The China Energy Technology Program (CETP) Methodology and Conclusions

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2. Highlights from

    - LCA
    - External Cost & ECOSENSE
    - RAINS-ASIA

3 Scenarios with MARKAL & CRETM

- Overall Conclusions

China Energy Technology Program (CETP)

1999-2003

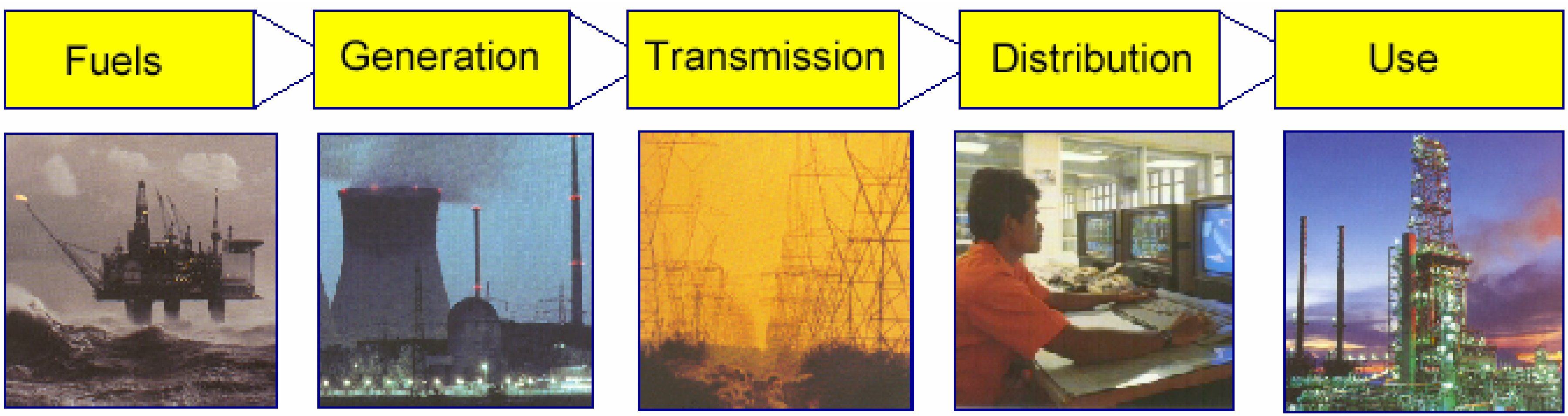
Funded by ABB in conjunction with „Alliance for Global Sustainability“ (AGS) of ETH, MIT, und Tokyo University

Goal: Development and application of methodology for assessment of real impacts of the future electricity supply. Detailed case study for the Shandong Province.

Participants: Institutes from USA, China, Japan & Switzerland

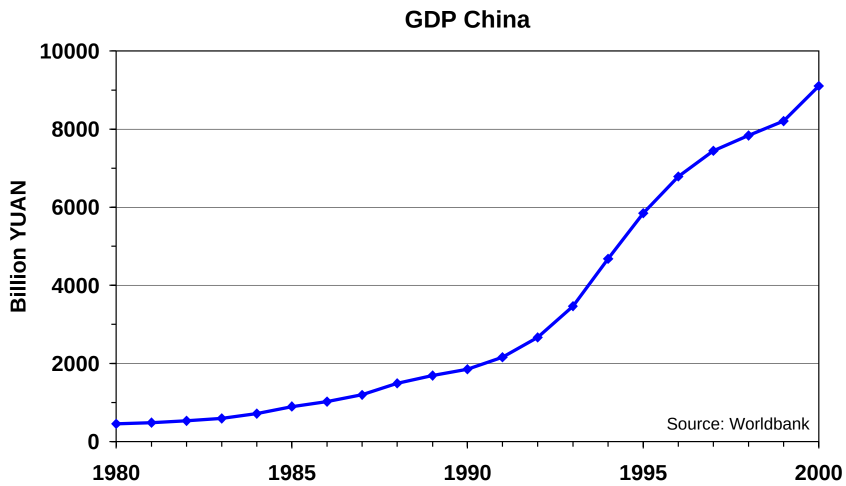
CETP Objectives & Scope

- "To develop a global cradle-to-grave methodology for analyzing the 'true' impacts of electric power generation, ... using Shandong province as a case study."

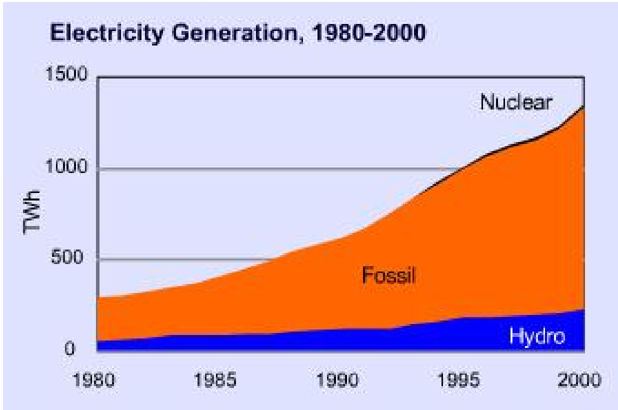


Technologies & Burdens - Problem Statement

- China is experiencing rapid economic growth, and this trend is expected to continue.



- Economic growth is accompanied by increasing electricity demand, with coal as the dominant source.



- Burning coal leads to extensive air, soil and water pollution unless environmentally friendly technologies are employed.

- CETP investigated the overall economic and environmental performance of technological options under consideration for avoiding damages to public health and environment, focussing on air pollution.

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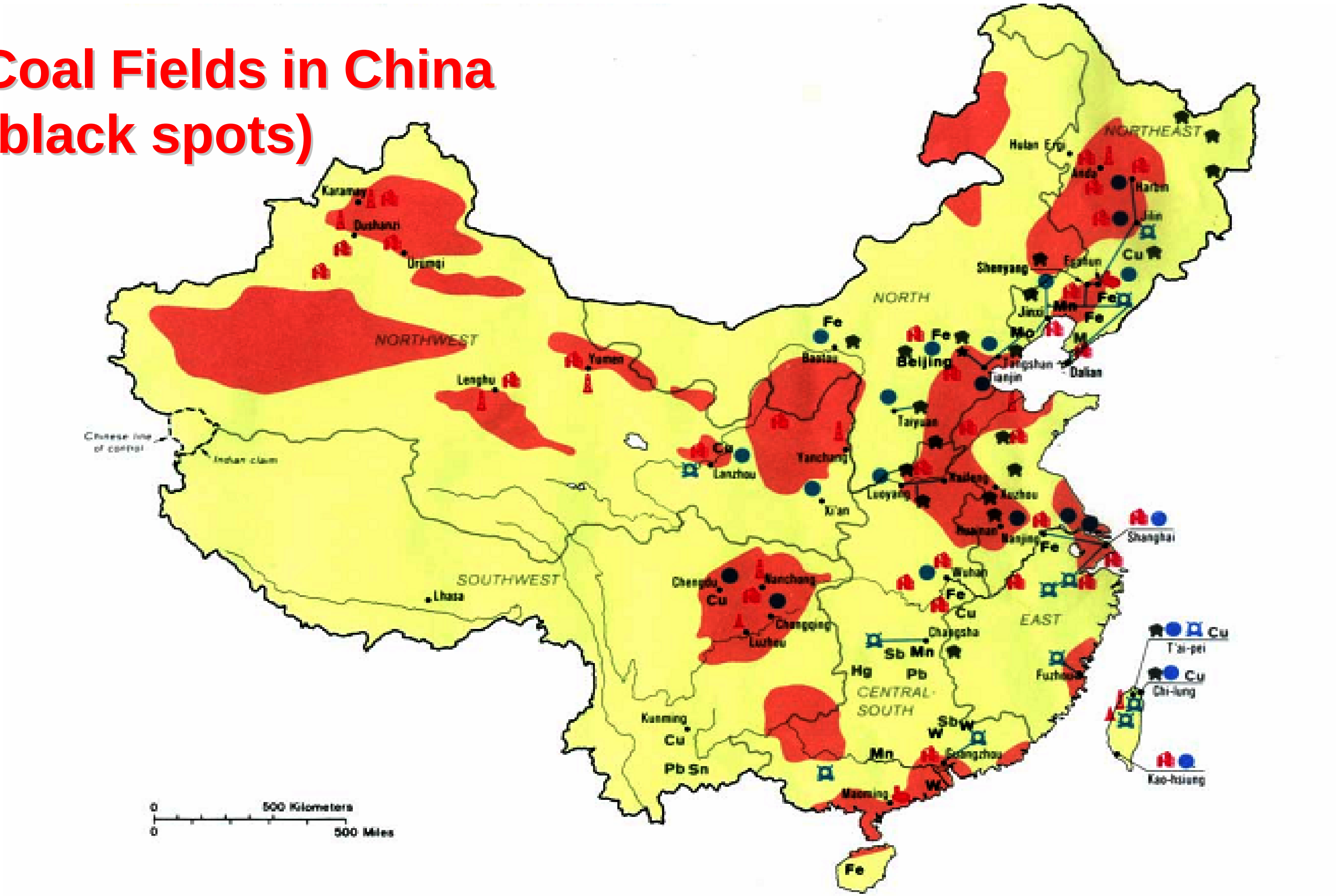
Coal Fields in China (black spots)

