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Wind power generates CO^2-free electricity and so it can also generate 'carbon credits' attached to each delivered kWh. If an environmental derivative market is available, the profitability of a wind power project will result from selling electricity to the energy market and also from selling 'carbon credits' on such a derivative market. And this will be more and more possible as the Kyoto Protocol and its attached main 'flexibility mechanism' the Clean Development Mechanism (CDM) enter into force in 2005 together with the European Trading System (ETS). This article describes a simple and reliable method to assess the increase in profitability by selling carbon credits.

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Carbon Credits and Wind Power

Assessing Their Potential Impact on Project Profitability

Comparing the economic profitability of a wind power project with or without carbon credits valuation over its lifetime is particularly simple and reliable using the 'Profitability Index Method'. Its definition, the related linear model, and the associated formulae and graphs presented here give direct results for reference cases and facilitate sensibility studies.

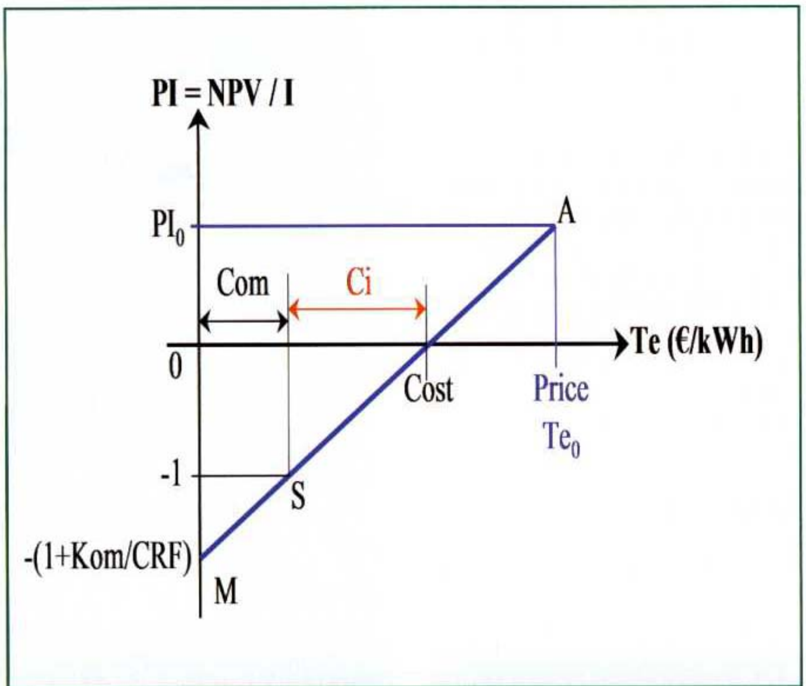


Figure 1 The linear profitability graph

Defining Basic Ratios

The following cost and performance ratios of a wind power plant will be used for its profitability analysis:

- *Iu* (€/kW), the initial investment cost ratio defined by the initial investment cost *I* (€) divided by the rated power *P* (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 pro visions for big repairs) divided by the initial investment cost *I*.
- *CRF*, the capital recovery factor, defined by:

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

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.

Defining the Project Profitability Index

The profitability index (PI) of a project is simply the ratio between its net present value NPV 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 between cash incomes and outcomes (including provisions for big repairs) before tax on annual profits.

From the project ratios defined before, the profitability index PI of a project is:

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

where Te is the equivalent constant selling price of wind energy (in €/kWh) during the n years of operation. One can see from this direct formula that the profitability index is proportional to the selling price of energy. This linear relationship will facilitate cost and profitability analysis and sensibility studies.

Using a Linear Profitability Graph

From the above equation for the profitability index, it is easy to draw the graph in Figure 1 representing the linear variation of the project profitability index versus the selling price of energy.

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 is defined by the relevant A point.
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.

So, from this preliminary analysis we can easily define the cost of delivered wind energy, its structure and, from its difference to the selling price of kWh on the electricity market, the project profitability index.

A 'Golden Rule' for Successful Investors

From Figure 1 it is easy to establish a relationship between the profitability index PI, the investment part of the cost of energy Ci and the margin on cost defined as:

$$MOC= \frac{(Price-Cost)}{Cost} ;$$

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

This universal direct link between the profitability index of an investment project and the commercial margin of the delivered product shows the strategic importance of the relative part of the cost of the product due to the initial investment cost.

