External and social costs of electricity generation

Rainer Friedrich

Institut für Energiewirtschaft und Rationelle Energieanwendung, Universität Stuttgart

rf@ier.uni-stuttgart.de

Erice

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Integrated Assessment (IA):

Aim of the ExternE methodology:
= helps to take into account all relevant externalities in a consistent way when making decisions

- *Investment decisions (e.g. power plants, railway lines)*
- *Technology assessment (subsidies, research support)*
- *Consumer decisions (e.g. by adjusting prices)*
- *Cost-benefit analyses, esp. for environmental and health regulation*

Steps of an integrated assessment:

- Defining the question:

  here: **which technologies for the generation of electricity should be built, promoted, supported now and in future?**
- Specification of possible solutions
- Exclusion (or improvement) of alternatives that violate fundamental standards
- Assessment of and /or compensation for local damage within an environmental impact assessment
- **Cost-effectiveness or cost-benefit analysis taking into account all monetized externalities**
- Qualitative description of non-monetizable impacts

Basic principles

1) Assessment or weighting of effects should as far as possible be carried out using quantitative figures and functions

   ->ensures transparency and reproducibility

2) Assessment of effects/damage (e.g. health risk), not of pressures (e.g. emissions of pollutants)

-> relation between pressure and effect is in general non-linear and

->effects depend on time and site of activity

-> *-> Bottom-up approach needed for the complex pathways: the 'impact pathway approach'*

Main Features of the Impact Pathway Approach

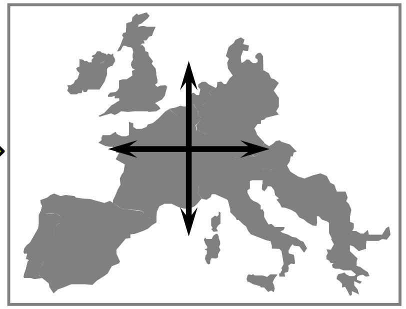
Assessment of impacts is needed at all spatial levels: local, regional, hemispheric, global. The relative importance of larger scale impacts is increasing.

Life cycle impacts (construction and dismantling, provision of fuels, waste treatment and disposal) should be taken into account (especially important for electricity production from renewable and nuclear energy).

Impact Pathway Approach – Part 1

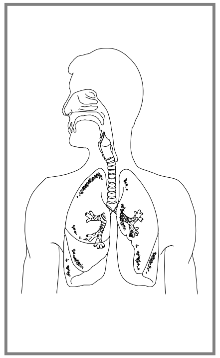
Pollutant/Noise Emission

Transport and Chemical Transformation; Noise Propagation



Calculation is made twice: with and without project!

