Global Warming Effect Assessment in the Electricity Sector Using Hybrid Life-cycle Inventory Assessment

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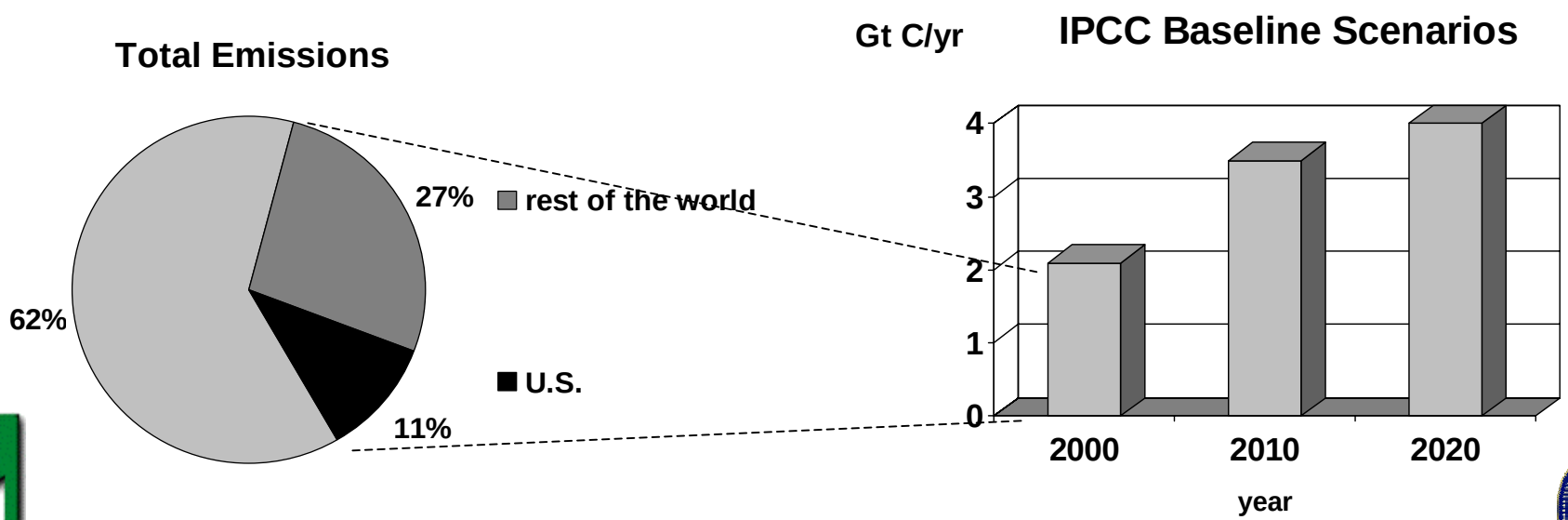
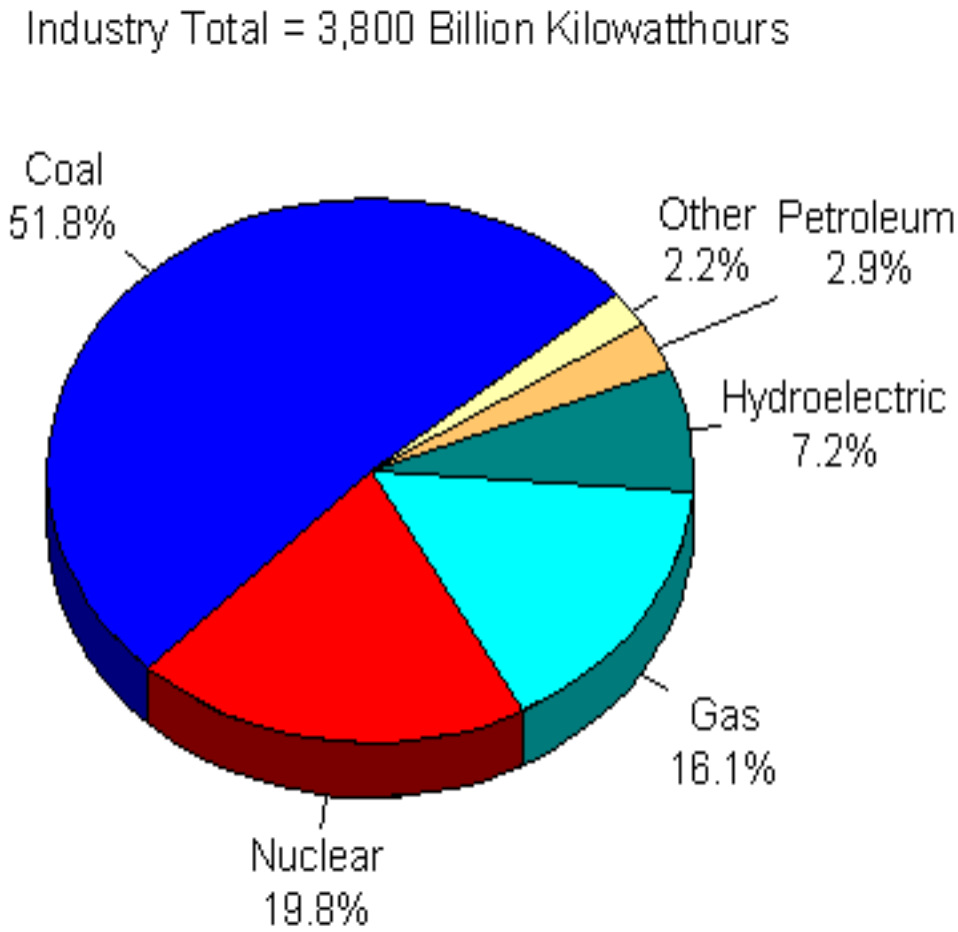
Global Climate Change

