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Estimation and Analysis of Wind Electricity Production Cost in Morocco

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ABSTRACT

The goal of this investigation is to evaluate, analyze and compare the cost of energy produced at nine wind farms in Morocco, namely Tarfaya, Fem El Oued, Essaouira, Tangier I, Haouma, Koudia al Baïda, Laayoune, Tetouan I and Tetouan II. We report the economic factors that influence the wind energy cost. Then, we give an easy and precise economic methodology to estimate it. The conducted analysis reveals that the minimum cost is attained at Koudia al Baïda park which is equal to 0.0164 €/kWh. The good result is obtained also at Essaouira, Tetouan I and Fem El oued with a cost <0.03 €/kWh. The parks where the energy cost is between 0.03 €/kWh and 0.04 €/kWh are Haouma, Tarfaya, Tetouan II and Tangier I. The park that generates energy with more than 0.04 €/kWh is Laayoune. The sensitivity analysis reveals that for the studied wind farms, the variables which have a greatest effect on the estimated wind energy cost are the interest rate, the produced energy and the project lifetime. The estimated energy cost is not very sensitive to the variation on operation and maintenance costs. The obtained results show also that for all the studied wind farms, the obtained costs of producing one kWh of energy are less than the purchase tariff of electricity in Morocco and compare favorably with solar energy production cost in Morocco. Thus, wind energy is economically beneficial in Morocco, which is due to the important wind resources and the available concessional finance.

Keywords: Investment Cost, Operation and Maintenance Cost, Annualized Cost, Interest Rate, Capital Recovery Factor, Levelized Cost of Energy
JEL Classifications: E4, Q4

1. INTRODUCTION[1]

Until a decade ago, 98.9% of Moroccan energy needs come from fossil fuel with oil price at the time at around 77 €/MWh. In 2010, this country set a national plan for renewable energy with an ambitious target which is to extract 42% of its energy from renewable energy by 2020 and 52% by 2030[2]. According to Moroccan investment development agency[3], Morocco has invested approximately 34 billion € to achieve this plan development, of which 78% is conditional upon international mechanisms to finance climate, like the Green Climate Fund.

Wind is a promising resource of electricity in Morocco, particularly in its north, north-east and south. The average wind speed is 5.3 (m/s) at more than 90% of the kingdom territory. According to the Moroccan wind atlas presented in Figure 1, wind speed varies between 9.5 and 11 m/s at height of 40 m in Essaouira, Tangier and Tetouan. It varies between 7.5 and 9.5 m/s in Tarfaya, Dakhla, Taza and Laayoune[4]. Thus, the country onshore wind potential is estimated to be 25 GW, where 6 GW will be installed by 2030. Morocco wants to bring the installed capacity of wind energy, from 280 MW in

1 To unify the monetary units in this work, we note that we converted all monetary units to Euro (€) by considering the following exchange rates: €/USD=1.3 and MAD/€=11.

