

WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN



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Overview of past work and recent advances in assessing the full costs of electricity provision

OECD NEA International Workshop, Paris, 20 January 2016

Components of total costs

Internal Costs

External Costs: A cost is external when it is not paid by those who have generated it.

Total Costs: Internal + External + (System effects)

Negative externalities are **internalised** when they are passed on to those who generate them.

Total costs may serve as an **aggregated measure of performance** and as a basis for **cost-benefit analysis**.

Total costs have been proposed as a measure of **sustainability performance** of technologies.

Costs & Purposes

- Marginal technology costs are used for system *operation* (electric system dispatch, oil/gas production, etc.)
- *Average* technology costs (e.g. average generation cost) are often used for planning (i.e. production or capacity factors are often *assumed* - it's better to model)
- System expansion planning *should* be based on the total *system* cost per unit (e.g. kWh) of service provided (to allow for both supply and demand side options, system costs, and load growth uncertainty).

Approaches to internal cost estimation

Bottom Up - Detailed, design-specific costing (component basis)

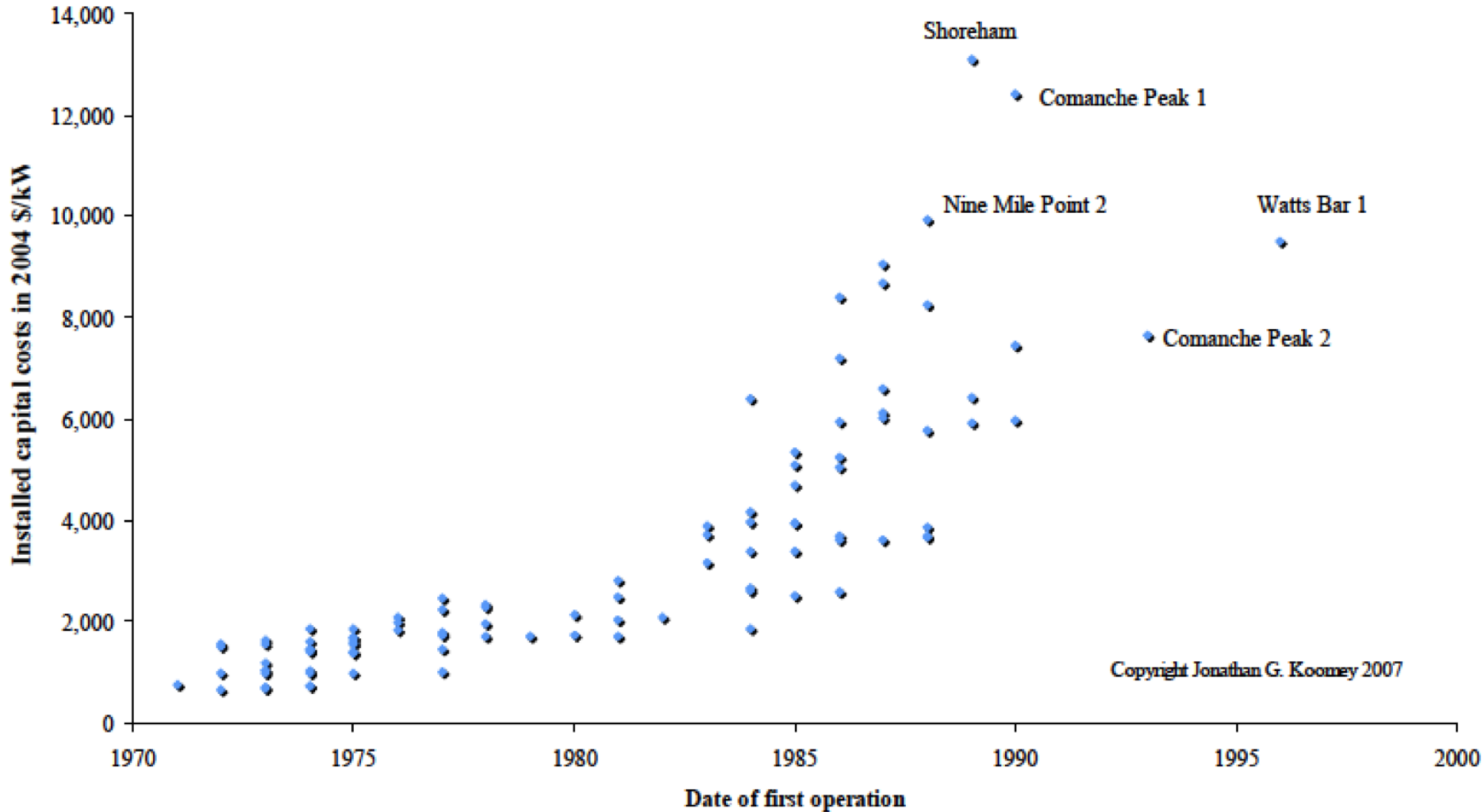
- Major effort, suitable for vendors
- Still contains many uncertain assumptions

Top Down - back of the envelope approximation (order of magnitude)

Intermediate - based on *similar* units, adjusting for

- Size (economies of scale)
- Time (Learning curves for state-of-the-art)
- Component costs (e.g. materials, labor and component cost shifts)

Historical nuclear costs



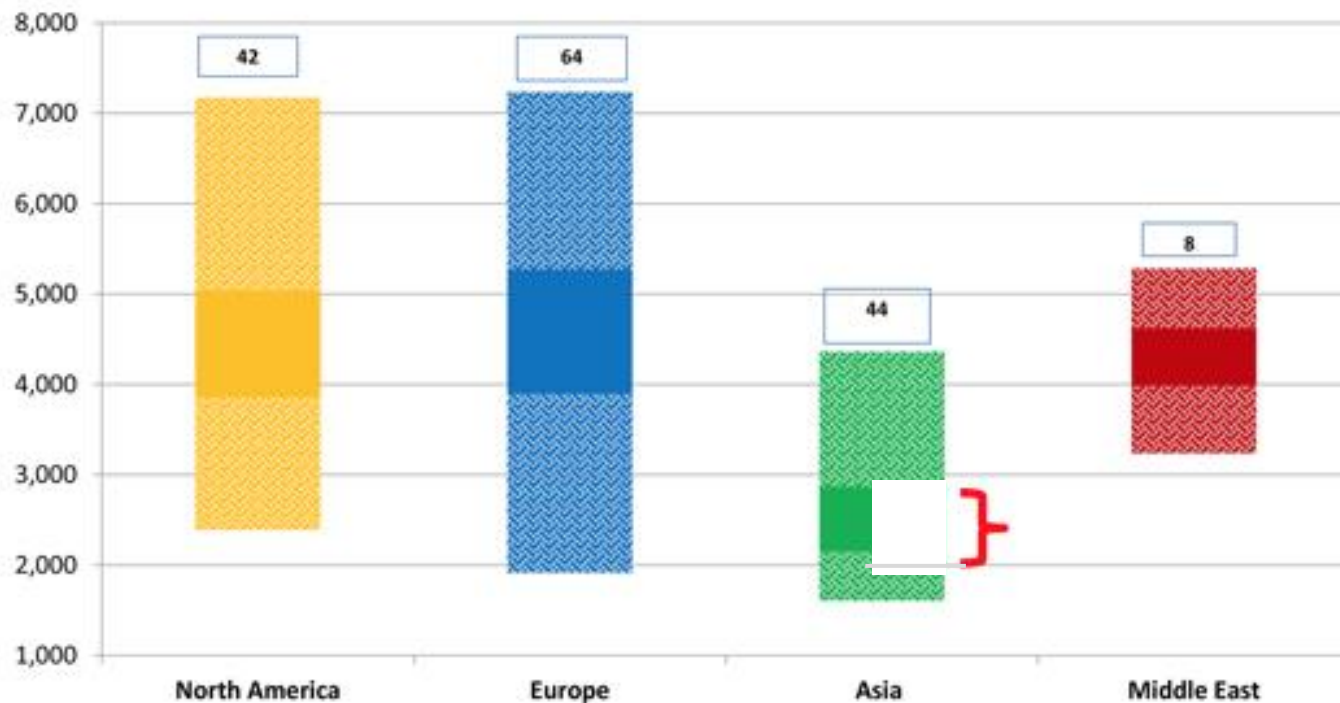
Copyright Jonathan G. Koomey 2007

Source: Koomey J. & Hultman N., 2007, "A Reactor-Level Analysis of Busbar Costs for US nuclear plants, 1970-2005," Energy Policy.

Nuclear Capital Costs by Region

Challenge: NPP investment cost uncertainty

Overnight capital cost range by region (US \$/kW)



Note: Data collected from various publications and studies to keep track of nuclear power plants investment costs, since 2008 (updated August 2014), all data in 2013 USD