From the analysis of success stories in different business sectors, it also allows us to suggest a 'fundamental golden rule' or a 'best kept secret' to be used by investors in search of a robust growth on competitive expanding markets:
'The Profitability Index of successful investment projects should be at least 0.3'

Fundamental golden rule

From this 'golden rule', the relevant 'energy tariff' Te_0 can be defined from the targeted value PI_0 of the project before selling carbon credits:

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

Defining Carbon Credit Characteristics

As wind power plants emit no greenhouse gases, 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 plants and zero emission ones. 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 during the n years of operation of the wind project at a net equivalent constant selling price of Vc €/$tCCO_2$ on environmental derivative markets. Such markets could derive from the European Trading System to be opened in 2005 or from the Clean Development Mechanism of the Kyoto Protocol.

Defining Impacts of Carbon Credits on Project Profitability

The resulting supplementary

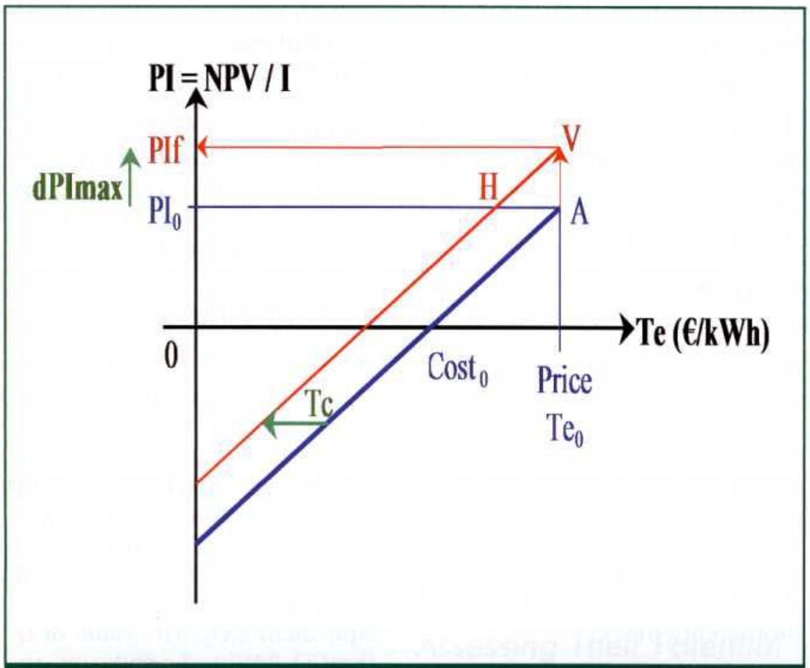


Figure 2 Impact of selling carbon credits on the PI versus Te line

income per kWh of wind energy sold to the grid will be:

$$Tc = 0.001.Qc.Vc \qquad (€/kWh)$$

Figure 2 shows the impact of this supplementary income: the effect is to translate the '*PI* versus *Te*' line horizontally towards the left by a value of *Tc* €/kWh.

So, for a fixed selling price of energy Te_0, the initial PI_0 value of the project profitability index will be increased to a *PIf* final value and the corresponding increase in profitability *dPImax* will be:

$$dP\,Imax = PIf - PIo = \frac{Tc}{Ci}$$

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 equals the ratio of the supplementary income per kWh resulting from selling the carbon credits to the investment part of the cost of delivered clean energy.'

Defining a Case Study

The reference 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* = 2,000h/year
- initial investment cost ratio: *Iu* = 1,000 €/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 % result 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.

Results for the Case Study

Figure 3 shows the impact of using carbon credits defined by a value *Vc* of avoided tonnes of CO2 varying from 5 to 40 €/tCO_2 on this reference wind power plant.

For *Vc* = 10 €/tCO_2, the carbon credit value is *Tc* = 0.4 c€/kWhe, and for a selling price of energy at 7.5 c€/kWh, the increase of profitability is *dPImax* = 0.092, leading to an impressive 35% increase of the profitability index of the project, with a final value of 0.354 well over the 0.3 'golden limit'.

