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THE ECONOMICS OF HYDROELECTRICITY

How can we produce the electricity we need? Is it better to use conventional thermal power plants that burn coal or natural gas, nuclear power stations, wind turbines or hydroelectric power plants ? The main choice criterion between these techniques is the cost of kWh production as economic resources (capital, qualified labour) at a society's disposal are rare and must be used as efficiently as possible. However it is not easy to calculate the cost of a hydroelectric kWh. Its content and parameters must thus be carefully defined.

1. Direct cost

These are the costs borne by the electricity producer and which determine profitability of the hydroelectric facility. They include investment expenses (buying the land, building the dam, purchasing turbines, ac generators and other electrical equipment, etc.) and operating expenses throughout facility lifetime (personnel salaries, fluids, maintenance, etc.). The latter, as they include no fuel, are reduced. They do not normally exceed 25 % of kWh cost (as compared to 40 % in nuclear and 70 to 80 % in coal or natural gas powered thermal power plants). The cost of the hydroelectric kWh is thus made up of 75 % of investment costs (initial capital and interest), which makes it a fixed cost electrical production channel.

Table 1 : Investment costs of the main electrical production channels

	$1990/kW
- gas turbines	325-350
- coal thermal	1150-1430
- pressurised water nuclear reactor	1500-2500
- large hydraulics	1840-2760
- small hydraulics (< 10 MW)	1150-3450

Source : International Atomic Energy Board.

The range of variation of hydroelectric investment costs is greater than that of the other channels because the geological and hydrographical differences of the sites to be equipped are considerable, as are the hydroelectric facilities themselves : low and high head, storage and pumping, etc.

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A high investment cost does not mean, however, that the hydroelectric kWh is more costly than the others as on an annual basis operating costs will be extremely reduced. Calculation of unit costs is, however, complicated by the extreme variability of the number of annual operating hours of a power plant. There are several reasons for this. Hydroelectric production depends on water course feeding conditions that all have flow rate fluctuations at a given point. Furthermore, not all power plants perform the same function the length of the power duration curve, according to the filling time of their reservoir that ranges from less than 2 hours for run-of-river power plants to more than 400 hours for storage power plants. While the former need to operate from 5 to 8000 hours at the base of the demand curve, the latter may only have to operate for a few hundred hours to reach their peak. Between the two, run-of-river hydro plants with pondage, are normally designed to cope with daily and weekly modulations in electricity demand. The annual operating duration of a power plant is also subjected to various internal and external factors. The former result from management of facilities, upstream and downstream, controlling the water volumes retained or released, while the latter result from constraints imposed by alternative uses of water (navigation, irrigation, fishing, leisure) that may in particular lead to reserved flow rates.

Despite their extreme variability, unit costs of hydroelectric kWh remain in a range that can bear without problem comparison not only with nuclear and conventional thermal power plants (3 to 5 cents $/kWh) but also with channels using renewable energy sources.

Table 2 : Mean unit costs of the various electrical production channels

	Current (cents $/kWh)	Future (cents $/kWh)
- Large hydraulics	2-5	2-5
- Conventional geothermal energy	2-10	1-10
- Small hydraulics	3-10	2-7
- Wind turbines	5-13	3-10
- Conventional biomass	5-15	4-10
- Gasified biomass + combined cycles	8-11	
- Tidal power	8-15	8-15
- Wave energy	8-20	
- Phosphoric acid PAFC fuel cells	10-20	
- Thermodynamic solar	12-18	4-10
- Dry-steam geothermal energy	12-20	
- Photovoltaic solar	25-125	5-25

Source : World Energy Assessment and World Bank.

2. External benefits and costs

The direct costs, borne by the electricity producer, do not cover all the advantages and disadvantages that are generated by a hydroelectric facility. The latter may indeed regularise flow rate of a water course and avoid devastating floods, guarantee passage for irrigated crops and raise farmers' income or make it possible to create a lake and leisure centre. On the other hand, it may also drown fertile land and cause populations to be moved, lead to clogging up of a water course or harm its aquatic wealth. It thus generates external benefits and costs that the State, in the name of general interest, must take into account in its energy choices. Positive and negative external factors are even more hard to quantify than direct unit costs, but we can note the excellent position of hydraulic energy in the hierarchy of external costs associated with the various electrical channels.

Table 3 : External costs of the various electrical channels (cents $/kWh)

- Coal thermal, after 2000	4.0
- Fuel thermal, after 2000	3.2
- Gas thermal with combined cycles	1.6
- Biomass thermal	0.8
- Nuclear	0.3
- Photovoltaic solar	0.28
- Wind turbine	0.13
- Hydraulic	0.04-0.74

Source : Rabl (Ari) and Spadaro (Joseph V), Revue de l'Energie, 525. The cost range chosen for hydraulics measures inclusion or not of a vast reservoir.

More precisely still, an analysis in terms of life cycle highlights the superiority of hydraulic energy over all the other comparable channels (Source : Luc Gagnon, Revue de l'Energie, 2003, no. 546):

- Greenhouse gas emissions (eq kt CO2/TWh) : in the worst possible case (reservoir in tropical zone), hydraulics emits less than photovoltaic solar power or the biomass and barely more than the wind turbine or nuclear power station ; run-of-river hydraulics takes first place over all channels ;

- SO_2 emissions (t SO_2/TWh) : with reservoir or run-of-river, hydraulics emits infinitely less than all the other channels without exception ;

- Territories used (km^2/TWh) : only nuclear power is better placed than run-of-river hydraulics ; the hydraulic reservoir consumes 4 times more than photovoltaic solar power and twice as much as the wind turbine, but far less than the biomass.

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To conclude

Whereas it is exhausting in Western Europe and the USA, except in terms of refurbishment of old and of small hydraulic, the economically usable potential is still considerable in the rest of the world. It is between 1500 and 2000 GW, i.e. 3 times that currently used. It is mainly located in Asia, Latin America and Africa, in other words the continents where unsatisfied electrical consumption needs are greatest as more than 2 thousand million inhabitants still do not have access to electricity. Neither nuclear power, wind turbines or photovoltaic solar power can meet such needs. The choice is thus between hydroelectricity and conventional thermal power, which generates greenhouse gases and thus serious risks of climatic change. To assess what is at stake here, bear in mind that 1600 million tonnes more of coal, i.e. 10 % of current greenhouse gas emissions, would be required to replace international hydroelectric production.

Based on its production costs, direct and external, the latter should develop at a pace greater than 2 % a year observed over several years. However, it comes up against several obstacles, first of which is its funding difficulties. In the context of a liberalised electrical industry, the high costs of hydroelectric investment seem extremely risky with respect to the management criteria of private companies. It is thus essential that public authorities and international organisations, in the name of collective interest, release long-term funding means.