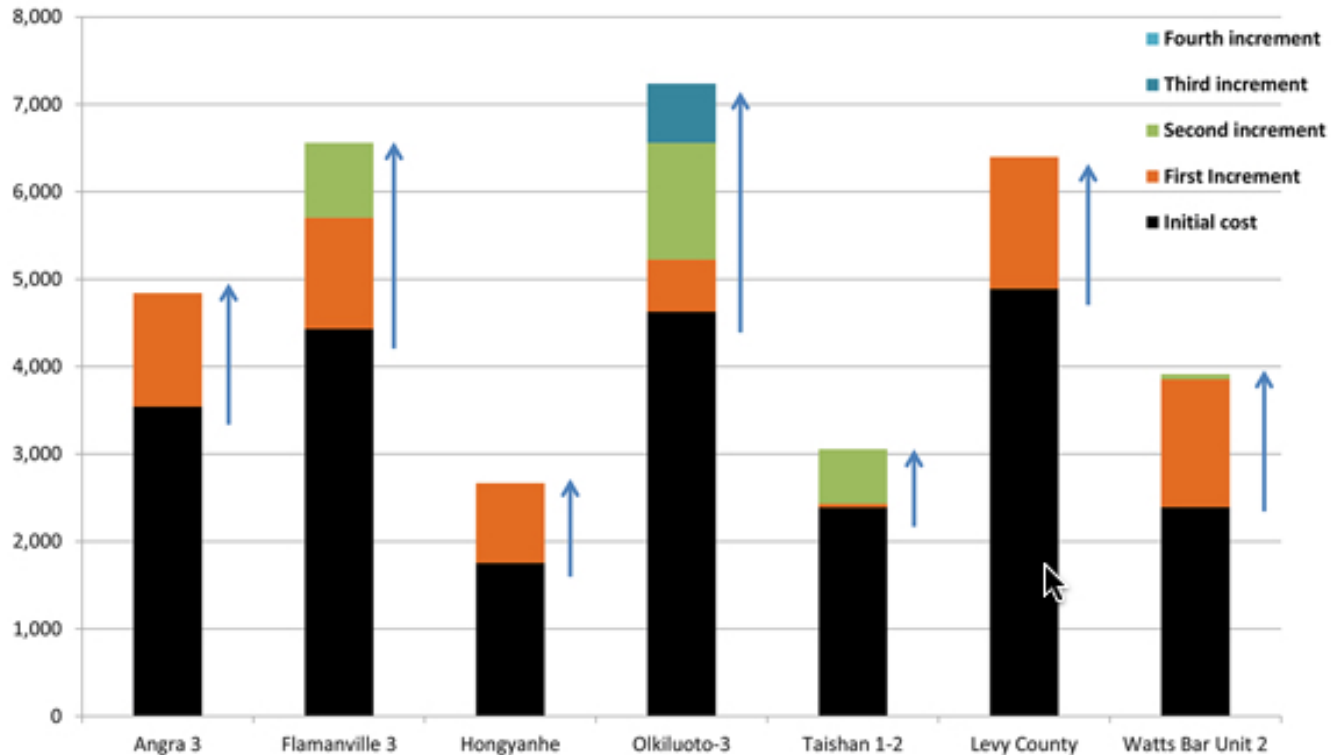
Source: Dr. N. Barkatullah, World Nuclear Association 2014 Symposium

Recent Nuclear Cost Overruns

Challenge: Construction risk



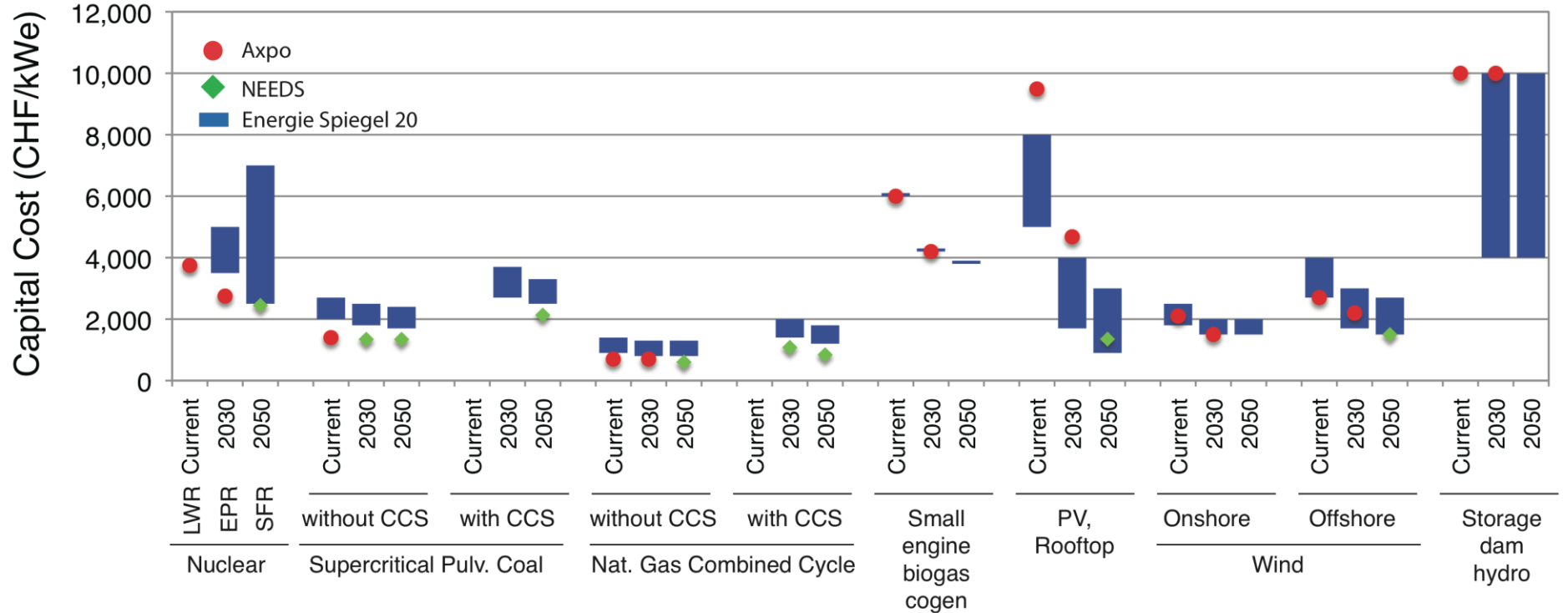
Investment Cost over time by Site (\$/kW) - 2013 prices



Source: World Nuclear News, Nuclonics and Other publications, 2008-2014

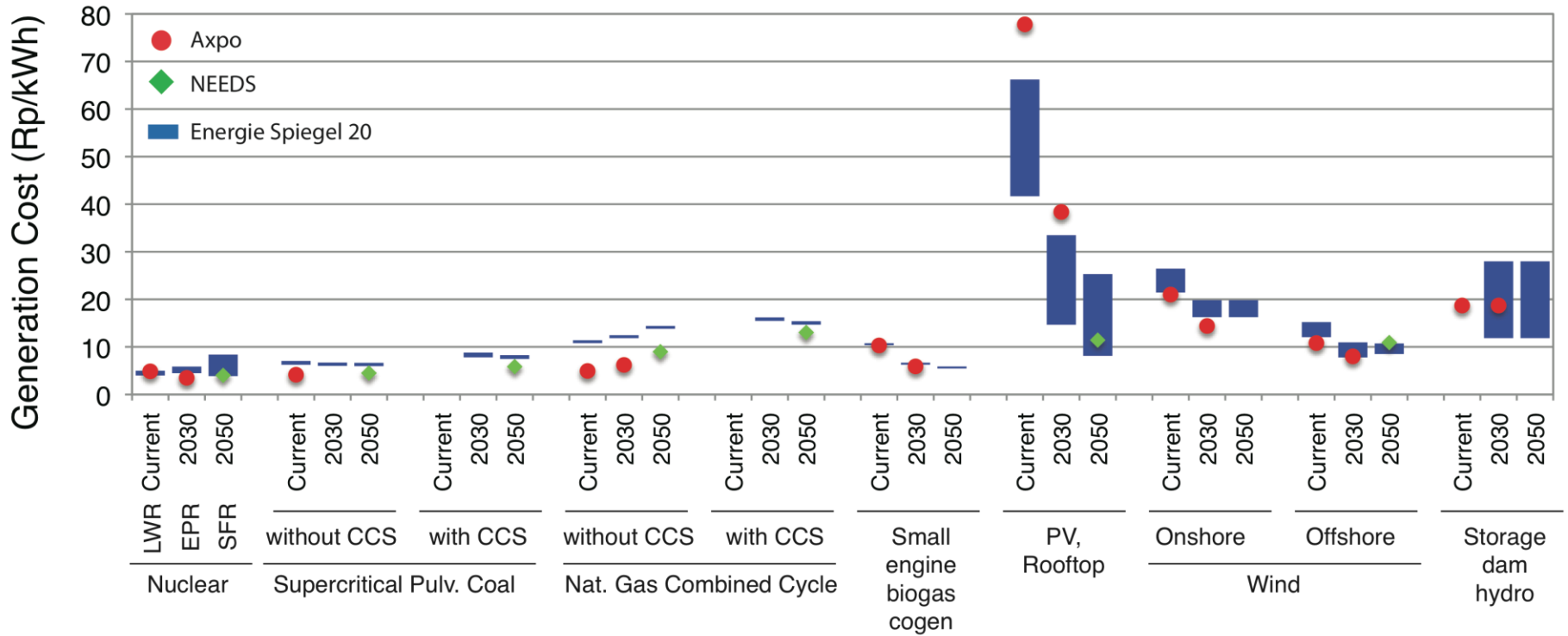
Source: Dr. N. Barkatullah, World Nuclear Association 2014 Symposium

Capital costs (new plants, Swiss conditions)

