

# Externalities in the Energy System

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# Contents

- Introduction - What are externalities ?
- Environmental impact and external costs assessment methodology
- Result examples
- Total costs and cost-benefit analysis
- Major limitations
- Multi-Criteria Decision Analysis (MCDA)
- Conclusions

## What are externalities?

Externalities are changes of welfare generated by a given activity without being reflected in market prices. They may be positive (benefits) or negative (costs).

A cost (benefit) is external when it is not paid (enjoyed) by those who have generated it.

Negative externalities are borne by society: they should be reduced, and passed on to those who generate them (application of the "polluter pays principle" through internalisation).

## Examples of external costs

Air pollution increases hospital admissions for respiratory illness

- Costs of health care
- Lost productivity
- Own pain and suffering
- Pain and suffering of others

Water pollution leads to loss of fish

- Reduced recreational opportunity
- Commercial losses
- Impact on biodiversity

Congestion leads to loss of time, productivity

## Externalities included in current state-of-the-art EC (NEEDS)

Impact Cat.	Pollutant / Burden	Effects
Human Health mortality	PM <sub>10</sub>	Reduction in life expectancy due to short and long time exposure
	SO <sub>2</sub> , O <sub>3</sub>	
	Benzene, BaP, 1,3-butad., Diesel part., radioact., HM	Reduction in life expectancy due to short time exposure Reduction in life expectancy due to long time exposure
	Noise	Reduction in life expectancy due to long time exposure
	Accident risk	Fatality risk from traffic and workplace accidents
Human Health morbidity	PM <sub>10</sub> , O <sub>3</sub> , SO <sub>2</sub>	Respiratory hospital admissions
	PM <sub>10</sub> , O <sub>3</sub>	Restricted activity days
	PM <sub>10</sub> , CO	Congestive heart failure
	Benzene, BaP, 1,3-butad., Diesel part., radioact.	Cancer risk (non-fatal)
	PM <sub>10</sub>	Cerebrovascular hospital admissions, cases of chronic bronchitis, cases of chronic cough in children, cough in asthmatics, lower respiratory symptoms
	O <sub>3</sub>	Asthma attacks, symptom days
	Noise	Myocardial infarction, angina pectoris, hypertension, sleep disturbance
	Mercury	Loss of IQ of children
	Accident risk	Risk of injuries from traffic and workplace accidents

**Other heavy metals Diverse health impacts**

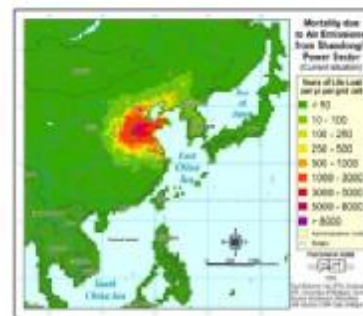
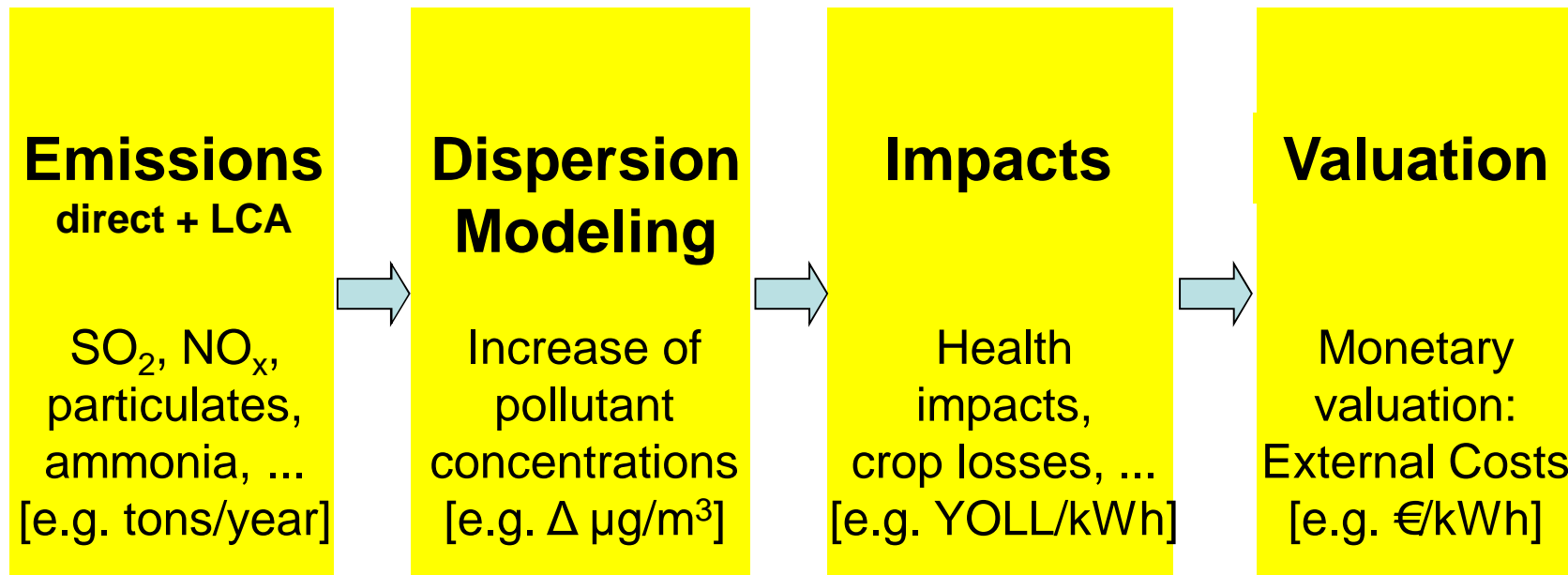
Source: NEEDS/RS1b, 2009

## Externalities included in current state-of-the-art EC (cont.)

<b>Impact Category</b>	<b>Pollutant / Burden</b>	<b>Effects</b>
<b>Building Material</b>	<b>SO<sub>2</sub>, Acid deposition</b> <b>Combustion particles</b>	<b>Ageing of galvanised steel, limestone, mortar, sandstone, paint, rendering, and zinc for utilitarian buildings</b> <b>Soiling of buildings</b>
<b>Crops</b>	<b>SO<sub>2</sub></b> <b>O<sub>3</sub></b> <b>Acid deposition</b> <b>N, S</b>	<b>Yield change for wheat, barley, rye, oats, potato, sugar beet</b> <b>Yield change for wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed</b> <b>Increased need for liming</b> <b>Fertilising effects</b>
<b>Global Warming</b>	<b>CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O</b>	<b>World-wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise</b>
<b>Amenity losses</b>	<b>Noise</b>	<b>Amenity losses due to noise exposure</b>
<b>Ecosystems</b>	<b>SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub></b>	<b>Eutrophication, Acidification</b>
<b>Land Use Change</b>		<b>'PDF' of species</b>

