Nuclear Energy and Economic Costs

Workshop on Nuclear Energy and Human Security

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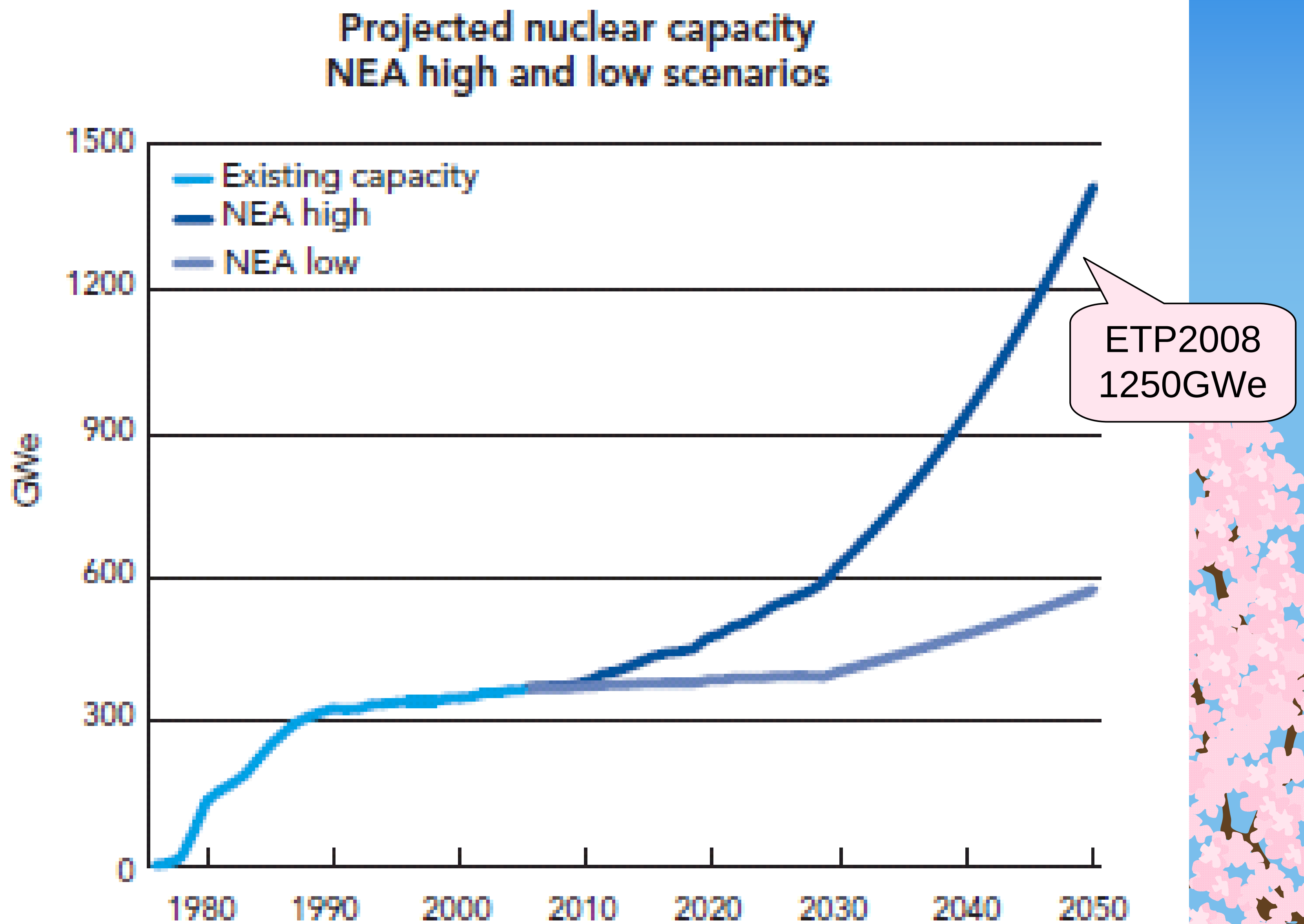
Nuclear Energy Outlook 2008

- Balancing growth of world energy demand with its resulting environmental, social and political impacts is a challenge for the 21st century
- Nuclear energy's role in minimizing the negative consequences of growing energy demand
- Meeting the challenges to nuclear energy growth
  - *Safety*
  - *Waste disposal and decommissioning*
  - *Non-proliferation and security*
  - *Cost*
  - *Nuclear energy and society*

