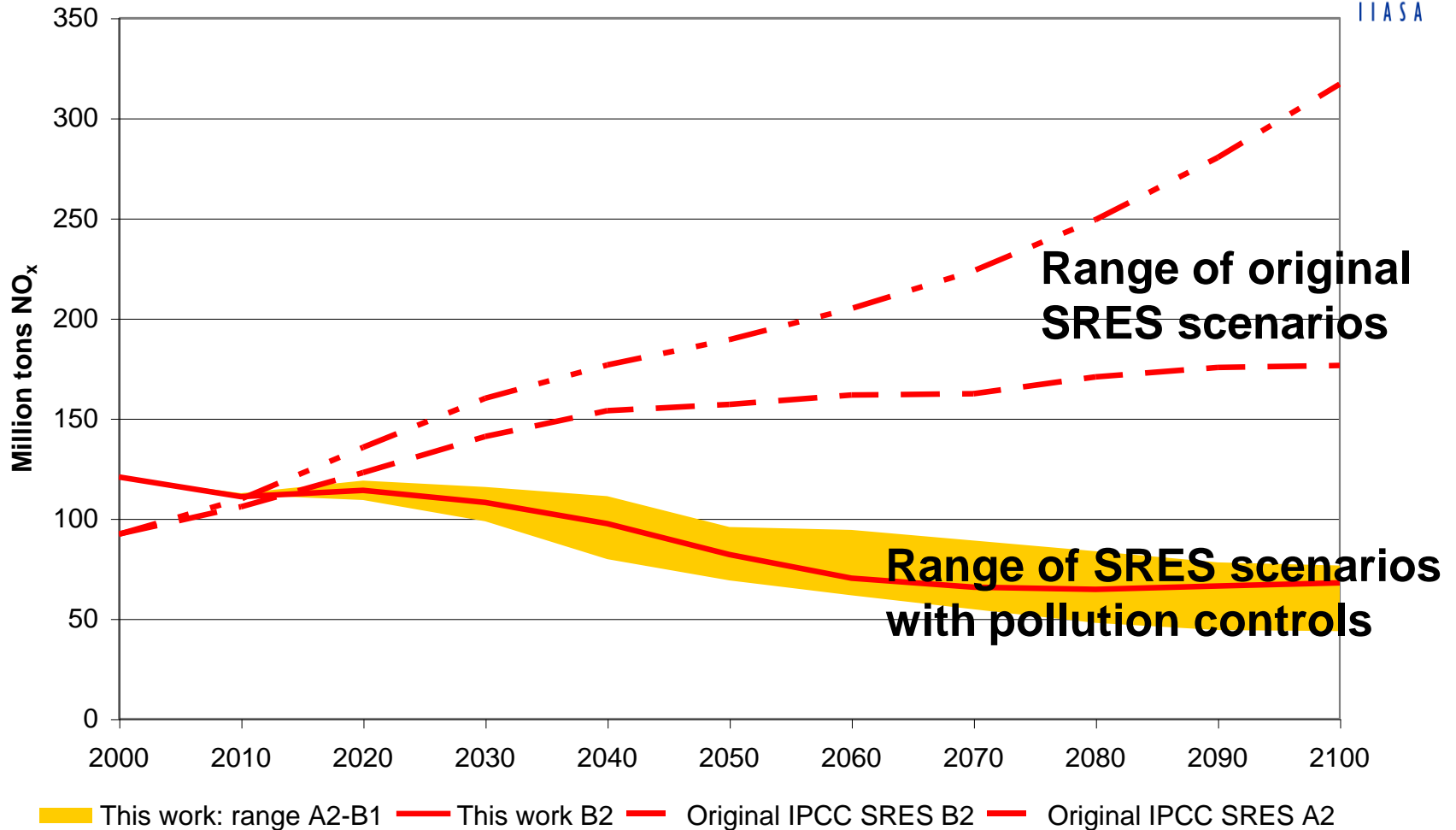


Key uncertainties



- How accurate are economic development plans (and thus the implied activity projections)?