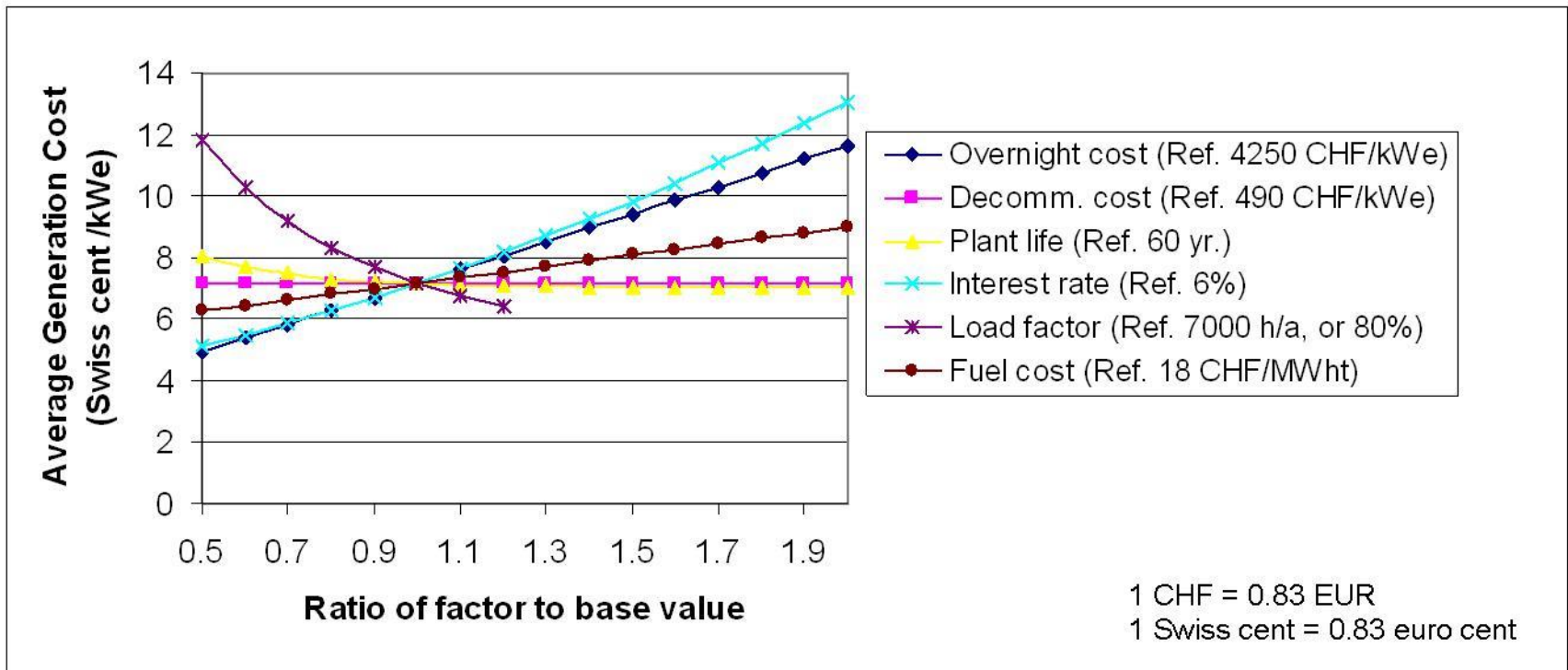


Source: PSI/Hirschberg et al., 2010

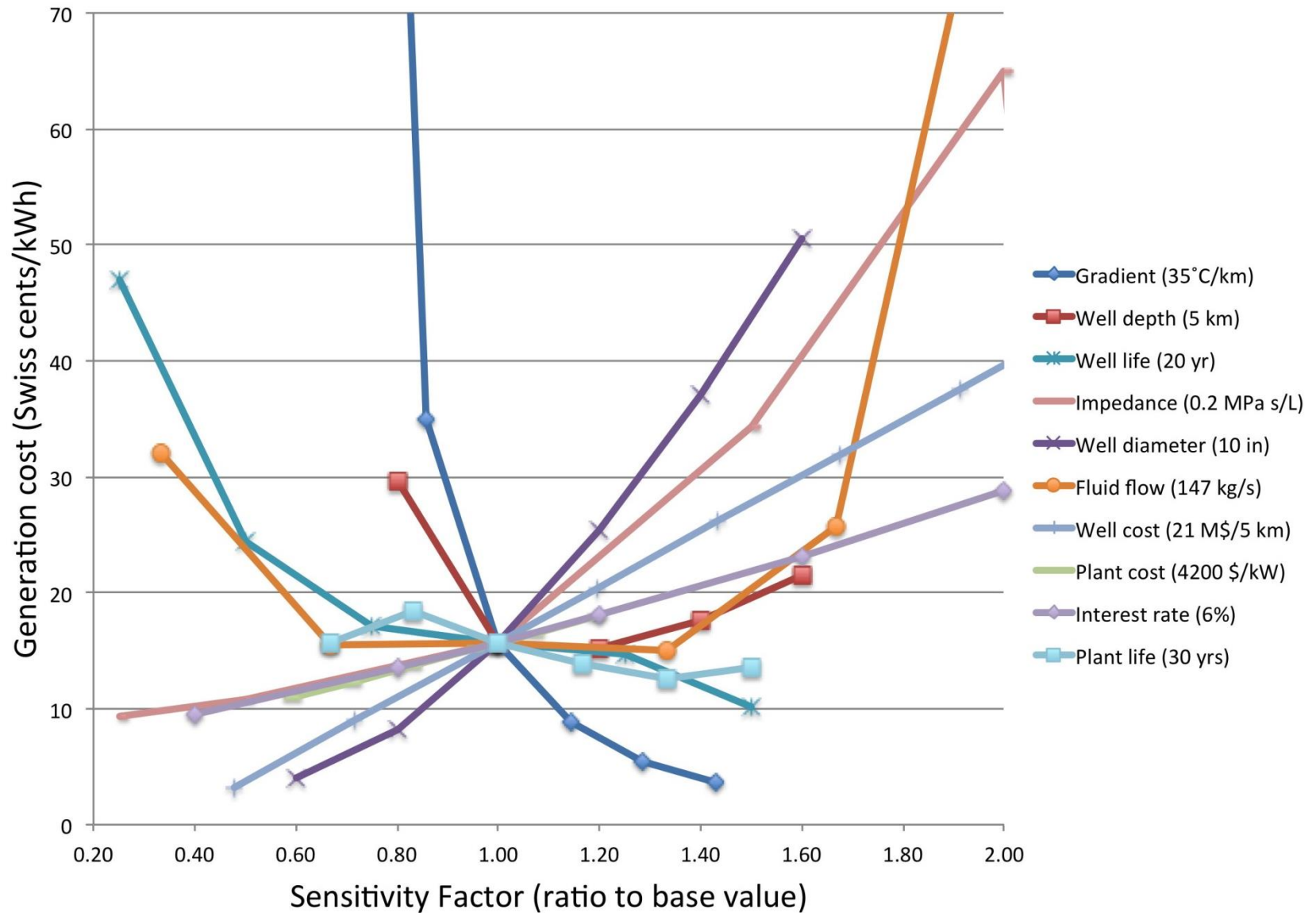
Generation costs (new plants, Swiss conditions)



Cost Sensitivities – EPR 2030



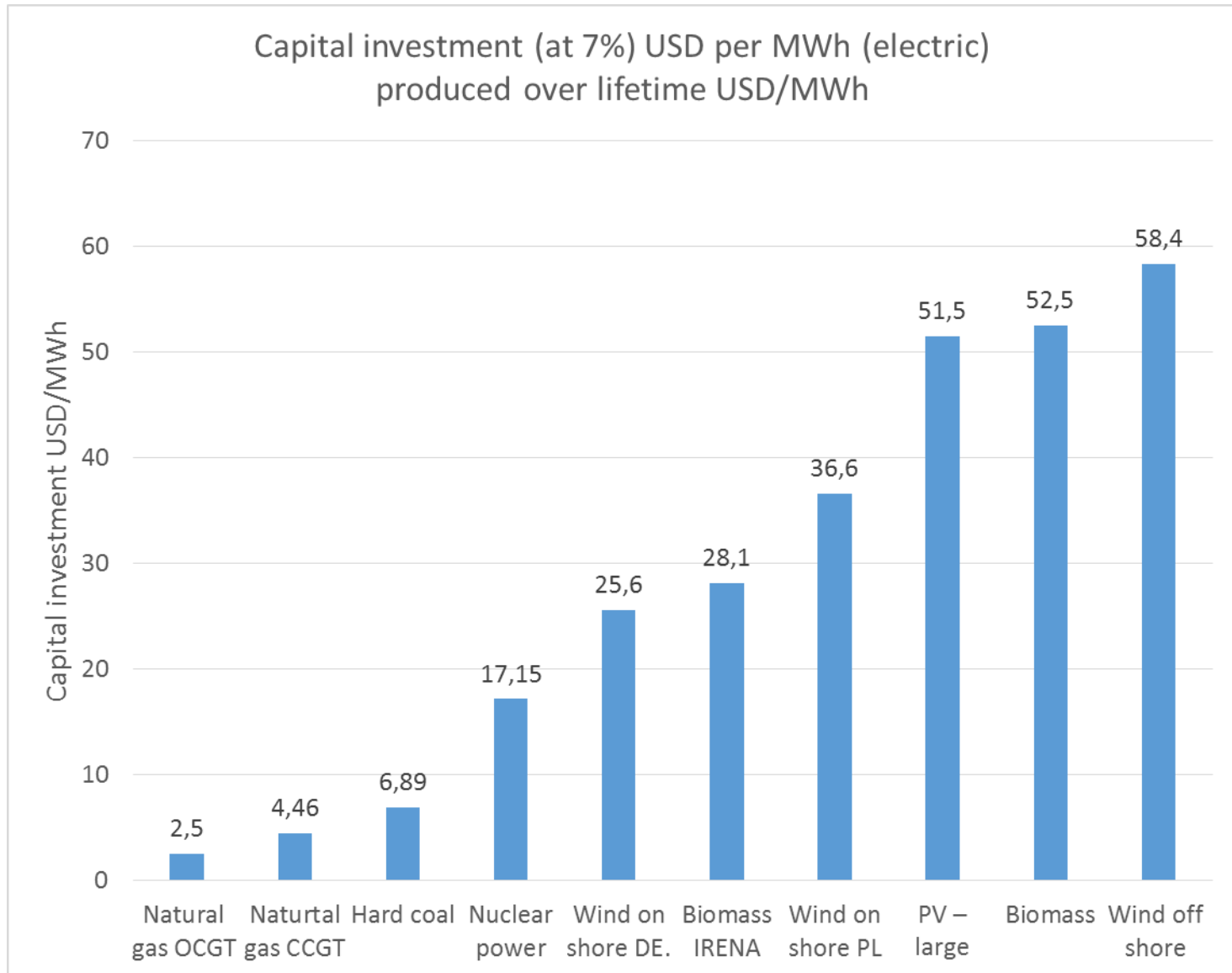
Deep geothermal energy: Sensitivity curves for model inputs