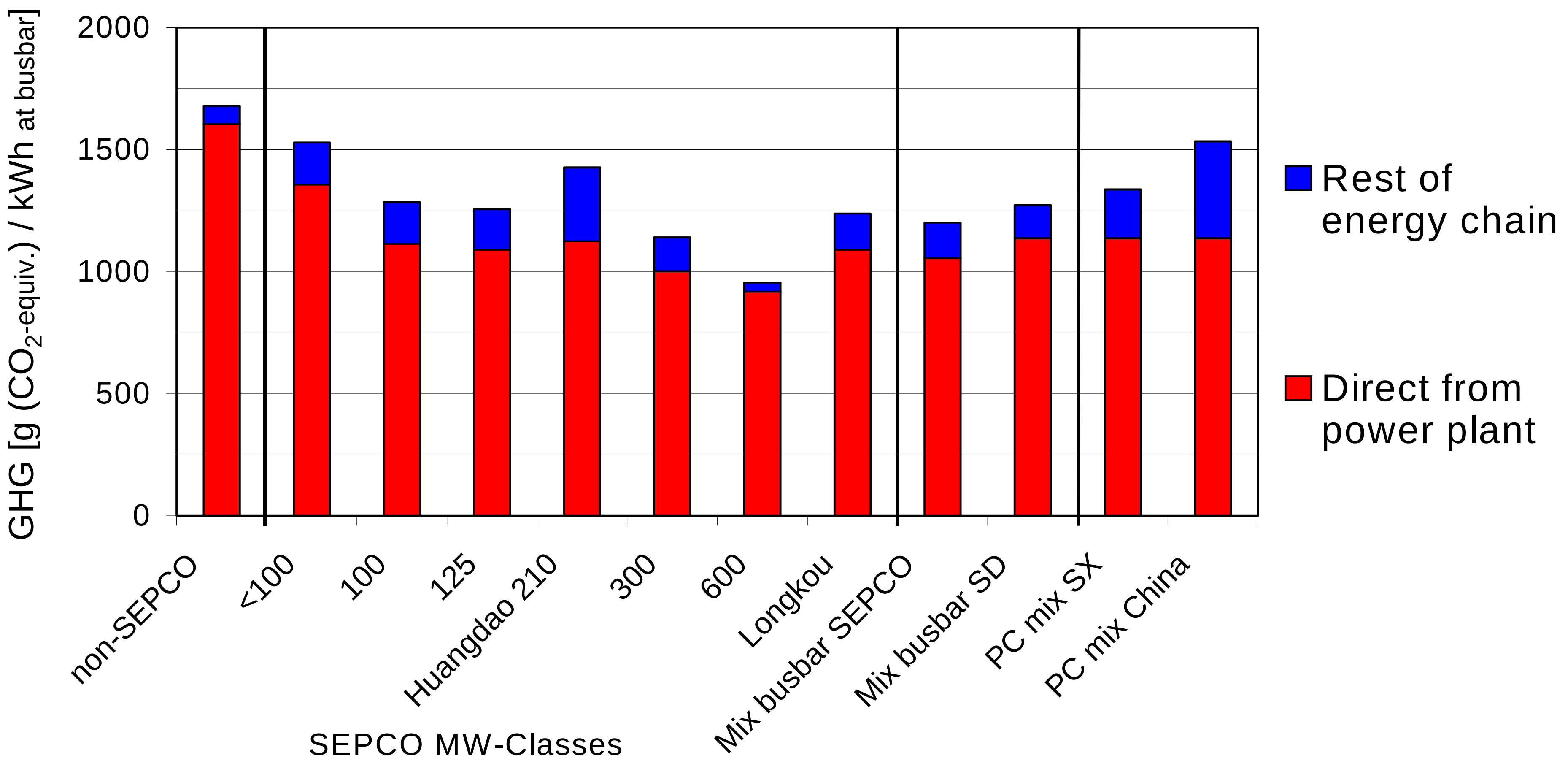


Map 7

Proposed Pipeline Routes in Northeast Asia

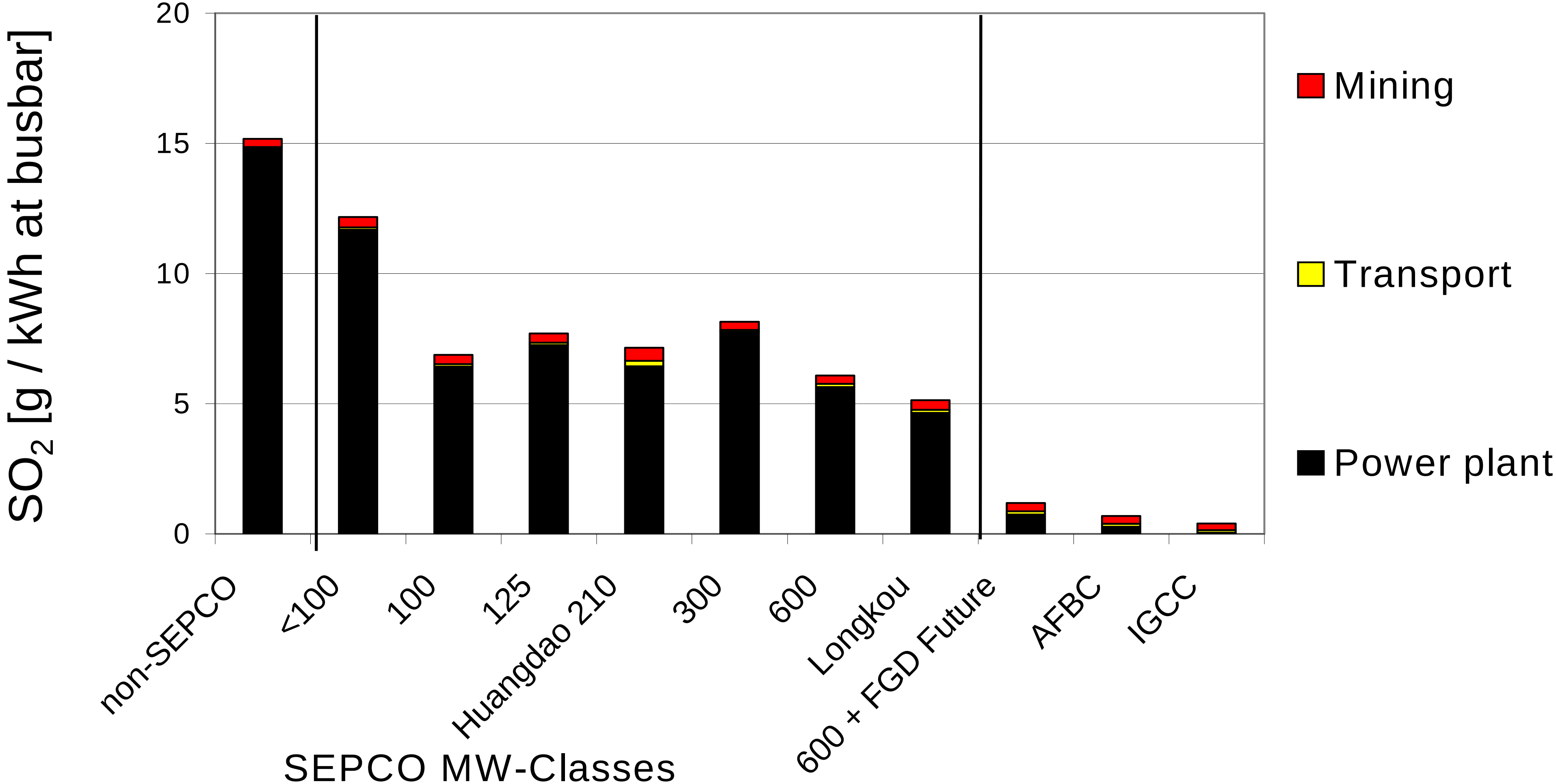
Source: IEA, Gas and Oil in Northeast Asia, and CNPC, 1999.

Greenhouse gas emissions from current coal chains



Source: Dones et al., 2003

SO2 emissions from current & future coal chains



Source: Dones et al., 2003

Full Chain Approach: Conclusions

⇒ **The environmental performance of present and future coal systems is the worst of all the energy chains considered.**

⇒ **The introduction of improved or advanced coal technologies may reduce significantly the harm to human health from airborne pollutants compared to conventional coal technology.**

⇒ **Rates of solid waste production from coal chains may not decrease for new coal power plant technologies, unless waste recycling is improved.**

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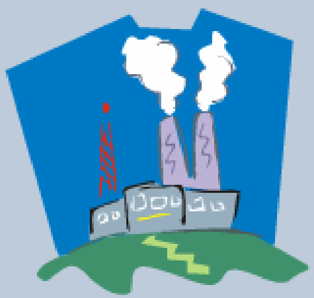
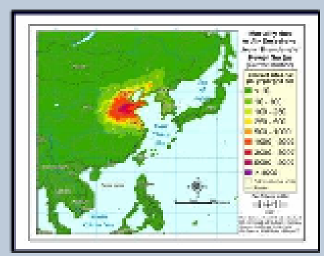
Impact Pathway Approach

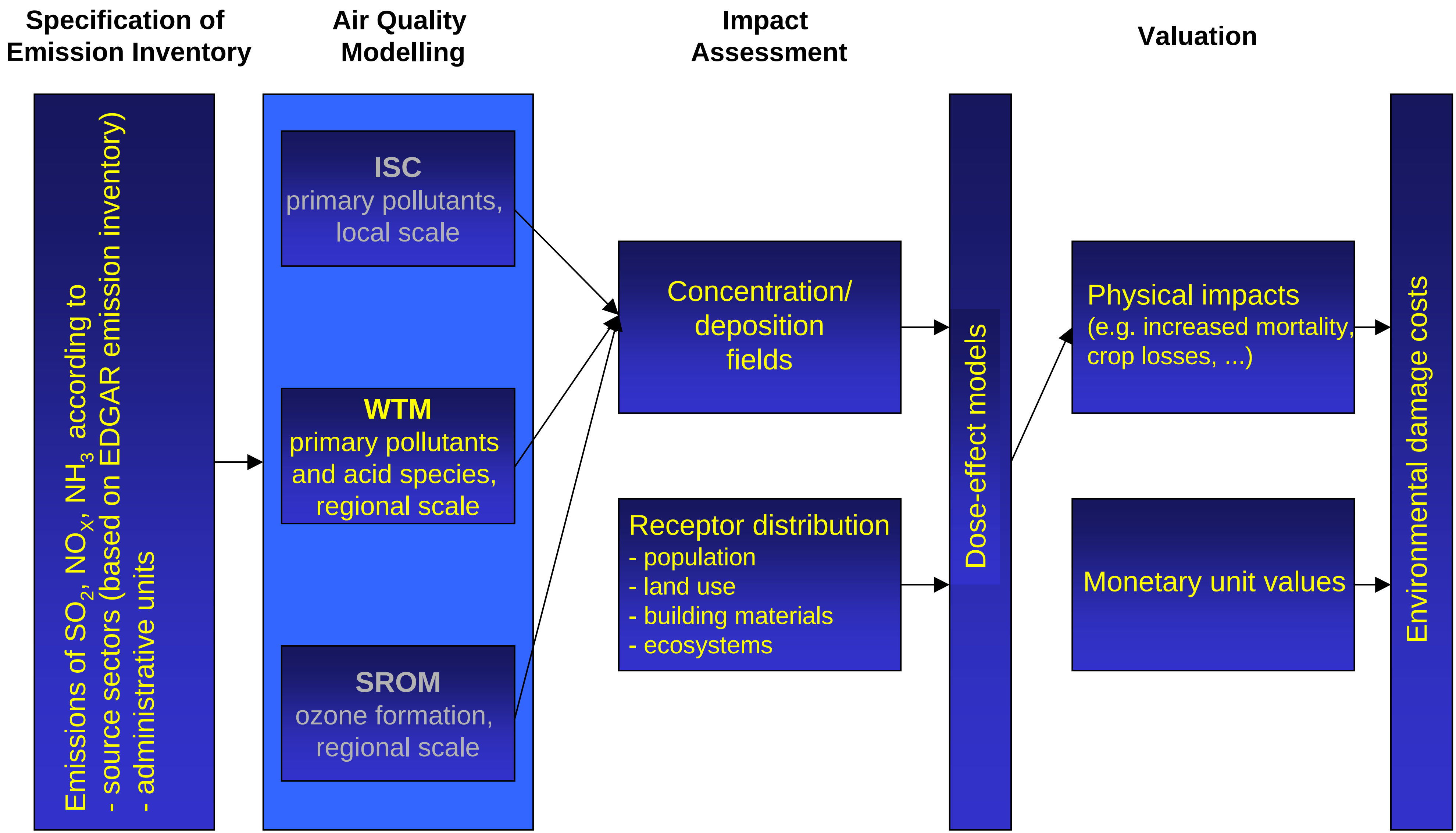
Emissions	Atmospheric Model	Impacts	Damage Costs
SO_2, NO_x, particulates, ammonia	Calculation of pollutant concentrations	Population and crops	Health and crop losses



