English version (translation of a few sections)

Study about costs and nuisances of windmills

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Aim of the study

Should a country build windmills? To find the answer, various electricity production methods are studied here to compute their costs and find the advantages and the nuisances concerning environmental matters.

The study of windmills profitability, especially in the Belgian Ardennes, shows astonishing results, mainly about the current state of disinformation on the advantages of windmills. To find the real costs, one has to get rid of subsidies and taxes.

The advantages claimed for windmills, reduction of greenhouse gases emissions and conservation of fossil fuels must be studied in the worldwide setting, including the Kyoto Protocol whose study was initiated a short time after the Chernobyl accident. The perceived situation about electricity production is full of false ideas spread at that time.

The perceptions of the implications of the climatic global warming, the emission of greenhouse gases and the depletion of fossil fuels are different in each country, especially in Asia.

A badly choosen symbol for renewable energies?

Does the windmill image is a good symbol the renewable energies? This study shows that this symbol could be better applied to the business of environment.

The questions studied here are:

- Why is the free energy of windmills so expensive? Why is the global process of producing electricity with wind almost as polluting as with gas?

- What is the price, excluding taxes and subsides of the kWh for each mode of electricity production?

- Why are inhabitants near windmills locations making committees to fight windmills? Why people who did not rebel initially felt to have been trapped? How do the promoters process the complaints?

- How much do the windmills contribute to the preservation of fossil fuels and to the reduction of greenhouse gases?

- Which is the contribution of windmill on the Kyoto Protocol? What is the long-term effect?

- How will the deficit of windmills be paid by the future electricity consumers?

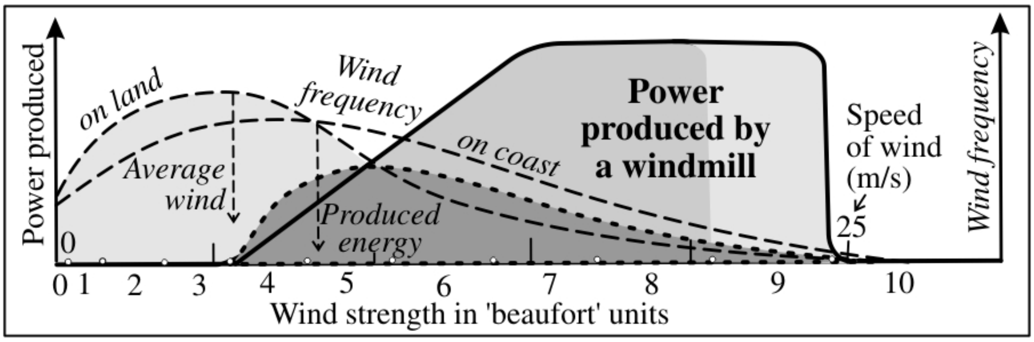
- How have the windmills lobbies succeeded to sell in Denmark and Germany and how are they trying to sell in Belgium and France?

"It ain't what you don't know that gets you into trouble.
It's what you know for sure that just ain't so." (Mark Twain).

(Only the first section on costs of the French dossier is translated and modified here)

(1) Cost structure for a windmill system

The methods of electricity production with wind must first be described as many items enter in the computation of the comprehensive cost.



Energy production using windmills.

A modern windmill (2 MW, 100 m tall, 3 blades, diameter 100 m) starts revolving when the wind reaches 2 or 3 beaufort (3 m/s) and then produces (continuous line) proportionally to the wind strength up to 7 beaufort (wind from 4 m/s to 17 m/s). The productivity is maximum between 7 to 9 beaufort (between 60 to 90 km/h).

The wind is irregular on the crests and gusts of wind can broke the blades. The windmill must be stopped (blades are turned to be parallel to the wind) if there is a risk that the wind blasts reach 9 beaufort (measured at 100 m high). To be safe, it is better to stop the windmills when a regular wind reaches 8 beaufort.

A windmill needs time to orient itself face to the wind or to change the blade relative angle to the wind. Thus irregular gusts of wind, as on top of hills, are less efficient than sustained wind.

Typical curves of wind frequency (dashed lines) are given as a function of its speed on sea coasts and inside land. The average speed is shown by a downside arrow.

The energy produced by the mill is the product of the instantaneous power (full line) by the frequency of this situation (dashed line), represented by the darkest zone.

On land, this surface (power load coefficient) is about 10 to 15 % of the energy if the wind was always blowing from 7 to 8 beaufort. On the Coast, this surface is about 25 %. The average load of all German windmills was measured and is said to be 16 % or 1400 h (no official figure seems to have been published).

The power curve is a little different for each type of windmill, local climate (wind frequency and regularity in force and direction). The wind on crests is hard to estimate before it has been measured on top of 100 m poles for several years.

The load factor is quite small on land in the Ardennes

Far from the Belgian Coast, the winds are usually too low or sometimes too strong, but are frequently irregular in direction and strength (blast of winds on hills). In the best locations on the Coast, a windmill may produce the equivalent of 2000 hours on [24 h * 365 j=] 8760 h (23 %). (2189 h for 25 % load factor). To compute the annual production, one multiplies the power by the useful working hours, i.e. 23 % * 365 days * 24 hours * 2 MW = 4 GWh.

The windmills on the Coast can thus produce 4 GWh/year when there are no incidents. The wind inside the land is much lower. In the Ardennes, until a better score is proven, a windmill, even on the top of hills, on the most visible and thus on the worst place for the environment, cannot produce more than 1500 h/year on the most windy years. Inside the land, a windmill produces here 2.6 GWh/year (15 % load).

The useful windy hours in Belgium, based on the experimental results on the first windmills installed in 2001 on the best or at least on the good locations, was 1315 hours (13.3%) [2], most of these locations being near the Coast. The computations are made here with 1500 h to show that the arguments are valid even in this optimistic situation. The figures in the promoter's papers are much better, but are not supported by measurements.

