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Nuclear: most effective on both Economic and Environmental Dimensions

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Preliminary caveat: how do we include acceptability in our assessments?

- All this presentation addresses environmental and economic performances under normal operation, excluding severe accident occurrence.
- When considered by a pure economist, nuclear power remains competitive even when accounting for the risk of occurrence of a Fukushima like accident. Taking into account the very low frequency of such accident, the related external risk is equivalent to 1 Euro/MWh as an order of magnitude.
- But such a risk will also deter many actors to invest in this technology.

Investment decision must take into account several dimensions: economic, social and environmental

The question addressed here: rating the performance of nuclear power

- Every power generation option brings about risks and benefits. The point here is to see how high nuclear power ranks, compared to other options providing equivalent services.
- Every power generation technology has to be assessed over the whole energy chain, from mine to waste, “from cradle to grave”.
- Well established methods can be used:
  - To assess the lifecycle cost of electricity supply (LCOE)
  - To assess environmental & health impacts through Life Cycle Analysis (LCA)
  - To estimate environmental costs
  - To develop multi-criteria analysis, offering common basis to the debate on preferable options; every stakeholder then will rank the options according to its own priorities

We need to rely on sound science
and Research Institutes have a key role to play

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The concept of external costs

- 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)

Lifecycle Cost of Electricity Generation

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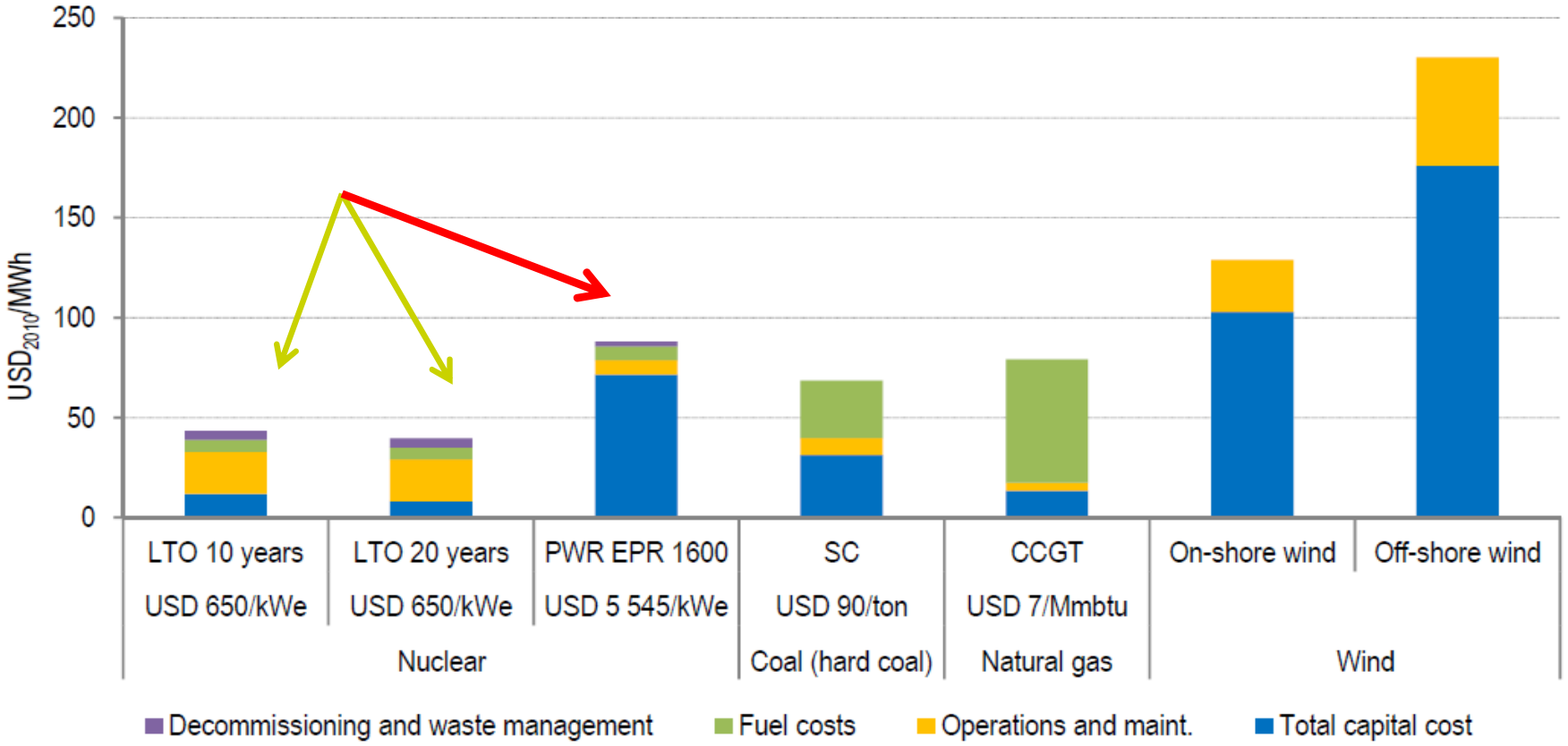
Example of LCOE comparisons
(no CO2 emission cost included)

Ref: NEA (2012) –Report N° 7054; Figure 5.4

Figure 5.4. Projected costs of electricity generation in Belgium, at 8% real discount rate



Note: CCGT = Combined-cycle gas turbine. PWR = Pressurised water reactor; EPR = European pressurised reactor; SC = Supercritical.