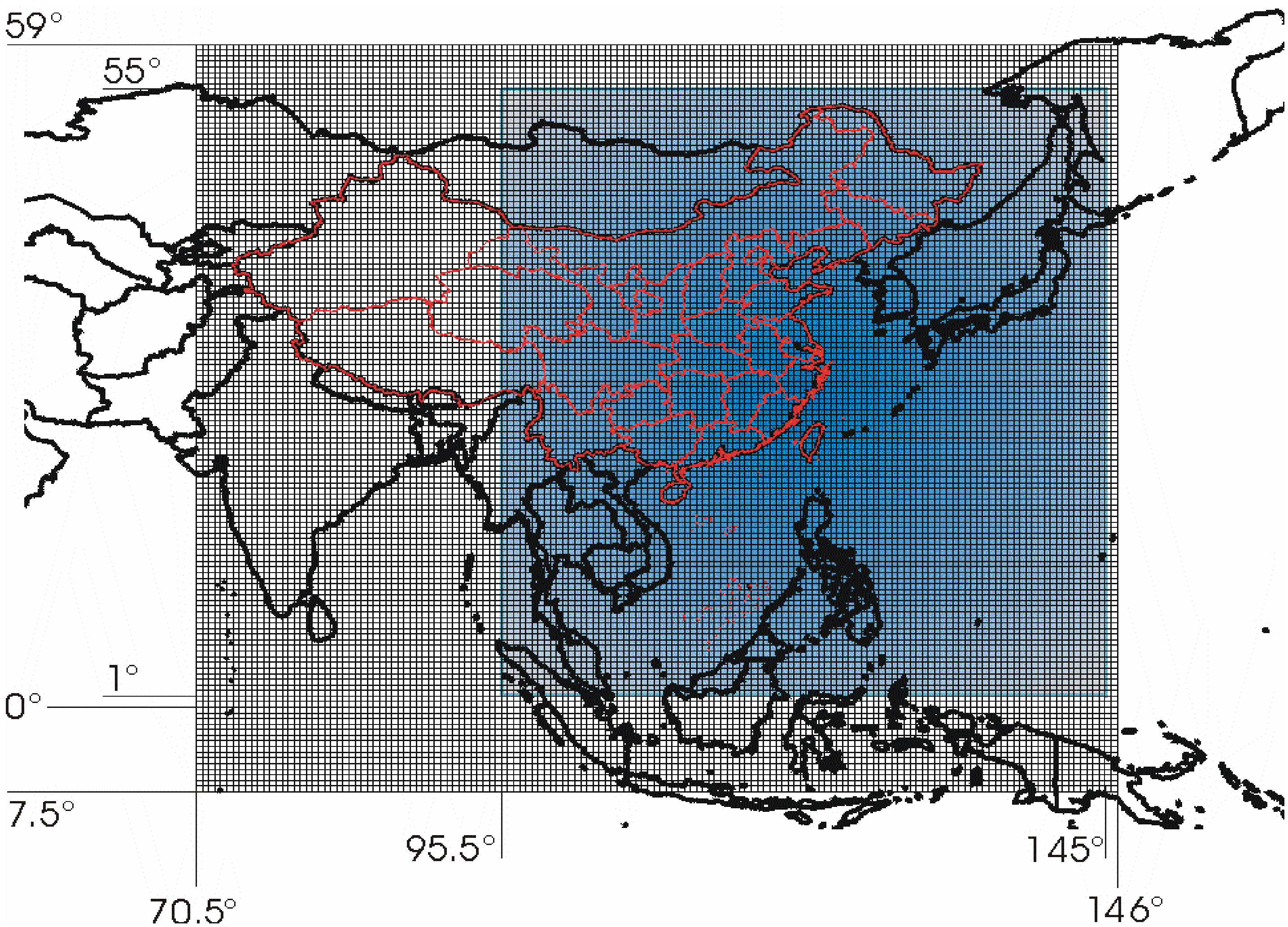


EIA Task

The EcoSense Model



Emission and Impact Areas



Major Health Exposure-Response Functions

Receptor	Impact Category	Pollutant	fer
ADULTS			
	Restricted activity days	PM_{10},	0.025
		Nitrates,	0.025
		Sulfates	0.042
	Chronic bronchitis	PM_{10},	2.5E-5
		Nitrates,	2.5E-5
		Sulfates	3.9E-5
ENTIRE POPULATION			
	Acute mortality (YOLL)	SO_2	5.4E-6
	Chronic mortality (YOLL)	PM_{10},	1.57E-4
		Nitrates,	1.57E-4
		$PM_{2.5}$,	2.60E-4
		Sulfates	2.60E-4

f_{er}, has units of [cases/(yr-person-µg/m^3)] for morbidity, and [YOLL/(yr-person-µg/m^3)] for mortality

Source: ExternE 2000

Valuation

Monetary valuation methods for morbidity impacts:

- Costs-of-Illness (medical costs, loss of value of time)
- Willingness-to-Pay

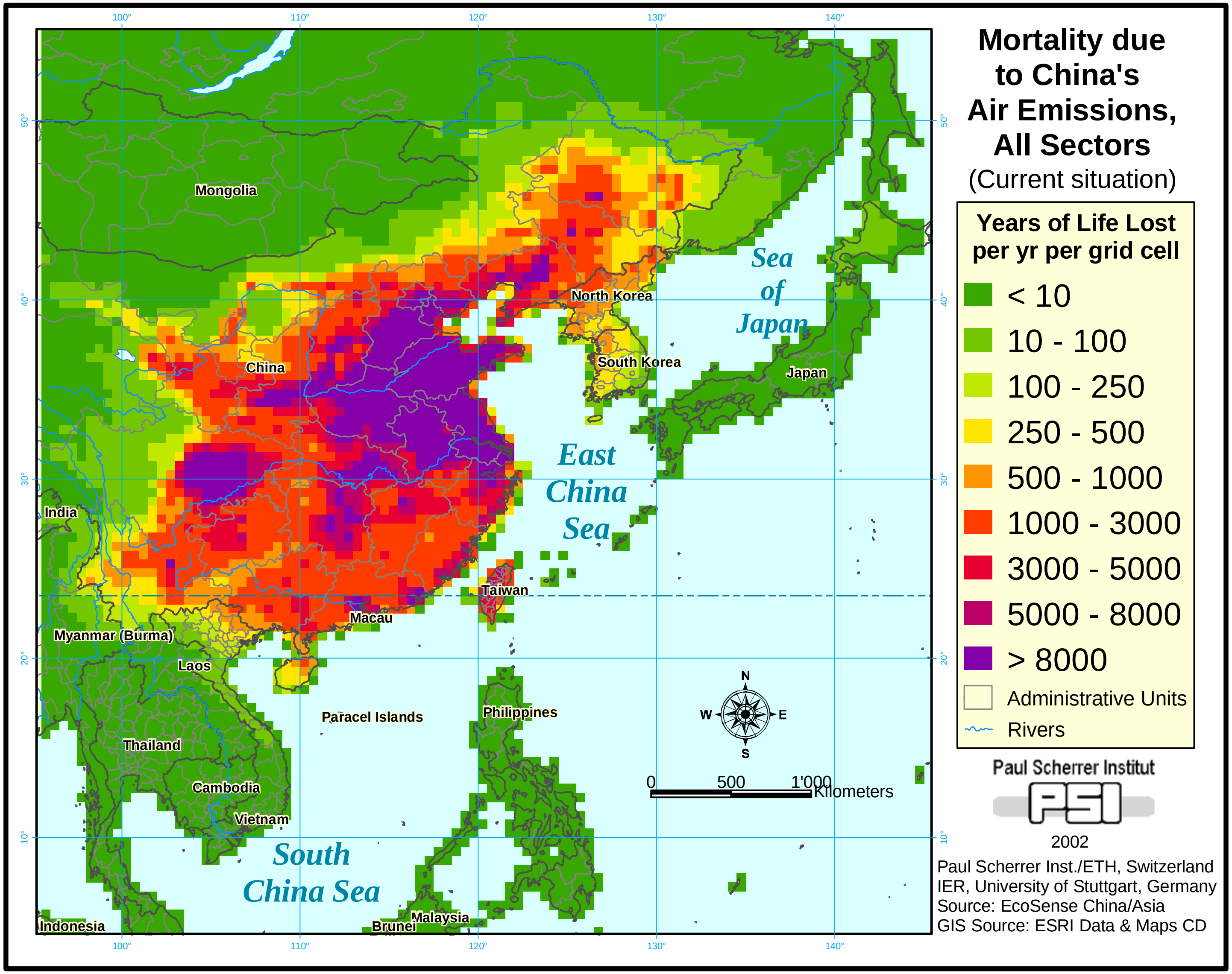
Monetary valuation methods for mortality impacts:

- Willingness-to-Pay
- Human Capital Approach

Valuation – Examples

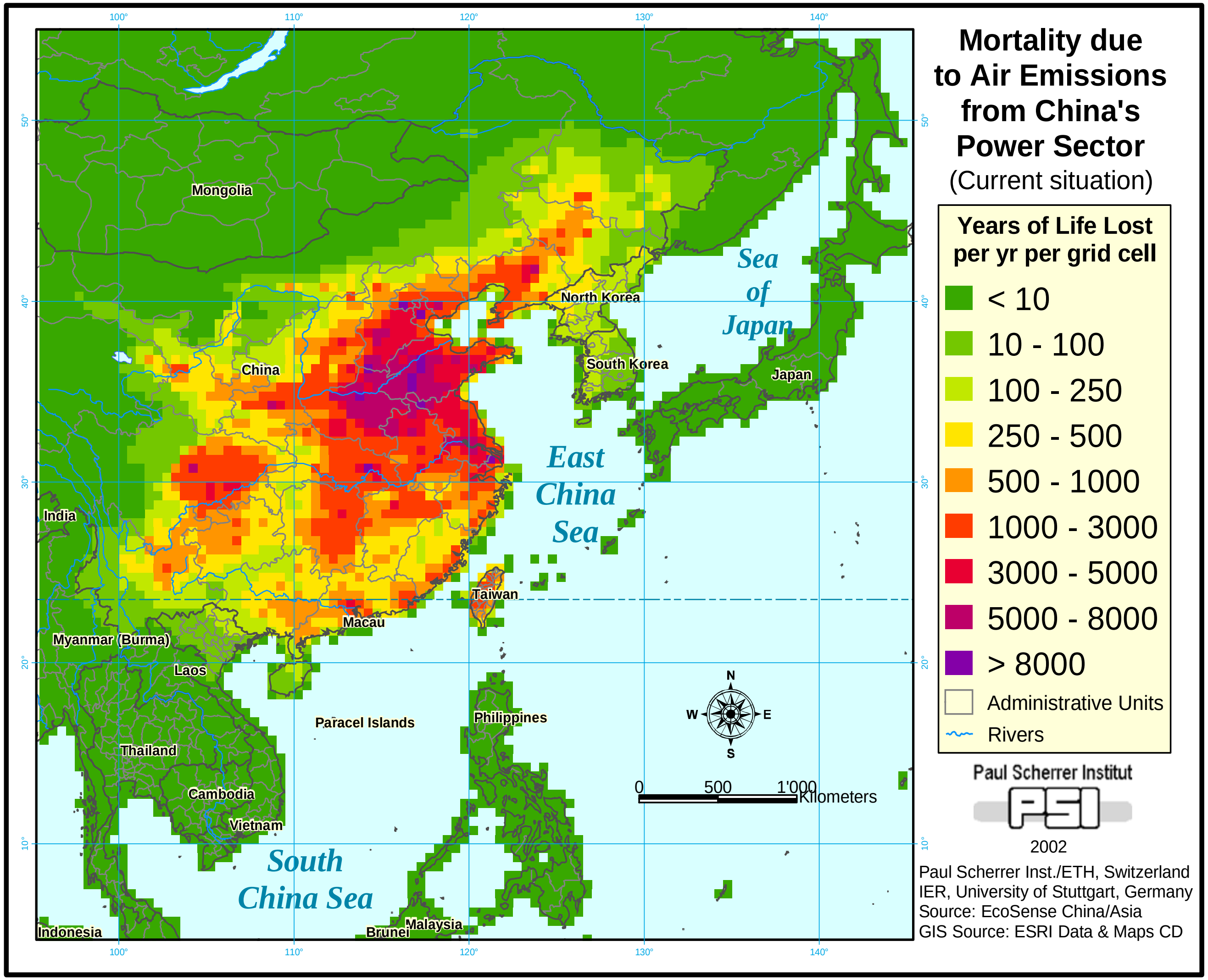
Health impact	EU-15	China	
Value of Statistical Life (ExternE)	3.1 Million	443‘000	US$
Acute YOLL (0% discounting)	110‘000	15‘710	US$/YOLL
Chronic YOLL (0% discounting)	110‘000	15‘710	US$/YOLL
Restricted activity days	116	17	US$/case
Chronic bronchitis	178‘000	25‘400	US$/case