2 According to the International Energy Agency, available at "www.iea.org", (accessed on 03 September 2017).

3 Moroccan Investment Development Agency, available at "www.invest.gov.ma", (accessed on 17 September 2017).

4 According to: Renewables Now, available at "www.renewablesnow.com", (accessed on 28 June 2017).

Figure 1: Moroccan wind atlas

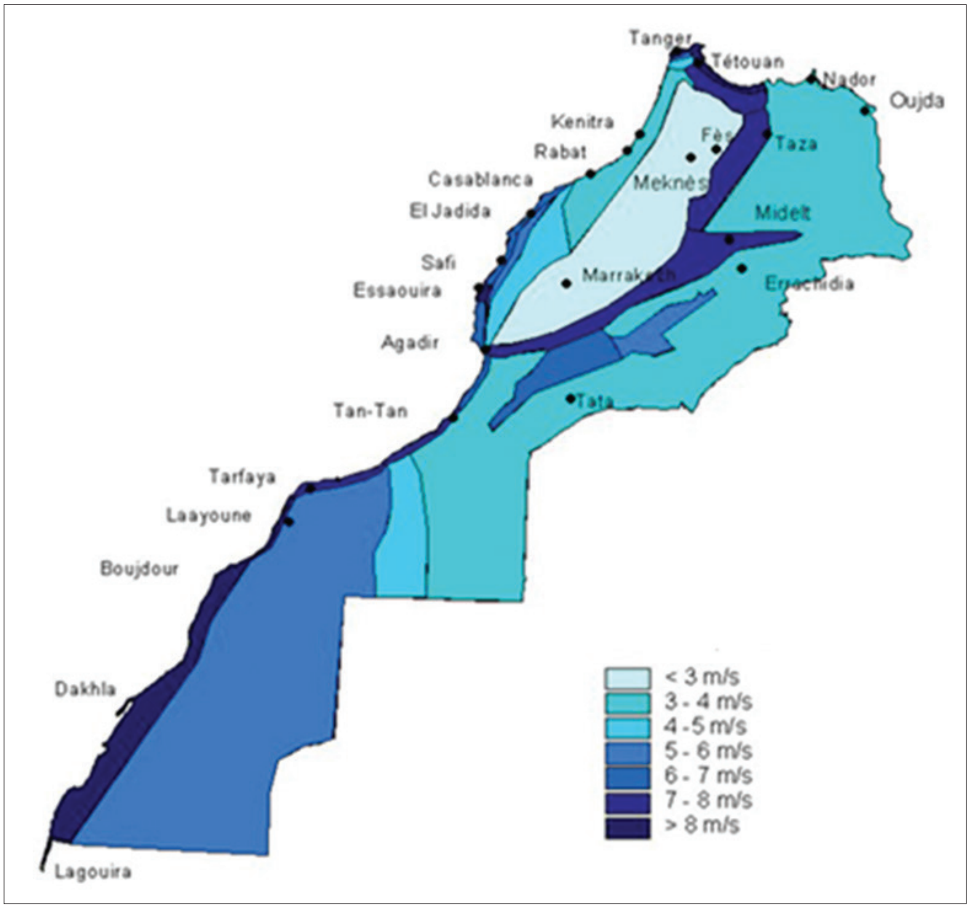
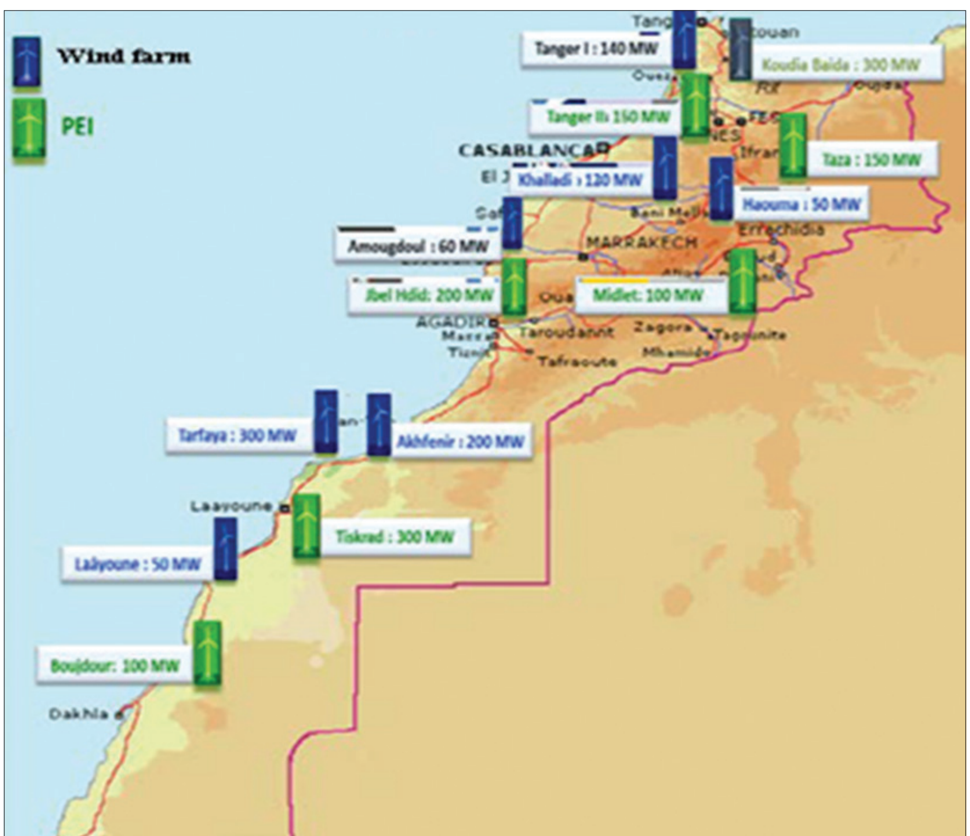


Figure 2: Morocco wind program. PEI: Integrated wind energy program



2010 to 2000 MW in 2020. To meet this aim, this developing country has launched a wind energy plan that aims to produce an annual energy of 6600 GWh by 2020. Figure 2 shows the achieved wind farms and other under development at Morocco. The kingdom invested 2.87 billion €. That will enable it to save annually 1.5 million tons of fuel and to match the sum of 577 million €. The last 850 MW was contracted in January, 2016 and is now under construction in five projects. Its commissioning is expected between 2017 and 2020. In its tender for 850MW, Morocco has announced an average wind energy cost of 23 €/MWh and a lowest at around 19.2 €/MWh[5]. This new cost in the world is reinforced by the strong wind resource in Morocco and available concessional finance. Indeed, to support its energy plan, Morocco has created an Energy Investment Company (SIE) with a capital of 90.9 million €. Its funding benefits from the resources mobilized under the frame of the Energy Development Fund with 153.8 million € as a contribution of the Hassan II Fund for Economic and Social Development and a donation from the Kingdom of Saudi Arabia (384.6 million €) and UAE (230.7 million €).

An economic evaluation is essential before, during and after 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. For that, calculating the Levelized cost of energy (LCOE) per kWh is very interesting. It takes into account all costs during the system lifetime[6]. Estimating LCOE is useful to assure expenses are paid and benefits are collected. LCOE is often used to compare competing energy producing technologies. In this study, it will be used to evaluate, analyze and compare the energy cost at nine wind farms in Morocco.