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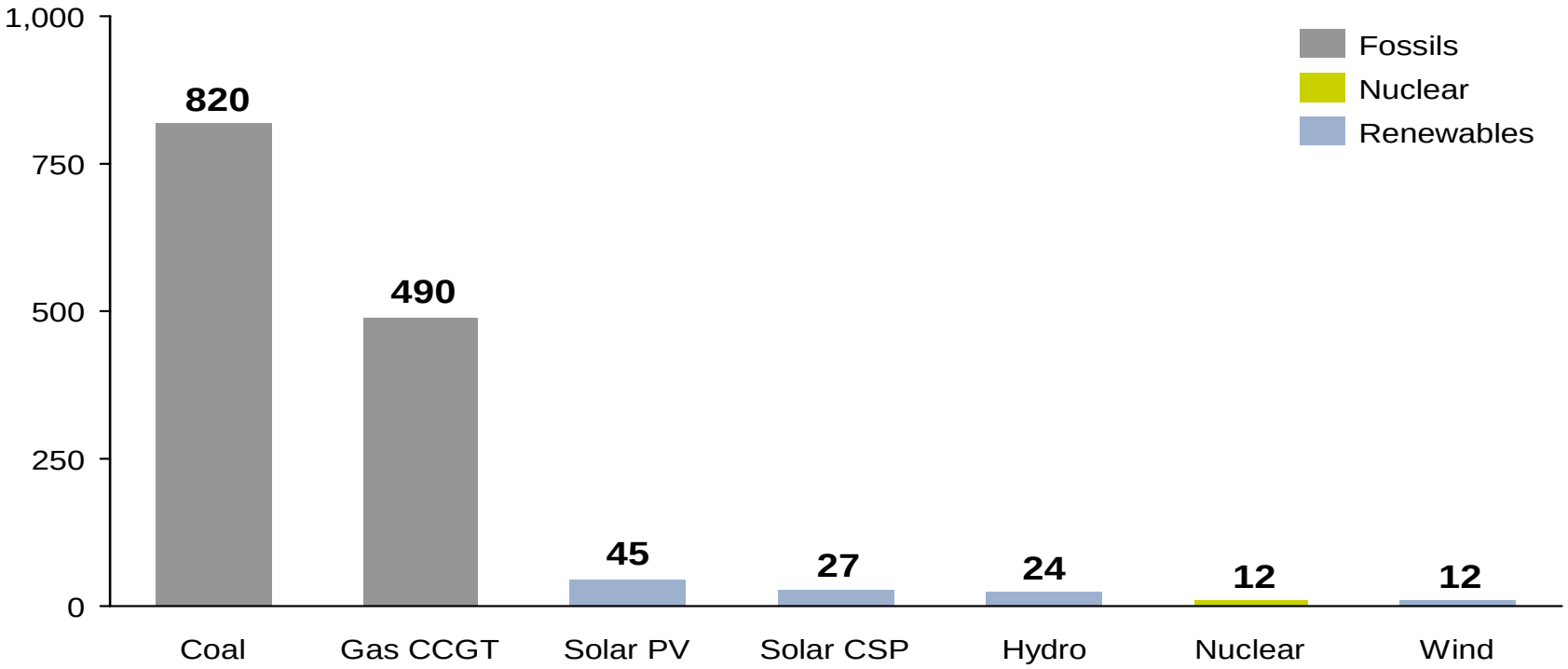
CO_2 Emissions

GHG emissions from power generation: nuclear among the lowest according to IPCC

Technology specific CO_2 emissions
(gCO_2-eq/kWh over the entire life cycle – median values)