Differences of Physical Impacts

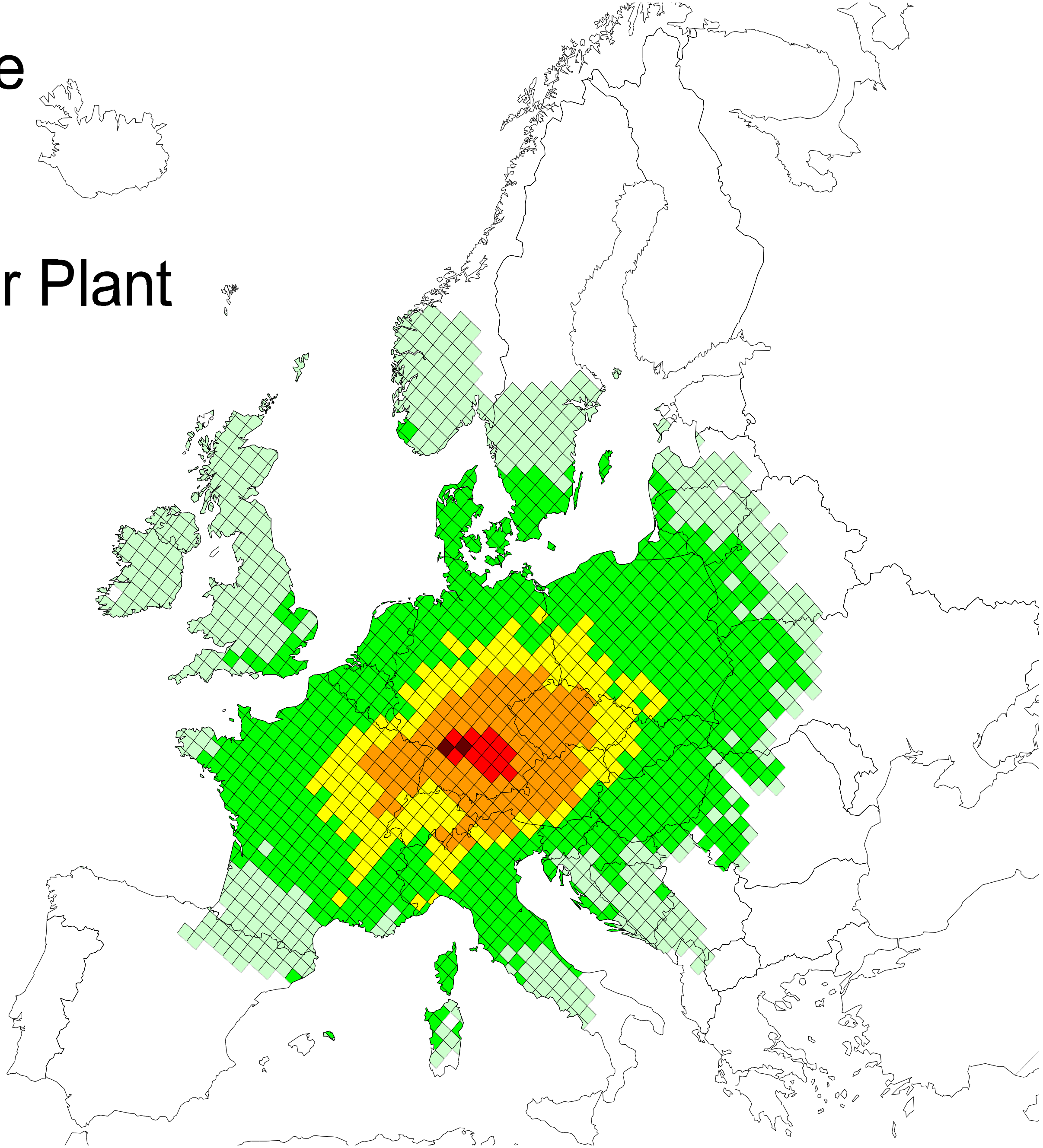


Additional Sulfate Concentration caused by Coal Fired Power Plant in Lauffen

(SW Germany)

[ng/m3]

	< 0.1
	0.1 - 0.5
	0.5 - 1
	1 - 5
	5 - 10
	> 10



Quantification of Impacts and Costs

Exposure Response Function:

Additional Years of Life Lost

$= 3.9 \cdot 10^{-5} \cdot \Delta \mathit{Sulfate} \cdot \mathit{Population}$

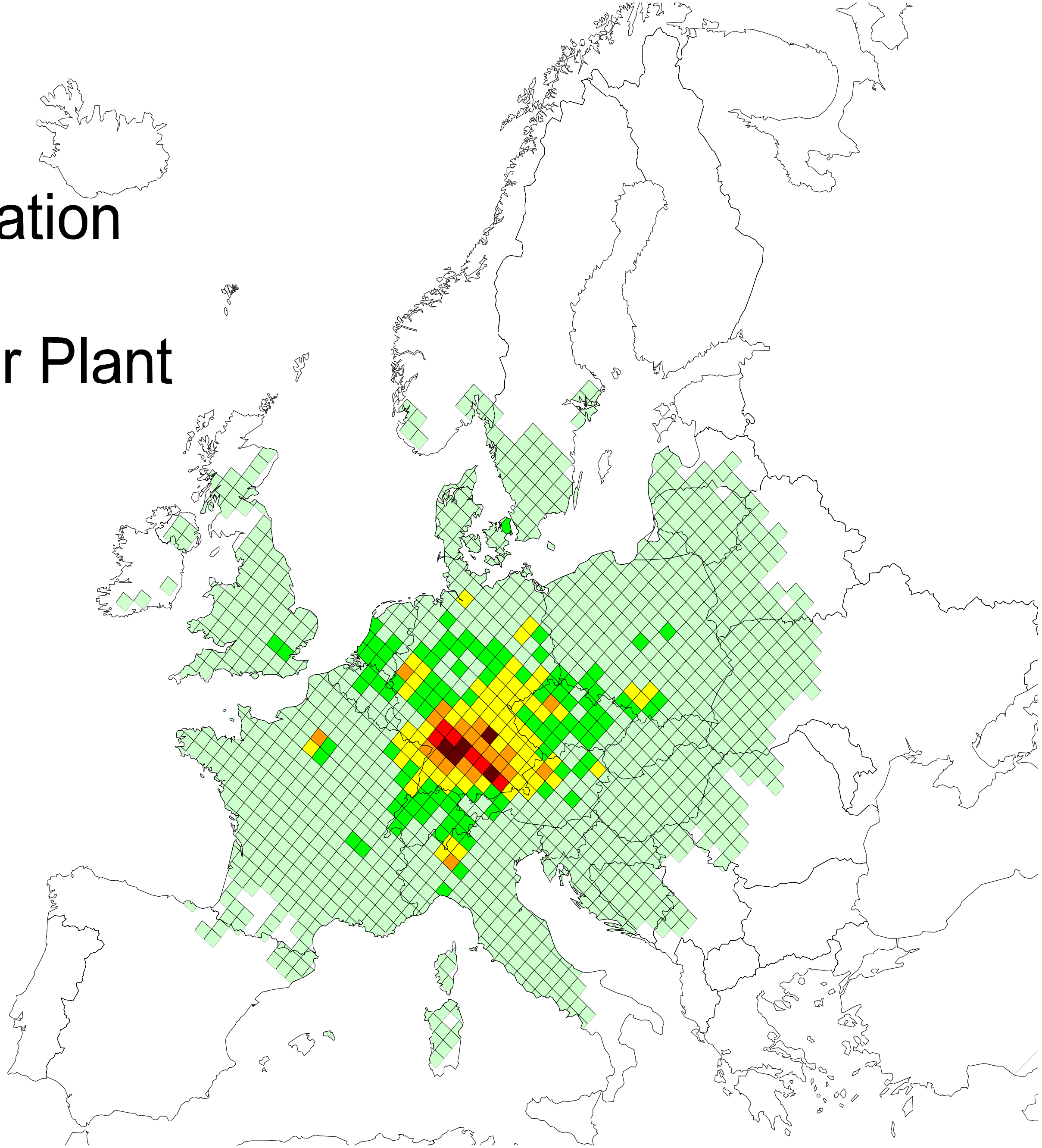
Quantified number of additional Years of Life Lost

