A Methodology for the Economic Study of a Wind Energy Project

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August 16, 2021

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***Abstract*—An economic evaluation is essential before any energy project. It can be used to decide on energy purchases, to select on the competing technologies, to finance an energy project, to control costs, to analyze benefits or to make a decision. This work summarizes the needed theory to support decision makers in evaluating the economic profitability of a wind energy project and making decision on investing in it. Moreover, those practical economics analysis can be applied for judging other renewable energies projects. It can be also used to compare different technologies, to compare alternative renewable energies or compare it with conventional energies. Moreover, the results of two applications of this methodology are presented (Estimation of the cost per kWh of wind produced energy at nine wind farms in Morocco and comparison of six turbine models to be installed at Dakhla city in Morocco basing on the cost per kWh of wind generated energy, the payback period and the net present values).**

Keywords- present value, cash flows, net present value, investment, income, cost of energy, payback period, profitability, annual saving, life cycle cost.

I. INTRODUCTION

Wind energy project needs an economics evaluation such as any project because it is an investment that generates an income. By the present work, we summarize the most used key performance indicators in the wind energy field. Which are very important for an engineer to know. Moreover, this note can help investors in evaluating the profitability of a wind energy project, comparing alternative wind energy technologies and making a decision or a judgment in investment on it. It can also be considered as a guide for an engineer outside the economy field that wants to make a decision regarding investment profitability or business performance. For a better prediction, a reliable estimation of the initial investment capital, all costs over the project life (include direct costs, indirect costs, taxes, etc) and incomes are necessary.

In the following part, we explain the Present Value (*PV*) concept, then, we describe the most used economic analysis in the literature for evaluating a wind energy project. The selected ten economics criteria are: the Discounted Cash Flows (*DCF*), the Net Present Value (*NPV*), the Internal Rate of Return (*IRR*), the Benefit to Cost Ratio (*BCR*), the Levelised Cost of Energy (*LCOE*), the Simple Payback Period (*SPP*), the Discounted Payback Period (*DPP*), the Profitability Index (*PI*), the Annual Saving (*AS*) and the Life Cycle Cost (*LCC*). We define each economic method and give its equation. These criteria may be also used to evaluate other renewable energy projects. To compare economically alternative renewable energy projects and compare it with conventional energy systems. Other indicators such as return on investment return on equity, debt to equity ratio and accounts receivable turnover are not reported her, it can be found in [1]. Afterword, we present an overview of works where we have applied some of these performance indicators in reel cases.

II. TOOLS TO EVALUATE AND MAKE DECISION ON INVESTING IN A WIND ENERGY PROJECT

A. The present value approach

One of the most important economic concepts is that money received today has more value than future money. So, to evaluate economically a wind energy project, the cash inflows (incomes) and outflows (costs) over the project lifetime must be brought to a common time reference (conveniently is the time of project starting). That is the present value approach which is shown in Figure 1. For a *PV* placed in a bank at interest *i*, the Future Value *FV* is: [1, 2, 3].

$$FV_1 = PV(1+i), FV_2 = PV(1+i)^2, ..., FV_n = PV(1+i)^n \quad (1)$$

where FV_1, FV_2 , … and FV_n are the future values in the 1st, 2nd, …and *n*th year respectively.

Then, the present value of a receipt or payment after *j* years is given by:

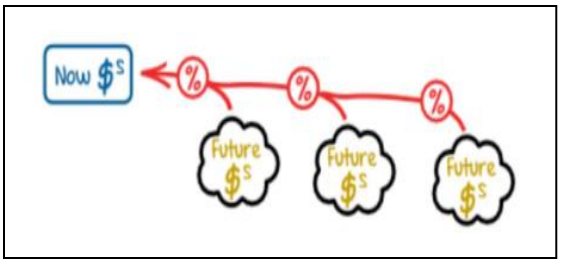

Figure 1: Present value approach. This method is used to bring all future benefits and costs to today's value taking into account the interest rate *i*. The goal is to compare various energies and technologies on an equal basis.

$$\mathrm{PV_j} = \frac{\mathrm{FV_j}}{(1+\mathrm{i})^{\mathrm{j}}} \tag{2}$$

B. *The discounted cash flows analysis*

Discounted cash flows analysis is one of the powerful and easier techniques to make a decision on an energy investment. To estimate the money that can be brought by an investment, this analysis projects and discounts all benefits and costs during the project lifetime at a present value. If the estimated inflows value is higher than the estimated outflows, the opportunity of investment may be good. The sum of cash flows can be expressed as follows [1, 5]:

$$\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{DCF_j} = \sum_{\mathrm{j=1}}^{\mathrm{n}} \frac{\mathrm{R_j} - \mathrm{C_j}}{(1+\mathrm{i})^{\mathrm{j}}} \tag{3}$$

where *n* is the expected project lifetime (years). For a wind energy project, *n* is approximately between 20 and 30 years. $\mathrm{R_j}$ and $\mathrm{C_j}$ are respectively the cash inflows (Return) and outflows (Costs) for the j^{th} year. Figure 2 illustrates the yearly cash flows. It shows the series of annual inflows $\mathrm{R_j}$ and outflows $\mathrm{C_j}$ for the jth year (*j* varies between 0 and *n*).