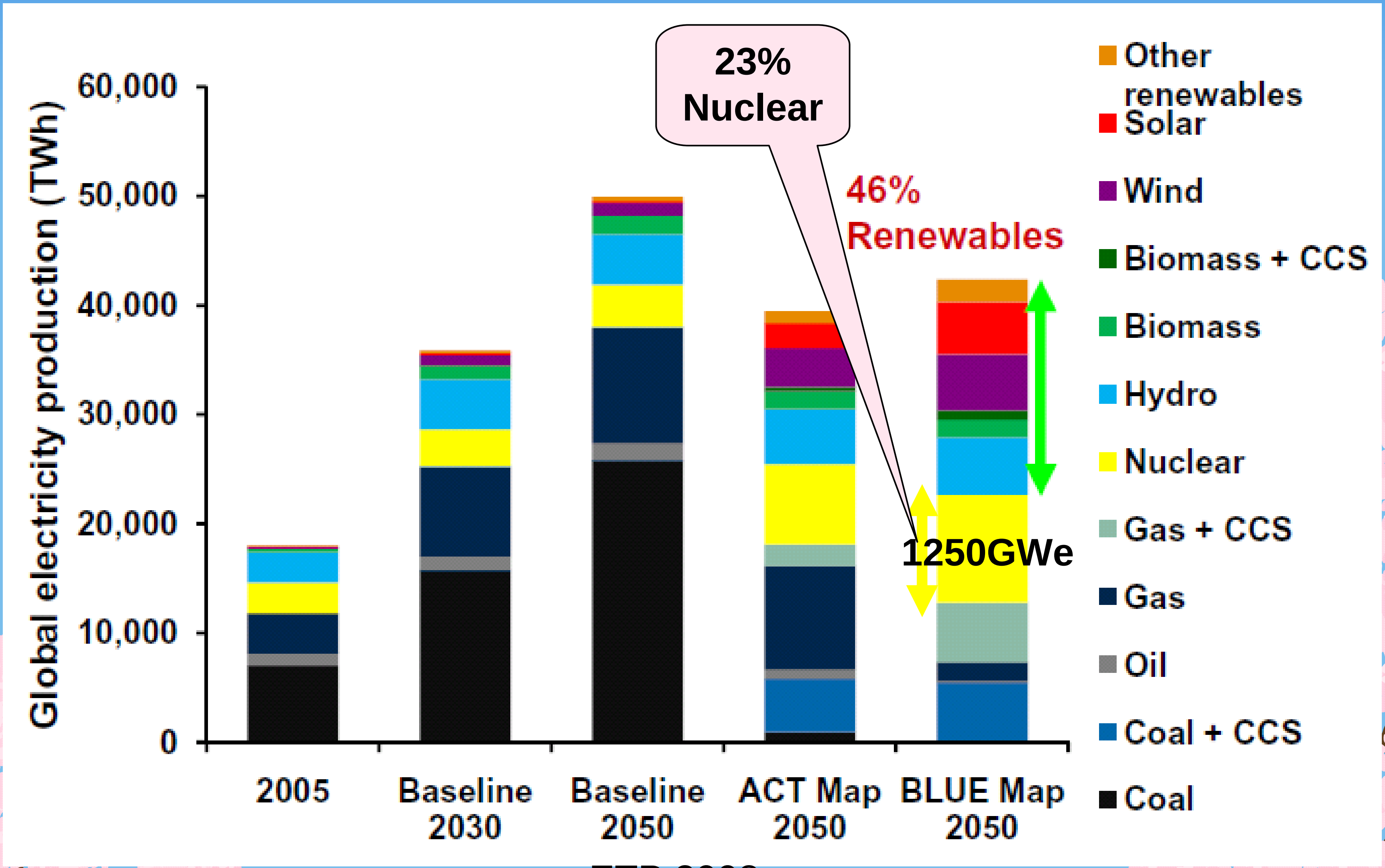


Nuclear Energy Outlook 2008, NEA

Energy Technology Perspectives 2008, *International Energy Agency, June 2008*

- Scenario analysis
  - Baseline WEO2007 Reference Scenario
  - Global stabilization by 2050 (ACT)
    - Energy CO2 emissions in 2050 back to the level of 2005
  - *Global 50% reduction by 2050 (BLUE)*
    - *-50% energy related CO2 in 2050 compared to 2005, consistent with 450 ppm @ 2100*
    - *only possible if the whole world participates fully*
    - *a completely different energy implies system*

Power Generation Mix (ETP2008)



ETP 2008

ETP2010 Draft for nuclear by NEA

- *Achieving the level of nuclear energy indicated in the Blue Map scenario does not require any technological development: it can be achieved with systems available on the world market today.*
- *It will, however, require attention to policy stability and promotion of public and investor confidence.*
- *Indeed, nuclear energy levels well beyond the Blue Map scenario could be achievable.*
- *Much is already going on in the international community to expand the use of nuclear energy and develop even more advanced systems, as well as some activity to establish non-electrical applications.*