due to one year operation : 103

Life Time Lost caused by Sulfate concentration due to Coal Fired Power Plant in Lauffen (SW Germany)

[Years per Year]

(light green)	< 0.1
(green)	0.1 - 0.2
(yellow)	0.2 - 0.5
(orange)	0.5 - 1
(red)	1 - 2
(dark red)	> 2



Impacts included (I)

Impact Cat.	Pollutant / Burden	Effects
Human Health mortality	PM_{10} SO_2, O_3	Reduction in life expectancy due to short and long time exposure
		Reduction in life expectancy due to short time exposure
	Benzene, BaP, 1,3-butad., Diesel part., radioact.,HM	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_{10}, O_3, SO_2	Respiratory hospital admissions
	PM_{10}, O_3	Restricted activity days
	PM_{10}, CO	Congestive heart failure
	Benzene, BaP, 1,3-butad., Diesel part.,radioact.	Cancer risk (non-fatal)
	PM_{10}	Cerebrovascular hospital admissions, cases of chronic bronchitis, cases of chronic cough in children, cough in asthmatics, lower respiratory symptoms
	O_3	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

Impacts included (II)

Impact Category	Pollutant / Burden	Effects
Building Material	SO_2, Acid deposition	Ageing of galvanised steel, limestone, mortar, sand-stone, paint, rendering, and zinc for utilitarian buildings
	Combustion particles	Soiling of buildings
Crops	SO_2	Yield change for wheat, barley, rye, oats, potato, sugar beet
	O_3	Yield change for wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed
	Acid deposition	Increased need for liming
	N, S	Fertilising effects
Global Warming	CO_2, CH_4, N_2O	World-wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise
Amenity losses	Noise	Amenity losses due to noise exposure
Ecosystems	SO_2, NO_x, NH_3	Eutrophication, Acidification
Land Use Change		'PDF' of species

Basic Approach of ExternE for the assessment (weighting) of impacts

Assessment of impacts is based on the (measured) preferences of the affected well-informed population

This implies:

- **Available information should be explained before measuring preferences**

Basic Approach

Preferences are expressed in (i. e. effects are transformed into) monetary units (e.g. €$_{2005}$)

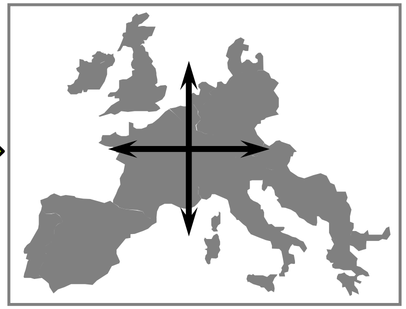
->allows transfer of values, units are conceivable, direct use of results in CBA and for internalising via taxes possible

-> however: 'utility points' would give the same results

Impact Pathway Approach

Pollutant/Noise Emission

Transport and Chemical Transformation; Noise Propagation



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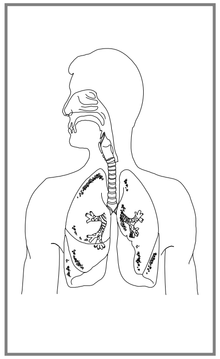
Differences of Physical Impacts



Monetary Valuation

Valuation methods for non-market goods

Revealed Preference (RP)
behaviour (shown in the past)

Stated Preference (SP)
surveys

Indirect valuation

assesses costs or efforts that can be linked to the non-market good

- Hedonic Price Method
- Averting Behavior Method
- Travel Cost Method
- Contingent Behavior Method
- Past behaviour of public decision makers

Direct valuation

- Contingent Valuation Method (CVM)
- Attribute Based Choice Modeling (ABCM)
- Participatory approaches
- Surveys for preferences of public decision makers

Benefit Transfer oder Value Transfer

Adjustment and use of monetary values, that have been measured in a study or context

Use of a specific value (unit value transfer): does not take into account different incomes, culture a.s.o.