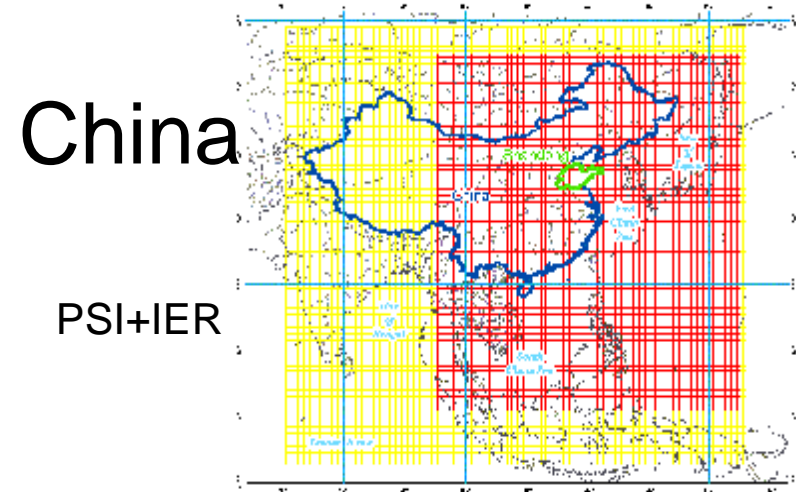
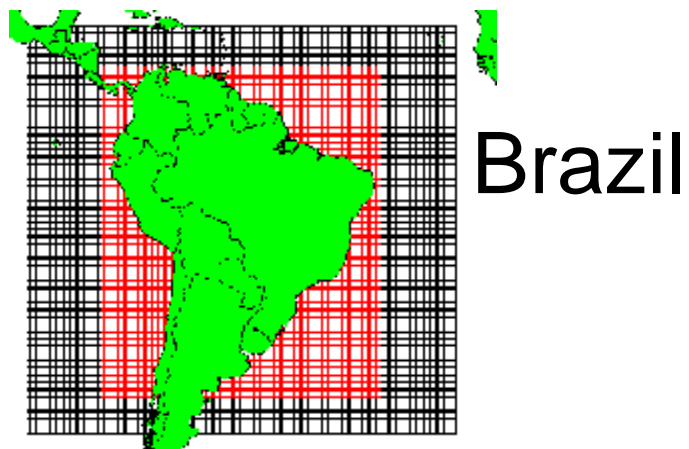
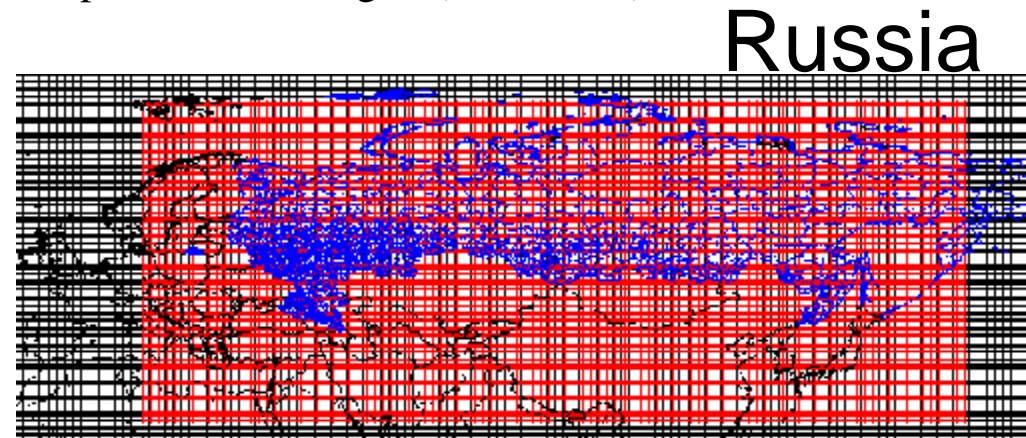
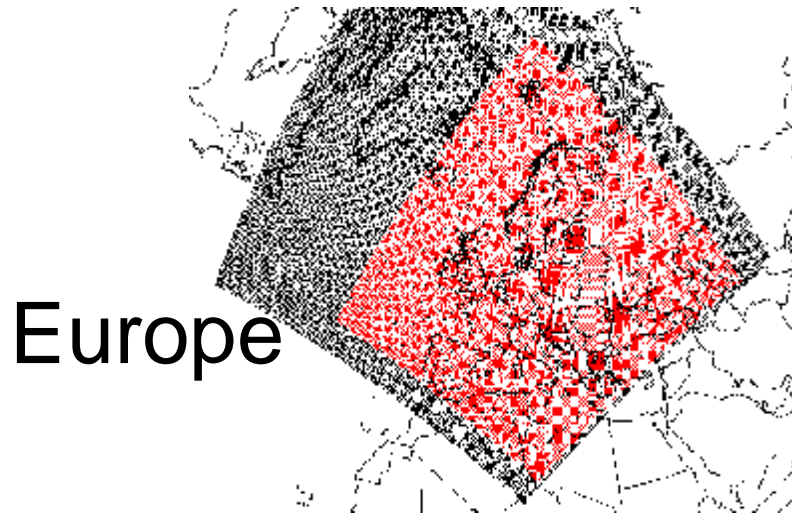
Source: NEEDS/RS1b, 2009

# EIA – The Impact Pathway Approach



# EcoSense Versions

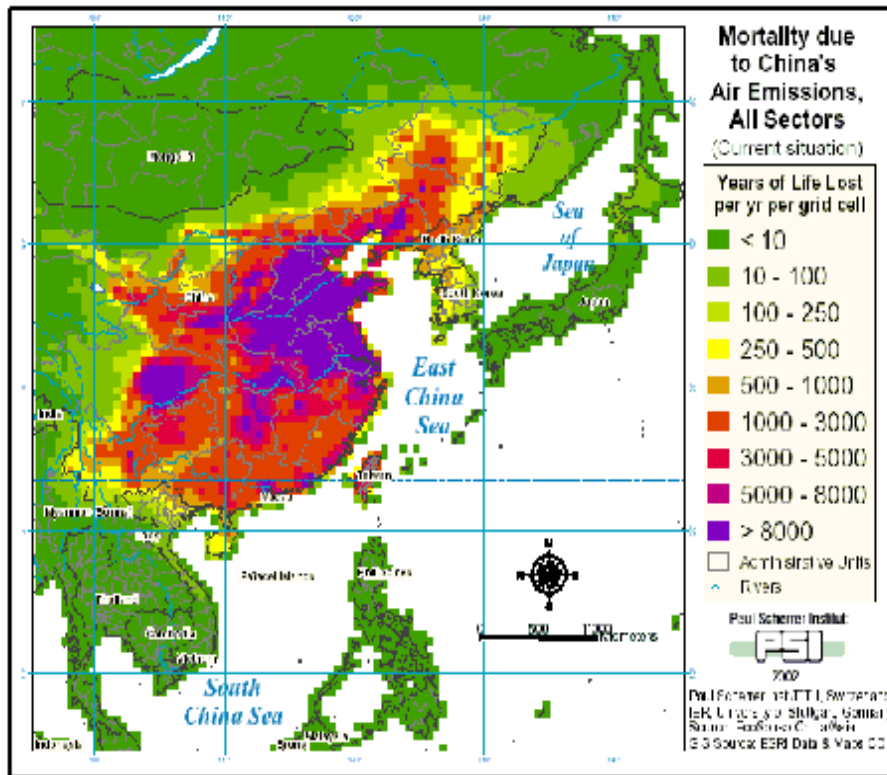
EcoSense multi-source developed at IER Stuttgart (Heck et al.)