Cost of Nuclear

- How much it would be for unit of energy, $/kWh? (Levelised unit lifetime cost)
- How much has to be prepared for the investment or construction of plant, $/MWe?
- How long for plan, siting, licensing? Uncertainties, risks?
- How long for construction, four or five years? Capital cost

  O&M and fuel costs

  Any legacy? Radioactive waste management and decommissioning

Projected Costs of Generating Electricity, 2010 edition -1

- According to a joint NEA and IEA study in 2010, in the low discount rate case, more capital-intensive, low-carbon technologies, such as nuclear energy are the most competitive solution compared with coal-fired plants without carbon capture and natural gas-fired combined cycle plants for base-load generation.
- In the high discount rate case, coal with and without carbon capture equipment, and gas-fired combined cycle turbines (CCGTs), are the cheapest sources of electricity.
- The cheapest options vary depending on local conditions but future measures for carbon pricing could further strengthen the position of nuclear as compared to fossil fuels.

Figure 1.1a: Regional ranges of LCOE for nuclear, coal, gas, and wind on-shore power plants (at 5% discount rate)

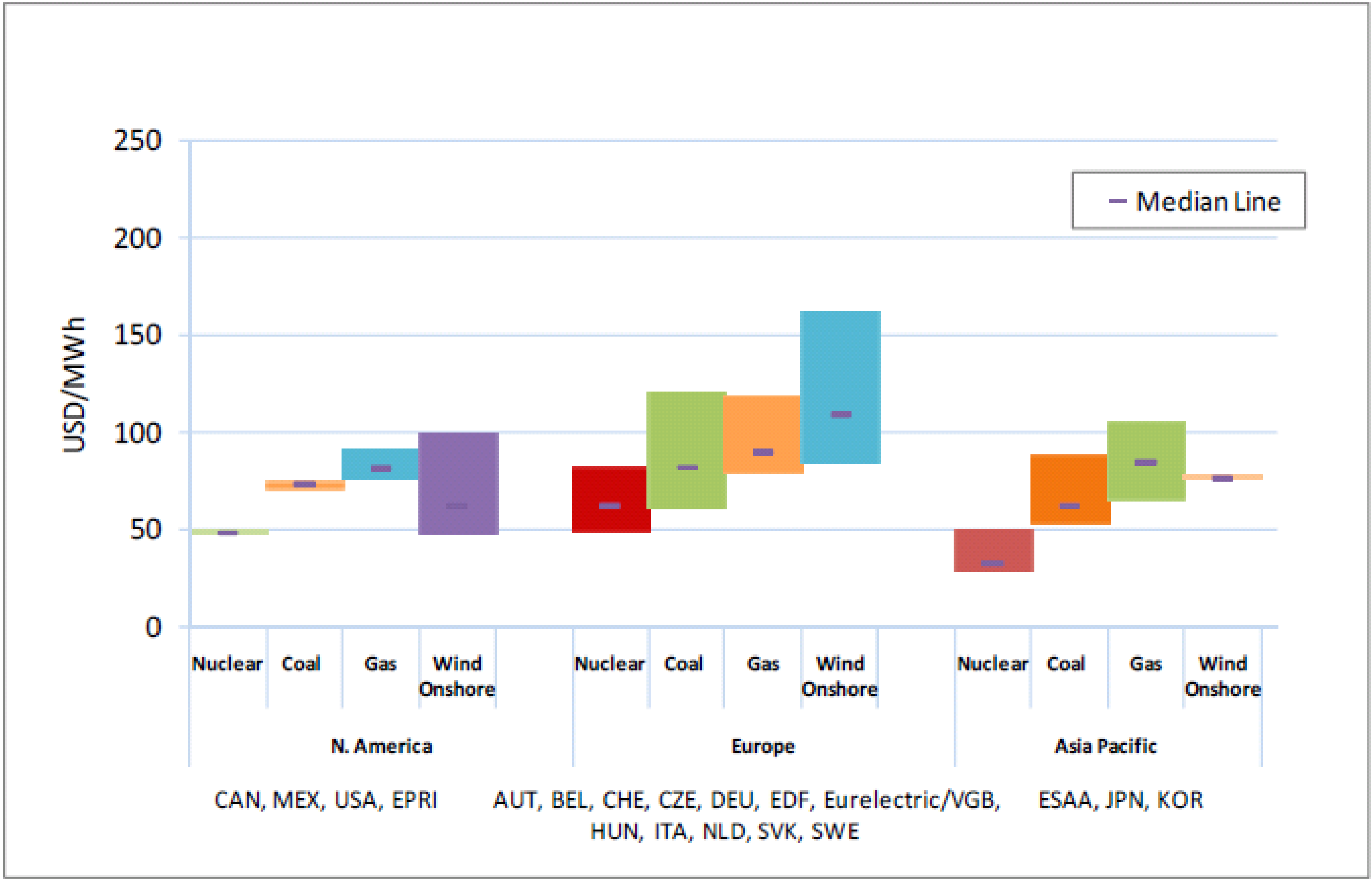


Figure 1.1b: Regional ranges of LCOE for nuclear, coal, gas, and wind on-shore power plants (at 10% discount rate)

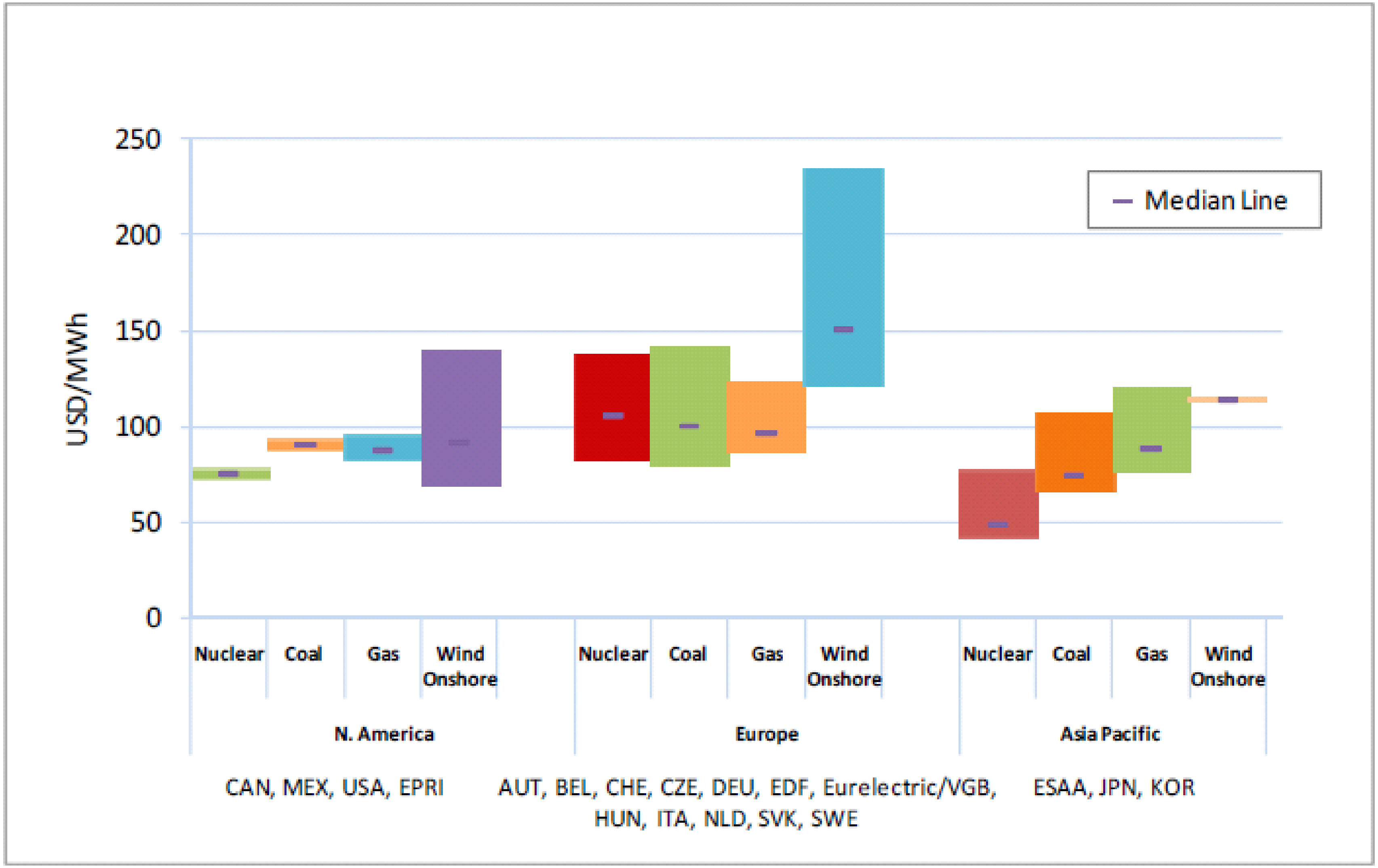


Table 3.7a: Nuclear power plants: Levelised costs of electricity in US dollars per MWh