Mortality in China - Emissions from all Sectors



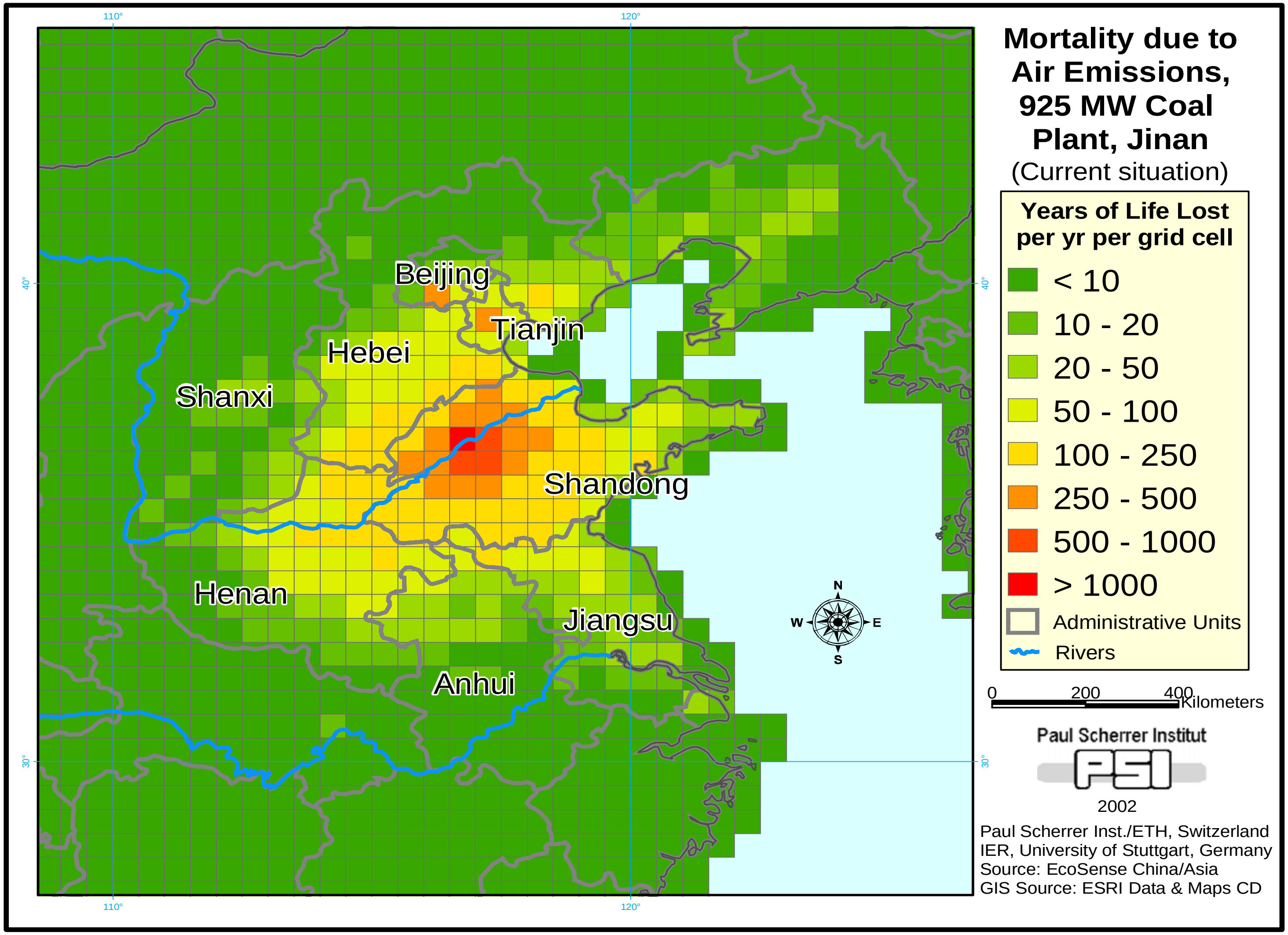
Source: Hirschberg et al., 2003

Mortality in China - Emissions from Power Sector



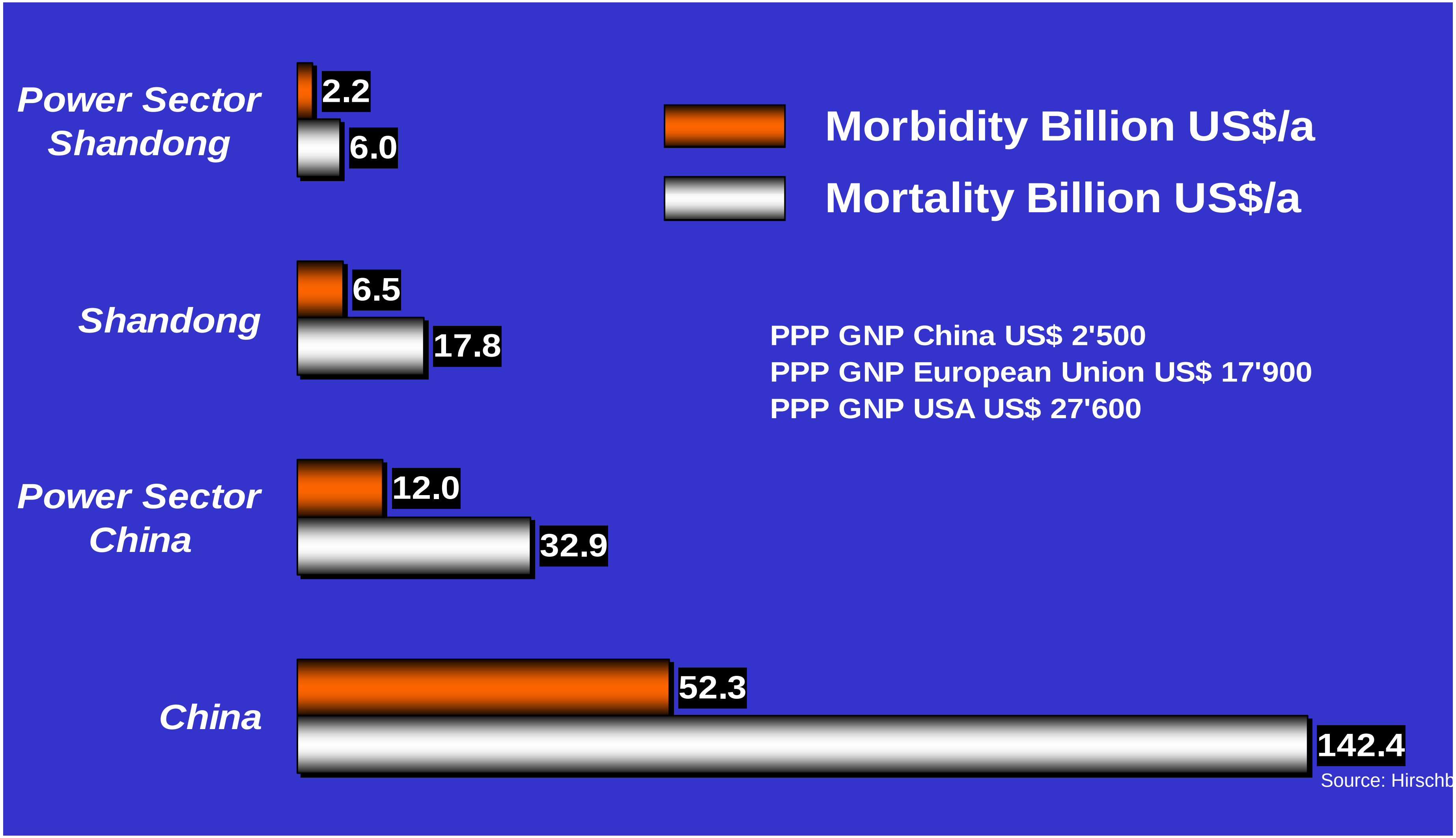
Source: Hirschberg et al., 2003

Mortality due to Air Pollution – Jinan Coal Power Plant



Source: Hirschberg et al., 2003

Monetary Damages



Uncertainties

Estimated geometric standard deviations:

	Chronic Mortality ExternE Europe (European Commission, 1999)	Chronic Mortality China (Hirschberg et al., 2003)
Emission data	1.2	1.5
Atmospheric modeling WTM	2	2
Exposure-response function, original study	1.3	1.3
Transfer of exposure-response function to other region	2	2.3
YOLL calculation from mortality	1.5	1.8
Latency	1.4	1.4
Population data	-	1.1
Total *(without monetary valuation)*	***3.2***	***3.9***

Source: Hirschberg et al., 2003

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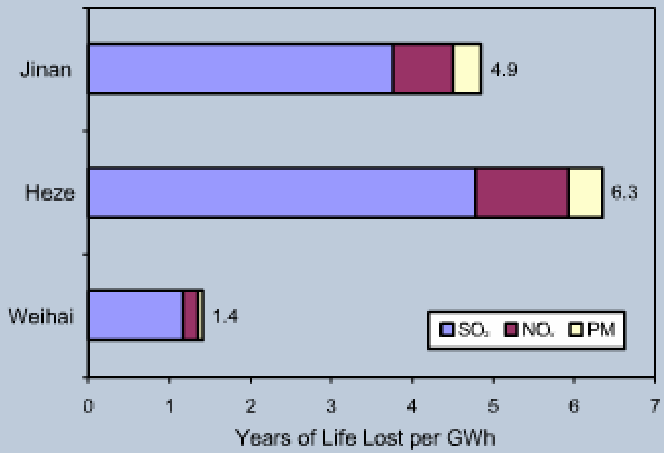
Overall Mortality: Dependence on Power Plant Location



- Influence of the location of emission (SO_2, NO_x, Particulates) on health impacts from power plant operation.
- Overall mortality includes long-distance effects beyond Shandong.
- A reference plant is used for this comparison. It is based on conventional pulverized coal technology, as implemented in the currently operating 860 MWe Huangtai plant in Jinan, Shandong.

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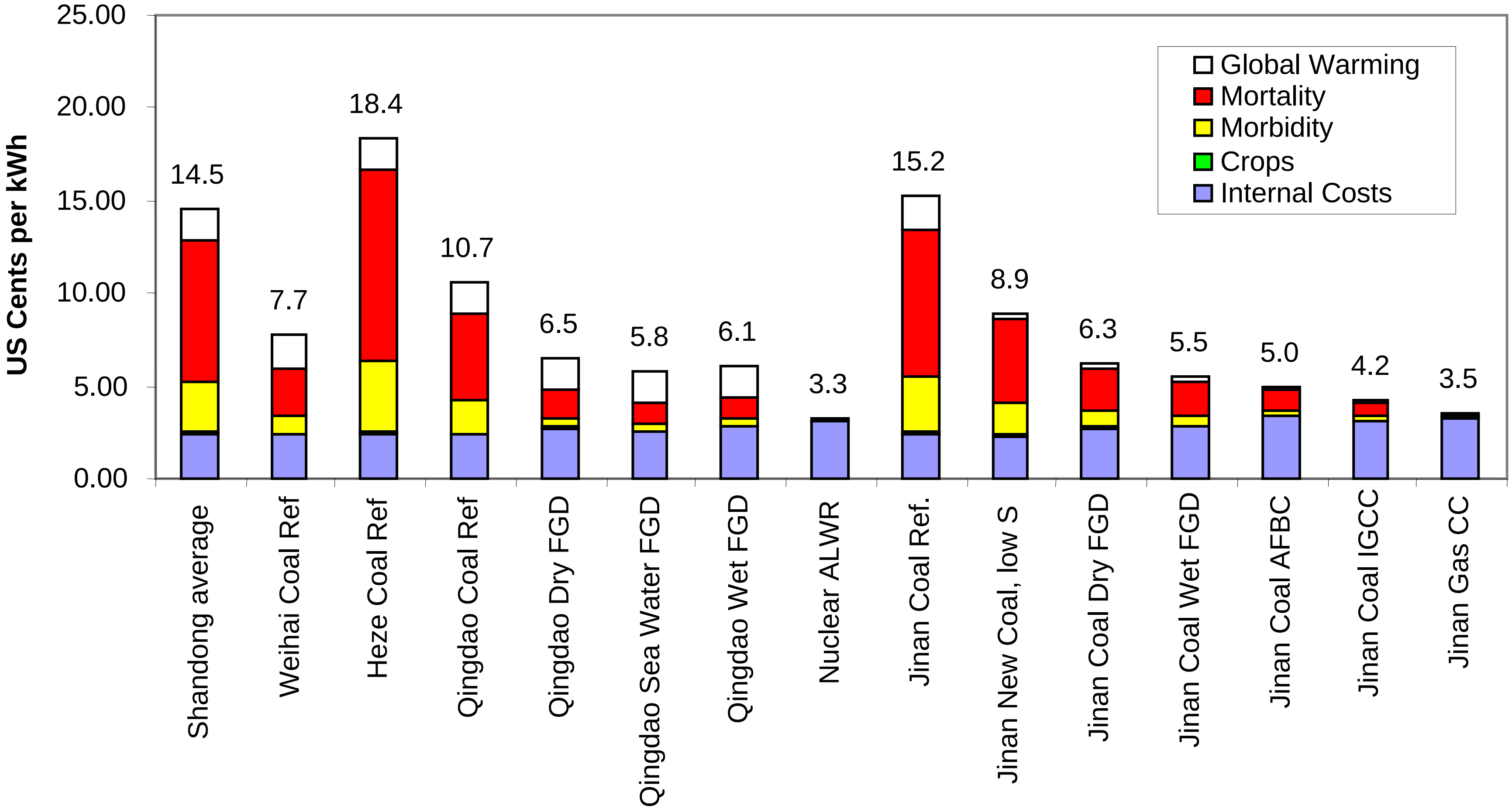
EIA Results

China Energy Technology Program
„True“ costs for power plants in Shandong Province and China