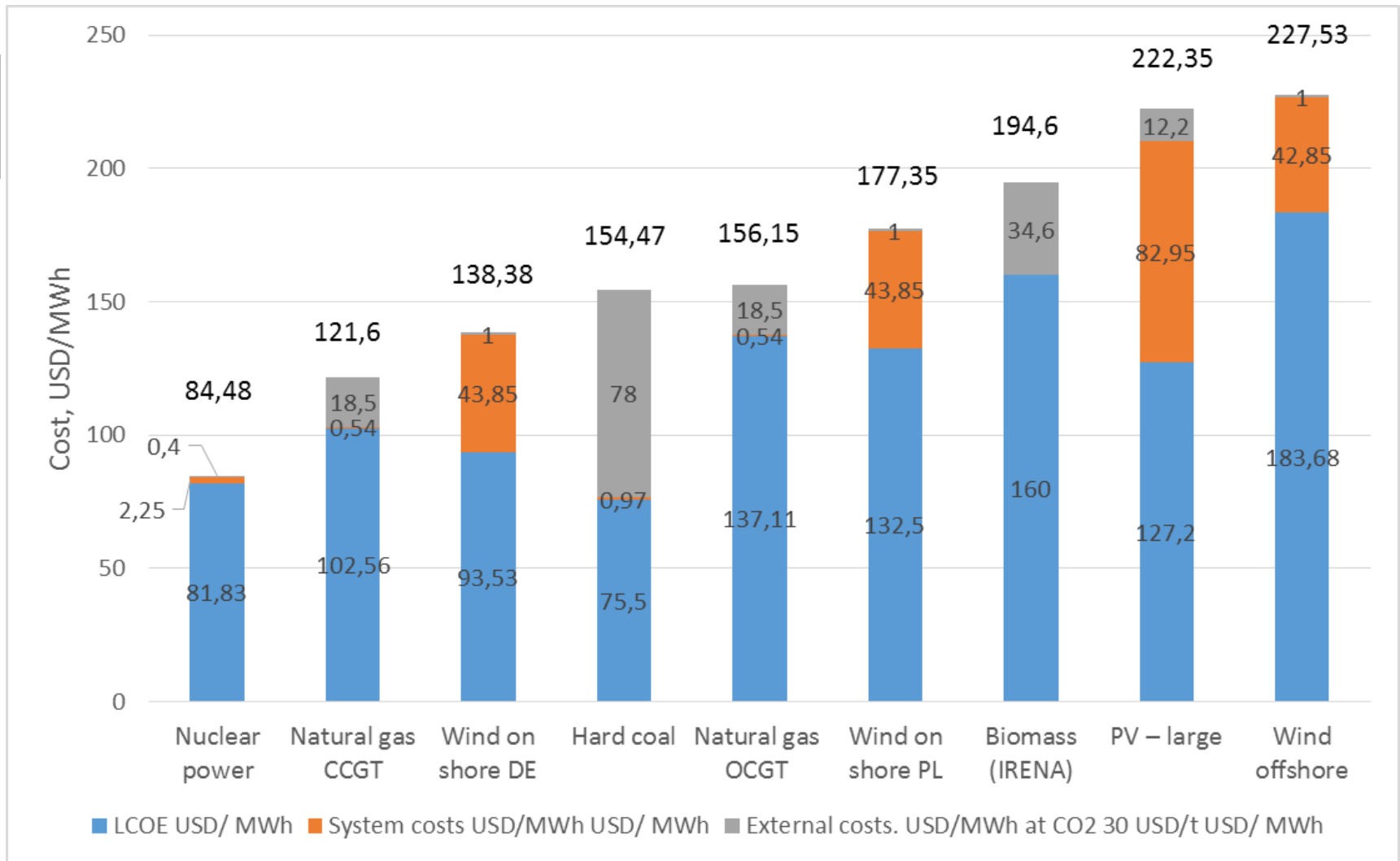
Nuclear & Renewables – System Effects

- Focus is on the interplay between nuclear and renewables
- Recognizes all major system costs & externalities, but only quantifies grid-related costs (5 categories)
- System problems caused by stochastic generation with zero marginal costs are due to subsidized penetration of solar/wind
- Damage to fossil and nuclear generators is due to “market competition,” but ultimately caused by renewables.
- Nuclear has a big role as swing capacity, but low capacity factors are a problem for recovering high capital costs, and hence a big problem for future nuclear construction

