Six Most Important Pollutants

- Particles (smoke and soot)
- Sulfur-dioxide (SO_2)
- Ozone (O_3)
- Lead (Pb)
- Nitrogen oxides (NO_x, i.e., NO and NO_2)
- Carbon monoxide (CO)

Table 13.1 Environmental and social concerns associated with the principal energy sources

Source	Potential causes for concern
Oil	global climate change, air pollution by vehicles, acid rain, oil spills, oil rig accidents
Natural gas	global climate change, methane leakage from pipes, methane explosions, gas rig accidents
Coal	global climate change, acid rain, environmental spoliation by open-cast mining, land subsidence due to deep mining, spoil heaps, ground water pollution, mining accidents, health effects on miners
Nuclear power	radioactivity (routine release, risk of accident, waste disposal), misuse of fissile and other radioactive material by terrorists, proliferation of nuclear weapons, land pollution by mine tailings, health effects on uranium miners
Biomass	effect on landscape and biodiversity, ground water pollution due to fertilizers, use of scarce water, competition with food production
Hydroelectricity	displacement of populations, effect on rivers and ground water, dams (visual intrusion and risk of accident), seismic effects, downstream effects on agriculture, methane emissions from submerged biomass
Wind power	visual intrusion in sensitive landscapes, noise, bird strikes, interference with telecommunications
Tidal power	visual intrusion and destruction of wildlife habitat, reduced dispersal of effluents (these concerns apply mainly to tidal barrages, not tidal current turbines)
Geothermal energy	release of polluting gases (SO_2, H_2S, etc.), ground water pollution by chemicals including heavy metals, seismic effects
Solar energy	sequestration of large land areas (in the case of centralized plant), use of toxic materials in manufacture of some PV cells, visual intrusion in rural and urban environments

Source: based on Ramage, J. R., 1997

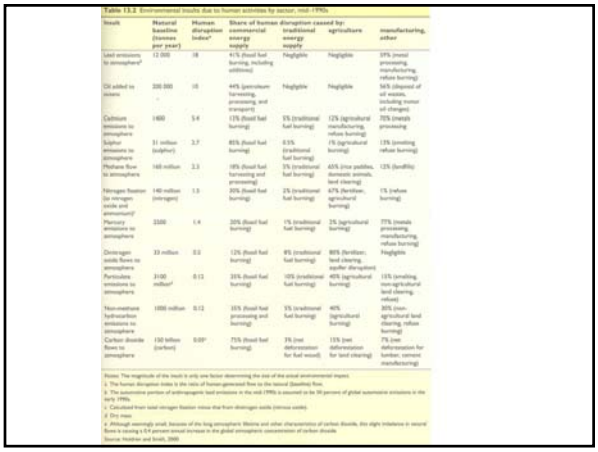


Table 13.4 Occupational hazards of electricity production by fuel cycle: number of deaths and diseases per gigawatt-year of output – including entire fuel cycle, excluding severe accidents

Fuel cycle	Occupational hazards per GWyr**		Public (off-site) hazards per GWyr**	
	Fatal	Non-fatal	Fatal	Non-fatal
Coal	0.2–4.3	63	2.1–7.0	2018
Oil	0.2–1.4	30	2.0–6.1	2000
Gas	0.1–1.0	15	0.2–0.4	15
Nuclear (LWR*)	0.1–0.9	15	0.006–0.2	16

*LWR= Light Water Reactor, the generic term for reactors using ordinary water for cooling, like PWRs; **GWyr = gigwatt year; 1 GWyr = 8.76 TWh

Source: Nordhaus, 1997.

Who is right?

