ASSESSMENT OF "CARBON CREDITS" IMPACTS ON WIND ENERGY PROJECTS PROFITABILITY

Bernard CHABOT
ADEME
500 route des lucioles, 06560 VALBONNE, France
Phone : +33 4 93 95 79 14 - Fax : +33 4 93 65 31 96 - Email: bernard.chabot@ademe.fr

ABSTRACT

A simple method to assess the impact of carbon credits on the profitability of wind energy projects is described and used to study a reference case and to propose conclusions and policy guidelines. This method is based on the "Profitability Index Method". The profitability index (PI) is simply the ratio between the net present value of a project and its initial investment cost. The carbon credits attached to a wind power plant are defined by the amount of avoided CO_2 emissions per delivered kWh of wind energy and their selling price on an environmental derivative market. The simple linear model, its graphic representation and the related formulas to calculate the initial profitability of a project before selling carbon credits are given. Then, a theorem is demonstrated to give directly the related increase in project profitability. This theorem highlights the prominent role of the investment part *Ci* of the overall discounted cost of delivered energy. Those results are integrated in a graphic presentation of profitability increases versus different values of market value of an avoided ton of CO_2 for a reference wind power plant. This graphic presentation is also used to assess and to discuss the different strategies to use the carbon credits: increasing project profitability only, decreasing the kWh selling price only or a combination of both. Some general conclusions will be given from this analysis on the respective role of tariffs systems and carbon credits markets to develop wind power.

KEY WORDS: Profitability, Carbon Credits, Tariffs, Avoided CO2, Derivative Markets

1) INTRODUCTION

Policies to reduce greenhouse gases emissions based on "carbon credits" are already implemented at the European level with the opening of the European Trading System in 2005 and at the international level with the Clean Development Mechanism of the Kyoto protocol. As wind power will be a major contributor to greenhouse gases emissions abatement with a world potential avoided CO_2 emissions of more than 1800 $MtCO_2$/year in 2020 [1] it is necessary to have access to a simple and reliable method to assess the potential impact of such mechanisms on the profitability of wind projects and on the potential development of this technology.
This paper presents the advantages of the "Profitability Index Method" to make this assessment and applies it to the case of a reference European wind power plant avoiding greenhouse gas emissions resulting from a mix of electricity production from conventional power plants emitting in average 0.4 $kgCO_2$/kWhe on a time span of 20 years to come.

2) THE PROFITABILITY INDEX METHOD

The basis of the Profitability Index Method are given in reference [2], together with its application to the design of efficient tariffs systems for onshore wind power.
The profitability index (*PI*) is the ratio between the net present value *NPV* of a project and its initial investment cost *I*. The net present value to take into account in this economic analysis results from the sum of the discounted economic cash flows during the *n* years of operation minus the initial investment cost *I*. Economic cash flows are simply the difference of cash incomes and outcomes (including provisions for big repairs) before tax on annual profits.
The first advantage of the Profitability Index is that and it can be calculated directly from the main parameters and ratios of a wind energy project:

- *Iu* (€/kW), the initial investment cost ratio defined by the initial investment cost *I* (€) divided by the rated power *P* of the wind power plant (kW) .
- *Nh* (hours/year), the mean annual capacity factor, expressed in equivalent hours at rated power and defined by the mean annual energy sold to the grid *Ey* (kWh/year) divided by the rated power *P* (kW).
- *Kom*, the operating and maintenance expenses ratio, defined as the mean annual O&M expenses (including provisions for big repairs) divided by the initial investment cost *I*.

- *CRF*, the capital recovery factor defined by: $CRF = \frac{t}{1-(1+t)^{-n}}$ {1},

  where *t* is the real discount rate defined as the averaged weighted cost of capital (AWCC) before tax resulting from debt and equity and *n* is the number of years of operation of the wind power plant taken into account for the economic analysis.