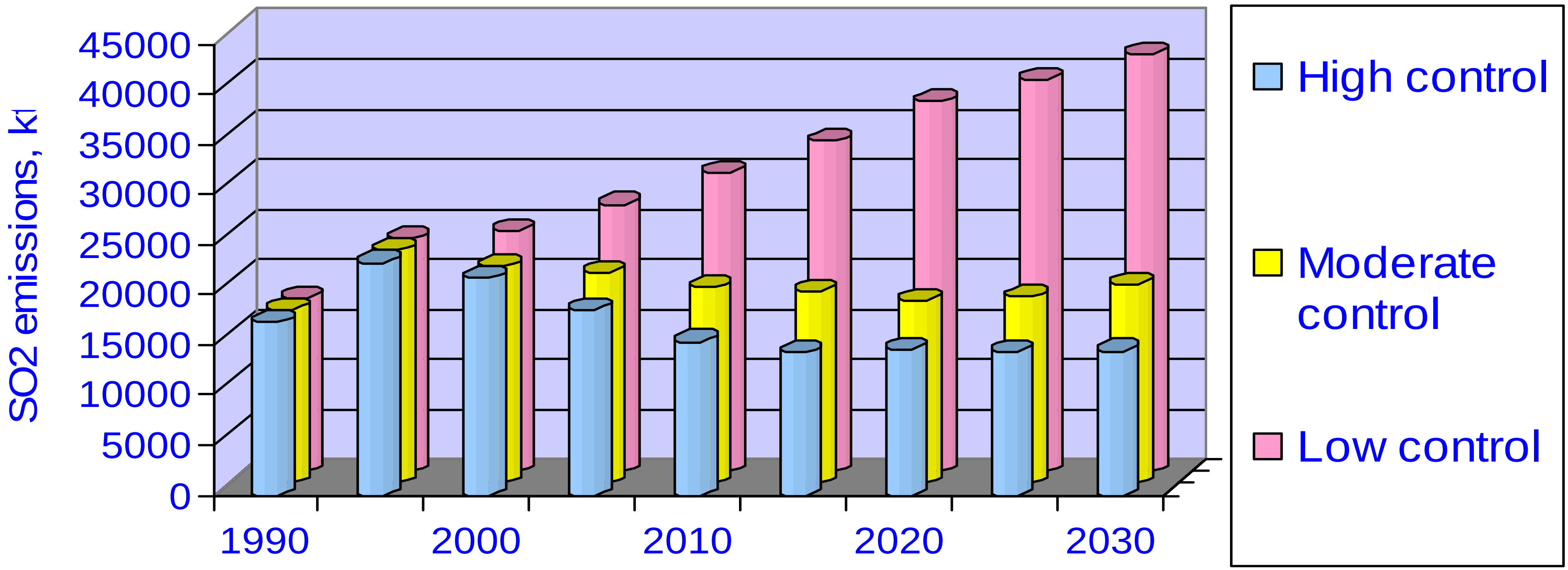


Source: Hirschberg et al., 2003

Conclusions

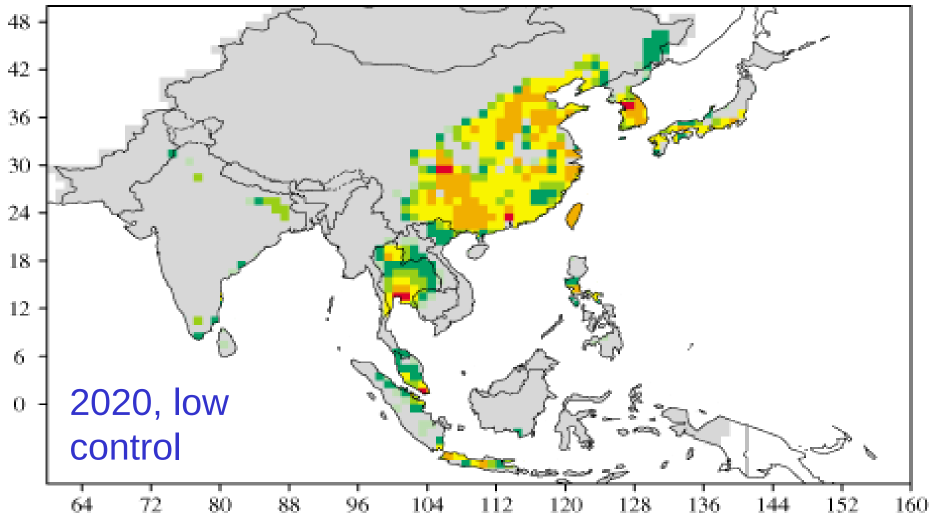
- Health impacts of air pollution in China are extraordinarily high. Associated mortality effects result in 9.1 million years of life lost per year in China.
- Secondary particulates dominate the impacts.
- The overall losses due to these damages are of the order of 6-7% of GDP.
- Mortality effects per ton of SO2 emitted in Shandong Province are about 11 times higher than the average in the European Union.
- The “true” costs of electricity are dominated by damages to health. Reducing damage by changing electricity generation strategies is feasible, economic and socially justified.

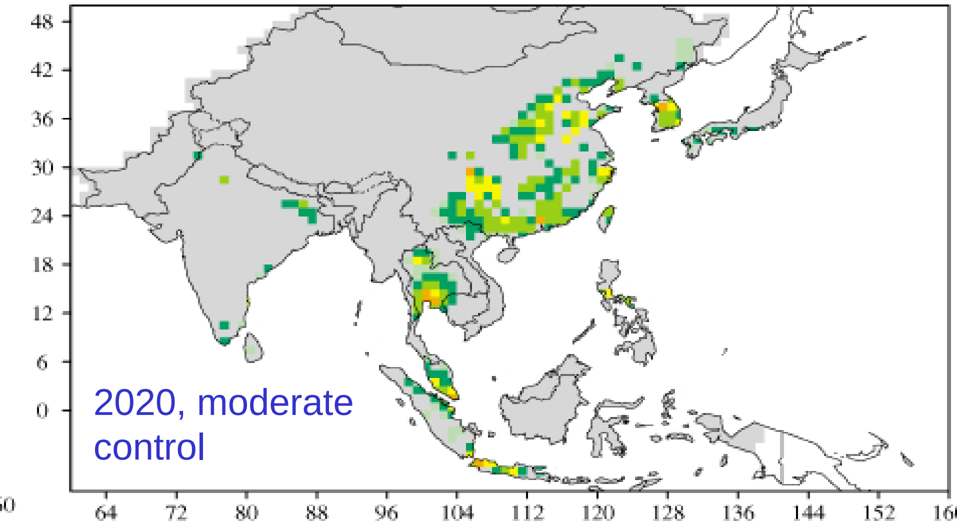
RAINS-ASIA; SO2 Emissions and Control in China



Source: Hirschberg et al., 2003

Environmental Impacts: In Excess of Critical Loads of acidification in 3 Scenarios