13.5 Estimated deaths from power generation per gigawatt-year of output

	Estimates by Hamilton				Estimates by Morris			
	Occupational accidents	Occupational Disease	Public	Total	Occupational accidents	Occupational Disease	Public	Total
	0.46	93	4–150	90–243	0.53–0.93	0.13–8.7	0–320	1–330
	1.63		1.3–130	3–130				
	0.21							
ar	0.35	0.18	0.067	0.6	0.14–0.6	0–0.90	0.2	0.4–1.7

e: Gipe, 1995

Table 13.9 Estimates of accident probabilities and consequences

Event	Activity released (Tbq)	Total dose to population (person-sieverts)	Consequent number of deaths		Probable number of events per million reactor-years	Predicted number of deaths per thousand reactor-years
			immediate	delayed		
Meltdown without major breach of containment	0–500	0–1000	0	0–10	10–100	0–1
Meltdown with breach of containment, under average conditions	500 000–5 million	0.1–1 million	1–10	1000–10 000	0.1–10	0.1–100
Meltdown with breach of containment under worst conditions	500 000–5 million	1–10 million	1000–10 000	10 000–100 000	0.001–0.01	0.001–1

See the main text for further explanation and comment on these figures

Source: Ramage, 1997, adapted from Rasmussen, 1975

We already showed some of these data

What is difference?

Table 13.11 Illustrative estimates of the environmental external costs (in pence per kilowatt-hour) for electricity production from selected energy sources

Cost category	Old coal	New coal	Oil	Gas	Nuclear	Solar	Wind	Hydro
Health								
– Mortality (dead)	0.32	0.32	0.29	0.02	0.01	0.07	0.04	0.03
– Morbidity (sick)	0.12	0.12	0.12	0.04	0.01	0	0	0
– Disaster	NE	NE	NE	NE	0.45	0	0	0
Crop damage	0.10	0.05	0.05	0.02	0	0	0	0
Damage to forests	0.84	0.07	0.98	0.03	0	0	0	0
Reduction of biological diversity	NE	NE	NE	NE	NE	NE	NE	NE
Damage to buildings	3.22	0.28	3.77	0.11	0	0	0	0
Noise	NE	NE	NE	NE	NE	NE	NE	NE
Global warming damage	0.40	0.34	0.35	0.16	0.01	0	0	0.01
Visibility impact	NE	NE	NE	NE	NE	NE	NE	NE
Water pollution	0.40	0.04	0.049	0.01	0	0	0	0
Land contamination	NE	NE	NE	NE	NE	NE	NE	NE
TOTAL	5.40	1.22	6.05	0.39	0.48	0.07	0.04	0.04

NE: not estimated but probably positive.

(Source: Adapted from Pearce et al., 1992)