Source: IPPC, Fifth Assessment Report, 2014

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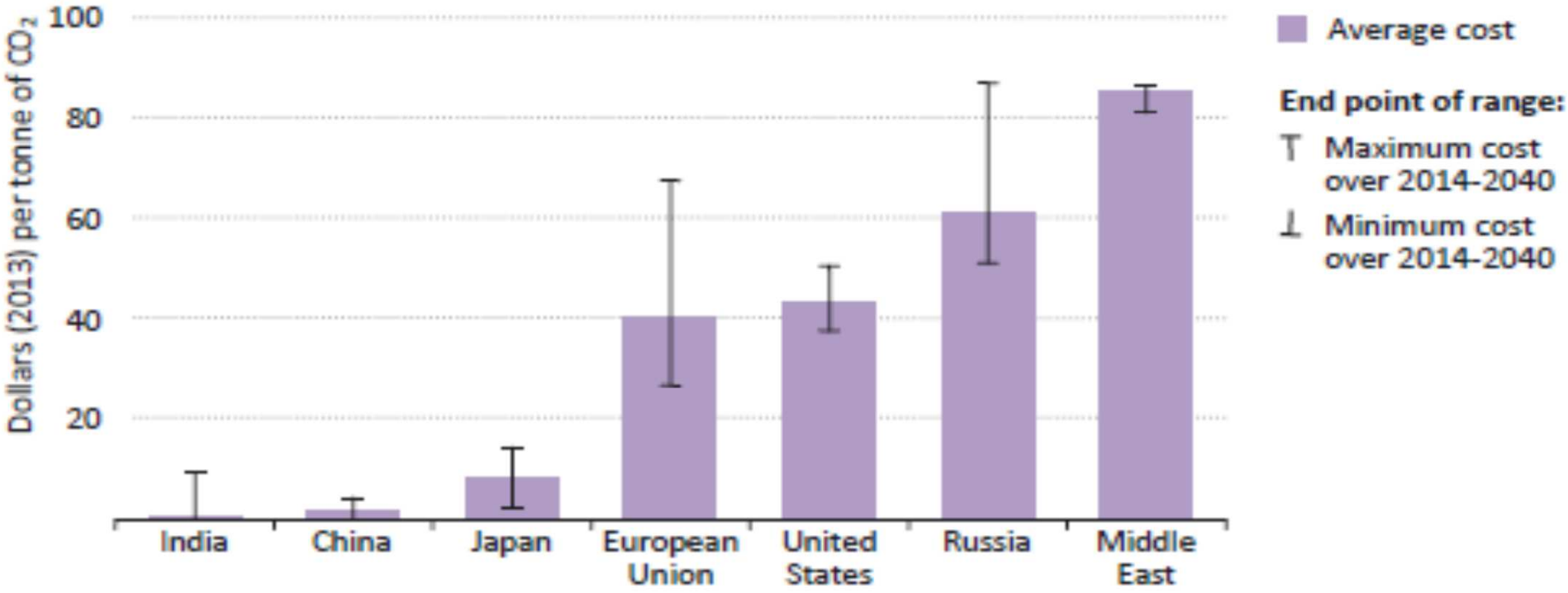
The future cost of CO_2 emissions avoided by nuclear according to IEA

Figure 12.8 ▷ Average cost of CO_2 emissions avoided by nuclear power by selected region in the New Policies Scenario, 2014-2040*



* In the absence of CO_2 pricing.

IEA/WEO 2014, p422

EU: Highly dependent on construction cost assumption

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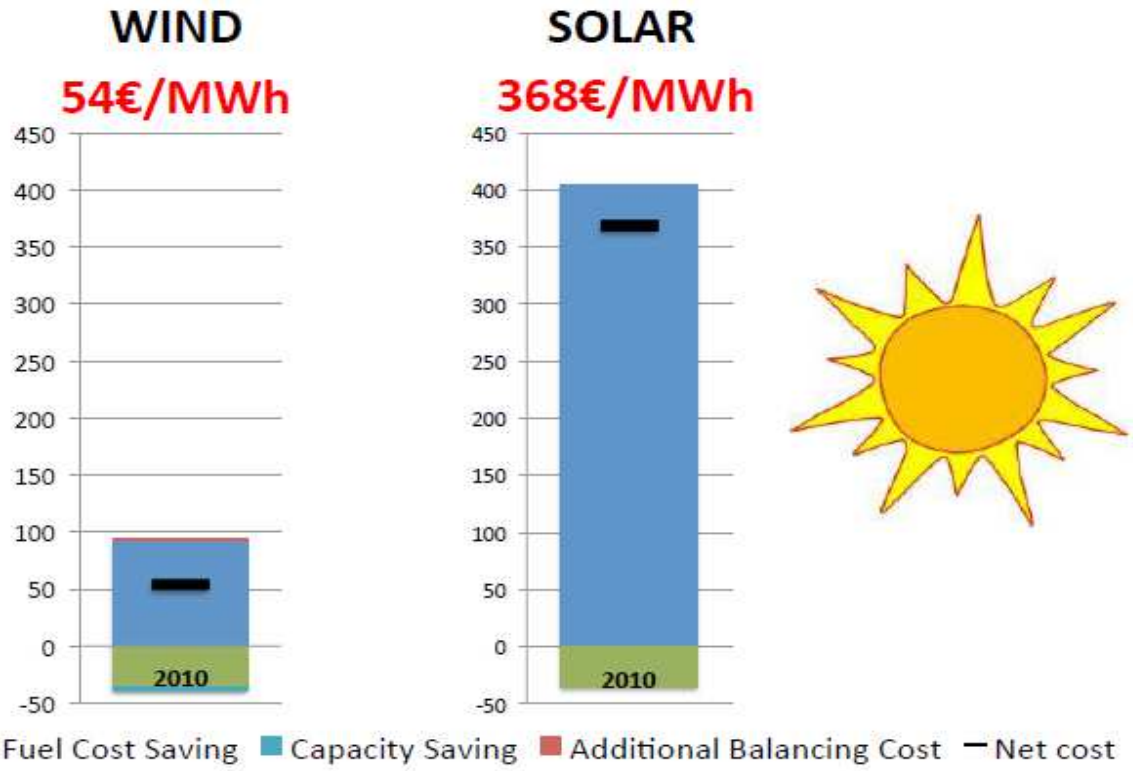
The implicite carbon price of renewable energy incentives (Claudio Marcantonini, 2014)

Germany
Net cost of RE



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Life Cycle Analysis applied to Nuclear Fuel Cycle