NO_x emissions for alternative economic and pollution control projections

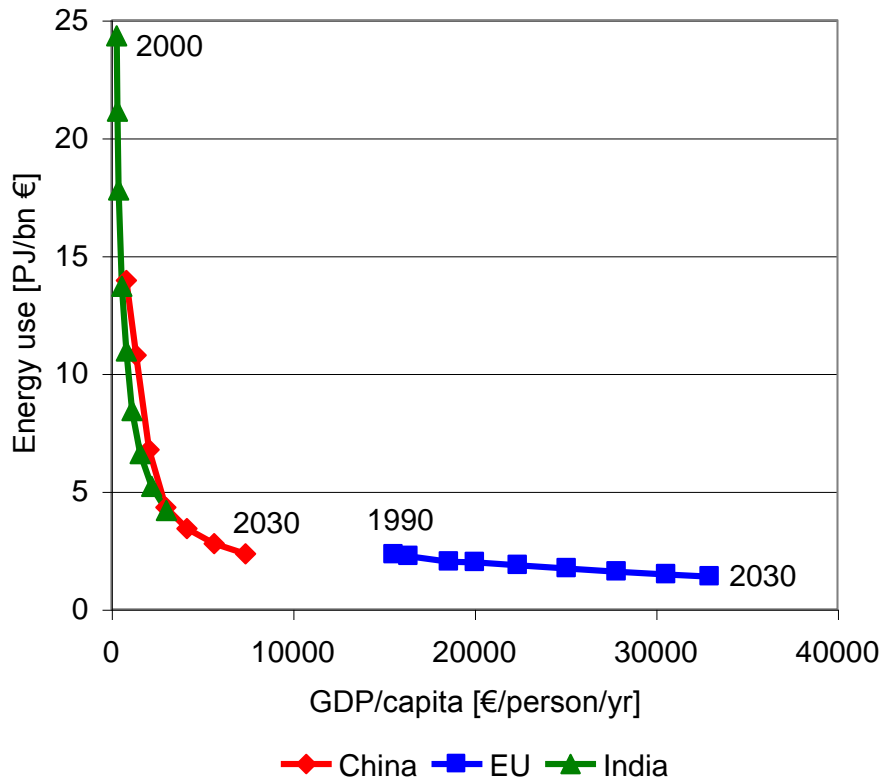


Key uncertainties

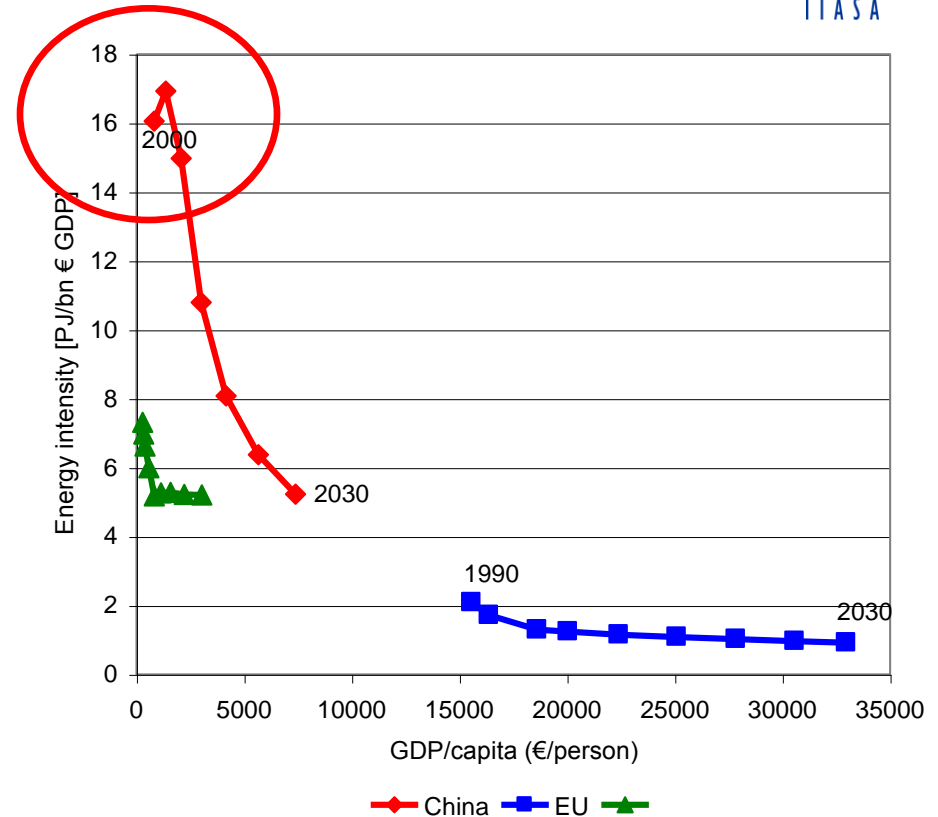


- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?