By considering a uniforms annual cash inflow *R* and outflow *C*, the accumulated present value of cash flows is:

$$\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{DCF_j} = \frac{\mathrm{R-C}}{(1+\mathrm{i})}\left(1+\frac{1}{(1+\mathrm{i})}+\ldots+\frac{1}{(1+\mathrm{i})^{\mathrm{n-1}}}\right) \tag{4}$$

The above equation is a standard geometric series. It can be reduced and simplified to:

$$\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{DCF_j} = \frac{\mathrm{R-C}}{(1+\mathrm{i})}\left(\frac{(1+\mathrm{i})^{\mathrm{n}}-1}{\mathrm{i}(1+\mathrm{i})^{\mathrm{n}}}\right) \tag{5}$$

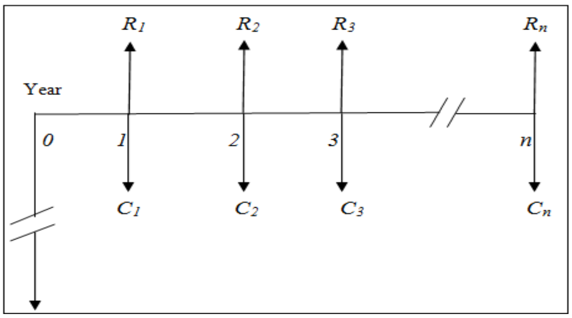

Figure 2: Cash flows diagram. It shows the series of annual inflows $\mathrm{R_j}$ and outflows C_j for the j^{th} year (j varies between 0 and *n*).

C. *The net present value*

The net present value analysis is known also as net present worth, net benefits and net savings. It is another effective and flexible method to determine the long-term profitability of an investment. It is the cumulated present value of cash flows during the project life minus the invested capital $\mathrm{I_c}$ ($\mathrm{I_c}$ includes the turbines purchase, its transportation and its installation) [6, 7, 8, 9]. It is expressed as:

$$\mathrm{NPV} = -\mathrm{I_c} + \sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{DCF_j} \tag{6}$$

Prospective project should be accepted when the *NPV* is positive and it should be rejected if *NPV* is negative. The higher *NPV* values gives the better investment projects.

The annual cash inflows *R* can be given by:

$$\mathrm{R} = \mathrm{E_T} \times \mathrm{E_{SP}} \tag{7}$$

where $\mathrm{E_T}$ is the annual generated electricity and $\mathrm{E_{SP}}$ is the energy sale price.

The annual cash outflow *C* can be estimated by considering the annual operation and maintenance costs, which includes maintenance cost, interest paid to finance the initial investment, annual tax, salary, insurance, rent, etc. It is defined as a percentage *m* of initial investment by:

$$\mathrm{C} = \mathrm{m} \times \mathrm{I_c} \tag{8}$$

Siyal et al. [8] have calculated m by the following formula:

$$\mathrm{m} = 0.25 \times \frac{\mathrm{I_c}}{\mathrm{n}} \tag{9}$$

By replacing *R* and *C* by their expressions in (4) and using (5), the *NPV* can be expressed as:

$$\mathrm{NPV} = \frac{\mathrm{E_T} \times \mathrm{E_{SP}}}{(1+\mathrm{i})}\left(\frac{(1+\mathrm{i})^{\mathrm{n}}-1}{\mathrm{i}(1+\mathrm{i})^{\mathrm{n}}}\right) - \mathrm{I_c}\left(1+\mathrm{m}\frac{(1+\mathrm{i})^{\mathrm{n}}-1}{\mathrm{i}(1+\mathrm{i})^{\mathrm{n}}}\right) \tag{10}$$

D. The internal rate of return

The internal rate of return is also a persuasive indicator to evaluate an investment potential. It determines the interest rate at which accumulated discounted benefits and expenses are equal. In other world, it is the interest which makes *NPV* equal to zero [10]. If the *IRR* is greater than the interest rate, the project may be accepted. For competing projects that require the same amount of investments and the same durations, the one that provides the largest *IRR* should be selected [11].

