Fair and efficient rates for large scale development of wind power: the new French solution

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ABSTRACT : A new electricity rate system for wind energy has been published on June 8th 2001 in France. The European and the French context that led to the decision to develop wind energy in France through this new rate system are presented. In order to achieve a minimal goal of 5 to 10 GW of wind capacity installed in 2010 (instead of 70 MW in operation at the end of 2000), the French system is designed to attract private investors by providing a minimum profitability for projects on medium quality sites while avoiding undue profitability for best quality sites. Following a 5 years period at a fixed rate, the specific rate for each project in years 6 to 15 is defined simply from the average capacity factor measured during the first five years of operation. In order to lower the extra-cost for electricity consumers, the system can give an incentive to use high performance wind turbines and good sites and can take into account the decrease of investment costs for new projects. The innovative economic analysis method used by ADEME to define this new rate system, the "profitability index method" is presented briefly and the main formulas to implement the method are given. From this "profitability Index Method" it is easy to establish a fundamental "free energy sources paradox" which must be taken into account when promoting renewables versus fossil fuels, because it demonstrates that in order to get the same profitability level for investors, the margin on cost of the delivered kWh must be two to three times higher in the case of renewables that have no fuel cost (as wind energy) than the margin on cost on kWh from fossil fuel based power plants. Detailed information is given on how to adapt this French solution to different wind and cost conditions.

1. THE EUROPEAN AND THE FRENCH CONTEXT

On September 7th 2001, the European Union adopted a directive to implement in the power sector its strategy defined in 1998 to double the renewable energy share in the energy consumption of the fifteen member states, from 5.3 % in 1995 to 12 % in 2010. According to this directive, the share of electricity from renewables (including large hydro) should increase from 13.9 % of the total electricity demand in 1997 to 22 % in 2010. The directive proposes a goal for each member states which is summarised for some of them in the figure 1 below:

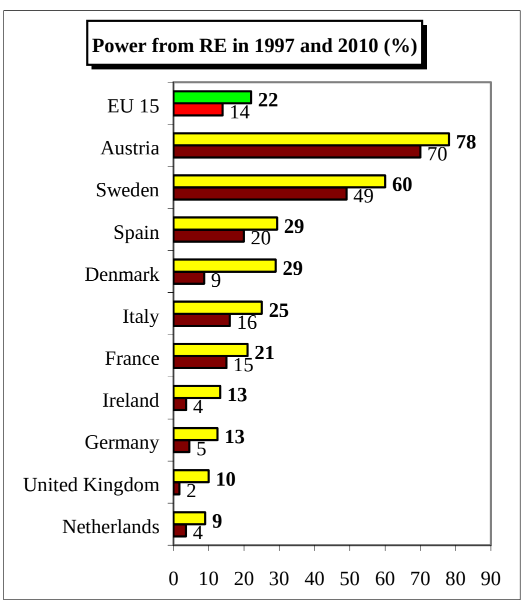

Figure 1: 1997 and 2010 share of electricity from renewables in the EU and in selected member states

In France, the past development of wind power was mainly driven by the "EOLE 2005" programme launched in 1996 and its related calls for tenders issued by the national utility EDF. Within this programme, 55 projects were selected, mainly on the basis of the lowest kWh rate asked by proponents. They represent 360 MW, of which 70 MW were installed at the end of 2000, and 47 MW were due do be installed in 2001.

Within the frame of the negotiation of this European directive on electricity from renewable energy sources under the French Presidency of the European Union, it was announced by the French government in May 2000 that 5 000 to 10 000 MW of wind power should be in operation in France in 2010, and that a new system based on fixed rates would replace the EOLE 2005 calls for tenders for projects under 12 MW. Table 1 shows what is the present ADEME estimate of renewables (excluding large hydro) required to achieve the 21 % goal attributed to France. Final official figures may be different, but what is clear is that wind power will have to make the larger contribution of this increase of renewables in the power sector.

