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# 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

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- 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

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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)

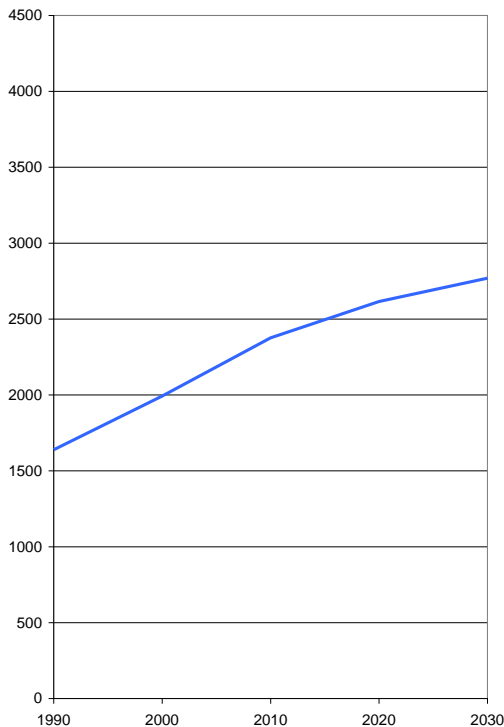
# GAINS emission projection of Cofala et al, 2007 (Atm. Env.)

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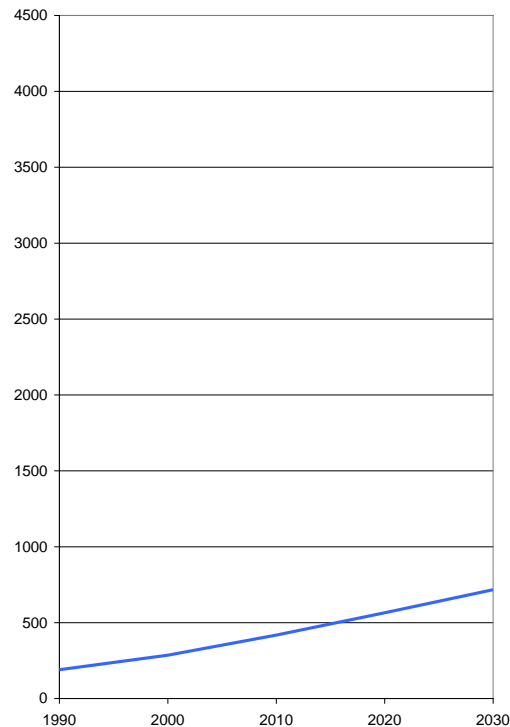


- Sources of activity projections:
  - Europe, China, India: GAINS model with national projections
  - North America, Russia: National sources
  - Other continents: IPCC SRES B2 scenario
- Local emission factors
- Implementation of current national emission control legislation, no additional measures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

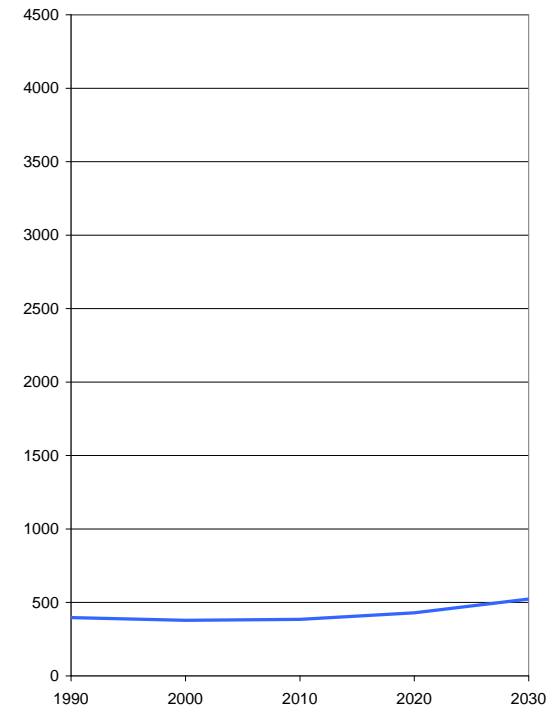
# Driving forces for global emissions 1990-2030: Economic wealth (GDP/capita) (Governmental and UN projections)



**OECD**



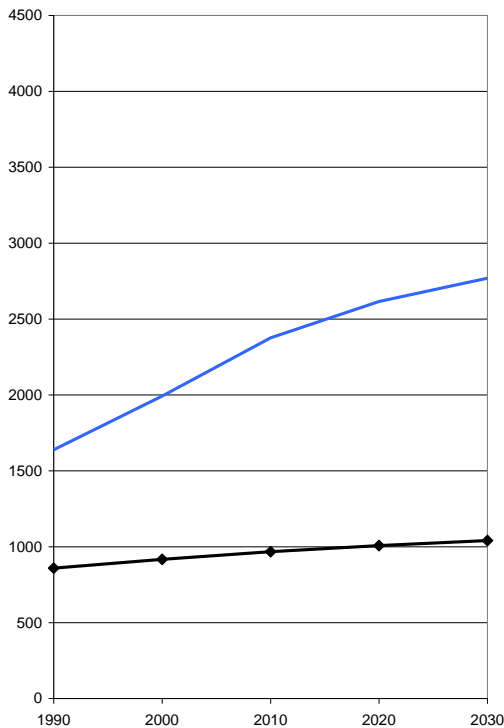
**Asia**



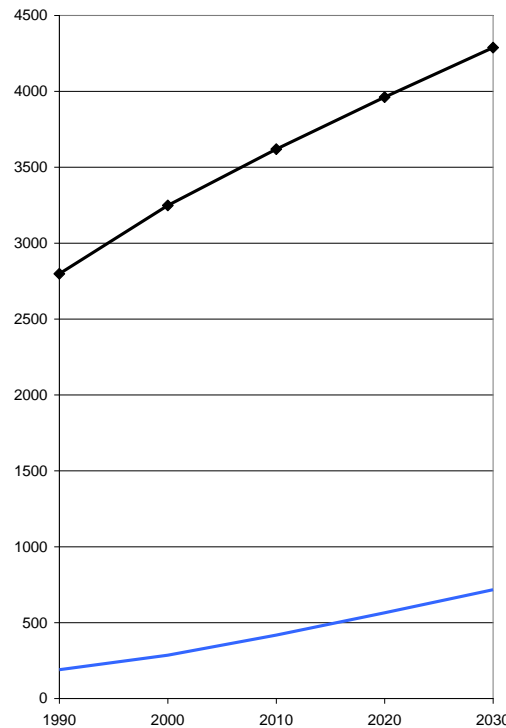
**Rest of world**

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

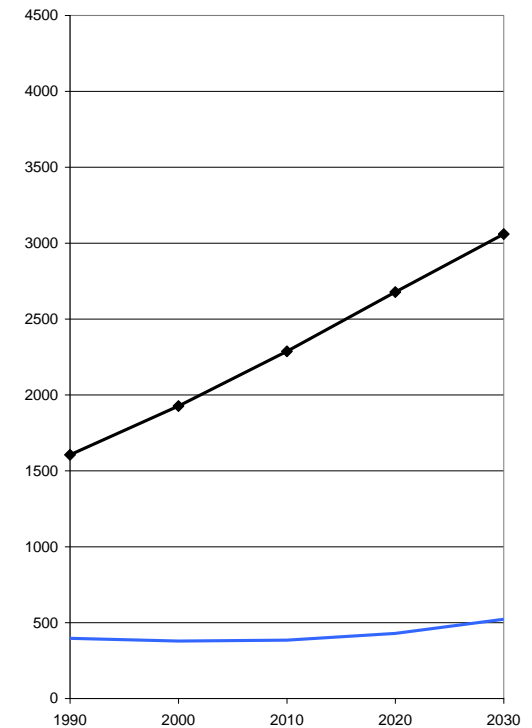
# Driving forces for global emissions 1990-2030: Population and per-capita income