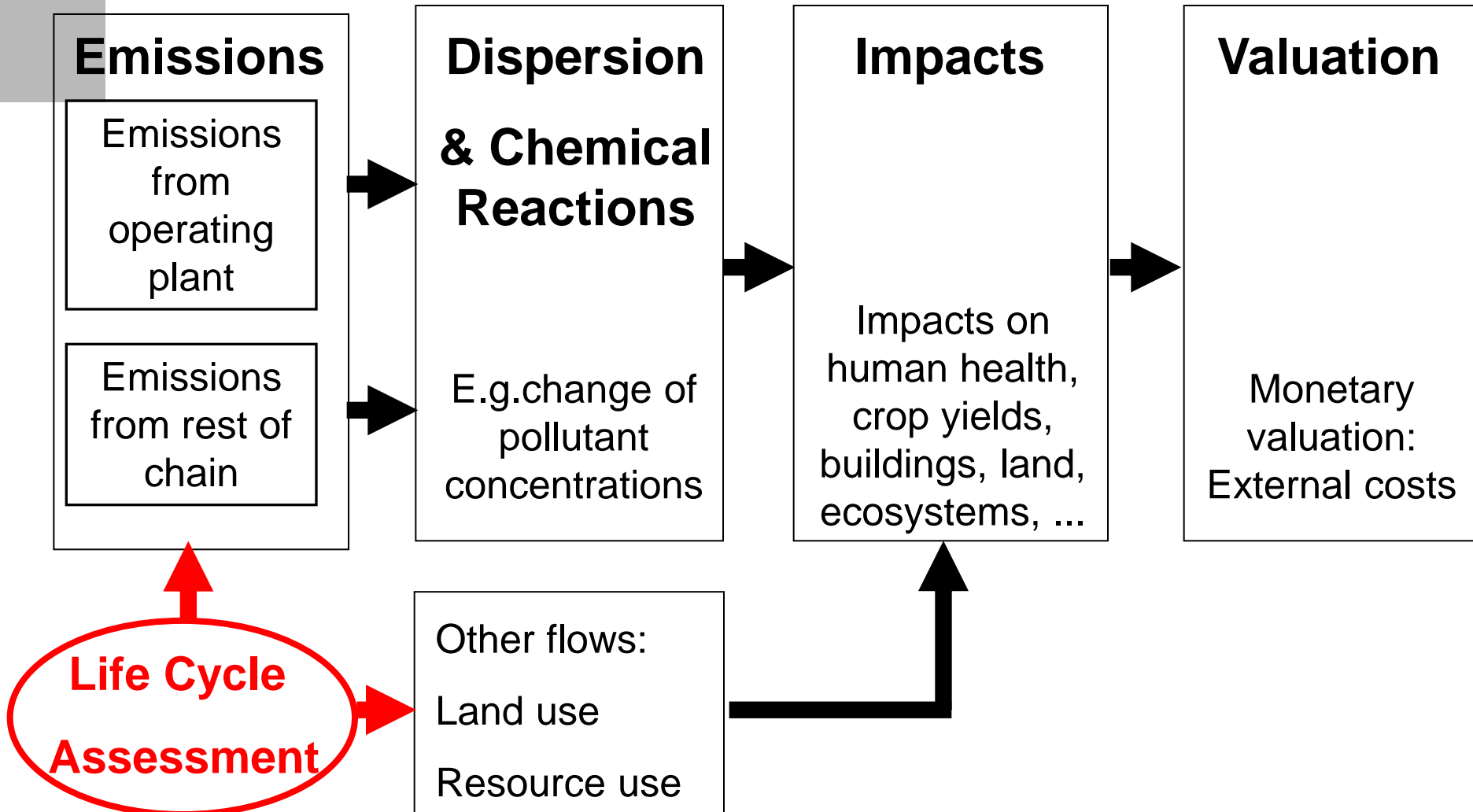
The Polish case



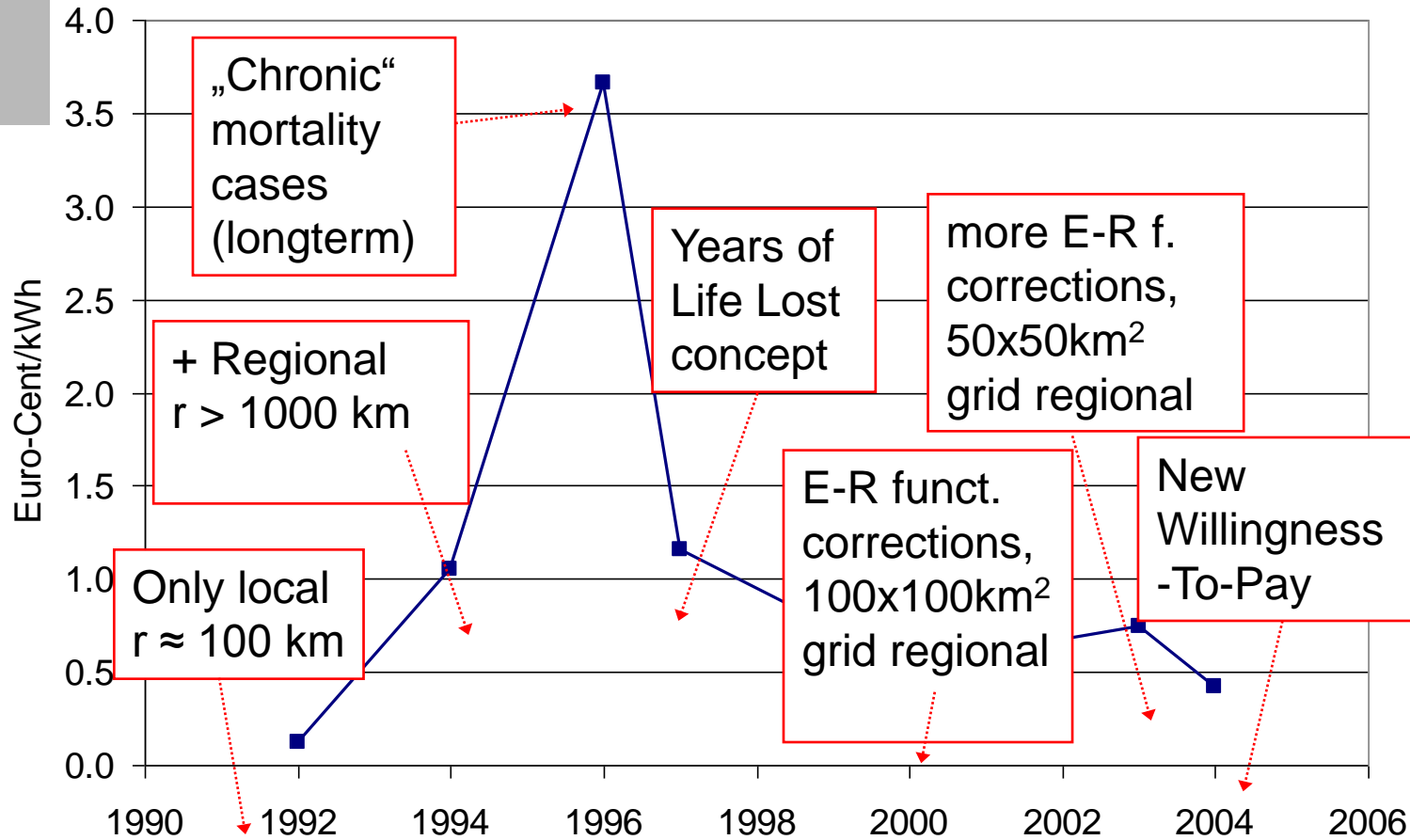
The Polish case



The impact pathway approach including LCA



Development of external cost modeling



Source: Heck 2004

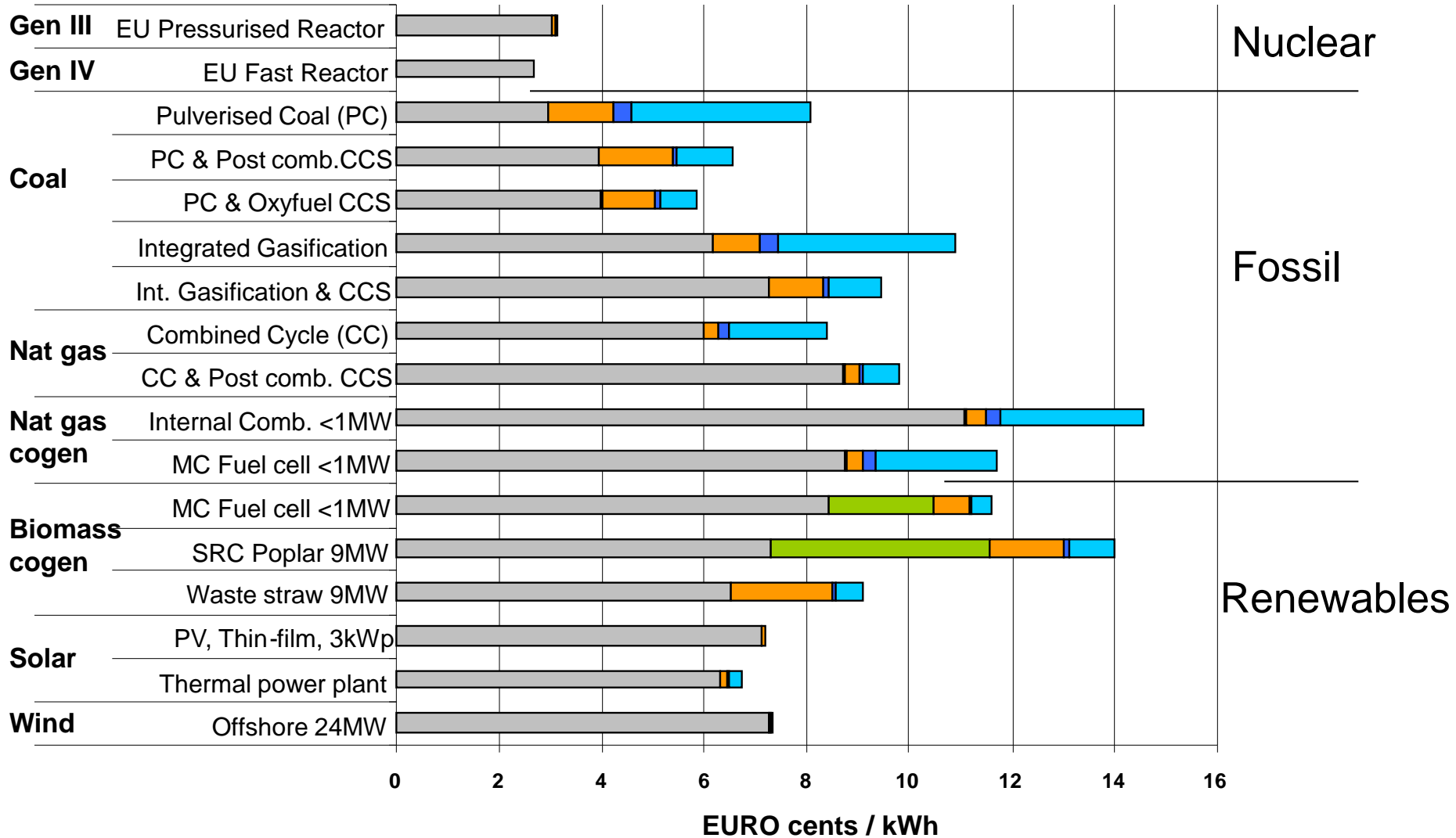
E-R funct.:
Exposure-Response function

Example:

Projected coal power plant, South Germany, parameters of power plant are constant. Only emissions from plant operation. ExternE method. CO₂ costs not included.

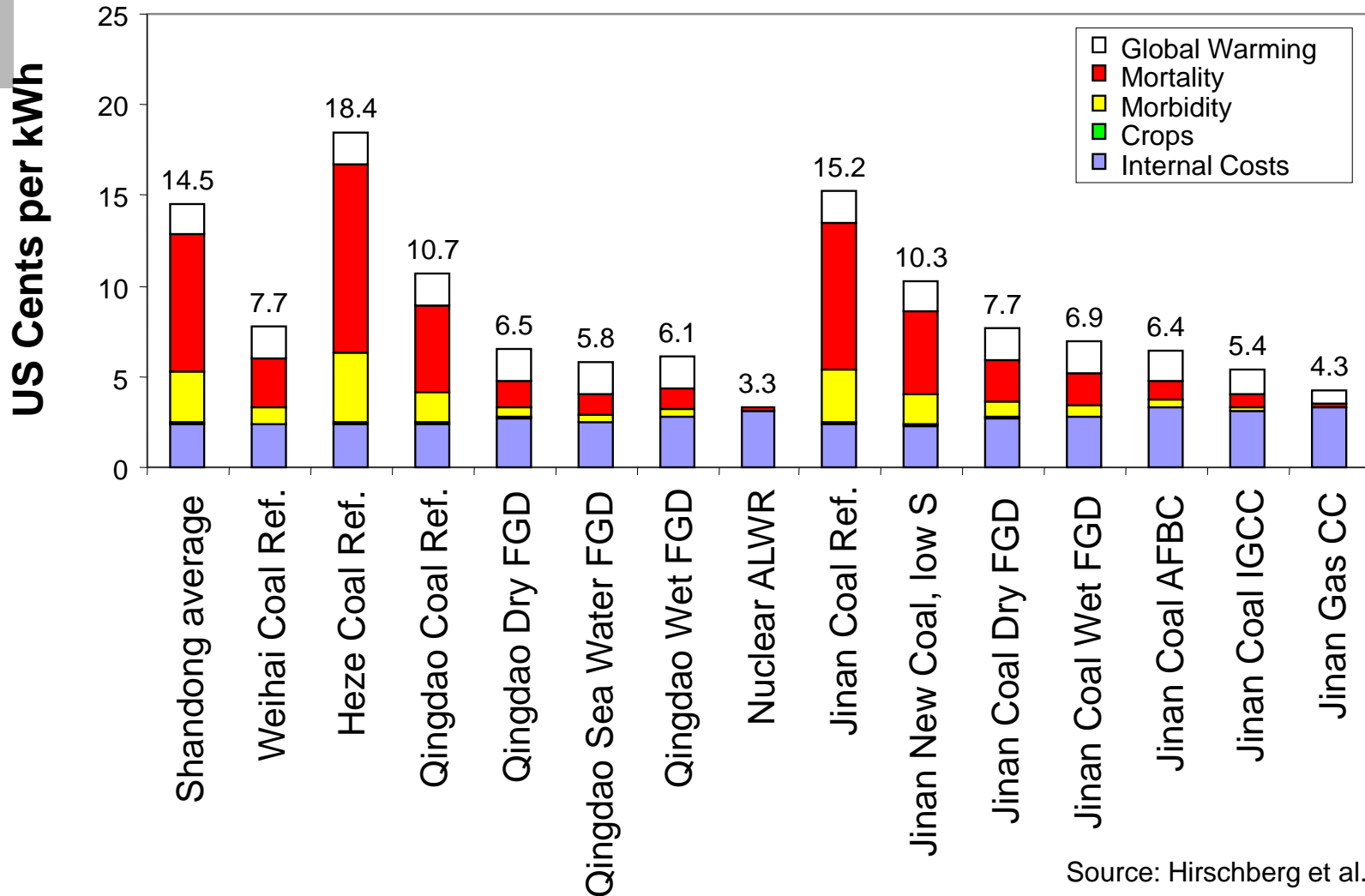
Total costs (2050)