IRR can be calculated using trial and error method or by numerical techniques such as the Newton-Raphson method.

$$\mathrm{NPV} = 0 \Rightarrow \frac{E_T \times E_{SP}}{(1+i)}\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right) = I_c\left(1 + m\frac{(1+i)^n - 1}{i(1+i)^n}\right) \qquad (11)$$

Use only the *IRR* to make a decision is not enough. It is important to consider other indicators. Figure 3 illustrates how *IRR* can be used together with *NPV* in case of comparing different projects. Thus, a project can be acceptable if *IRR* is the higher and *NPV* is positive.

E. The benefit to cost analysis

This analysis bases on calculation of benefit to cost ratio. *BCR* is a ratio of present value of benefits (numerator) to the present value of all costs (denominator).. This method is similar to *NPV*, the only difference is that it is a ratio instead of a difference. This method is generally utilized in case of competing projects with a limited budget. Projects with a *BCR* greater than 1 are acceptable. Priority is given to projects which have the highest benefit to cost ratio [5, 12, 13].

$$\mathrm{BCR} = \frac{R\left(\frac{(1+i)^n - 1}{i(1+i)^n}\right)}{I_c\left(1 + m\frac{(1+i)^n - 1}{i(1+i)^n}\right)} \qquad (12)$$

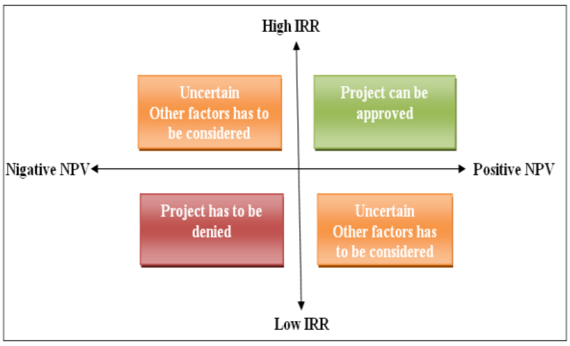

Figure 3: Considering IRR and NPV together [1]

F. The levelised cost of energy

To decide which project or technology merits funding or to compare a renewable energy project with a conventional energy source, levelised cost of energy can also be used. To estimate this indicator, all costs are added, converted to an Annual Cost (*AC*) and devised by the annual produced energy [4, 10, 14]. The annual cost is given by:

$$\mathrm{AC} = \frac{I_c}{n}\left(1 + m\frac{(1+i)^n - 1}{i(1+i)^n}\right) \qquad (13)$$

The *LCOE* is defined as the average cost per kWh of the produced wind electricity. *LCOE* is obtained by dividing *AC* by the annual electricity generation. It is given by:

$$\mathrm{LCOE} = \frac{\mathrm{AC}}{E_T} \qquad (14)$$

The annual produced energy (in kWh/year) can be calculated by:

$$E_T = 8760 \times C_f \times P_R \qquad (15)$$

where C_f and P_R are respectively the capacity factor and nominal power of the installed turbine.

Levelised cost of energy indicates the minimum price needed to break-even. A project is economically feasible when *LCOE* is less than the local electricity price.

G. The simple payback period analysis

Payback period method is the popular economic tool to compare alternatives energy projects in term of number of years to receive the invested capital. It determines the time where an investor is under risk. This criterion gives not any idea about longevity of turbine, for example two turbines may have the same payback period but not the same lifetime. It is not also useful to select the alternative that brings more incomes because it ignores benefits after payback.

Simple payback period is a ratio of the investment costs to the difference of returns and cost per year. It does not take into account the future value of money [2, 15]. It is given by:

$$\mathrm{SPP} = \frac{I_c}{(R - C)} \qquad (16)$$

H. Discounted payback period analysis

Unlike the *SPP*, discounted payback period takes into consideration the variation of money with time [1, 12]. At *DPP* the present value of benefits equals to the present value of all costs. That can be expressed as follow:

$$R\left(\frac{(1+i)^{DPP} - 1}{i(1+i)^{DPP}}\right) = I_c\left(1 + m\frac{(1+i)^{DPP} - 1}{i(1+i)^{DPP}}\right) \qquad (17)$$

The previous equation can be reduced to:

$$(1+i)^{DPP} = (1-\frac{iI_c}{R-mI_c})^{-1} \tag{18}$$

After simplification, we have:

$$DPP = \frac{\ln(1-\frac{iI_c}{R-mI_c})}{\ln(1+i)} \tag{19}$$

I. The profitability index

The profitability index is defined as a ratio of the present value of cash flows to the initial investment capital. If its value is greater than 1, the investment is profitable [2, 16]. *PI* is given by:

$$PI = \frac{DCF}{I_c} \tag{20}$$

J. The annual saving

The purpose of the annual saving is to give an idea about amount of income that can be gotten yearly. *AS* can be estimated using annual wind energy production, wind energy sell price and operation and maintenance cost *C* per unit generated energy as given in following equation [8, 17].