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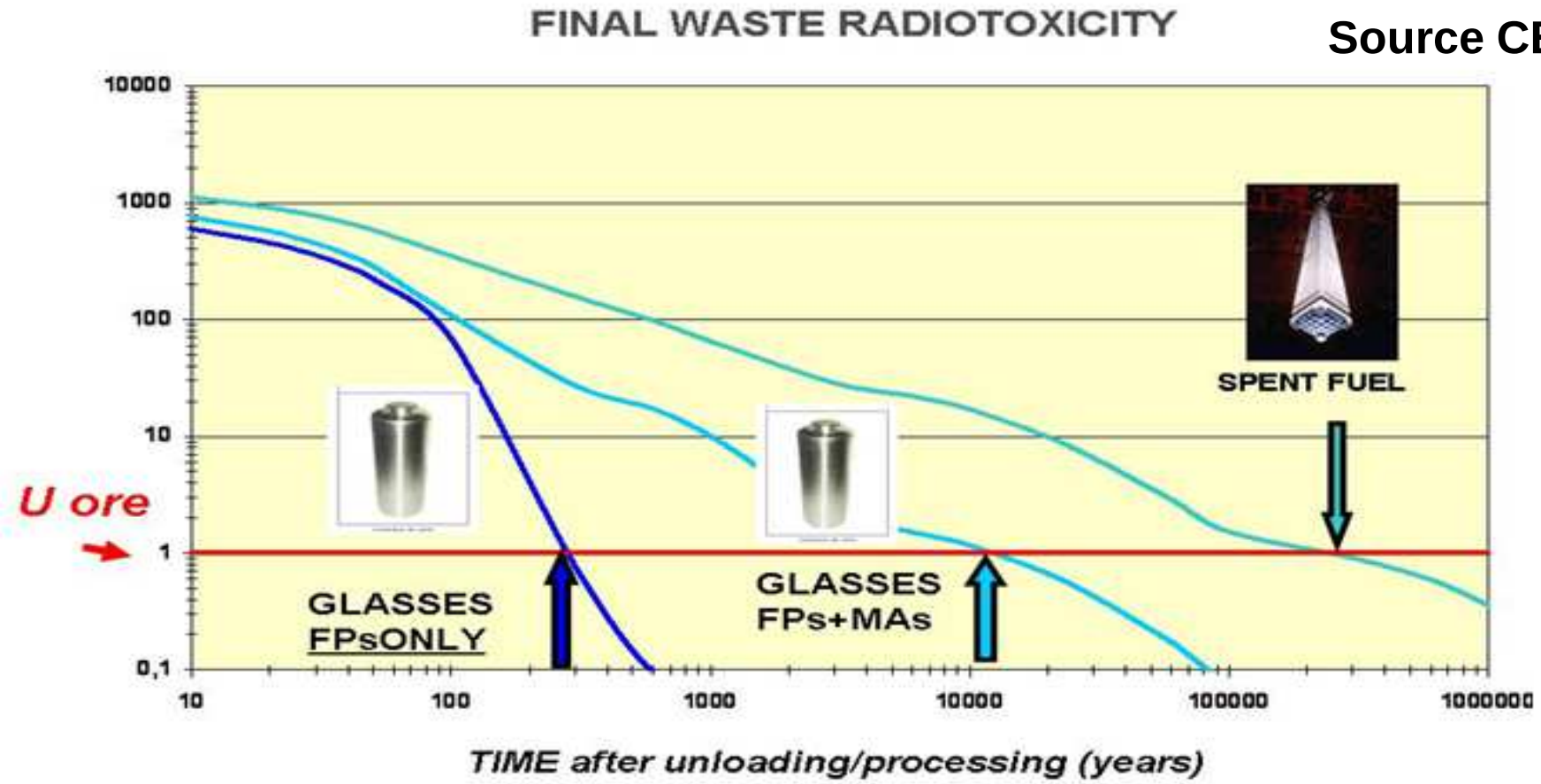
LCA yields comprehensive environmental assessments thanks to numerous indicators

- For instance, the nuclear fuel cycle LCA indicators can be grouped in 5 categories:

Consumption of natural resources	Emissions to the atmosphere	Impact on ecosystems and health	Waste production	Radiological impact
◆Materials consumption ◆Energy consumption ◆Water use	◆Greenhouse gases (GHG) ◆Ozone depleting gases ◆Other air pollutants	◆Pollution ◆Land use ◆Impact on human health	◆Conventional waste ◆Radioactive waste	◆Radiological waterborne emissions ◆Radiological airborne emissions

Focus on nuclear waste management: "the necessary confinement time for critical waste”



HLW from spent fuel reprocessing contain very little U and Pu. It takes much shorter to decay down to Nat U ore radiotoxicity