Income is usually taken into account with:

$$B_{new} = B_{Original} * (Y_{new} / Y_{Original})^{ß}$$

B= monetary value (benefit); Y = income per capita, β = elasticity (between 0,7 and 1)

Income in different countries is usually transferred using PPP (purchase power parity)

Monetary Valuation: recommended values for the EU

Health end-points	Euro per case / per YOLL
Increased mortality risk (infants)	3,000,000
New cases of chronic bronchitis	200,000
Increased mortality risk - YOLLacute	60,000
Life expectancy reduction - YOLLchronic	40,000
Respiratory hospital admissions	2,000
Cardiac hospital admissions	2,000
Work loss days (WLD)	295
netto Restricted activity days (netRADs)	130
Minor restricted activity days (MRAD)	38
Lower respiratory symptoms	38
LRS excluding cough	38
Cough days	38
Medication use / bronchodilator use	1

Discounting

- Time preference describes the preference for present consumption over future consumption
- strength of preference is measured by the rate of time preference

The rate of time preference can be fractionised into the components ρ_i and $\theta_i \cdot g_i$:

$$r_i = \rho_i + \theta_i \cdot g_i$$

with

ρ_i the pure rate of time preference (extent of preference for the present)

g_i the growth rate of per capita consumption from the present to the future period

θ_i the elasticity of marginal utility with respect to consumption

Assumptions. ρ= 0 %, 1.5 %, 3 % ; g = 1,5% -> r = 1.5 %, 3 %, 4.5 %,

WTP for avoidance of health risks is assumed to increase with income

Stochastic analysis leads to Weitzman discounting = declining discount rate

Marginal Costs of Carbon

[Euro 2005 per tonne CO2]	2005	2010	2015	2025	2035	2045	2050
1) MDC_NoEW	7	9	11	14	15	17	22
2) PP_MAC_Kyoto plus		23.5	27	32	37	66	77
3) PP_MAC_2°		23.5	31	51	87	146	190

MDC NoEW = marginal damage costs, calculated with FUND, 1% pure rate of time preference, no equity weighting

**PP MAC Kyoto plus: precautionary principle, marginal avoidance costs:
– Kyoto 2010, - 20% 2020, increase 3%/a**

PP MAC 2° : precautionary principle, marginal avoidance costs: warming should not exceed 2°

Assessment of Damocles Risks

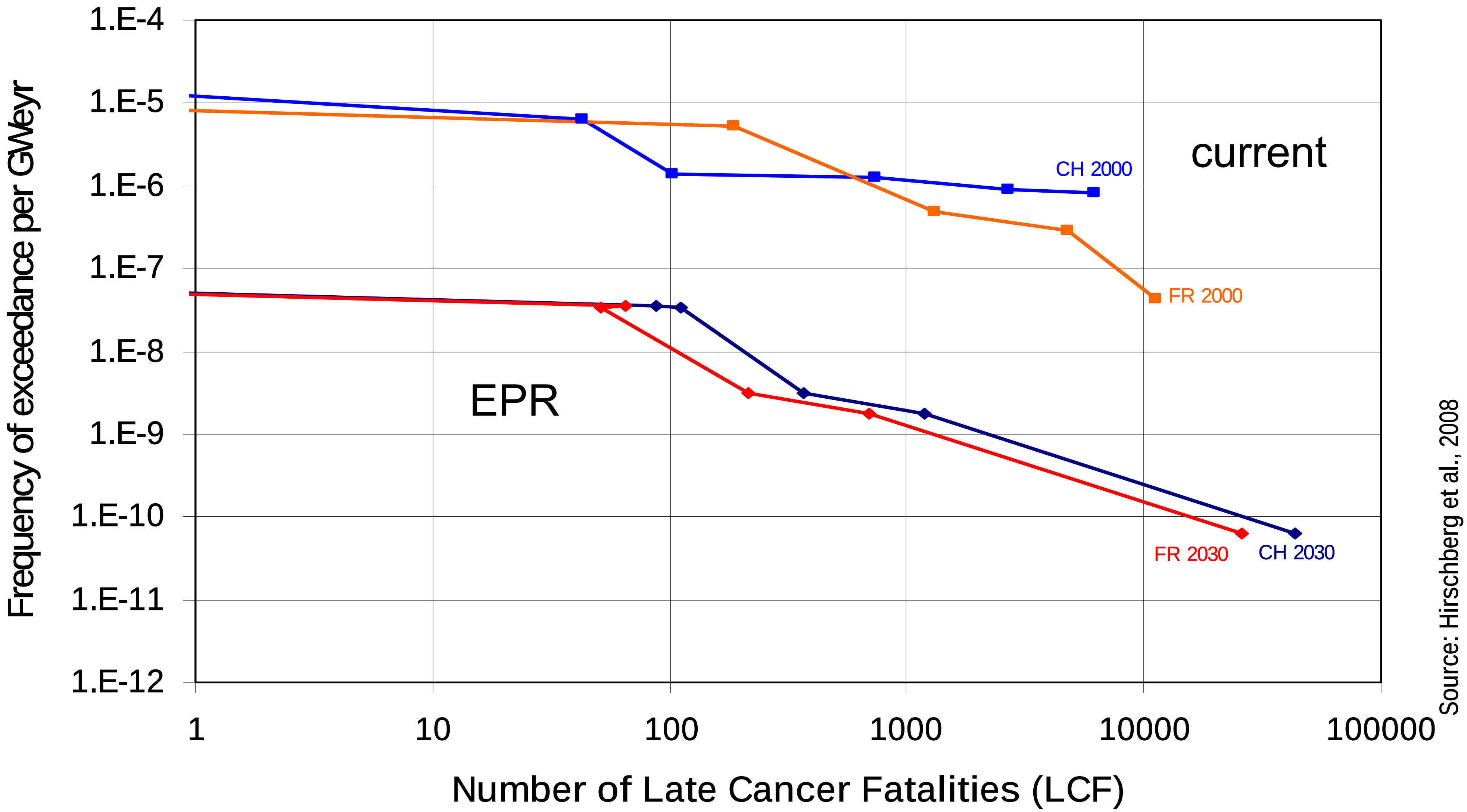
Risk = frequency * damage = expectation value of damage