$$AS = (E_T \times E_{SP}) - (E_T \times C) \tag{21}$$

K. The life cycle cost analysis

Life cycle cost analysis considers the present value of all costs over the system lifetime (construction costs, operation costs, maintenance costs and end of life costs). *LCC* method can be used to compare alternative energy systems or the alternative of not making the investment. The limit of this technique is that it takes not into consideration the project cash inflows, so, it is adequate only in case of comparing the cost per unit of output. The disadvantage of not considering the incomes is that some costs are influenced by return such as the taxes on income [18, 19, 20]. *LCC* is expressed as follows:

$$LCC = I_c + O\&M + Repl - Res \tag{22}$$

where *O&M* is the present value of operation and maintenance costs.

Repl is the present value of capital replacement costs. It is the cost to replace goods of company such as a building, means of transport, security etc.

Res is the present value of residual costs (salvage value).

III. APPLICATION TO A WIND ENERGY PROJECT

Investor should choose the type of analysis that is suitable to their case and answer to their questions. For example, a project with short lifetime is less influenced by future value of money, so, the simple payback method can be used to accomplish its cost effectiveness. However, for a project with a long life, life cycle cost analysis may be the useful method. It is recommended to consider many key performance indicators because the higher number of used economic indicators gives the better prediction [1]. We present in this section an overview of works in which we have applied some of these economic analysis in reel cases.

A. Estimate the LCOE at nine wind farms in Morocco

In [21] we have estimated and compared the *LCOE* at nine wind farms in Morocco, namely Tarfaya, Fem El Oued, Essaouira, Tangier I, Haouma, Koudia al Baïda, Laayoune, Tetouan I and Tetouan II. In that study, the economic factors that influence the wind energy cost were reported and deeply detailed. Moreover, an easy and precise economic methodology to estimate it was presented. Results reveals that the minimum *LCOE* is attained at Koudia al Baïda park which is equal to 0.0164 €/kWh. An encouraging cost is obtained also at Essaouira, Tetouan I and Fem El oued with a cost <0.03 €/kWh. For Haouma, Tarfaya, Tetouan II and Tangier I, the *LCOE* is between 0.03 €/kWh and 0.04 €/kWh. While, the park which generates energy with more than 0.04 €/kWh is Laayoune. In general, the obtained *LCOE* are less than the purchase tariff of electricity in Morocco and compare favorably with solar energy production cost in Morocco. Thus, we have concluded that wind energy is economic option to produce energy in Morocco.

B. Compare six turbine models to be installed at Dakhla city in Morocco

In [22] we have reported the key requirement to make a decision on investment in a wind energy project. The wind data were obtained and analyzed at height of 50 m during 5 years at Dakhla city in Southern Morocco. Six turbines with a hub height of 80 m and in which the rated power ranges from 1.5 to 2 MW were tested. In addition to estimation of the energy output and the net capacity factor as a performance indicator, we have conducted an economic assessment for each turbine. The *LCOE*, the payback period and the net present values were calculated. It was found that Acciona AW 82/1500 is the best turbine which achieved the minimum values of *LCOE* and payback period (0.0194 $/kWh and 3.98 years respectively), Moreover, it is ranked second for net present value with a value of 144,243.9279 $. As a conclusion, the turbine

Acciona AW 82/1500 is the most appropriate to be installed at Dakhla city.

IV. CONCLUSIONS

The objective of this work is to provide a brief view on economic methods in deciding the merit of a wind energy project (evaluate its profitability and decide to make the investment or not). The presented economic indicators may be also used in evaluating other renewable energy projects, comparing it with conventional energy sources and comparing alternative energy systems. Thus, this study can be considered as a guide to evaluate and make a decision on a wind energy project in particular and on a renewable energy project in general. For reliability, all costs and incomes should be estimated with maximum precision. Moreover, a sensitivity analysis should be assessed for each indicator (discount rate, project lifetime, initial invested capital, maintenance and operation costs, residual value etc) by varying its value around the original case. The aim is to visualize the effect of each input variation because any change or uncertainty in inputs impacts dramatically the output parameter value. The project environmental and social impacts should also be considered in making a decision.

ACKNOWLEDGEMENTS

The authors would like to thank the Moroccan National Centre for Scientific and Technical Research (CNRST) for sponsoring this study.