Table 1: ADEME estimate of the increase of renewables :

Additional contribution of RETs in France in 2010 (2001 ADEME estimate)	TWh/year	%
Wind Power	**29**	**73%**
Biomass	5,9	15%
Small Hydro Power	4	10%
Geothermal Energy	0,8	2%
Photovoltaics	0,3	1%
TOTAL new RE contribution	**40**	100%
Total with large Hydro	107	
Total 2010 demand incl. DSM	510	21%

To help to define the new rate system, an ad-hoc working group was created by the Ministry of Industry in August 2000. The final system as described in the June 8th 2001 *arrêté* [1] for the first 1 500 MW of signed contracts is mainly based on the proposals and conclusions of this working group, with some details added further by the French Authorities.

2. PRINCIPLES FOR EFFICIENT AND FAIR RATES

From the past decade, it is clear that a key factor for the fast wind energy development in Europe was the success of the policies based on fair fixed rates versus the ones based on competitive calls for tender [2].

That is why, in France, it was decided within the general frame of the February 10th 2000 new law on electricity that competitive calls for tenders will be used only for wind power projects over 12 MW. Under this power limit, considering that the European market for green certificates was not existing and that it was not proven that such an economic instrument would be able to achieve the 2010 goals, it was decided for projects under 12 MW to consider the "premium rates schemes" in Europe, mainly the past Danish and the recent Spanish and German ones who proved to be very successful.

So the basis of the new French rates system is also to create the conditions for a "fair profitability" for private investors in wind power projects, using state of the art wind turbines, so that on medium quality sites (in France, approximately from 6 m/s at hub height) a minimum profitability is possible, and so that on high quality sites (in mainland France, practically under 8.5 m/s at hub height) the profitability may be higher, but not undue. The initial ADEME proposal to the ad-hoc working group and the final system are inspired from the German system, but as it will be detailed later, they differ on tariff conditions after the first five years of operation.

The "over-cost" implied by those tariffs will not be covered by the national public budget. It will be charged equally on all electricity consumers, from their equal contribution per kWh consumed to a specific fund raised to cover all the public services charges of the electricity sector. Among them, are charges resulting from the development of renewable energy technologies (RETs) for power production in order to comply with the Kyoto agreement and also with the adoption of the European directive on electricity from renewable energy sources.

The ADEME proposal for profitability levels and the detailed rates values are based on the "Profitability Index Method" (PIM) already described for its application to grid connected wind power plants [3]. The conclusions from this global economic analysis method were also checked from the rates proposal by the French professional associations FEE and SER using a conventional financial analysis including profitability results on equity. The official rates system as described in [1] for the first 1 500 MW of signed contracts differs only slightly from the conclusions of those two analysis.

As the PIM is so simple and powerful to define a rate system, it will be described shortly before detailed results for the French system are described.

3. THE PROFITABILITY INDEX METHOD (PIM)

3.1 Definitions, basic parameters and formulas

The profitability index (*PI*) is simply the ratio between the Net present Value (*NPV*) of a project and the required initial investment *I*: $PI = NPV / I$

The discount rate to use with the PIM is not the targeted internal rate of return (*IRR*), but the Average Weighted Cost of Capital (AWCC). Its reference value used to define the French rates is t = 6.5 % (real, corrected from inflation, as all rates and parameters will be defined in constant 2001 Euros).

Other basic parameters and reference values used to define the rates are:

- The depreciation period n (15 years).
- The capital recovery factor *Kd*, defined by:

$$Kd = Kd(t,n) = \frac{t(1+t)^n}{(1+t)^n - 1}$$

- The investment cost ratio: $Iu = I / P$, and the residual value *Valres* of the project after n years of operation, as a fraction of the initial investment.
- The yearly constant average O&M expenses ratio $Kom = Dom / I$, where *Dom* is the annual O&M expenses (including provisions for big repairs).
- The yearly average capacity factor expressed as $Nh = Ey / P$ (hours/year at rated power), where *Ey* is the mean yearly amount of energy sold to the grid.

For a targeted profitability index value *PI*, the required constant rate *Teq* from year 1 to year n is:

$$Teq = \frac{\left(1 + PI - \frac{Valres}{(1+t)^{(n+1)}}\right)Kd + Kom}{Nh} Iu \quad (1),$$

and of course, for *PI* = 0, the rate *Teq* is equal to the Overall Discounted Cost (*ODC*) of the kWh.