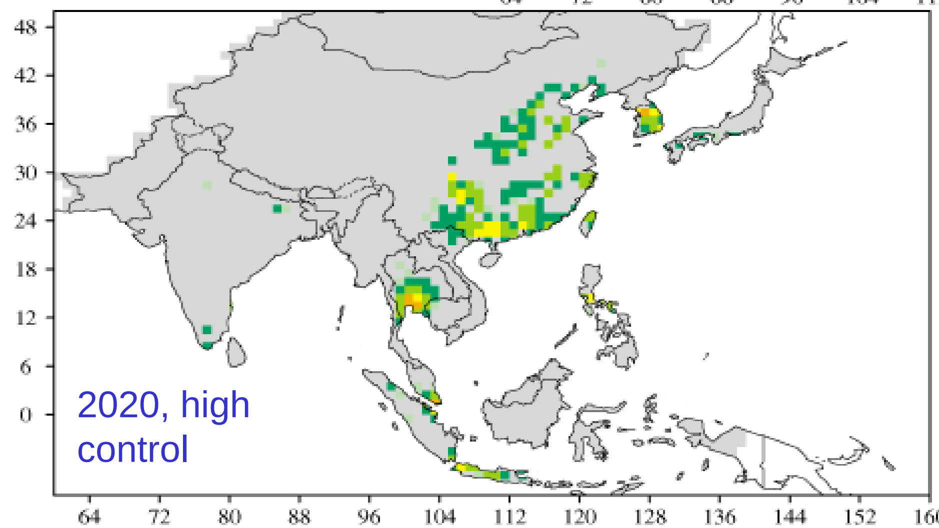




Unit: eq/ha-yr

0
0
63
313
625
1250
3125
6250
12500
60000

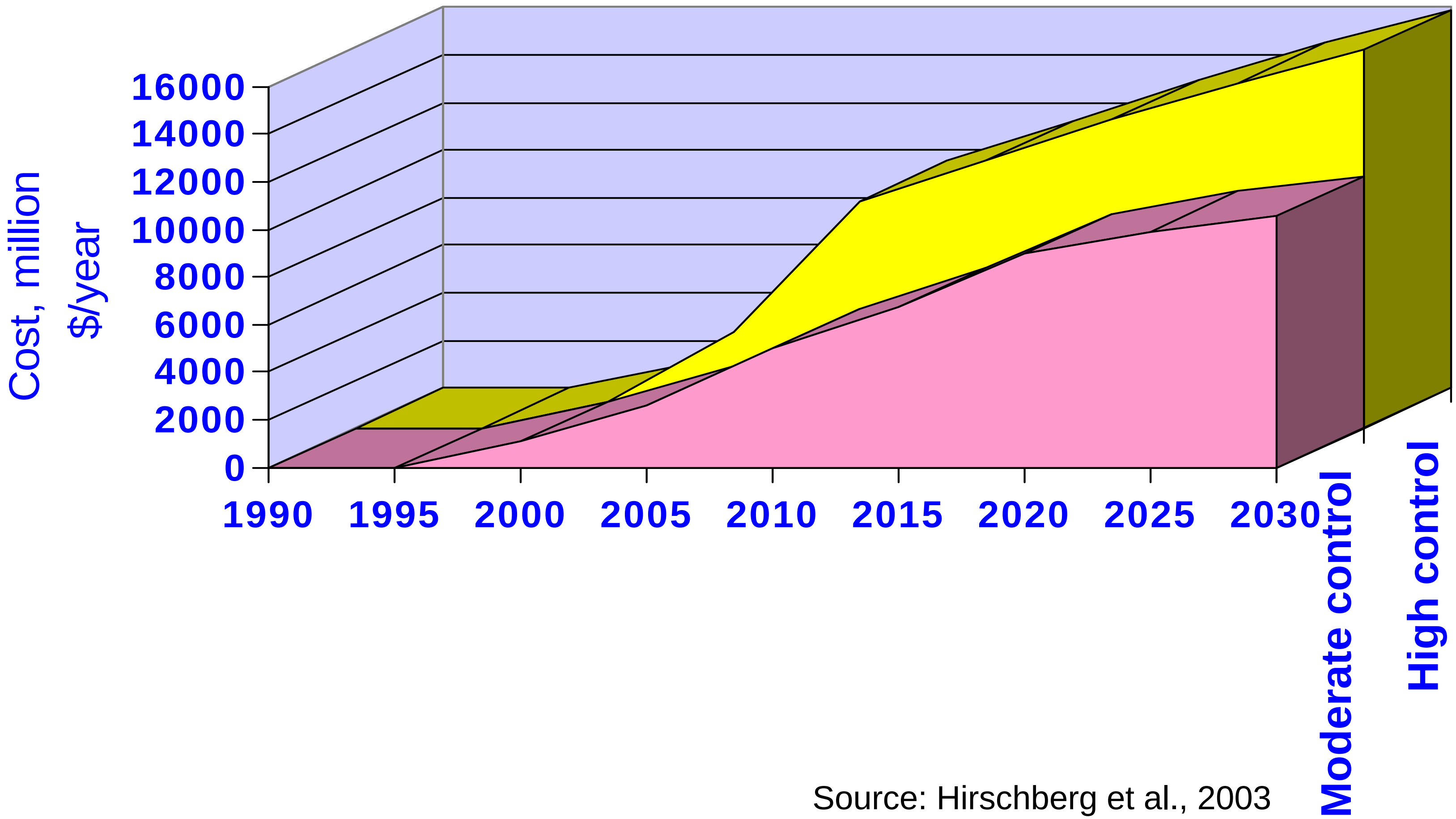
1 eq/ha.y=1.6 mg/m².y



Source: Hirschberg et al., 2003

SO2 Emissions and Control: Cost Analysis

Control costs of scenarios in China



Source: Hirschberg et al., 2003

Energy Policies & Strategies

Policy Options in China and Shandong

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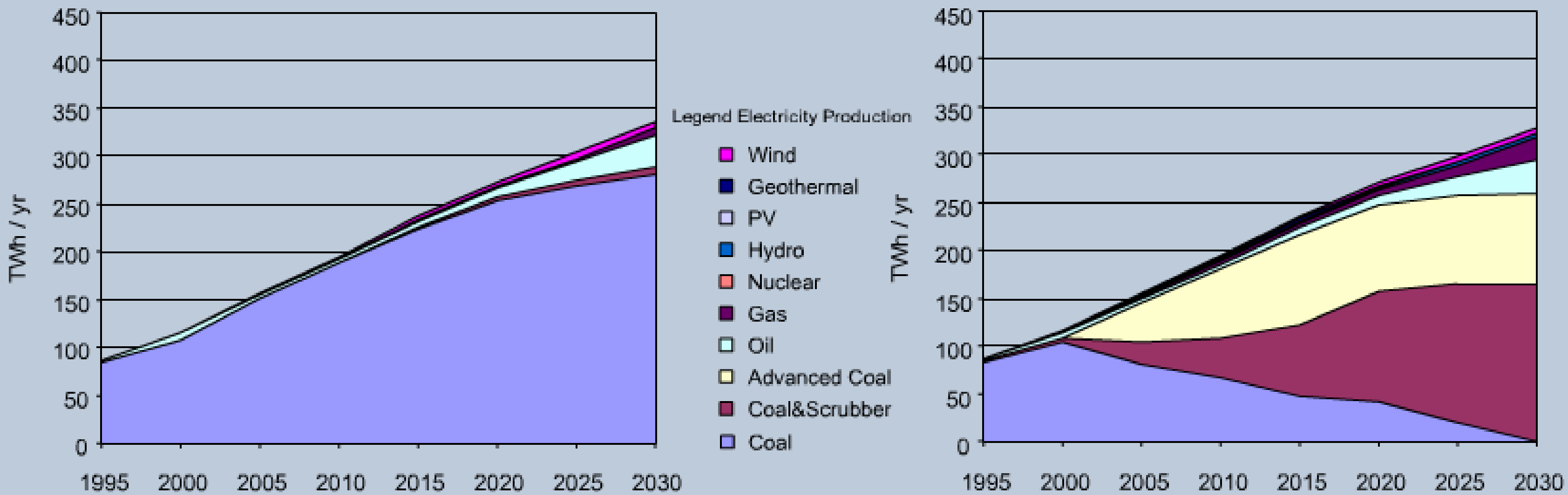
Curbing SO_2 – Electricity Production in Shandong by Technology

BLC no Caps or Taxes, Low Demand, Constant Fossil Fuel Prices

SLC15 Tax on SO_2 (1500 $/t C), Low Demand, Constant Fossil Fuel Prices

Electricity Production



- Capping SO_2 emissions favors replacing conventional Pulverized Coal with Clean Coal technologies (use of scrubbers and advanced coal technology).
- The average cost for the BLC scenario is 3.4 ¢/kWh, for SLC15 it is 4.2 ¢/kWh.

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EEM Results

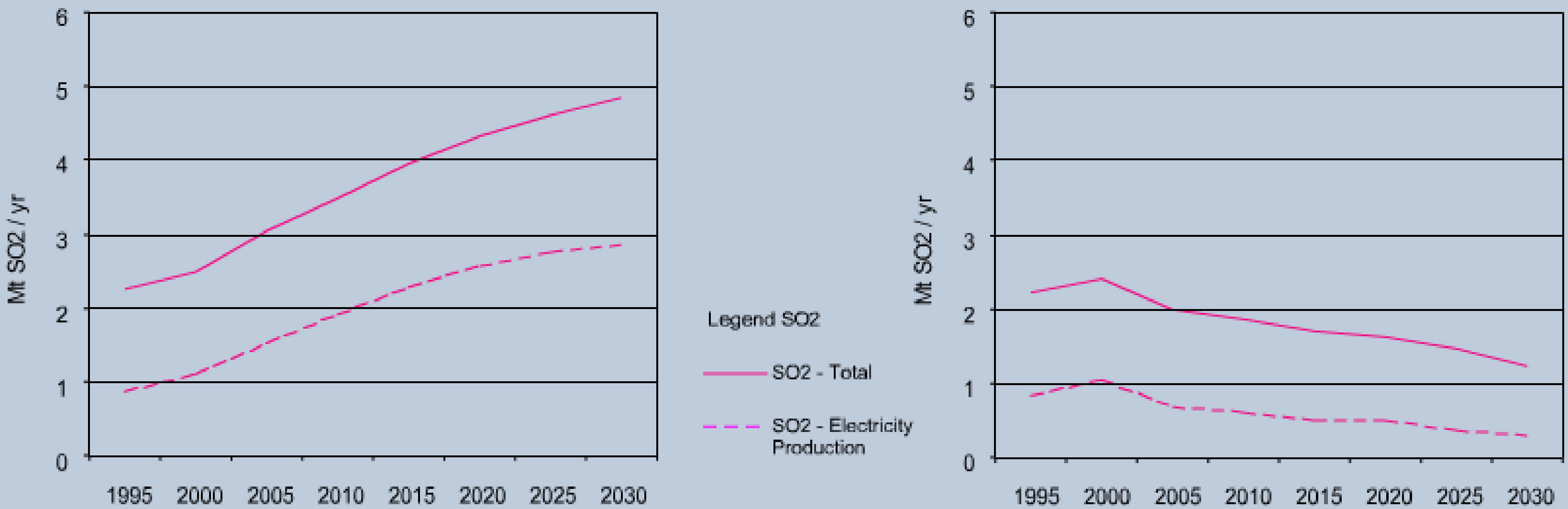
Source: Kypreos et al., 2003

Curbing SO_2 – SO_2 Emissions in Shandong from Electricity and Energy Sectors

BLC no Caps or Taxes, Low Demand, Constant Fossil Fuel Prices

SLC15 Tax on SO_2 (1500 $/t C), Low Demand, Constant Fossil Fuel Prices

Emissions of SO2



- The SLC15 case (right) reduces annual SO_2 emissions fivefold in the year 2020 compared to the BLC case (left).
- Total CO_2 emissions are only marginally affected.

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EEM Results

Source: Kypreos et al., 2003

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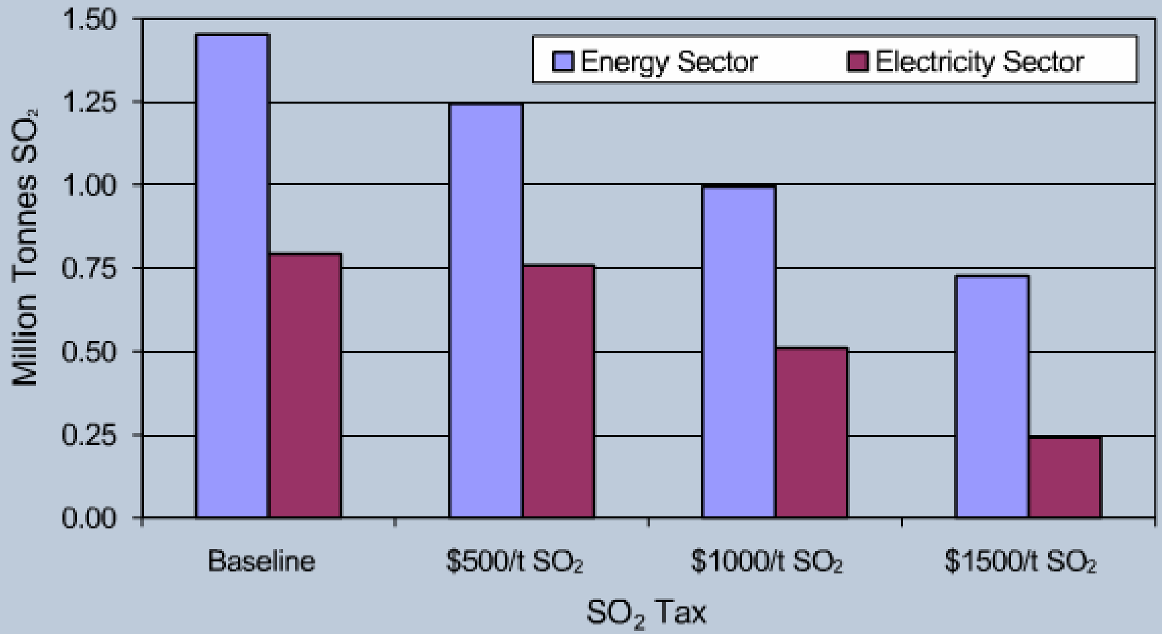
SO_2 Tax Effects – Shandong Emissions in 2030



- The SO_2 tax is clearly effective only for levels above 500 $ per tonne of SO_2.
- The current tax of 50 $ per tonne of SO_2 emission has no effect.

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EEM Results

Source: Kypreos et al., 2003

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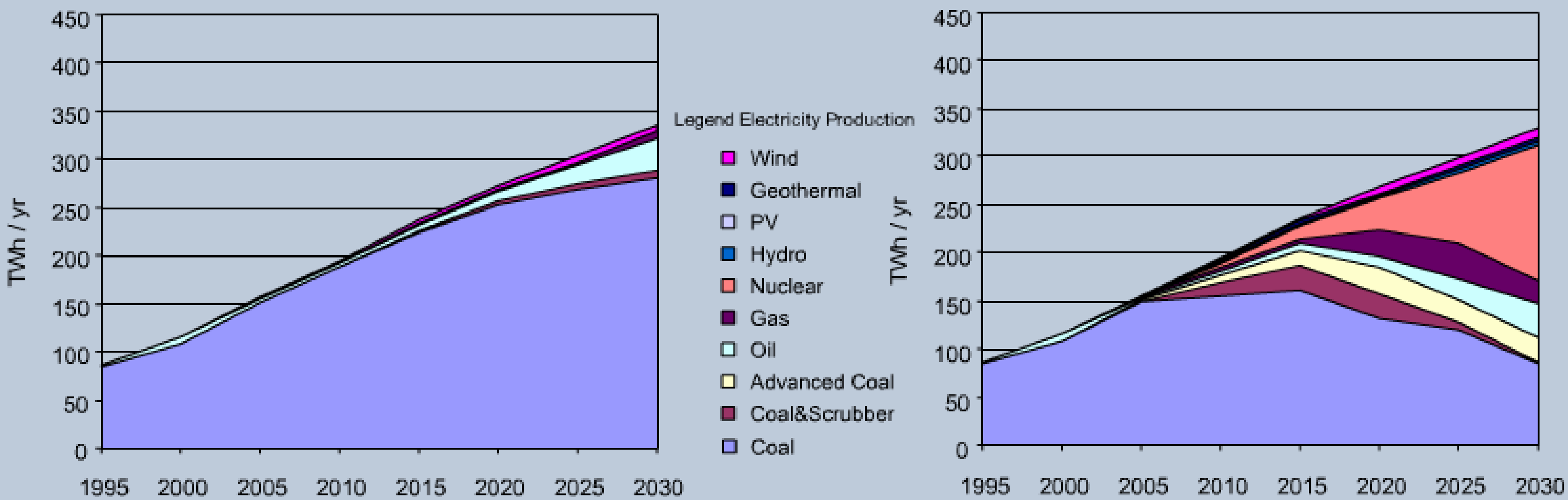
Curbing SO_2 and CO_2 – Electricity Production in Shandong by Technology