For specific areas and different wind turbines technology, several studies have been made by authors to analyze the wind energy economics notably the energy production cost. For instance, Marafia and Ashour (2003) have analyzed the cost of energy at two parks in Qatar. They have compared on one hand the cost of energy generated by wind and gas turbines and on another hand the cost of energy generated by onshore and offshore wind turbines. The results have proved that the cost of energy output from a wind turbine is 0.0289 €/kWh which is low compared with 0.0342 €/kWh for energy produced by a gas turbine. For offshore wind turbines, the cost of energy is less about 8% compared with onshore one. In Iran, Mohammadi et al. (2016) have compared the cost of electricity delivered by four types of wind turbines in order to select the most appropriate economical turbine. The lowest value that they have obtained is 0.044 €/kWh, which is lower than the electricity price in Iran (0.1 €/kWh). Saeidi et al. (2013) have evaluated the energy cost produced by a vertical axis wind turbines. They have shown that this type of turbines generates more energy, especially at areas with low turbulence and low wind speed. That proved a reduction of 0.046 €/kWh in energy cost. We also cite Mostafaeipour (2013) who has conducted an economic assessment of three small wind turbines by analyzing their costs and benefits. Fazelpour et al. (2017) have conducted an economic assessment in order to evaluate the energy cost in four sites and propose the suitable turbines that maximize the benefit for each one. At three towns in the south of Morocco (Tan-Tan, Laayoune and Dakhla), Zejli et al. (2004) have compared the cost of sea-water desalinated by vapor compression powered by wind turbines and reverse osmosis. The obtained LCOE by wind turbine is 0.05 €/kWh, which shows that using wind energy is the most interesting solution.

Basing on the literature, Section 2 focuses on reporting the factors that influence the wind energy cost. In fact, before any wind project, it is very important for an engineer to know those factors. Furthermore, an overview on methodology to estimate the wind energy cost is presented. Thus, the methodology summarized in this section can be considered as a guide for an engineer outside the economy field that wants to estimate the wind energy cost for making a decision. Section 3 of this work.

Concerns the description of nine wind farms in Morocco, namely Tarfaya, Fem El Oued, Essaouira, Tangier I, Haouma, Koudia al Baïda, Laayoune, Tetouan I and Tetouan II. To assess the cost of the delivered energy at those parks, the available data and many economics assumptions are presented. Afterwards, Section 4 gives an evaluation, analysis and comparison of energy cost at the cited wind farms. To determine the effects of varying the key assumptions on LCOE, we carry out the sensitivity analysis by changing the values of interest rate, operation and maintenance costs, energy output and projects lifetime. Moreover, we deal with comparing the cost of wind and solar energies in Morocco.

2. METHODOLOGY ON ESTIMATION OF WIND ENERGY PRODUCTION COST

The purpose of this section is to analyze the most important economic indicators that influence directly the wind electricity cost and give an overview on methodology followed in the literature to estimate the net present cost (NPC), the total annualized cost and finally the LCOE. Figure 3 summarizes the methodology to estimate the wind energy production cost.

2.1. Economic Factors Influencing the Wind Energy Cost

The wind electricity cost is strongly influenced by the investment cost, the operation and maintenance cost and the financing cost. Those factors are defined in the following part.

2.1.1. Investment cost

The investment cost or initial capital cost (I_c) is any cost from the project idea until the operation date. I_c depends on the used technology and site. As stated by Johnson (2006) and Manwell et al. (2009), I_c involves the turbine and its component purchase, its transportation and installation (foundation construction, installing the turbine, connection to the grid, testing, and commissioning).