**OECD**



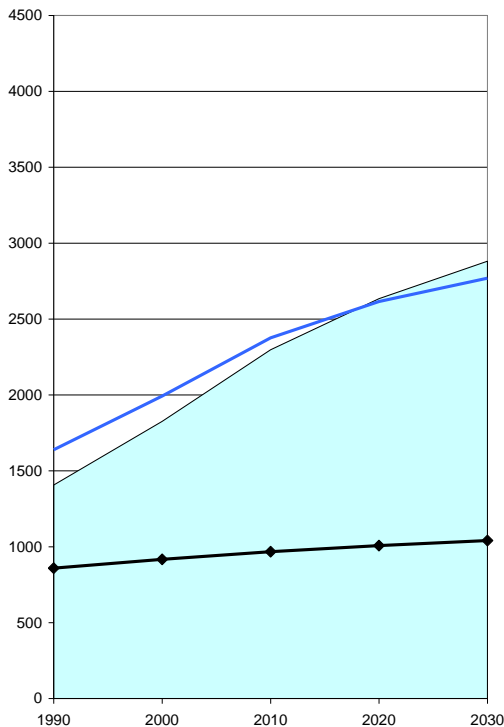
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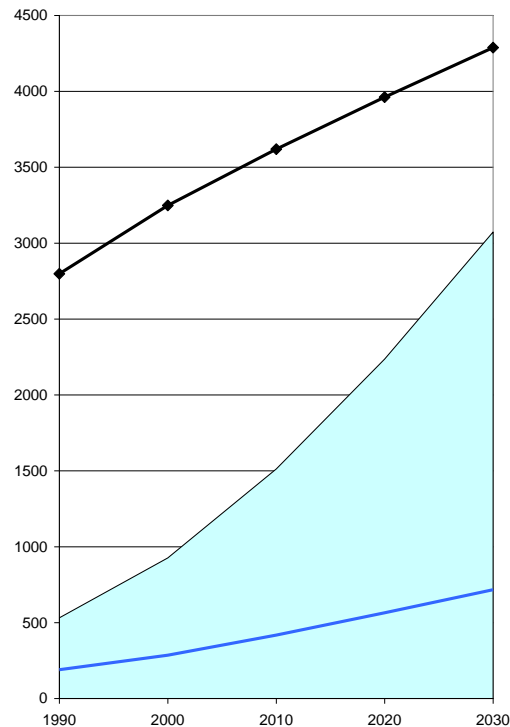
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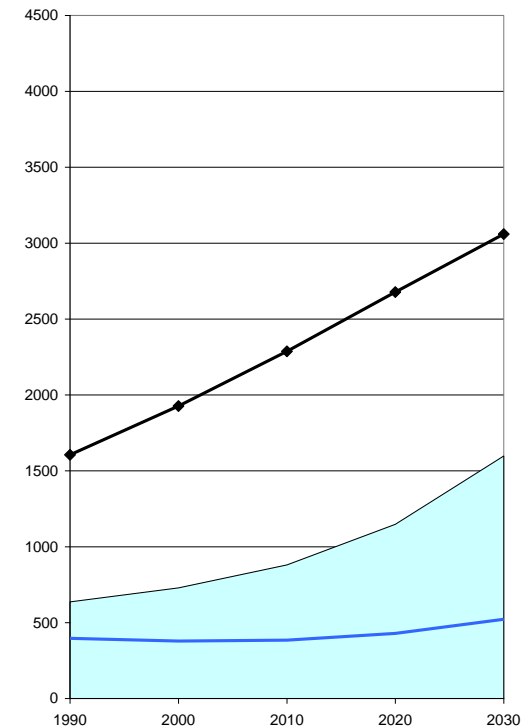
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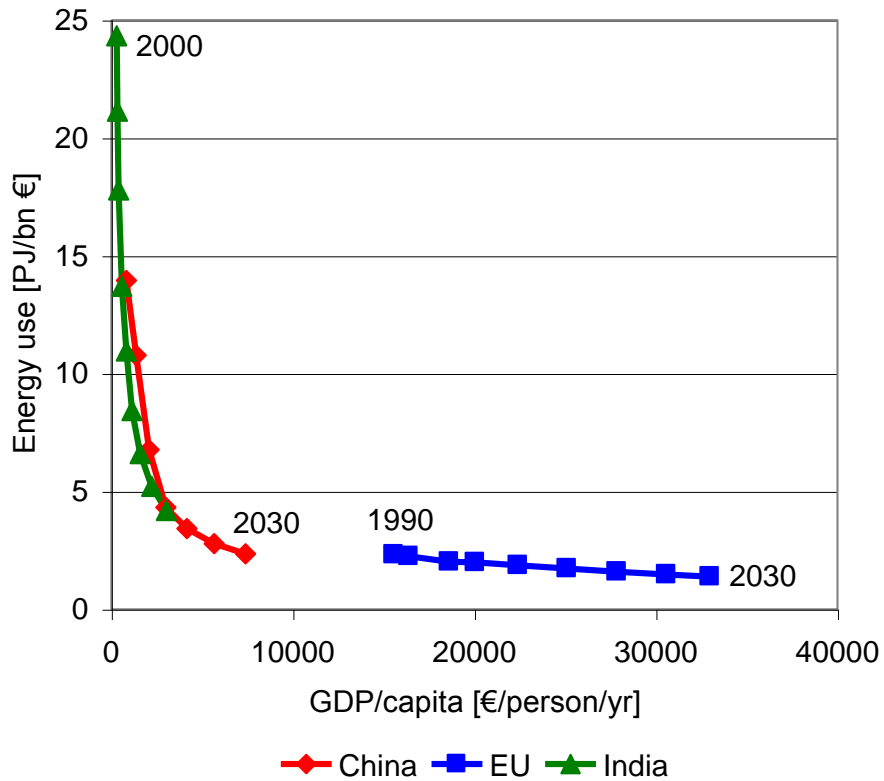
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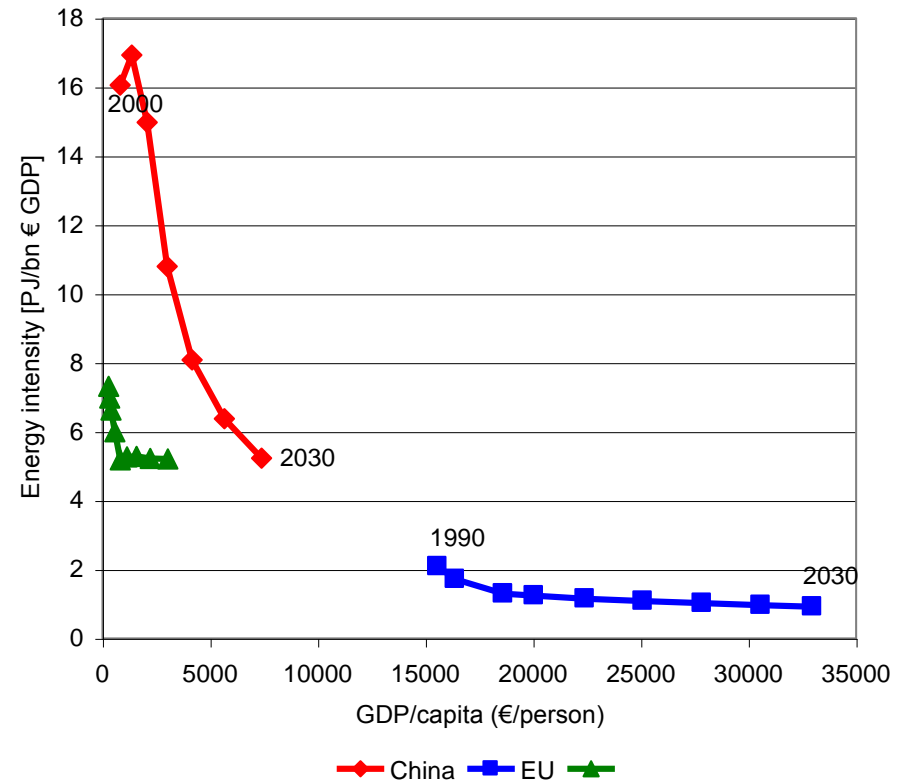
**Rest of world**