From those parameters, the profitability index *PI* of a project is:

$$PI = \frac{Nh}{CRF.Iu}Te-(1+\frac{Kom}{CRF}) \quad \{2\},$$

where *Te* is the equivalent constant selling price of wind energy (in €/kWh) during the *n* years of operation. This linear relationship between *PI* and *Te* is represented in figure 1:

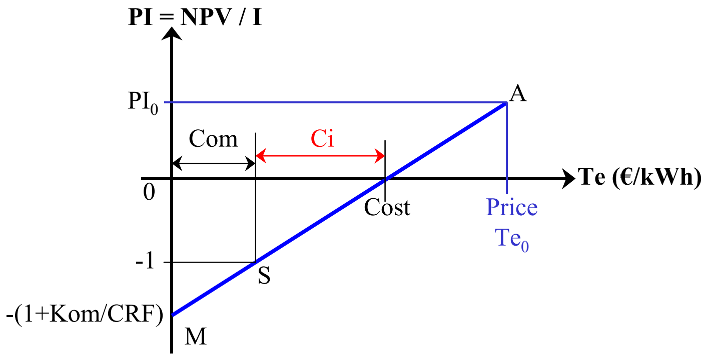

Figure 1: The Profitability Index versus Price of Energy Graph

The point where the *PI* versus *Te* line crosses the horizontal axis defines the Cost of energy (€/kWh), and for a specific selling price of energy Te_0, the profitability index defined by the relevant A point is PI_0 defined by equation {2}.

The S point on the line is defined by an ordinate of -1. Its horizontal coordinate $Com = \frac{Kom}{Nh}Iu$ (€/kWh) represents the operating and maintenance part of the cost of energy, and $Ci = \frac{CRF}{Nh}Iu$ (€/kWh) represents the investment part of the cost of energy.

From above equations or from Figure 1, it is easy to establish a direct relationship between the profitability index of a project *PI*, the investment part of the cost of energy *Ci* and the margin on cost defined as $MOC = \frac{(Price - Cost)}{Cost}$:

$$MOC = \frac{Ci}{Cost}PI \quad \{3\}$$

In order to attract investors in a new technology sector with a global market experiencing a rapid growth such as wind power and in order to ensure a reliable and sufficiently profitable operation of relevant projects, many clues indicate that the minimum global economic profitability level of a project before taxes should be a minimum profitability index value of 0.3. Taking into account this "golden rule", it is easy from equation {2} or equation {3} to define the relevant "efficient selling price of energy (or tariff)" Te_0 from the targeted value PI_0 of the project before selling carbon credits:

$$Te_0 = \frac{(1+PI_0).CRF+Kom}{Nh}Iu = Cost + Ci.PI_0 \quad \{4\}$$

From equations {3} and {4}, one can see that the investment cost part *Ci* and the corresponding cost structure expressed by the ratio between *Ci* and the total cost of energy is of paramount importance in an economic analysis of an investment project.

So, from equation {2} and its related graph in figure 1, one can see that the Profitability Index Method gives the cost of energy, its structure and the project profitability expressed directly in discounted euros per euro invested for a specific selling price of energy Te_0 above its cost. It is also very easy to make sensibility studies for an investment project, as its profitability is given directly by explicit formula within the Profitability Index Method.

3) CARBON CREDITS AND THEIR POTENTIAL IMPACTS ON PROJECT PROFITABILITY

As wind power plants emit no greenhouse gases during operation, each kWh of wind energy can avoid *Qc* kg of equivalent CO_2. The value of *Qc* (kgeCO_2/kWh) depends on the local or regional mix of electricity during the *n* years of operation of the wind power plant.
We will consider further an equivalent constant value Qc = 0.4 kgeCO_2/kWh, resulting from a potential future mix of electricity from fossil fuel-based conventional power plant (steam power plants using coal and emitting around 0.8 kg CO_2 per kWh and combined cycle power plants using natural gas emitting around 0.3 kgeCO_2 per kWh).
Carbon credits will result from those avoided CO_2 emissions, and we will consider that the owner of the wind power plant will be able to sell those carbon credits at a net equivalent constant selling price of *Vc* €/tCO_2 on environmental derivative markets, for example within the frame of the European Trading System to be opened in 2005 or within the frame of the Clean Development Mechanism of the Kyoto protocol. Transaction costs related to this business will be considered as negligible during this analysis.