5 According to: EcoMENA, Echoing Sustainability in MENA, available at "www.ecomena.org", (accessed on 15 June 2017).

6 A wind energy system is expected to operate for a limited duration which is called lifetime.

Figure 3: Methodology to estimate the wind energy production cost

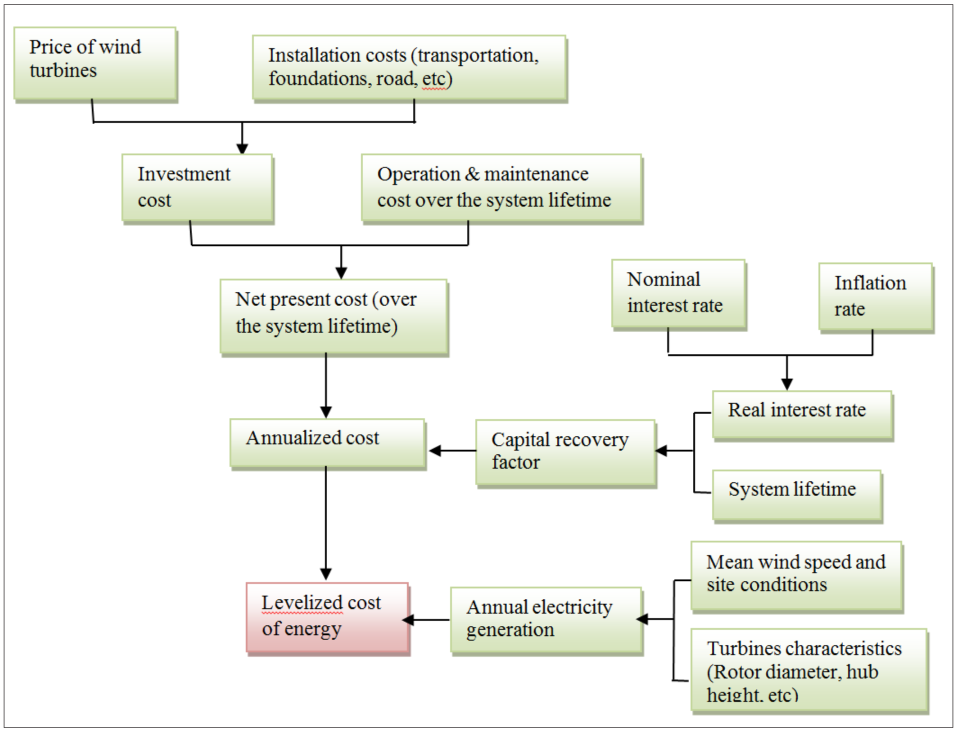
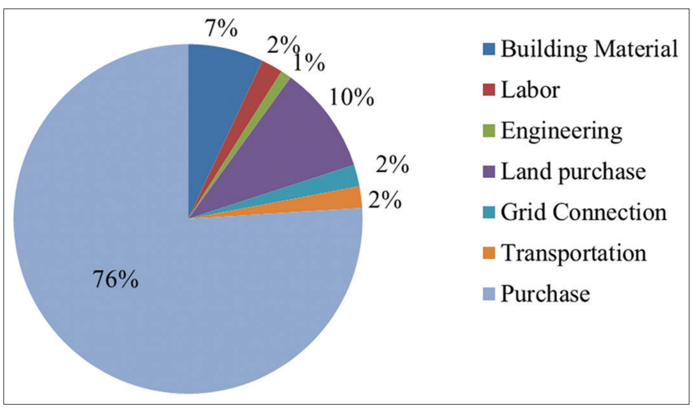


Figure 4: Investment cost distribution



It includes also, indirect costs such as the purchase of land, roads to access the site and legal fees. The investment cost distribution differs from one author to another. For example, for installing a small wind turbine in US.

Bortolini et al. (2014) have considered the investment cost distribution reported in Figure 4. As one can note, the cost of the wind turbines makes more than 70% of the whole cost of wind farm project. Recently, the wind turbine price has increased because of its size growth (increase in height, blades and rotor diameter), which increases its weight and the cost of its installation (transportation, tower and foundation). However, the International Renewable Energy Agency has stated that compared to 2016 levels, wind turbine prices will decline by 27% in 2025 (IRENA 2016). As specified by Hemami (2012) and Manwell et al. (2009), a typical cost for an onshore wind turbine is 769.23 €/kW of its rated power, and for offshore wind turbine is 1230.77 €/kW. Other initial costs are in general taken to be 40% of the wind turbines price.

2.1.2. Financing cost

The cost of wind electricity is also impacted by financing costs, which are defined by Manwell et al. (2009) to be the costs that have been burned at the beginning to finance the equipments purchase and installation. The wellspring of capital might be a bank or speculators. The money lenders will expect a return on the credit. In the case of a bank, the return is called interest. Over the project life, the cumulative interest can add up to an important amount of the total costs.

2.1.3. Operation and maintenance cost

Operation and maintenance cost (O&M) starts when the wind project is delivering electricity. It is the cost of repairing turbines damages and keeping it operating under safe conditions during the project lifetime. In other word, O&M gathers the costs of requiring monitoring and maintenance to optimize performance from specialized wind technicians and operators (corrective maintenance, preventive maintenance, insurance, lease, taxes, salary, insurance, running, etc). Fazelpour et al. (2017), Mohammadi et al. (2016) and Minaeian et al. (2017) have defined O&M as a percentage *m* of I_c by:

$$O\&M = m\ I_c \tag{1}$$

m ranges generally from 1.5% to 3% and it increases with the age of the turbine. For old wind turbines, it is approximately equal to 3% and for modern machine it varies between 1.5% and 2%[7]. In an economic evaluation of a wind project in Morocco[8], *m* was taken to be 2%.

7 According to: Wind Measurement International, available at "www.windmeasurementinternational.com", (accessed 01 October 2017).

8 Sahara Wind, available at "www.saharawind.com" (accessed on 17 September 2017).

2.2. NPC

Ramli et al. (2016) and Al-Sharafi et al. (2017) have defined the NPC of a system as the total cost of installing and operating the system over its lifetime. The same authors have calculated the NPC using the following formula:

$$NPC = I_c + O\&M \tag{2}$$

Siyal et al. (2016) have defined NPC as a life cycle cost of a wind energy system. For them, total NPC of a wind energy system is the sum of initial investment cost, operation and maintenance cost and salvage cost. They have used this equation to estimate NPC.

$$NPC = I_c + O\&M + S_C \tag{3}$$

Where, S_C is the salvage cost of the wind energy system, which is the cost of decommissioning a wind energy system, transport and sell its components to another power supplier.

2.3. Total Annualized Cost

As we cited previously, NPC is the total cost of a wind energy system over lifetime. To convert it into total annualized cost, it is important to note that in economic field, money today has not the same value as tomorrow. This difference is due to the interest rate, which is used to convert from one-time costs to annualized costs (AC).