A study has used 4 M € as an average cost, after subsidies, of the European windmills operating in 2004. The costs are going down but the size and the nuisance are going up. The hopes for better technologies are not documented and seem less promising than for the alternatives technologies (solar, nuclear, biomass).

Costs to install and run windmills

For the computations here, a large windmill (2 MW) needs an investment of 4 M € without subsidies. One has to add an underground cable up to the electric grid (3 M€ per windmill in the sea). The land is worth 1 €/m^2 in Belgium, so one needs 3 M€ to purchase 3 km^2 to build a windmill park. This is not included in the usual presentation of costs. The trick is to rent the land, which reports the costs many years later but is more expensive at the end. The costs of the nuisances are never included but the city or the promoter could be condemned to pay them, which would double or triple the costs in the heavily populated Belgium.

Financing infrastructure costs of an industrial park is justified because this investment attracts jobs that will be taxed while windmills are producing the contrary effect. The windmills do not have to pay taxes and the local industries, tourism and residential developments, will fly away.

Information transferred to distant location allows verifying centrally the operations of the windmills but, as for the electric distribution network, one must have at least 4 teams to intervene 24h/24h to maintain windmills, cables, restricted access areas and electric cabins. The annual costs include also land rental, grants to the municipality, and insurance. The annual costs are supposed here to be equal to 50 % of the annuities to reimburse the investment.

The investment for a nuclear reactor producing 7.2 TWh (82 % use) is worth 1,875 G €. The operating costs are supposed here to be equal to 100 % of the financial costs to reimburse the investment. They include insurances and a military protection which have increased with the recent events. The nuclear fuel was equal to 5% of the annual cost in 1997, i.e., a total of 220 % [= (100 % + 100 %) * 1.05].

The operating costs for the gas power plant are also twice the annuity but this one is much lower. The fuel was twice more expensive than the operating costs and the annuities in 1997. The total is 600 % [= 200 % * 3]. For the coal power plant, the fuel is equal to the annual fixed costs, i.e. the total is 400 % [=200 % * 2]. The overall costs increase with the prices of fuel.

Comparison of prices for power plants

Two methods to compute prices are given in the two subsequent sections.

The first computation is traditional and computes the costs of an isolated windmill and of other power plants. This method gives no clues on the value of the intermittent electricity produced by windmills.

The second method explains and compares the total costs of all the systems included in a whole process that produces a permanent supply of electricity. This method is more complex but is the only one valid.

The data used here are averages found in various sources which have not been verified. The costs published in the US are preferred here because they seem to do not include hidden taxes or subsidies.

The differences between prices here and in the literature are probably due to presentations favouring a solution or not. More precise prices will only be available when the administration will use transparent accounts without taxes, subsides and hidden items. The computation method here is designed to use a minimum of data (investment, operating costs, and fuels), so it can be easily updated if validated items costs become available. Most of the initial data are ratio, so the comparison remains valid if systematic errors subsist.

Glossary of abbreviations

- (T) **Tera**: 1000 000 000 000 (Belgium produces annually 82 TWh, *térawatt-hours*)

- (G) **Giga**: 1000 000 000 [A nuclear reactor 1 GW (Gigawatt) *power*. The power in kW is multiplied by the working hours, giving energy in kWh. A reactor produces annually for 8700 h (365 days * 24 hours) a total of 8.7 TWh]

- (M) **Mega**: 1000 000 (An industrial windmill has 2 MW (Megawatt) power and an average production for 1500 h of useful wind of 2.6 GWh per year)

- (k) **Kilo**: 1000 (The consumption unit for the electricity user is a kWh *(kilowatt-hour)*, which is the energy produced by a 73.6 kW or a 100 HP *(horsepower)* engine during 49 seconds. If this engine consumes 20 litres of oil per hour when running at full power, it would use 0.27 litres at the price of [54 € out of taxes for a 158 litres oil barrel =] 34 c€/litre, i.e. 9.2 c€/kWh).

(2) Cost computation for isolated power plants

In the following computation sheets, the “use” is the percentage of time when the plant is producing. A column gives the initial investment to install a plant having a given power and an annual energy production. The rate for the financial yearly payment is based on an average interest rate (4% here). The operating and financial costs (F&O) are given as a ratio. The fuel is a ratio of financial and operating cost in 1997. The computation is done for fuel prices multiplied by 3 (in 2003) or 4 (In 2006). The price of one kWh is given in $, in € or in cents or centimes. To ease comparisons, the price is compared to the price of nuclear kWh at the same time *(P/N)*.

Price kWh		Invest.		Power	Product.	Rate	Yearly	Relative	*	F&O	kWh	kWh	P/Nucl
(in 2003)	% use	M $	M €	MW	GWh	4%	F&O	Fuel		& fuel	c$	c€	
Land windmills	15 %	5,33	4	2	2,61	5,8	150%	0%	0	150%	17,77	13,33	3,36
Windmills on sea	23 %	5,33	4	2	4,00	5,8	150%	0%	0	150%	11,59	8,69	2,19
Nuclear	82 %	2500	1875	1000	7134,00	5,8	200%	10%	3	260%	5,28	3,96	1,00
Gas power plant	30 %	115	86	115	300,00	5,8	200%	100%	3	800%	17,79	13,34	3,37
Gas power plant	100 %	115	86	115	1000,00	5,8	200%	100%	3	800%	5,34	4,00	1,01
Coal power plant	60 %	180	135	115	600,00	5,8	200%	50%	3	500%	8,70	6,53	1,65
Coal power plant	90 %	180	135	115	900,00	5,8	200%	50%	3	500%	5,80	4,35	1,10
Coal power plant	100 %	180	135	115	1000,00	5,8	200%	50%	3	500%	5,22	3,92	0,99