Country	Technology	Net Capacity	Overnight Costs[1]	Investment Costs[2]		Decommissioning Costs		Fuel Cycle Costs	O&M Costs[3]	LCOE	
				5%	10%	5%	10%			5%	10%
		MWe	USD/kWe	USD/kWe		USD/MWh		USD/MWh	USD/MWh	USD/MWh	
Belgium	EPR-1600	1 600	5 383	6 185	7 117	0.23	0.02	9.33	7.20	**61.06**	**109.14**
Czech Rep	PWR	1 150	5 858	6 392	6 971	0.22	0.02	9.33	14.74	**69.74**	**115.06**
France*	EPR	1 630	3 860	4 483	5 219	0.05	0.005	9.33	16.00	**56.42**	**92.38**
Germany	PWR	1 600	4 102	4 599	5 022	0.00	0.00	9.33	8.80	**49.97**	**82.64**
Hungary	PWR	1 120	5 198	5 632	6 113	1.77	2.18	8.77	29.79/29.84	**81.65**	**121.62**
Japan	ABWR	1 330	3 009	3 430	3 940	0.13	0.01	9.33	16.50	**49.71**	**76.46**
Korea	OPR-1000	954	1 876	2 098	2 340	0.09	0.01	7.90	10.42	**32.93**	**48.38**
	APR-1400	1 343	1 556	1 751	1 964	0.07	0.01	7.90	8.95	**29.05**	**42.09**
Netherlands	PWR	1 650	5 105	5 709	6 383	0.20	0.02	9.33	13.71	**62.76**	**105.06**
Slovak Rep	VVER 440/ V213	954	4 261	4 874	5 580	0.16	0.02	9.33	19.35/16.89	**62.59**	**97.92**
Switzerland	PWR	1 600	5 863	6 988	8 334	0.29	0.03	9.33	19.84	**78.24**	**136.50**
	PWR	1 530	3 681	4 327	5 098	0.16	0.01	9.33	15.40	**54.85**	**90.23**
United States	Advanced Gen III+	1 350	3 382	3 814	4 296	0.13	0.01	9.33	12.87	**48.73**	**77.39**
NON OECD MEMBERS											
Brazil	PWR	1 405	3 798	4 703	5 813	0.84	0.84	11.64	15.54	**65.29**	**105.29**
China	CPR-1000	1 000	1 763	1 946	2 145	0.08	0.01	9.33	7.10	**29.99**	**44.00**
	CPR-1000	1 000	1 748	1 931	2 128	0.08	0.01	9.33	7.04	**29.82**	**43.72**
	AP-1000	1 250	2 302	2 542	2 802	0.10	0.01	9.33	9.28	**36.31**	**54.61**
Russia	VVER-1150	1 070	2 933	3 238	3 574	0.00	0.00	4.00	16.74/16.94	**43.49**	**68.15**
INDUSTRY CONTRIBUTION											
EPRI	APWR, ABWR	1 400	2 970	3 319	3 714	0.12	0.01	9.33	15.80	**48.23**	**72.87**
Eurelectric	EPR-1600	1 600	4 724	5 575	6 592	0.19	0.02	9.33	11.80	**59.93**	**105.84**