- Effects manifest over long time horizons
- Global problem
- Electricity production is a major stressor
- Greenhouse gases (GHG): CO_2, CH_4, N_2O, CFCs



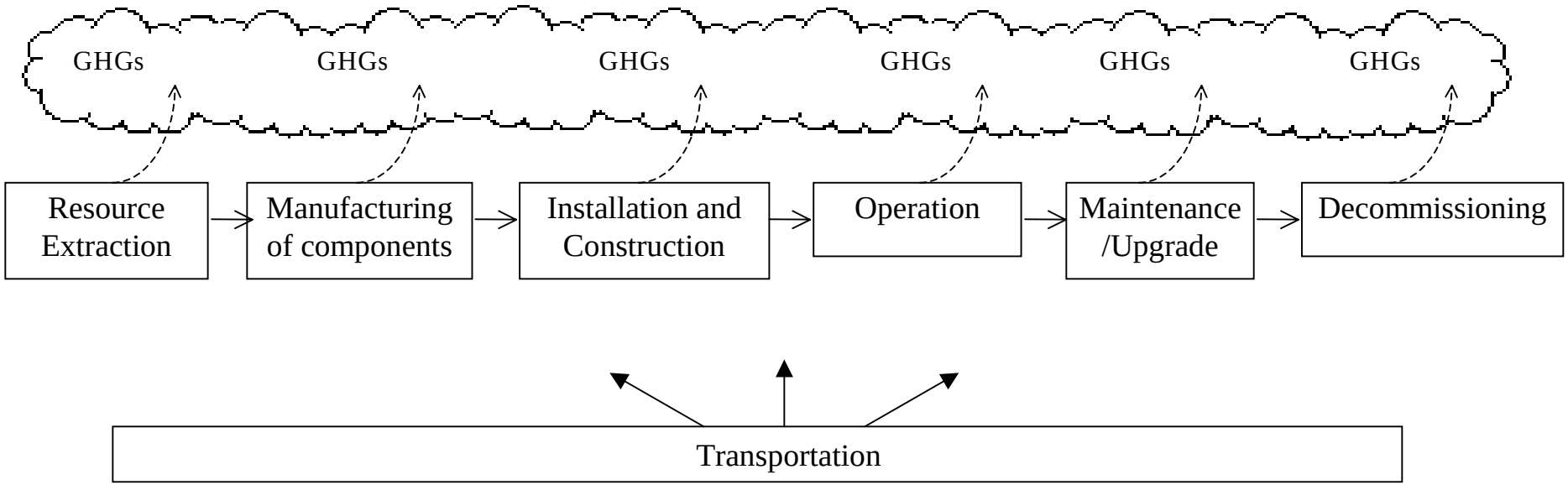
Electricity Production in the U.S.