So, the resulting supplementary income per kWh of wind energy sold to the grid will be:

$$Tc = 0.001.Qc.Vc \text{ (€/kWh)} \qquad \{5\}$$

Taking into account this supplementary income will transform equations {2} and {4} in:

$$\boxed{PIf = \frac{Nh}{CRF.Iu}(Te_0 + Tc) - (1 + \frac{Kom}{CRF})} \qquad \{6\}$$

$$Te_0 = \frac{(1+PIf).CRF + Kom}{Nh} Iu - Tc = Costf + Ci.PIf \qquad \{7\},$$

where *Pif* is the profitability index of the project after selling carbon credits.

So, *Costf* , the resulting cost of energy after selling the carbon credits will be the cost of energy before selling carbon credits minus *Tc*:

$$Costf = Ci + Com - Tc \qquad \{8\}$$

Figure 2 shows the impact of selling carbon credits : the effect is to translate the "*PI* versus *Te*" line horizontally towards the left by a value of *Tc* €/kWh:

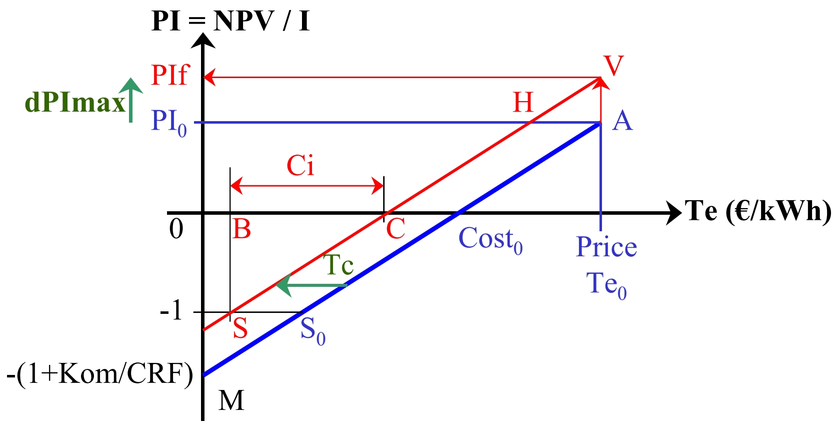

Figure 2: impact of selling carbon credits on the *PI* versus *Te* line

If the selling price of energy TE_0 is not changed, one can see that the profitability index of the project is increased by a *dPImax* value from its initial value PI_0 and is reaching a final value *Pif* defined by:

$$Pif = PI_0 + dPImax \qquad \{9\}$$

4) A FUNDAMENTAL THEOREM

From equations {2} and {6} or from the figure 2 above when applying the Thales theorem to the two triangles AVH and CBS, *dPImax* is given by a very simple relationship:

$$\boxed{dPImax = \frac{Tc}{Ci}} \qquad \{10\},$$

which can be expressed as the "T-C" theorem:

> "The maximum increase of profitability of a sustainable energy project expressed as its maximum change in profitability index is equal to the ratio of the supplementary income per kWh resulting from selling the carbon credits attached to the project to the investment part of the cost of delivered clean energy"

From the definition of *Ci* the relationship {10} can also be detailed as:

$$dPImax = \frac{0.001.Nh.Qc.Vc}{CRF.Iu} \qquad \{11\}$$

And this relationship {10} can also be written as:

$$dPImax = \frac{\frac{Tc}{Cost}}{\frac{Ci}{Cost}} = \frac{relative\_value\_of\_carbon-credit\_to\_the\_cost\_of\_energy}{relative\_part\_of\_investment\_cost\_to\_the\_cost-of-energy} \qquad \{12\}$$

From the above figure 2, the relative increase of profitability from its initial value PI_0 before using carbon credits can be expressed as:

$$\frac{dPImax}{PI_0} = \frac{Tc}{Te_0 - Cost_0} \qquad \{13\},$$

where Te_0 and $Cost_0$ are the values of the cost of energy and of its selling price before using the carbon credits.

5) STRATEGIES TO USE CARBON CREDITS

In the above analysis, all the benefits of carbon credits were used to increase the profitability of the project, leaving the selling price of energy *Te* at the same initial value Te_0.

If the initial profitability level PI_0 of the project is sufficient, an other strategy would be to keep the project profitability at this initial level and to decrease the energy tariff *Te* by a value $dTe = Tc = 0.001.Qc.Vc$ as indicated on the path A-H in the above figure 2. In some cases, this selling price decrease may give a competitive advantage for the project on the electricity market.