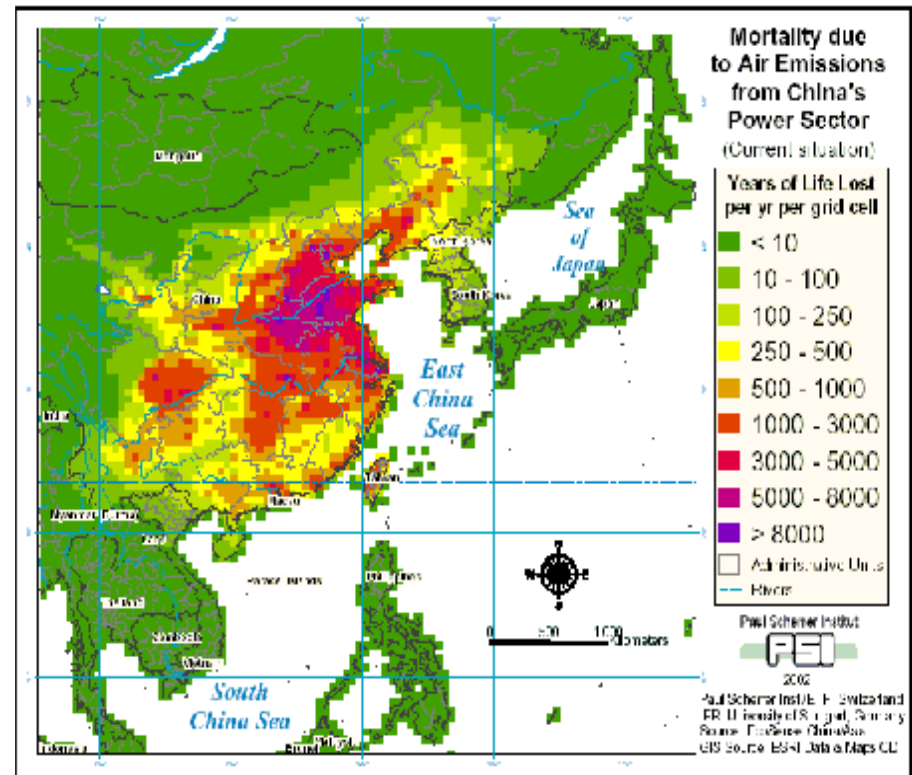


# Mortality in China due to Air Pollution

## Emissions from all Sectors

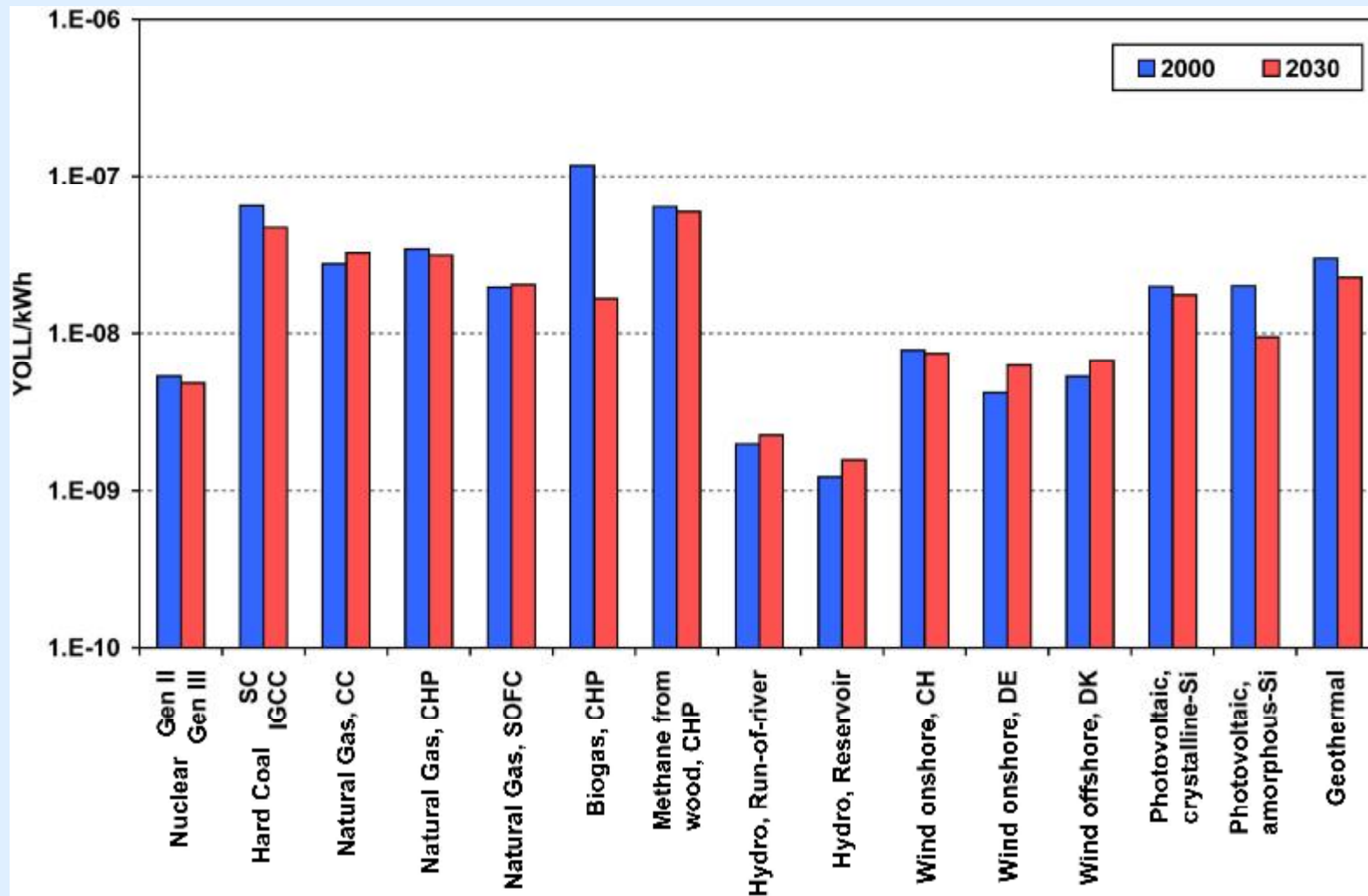


## Emissions from Power Sector



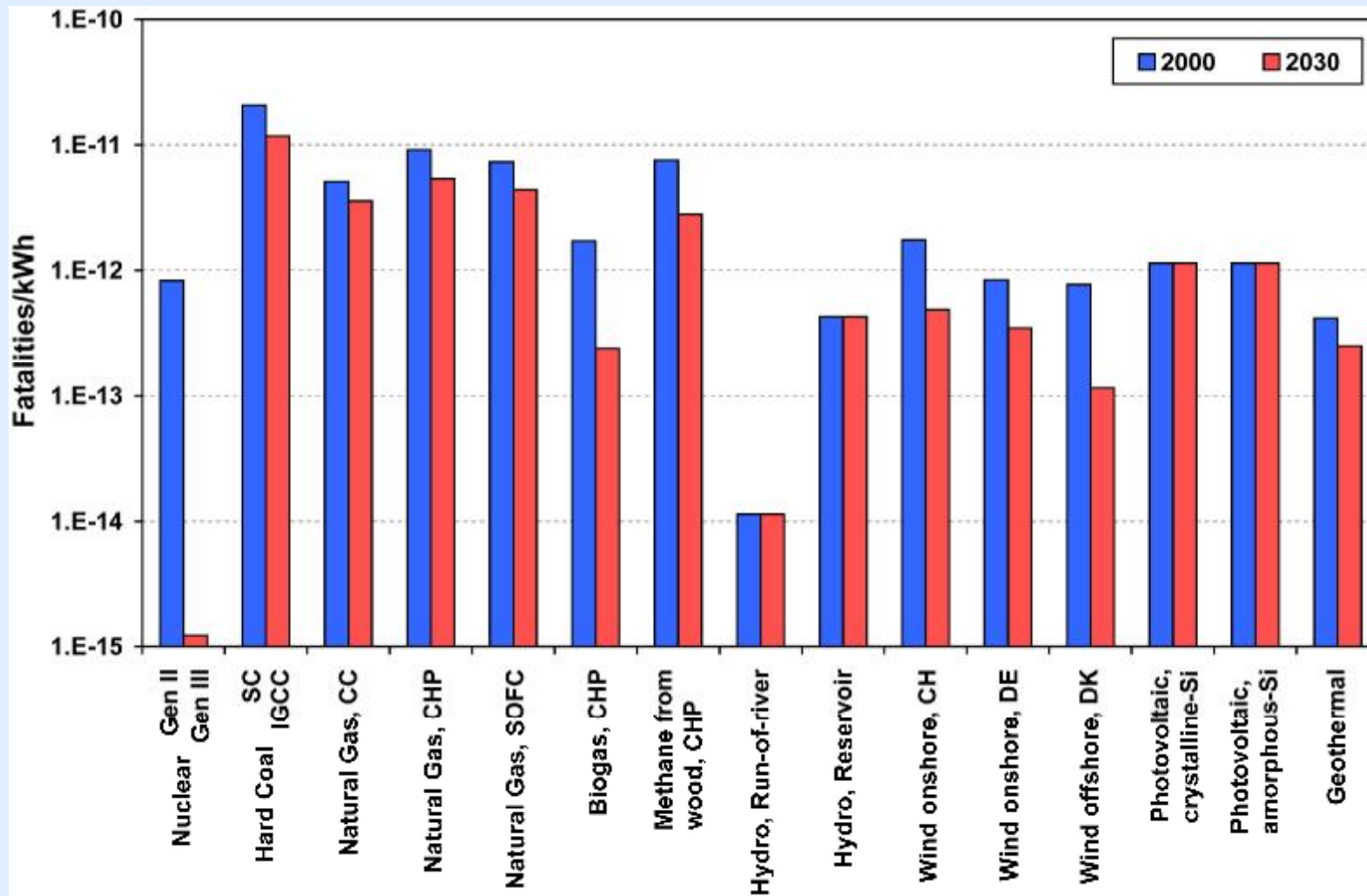
Source: Hirschberg et al., 2003

# Mortality from Normal Operation



Source: Hirschberg et al., 2008

# Severe Accident Fatality Rates



Source: Hirschberg et al., 2008

# Valuation – Examples

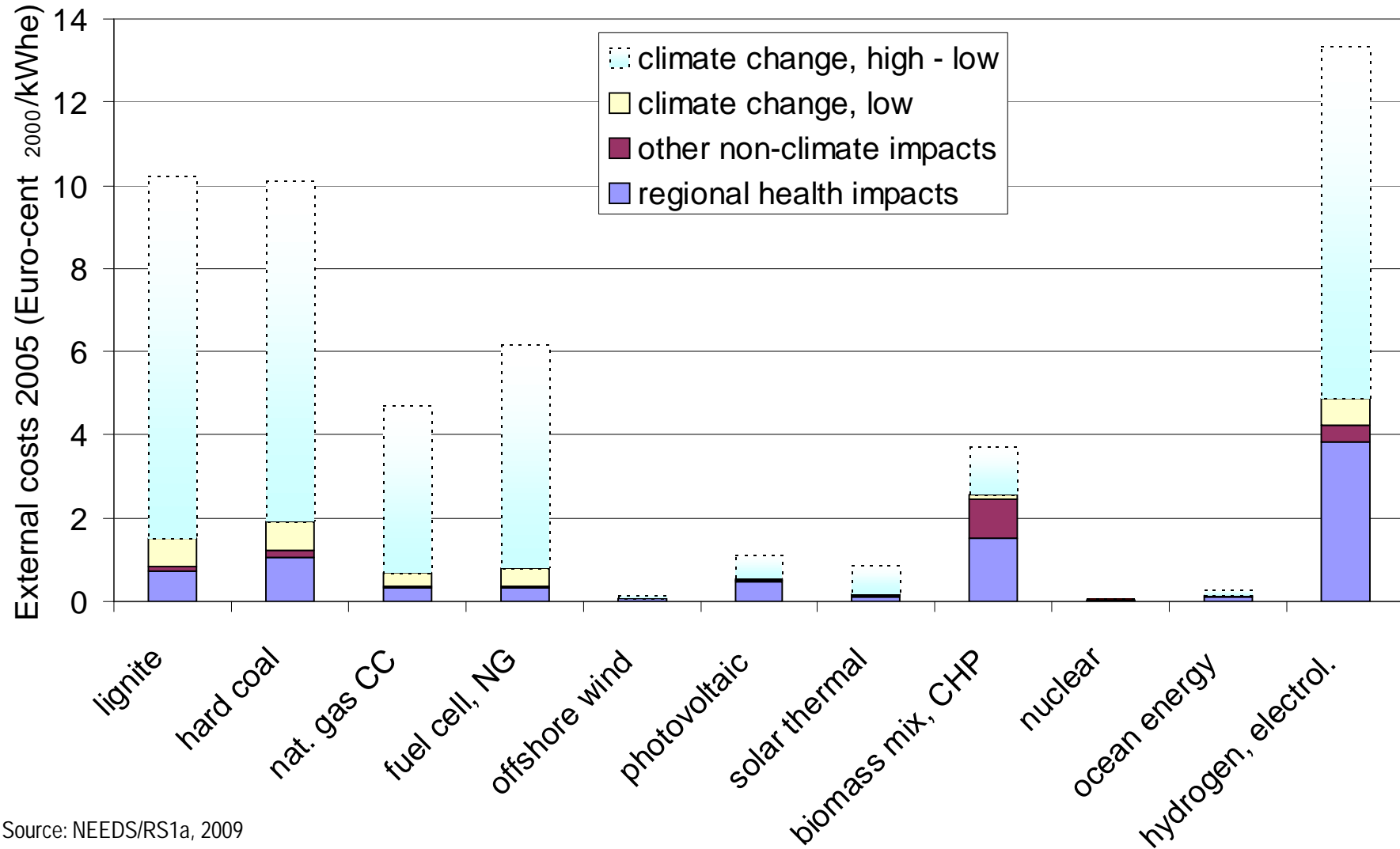
Health impact	EU current* (EUR 2000)	EU 1999** (US \$2000)	China*** (US \$ 2000)
Value of Statistical Life	3'000'000	3'000'000	440'000
Acute Years of Life Lost / reduction of life expectancy (per YOLL)	60'000	110'000	15'710
Chronic Years of Life Lost / reduction of life expectancy (per YOLL)	40'000	110'000	15'710
Restricted activity days (per case)	130	116	17
Chronic bronchitis (per case)	200'000	178'000	25'400