U.S. Shares of Net Generation by Energy Source and Industry Sector, 2000

Source: http://www.eia.doe.gov/cneaf/electricity/epav1/fig5.html, accessed 10/8/02

Life-cycle of Power Systems



Emissions: Spatial & Temporal Distribution

Comparing Large Scale Electricity Generation Options Through Global Climate Change Impacts

Hydro, Solar-photovoltaic, Wind, Natural gas, Coal

→ Global warming effect (GWE)

$$GWE = LCA + GWP$$

Process Analysis + EIO-LCA

$$\frac{\int_0^{TH} a_x . x_{(t)} dt}{\int_0^{TH} a_r . r_{(t)} dt} = GWP$$

GHGs: CO_2, CH_4, N_2O over 10, 20, 30, 40 yr planning horizons

GWE Calculation

$$GWE = \Sigma\, M_j \times GWP_{j,TH}$$

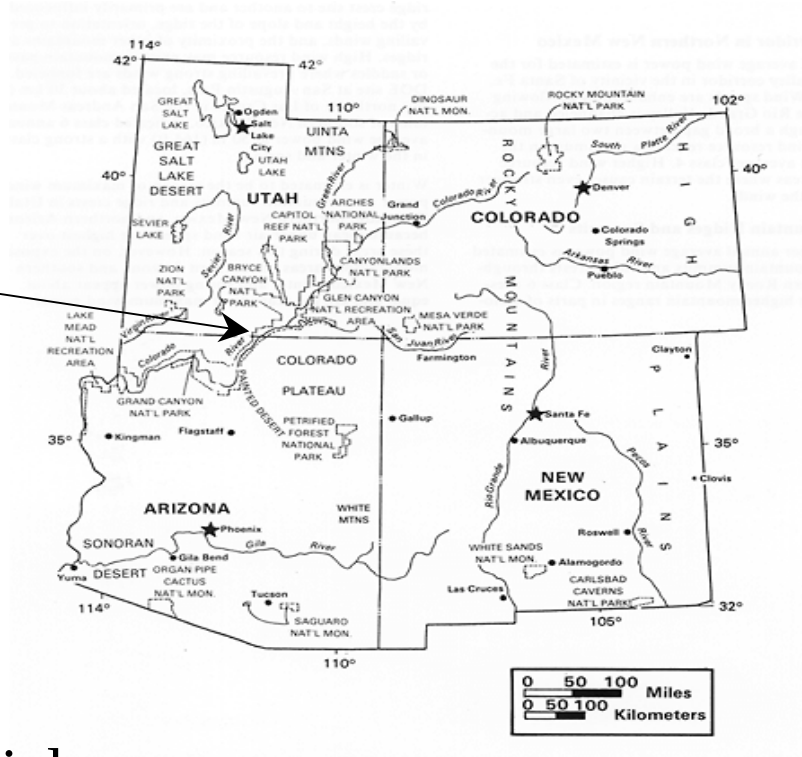
M_j is the instantaneous emission of each GHG "j" (in metric tons)

$GWP_{j,\,TH}$ is the global warming potential for each GHG "j"

For example, the GWE of CH_4 emissions over 20 years is equal to the releases in years 1, 2, 3, …20 multiplied by methane's GWPs when the *TH* is 20, 19, 18, …1 years and summed for the total.

Case Study

Glen Canyon Dam (1964)