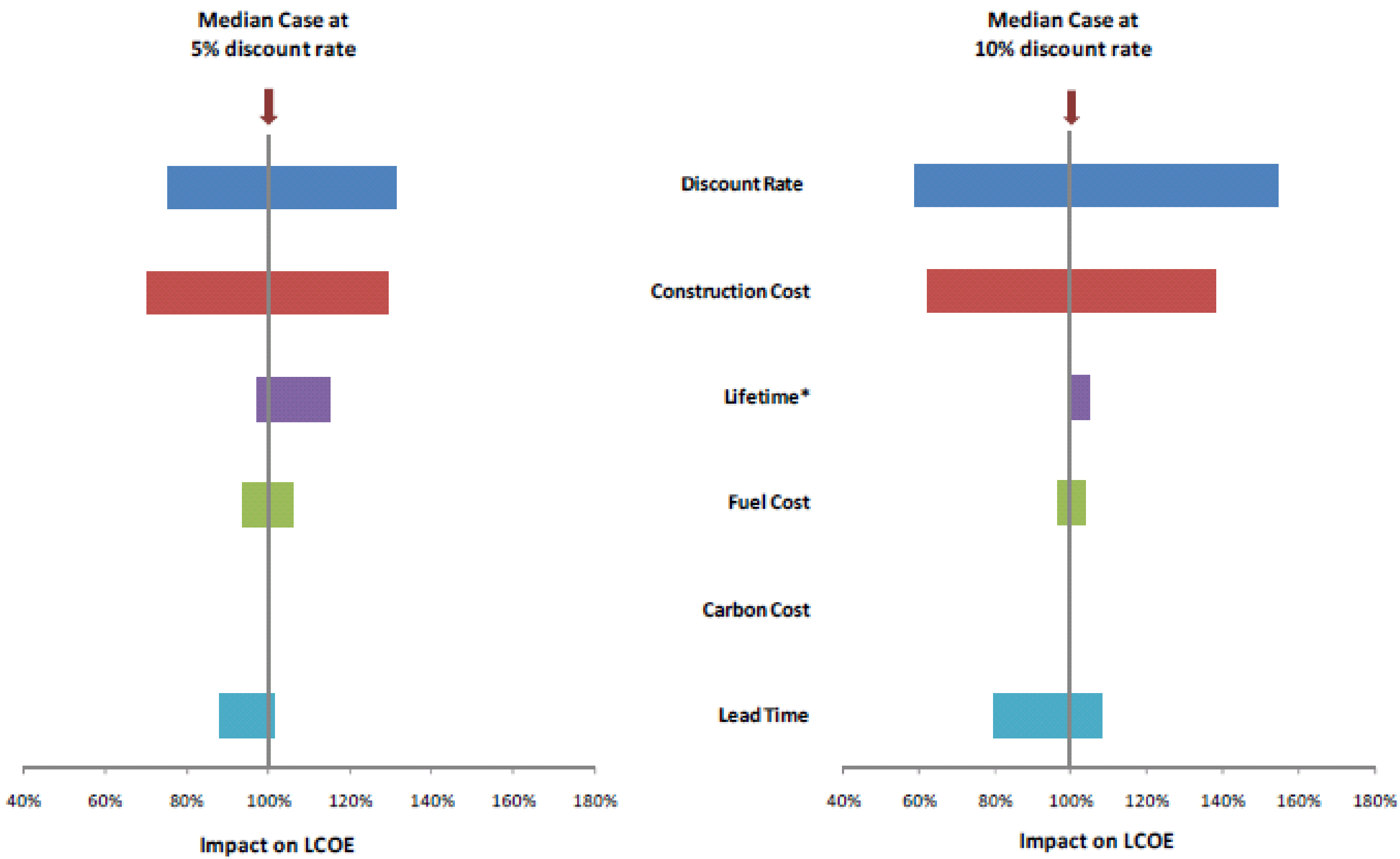
*The cost estimate refers to the EPR in Flamanville (EDF data) and is site-specific.

1. Overnight costs include pre-construction (owner's), construction (Engineering, Procurement and Construction) and contingency costs, but not Interest During Construction (IDC).
2. Investment Costs include Overnight Costs as well as the implied Interest During Construction (IDC).
3. In cases where two numbers are listed under O&M Costs, numbers reflect 5% and 10% discount rates. The numbers differ due to country-specific cost allocation schedules.

Projected Costs of Generating Electricity, 2010 edition -2

- Typically about 60% of the total cost of nuclear electricity generation is due to the capital investment required to construct a nuclear power plant, while operation and maintenance with about 25% and the fuel cycle with about 15%.
- The cost of the natural uranium itself amounts to only around 5%.
- Therefore, the cost of generating nuclear electricity is highly sensitive to overnight construction cost and to the cost of capital and very insensitive to the price of its fuel.