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

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



**Domestic sector**

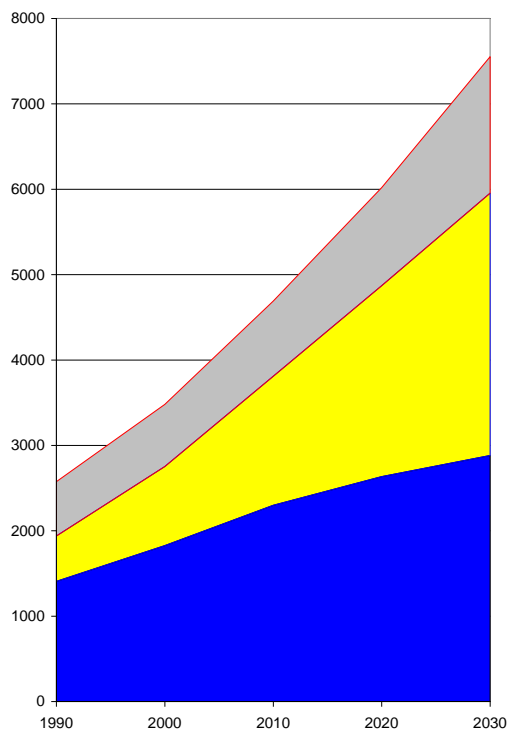


**Industry**

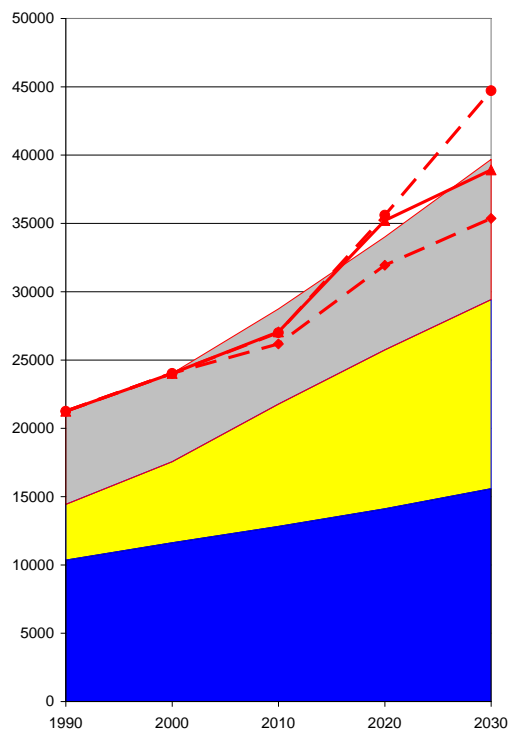


# Projections of global GHG emissions

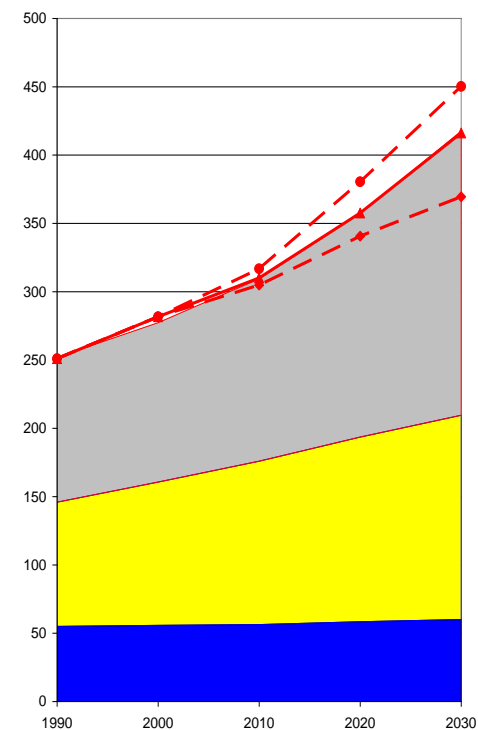
## GAINS vs SRES estimates



**GDP**



**CO<sub>2</sub>**



**CH<sub>4</sub>**

■ 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 <sup>a</sup>																				
Bangladesh <sup>b</sup>																				
Hong Kong, China																				
India <sup>c</sup>																				
India <sup>d</sup>																				
Indonesia																				
Malaysia																				
Nepal																				
Pakistan																				
Philippines																				
PRC <sup>a</sup>																				
PRC <sup>e</sup>																				
Singapore <sup>a</sup>																				
Singapore <sup>b</sup>																				
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

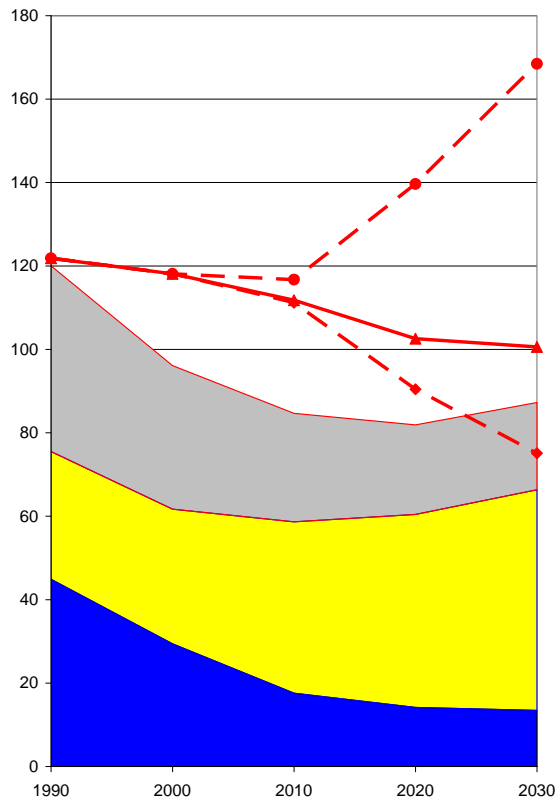
e – Beijing and Guangzhou (as of 01 September 2006) have adopted Euro 3 standards; Shanghai has requested the approval of the State Council for implementation of Euro 3