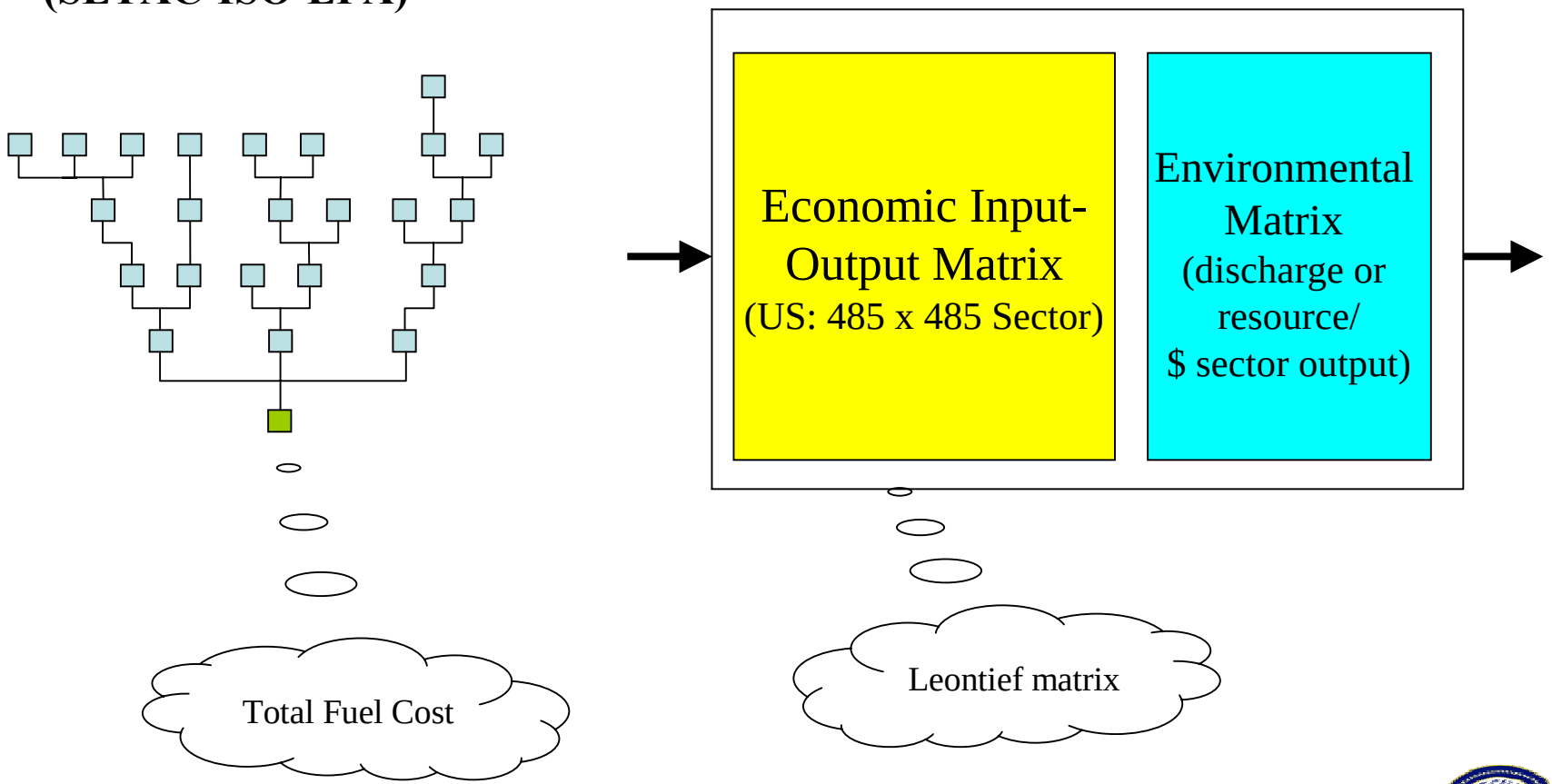
GWE

- Construction materials
- Energy input over the life-cycle
- Emissions from flooded biomass in reservoir
- Lost ecosystem productivity displaced by reservoir

Power plant upgraded in 1984: 952 MW → 1296 MW

Hybrid LCA

Process-based methods (SETAC-ISO-EPA) + **Economic input-output method (EIO-LCA)**



Major Construction Inputs and GWE (after 20 years) for the Glen Canyon Hydroelectric Plant

TABLE 1. Major Construction Inputs and GWE (after 20 yr) for Glen Canyon Hydroelectric Plant[a]

inputs	total MT	unit cost (1992 $/MT)	total cost (1992 $)	GHG emissions (MT of CO_2 equiv)			
				CO_2	+ CH_4	+ N_2O	= GWE
concrete	9 906 809	30[b]	297 652 257	400 792	751	7 898	409 441
excavation (m^3)	4 711 405	na	114 839 000	3 812			3 812
turbines and turbine generator sets	na	na	65 193 084	41 725	45	249	42 019
power distribution and transformers	na	na	13 754 764	12 358	16	79	12 453
steel	32 183	385[c]	12 402 138	43 710	29	244	47 583
copper	90	2 368[c]	214 167	186	0	2	188
aluminum	67	1 268[c]	84 804	157	0	2	159
total			503 240 216	500 000	1 000	9 000	500 000