\*NEEDS 2009

\*\* ExternE 1999

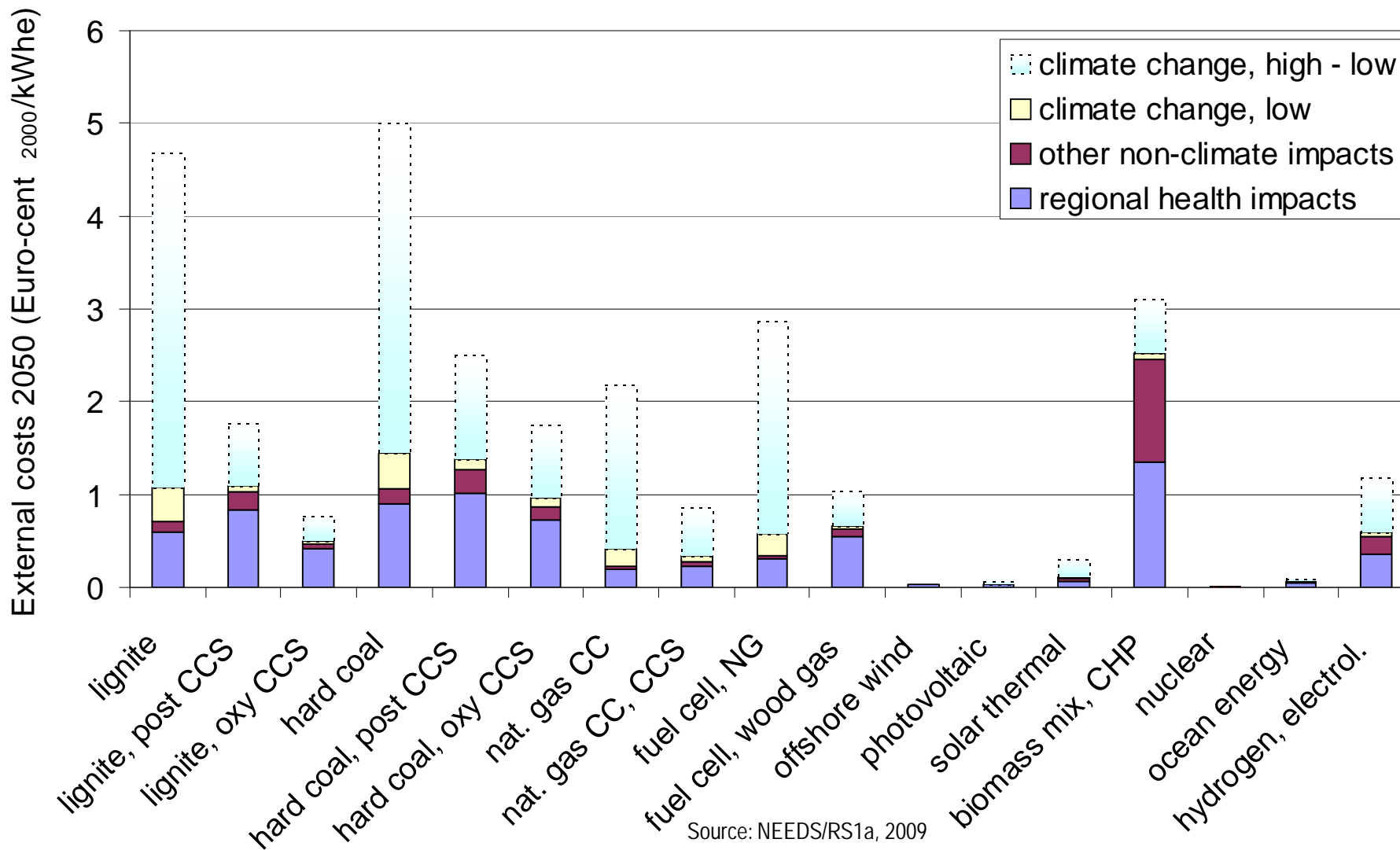
\*\*\* Hirschberg et al. 2003

# External Costs: Today, Western Europe (NEEDS Results)



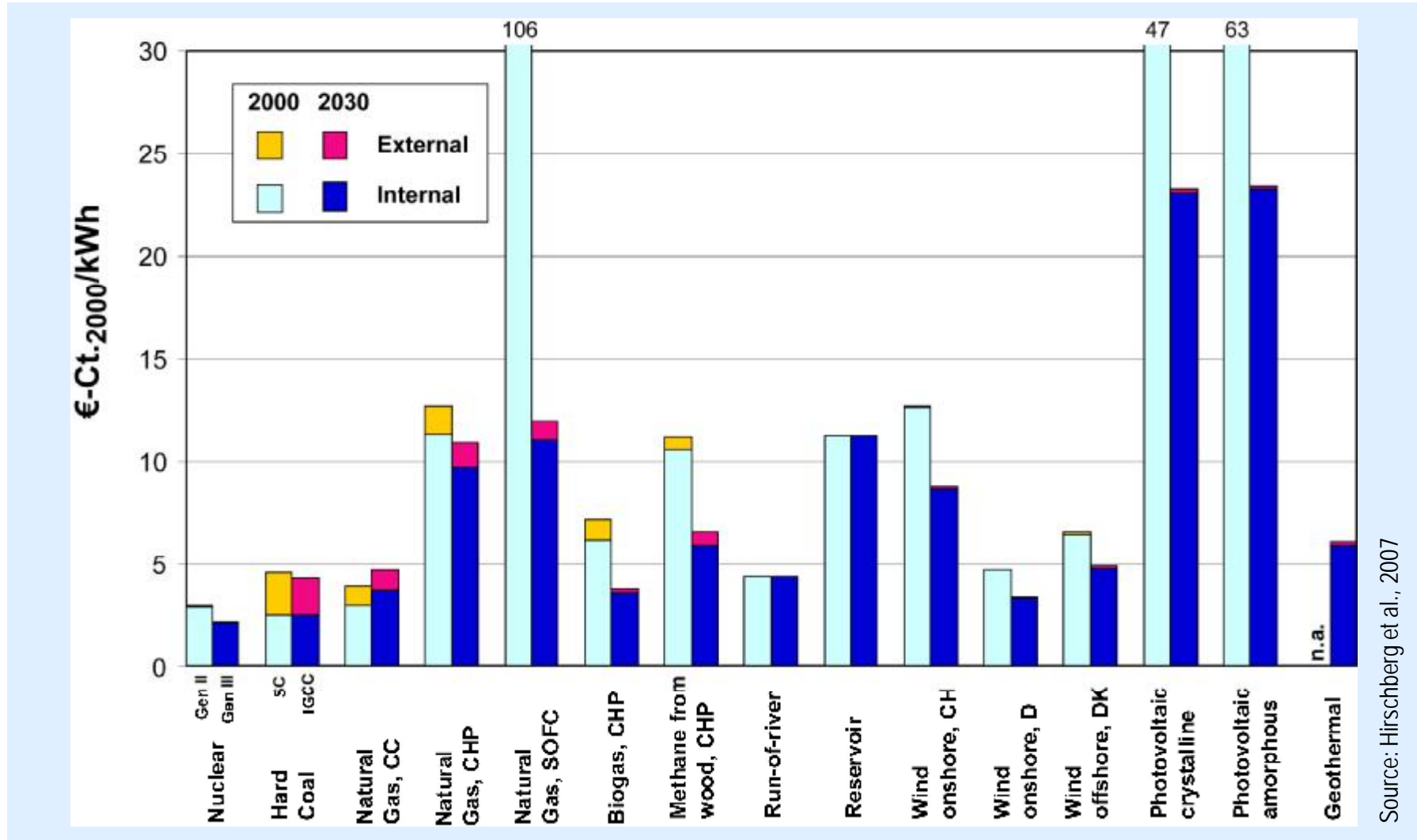
Source: NEEDS/RS1a, 2009

# External Costs: Year 2050, Western Europe (NEEDS Results)



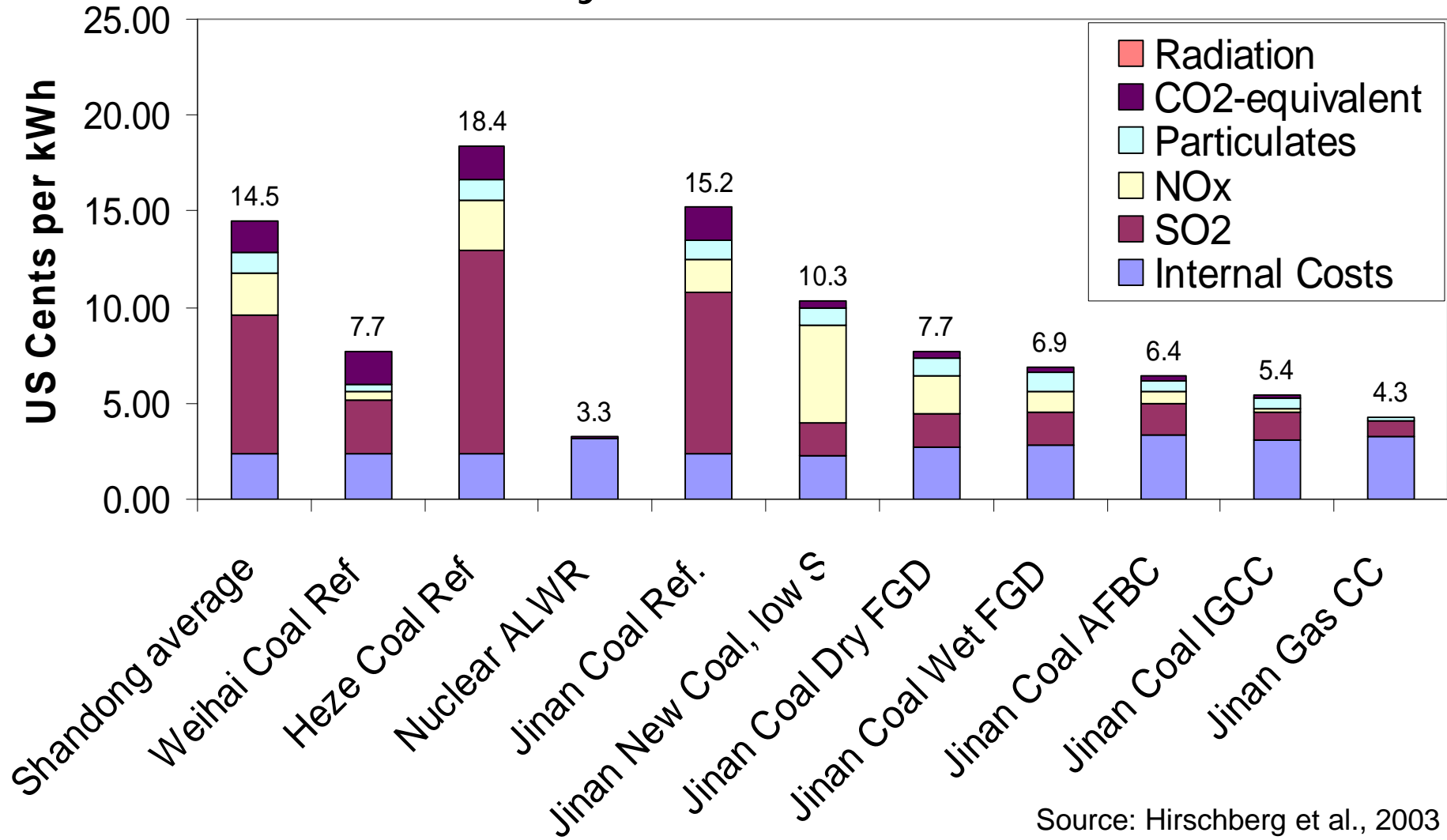
Source: NEEDS/RS1a, 2009

# Full Costs of Electricity Generation Options (primarily CH)



Source: Hirschberg et al., 2007