From (1), if *Valres* = 0, there is a direct relation between the *PI* value of a project and its IRR (Internal rate of return) value:

$$Kd(IRR, n) = (1 + PI)Kd(t, n) \quad (2)$$

For example, for n = 15 years and t = 6 %, for *PI* = 0.3, IRR = 10 %, an IRR value considered as a minimum to attract private investors in long term projects such as wind power projects.

3.2 The margin between cost and price

The first advantage of the PIM is to make a clear difference between the “cost” of a kWh ant its “selling price” (the rate). The difference between the two values defines the profit margin and creates the profitability of the project.

Using the “Margin on cost” *MOC*, defined as:

$$MOC = \frac{(Price - Cost)}{Cost} = \frac{Teq - ODC}{ODC} \quad (3),$$

then for all power plants with constant annual cash flows:

$$MOC = Kfuel \frac{Kd}{Kd + Kom} PI \quad (4)$$

With $$Kfuel = 1 - \frac{FCP}{ODC} \quad (5),$$

where *FCP* is the “Fuel Cost Part” of the kWh (the part of the total cost related only to fuel expenses).

Of course, for all RETs without fuel expenses (hydro, wind, solar, geothermal based power plants), *Kfuel* = 1. Instead, for fossil based power plants, *Kfuel* < 1. For example, *Kfuel* is around 0.5 for modern coal based power plants and around 0.33 for natural gas based combined cycles power plants.

3.3 The “zero fuel cost RETs” paradox

Using (4) both for zero fuel cost RETs (index *r*) based and fossil based power plants (index *f*) gives:

$$\frac{MOCr}{MOCf} = \frac{1}{Kfuelf} \frac{Kdr}{Kdf} \frac{(Kdf + Komf)}{(Kdr + Komr)} \quad (6)$$

If we compare a renewable energy based project (without fuel costs, so excluding biomass projects) and a fossil one, with the same discounting conditions t and n

and the same targeted profitability, then $Kdr = Kdf$, and as *Kom* is in general lower from RETs based power plants than from fossil based ones, (6) demonstrates the "**Zero fuel cost renewable energy technologies paradox**":

$$\frac{MOCr}{MOCf} > \frac{1}{Kfuelf} \qquad (7)$$

So, from this paradox based on (7), in order to get the same profitability from a zero fuel cost RET power plant project and from a fossil based one, the margin on cost for the renewable project must be higher than the one of the fossil based project.

For example, for the same profitability, a zero fuel cost RET project must have a margin on cost:

- Around two times higher than in the case of a coal based power plant.
- Around three times higher than in the case of a natural gas combined cycle power plant.

In other words, if a wind power plant is delivering a kWh at the same cost level (e. g. 100) than the cost levels of a coal and a natural gas power plants, to get the same profitability (e.g. $PI = 0.3$), the relevant selling prices of each kWh must be around:

- Only 104 for the natural gas power plant.
- 110 for the coal based power plant.
- And 120 for the wind power plant!

In liberalised electricity markets, the minimum margin on cost for coal power plants is around 10%. As this margin corresponds for a modern coal plant to a profitability level PI = 0.3 (see example in reference [3]), the minimum profitability index level for a wind power plant project should be also 0.3, a minimum value also derived as seen above from the link between *PI* and *IRR*.

This minimum value of profitability index of 0.3 for reference wind power projects was used by ADEME to propose the first reference rates values. Final official rates are slightly different and as it will be seen below, the final profitability index values for reference projects can differ from this theoretical minimum value of 0.3.