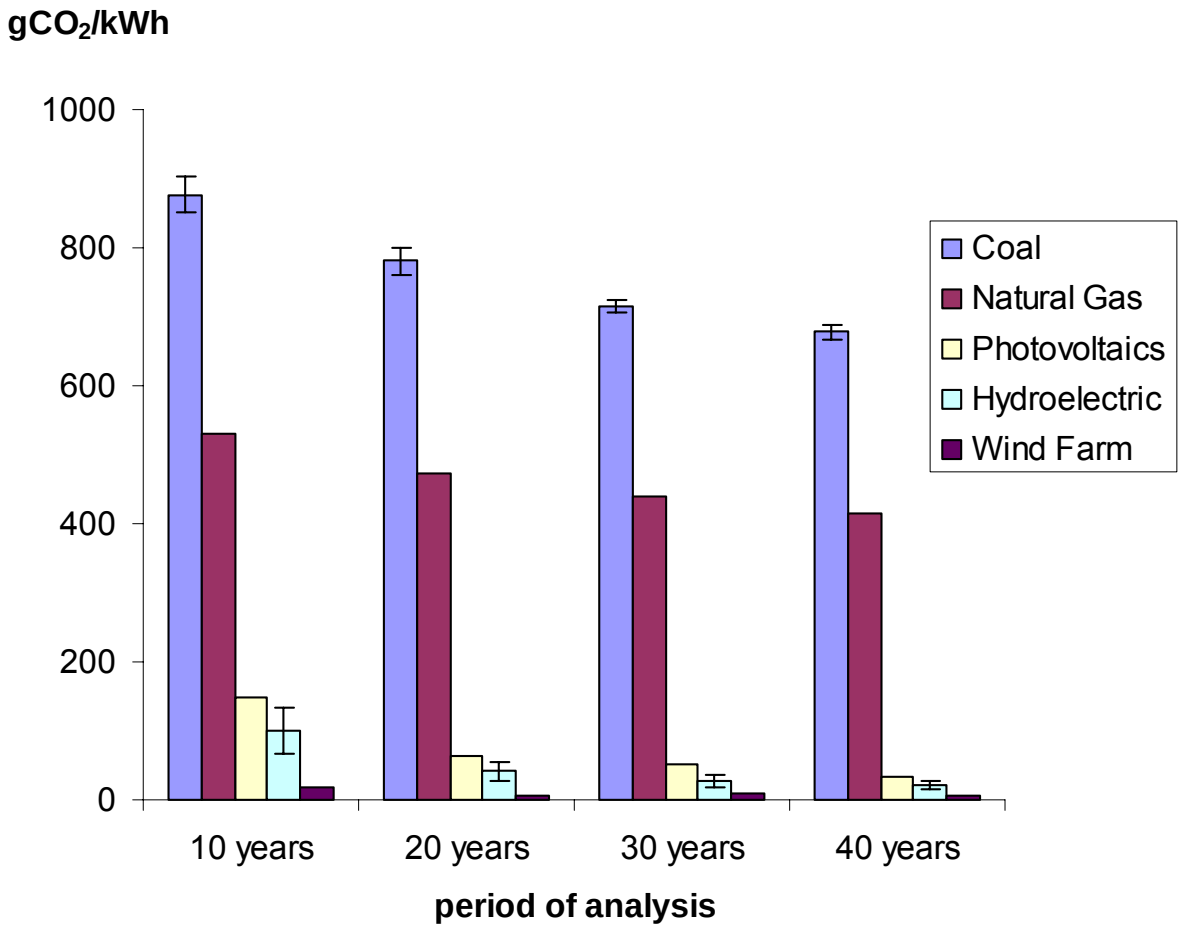
[a] Total emissions are rounded to one significant digit. MT, metric ton; GWE, global warming effect; na, not available. [b] Ref *39*. [c] Ref *40*.