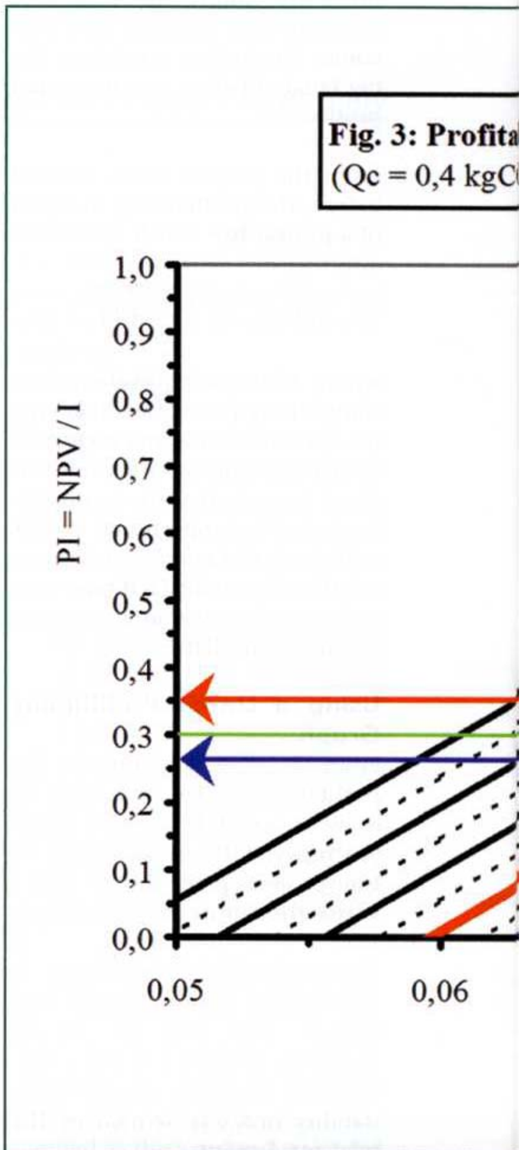


Figure 3 Project profitability graph

If all the value of the carbon credit is used to lower the selling price of energy the price decrease would be -0.4 c€/kWh, or -5.3% .
And if the choice is to get *PIf* = 0.3, the price of energy decrease would be *dTe* = -0.23 c€/kWh or -3%.

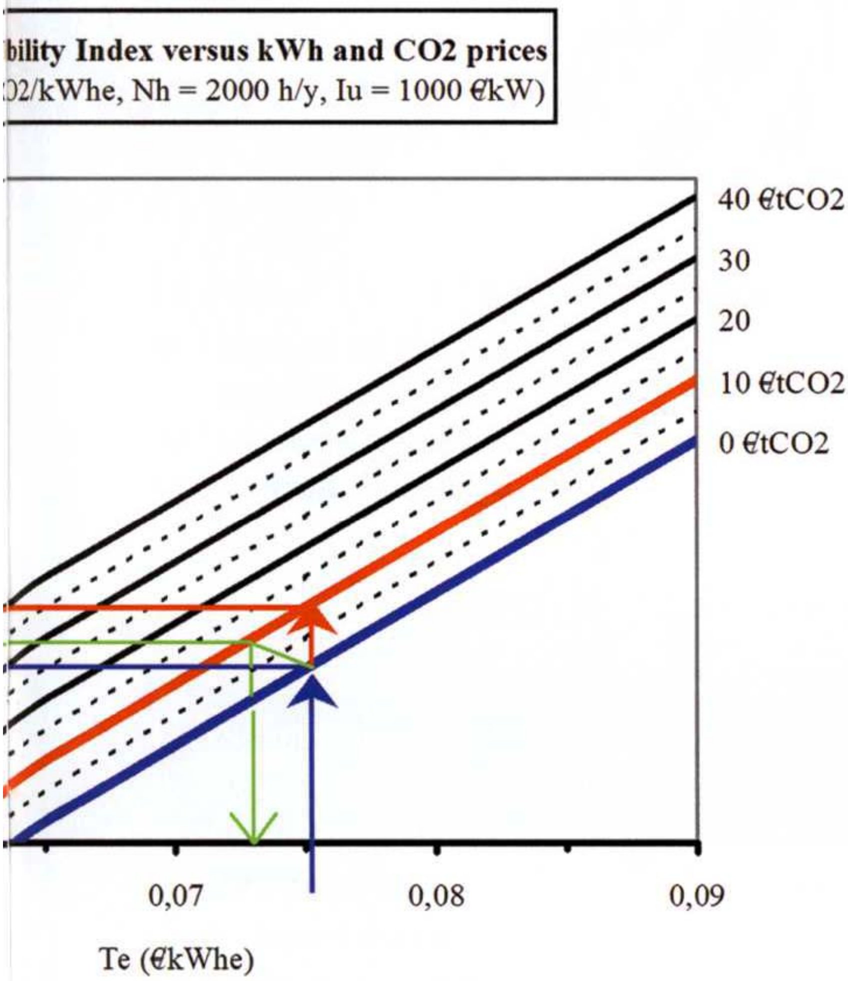
Conclusions

Using the Profitability Index Method clearly gives a competitive advantage in assessing carbon credit impacts and, as shown in the case study, the potential effect of carbon credits is noticeable. 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.
- The market value of an avoided tonne of CO_2 and the duration of purchase con tracts for carbon credits are not yet known.
- In case of tariffs based only on the market price of electricity (less than 4 c€/kWh), the profitability increase from carbon credits would be too low to make the related wind energy projects sufficiently profitable.