Energy intensity vs. economic wealth of the household and industrial sectors, 1990-2030

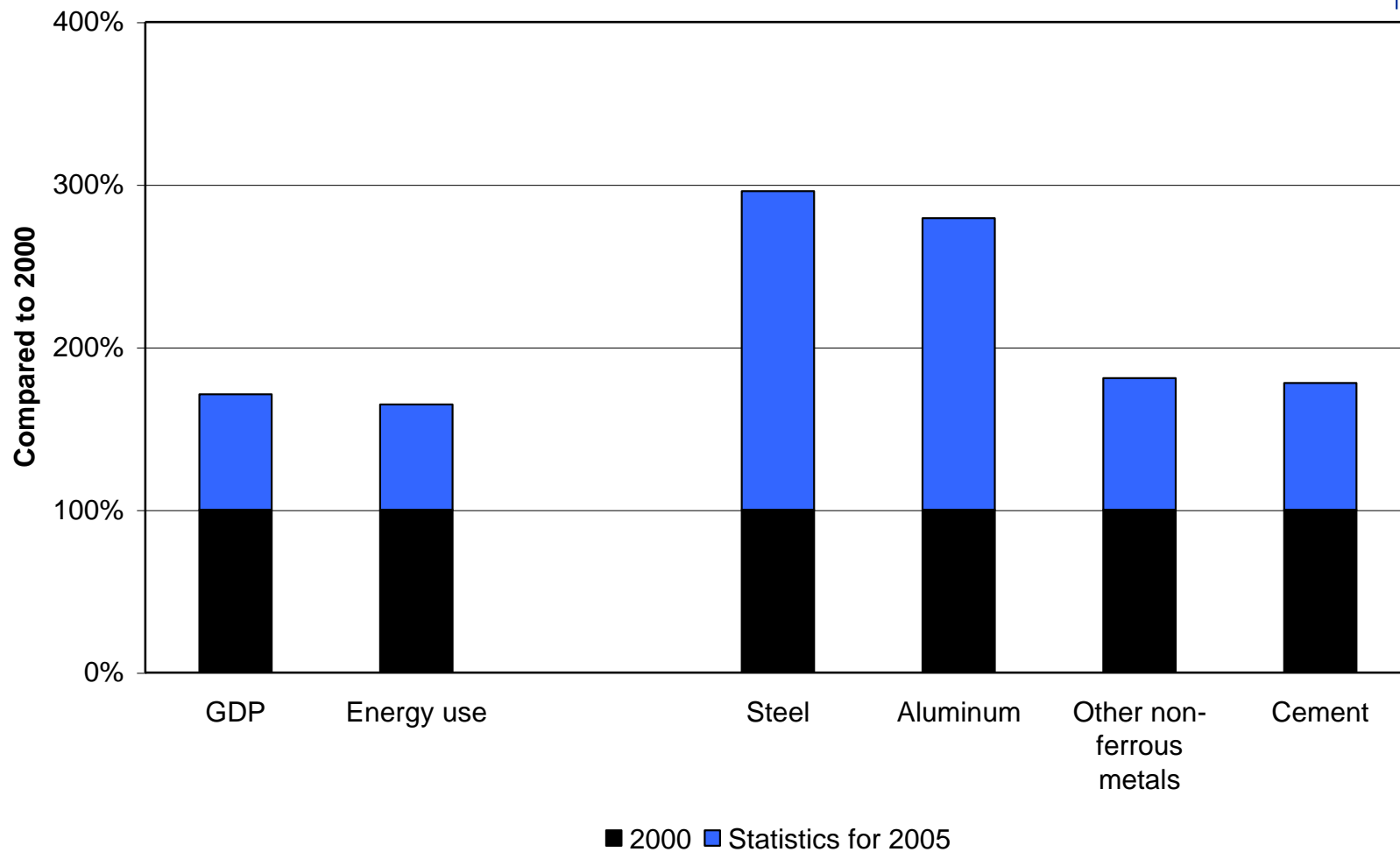


Domestic sector