4. PRINCIPLES FOR FRENCH RATES DEFINITION

4.1 Basic principles, parameters and formulas

Referring to the figure 1, the main parameters of the French wind rate system for projects under 12 MW are:

- *T1*, a fixed rate for all new contracts in a specific year for their first 5 years of operation (years 1 to *j*).
- *T2*, the specific different rate for each project for years $j+1 = 6$ to $n = 15$.
- *Teq*, the equivalent constant rate from year 1 to *n* resulting from *T1* and *T2* and *t* and leading to a final economic profitability *PI*.
- *Nhmin* and *Nhmax*: the minimum and maximum reference values of average energy yield or capacity factor (expressed in hours per year at rated power).
- *PImin* and *PImax*, the minimum and maximum reference values of the profitability index for reference projects with *Nhmin* and *Nhmax*.
- Reference cost parameters e. g. for mainland France, 2001 contracts: Iu = 1067 EUR/kW, *Valres* = 15 % of initial investment, Kom = 4%, t = 6.5%.

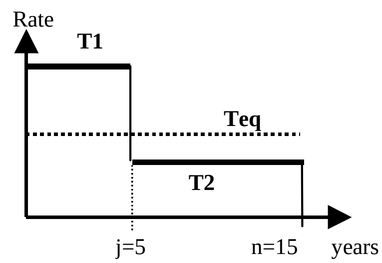

Figure 1: parameters for the French rates system

From those parameters, it is easy to define:

- $T1 = T2max = Teq$ for the "low reference project", defined by $Nh = Nhmin$ and $PI = PImin$. So, *T1* is calculated from equation (1), with $PI = PImin$ and $Nh = Nhmin$.
- *T2min*, the minimum value of *T2* for the "high reference project" defined by $Nh = Nhmax$ and $PI = PImax$. Its value is calculated from the following equation:

$$T2\,min = K\left(\frac{Teq\,min}{Kd(t,n)} - \frac{T1}{Kd(t,j)}\right) \qquad (8),$$

where $$\frac{1}{K} = \frac{1}{Kd(t,n)} - \frac{1}{Kd(t,j)} \qquad (9),$$

and where *Teqmin* is the value of *Teq* resulting of equation (1) using $Nh = Nhmin$ and $PI = PImin$.

4.2 Final data

Table 2 and Figure 2 give the *Nh*, *T1* and *T2* values defined in the "June 8th *arrrêté*" [1] for mainland France. The values for *Teq* are given here only for information and are calculated from t = 6.5 %. For a specific real project, its *Teq* value can be calculated from *T1* and *T2* and from the AWCCC *t* of the investor, using the following equation:

$$Teq = \left(\frac{T1}{Kd(t,j)} + \frac{T2}{K}\right)Kd(t,n) \qquad (10)$$

Table 2 : Parameters for wind power rates in France:

Reference values for 2001 rates					
Mainland France, projects < 12 MW					
	P (MW)	P (MW)	cEUR / kWh		
Nh:	<1500	>1500	T1	T2	Teq
Nhmin:	2000	1900	8,38	8,38	8,38
Nhint:	2600	2400	8,38	5,95	7,02
Nhmax:	3600	3300	8,38	3,05	5,41

For projects with applications and contracts in further years, reference [1] gives all the details and the formulas required to calculate how reference rates *T1* and *T2* will vary according to the forecasted decrease in reference investment cost *Iu* and how they are corrected from the impact of inflation.

For a specific project, the high initial rate *T1* applies for the first five years of operation. Then, as indicated in figure 2 below, the rate *T2* from year 6 to 15 is calculated from two linear variations versus *Nho*, the mean actual yearly energy yield measured during years 1 to 5 (after excluding the best and the worst year).

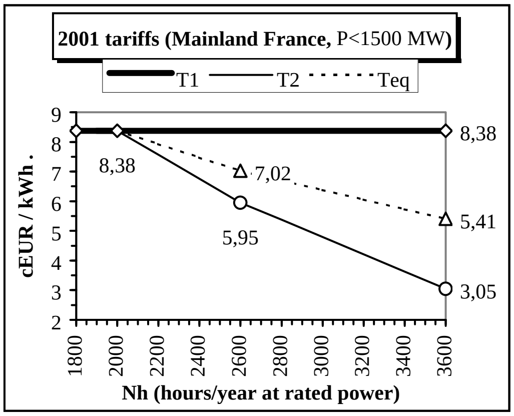

Figure 2: Rates (tariffs) *T1, T2 and Teq* versus *Nh*

In order to avoid an artificial lowering of *Nho* by operators during the first five years in order to maximise the *T2* value, the number of kWh benefiting from *T2* is limited each following 5 years period to 5*PNho*. For kWh beyond this limit, *T2* is lowered by 25%. In a specific contract, rates values are corrected each year from inflation, but only partially, with 40% of their value not taken into account in the relevant formula [1].