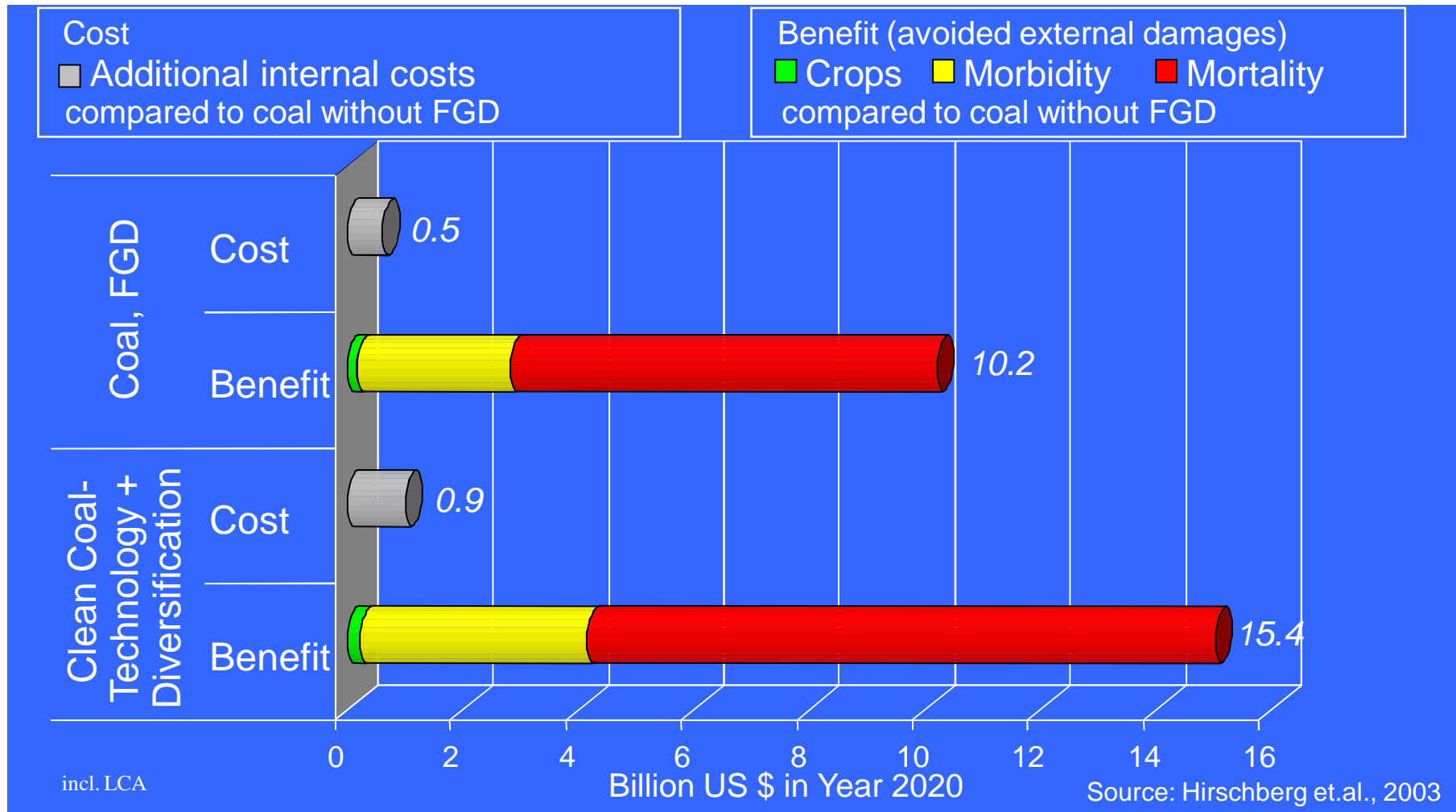
# Total Costs of Electricity – China



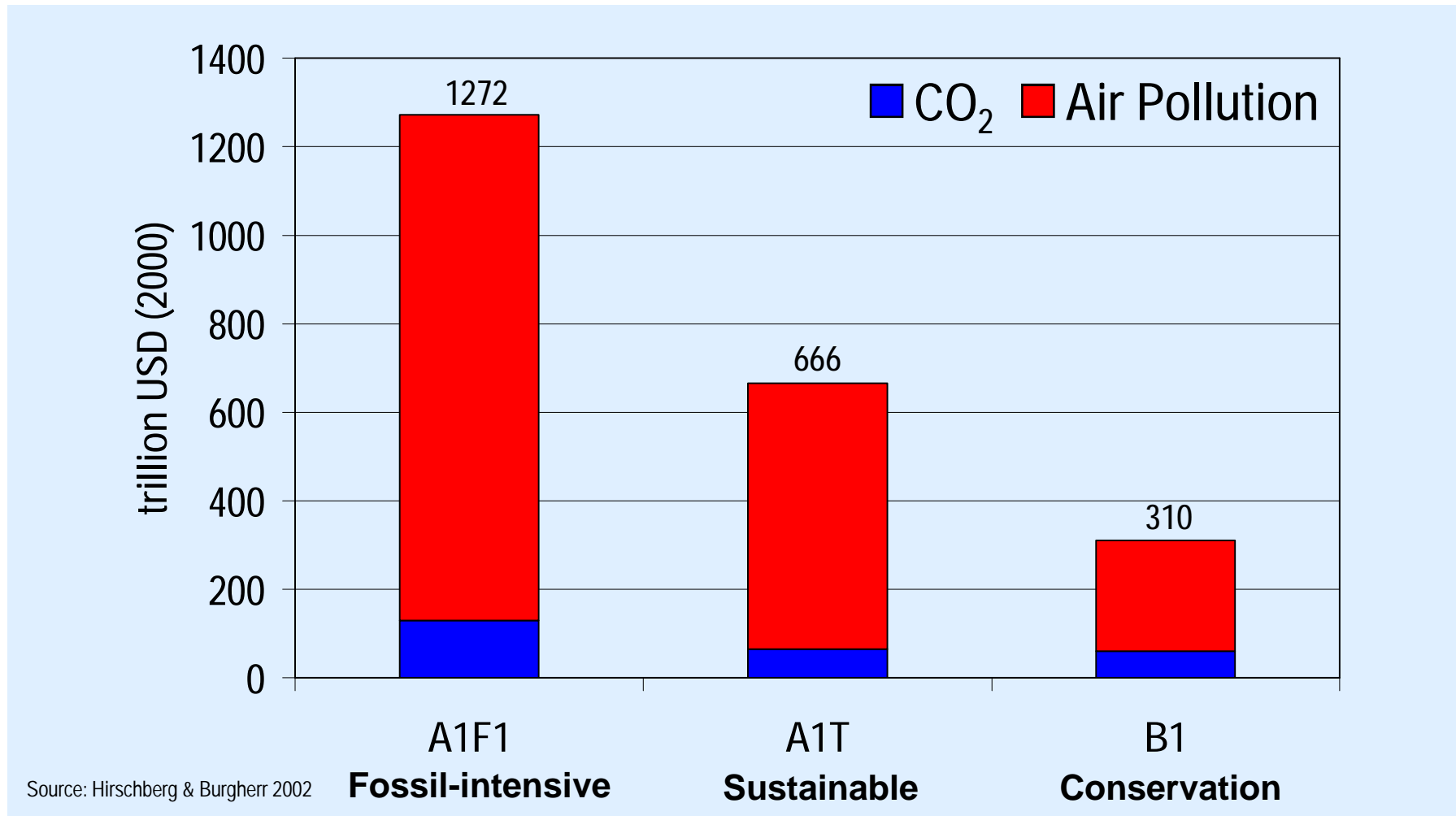
Source: Hirschberg et al., 2003



# Cost-Benefit Analysis for Selected Electric Sector Simulation Scenarios, Province Shandong in Year 2020



## Total Cumulative Damage (1990 – 2100) for Selected IPCC Scenarios

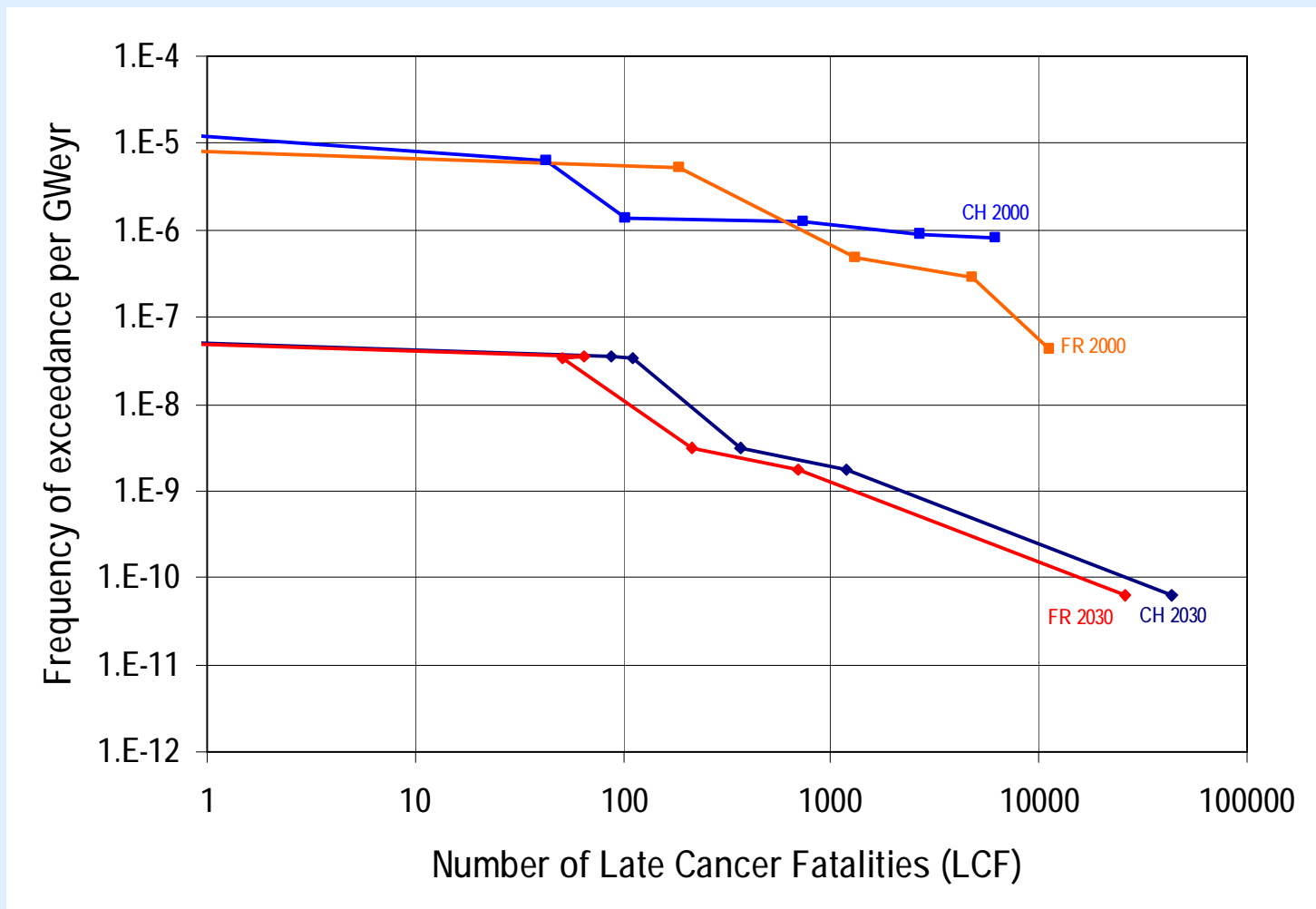