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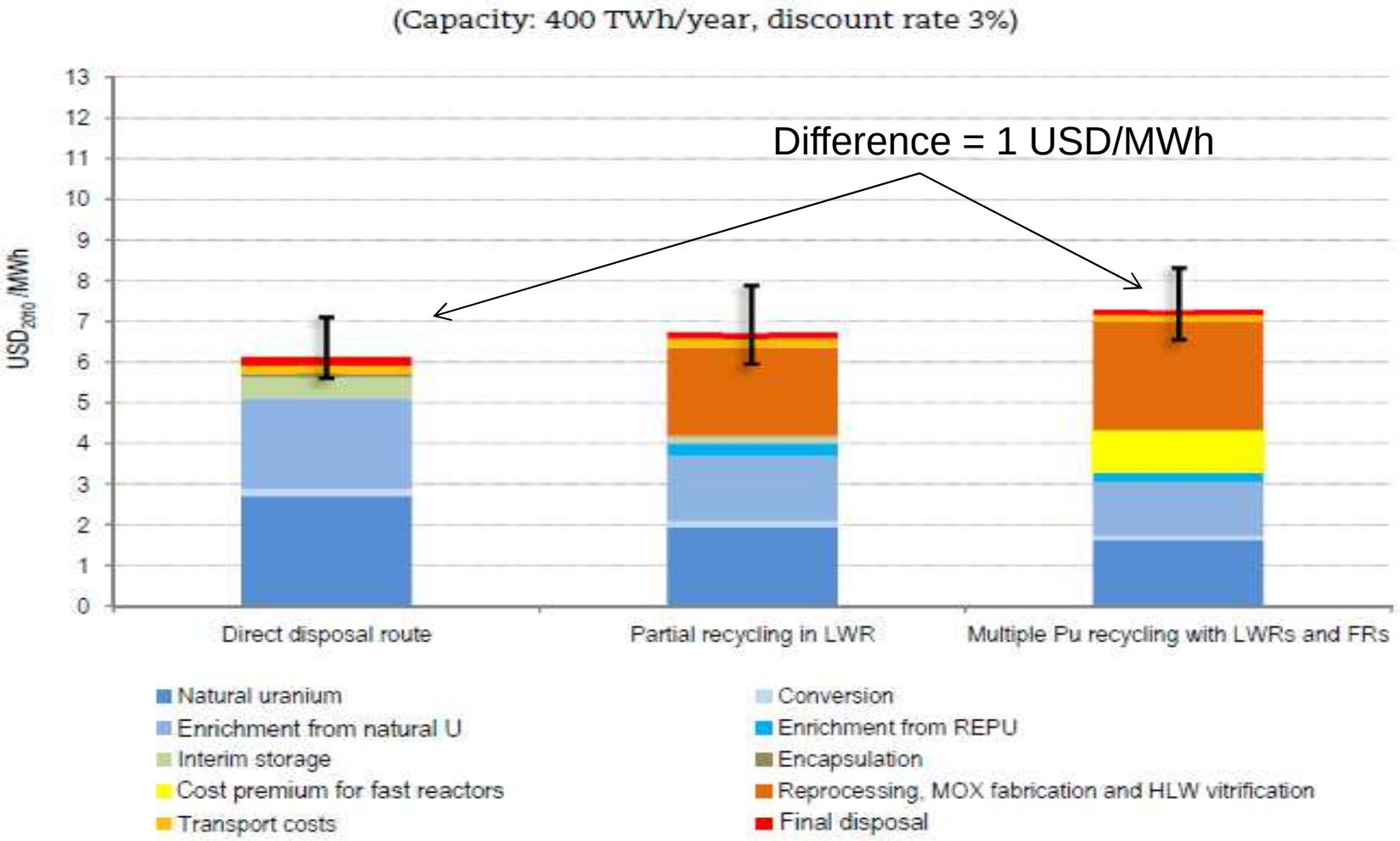
The choice of Recycling is supported by the small incidence on total lifecycle cost (OECD/NEA 2013 Study)



Note: The central values represent the results from the reference cost scenario, and the error bars correspond to the low and high cost scenarios.