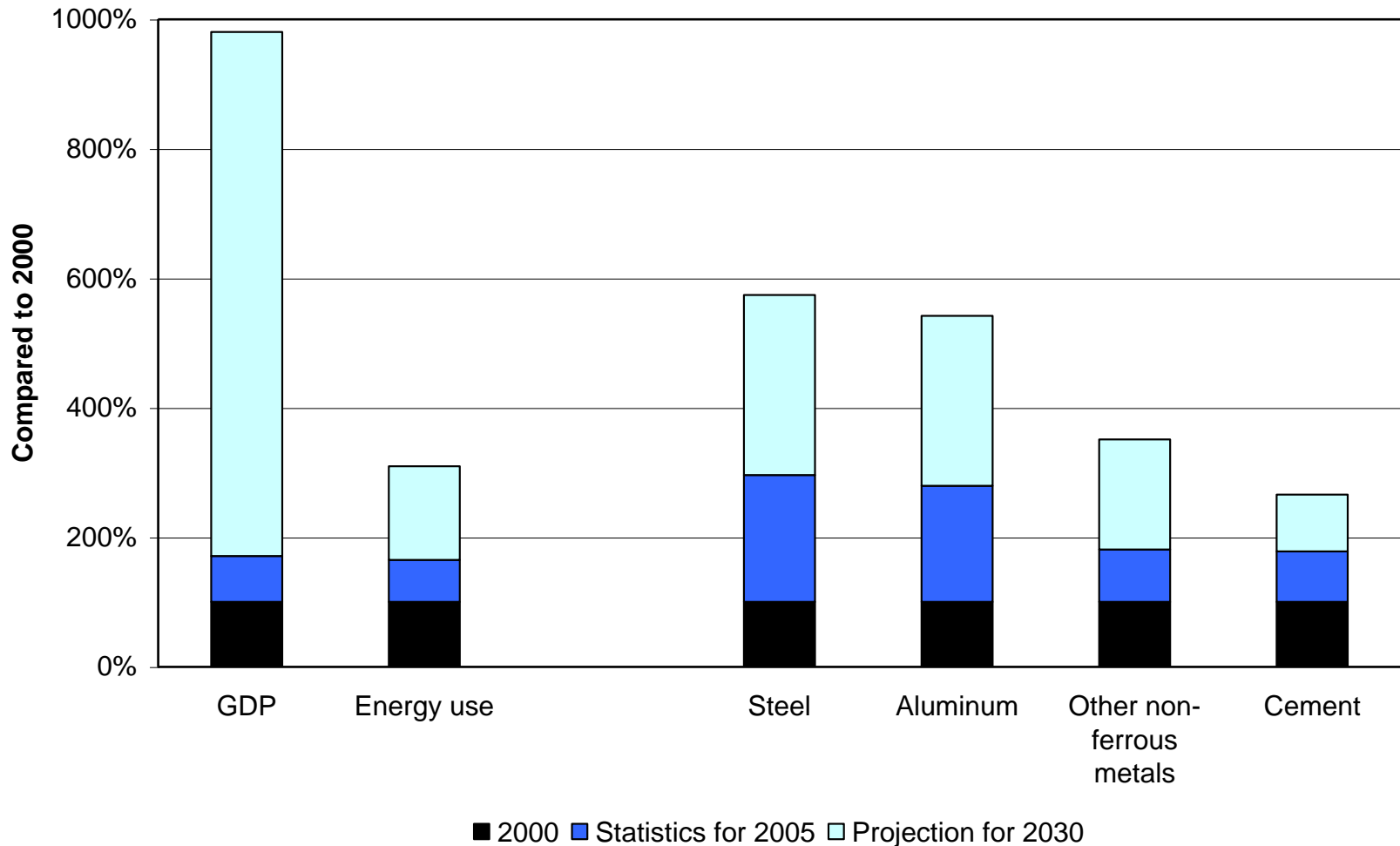


Industry

GDP and industrial production in China 2000-2005



GDP and industrial production in China 2000-2005-2030 (Chinese projection ERI)