## Examples of controversial/difficult to estimate external effects

- Severe accidents, terrorism, risk aversion
- Visual intrusion
- Resource depletion
- Nuclear proliferation
- Biodiversity losses
- Security of supply
- Social justice and conflict potential

Serious attempts to estimate the corresponding costs mostly lead to low estimates but this does not resolve the controversy!

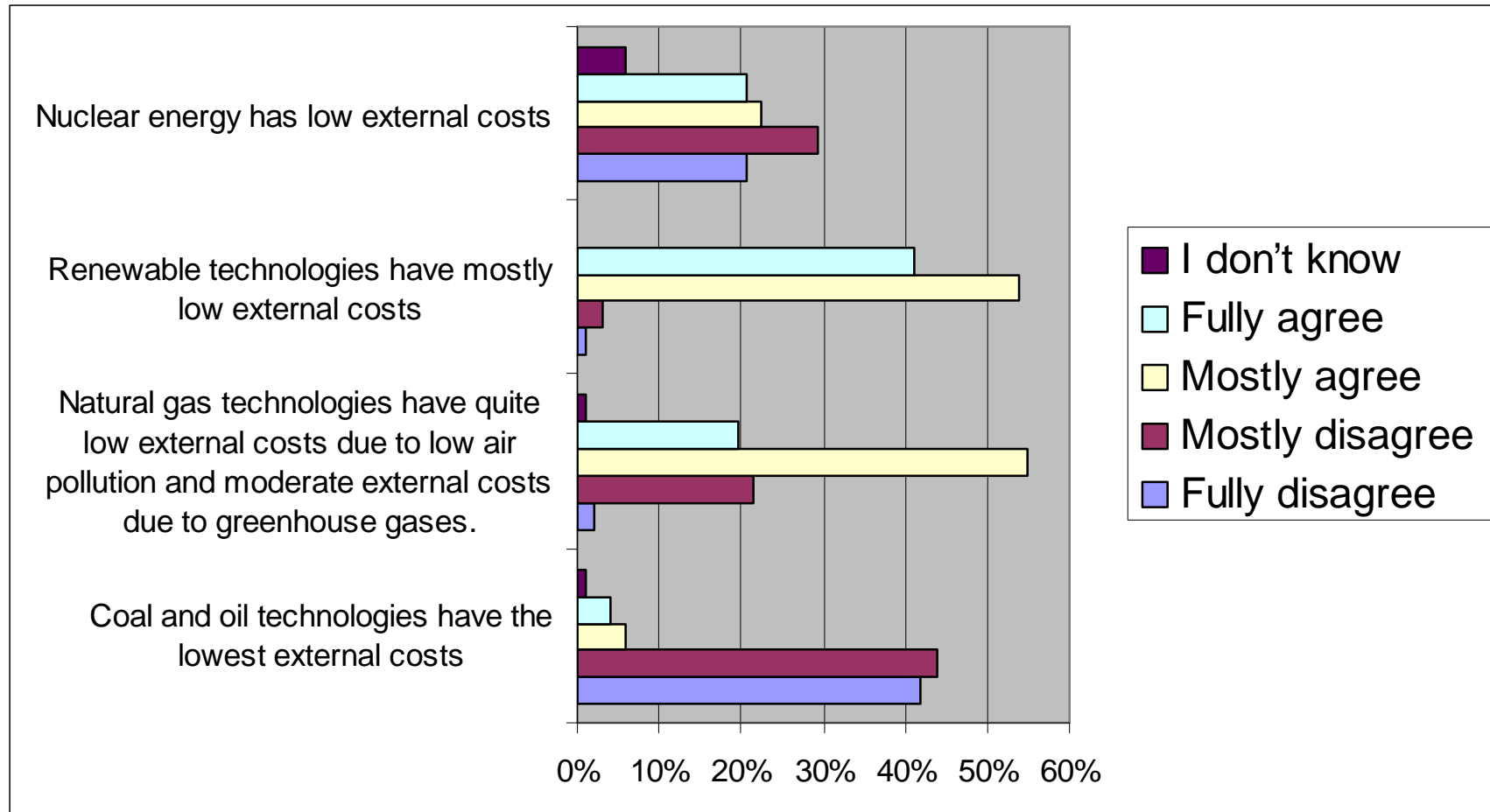
# F-N Curves for Nuclear: Late Cancer Fatalities (LCF)