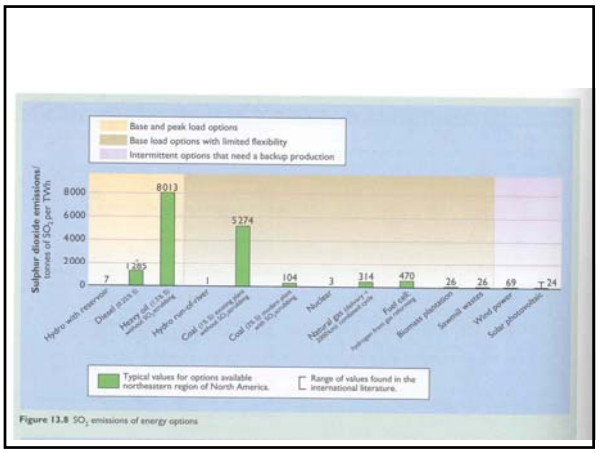


Figure 13.8 SO_2 emissions of energy options

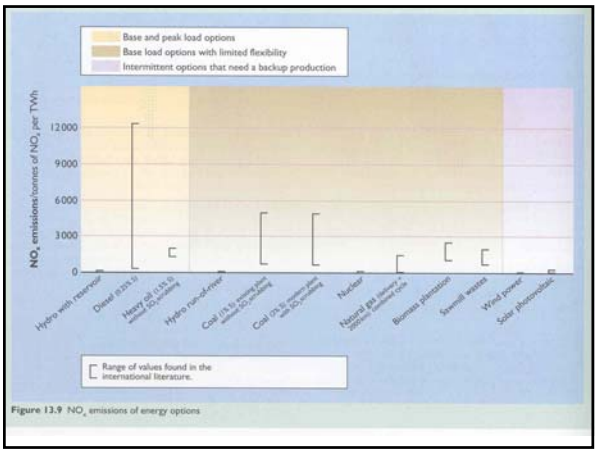


Figure 13.9 NO_x emissions of energy options

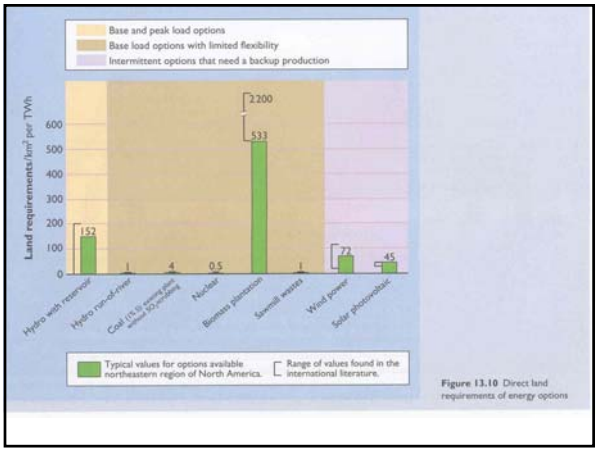


Figure 13.10 Direct land requirements of energy options

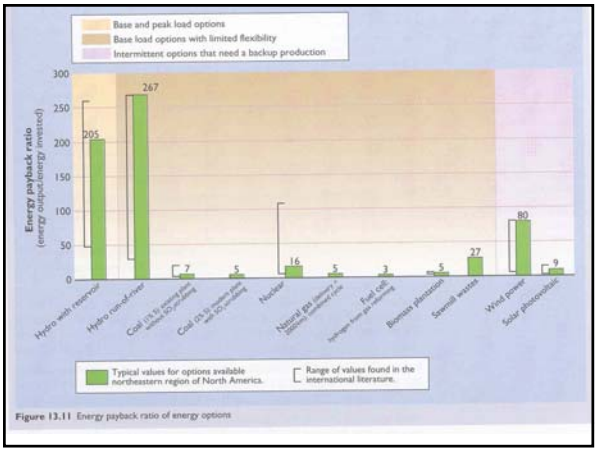


Figure 13.11 Energy payback ratio of energy options

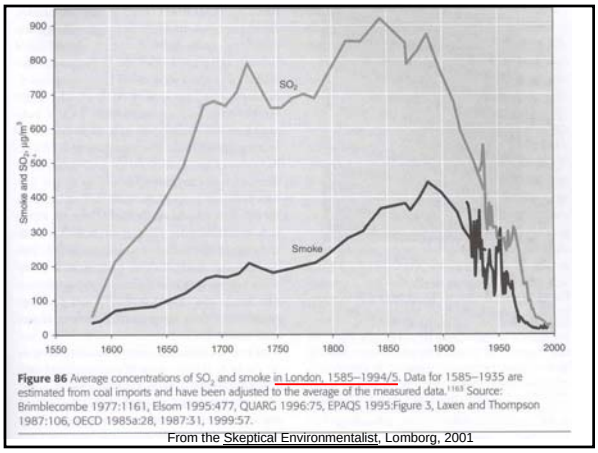
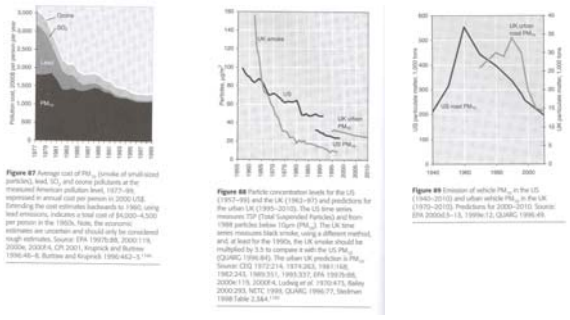


Figure 86 Average concentrations of SO_2 and smoke in London, 1585–1994/5. Data for 1585–1935 are estimated from coal imports and have been adjusted to the average of the measured data.[1163] Source: Brimblecombe 1977:1161, Elsom 1995:477, QUARG 1996:75, EPAQS 1995:Figure 3, Laxen and Thompson 1987:106, OECD 1985a:28, 1987:31, 1999:57.