Price kWh		Invest.		Power	Product.	Rate	Yearly	Relative	*	F&O	kWh	kWh	P/Nucl
(in 2009)	% use	M $	M €	MW	GWh	4%	F&O	Fuel		& fuel	c$	c€	
Land windmills	15 %	5,33	4	2	2,61	5,8	150%	0%	0	150%	17,77	13,33	3,12
Windmills on sea	23 %	5,33	4	2	4,00	5,8	150%	0%	0	150%	11,59	8,69	2,04
Nuclear	82 %	2500	1875	1000	7134,00	5,8	200%	10%	4	280%	5,69	4,27	1,00
Gas power plant	30 %	115	86	115	300,00	5,8	200%	100%	4	1000%	22,23	16,68	3,91
Gas power plant	100 %	115	86	115	1000,00	5,8	200%	100%	4	1000%	6,67	5,00	1,17
Coal power plant	60 %	180	135	115	600,00	5,8	200%	50%	4	600%	10,44	7,83	1,83
Coal power plant	90 %	180	135	115	900,00	5,8	200%	50%	4	600%	6,96	5,22	1,22
Coal power plant	100 %	180	135	115	1000,00	5,8	200%	50%	4	600%	6,26	4,70	1,10

The cells with the outside data are in gray. The other cells contain results computed. The cost of producing one kWh in a plant (windmill or gas, coal or nuclear power plant) is computed for various cases. The cost of backup gas power plants depends on their rate of use. If the plant is only used when the load on the power grid is maximum (during the period of maximum consumption in winter), the kWh price is high as more financial costs are concentrated on these short periods.

It is assumed that the plants have a very long life (30 years) and have a low discount rate (5.8%) for an average interest rate of 4%. It is assumed that inflation is null, a method financially equivalent to a computation with constant real prices.

The windmills in the Ardennes produce 2.6 GWh/year with an optimistic load factor of 15%. The windmills near the Coast produces 4 GWh, but have the same fixed costs, so the price per kWh is higher on land.

Electrical supply of intermittent current

The power grid of a country must supply all the electricity demanded, or the network collapses. The recent incidents (e.g., on November 4th 2006, in the European North area, which has the highest concentration of windmills) have shown that a general failure cannot be repaired in less than half a day. The general failure was caused by many simultaneous events among which the fact that the windmills were designed to plug automatically to the grid has contributed when the wind was restarting to blow [32].

To continue producing electricity without failure when the wind stops blowing, the grid must be connected to other power sources ready to produce the demanded current. The nuclear power plants cannot modify their output current within a short period and cannot thus be used as backup. The backup power plant using fossil fuels can increase their output power in minutes but only if their boilers are already maintained hot. The hydraulic power plants can increase their output in seconds but they need to have a constant supply of water from large hydraulic dams. The power ready to be tapped must be equal to the sum of the power of the windmills. Thus, the country must pay for the investment and the operating costs of these power plants. There is thus a double investment for the wind energy: power plants and windmills.

The traditional power plants must still be operating if windmills are installed

As the windmills have a factor load from 10 to 25 %, the backup power plants using fossil fuel must produce during 75 to 90 % of the time. Thus they emit greenhouse gases for 75 to 90 % of the time (90 to 85 % in the Ardennes, 85 to 75% in the Flanders).

If one could find a buyer for intermittent current, he would not purchase this electricity at the same price but only at half or a third of the average price. The current supplied according demand is purchased at a higher price which justifies the necessity of gas power plants which are only used at 30% of their capacity. To help windmills to sell their current despite its low usefulness, the green authorities have imposed the following regulation. The power grid (which is always a monopoly) must purchase the intermittent green current as soon as it is available (the plug-in is automatic) and the price is fixed at about 3 times the average price, while this current is worth only a fraction. The grid operators have no more a free market and cannot sell and purchase slices of current at the best price. As one knows, a free market usually evolves to the lowest price while an authoritarian directed market cannot fully control the price which tends to increase.

A nuclear power plant produces normally close to its full capacity and can only increase or reduce its power slowly and within a limited range. They must continue producing at night. This constraint had justified to install lighting on the highways in Belgium. A hierarchy of prices for the kWh would be thus as follows: hydroelectricity from dams (250%), gas (200%), coal (150%), nuclear (100 %), windmills (50 %), solar (30 %, as when the sun shines, nobody needs electricity), but the market is more complex, as it depends of the time in the day, the season and the working hours, changing during holidays and week-ends.

As Europe has a good score for preventing incidents in its nuclear power plants, the cost of insurance is not too high here.

Growing consumption of coal, the most polluting fuel

Coal combustion emits 1.7 times more greenhouse gases for producing the same heat than natural gas. A coal power plant emits also particles of dirt which are very slightly radioactive but which are emitted so massively that, for an equivalent production of power, they produce more radioactivity than a nuclear power plant if this one would send its wastes as dirt in the air. The power plant which burns the refusal (garbage) of a city must usually add coal to have a good combustion and are quite strong polluters, although they are classified as producing green energy and no greenhouse gases.

One hopes that the future technologies will allow cleaning up the fumes and capturing the CO_2 and store it inside earth, but these hopes are currently speculations which could not be operational before 10 or 50 years. The coal workers have a hard job, due to the frequent accidents but also to the lung health problems latter in life. They are well protected in Occident but have a low pay and a poor social protection in developing countries, so the coal is the energy source having there the lowest price when nuclear power is not available. The coal is abundant and its consumption grows rapidly.

(3) Computation of electricity costs for global production systems

The following computation sheet gives the relative costs of various production systems. The data cells are in gray. The other cells contain results computed. The price adds a fixed payment per year for financial reimbursement of the investment and the operating costs excluding fuels (Finan.+oper). The value used is an index with value 100 for a nuclear power plant in 1997. The nuclear fuel was 5% of the fixed costs in 1997. The power plants with fossil fuels have investments grossly 3 times lower than an equivalent nuclear power plant. When operating at 100%, their fuel price was in 1997 two times above their fixed price.