Problem: If the frequency/probability of occurence of a risk is very low, however the potential damage is very high (in the order of the total benefit of a technology/activity), then the risk is for some not the appropriate measure for an assessment.

On individual basis: risk aversion
Individual prefers risk with lower damage to a similar risk with higher damage.

Currently there is no methodology to include risk aversion, so the expectation value is used.

F-N Curves: Latent Cancer Fatalities (LCF) for current nuclear power plants and EPR (European Pressurized Reactor)



Applications of the ExternE Methodology I

European Union:

Energy: justification for promoting and subsidizing renewable energy; recommended cap on subsidies for renewables

Transport: cost-benefit analysis mandatory for all major infrastructure projects; planned to levy tolls according to infrastructure and external costs

Environmental Protection: Cost-benefit analysis for all recently implemented directives for Air Pollution Control:
e.g. Non-Hazardeous Waste Incineration Directive, Large Combustion Plant Directive, National Emissions Ceilings Directive, Daughter Directives to Air Quality Directive: ozone, CO and benzene

UN: cost-benefit analysis for the UN/ECE multi-pollutant multi-effect protocol

Applications of the ExternE Methodology II

EU member states:
Numerous national applications: UK, Netherlands, Finland, Belgium, France, Ireland, Greece, Spain ..., e.g. in Germany: external costs of biomass; subsidies for renewable energies; extension Frankfurt airport;

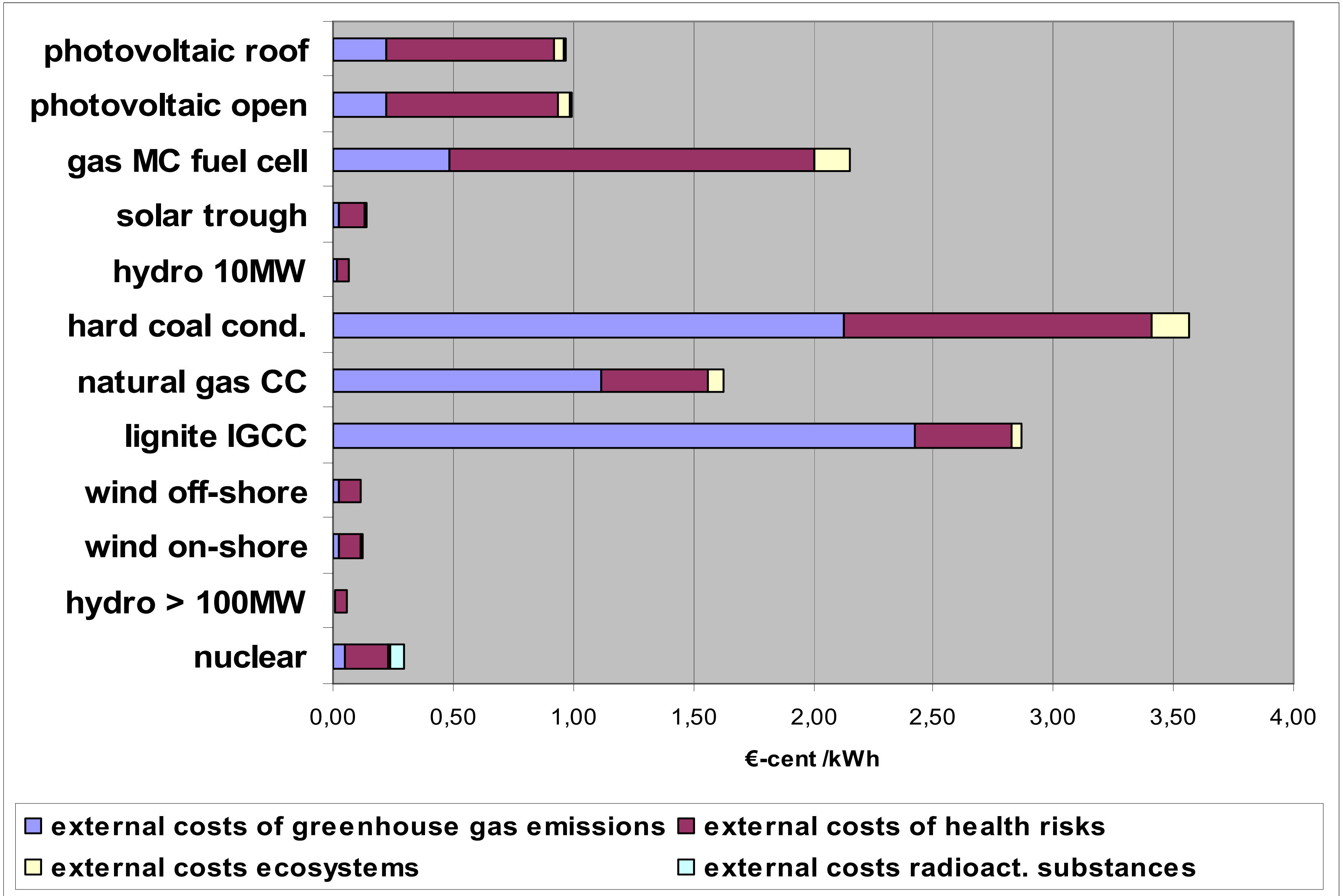
In other parts of the world – together with local partners: Russia, China, Brazil, Ukraine, Japan