■ Generation cost
 ■ Land use
 ■ Pollution
 ■ GHG low
 ■ GHG high

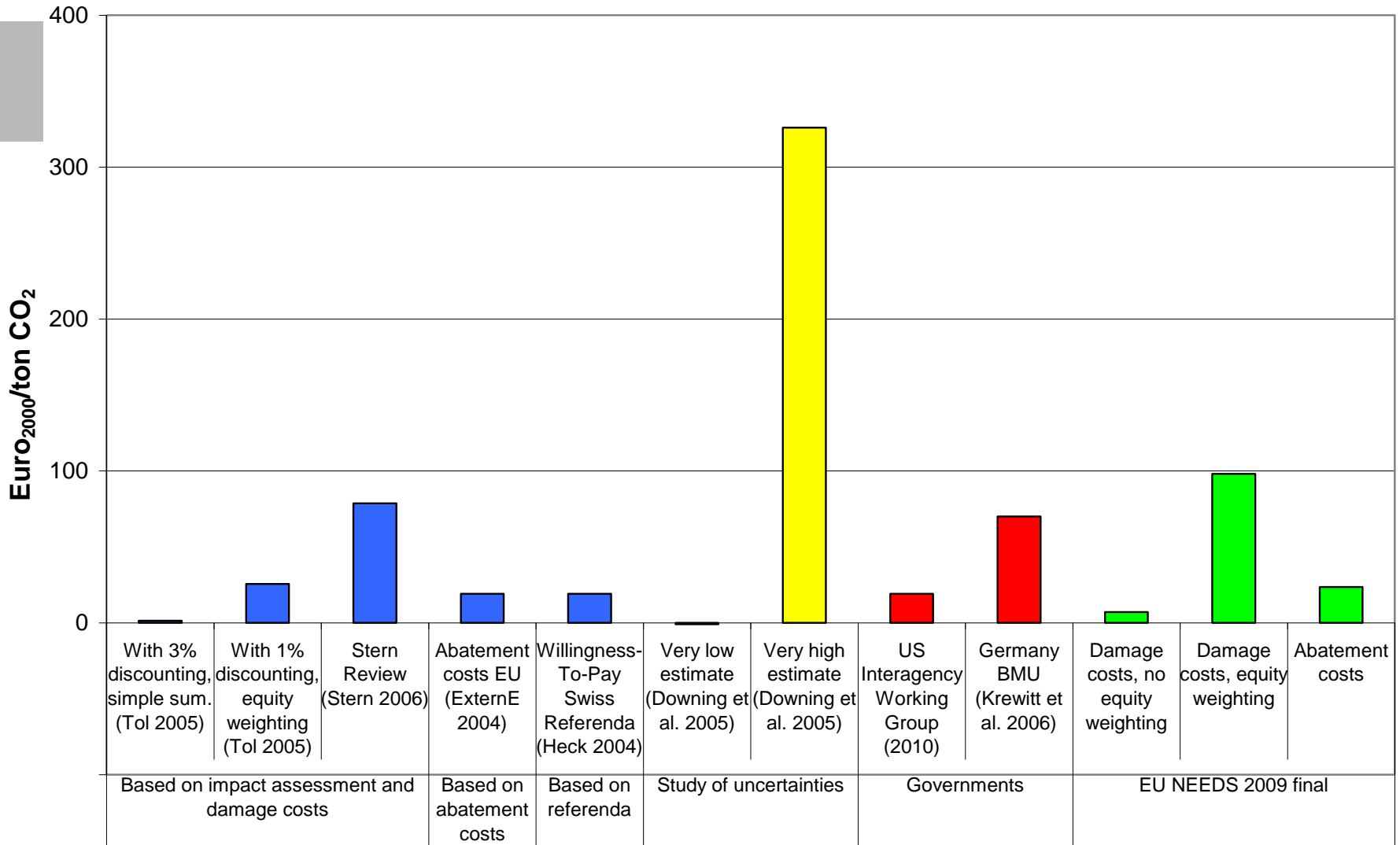


China Energy Technology Program

Internal and External Costs for Power Plant Options in Shandong Province



Different estimates of external costs of CO₂

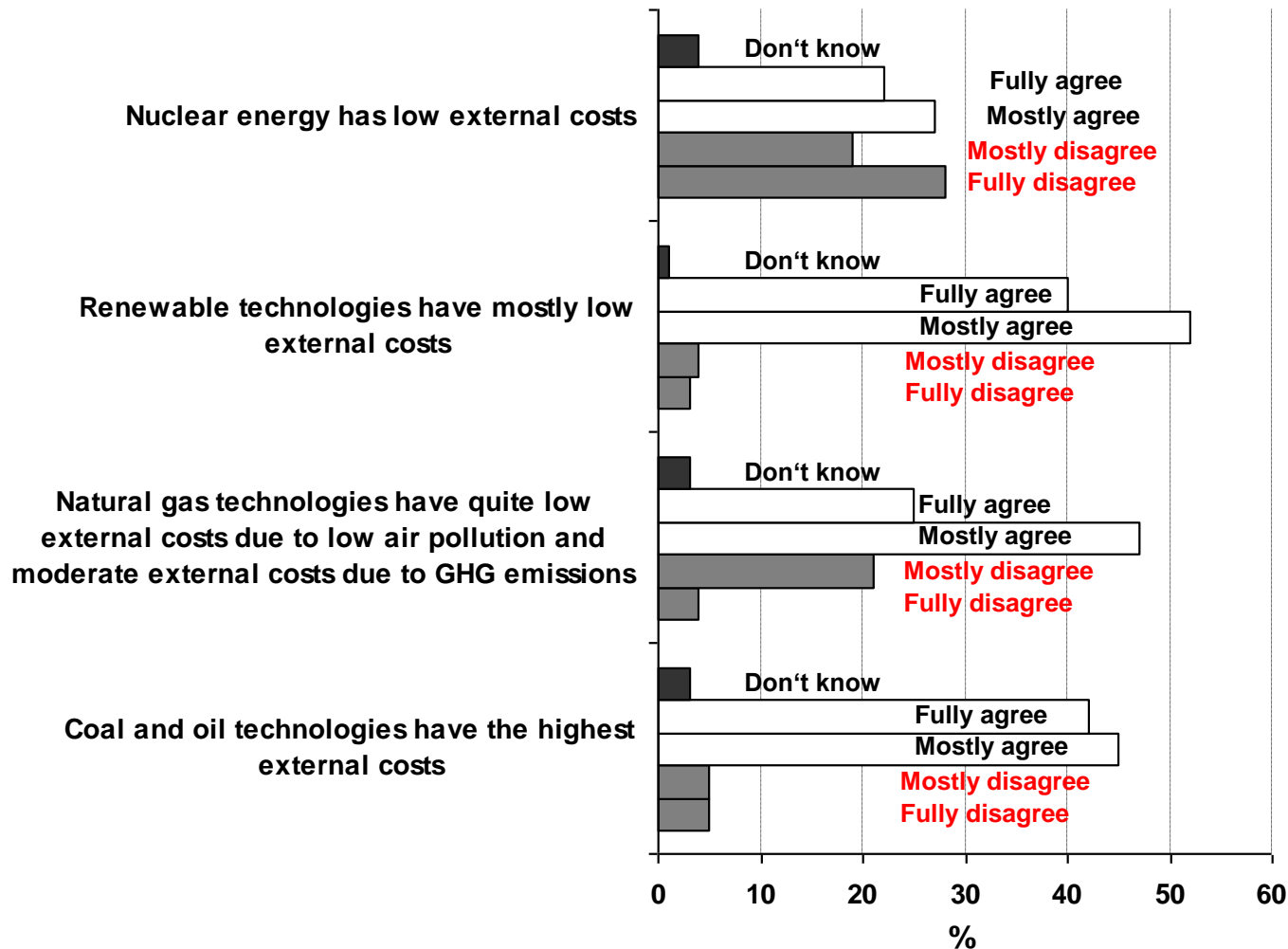


Examples of controversial/difficult to estimate external effects

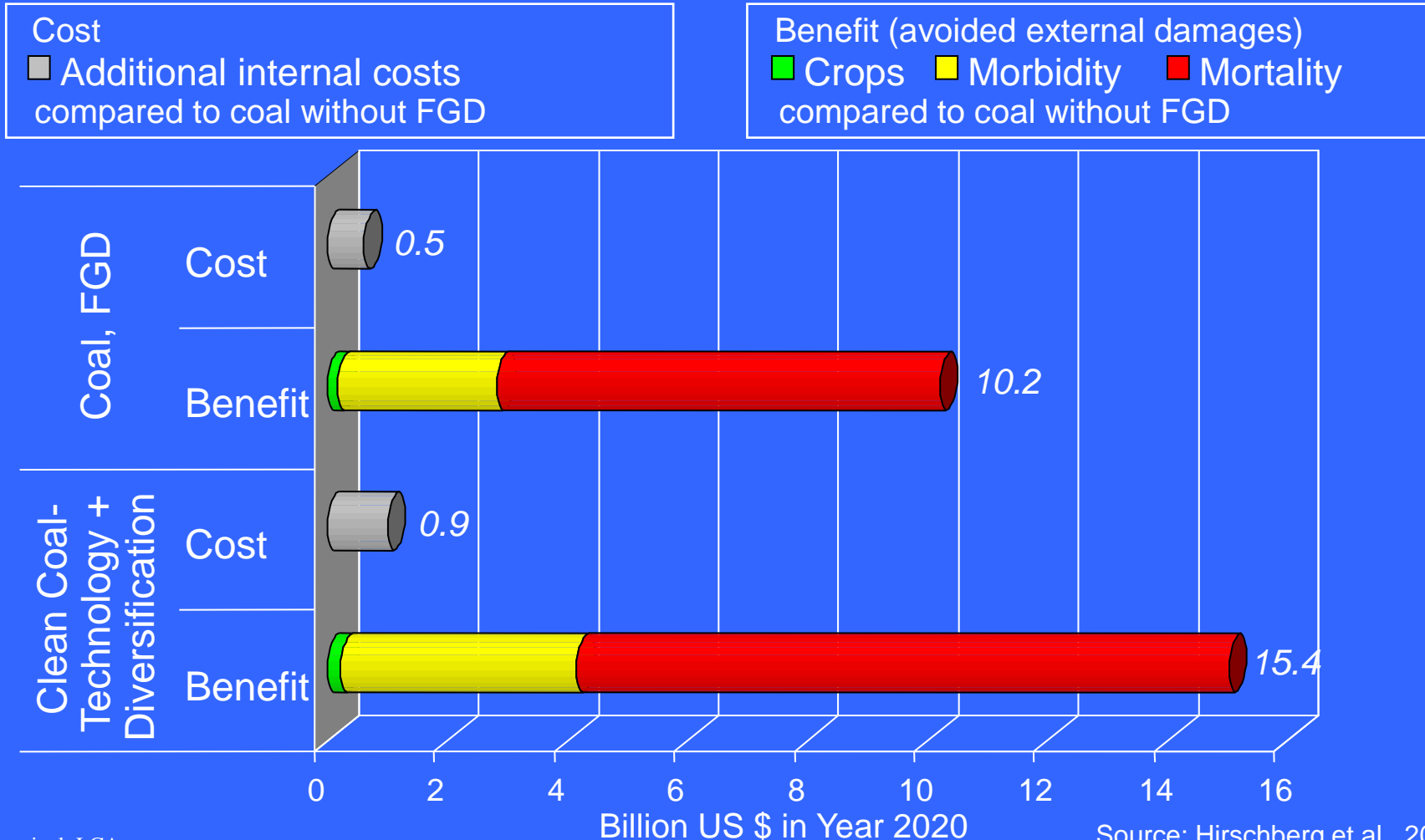
- Severe accidents, terrorism, risk aversion
- Visual intrusion
- Resource depletion
- Nuclear proliferation
- Biodiversity losses
- Security of supply