Comparaison of prices	Use	Finan.	Fuel	Price	P/N	*	Price	Prix	P/N	*	Fuel	Price	P/N	*	Fuel	Price	P/N	*	Fuel	Price	P/N
in power plants	%	+ oper.	1997				2003				2005				2006				2012		
Oil barrel ($)			18			2	36			3	54			4	72			6	108		
Oil barrel (€=0,75$)			13,5			2	27			3	40,5			4	54			6	81		
(F) Gas power plant	100%	30	60	90	0,90	2	120	150	1,43	3	180	210	1,91	4	240	270	2,35	6	360	390	3,12
(F) Gas power plant	50%	30	60	150	1,50	2	60	180	1,71	3	90	240	2,18	4	120	300	2,61	6	180	420	3,36
(C) Coal power plant	100%	50	50	100	1,00	2	100	150	1,43	3	150	200	1,82	4	200	250	2,17	6	300	350	2,80
(C) Centrale au charbon	50%	50	50	150	1,50	2	50	200	1,90	3	75	250	2,27	4	100	300	2,61	6	150	400	3,20
(N) Nuclear power plant	100%	95	5	100	1,00	2	10	105	1,00	3	15	110	1,00	4	20	115	1,00	6	30	125	1,00
(N) Gas and nuclear	50%		60	95	0,95	2	120	128	1,21	3	180	160	1,45	4	240	193	1,67	6	360	258	2,06
(N) Coal and nuclear	50%		50	100	1,00	2	100	128	1,21	3	150	155	1,41	4	200	183	1,59	6	300	238	1,90
(E) Windmill	x	74	0	74																	
(V) Located on coast	25%			149	1,49			194	1,85			239	2,17			284	2,47			374	2,99
(A) Located on land	15%			155	1,55			206	1,96			257	2,34			308	2,68			410	3,28
(M) Belgian windmills	20%			152	1,52			200	1,90			248	2,25			296	2,57			392	3,14

The price of an oil barrel is shown on the top of the sheet. The price is multiplied by a factor (column *) during the years shown and is still expected to grow in the future. All fuel prices evolve as the oil price. It is assumed here that uranium price increases also at the same rate than oil. The price of uranium was very low around 2000 but, on the long range, it did not grow as fast as oil.

A computation shows a production channel in which 50 % of the constant load of electricity comes from nuclear and 50% of the variable load comes from coal or gas. A nuclear power plant (1 GW worth 1.875 €) produces 8.7 TWh/an (7.2 TWh/year with 82 % use). This is equivalent to (7200/2.6=) 2770 windmills in the Ardennes (each one is worth 4 M € not including the backup power plants), i.e. 11 G €, the investment for 6 nuclear reactors producing 6 times more. Alternatively the set is also equivalent to 1800 windmills on the Coast, i.e. 7.3 G €, the investment for 4 nuclear reactors producing 4 times more. The modification of the exchange rate between $ and € has produced price divergences between 1995 and 2003, complications which are not taken into account here.

Computation of a combined production: windmills and gas power plants

If a windmill received strong wing to produce always at full power, its production relative to a nuclear plant would be 8.7 TWh / 17 GWh =] 488 times lower. The ratio of the installation costs are [1.875 G €/4 M €=] 468.75. Le ratio of their annual operating costs (financial charges + operations) are, without fuel [200/150=1.33]. At the computation end, the ratio production/cost is [488/(468.75*1.33) =] 0.78 lower than for nuclear power. When the windmills are fully operating, the windmill energy is produced at a lower cost than nuclear (78 in relation to 100, or 74 in relation to 95). As the windmills are producing only a fraction of the time, they must operate together with gas power plants as backup. The financial charges and the operating costs of the windmills and of their backup have to be paid whether there is wind or not. To compute the price of the combined system, wind and gas, the formula adds the fixed costs (annuities and operating costs) of windmills and backup plants and then adds the price of the gas fuel for the period when the backup plant is operating.

The combined system emits from 75 to 90% of the greenhouse gases in comparison to normal power plants while the nuclear power plants emit almost no greenhouse gases. While they are producing, the windmills save only the price of the fuel, relatively high for oil, gas and coal, but quite small for uranium. The global cost has no meaning if it does not include the costs of the backup power plants. The result is that the full costs of windmills (1.53 M€ /GWh) are higher (7 times per unit of energy) than those of nuclear power plants (0,215 M € /GWh). The real cost of nuclear power is lower than shown here because the inspection have confirmed that the current nuclear reactors can operate for more than 30 years

An index comparing the relative production costs without subsides

The nuclear (N) receives the index 100 in 1997. The electricity from fossil fuel (F) was produced at 90% of this cost. The intermittent electricity produced with a windmill and its backup plants would have an index of 149 (sea) to 155 (land) in 1997. The increase of the price of the fossil fuels is shown in the column with an *. When the prices are multiplied by 4 (this happened in 2006), the windmill index, which includes the backup contributions, is 298 and the price is 2.5 times higher than the nuclear price (column P/N). If the fuel is 6 times more expensive, the windmills system price in the Ardennes remains almost at the same price than with the fossil fuel and is 3 times more expensive than the nuclear

It is a fascinating paradox that the energy produced by windmills, which one would believe is free, is in fact as expensive as the one from power plants with fossil fuels. This energy will not even be competitive when oil reach 100$ per barrel. It is anyway much more expensive than from nuclear plant and the windmill combined system is incompatible with more economical systems as shown in the following.

Hidden subsides have favoured the diffusion of false information

In the national accounts, subsides and taxes are included in the investment costs or hidden in other items. The subsidies are entered with the investment and not paid by any other national account. This method prevents to estimate how much the community wins or looses. This method does not allow finding the real costs of decisions and the return on investment. This is not a serious accounting method, except if the aim is to favour a decision and hide the true reasons. The state officials who do not question this kind of accounting cannot be good managers of the public goods as the frequent insertion of huge hidden subsides prevents management as in private accounting.