4.3 Results for profitability of reference projects

Reference projects in this analysis are defined by *Iu*=1067 EUR/kW, *Valres*=15 %, *Kom*=4 %, and t=6.5 %.

For 2001 reference projects of less than 12 MW, their profitability index variation versus their Nh value is presented in figure 3, and their Internal Rate of Return versus Nh are presented in figure 4. With the reference costs described above, profitability is not always beyond the proposed minimum value of *PI* = 0.3. But profitability is increasing with *Nh*, as designed in order to give incentives to developers using good sites with high yield wind turbines. One can see also that the forecasted mean inflation rate over the next 15 years has a great effect. For an inflation of only 2%, the decrease in PI vary from 46% to 21% from Nh = 2 000 to 3 600 h/y, and the IRR decrease is more than 1 point.

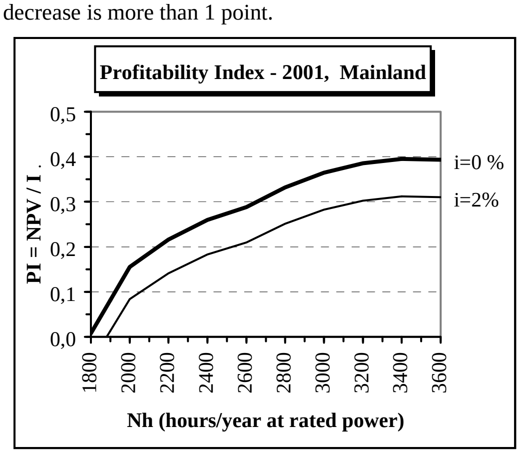

Figure 3: Profitability Index of a 2001 reference project

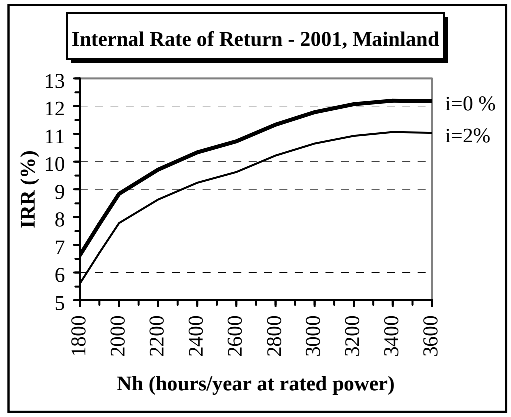

Figure 4: IRR versus Nh for a 2001 reference project

5. CONCLUSIONS

With this new rate system, France can now develop its huge wind potential at a pace as high as those experienced recently in other countries with “fixed premium rates”. A minimum of five and up to ten GW could be installed in France in 2010, provided that all potential problems for grid connection and public acceptance are solved. And “fair and efficient rates” as the new ones are a prerequisite for that, as they can help farmers, citizens and local authorities to be involved as investors in wind projects.

The over-cost of the new tariff system is not too high. From an extrapolation of a previous study [4], for 9 GW installed at the beginning of 2010, around 325 cumulated TWh of wind energy delivered from relevant contracts from 2001 to 2025 would charge the French electricity sector by around 5 bEUR (discounting at 5% and with a mean avoided cost of 4 cEUR/kWh). The maximum yearly over-cost would be 670 current MEUR in 2018, less than 11 EUR per people or less than 0.15 cEUR/kWh.

As the over-cost from those rates will be passed equally over all electricity consumers, this rates system is compatible with the liberalisation of the electricity sector, as it does not involve unfair competition. And it will help France to comply with its national, European and international commitments related to environment, and firstly, to comply with the objectives of the European directive on electricity from renewables.

As the principles, the method and the formula to define such a new rate system are very simple, it would be very easy to adapt it to different wind and cost conditions which prevails in other countries or regions.

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