2.3.1. Annual interest rate

In the economic assessment, it is supposed that all costs escalate at the same rate. The annual real interest rate (*i*) can be defined as the yearly yield that a lender anticipates from borrowers. It can be calculated as follows:

$$i = \frac{i' - f}{1 + f} \tag{4}$$

Where *i'* is the annual nominal interest rate, and *f* is the annual inflation rate.

2.3.2. Capital recovery factor (CRF)

The CRF is a ratio used to convert total NPC value into total annualized cost over a number of years *n* (system lifetime) and at a specified interest *i*. As reported by Hemami (2012), CRF can be calculated as follows.

$$CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{5}$$

A period of n = 20 years is often assumed for an economic assessment. By improving the wind turbine design, a lifetime of 30 years was utilized in US economic studies. But that demands a major annual maintenance of wind turbines to replace key parts.

Haghighat Mamaghani et al. (2016) have estimated AC using the following equation:

$$AC = NPC * CRF \tag{6}$$

To estimate AC, Drew et al. (2015) annualized just I_c, because they have estimated the O&M costs for 1 year, they have used the following equation:

$$AC = I_c * CRF + O\&M \tag{7}$$

2.4. Levelized Production Cost of Energy

Hosseinalizadeh et al. (2017) and Haghighat Mamaghani et al. (2016) have defined the levelized cost of energy as the average cost per kWh of the produced wind electricity. LCOE is obtained by dividing AC by the annual electricity generation E_T (in kWh/year). It is given by:

$$LCOE = \frac{AC}{E_T} \tag{8}$$

In other word, LCOE is the minimum price needed to break-even. A project is economically feasible when LCOE is less than the local electricity price. Recently, LCOE has recently decreased because of the significant advancement in the technology, markets competition and the economies of scale. That is due also to the wind turbine size growth (increase in height, blades and rotor diameter) which allows a greater energy generation (because wind speed increases with height and the produced energy is proportional to the swept area).

2.5. Sensitivity Analysis

For a complete economic assessment of a wind energy project, it is very important to include sensitivity analysis for estimation of the output variable. In fact, there is a degree of uncertainty in the assumed economic variables and any change in this inputs impacts dramatically the output parameter value. Each variable must be varied around the original case in order to visualize its influence.

Several studies that assess the wind energy economics perform a sensitivity analysis of the calculated parameter. For example, to assess the sensitivity analysis of LCOE in Essaouira wind power project[9], O&M costs and the discount rate have been increased by 10% and 2% respectively. Athanasia (2012) has conducted a sensitivity analysis of cost and income of electricity by varying the tax rate and the project lifetime. He has concluded that the cost of electricity increases as the tax rate increases and the project lifetime decreases. Siyal et al. (2016) have analyzed the influence of initial capital, interest rate and selling price of electricity on the cost of produced wind energy, the net present value and the payback period. The obtained results show that the cost of electricity increases as the interest rate and the initial investment cost increase. To visualize the sensitivity of the calculated net present value, Johnson and Solomon (2010) have varied the interest rate, electricity prices, produced electricity and other costs. Liu et al. (2016) have performed the sensitivity analysis of LCOE by changing values of initial investment, interest rates, O&M costs and wind turbine power and diameter. We cite also Neij (1999) who has analyzed the impact of varying the progress ratio on the cost of generated wind energy. His results show that this variable has significant impact on the calculated energy cost.

3. WIND ENERGY COST ASSESSMENT AT NINE MOROCCAN WIND FARMS

In this study we selected nine onshore Moroccan wind farms for which the needed details of an economic evaluation are available. Those farms are named Tarfaya, Fem El Oued, Essaouira,

9 Clean Development Mechanism Project (2004), Design Document Form (CDM PDD).

Table 1: Geographical coordinates and the commissioning date of the studied parks[11]

Wind farm	Geographical coordinates	Commissioning date
Tarfaya	27.715871, −12.946883	December, 2014
Fem El oued	27.015034, −13.388821	2013
Essaouira	31.413263, −9.802698	March, 2007
Tangier I		
Beni Mejmel	35.760841, −5.688281	April, 2009
Dhar Saadane	35.592920, −5.574541	April, 2010
Haouma	35.80772, −5.490889	2013
Koudia al Baïda	35.79292, −5.461139	August 2000 (50.4 MW)/2001 (3,5 MW)
Laayoune	27.15642, −13.34039	October, 2011
Tetouan I	35.605864, −5.438227	May, 2005
Tetouan II	35.614724, −5.430151	December 2008 (5 T*)/June 2009 (6 T)

*: T=Turbine

Table 2: Technical data of installed wind turbines at the studied farms[12]

Wind farm	Turbine model	Number of turbines	Rated power (kW)	Hub height (m)
Tarfaya	SWT-2.3-101	131	2300	80
Fem El oued	SWT-2.3-101	22	2300	80
Essaouira	G52/850	71	850	---
Tangier I				
Beni Mejmel	G52/850	39	850	65 (127 T), 55 (19 T) and 49 (19 T)
Dhar Saadane		126		
Haouma	SWT-2.3-93	22	2300	80
Koudia al Baïda	V42/600	84	600	---
	E40/500	7	500	
Laayoune	G52/850	6	850	---
Tetouan I	G52/850	12	850	44
Tetouan II	G80/2000	11	2000	60 (6 T) and 67 (5 T)

---: Data not available

Tangier I, Haouma, Koudia al Baïda, Laayoune, Tetouan I and Tetouan II. Table 1 gives the geographical coordinates and the commissioning dates of the studied parks, whereas Table 2 presents the technical characteristics of the installed wind turbines at the studied farms. An economic evaluation by calculating LCOE for each park is the goal of this section.