Key uncertainties



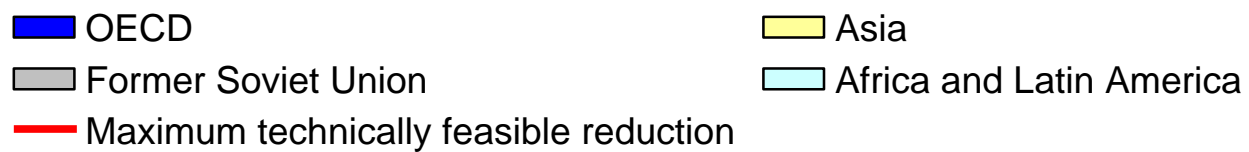
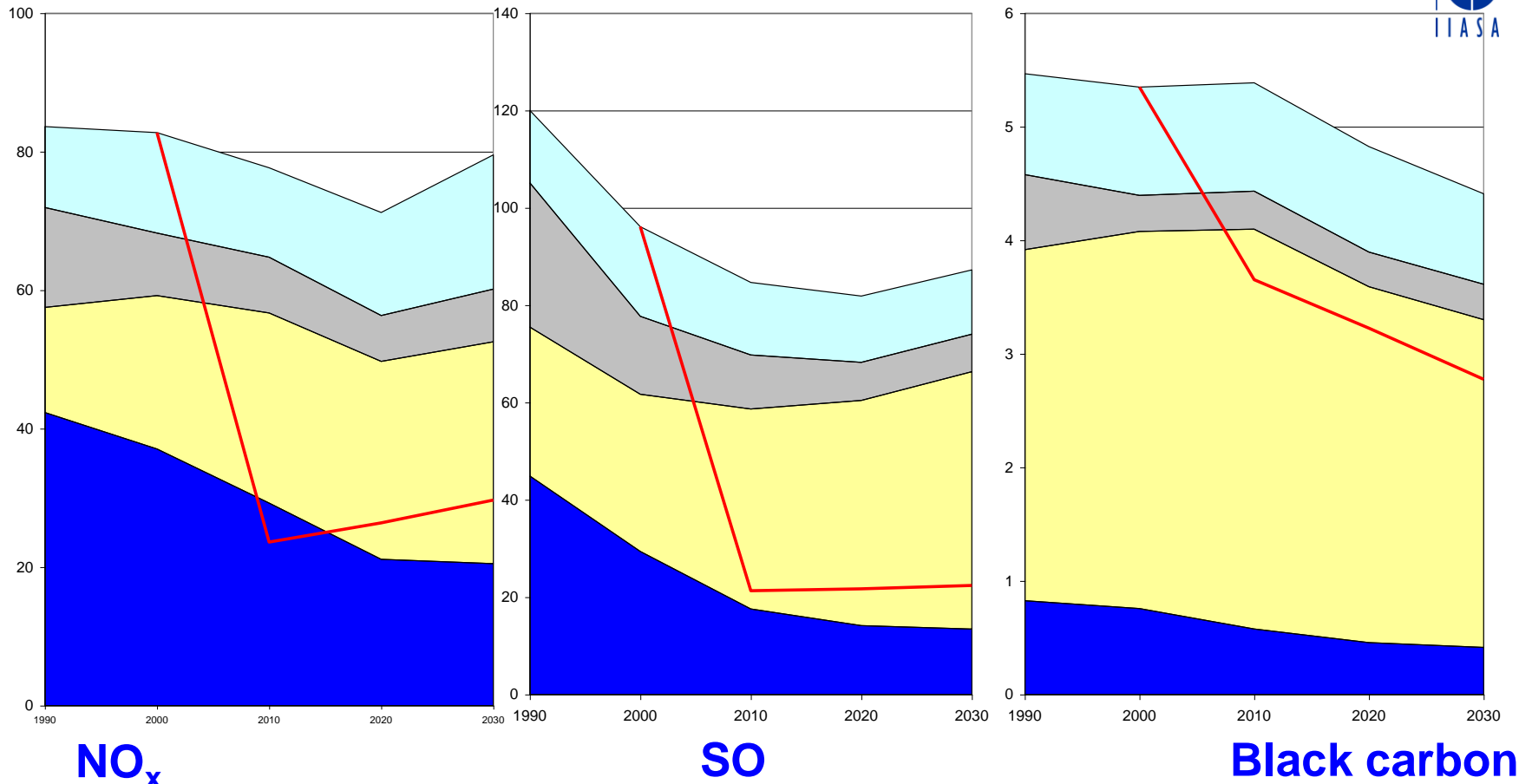
- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?
- How efficiently will emission controls be implemented?

Key uncertainties



- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?
- How efficiently will emission controls be implemented?
- Will additional emission controls be adopted and implemented?