Since the oil crisis in 2003, uranium is again in demand and has been prospected. The uranium is a metal as abundant as zinc as its supply is almost unlimited but the price of extraction and treatment are much higher for ore less rich in uranium. The proven reserves, including all types of ores, have been multiplied (lets say, by 10) as the price was multiplied by 3 [16].

There are various designs for nuclear power plants, some being safer than others. The power plants are now built according to safe criteria (which was not the case in the Soviet Union which used reactors to produce plutonium for military purpose). Current researches in the nuclear industry are directed to improve the security, to better use the fuel and to reduce the amount and dangerousness of the wastes.

The actual problem of nuclear proliferation is that the emergent countries (China, India, Pakistan, Russia, Brazil and many others) are going anyway to install nuclear power plants that are the less expensive to run.

Occidental countries or Greenpeace have no power to prevent this to occur. The security operations could not be as tight as in Occidental countries if these cannot help and watch because their antinuclear activists would complain that this would mean the acceptance of this proliferation. Finland, some Asian countries, England and probably France are going soon to install nuclear power plant.

Economic statistics have shown that research is followed usually by a good return on investment. The interest of a state is thus to subsidy promising researches. The nuclear was subsidized by the military during the Second World War and the Cold War. Recent researches in the nuclear domain would improve nuclear power plants. The first windmills have been subsidized for many years but few improvements are currently suggested, except the increase of size and nuisance, so there is little justification for continuing to subsidy research. Contrary to research or development, it is not a good economic practice to subsidy exploitation. Subsidies for exploitation in nuclear industry are not known but this study shows that exploitation if fully subsidised in windmill industry.

(4) Continuous supply of electricity according demand

Transport of energy

The methods or transporting electrical power are presented here in a simplified and standardised way. For long distances, very high voltage is used (500 kV on 50 m high poles). The lines are installed in corridors as large as those of highways. They can be installed on the inclined side of a mountain. One can cultivate the land in the corridors, except planting trees. It seems dangerous to inhabit at close proximity of these lines. The lines are not making noise and it is possible to live in a home within a km from the line. The poles do not move as the windmill blades and one gets used to them, contrary to the windmills. The high voltage lines are infrequently installed under ground as this is quite expensive. The 50 kV lines are installed on small 20 m high poles. The distribution to the cities is made on 5 kV lines which can be more easily put under the ground. The distribution to each house is done on three wires (380 Volts). For a given diameter of conducting wire, the loss of energy on a 100 km line in 500 kV is the same as on 10 km in 50 kV or 1 km in 5 kV or on 75 m on 380 V. Electricity is thus distributed in a sequence of 4 steps. An average transport on 50 km from a power plant to a user implies a loss of energy around 7%. For a given size of wire, a 500 kV line carries 100 times more than a 50 kV line. The voltage is reduced in stations and cabins having transformers. These stations and cabins represent a heavy part of the total cost. The high voltage stations are quite expensive and it is thus less expensive to have a big central plant rather than many distributed ones. The windmills are plugged to the grid on nodes that must be able to support this increase in power. This additional transport on 20 kV connecting lines may spend 5 % of the windmill power.

Variable demand on the electric grid

The consumption of electricity is irregular, as it can be twice higher in the afternoon or the evening than in the end of the night. Intelligent meters allow applying a different hourly price during the heavily loaded periods and the emptier hours. A household can heat water in a boiler during night and use it the day after. The industries can plan using more electricity at the time when the price is lower. A good pricing policy can thus regularise the consumption and reduce the hills and the valleys in the demand curve.

The price of electricity for the user

The customer must pay a price much above those shown here. The bill of the electricity provider has to add the production, the management and the distribution costs and also the taxes which the state tends to increase as the household is captive and has few possibilities to generate its own electric power at home. The kWh for an industrial customer with a flat and regular consumption is sold for 5 c€. This price goes up to 20 c€ for the average household on top of various fixed payments for the connection to the grid. The high level of taxes allows hiding the subsidies as a reduction of taxes but, in the end, the consumers have to pay a greater total amount.

Connect to the windmill power today! [45]. This message is diffused by the windmill lobbies, but it is currently not allowed to choose to pay for the nuclear energy or for the green energy at their respective real costs. Few customers would pay 3 times more for wind energy, especially if they know that the production assisted by wind emits more greenhouse gases than alternative, less expensive methods.

Pumping stations to regularise the production of electricity

As the nuclear power plants cannot change significantly their level of production, a solution is to insert them in a power grid having pumping stations. These systems store the energy by pumping water up in a high reservoir and reuse it in a hydraulic power plant. They pump at night and reuse the power the day after during the heavily loaded periods. Such a station is already built in the Ardennes at Coo, but with a small reservoir as the aim is to react to sudden load peaks.

Let's compute how to regularise the load. Assume 3 nuclear reactors producing 3 GW and a pumping station whose pumps and turbines have the power of one or 2 reactors. This system provides a power varying from one to five (from 2 GW to 4 GW, or, for short periods, from 1 to 5 GW), as far as the total consumption on a full day is below 73 GWh [= 3 GW * 24h]. One can thus suppress all polluting power plants and produce almost without greenhouse gases emissions. All windmills can be dismounted as soon as the crisis of depleted fossil fuels would have constrained the country to switch to the 100 % nuclear solution.

Using the energy in one kWh, one can lift 367 m^3 on 100 m or 183 m^3 on 200 m. The turbines and the pumps have a yield of 90%. One can thus store and reuse 80% of the energy. A power of 1 GW can lift, with a yield of 80%, 2.7 Mm^3 on 200 m within 12 hours. One needs 2 reservoirs, each with a dam capacity of 3 Mm^3. Let's assume that the reservoir is built in a high valley closed by a dam. It has the shape of an inverted pyramid whose volume is its water surface times its height divided by 3. This reservoir, 24 m high, should have a surface of 3.7 km^2 or 4 km^2 with 20 m variations of the level of water.