3.1. Economic Analysis Data and Assumptions

To carry out the economic assessment, the available data and the assumptions differ from one author to another. For our case:

- The total investment capital including all costs (turbines purchase, site, land preparation, consultancy, design, equipment, transportation and project management, etc.) is available. It is reported in Table 3.
- The yearly produced wind energy is also available. It is reported in Table 3.
- The normal interest rate is i = 2.25% and the inflation rate is 2.1% (for January, 2017[10]).
- The following information was supposed.
- The lifetime of the studied turbine is taken to be n = 20 years (Marafia and Ashour, 2003, Mohammadi et al. 2016).
- To estimate O&M over the project lifetime, we use equation (1). As per (Fazelpour et al. 2017), m is taken to be 2% of the wind turbine cost.
- To estimate NPC, we use equation (2). In this study we don't take into account the salvage cost, because we estimate that the remaining value of a wind power system can be used to cover the cost of decommissioning the farm.
- To calculate AC, we use equation (6).
- The purchase tariff of electricity in Morocco is 0.0830 €/kWh (Zejli et al., 2004).

4. RESULTS AND DISCUSSION

4.1. Analysis and Comparison of the Estimated LCOE

We developed an Excel calculation tool for the evaluation of the LCOE. Using the mentioned values of normal interest rate, inflation rate and turbines lifetime, the annual real interest rate and the CRF are 4.84% and 0.0792 respectively. Basing on the available data and assumed value of m, the estimated O&M, NPC and AC are presented in Table 4.

Table 4 shows also the obtained results for LCOE per kWh at the studied wind farms. This cost is affected by the sites characteristics and the installed technologies. The wind park that produces energy with less cost is Koudia al Baïda (0.0164 €/kWh) followed by Essaouira, Tetouan I and Fem El oued (with 0.0227 €/kWh, 0.0234 €/kWh and 0.0245 €/kWh respectively). The parks where the LCOE is between 0.03 €/kWh and 0.04 €/kWh are Haouma, Tarfaya, Tetouan II and Tangier I. The park that generates energy with more than 0.04 €/kWh is Laayoune. Figure 5 illustrates the estimated LCOE for each park. We observe that the highest cost of kWh is obtained at Laayoune farm which is equal to 0.0459 €/kWh, while

10 Trading economics, available at: "www.tradingeconomics.com" (accessed on 07 September 2017).

11 Wiki eolienne, the wind power collaborative project, available at: "https://eolienne.f4jr.org" (accessed on 20 September 2017).

12 The Wind Power, Wind Energy Market Intelligence, available at "www.thewindpower.net" (accessed on 24 June 2017).

the lowest value is observed at Koudia al Baïda park which is equal to 0.0164 €/kWh. Thus, we conclude that in terms of LCOE, the park of Koudia al Baïda is more promising. The private sector and the government can keep and expand the investment in this park. In general, all studied farms generate a benefit because for all of them, the LCOE is less than the electricity price which is 0.0830 €/kWh in Morocco. This is clearly beneficial for investors and government.

4.2. Sensitivity Analysis

To perform the sensitivity analysis of the estimated LCOE at the studied parks, we change individually the interest rate, the O&M costs, the energy output and the projects lifetime. Figure 6 illustrates the sensitivity analysis of LCOE by varying the interest rate over the interval [1%, 10%]. From this figure, we can say that the LCOE depends strongly on the interest rate variation. We note that an increase in the interest rate generates an increase in the LCOE and a decrease of the interest rate results a decrease in LCOE. Figure 7 presents the effect of O&M cost variation on the LCOE. For all parks, as it can be seen, O&M costs have the lower effect on the LCOE. We vary the O&M costs over the range of [−60%, +60%] but we don't note any significant change on LCOE. Figure 8 clarifies the dependence of the LCOE on the energy output. For the studied farms, we vary the produced energy by a margin of ±10, 20, 30%. It is clear that LCOE drops with the increase of the energy output. Figure 9 shows the impact of varying the studied projects lifetime between 15 and 30 years. We note that an extend in a project lifetime leads the cost of energy production. In contrast, lowering the projects lifetime causes a great increase in LCOE.