If the initial profitability index PI_0 is considered as too low and if the initial selling price of energy Te_0 is considered as too high, a possible strategy could be to limit the increase of profitability to a specific value $dPI_1 < dPImax$ and to lower the selling price of energy to the relevant value dTe_1 given by:

$$dTe_1 = Tc - Ci.dPI_1 \qquad \{14\}$$

6) CASE STUDY FOR A REFERENCE EUROPEAN WIND POWER PLANT

This reference European wind power plant used in this case study is defined by the following parameters:

- 20 years of operation with no residual value of the project.
- Average annual capacity factor expressed in equivalent hours per year at rated power: Nh = 2 000 h/year.
- Initial investment cost ratio: *Iu* = 1000 €/kW.
- O&M expenses ratio: *Kom* = 4 % of initial investment each year.
- CO_2 content of avoided kWh from the wind power plant: *Qc* = 0.4 kgeCO_2/kWhe.

- Equivalent constant selling price of energy on 20 years before selling carbon credits: Te_0 = 7.5 c€/kWh.

Before using carbon credits, the characteristics of the project are:
- Cost of energy : 6.4 c€/kWh, of which 69 % are resulting from the investment part Ci = 4.4 c€/kWh and 31 % from the O&M part Com = 2 c€/kWh.
- Initial profitability index: PI_0 = 0.262

Figure 3 shows those initial characteristics and the impact of using carbon credits defined by a value Vc of avoided ton of CO_2 varying from 5 to 40 €/tCO_2 and a fixed value of avoided CO2 of Qc = 0.4 kgeCO_2/kWhe :

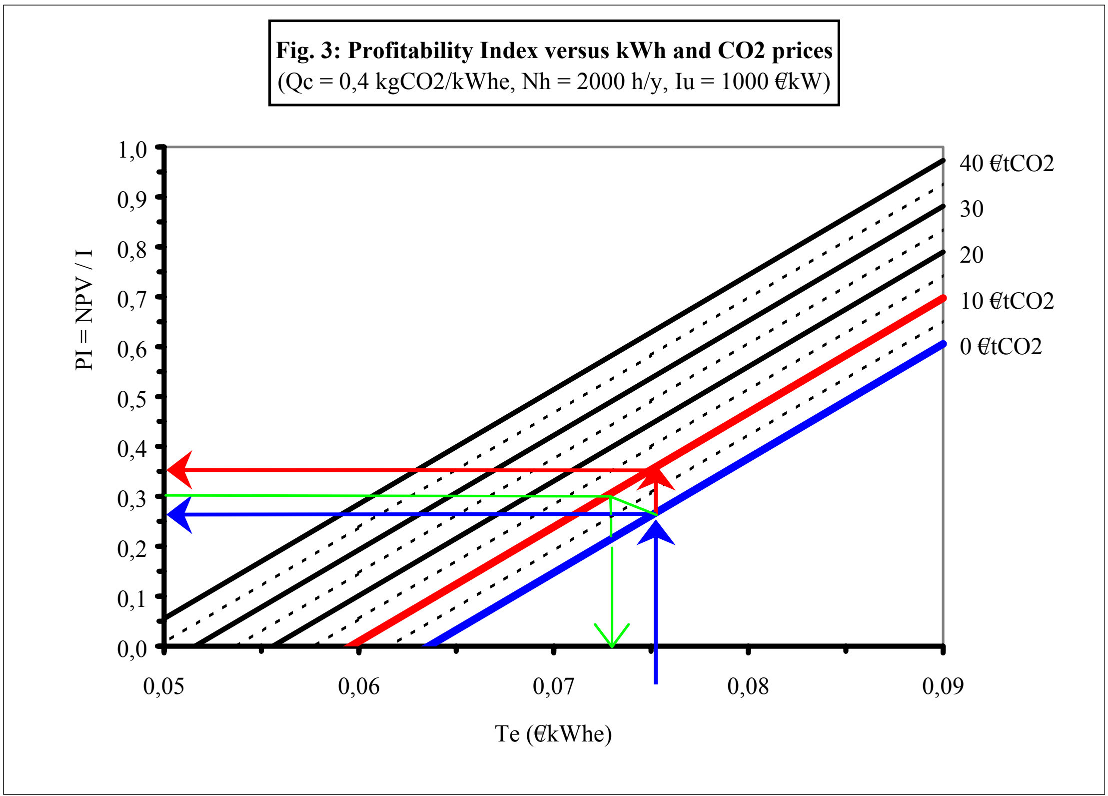

Figure 3: changes in project profitability after using carbon credits with different avoided €/tCO_2 values