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

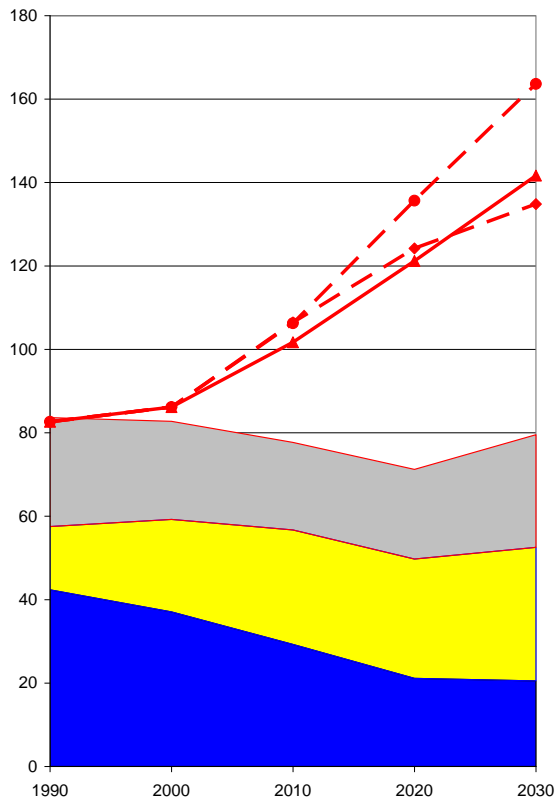
g – Gasoline vehicles under consideration