Table 3: Investment cost and yearly energy output at the studied parks[11]

Available data	Tarfaya	Fem El oued	Essaouira	Tangier I	Haouma	Koudia al Baïda	Laayoune	Tetouan I	Tetouan II
I_c (million €)	450.0000	61.6000	59.0909	250.0000	72.7273	46.0000	9.0909	11.0000	35.0909
E_T (MWh/year)	1187724.6	202700	210000	526500	192000	226000	16000	38000	77000

Table 4: Estimated O&M, NPC, AC and LCOE for the studied parks

Costs	Tarfaya	Fem El oued	Essaouira	Tangier I	Haouma	Koudia al Baïda	Laayoune	Tetouan I	Tetouan II
O&M (million €)	9.0000	1.2320	1.1818	5.0000	1.4545	0.9200	0.1818	0.2200	0.7018
NPC (million €)	459	62.8320	60.2727	255.0000	74.1818	46.9200	9.2727	11.2200	35.7927
AC (million €)	36.3333	4.9736	4.7710	20.1852	5.8721	3.7141	0.7340	0.8881	2.8333
LCOE (€/kWh)	0.0306	0.0245	0.0227	0.0383	0.0306	0.0164	0.0459	0.0234	0.0368

Figure 5: Estimated LCOE for each park (in €/kWh)