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

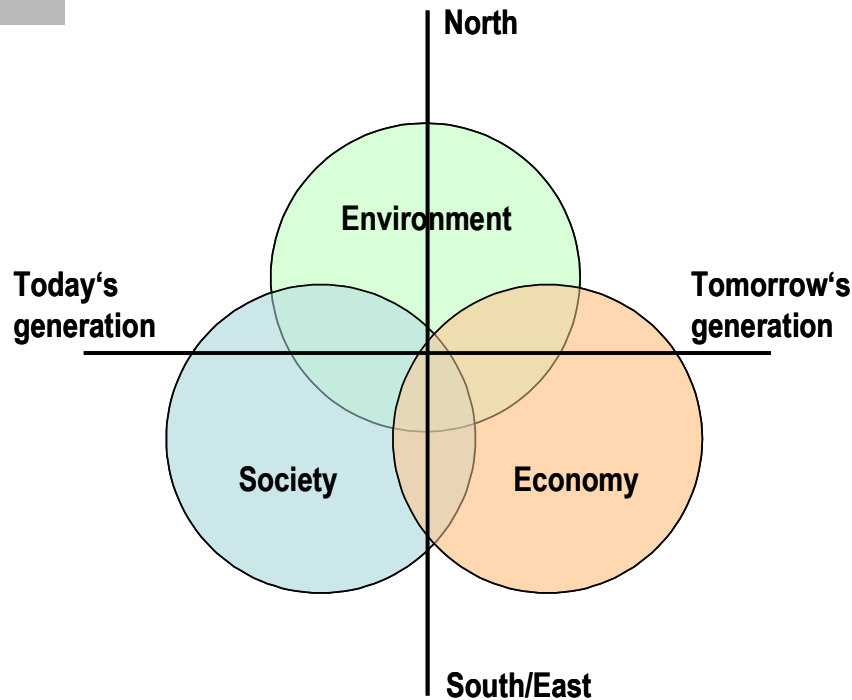
In spite of the limitations, there is general acceptance of the concept of externalities, of the internalisation of external costs and of most results, but...



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



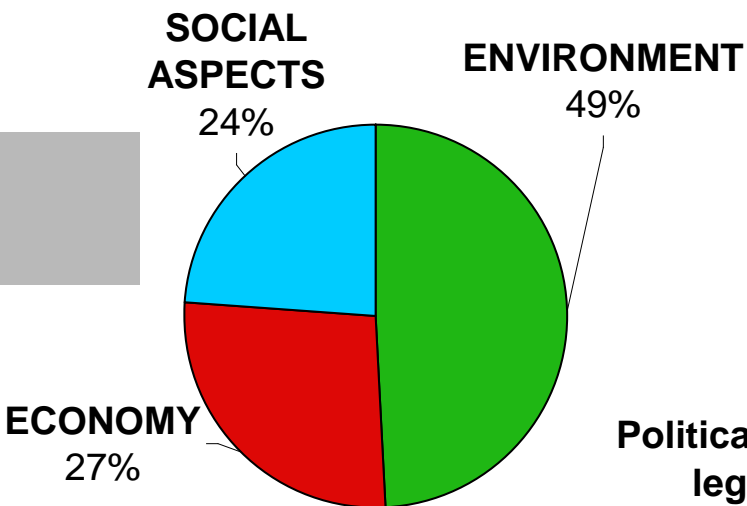
Sustainability Criteria



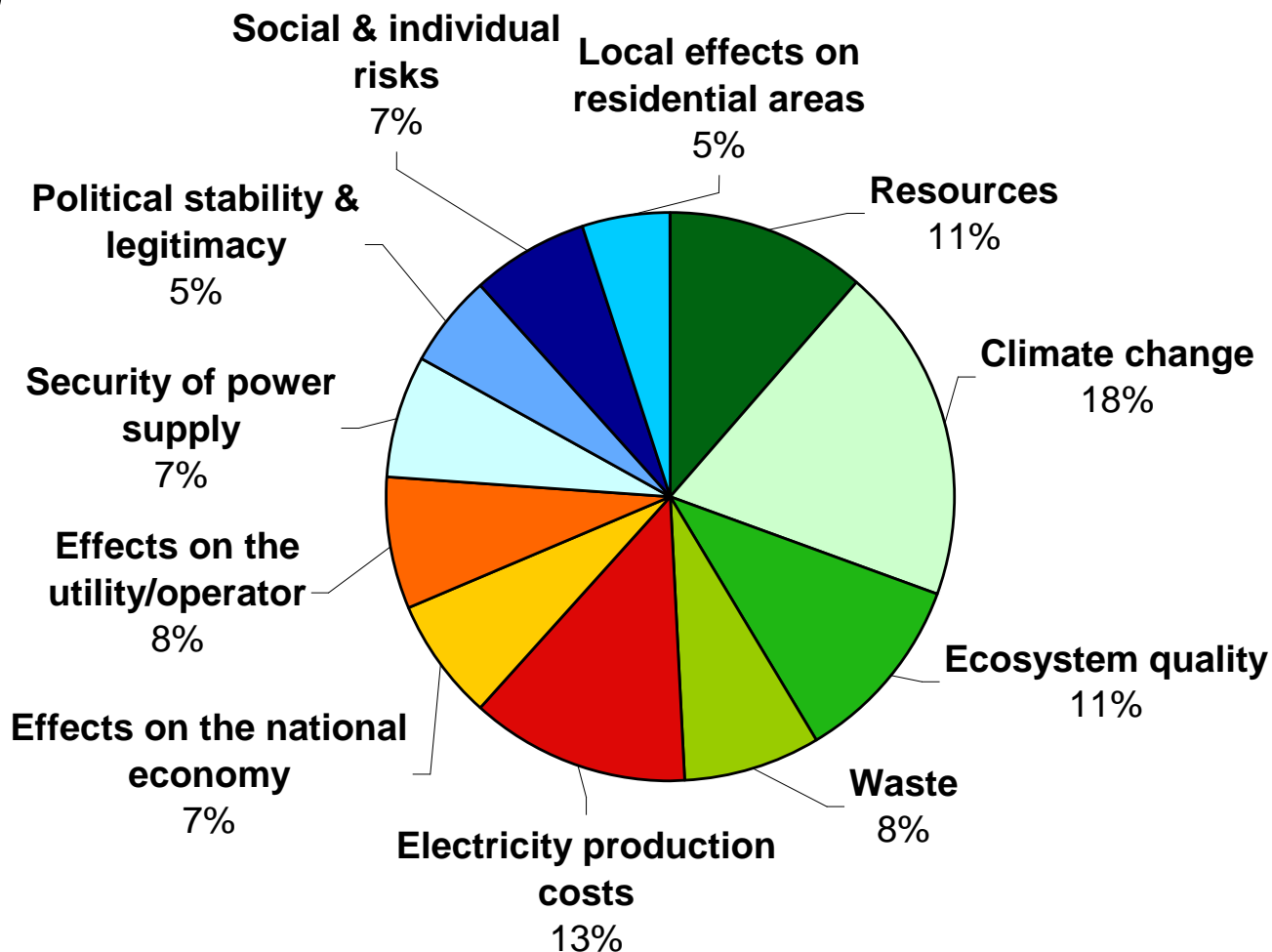
	Criterion
ENVIRONMENTAL DIMENSION	RESOURCES
	Energy Resources
	Mineral Resources (Ores)
	CLIMATE CHANGE
	IMPACT ON ECOSYSTEMS
	Impacts from Normal Operation
	Impacts from Severe Accidents
	WASTES
	Special Chemical Wastes stored in Underground Depositories
	Medium and High Level Radioactive Wastes to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