Table 2: Technical characterization

Considered technologies

Energy carrier	Technology	net, el. power, net [MW]	net, el. efficiency [%]	Investment costs [€/kWel]	Technical lifetime [a]
Nuclear	PWR	1300	33	1850	40
Hard coal	Condensing	600	46	1000	35
	IGCC	450	45	1350	35
Lignite	Condensing	965	44.5	1300	35
	IGCC	450	44	1200	35
Natural gas	CCGT	800	57.5	500	35
	Run of river	1	85	5500	70
	Run of river	50	85	3500	70
	Dam	1000	83	3500	120
Wind	On-shore	2	100	1000	20
	Off-shore	2	100	1650	20
Photovoltaic	Roof	0.00312	15	5200	25
	Open space	0.00312	15	4275	25

External Costs, current technologies



Nuclear without Damocles risk assessment, terrorism, wind without visual intrusion

Private Costs per kWh generated: averaged lifetime levelised generating costs

$$ALLGC = \frac{\sum_{t=0}^{T} \frac{[I_t + M_t + F_t]}{(1+r)^t}}{\sum_{t=0}^{T} \frac{[E_t]}{(1+d)^t}}$$

I_t	= Investment expenditures in year t
M_t	= Operation and Maintenance expenditure in year t
F_t	= Fuel expenditures in year t
E_t	= Electricity generation in year t
r	= Discount rate
ALLGC	= Average Lifetime Levelised Generating Costs ($\overline{p}$)

Back-up Costs

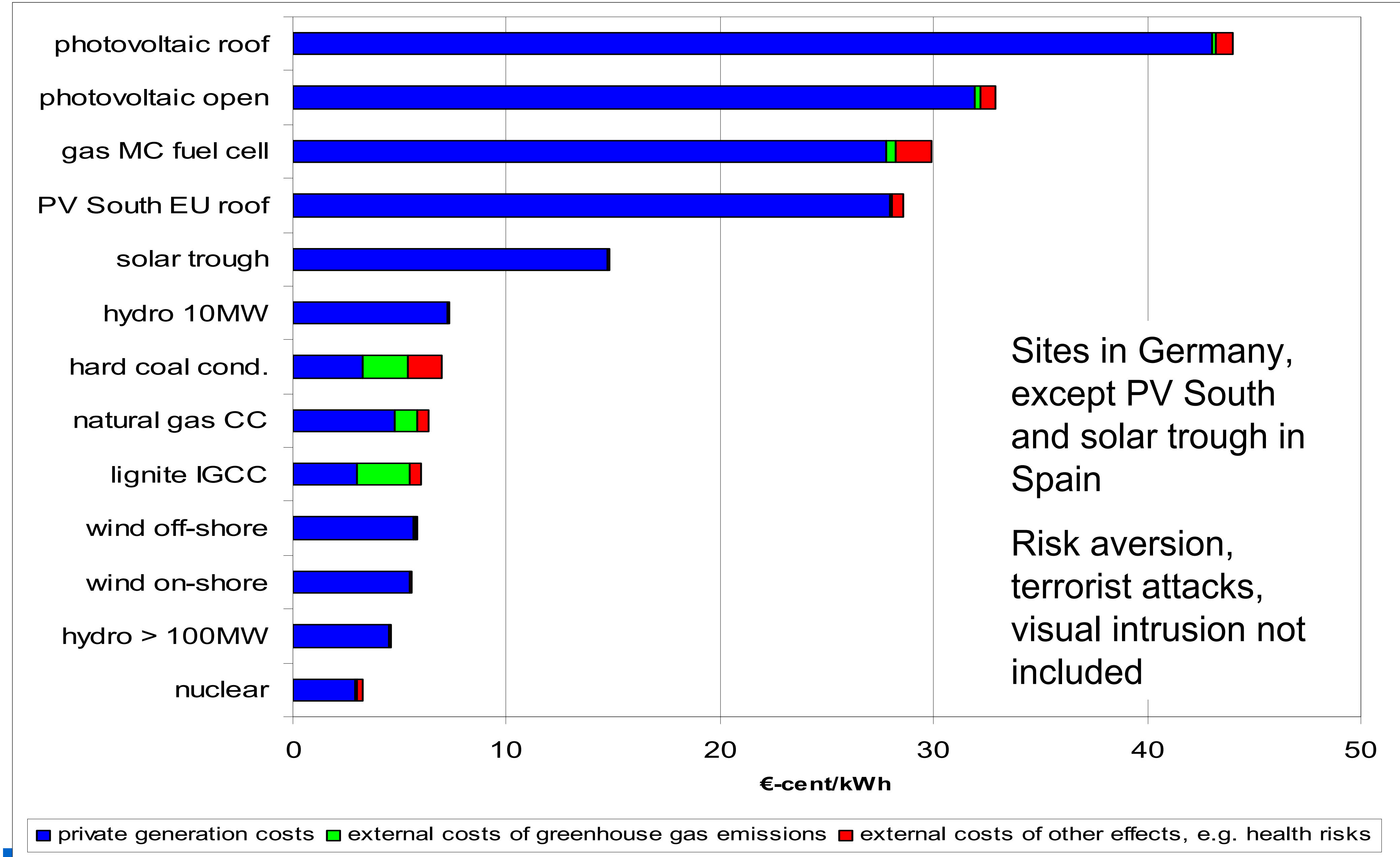
$$C_{BU} = \frac{A_k}{h_F} - \frac{A_k \cdot P}{h_w} = A_k \cdot \left(\frac{1}{h_F} - \frac{P}{h_W} \right)$$