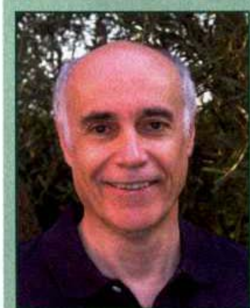
So, it would be premature to base the development of wind power only on 'carbon credits' market mechanisms: the main policy should remain 'advanced tariffs', as those decided in Germany, Spain, France or Portugal. And carbon credits should be tested only to 'experimentally boost' project profitability with associated risks and rewards.

Profitability Index Method gives a competitive advantage



Biography of the Author

Bernard Chabot is Senior Expert at ADEME. As an engineer and economist he is in charge of strategic studies on renewable energy technologies, market deployment and forecast. Since 1998, he has designed a new economic analysis method, the 'Profitability Index Method', and applied it to design the French wind tariff system.



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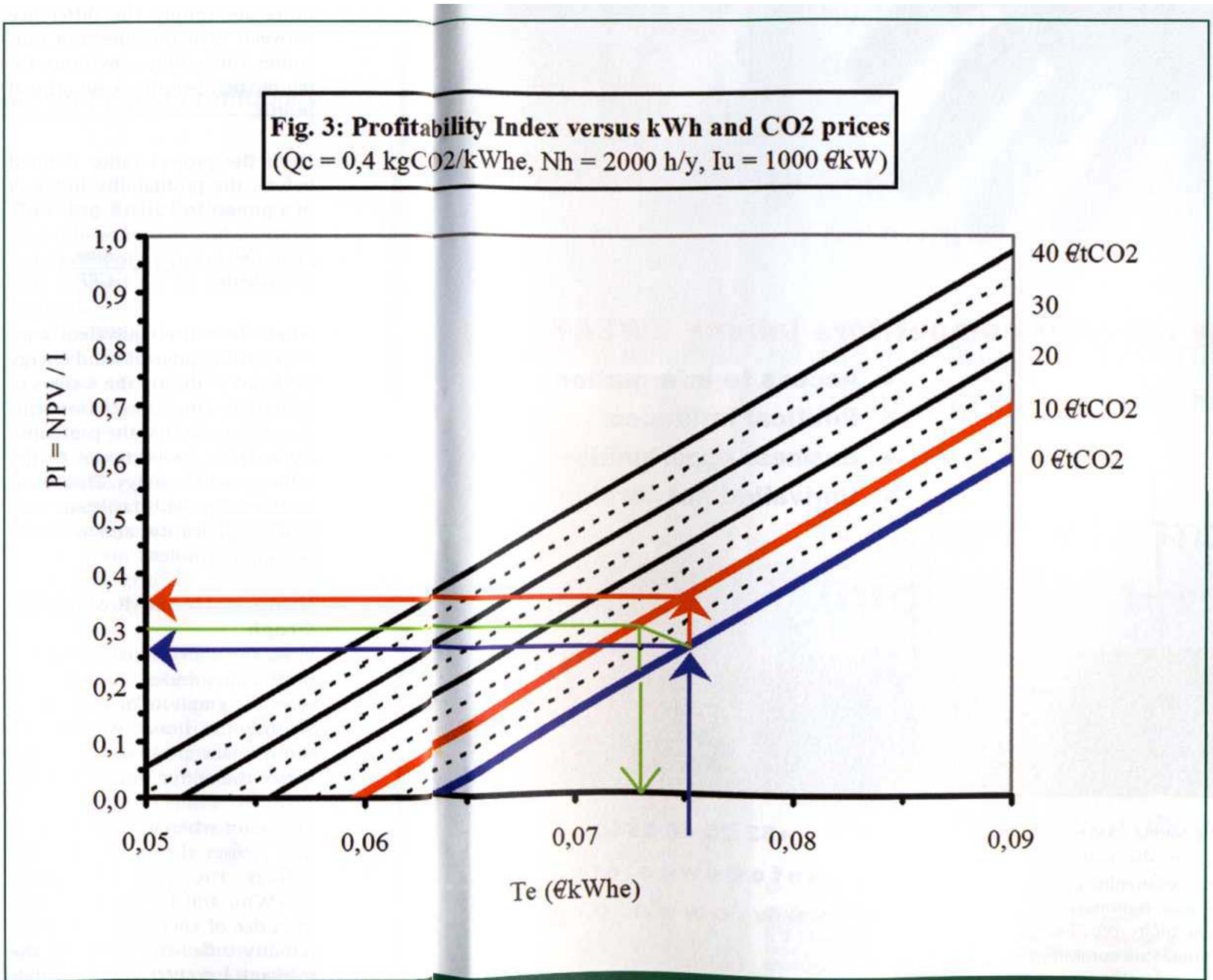

Figure 3 Project profitability graph