The cost of the reservoirs depends on the geography and the geology to find waterproof ground. The Alps valleys were adapted to build a system at Grandmaison in France. A project concerning Canada and US is to use the natural pumping site of the Niagara Falls (99 m high) between two reservoirs, Lake Ontario and Lake Erie. Belgium has built many reservoirs (La Gileppe, la Vesdre, Robertville, Vianden, l'Eau d'Heure) but they were justified to regularise the level of water for transportation on canals, for supply of drinking water or of clean water for paper and textile industry.

Let's compute the cost of two global systems added to a nuclear power plant with 2 reactors to produce a power of 4 GW. The 100% nuclear solution needs one more reactor (1.875 G€) and a pumping station. The wind and gas system uses 2 GW of windmills and their backup fossil fuel power plants. One needs from 500 windmills on the Coast to 770 windmills on the land (value 2 G€ to 3 G€) to produce 2 GW and 2 GW backup gas power plants for 1.5 G€, thus from 3.5 to 4.5 G€. If the same investment is available for the 2 solutions, the pumping station and the reservoirs can thus invest between 1.625 and 2.625 €. The 100% nuclear solution is clearly better than the windmills in the Ardennes as it produces no greenhouse gases and is not dependent on foreign fuel supply. The electrical power supply of Belgium would need 3 such systems, i.e. 9 reactors and 3 pumping stations.

Storage of windmill energy

Can the pumping stations be used for windmill storage? In Central Europe, strong wind periods alternate with calm wind periods. The weather pattern changes in average, say, after every 10 days. Instead of alternating the filling and emptying every 12 hours, one must thus wait 20 times longer and the reservoirs should be at least 20 times bigger. As in Belgium, the cost of a reservoir is mainly in proportion of its capacity, the cost may be 20 times higher and there are not enough sites. To be 100% wind powered with a 20% load factor, Belgium would need 5 times more windmills than for the power needed. It thus needs 300 pumping stations [3 systems * 20 periods * 5 =], each one including a pair of reservoirs sized as described above. The power consumption of the countries on both sides of Lake Erie which is as great as ¾ of Belgium, is around 300 TWh/year. 30 % of their energy is produced by hydropower. If they produced the rest with wind, they could store it by pumping, but the height variation of Lake Erie would be 2 m (computed in [48], but with twice the energy produced and periods of 10 days). This solution would cause many problems for the Lake, e.g. when it carries patches of ice in winter. If this solution is not valid near the Niagara Falls, it would be even worse in Belgium.

(5) Windmills and environment

Confusion between two problems concerning planet preservation

The problem of global warning caused by greenhouse gases should not be confused with another important problem, the depletion of fossil fuels which became obvious for oil in 2006 and is expected to occur later on for natural gas. Coal is still abundant but its reserves are limited.

Both problems have almost the same solution: a reduction of the consumption of fossil fuels.

There were many false rumours about the depletion of uranium: highly concentrated ore are expected to be depleted within 50 to 100 years, but less rich ores are abundant although more expensive to extract and to concentrate.

Depletion has the economic effect of increasing the prices at a level much higher than the extraction cost. This depletion will cause an economic crisis initiated by an increase of the fossil fuels.

Existing power plants using fossil fuels

Most countries have many aging power plants using coal and a few ones using natural gas. When promoters have done a financial study on the cost of installing a windmill, they have assumed that the backup already exists and should not be accounted for. This would be true if the lifetime of the windmill is shorter than those of the polluting power plants, but this is not the case: almost all of these plants would have too be replaced within 20 years and the windmills will have no backup if less expensive power generation is used.

The enquirers searching for long range plans in the economic policies believed that the current heavy windmill subsides have been engineered by the gas producers or by the antinuclear fanatics to force European countries to continue building highly polluting power plants while they are put themselves in a corner where they need them as windmills backup.

How to reduce the emission of greenhouse gases?

One can check whether someone has understood how each proposal remedies to the global warming explained by al Gore in his papers and movies. The windmills could at best reduce the greenhouse emission by 5%. Windmills could only produce 20% of the electricity which accounts for 25% of the energy consumption. As only 3% of the energy (as in Germany) can be produced by windmills without damaging too much the landscape environment, the saving in greenhouse emissions is only 0.75%. The best known solution which, despite its problems, suppresses 25% of emissions (against only 5% or less for the windmills) is the 100% nuclear production of electricity.

It is unfortunate that the works on the Kyoto Protocol had been initiated soon after the Chernobyl disaster and that the opportunity of nuclear power plants could not be included as a way to fight global warming in the political context of strong antinuclear feelings at that time. One should hope that the countries, facing a hard to implement and poorly efficient Protocol, will work on a renewed Protocol treating nuclear fuel as a renewable resource not producing greenhouse gases.

Historical major mistakes similar to the windmill fancy

In 1960, a bubble for modern buildings has promoted erecting big towers for offices. These towers were built in the middle of urban zones for residence among houses with few stories. The citizens were not consulted and were unaware of the nuisance: big wind gusts and privacy violation. Traffic and parking were perturbed. The citizen’s reactions were strong but were very late. The cities were thus destroyed. Today big towers are no more allowed in residential areas but the existing towers have not been demolished. The houses close to the tower have lost part of their value and their owners were never compensated for their losses.

The current story on the windmills is similar. The countryside inhabitants do not know about the windmills nuisances and claim afterwards to have been trapped. Their complaints are discarded with nice words. No one has ever received compensation, as the costs of windmills would double if the promoters were constrained to pay for having destroyed the landscape of the common land.