For a reference value of Vc = 10 €/tCO_2, the carbon credit value is Tc = 0.4 c€/kWhe, and one can see that with a fixed selling price of energy at 7.5 c€/kWh, the increase of profitability is $dPImax$ = 0.092 (an impressive + 35 % increase for the profitability index and for the net present value of the project), leading to a final profitability of 0.354 well over the 0.3 "golden limit".

If all the value of the carbon credit is used to lower the selling price of energy (with a constant profitability value of PI_0 = 0.262), the relevant value would be - 0.4 c€/kWh (a 5.3 % decrease from the initial value of 7.5 c€/kWh) leading to a final selling price of 7.1 c€/kWh.

And if for example the choice is to increase the profitability level to the "golden value" of PIf = 0.3 (with a profitability index increase dPI_1 = + 0.038 or + 14.5 % of the initial profitability index PI_0 = 0.262) the relevant price of energy decrease from {14} would be dTe = - 0.23 c€/kWh or - 3 % of its initial value of 7.5 c€/kWh, with a final value Tef = 7.27 c€/kWh.

7) CONCLUSIONS

From this analysis, one can see that using the Profitability Index Method gives clearly a competitive advantage to assess carbon credits impacts, to make related sensibility studies using directly the explicit formula and related linear graphs on which the method is based and to choose the best strategies to use those potential carbon credits.

Establishing from this method the "T-C" theorem puts in evidence the prominent and strategic role of the investment part *Ci* of the cost of energy before using carbon credits. As this investment part is around 70 to 80 % of the cost of energy in the case of wind power instead of around 50 % for coal-based power plants and around 30 % for combined cycle natural gas power plants, taking into account this theorem and its related formula gives also a competitive advantage when assessing the potential effects of both carbon credits for wind power and carbon taxes for fossil fuels based power plants.

As shown in the case study based on a reference European wind power plant, the potential effect of carbon credits with a realistic value of avoided CO_2 of only 10 €/tCO_2 over 20 years is noticeable, as the increase in profitability for the wind power project is more than one third in profitability index and in net present value. But this example must be put in perspective with some questionable topics:

- The real value of the avoided amount of CO_2 from a kWh delivered by a wind power project may vary widely from place to places and during its typical 20 years of operation.
- The derivative market value of an avoided ton of CO_2 is not yet known. It will be only during the 2008-2012 time frame of the application of the Kyoto protocol and its flexibility mechanisms that those derivative markets will be firmly established and active with related well known values of avoided ton of CO_2. And after this time frame, new conditions for those markets are not known at present.
- The related contracts for buying carbon credits from wind energy projects are not yet sure to cover a sufficient time frame compared to the 20 to 30 required years of operation of wind projects, adding uncertainties to the above ones.
- The potential decreases for the selling prices of kWh of wind energy assessed in the above case study are relatively low compared to the "base tariff" of 7.5 c€/kWh taken into account in this reference case study. In case of "base tariffs" based only on market price of electricity (around or under 3 c€/kWh), the profitability increase from carbon credits would be clearly too low to make the related wind energy projects sufficiently profitable.

So, it would be clearly premature to decide to base the large scale development of wind power in Europe only on "carbon credits" market mechanisms: the main basis should remain "advanced tariffs", particularly for countries which have already chosen such systems like Germany, Spain, France or Portugal. And carbon credits should be tested only to "boost experimentally" projects profitability with associated risks and rewards.

REFERENCES:

1. EWEA, GREENPEACE, Wind Force 12: A Blueprint To Achieve 12% Of The World's Electricity From Wind Power By 2020, Brussels, 2004.

2. Chabot B, Kellet P, Saulnier B. Defining Advanced Wind Energy Tariffs Systems to Specific Locations and Applications: Lessons from the French Tariff System and Examples. *Proceedings of the 2002 Paris Global Windpower conference*, EWEA, 2002.