Potential for further emission controls from existing end-of-pipe technologies [Tg]

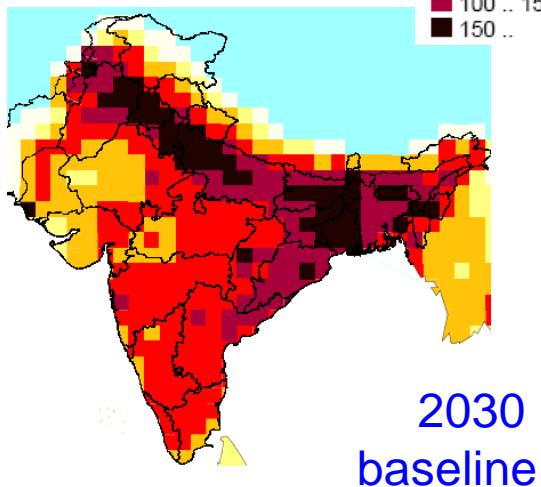
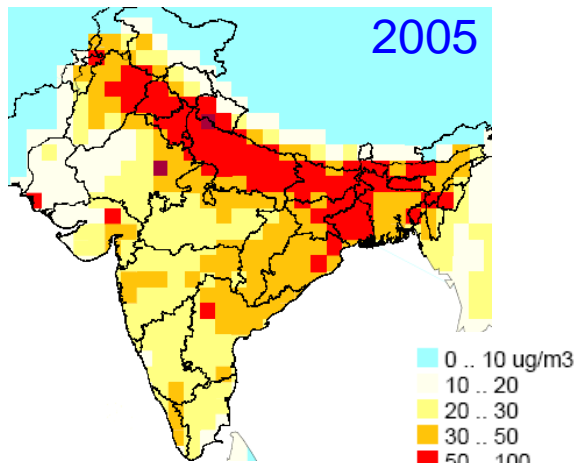


Air pollution counteracts human development

GAINS-Asia results for India

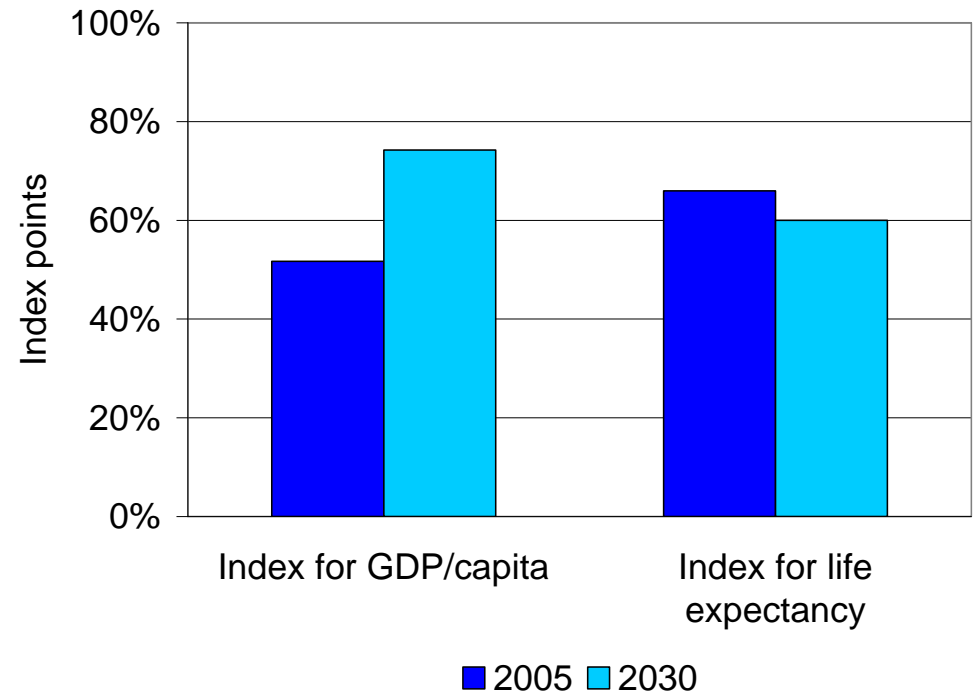


PM2.5 concentrations



Human development index defined by

- education,
- life expectancy,
- per-capita income.