# Projections of global air pollution emissions

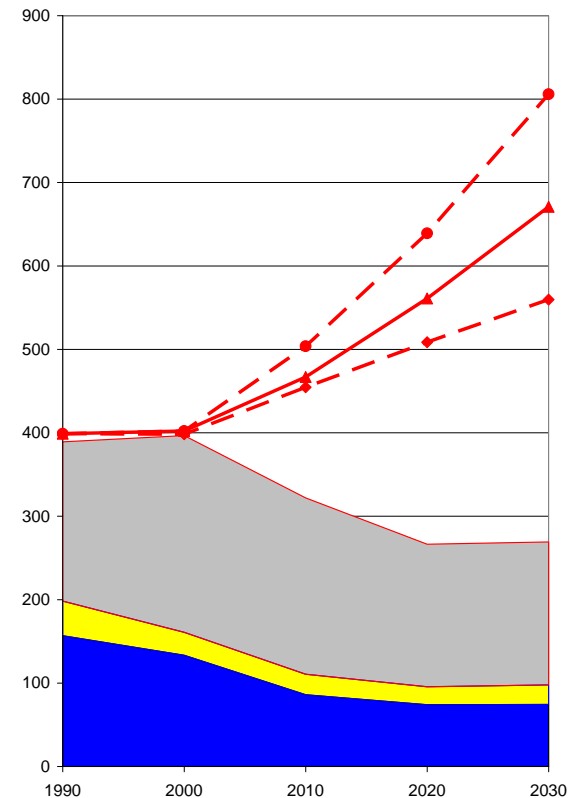
## GAINS vs SRES estimates



SO<sub>2</sub>



NO<sub>x</sub>

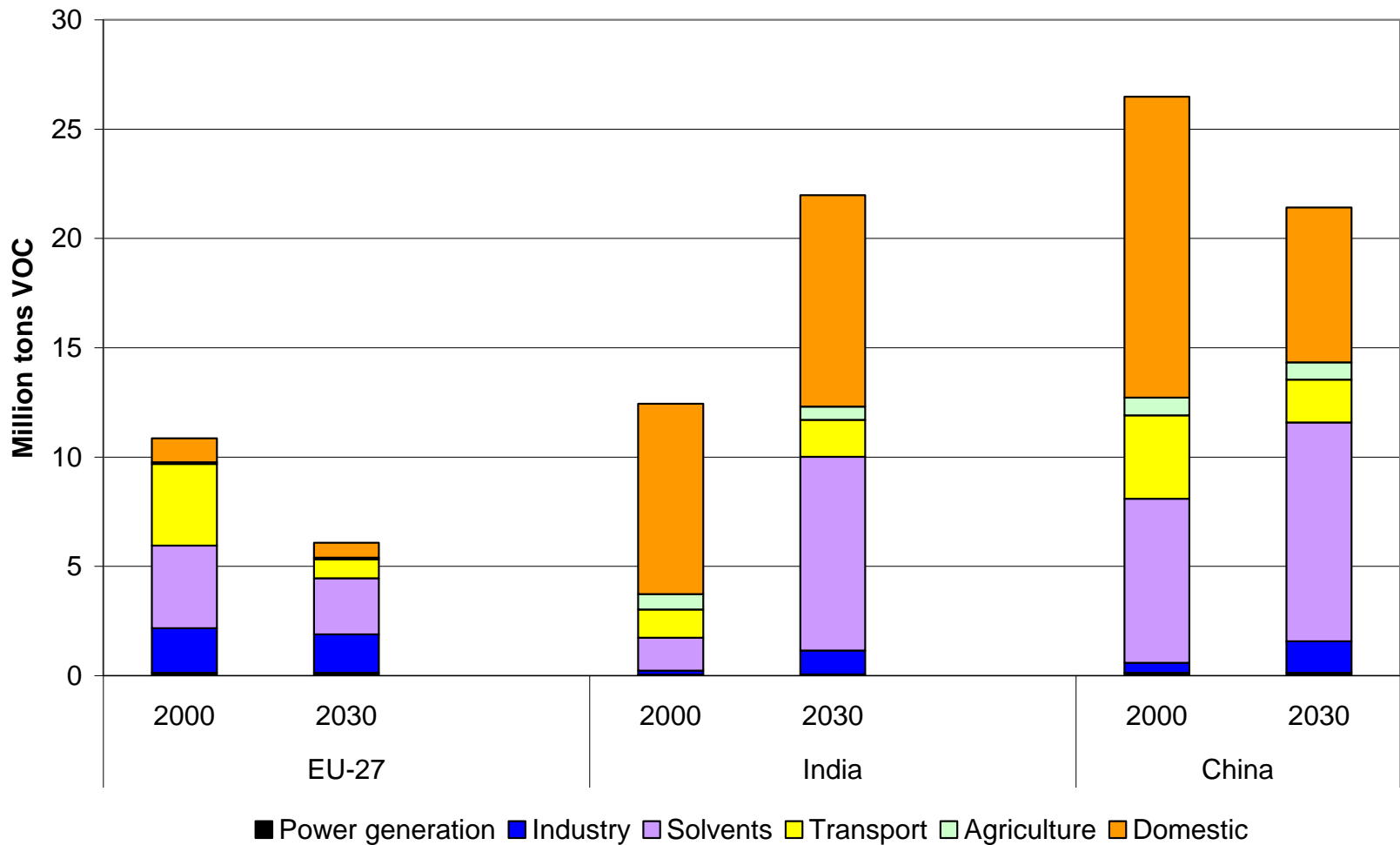


CO

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

# Sources of anthropogenic VOC emissions

EU-27 - India - China, 2000 and 2030



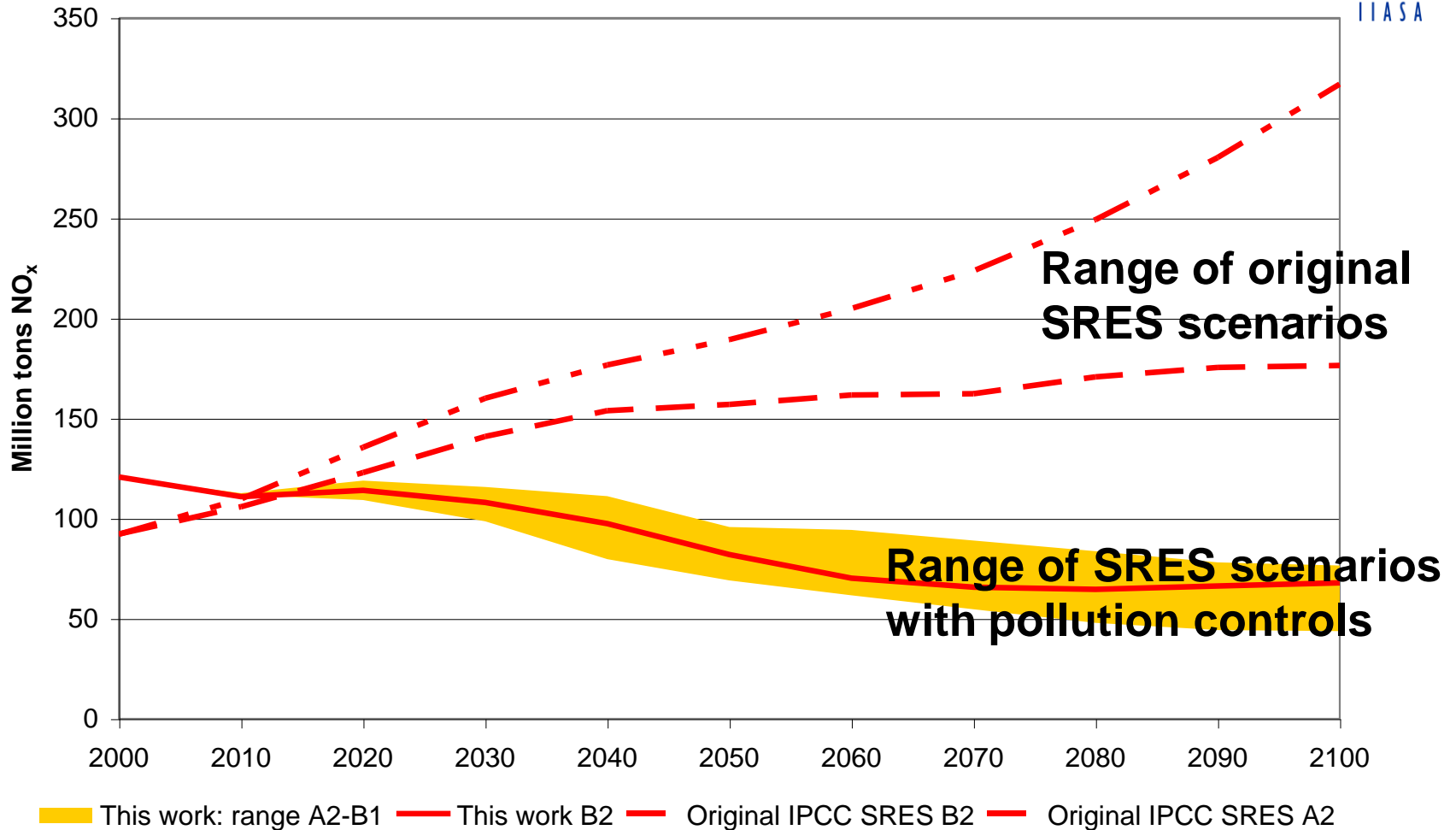