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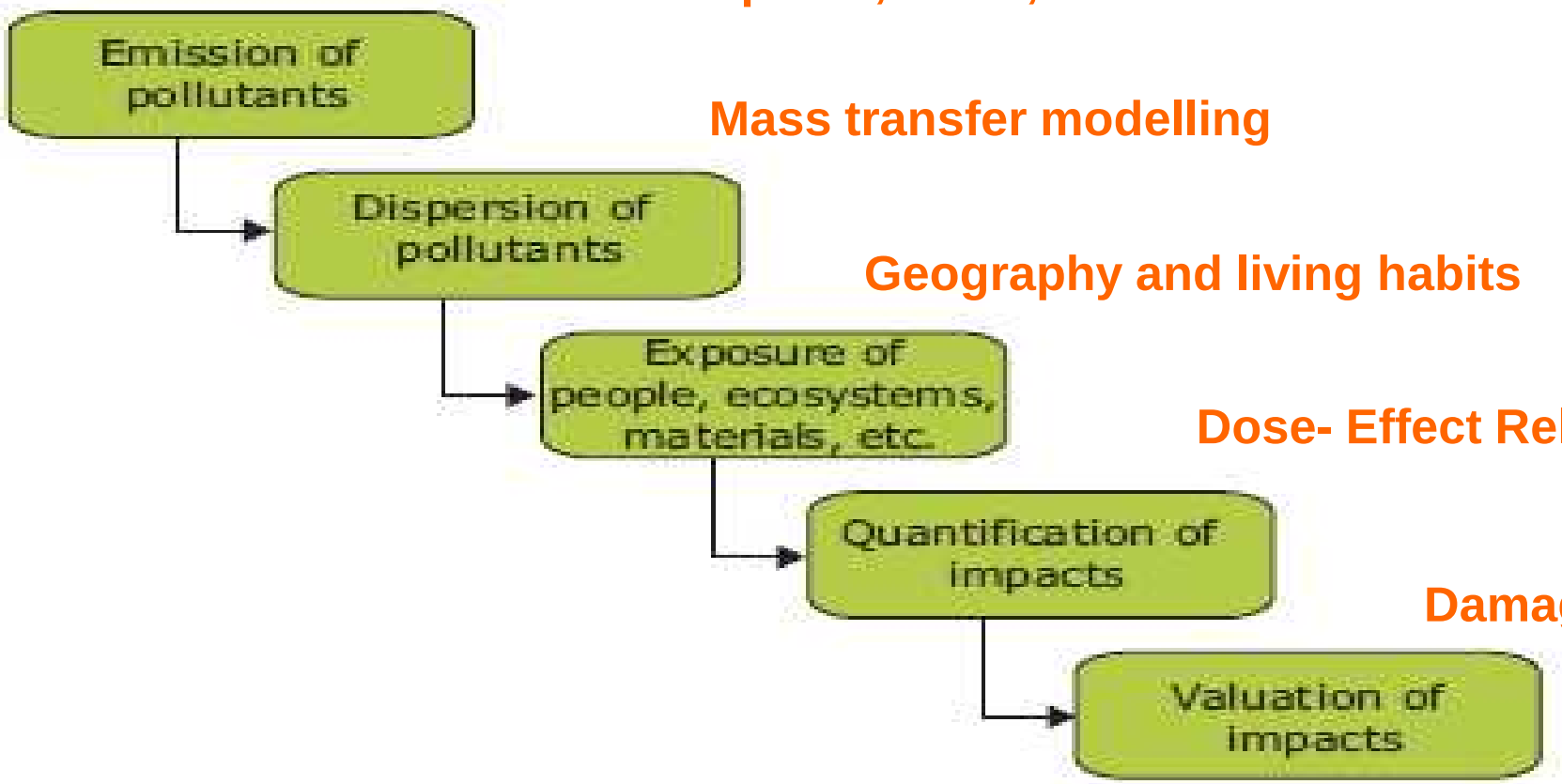
Containment: short term cost preventing from long term damages

- **Containment is the driving principle of waste management in nuclear industry. Effluent treatment produces solid waste where radioactivity is concentrated.**
- **A good reason to confine into solid waste is to circumscribe and better control the source of risk. In case of failure, the environmental impact will remain very local.**
- **For very long term containment in deep repositories, decision can be progressive and reversible: reversibility is one key reason to confine rather than to disperse.**
- **Containment and concentration leaves the recycling option possible.**

Conversely, the dispersion of greenhouse gases into the atmosphere is not reversible and the impact will be global

Envronmental & Health Impacts

The Impact Pathway Approach



To atmosphere, water, soil

Mass transfer modelling

Geography and living habits

Dose- Effect Relationship

Damage valuation

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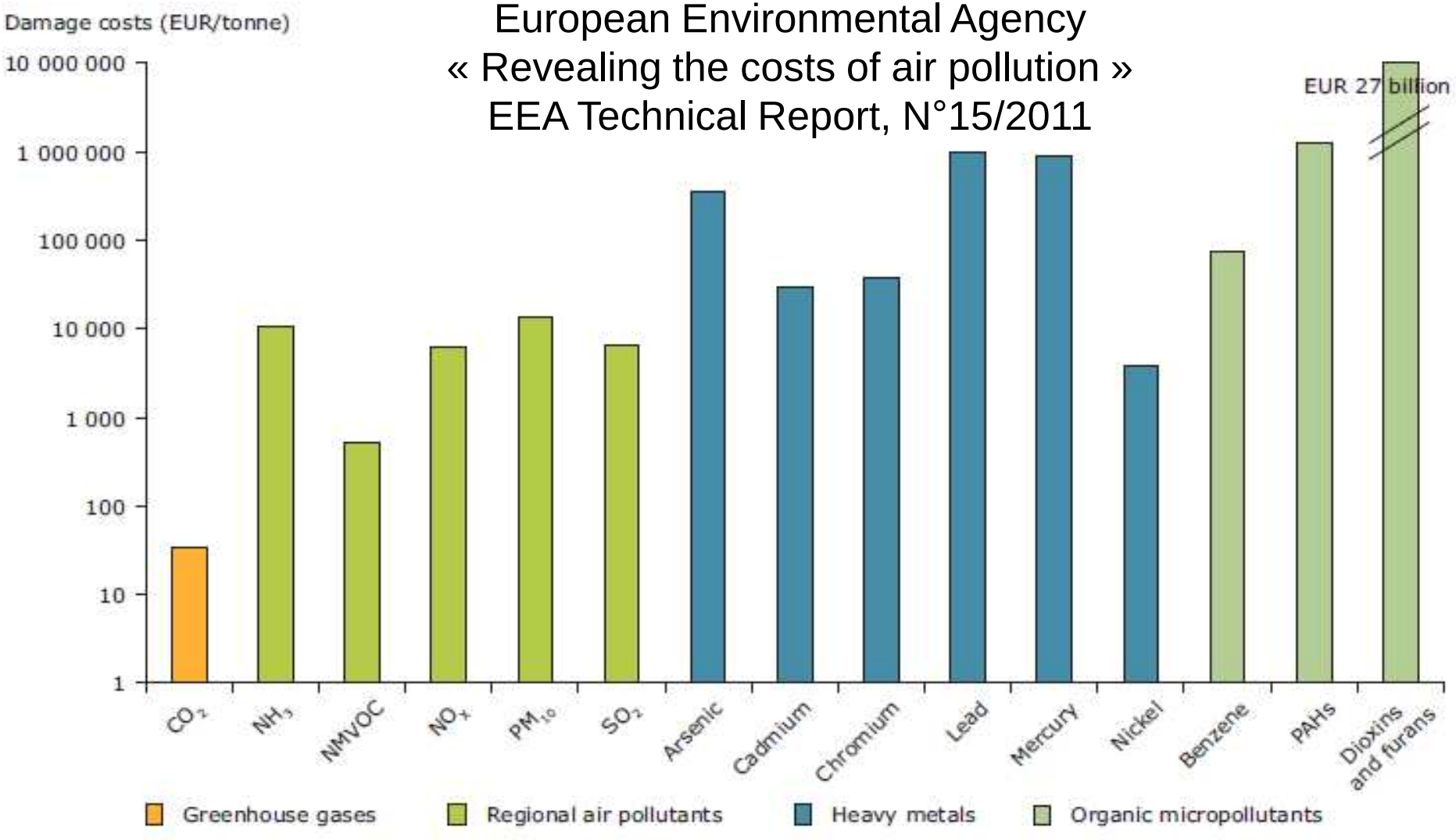
Estimates of the European average damage cost per tonne emitted (logarithmic scale)