GWE from initial construction (1964): 800,000 MT of CO_2 equiv.

GWE from upgrade (1984): 10,000 MT of CO_2 equiv.

Pacca, S., Horvath, A., "Greenhouse Gas Emissions from Building and Operating Electric Power Plants in the Upper Colorado River Basin." *Env.Sci.Techn*., 36(14), 2002, pp. 3194-3200

GWE Normalized by Electricity Output for Various Alternatives and Four Time Periods after Construction



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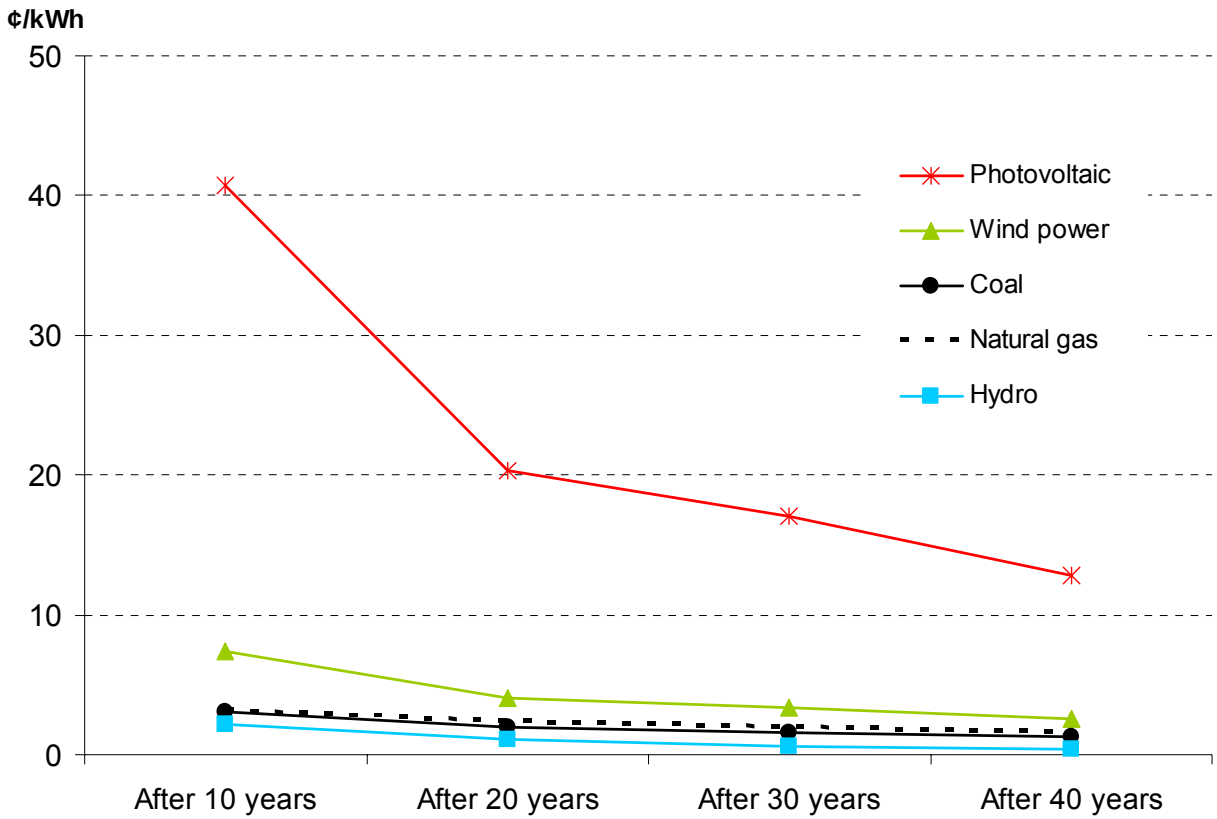
Electricity Costs



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Summary

- We compared five electricity generation options in the same location: hydro, solar-PV, wind, coal and natural gas
- Accounted for construction, operation, maintenance/upgrade, reservoir (biomass decay and NEP), and land use (NEP) effects
- Wind and hydro were found to have the lowest GWE after 10, 20, 30 and 40 years of operation
- The upgrade of the hydro plant resulted in negligible emissions, but increased power by 39%