# Key uncertainties

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

# NO<sub>x</sub> emissions for alternative economic and pollution control projections



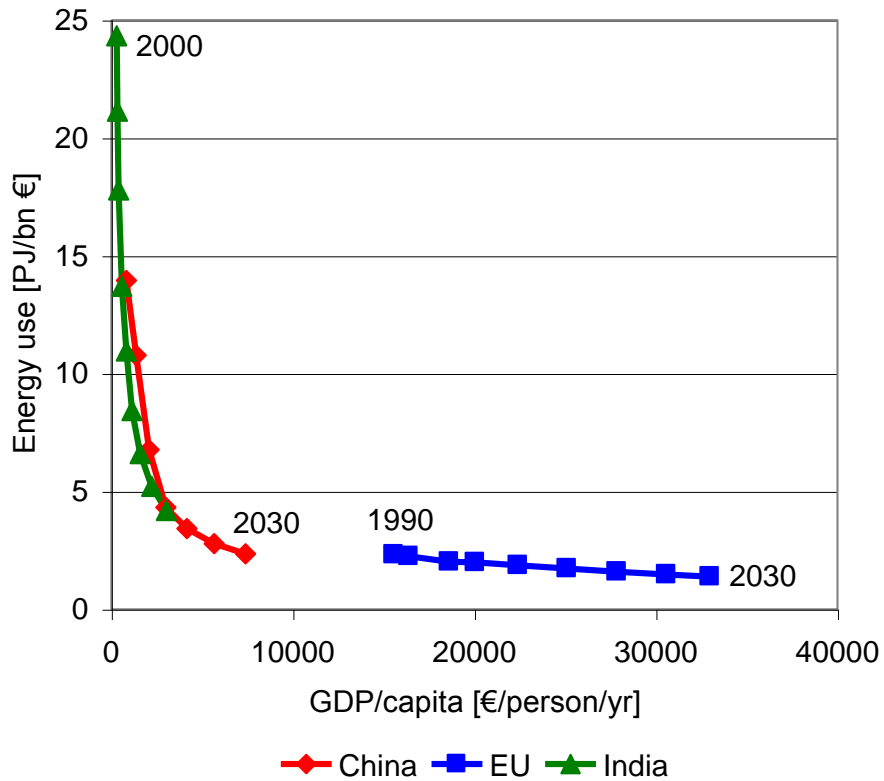
# Key uncertainties

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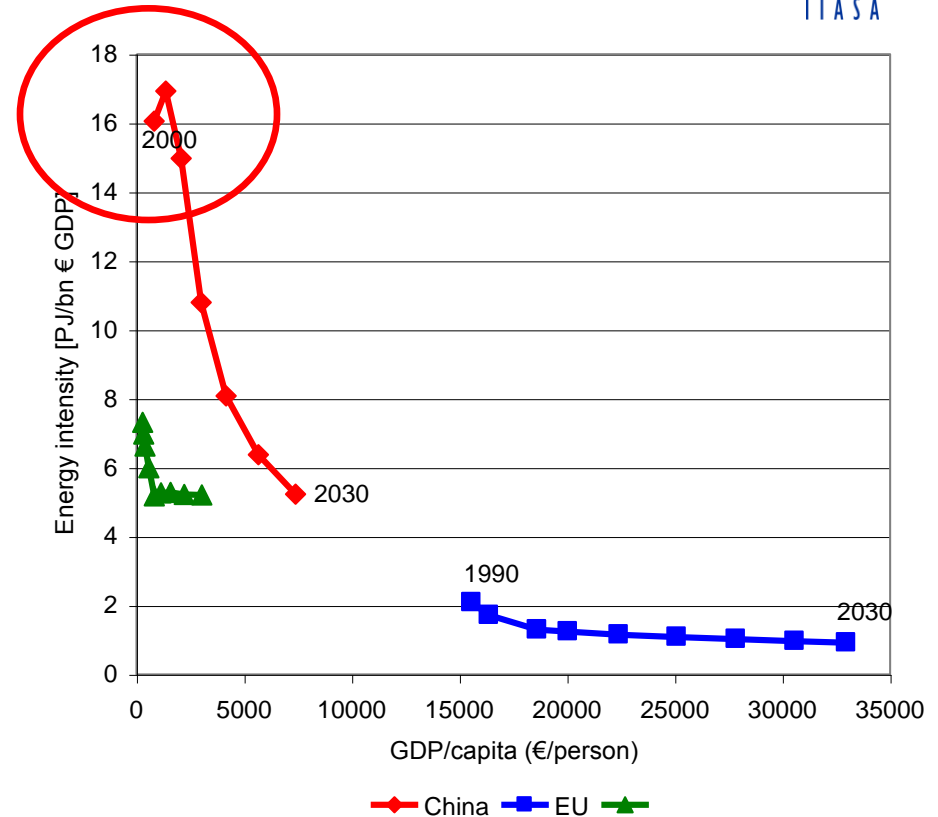


- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?