Weighting of MCDA indicators

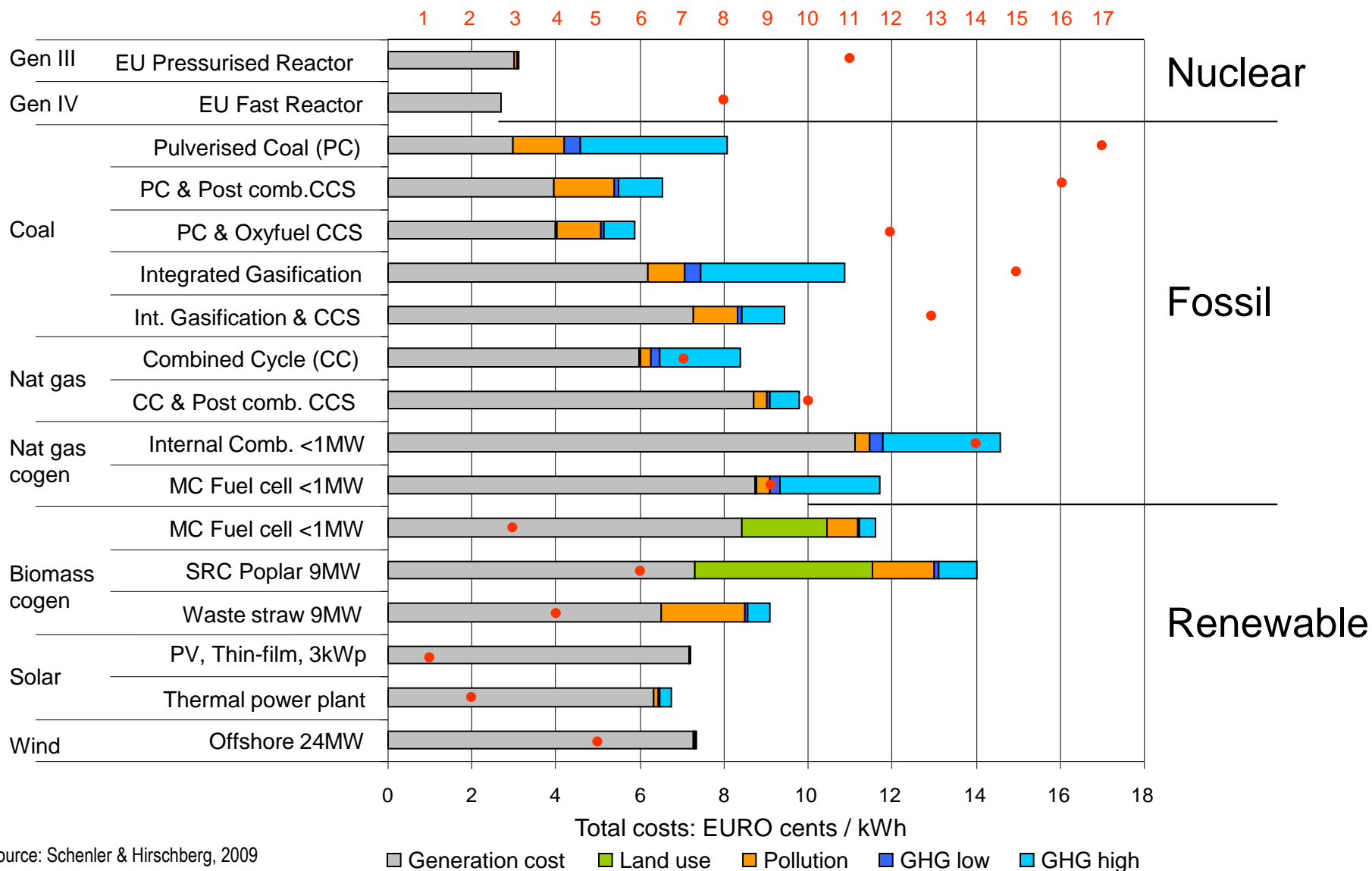
2nd level



1st level

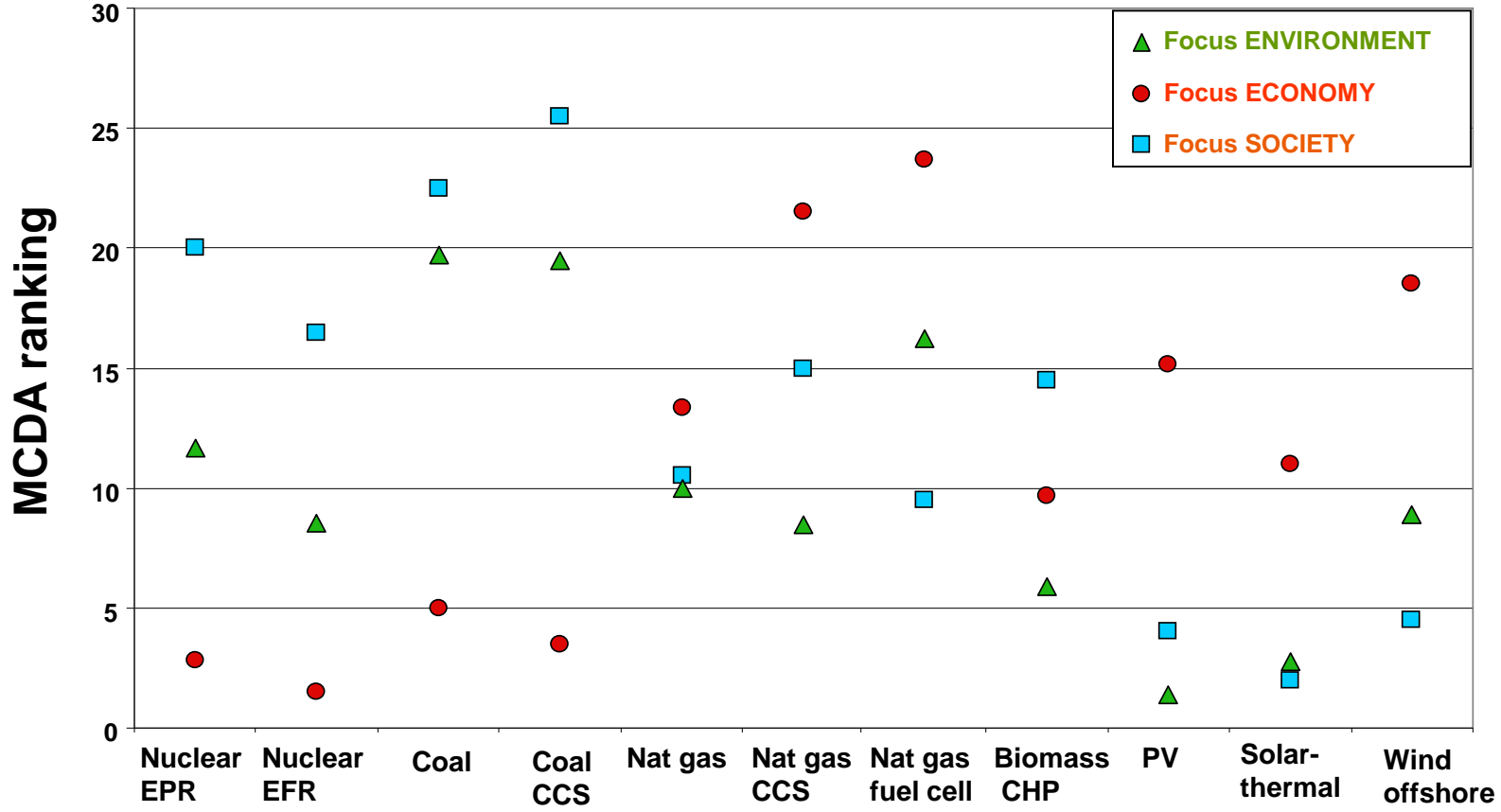
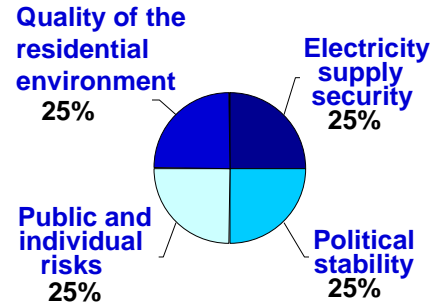
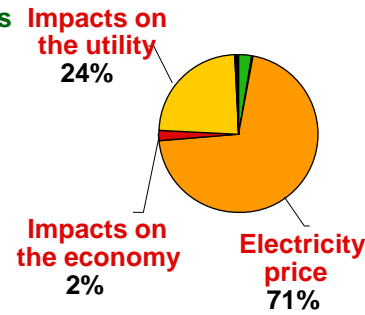
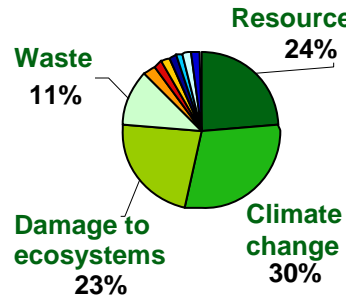
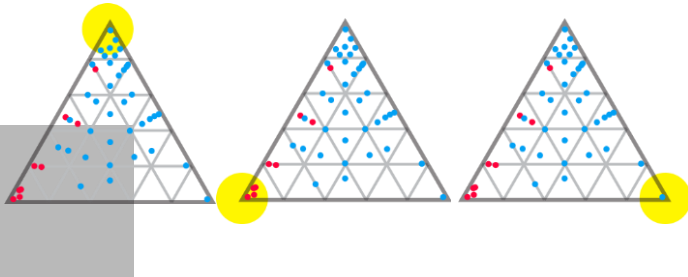


Average MCDA ranking



Source: Schenler & Hirschberg, 2009

Technology ranks and stakeholder weighting



- Most basic distinction between generation technologies is in **fixed v. variable costs**, i.e. capital cost v. dispatch costs.
- **Common features of “good” NPPs include:** turn-key delivery contract, not first-of-its-kind, short construction time, clear licensing regime with no major changes during the construction, reasonably low interest rates, and high load factors with minimum unplanned interruptions of operation.
- External environmental costs may be substantial but **large variety between technologies and sites**. Good technologies including advanced fossil have rather low pollution costs.
- **External costs of nuclear and renewables are low; external costs of natural gas are moderate; external costs of coal and oil are highest.**
- **Social aspects** of energy systems are represented to limited extent by current estimates of external costs.
- **Internalisation** of external costs is economically and socially justified. It leads to more efficient overall economy.
- Total costs are attractive as an **aggregated measure of performance** and as a basis for **cost-benefit analysis**.
- Total costs remain to be controversial as a measure of **sustainability performance** of technologies.
- **Total cost approach favours nuclear.**

Thank you!