BLC no Caps or Taxes, Low Demand, Constant Fossil Fuel Prices

ELC Caps on CO_2 and SO_2, Low Demand, Constant Fossil Fuel Prices

Electricity Production



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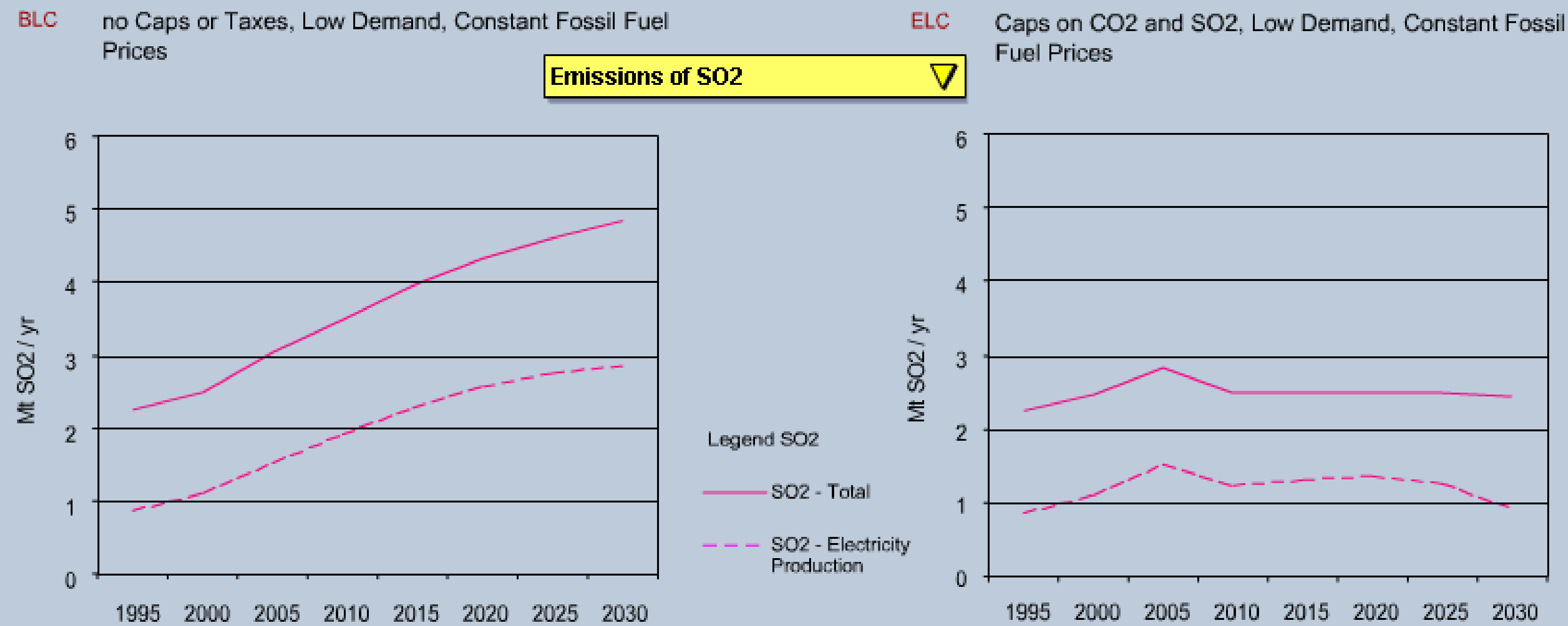
- Capping SO_2 emissions (BLC scenario, right) implies abandoning conventional PC for Clean Coal technologies (primarily scrubbers and advanced coal technology) primarily. The ELC scenario achieves a smaller SO_2 reduction in 2020 than the SLC15 scenario, when compared to the BLC scenario.
- The average cost for the BLC scenario is 3.4 ¢/kWh, for ELC it is 4.0 ¢/kWh.

EEM Results

Source: Kypreos et al., 2003

Energy Policies & Strategies
Policy Options in China and Shandong

Curbing SO_2 and CO_2 – SO_2 Emissions in Shandong from Electricity and Energy Sectors



- The ELC case (right) reduces SO_2 from the electricity sector by a factor of about two compared to the BLC case (left).

EEM Results

Source: Kypreos et al., 2003

Energy Policies & Strategies

Policy Options in China and Shandong

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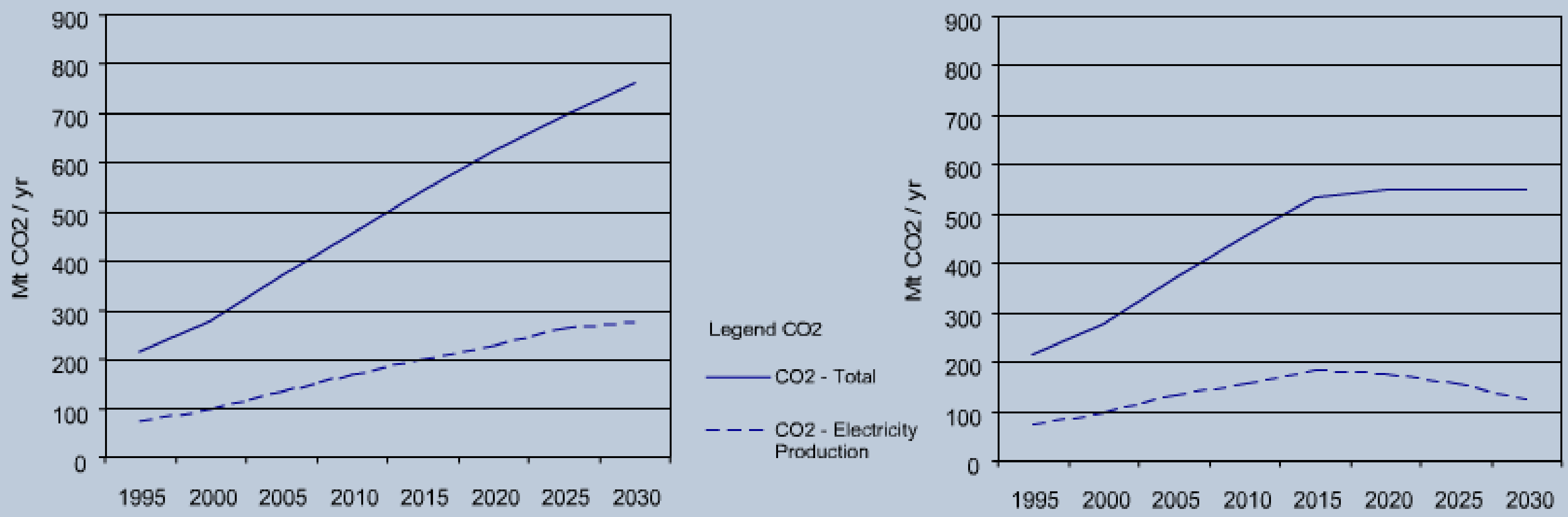
Curbing SO_2 and CO_2 – CO_2 Emissions in Shandong from Electricity and Energy Sectors

BLC no Caps or Taxes, Low Demand, Constant Fossil Fuel Prices

ELC Caps on CO2 and SO2, Low Demand, Constant Fossil Fuel Prices

Emissions of CO2



- The ELC case (right) reduces CO_2 from the electricity sector in 2020 by about 20% compared to the BLC case (left).

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EEM Results

Source: Kypreos et al., 2003

Penetration of New Electricity Supply Technologies

	Coal existing	Coal FGD	Coal Advanced	Gas CC	Nuclear
Caps or Tax					
moderate SO_2	--	+	+	++	++
moderate CO_2	--	--	--	-	++
Discount Rates					
high	+	-	-	++	--
low	-	+	+	--	++
Coal Price					
high	--	--	-	++	+
low	++	+	+	--	-
Gas Price					
high	++	+	+	--	+
low	0	0	-	++	-

Driving factors and uncertainties will influence the future penetration of new generation technologies, as indicated by the range given above from lowest (- -) to highest (+ +).

Environmental Burdens, Impacts and Damages

Burdens: Coal is and will remain the main contributor to environmental burdens.

Health Impacts: Health impacts of outdoor air pollution in China are extraordinarily high and negatively influence economic growth.

"True" Electricity Costs: The "true" costs of electricity are dominated by damages to health and the environment. Reducing damage by changing electricity generation strategies is feasible, economic and socially justified.

Acidification: The risk of high exposure to acidification in China can be controlled if the current policy is fully implemented and, if feasible, enhanced.

Accident Risks: The Chinese coal chain has extremely high accident fatality rates, particularly in small mines.

Energy Policies and Strategies

Effects of Emissions Taxes: SO_2 taxes much higher than the current level are necessary for such taxes to be effective. The effective tax levels remain far below the estimated damage costs.

Curbing SO2 and CO2: Cost-effective strategies have been identified that lead to large reductions of major air pollutant emissions and substantially reduce the increase of greenhouse gas emissions.

Coal Technologies: The main priorities are to improve the environmental performance of the existing plant base and to install scrubbers at new plants.

Electricity supply diversification: Diversification of electricity supply is necessary to limit the growth of CO2 emissions. Expansion of natural gas depends on low gas prices; expansion of nuclear depends on low discount rates.

Outlook

- **Integrated Assessment with Stakeholder Integration:** CETP is an exemplary case study of how integrated assessment of energy systems can support decision makers involving stakeholders during the progress of the study.

- **Integration of analytic tools:** Further integration of analytic tools based on the CETP framework is straightforward.

Proposal

- Link regional MARKAL models of China with ECOSENSE and RAINS to perform:
  - A successive internalization of external cost policies and of critical load constraints on acidification
  - Map results and discuss costs and benefits with stakeholders
  - Define technology portfolio to address issues of resource availability, costs and environmental concerns