Figure 6.1: Tornado graph 1 nuclear



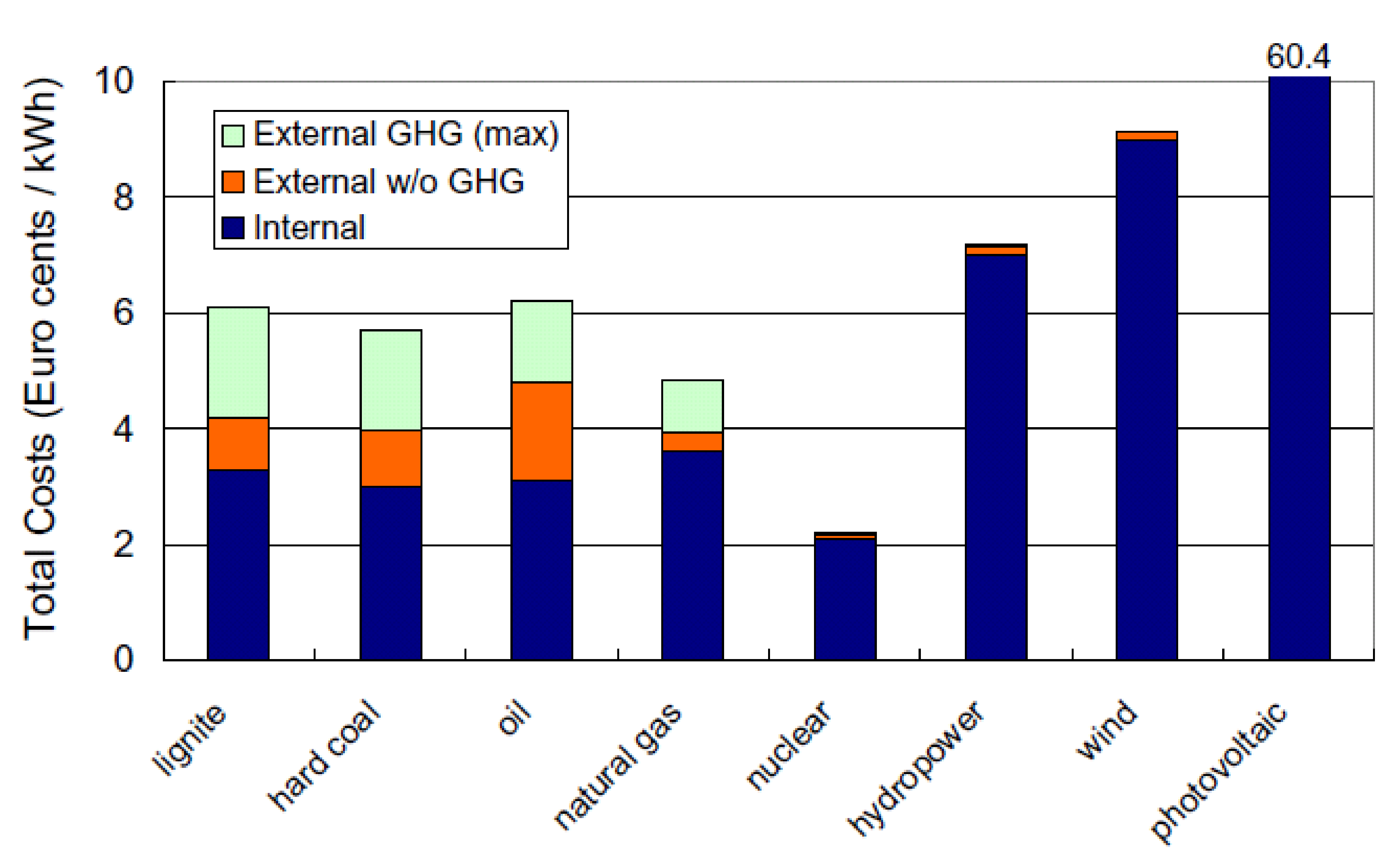
* Lifetime and LCOE vary in opposite directions, as a lifetime extension results in total levelised cost reduction and a lifetime decrease leads to generation cost increase.

Projected Costs of Generating Electricity, 2010 edition -3

- Most costs have been internalized for nuclear power (e.g. waste disposal and decommissioning etc.).
- The results from different studies (ExternE) indicate that for fossil fuels and biomass, external costs are of the same order of magnitude as direct costs, while for nuclear, solar photovoltaic and wind power, external costs are at least one order of magnitude lower than direct costs.

Total costs of electricity generation in Germany

Nuclear Energy Risks and Benefits, NEA, 2007



(Hirschberg *et al.* 2004)