Source: Hirschberg et al., 2008

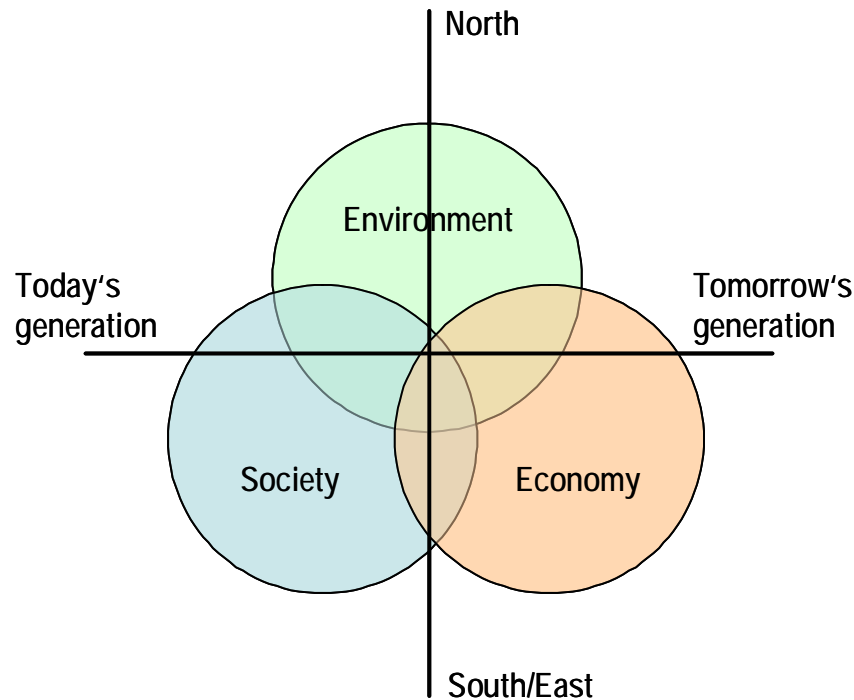
## NEEDS Survey I: Externality Concept, Results and Uses

**In spite of the limitations, there is general acceptance of the concept of externalities, of the internalisation of external costs and of most results, but...**



Source: Faberi et al., 2007

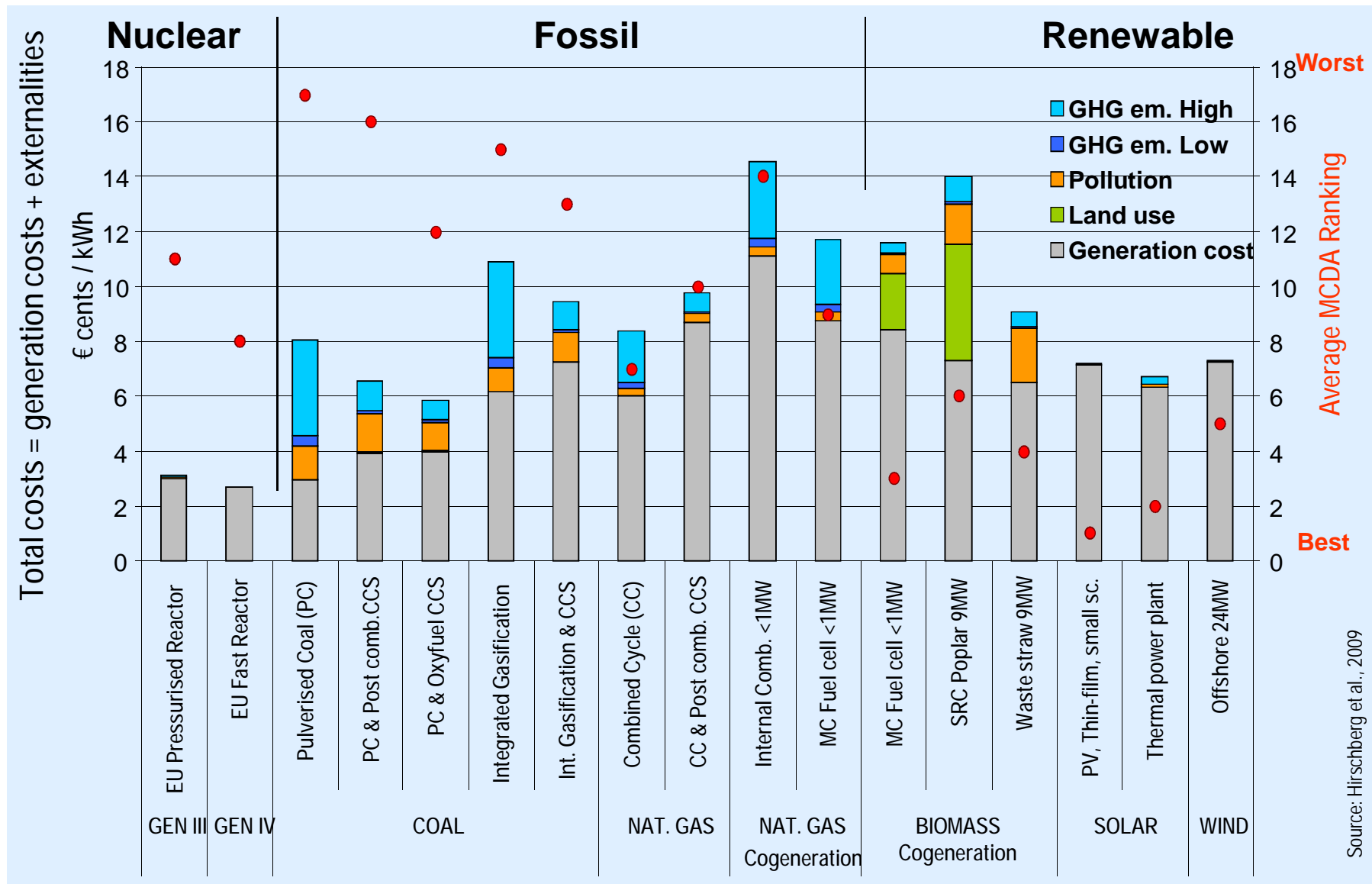
# Sustainability Criteria



Criterion		
ENVIRONMENTAL DIMENSION	<b>RESOURCES</b> Energy Resources Mineral Resources (Ores)	
	<b>CLIMATE CHANGE</b>	
	<b>IMPACT ON ECOSYSTEMS</b> Impacts from Normal Operation Impacts from Severe Accidents	
	<b>WASTES</b> Special Chemical Wastes stored in Underground Depositories Medium and High Level Radioactive Wastes to be stored in Geological Repositories	
	ECONOMIC DIMENSION	<b>IMPACTS ON CUSTOMERS</b> Price of Electricity
		<b>IMPACTS ON OVERALL ECONOMY</b> Employment Autonomy of Electricity Generation
		<b>IMPACTS ON UTILITY</b> Financial Risks Operation
	SOCIAL DIMENSION	<b>SECURITY/RELIABILITY OF ENERGY PROVISION</b> Political Threats to Continuity of Energy Service Flexibility and Adaptation
		<b>POLITICAL STABILITY AND LEGITIMACY</b> Potential of Conflicts induced by Energy Systems. Necessity of Participative Decision-making Processes
		<b>SOCIAL AND INDIVIDUAL RISKS</b> Expert-based Risk Estimates for Normal Operation Expert-based Risk Estimates for Accidents Perceived Risks Terrorist Threat
<b>QUALITY OF RESIDENTIAL ENVIRONMENT</b> Effects on the Quality of Landscape Noise Exposure		

Source: Hirschberg et al., 2007&2008

# Total Costs vs. MCDA



# Conclusions

- Health effects due to air pollution and global warming impacts dominate current estimates of external costs.
- External environmental costs may be substantial but large variety between technologies and sites. Good technologies including advanced fossil have rather low pollution costs.
- Uncertainties are large but ranking of technologies is relatively robust.
- External costs of nuclear and renewables are low; external costs of natural gas are moderate; external costs of coal and oil are highest.
- Internalisation of external costs is economically and socially justified. It leads to more efficient overall economy.
- Total cost as a measure of economic and environmental efficiency of energy systems favors nuclear but estimates for nuclear are controversial and are only partially accepted.
- Social aspects of energy systems are represented to limited extent by current estimates of external (and total) costs.
- Broader inclusion of social factors in the multi-criteria decision analysis framework favours renewables and is a challenge for future nuclear.