REFERENCES

[1] T. Erményi, “Evaluating Investment Profitability and Business Controlling Methods”, *Journal of Economic Literature*, pp. 183-197, 2015.

[2] Investopedia, available at www.investopedia.com (accessed on February, 03, 2019)

[3] G. L. Johnson, “Wind Energy Systems”, Electronic Edition, Manhattan KS, 2006.

[4] A. L. Berka, J. Harnmeijer, D. Roberts, E. Phimister and J. Msika, “A comparative analysis of the costs of onshore wind energy: is there a case for community specific policy support?”, *Energy Policy*, vol. 106, pp. 394–403, 2017.

[5] R. D. Prasad, R. C. Bansal and M. Sauturaga, “Economic analysis for a wind turbine in Vadravadra Village in Fiji”, *Int. J. Agile Systems and Management*, vol. 4, pp. 41–59, 2009.

[6] M. Bortolini, M. Gamberi, A. Graziani, R. Manzini and F. Pilati, “Performance and viability analysis of small wind turbines in the European Union”, *Renew. Energy*, vol. 62, pp. 629–639, 2014.

[7] S. Abdelhady, D. Borello and S. Santori, “Economic Feasibility of Small Wind Turbines for Domestic Consumers in Egypt Based on the New Feed-in Tariff “, *Energy Procedia*, vol. 75, pp. 664–670, 2015.

[8] S. H. Siyal, D. Mentis and M. Howells, “Mapping key economic indicators of onshore wind energy in Sweden by using a geospatial methodology”, *Energy Convers. Manag*, vol. 128, pp. 211–226, 2016.

[9] A. Hemami, “Wind Turbine Technology”, USA Cengage Learning, 2012.

[10] G. C. van Kooten, “The Economics of Wind Power”, *Annu. Rev. Resour. Econ*., vol. 8, pp. 181–205, 2016.

[11] L. De Araujo Lima and C. R. Bezerra Filho, “Wind energy assessment and wind farm simulation in Triunfo-Pernambuco, Brazil”, *Renew. Energy,* vol. 35 pp. 2705–2713, 2010.

[12] S. Mathew, “Wind Energy Fundamentals, Resource Analysis and Economics”, Springer (New York Library of Congress, pp1-246, 2006.

[13] A. Ouammi, R. Sacile, D. Zejli, A. Mimet and R. Benchrifa, “Application to different Moroccan sites”, *Energy Sustainability of a wind power plant,* vol. 35, pp. 4226–4236, 2010.

[14] F. Fazelpour, E. Markarian and N. Soltani, “Wind energy potential and economic assessment of four locations in Sistan and Balouchestan province in Iran”, *Renew. Energy*, vol. 109, pp. 646–667, 2017.

[15] T. Kealy, M. Barrett and D. Kearney, “How Profitable are Wind Turbine Projects? An Empirical Analysis of a 3.5 MW Wind Farm In Ireland”, *Int. J. Recent Technol. Mech. Electr. Eng.,* vol. 2, pp. 58–63, 2015.

[16] D. Zejli, R. Benchrifa, A. Bennouna and K. Zazi, “Economic analysis of wind-powered desalination in the south of Morocco”, *Desalination,* vol. 165, pp. 219–230, 2004.

[17] M. Hammad and M. S. Y. Ebaid, “Comparative economic viability and environmental impact of PV, diesel and grid systems for large underground water pumping application (55 wells) in Jordan”, *Renewables Wind. Water, Sol.,* Vol. 2, pp. 12, 2015.

[18] D. Coyle, “A Life Cycle Cost Analysis of an Irish Dwelling Retrofitted to Passive House Standard : Can Passive House Become a Cost-Optimal Low-Energy Retrofit Standard ?”, *Dublin Institute of Technology,* 2015.

[19] Whole Building Design Guide available at www.wbdg.org (accessed on March, 11, 2019).

[20] W. Sousa De Oliveira and A. J. Fernandes, “Investment Analysis For Wind Energy Projects”, *Rev. Bras. Energ.*, vol. 19, pp. 239–285, 2013.

[21] I. Tizgui, F. El Guezar and H. Bouzahir, “Economics and Policy Estimation and Analysis of Wind Electricity Production Cost in Morocco*”, International Journal of Energy,* Vol. 8, No. 3, pp. 58-66, 2018.

[22] I. Tizgui, F. El Guezar and H. Bouzahir, “Techno-economic Assessment of a Wind Energy Project at Dakhla in Morocco”, *International Multidisciplinary Research Journal,* vol. 8, pp. 10, doi: 10.25081/imrj.2018.v8.3674, 2018.