European Environmental Agency
« Revealing the costs of air pollution »
EEA Technical Report, N°15/2011



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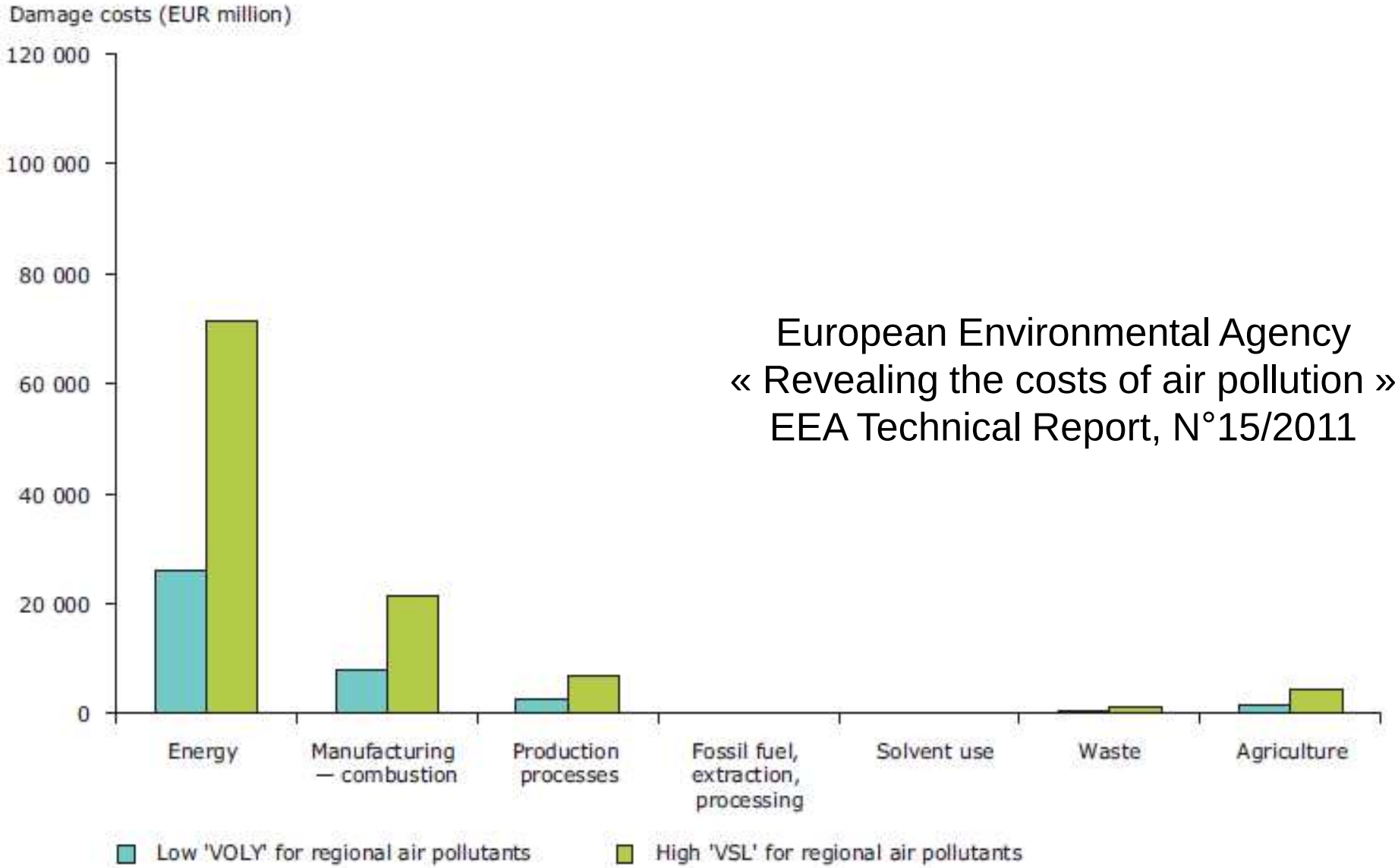
Damage Costs Aggregated by Sector excluding CO_2