In the same way that an office tower became, in the 1970s, a symbol of the destruction of the quality of life in the cities for a false ideal of progress, a windmill image will become a symbol of the countryside destruction for a false ideal of climate protection while, in the reality, the windmill system increases the greenhouse gases relatively to other solutions they prevent.

(6) Windmills nuisances

Nobody contests that modern three blades windmills are elegant and less hideous than electric poles or derricks. What local residents complain about is that they rotate. After some time, most inhabitants do not notice anymore the electric poles but cannot get habituated to the rotating stimuli even after a long time.

Why is our vision attracted by windmills?

It is not because windmills are beautiful. An innate tendency of visual attention is to look at moving stimuli, some being better at capturing attention than others. Twirling or rotating movements with the arms are the best way to attract attention when sounds cannot be used. A large windmill located at 3 km has the same relative size as a person located at 50 m which rotates its arms. Both attract your attention equally with the difference that a windmill never gets tired and continues perturbing your attention even if you ignore it.

After some time, the mind gets used to repeated stimuli, but this habituation depends on the stimuli. It is quite difficult to get used to listening a dripping tap, especially when trying to get sleep. Rotating and noisy windmills do not facilitate habituation. The rotating stimuli activate a quite powerful reflex of attention. One cannot let the glance roaming and enjoy looking at landscape scenery if a conspicuous point catches the eyes as a flashing light. Attention is captured by the rotating bodies. Even if windmills have a load factor of 16%, their blades are turning even when the wind is too slow for full production (50% of the time) and thus they are an almost permanent nuisance.

Many people get interested the first time they see a modern windmill but this is not the same as having to live all the time seeing them in the background. One notices early that it is difficult to detach eyes from this hypnotic stimulus. The Germans, Dutch's and Danishes are saturated seeing windmill farms. On the Coast, the windmills have to be further than 15 km to get unnoticed (20 km for the bigger current windmills).

Noise and nuisances on wildlife

If a 100 m diameter windmill rotates in 6 seconds (10 rotations per minute), the speed of the blade ends at the periphery is (3.14 * 100 * 3600/6) = 188 km/h. Such a speed produces repetitive strong noises in the calm areas of the countryside, especially in the tourist area of the Ardennes where silence is the quality prized by the citizens coming for holidays or tourism or by the old age people enjoying a quiet home. As with an old car, it happens that the noise of the windmill gearbox becomes grinding and will does it for a year until repaired.

The fact that two people succeed talking under a windmill is not criteria sufficient for an acceptable noise. The quietness of a countryside night is well below 60 dB (it is about 4 dB). In the industrial zoning, one can make a lot of noise by day before this noise is noticed. In a tourist or residential area, a repetitive disturbing noise is not acceptable.

The noise of a windmill is similar to a helicopter's sound but at a much slower rhythm. The sound is emitted at 100 m high and propagates without obstacles due to trees. The attenuation of noise with the distance depends on the frequency of the sound which is very slow for windmills. Very low frequencies propagate at very long distances, as one can notice when listening to a distant loudspeaker: the boom-boom of a battery is overpowered but not the sounds emitted with the same intensity at a higher pitch. The elephants are using bass sounds or infrasounds to communicate very far. The bass sounds are better attenuated by hot and humid air than when it is cold and that humidity condenses. That explains that these kinds of sound are quite noticeable at night. In summary, windmills send disturbing repetitive whirling sounds at long distance.

Using a device measuring the sound intensity is almost irrelevant as the disturbing effect is more related to the quality of sound in the countryside background than to its intensity. The windmills promoters continue doing irrelevant measurement to negate the nuisance [26] as they know that a realistic test would justify the Nimby claims.

The flashes at night of the few windmills are already disturbing when looking at stars. Those on the crests are visible at 50 km. The windmills perturb the radars at sea and the pilots need also a backup light replacing their deficient radars. The birds do not understand these lights. When planes are flying at low altitude near airports, teams of specialists are needed to chase them. Each time a bird crosses a windmill it has 2 seconds to go between two fast blades arriving from nowhere near 200 km/hour and it has a chance on 10 to lose a wing. The birds of prey and the bats are not afraid to venture everywhere but are found in large number on the ground near the feet of windmills. These birds risk eradication, letting rodents and mosquitoes proliferated, favored by the global warming.

Impact on landscape, green tourism and house value

One can measure the difference of value of two identical houses, one being in a wonderful landscape, the other being in an industrial area or near a windmill farm. The difference in value is at least 10%. On top of that, the value of land looses at least 20 %. If a windmill farm has an impact on 300 houses and 3000 potential building parcels, the value lost for the houses is 10 M € (= 300 * 333 000 € * 10 %) and for the land, 6 M € (= 3000 * 10 000 € * 20 %). Normally the promoter or the city delivering the authorization should pay this compensation to the owners. The additional cost is thus 16 M€. For larger windmills that have an impact on a larger land, the houses concerned and the compensation prices go up with the square of the windmill height.

The negation of the nuisances

The willingness of the lobbies, promoters and their delegates to wipe off the windmills nuisances can be explained only if they have deep motivations to negate what is obvious. Their business would be definitely ruined the day they loose a legal case that constrains them to pay compensations for the damage done.

Facing lobbies that do not accept that there are obvious nuisances, the tenants menaced by the installation of windmills have a hard time protesting against illogical peoples. That could be the reason of the deep furor observed on the web sites of the associations of defense. The simplified arguments that windmills are needed to preserve fossil fuels and to fight against global warming do not stand for long when one studies the case and finds the real motivation of the promoters. The victims, after understanding that they have been falsely accused to be Nimby, feel that they face crooks using anything, including manipulated environmental arguments, for their self-interested aims. They then treat these promoters accordingly.