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



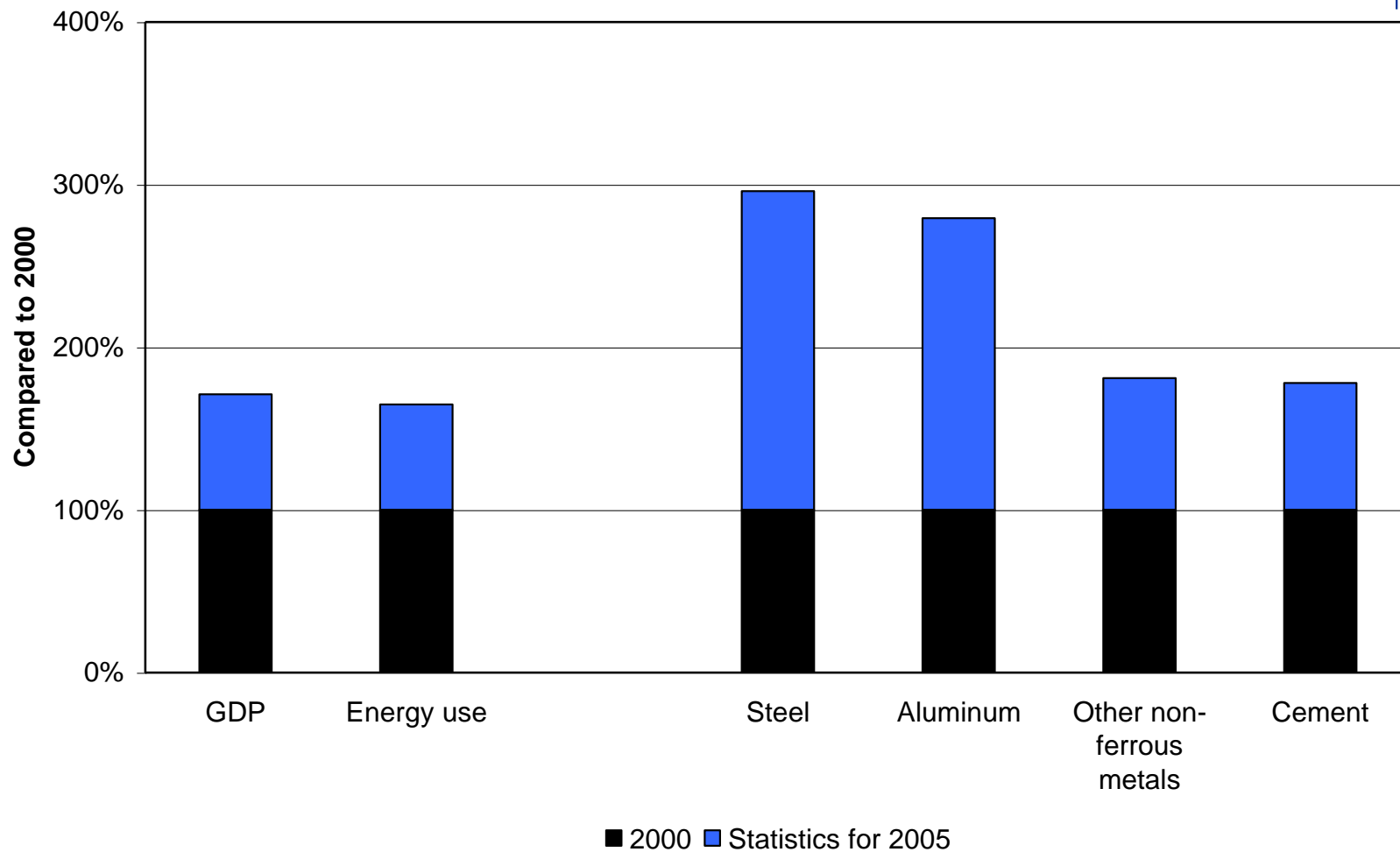
**Domestic sector**



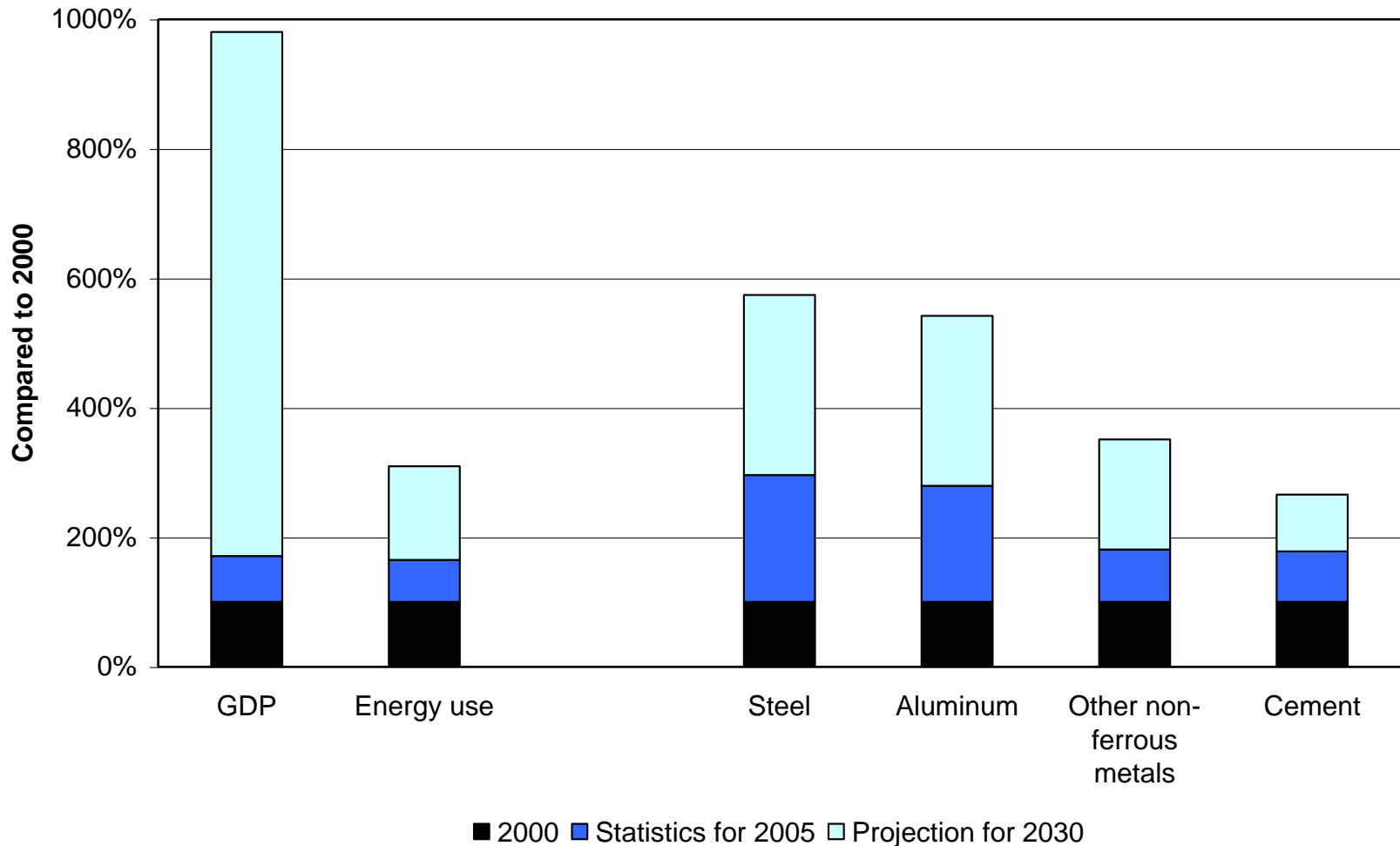
**Industry**



# GDP and industrial production in China 2000-2005



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



# Key uncertainties

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- 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?

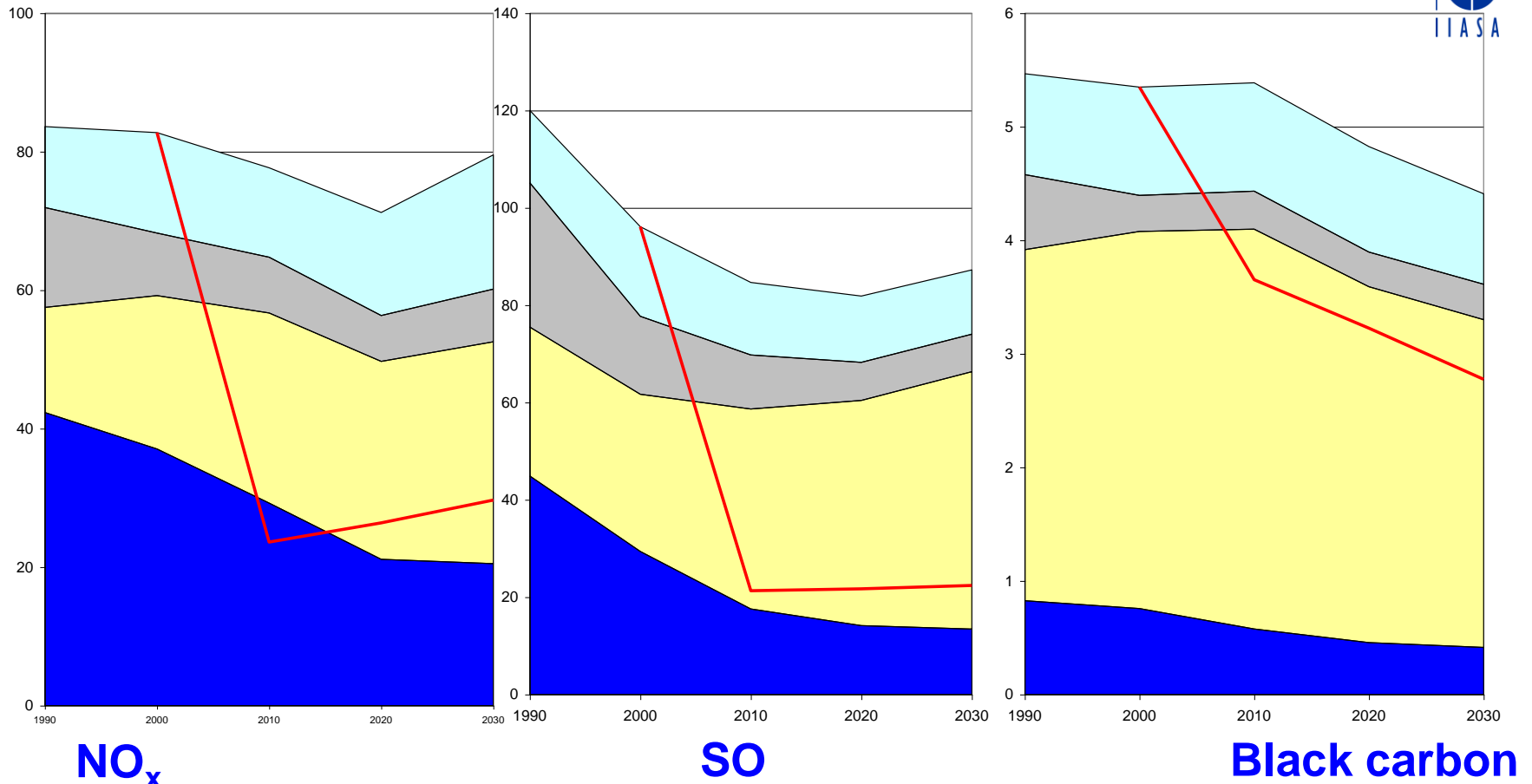
# Key uncertainties

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- 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]



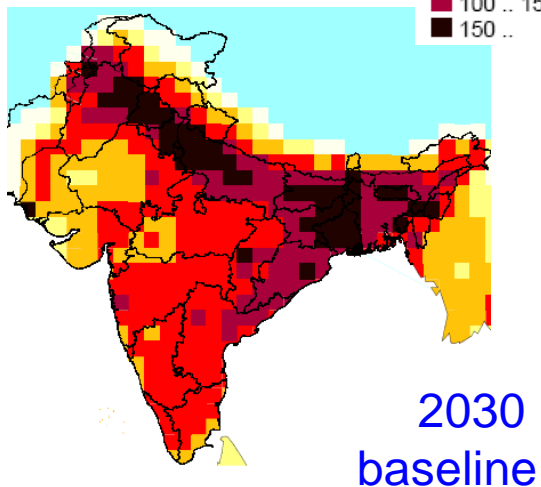
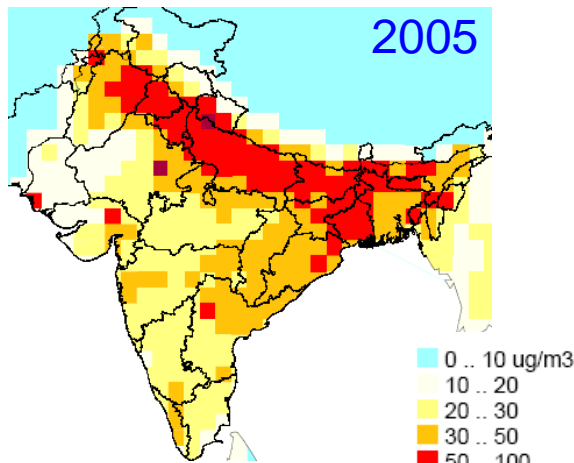
- OECD
- Former Soviet Union
- Asia
- Africa and Latin America
- Maximum technically feasible reduction