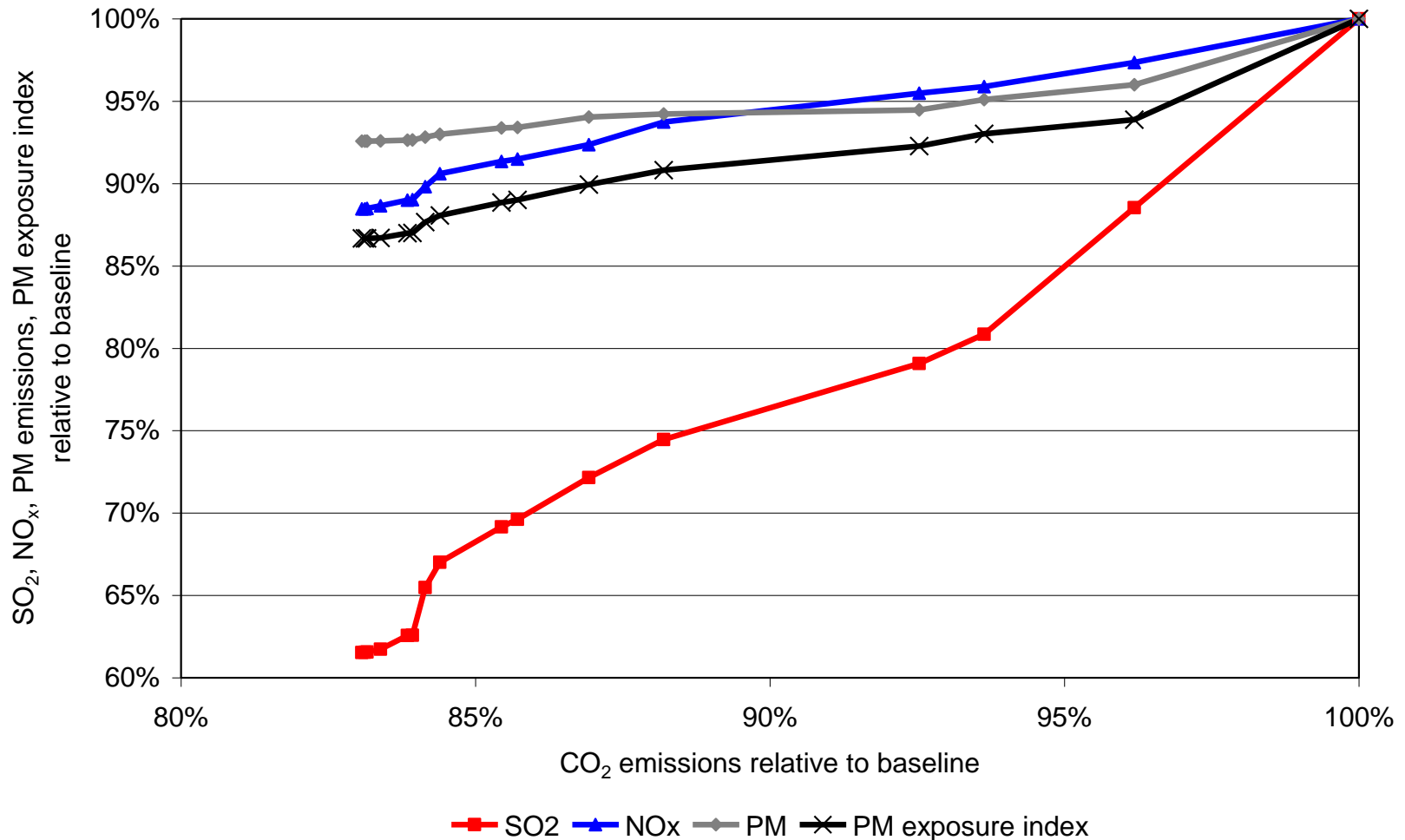
Key uncertainties



- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?
- How efficiently will emission controls be implemented?
- Will additional emission controls be adopted and implemented?
- Will policies in other areas (e.g., climate, energy supply security, etc.) change and influence air pollution emissions?

Changes in air pollutants emissions and health impacts from low CO₂ energy pathways

China, 2020 (Source: GAINS-Asia)



Conclusions



- In contrast to GHGs, air pollutant emissions are not likely to further increase at the global scale, although increases will occur in some regions.
- The main factors influencing future emissions constitute at the same time major uncertainties:
 - Economic projections
 - Enforcement of existing legislation
 - Further tightening of air quality legislation
 - Future policies on CO₂ mitigation
- Important knowledge gaps:
 - VOC emissions from anthropogenic and biogenic sources
 - International shipping and aviation
 - Biogenic emissions (impacts of climate change)