Projected Costs of Generating Electricity, 2010 edition - conclusion

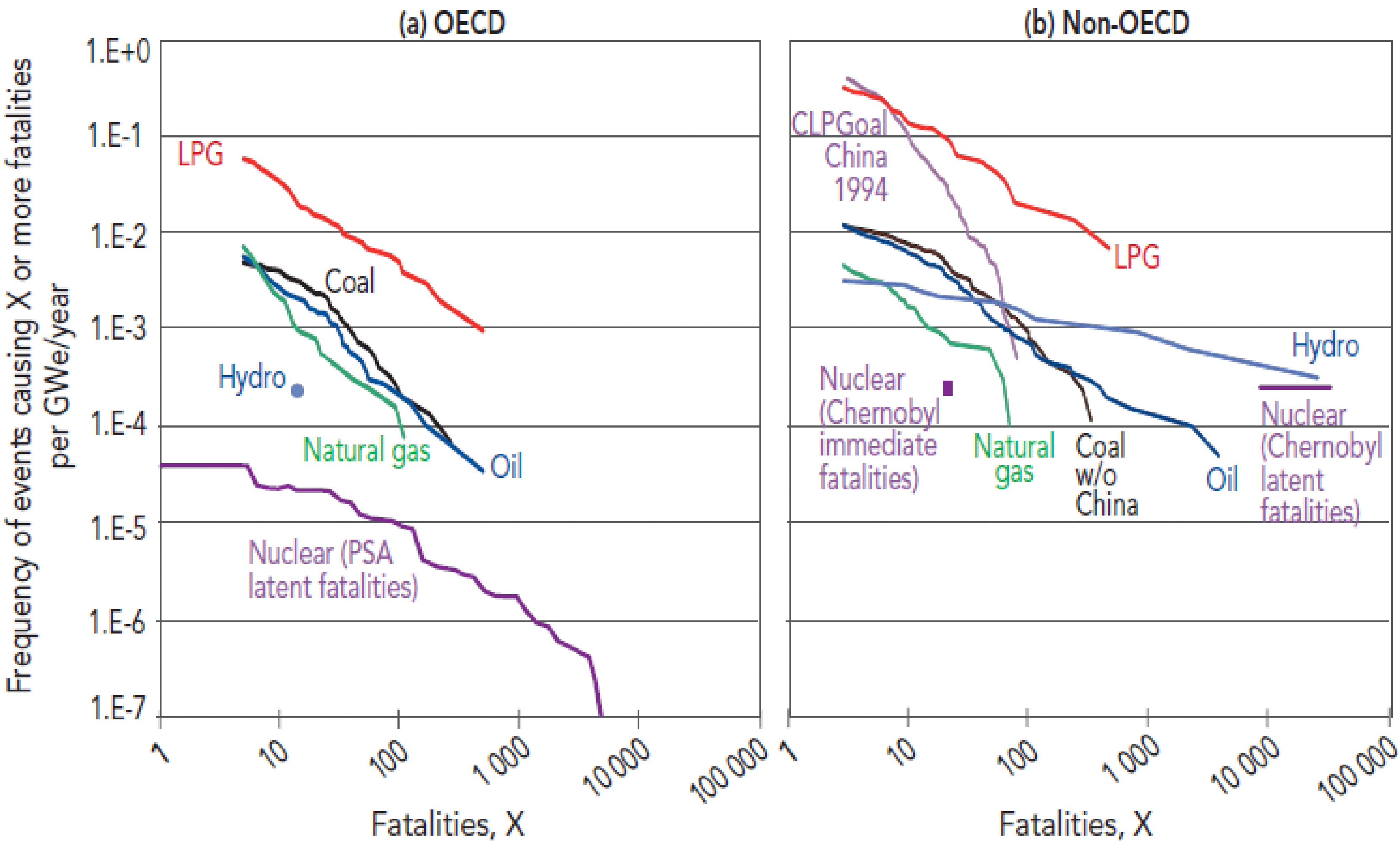
- Building and operating a new nuclear power plant can be economically viable, but is a long-term and high capital-cost project.
- Investment risks need to be well understood and limited to acceptable levels to facilitate the implementation of new projects.
- Achieving a broad national consensus on the nuclear program reduces political risks to investors.
- Countries wishing to take advantage of the nuclear option for security of supply and climate change reasons may need to remove or mitigate investment risks of those associated with the licensing and planning processes.

Table A4.1: Summary of severe (≥ 5 fatalities) accidents that occurred in fossil, hydro and nuclear energy chains in the period 1969-2000						
Energy chain	OECD		Non-OECD		World total	
	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	75	2 259	102 1 044 (819)[a]	4 831 18 017 (11 334)[a]	1 221	25 107
Oil	165	3 713	232	16 505	397	20 218
Natural gas	90	1 043	45	1 000	135	2 043
LPG	59	1 905	46	2016	105	3 921
Hydro	1	14	10	29 924	11	29 938
Nuclear	0	0	1	31[b]	1	31
Total	**390**	**8 934**	**1 480**	**72 324**	**1 870**	**81 258**

a. First line: Coal non-OECD w/o China; second and third line: Coal China 1969-2000, and in parentheses 1994-1999. Note that only data for 1994-1999 are representative because of substantial under-reporting in earlier years.
b. Only immediate fatalities.
Source: based on slightly updated data from Burgherr *et al.*, 2004.

Nuclear Energy Outlook 2008, NEA

Figure A4.3: Comparison of frequency-consequence curves for full energy chains



Based on historical experience of severe accidents in OECD and non-OECD countries for the period 1969-2000, except for China 1994-1999.
Source: based on slightly updated data from Burgherr *et al.* (2004).

Nuclear Energy Outlook 2008, NEA