# Air pollution counteracts human development

## GAINS-Asia results for India

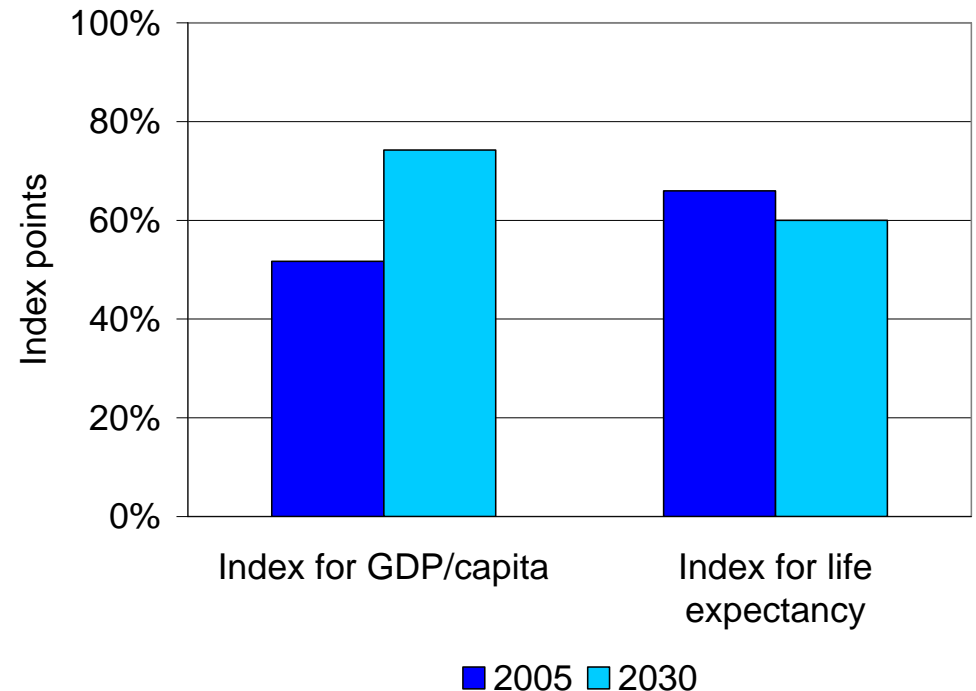


### PM2.5 concentrations



### Human development index defined by

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



# Key uncertainties

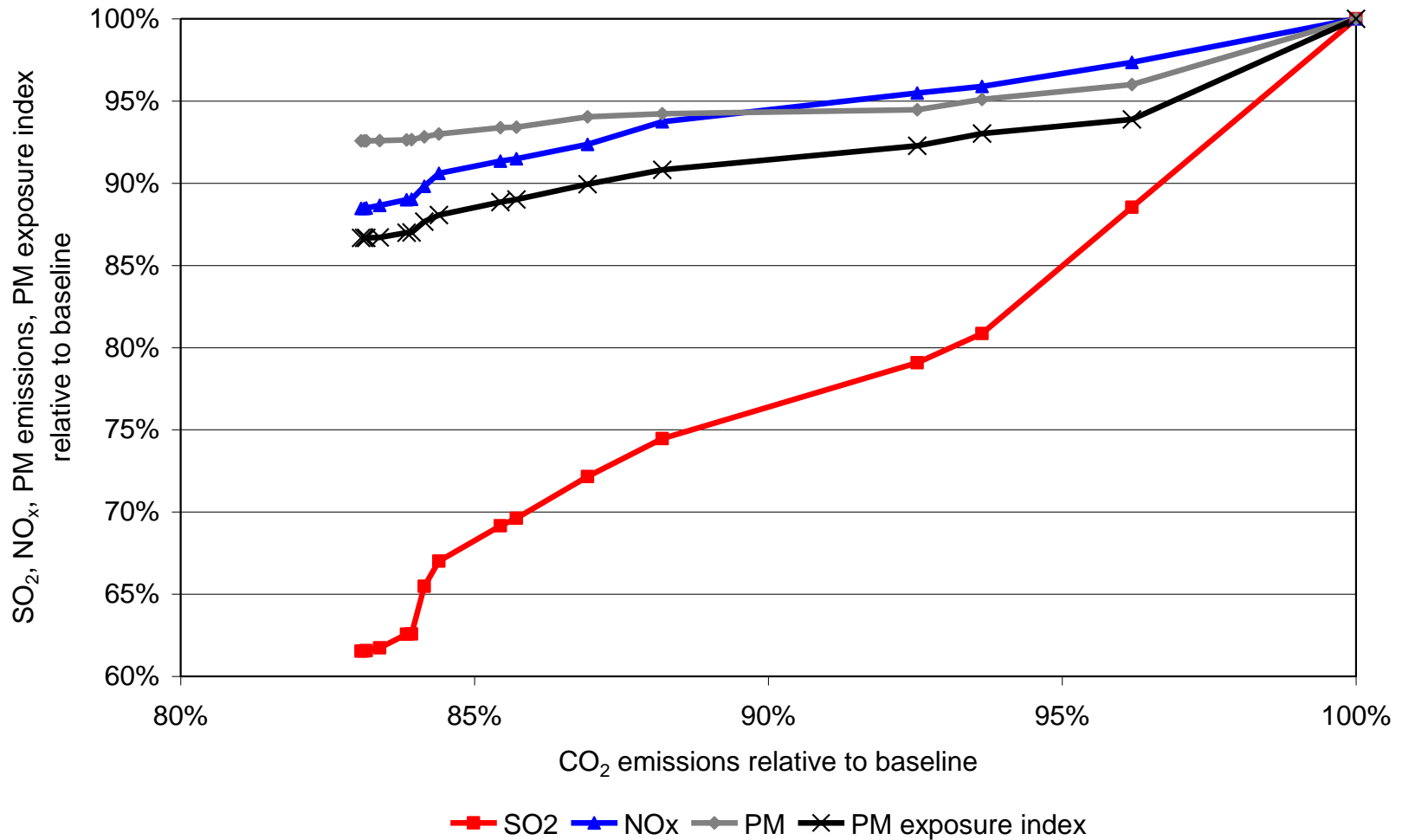
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- How accurate are economic development plans (and thus the implied activity projections)?
- Will historic trends (e.g., in energy intensity improvements) hold in the future?
- How efficiently will emission controls be implemented?
- Will additional 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 CO<sub>2</sub> energy pathways

## China, 2020 (Source: GAINS-Asia)





# Conclusions

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- 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 CO<sub>2</sub> mitigation
- Important knowledge gaps:
  - VOC emissions from anthropogenic and biogenic sources
  - International shipping and aviation
  - Biogenic emissions (impacts of climate change)