C_{BU}	=	Cost Back-Up
h_F	=	Full loading hours, back-up
h_w	=	Full loading hours of the renewable power station
P	=	Power credit of the renewable energy plant (power at peak load times) per kW installed
A_k	=	Annuity per kW, incl. the annual fix costs per kW of the back-up technology

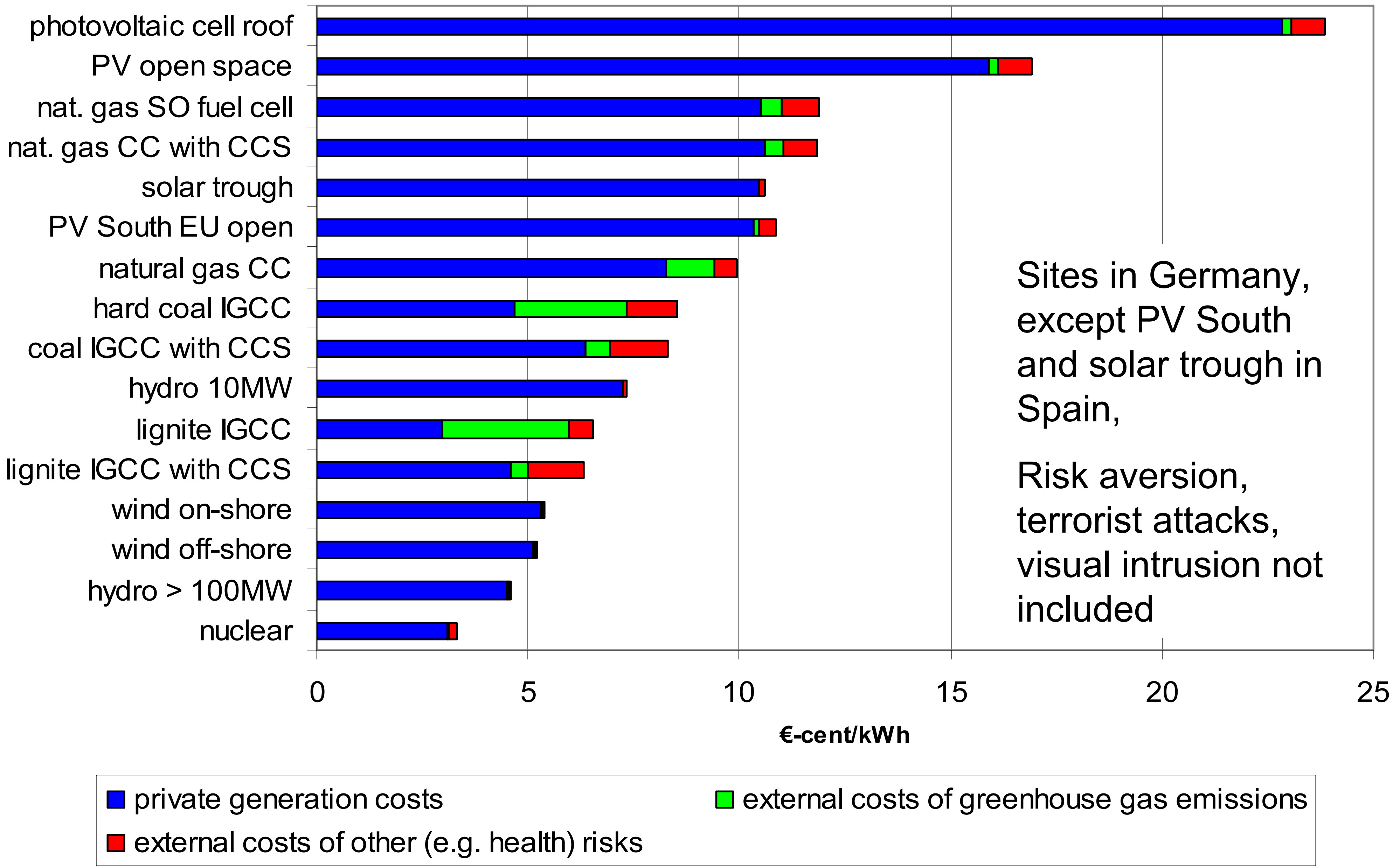
Back-up costs:

Wind energy and PV ca 0,9 €-cent/kWh

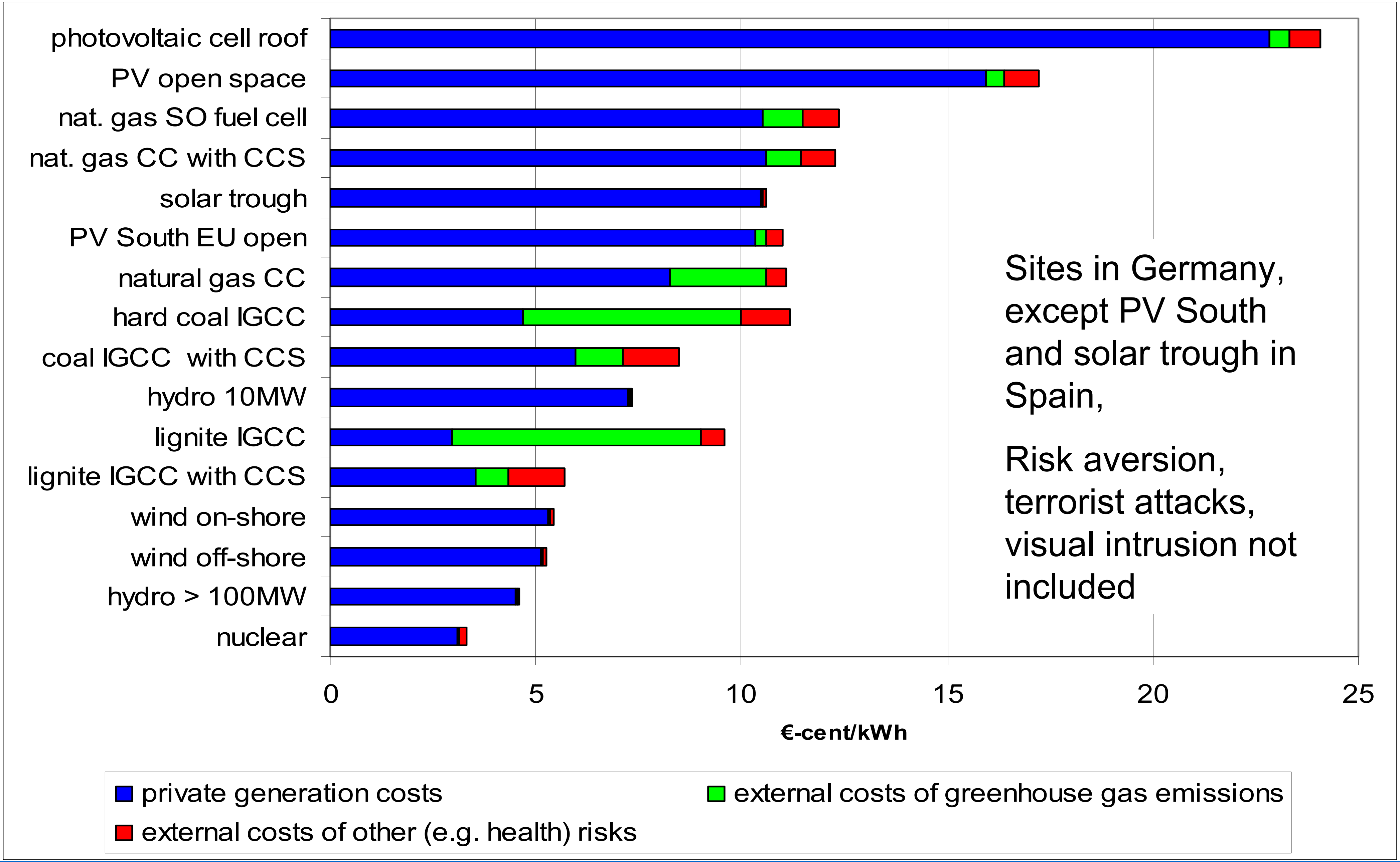
Social Costs per kWh, technologies 2008



Social Costs per kWh, Technologies 2030, 34,5 €/t CO2



Social Costs per kWh, Technologies 2030, 96 €/t CO2



Conclusions

- **Nuclear, wind and water are the electricity generating options with the least social costs. However, wind and water have a limited potential; for nuclear in some countries problems with the acceptance occur and the limited potential has to be extended by using breeders.**
- **Lignite will continue to play a major role regionally, followed by coal – with or without CCS, depending on the level of ambition for reducing global warming, provided that CCS can be installed with the estimated costs. The costs of coal systems can be reduced by using CHP (combined heat and power production) and additional biomass (that can not be used for food production).**
- **Furthermore, especially if CCS becomes too expensive or has limitations in capacity, solar thermal systems e.g. in the Mediterranean countries become a feasible option.**

More information on the ExternE webpage:

www.ExternE.info