European Environmental Agency
« Revealing the costs of air pollution »
EEA Technical Report, N°15/2011

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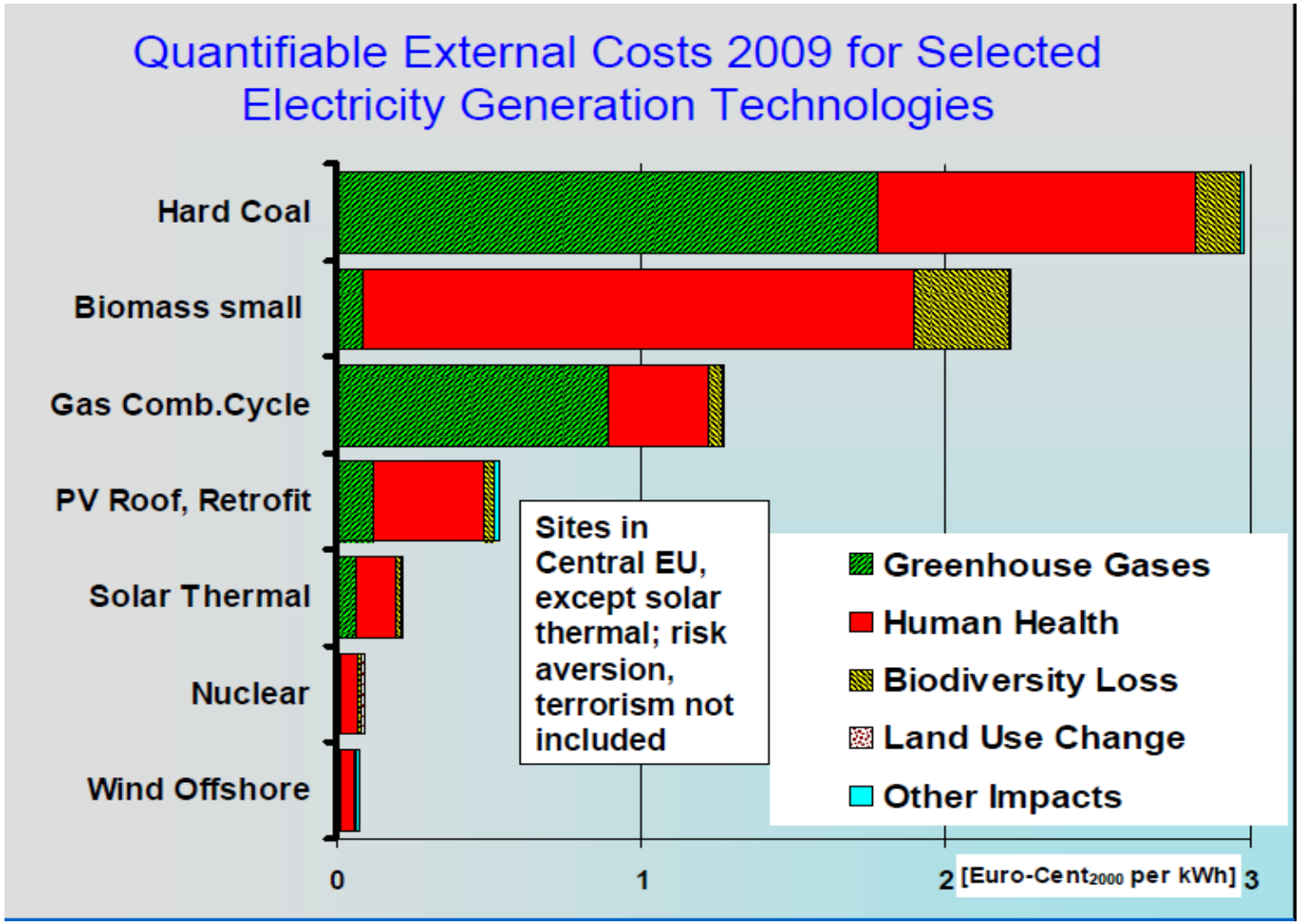
Impacts translated into external costs: less than 2 Euro/MWh for nuclear



Source: NEEDS, 2009

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Conclusion

- **Nuclear is not cheap in the early lifetime**
  - The capital cost of Gen3 reactors has to come down to open the way to wide deployment
- **Low sensitivity of LCOE to uranium price volatility**
  - Backend fuel costs low; full fuel cycle is cheap
  - No long term uranium resource issue
- **Negligible environmental costs**
  - Carbon pricing makes nuclear more competitive
- **Programmable capacity with high availability:**
  - No need of fossil back-up capacity, low system costs

→ Overall, nuclear is among the most competitive low-CO_2 electricity means

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Thank you for your attention !

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