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The following assertions are explained and justified in the (French) study

Productivity of windmills in the Ardennes

- Windmills in the Ardennes are twice less productive than in the Flanders.
- Windmills seem profitable only because of large hidden subsidies.
- Windmill promoters use various tactics to do not pay for the nuisances.
- Intermittent electricity is sold at best at half the price of electricity delivered on demand.
- Windmill electricity is produced at 3 times the prices of the market, but can only be sold at half the price. Contracts signed by the governments force the consumers of future electricity to pay for the deficits.

Requirement of a power generation by fossil fuels for windmills backup

- The full power of the operating windmills must be ready to be generated with fossil fuels when there is not enough wind or when the wind is too strong.
- Nuclear generation cannot be used because the reactors have a continuous output.
- The current surplus of power generation by fossil fuels allows providing the backup with the existing installations, but those are old power units which would have to be replaced soon.
- An alternative backup source is hydroelectricity from water barrages, but this is fully exploited in Belgium.
- The combined production by windmills and fossil fuels emits almost as much greenhouse gases than fuel (75 % on the Coast, 90 % in the Ardennes). The global production of electricity depends thus on the price and availability of gas decided by foreign countries.
- Windmills have been celebrated as examples of clean energy but, in reality, the global system produces almost as much pollution.
- The windmills are symbols of greenhouse perpetuation rather than of clean energy.

Windmills are much more expensive than fossil fuels or nuclear power.

- That the windmills are so expensive is a paradox fully explained.
- Using windmills, one must pay for the installation and operating costs for the generation of twice the power, one by windmills and the other by fossil fuels.
- The only savings of windmills are the cost of fuel during the operation time but one must pay for the investments of a duplicate system.
- If windmills are installed, the Belgians (or only the Walloons) would have to pay their electricity at a much higher price during 15 years because their politicians did not compute.
- The deficit of a project of 1800 windmills in Belgium would be paid by the consumers as an increase of the kWh for the next 15 years, i.e. as a global payment of 2500 € per house.

Nuclear power generation misunderstood by most environmentalists

- The electricity generation by nuclear power plant is the only known large-scale method to reduce the greenhouse gases and to preserve the fossil fuels.
- The price of electricity generated by nuclear power plants is much lower than by fossil fuels.
- As uranium is 10 times less expensive than coal or gas for the same power, the fuel saved by windmills is negligible when the country uses mainly generation by nuclear power.
- The decisive advantage of producing electricity at half the price will tend to delocalise many power hungry industries into the countries using nuclear power.
- An indiscriminate nuclear ban is an efficient path to reduce the purchasing power of a country and to condemn it to the unemployment following industry migration.

The Ardennes have promoted renewable energies adapted to their area

- Belgians generate electricity with very few CO_2 emissions, well below average (43% against 63% in OECD).
- The Ardennes can exploit hydroelectricity, the Flanders can exploit wind.
- It is not true that the Kyoto protocol condemns the Ardennes to make havoc of tourism.

Why are windmills projects turned down in all densely inhabited regions?

- Pictures of elegant windmills are deceiving as they do not rotate.
- A definite nuisance of windmills is the hypnotic power of an uninterrupted rotating stimulus.
- Any landscape looses aesthetic value when a windmill captures the attention. The environmental damage to the landscape grows with the windmill size.
- Nobody likes to go for a relaxed walk neither under power lines nor near gigantic windmills farms.
- Windmills in the Ardennes would destroy the green tourism and the residential industries.
- Windmills are accepted amid industrial complexes (such as Zeebrugge harbour) but not near tourist coasts.
- The obstinate determination of windmills promoters to reject complaints on nuisances has a financial justification.

Loss of value of houses and building sites near windmills

- One cannot enjoy a relaxed view of a landscape near a windmill. No residential homes are built near windmills farms.
- If the area is densely populated as in Belgium, the windmills will be more disturbing.
- The people of the Ardennes who have worked hard to promote green tourism and residential houses will loose their investment.
- No solvable entity (promoter, municipality, electricity provider) is identified to pay for the compensations (an amount as big as the investments in windmills).

Windmills can only provide a very small amount of energy compared to other systems

- If one wants to provide more than 10% of energy by windmills, one needs to build more than 20 windmill farms in the Ardennes, letting no area free of this nuisance.
- A nuclear power plant (2 reactors) provides the energy of 5540 windmills on a continuous supply, without the need of backup generators which are very polluting.

Confusion of the problems of CO_2 emission and depletion of fossil fuels

- Everybody knows that Earth is becoming hotter and that on must be prepared
- Depletion of fossil petrol and gas is expected and will cause an economic crisis.
- Huge energetic resources are needed, much more than what the renewable energies can provide as solar power cannot be currently economically exploited.
- CO_2, a greenhouse gas produced by cars and industries, is now a symbol of the industrial world for the activists wishing that nature reverses as before the industrial revolution
- For the third world, the fight against CO_2 means that the developed world will not finance classical power generators, a way to prevent development.

International responses to the depletion of petrol

- The growing consumption of coal produces a growing pollution and emission of CO_2.
- Nuclear power generation is growing in emergent countries (China, India, and Russia) whatever the advices of Europe and US.
- Nuclear electricity at half the price is a definite economic advantage. If a country refuses the nuclear power, this will cause the migration of industries and unemployment.
- Nuclear power generation is the only known method having the size to provide enough energy, to remedy to fossil depletion and to reduce greenhouse gases.
- The redhibitory defect of windmills is that an investment in this technology will block an evolution to less expensive sources and to better methods against greenhouse gases. This is why some analysts have conjectured that, because windmills will maintain the requirement for fossil fuels, the windmill lobbies are paid by petrol producers. Others are suspicious that the environmental militants against nuclear power plants, the best solution against the climate change, are also paid through several untraceable relays from the same source.
- A joke on European madness about windmills is diffused by CNN as an advertisement by Chevron. One sees the Eiffel tower fitted as a windmill and the comment tells that wind energy cannot provide the energy Paris needs.