From the Skeptical Environmentalist, Lomborg, 2001

Particles



Message: We are doing much better!

From the Skeptical Environmentalist, Lomborg, 2001

Lead

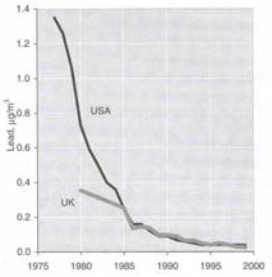


Figure 90 Lead concentration in the US (1977–99) and the UK (1980–96). The US data measure highest quarterly average of 122 monitoring stations until 1986 and 208 thereafter. The UK data measure the annual average over 9 monitoring stations. Source: EPA 1997b:88, 2000e:118, 2000f:4, DETR 1998a:Table 2.18.[1231]

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SO_2

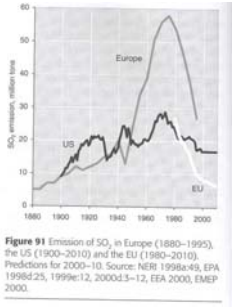

Figure 91 Emission of SO_2 in Europe (1880–1995), the US (1900–2010) and the EU (1980–2010). Predictions for 2000–10. Source: NERI 1998a:49, EPA 1998d:25, 1999e:12, 2000d:3–12, EEA 2000, EMEP 2000.

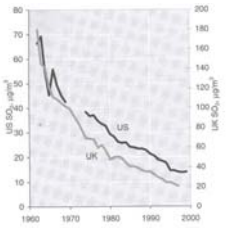

Figure 92 Annual average concentration of SO_2 in the US (1962–99) and the UK (1962–97). Source: CEQ 1972:214, 1981:167, 1989:351, 1993:337, EPA 1997b:88, 2000e:119, 2000f:4, Ludwig *et al.* 1970:474, Bailey 2000:297, NETC 1999.[1246]

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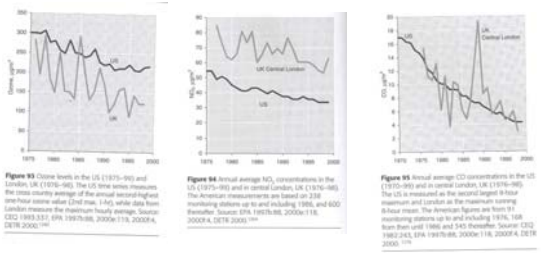
O_3 NO_x CO



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Particles SO_2

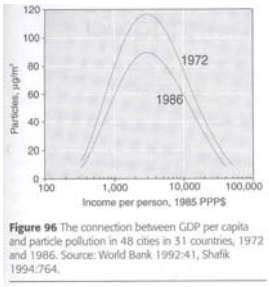

Figure 96 The connection between GDP per capita and particle pollution in 48 cities in 31 countries, 1972 and 1986. Source: World Bank 1992:41, Shafik 1994:764.

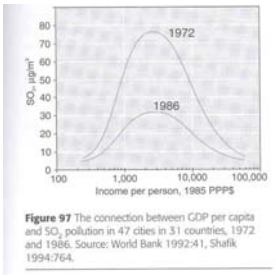

Figure 97 The connection between GDP per capita and SO_2 pollution in 47 cities in 31 countries, 1972 and 1986. Source: World Bank 1992:41, Shafik 1994:764.

From the Skeptical Environmentalist, Lomborg, 2001