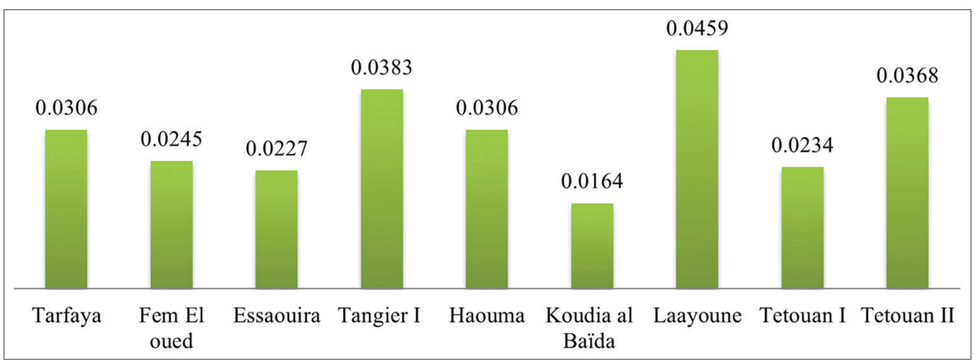


Figure 6: Effect of varying interest rate on the LCOE

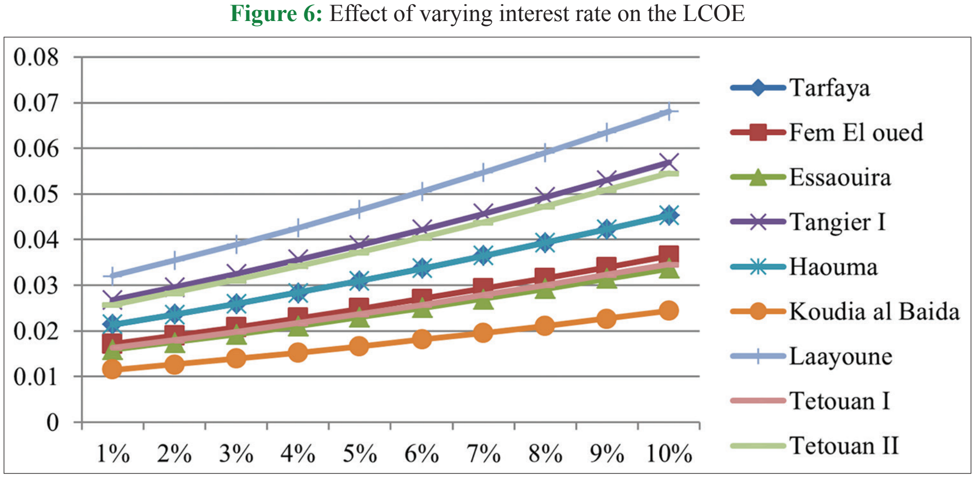


Figure 7: Effect of varying O&M on the LCOE

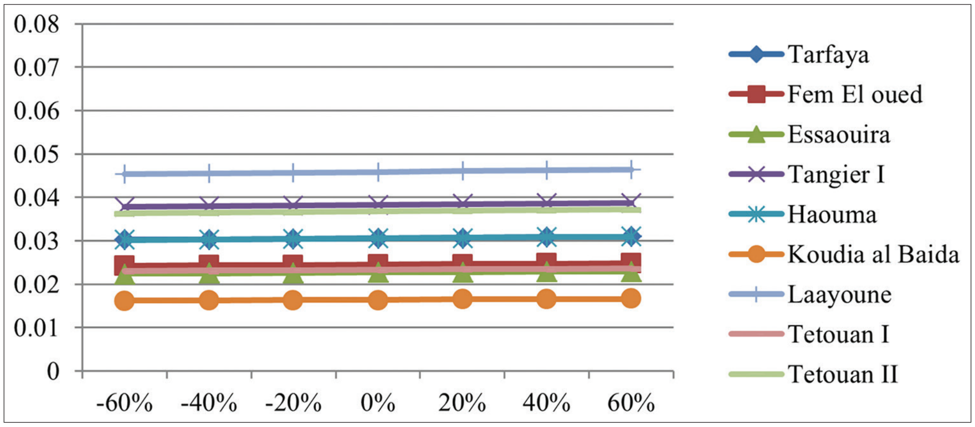


Figure 8: Effect of varying the energy output on the LCOE

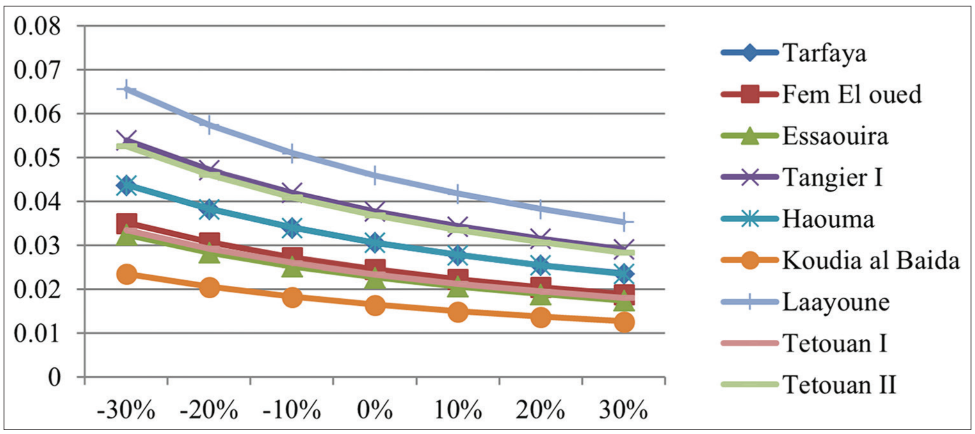
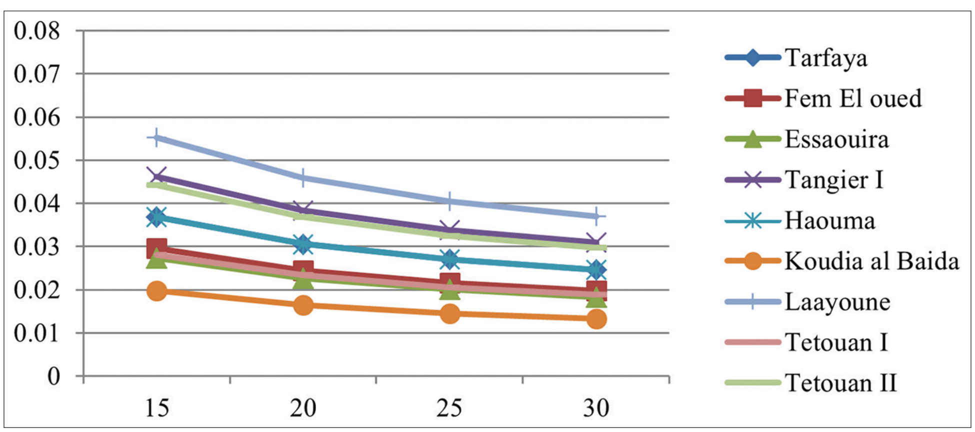


Figure 9: Effect of varying the project lifetime on the LCOE



4.3. Comparison of Wind and Solar Energies LCOE in Morocco

In Morocco, wind energy is more attractive and competitive with other energy sources. In fact, its cost compares favorably with the solar energy one.

For example, according to World Bank[13] the energy generated by the solar farm NOOR I costs 0.2050 €/kWh, and 0.1506 €/kWh in case of concessional financing. It costs 0.1590 €/kWh for NOOR II and 0.1464 €/kWh for Redstone. Indeed, for installing the same capacity of 2000 MW of wind and solar energies, Morocco has invested in solar energy more than wind energy (3.13 billion € for wind energy plan and 8.12 billion € solar energy plan), that is due to the expensive solar energy technologies, its maintenance and operation costs. By 2020, the generated wind energy will be 6600 GWh, while, the generated solar energy will be just 4500 GWh. That explains a good capacity factor of wind energy systems comparing with solar systems. Thus, in Morocco, wind is economically more appropriate for producing energy.

13 The World Bank, IBRD. IDA, available at: "www.worldbank.org" (accessed on 03 September 2017).

5. CONCLUSION

This paper summarizes the most important economic factors that affect the energy cost and summarized the method of determining the levelized cost of electricity. Then, a case study of nine wind parks in Morocco, namely Tarfaya, Fem El Oued, Essaouira, Tangier I, Haouma, Koudia al Baïda, Laayoune, Tetouan I and Tetouan II is achieved. The following results can be extracted from the evaluation, analysis and comparison of energy cost at the cited wind farms.

- The minimum LCOE is attained at Koudia al Baïda park which is equal to 0.0164 €/kWh. The good result is obtained also at Essaouira, Tetouan I and Fem El oued with a LCOE <0.03 €/kWh.
- The parks where the LCOE is between 0.03 €/kWh and 0.04 €/kWh are Haouma, Tarfaya, Tetouan II and Tangier I. The park that generates energy with more than 0.04 €/kWh is Laayoune.
- For all the studied wind farms, the obtained costs of producing one kWh of energy are less than the purchase tariff of electricity in Morocco (0.0830 €/kWh). Moroccan government should encourage investors to continue investment at those parks considering that the current wind energy projects are expected to operate for a limited duration. That will help the country to become more independent in the energy field and make investors and government generating an enormous profit in addition to fuel saving and emissions reduction.
- From the sensitivity analysis, we conclude that for the studied wind farms, the variables which have a greatest effect on LCOE are the interest rate, the produced energy and the project lifetime. The LCOE is not very sensitive to the O&M costs variation.
- Due to important wind resource and investment in wind technology manufacturing, the wind energy cost in Morocco compares favorably with the solar energy cost. Thus, in Morocco, wind is economically more appropriate for producing energy.

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