American Journal of Modern Energy
2019; 5(1): 1-4
http://www.sciencepublishinggroup.com/j/ajme
doi: 10.11648/j.ajme.20190501.11
ISSN: 2575-3908 (Print); ISSN: 2575-3797 (Online)

Modified Levelized Cost of Electricity or Energy, MLOCE and Modified Levelized Avoidable Cost of Electricity or Energy, MLACE and Decision Making

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To cite this article:
Huseyin Murat Cekirge, Serdar Erturan. Modified Levelized Cost of Electricity or Energy, MLOCE and Modified Levelized Avoidable Cost of Electricity or Energy, MLACE and Decision Making. *American Journal of Modern Energy*. Vol. 5, No. 1, 2019, pp. 1-4.
doi: 10.11648/j.ajme.20190501.11

Received: MM DD, 2019; **Accepted**: MM DD, 2019; **Published**: MM DD, 2019

Abstract: LCOE is the Levelized Cost of Electricity or Energy, which is an economic measure of the minimum price at which energy can be produced over the lifetime of the power plant. This value determines the minimum value at which energy could be sold during the lifetime of the installation, and this value is considered as the net present value of unit cost electricity. It is estimated dividing the net present value of the total expenditure by the total production. The LACE is the Levelized Avoided Cost of Electricity or Energy which is a measure of income for the unit value of electricity. Of course, the value of LCOE should be less than the LACE for considering the project, these metrics are necessary but not sufficient to start the project. For overcoming these difficulties, in this paper MLCOE (Modified Levelized Cost of Electricity or Energy) and MLACE (Modified Avoided Cost of Electricity or Energy) are introduced to the calculations for considering dominant factors of construction of a plant and these are the actual estimations of CAPEX (Capital Expenses) and OPEX (Operation Expenses) through the payback period. The methodology presented in this paper will be an important supporting tool for power plant investments of go - or - not go decision.

Keywords: Levelized Cost of Electricity, LCOE, MLOCE, Levelized Avoidable Cost of Electricity, LACE, MLACE, Discount Sensitivity, Payback Period

1. Introduction

The cost of electricity or energy generation may differ considerably if the source is considered in production. The cost of electricity is given as per kilowatt-hour or megawatt-hour which includes the initial capital, finance costs, fuel costs, waste disposal and other operation costs, i.e. CAPEX and OPEX costs. These estimations are for assisting policymakers, investors and decision makers. The LCOE [1, 2] is dividing the total expenditure on the power plant over its expected lifetime by the total energy produced during this period. The LCOE calculations include capital costs, fuel costs, fixed and variable operations and maintenance costs, financing costs, and an assumed utilization rate for each plant type. The LCOE is an assessment of the average cost of for building and operating a power plant. The LCOE provides a means or metric for conveniently summarizing and measure the overall competitiveness of different energy-generating technologies but does not consider all possible factors when making an investment decision. It should be that these values are calculated by using through proper discount rate.

The LACE is the income from the grid or the possible revenue from the plant that is the sum of the years the present value of economic income generated over the life of the power plant divided by the sum of energy generation over the lifetime of the plant.

Power plants may be thought economically feasible, when their projected LACE (value) is more than their projected

LCOE (cost). The LCOE and LACE are the net present values during the lifetime of the plant, these values are in dollars per megawatt hour. These values differ the situation of locality of the plant, sources, fuel costs, other factors and governmental regulations, these are CAPEX and OPEX.

The levelized cost of electricity (LCOE) is a metric of the average income per unit energy from an economically viable power plant. If the metric LCOE compared with the levelized avoided cost of electricity (LACE), or projected average revenue obtained by the power plant, a rough estimate of economic acceptable production technology that can be determined.

In the planning of a large power plant, the lowest LCOE is desired for continue towards to construction, [3]. The LCOE has several limitations, that metric simplifies CAPEX AND OPEX coasts without considering interest rates and financial constraints., [4]. In these calculations, the project risks, non-financial factors and unreal objective truths are not considered. The important factor, such as fuel costs and OPEX, differ in various production technologies, there is no possibility that a single metric can be the answer for investment decisions, [5, 6].

However, the major factor in these calculations are the loans' interest values and payback period requirements. These factors influence the values of LCOE and LACE significantly and they should be considered in these estimations. Therefore MLCOE (Modified Levelized Cost of Electricity or Energy) and MLACE (Modified Levelized Avoidable Cost of Electricity or Energy, MLACE) are introduced for considering these factors. These calculations explained in the next section.

2. MLOCE and MLACE

The LCOE is that the value of total levelized expenditure over the life of the plant divided by total energy production,

$$\text{LCOE} = \frac{Sum\ of\ costs\ over\ plant\ life}{Sum\ of the\ \text{electricity}\ produced\ over\ plant\ life}$$

The Levelized Cost of Electricity (LCOE) is given as:

$$\text{LCOE} = \sum_{t=1}^{n} \frac{I_t + O_t + F_t}{(1+i)^t} \Big/ \sum_{t=1}^{n} \frac{E_t}{(1+i)^t} \quad (1)$$

where

I_t = levelized annual cost of the plant finance,

O_t = levelized annual operation and maintenance expenditure,

F_t = levelized annual other expenditure,

E_t = amount of electricity produced annually,

n = total lifetime in time of years

t = year and

i = is the discount rate.

This formula takes into account both the CAPEX and OPEX of the plant. The above equation is strongly influenced by the payback period; after this period,

$I_t = 0$,

therefore Equation (1) should be used as MLCOE (Modified Levelized Cost of Electricity or Energy);

$$\text{MLCOE} = \left(\sum_{t=1}^{m} \frac{I_t + O_t + F_t}{(1+i)^t} + \sum_{t=m+1}^{n} \frac{O_t + F_t}{(1+i)^t}\right) \Big/ \sum_{t=1}^{n} \frac{E_t}{(1+i)^t} \quad (2)$$

where

m = year in which the payment of capital expenses ends.

It should be noted that in solar power plants, the fuel cost,

$$F_t = 0,$$

that influences the LCOE significantly, and the MLCOE, should be used for the solar power plants. After the year of m, the CAPEX expenses become unnoticeable, then Equation (3) becomes for solar power plants [7, 8],

$$\text{MLCOE} = \left(\sum_{t=1}^{m} \frac{I_t + O_t}{(1+i)^t} + \sum_{t=m+1}^{n} \frac{O_t}{(1+i)^t}\right) \Big/ \sum_{t=1}^{n} \frac{E_t}{(1+i)^t} \quad (3)$$

It may be awkward, however the production in the denominator of Equation (1) is also discounted, that is sometimes referred to as the “discounted energy” [9 - 11], the discounting is actually a result of the algebra in Equation (1) where revenues were discounted. Through, these facts, virtual overproduction of energy is prevented.

LACE in mathematical form, Namovicz [12], is introduced as,

$$\text{LACE} = \frac{Sum\ of\ energy\ revenues\ over\ plant\ life}{Sum\ of\ the\ \text{electricity}\ produced\ over\ plant\ life}$$

which can be written in the following form [13-15],

$$\text{LACE} = \sum_{t=1}^{n} \frac{R_t + C_t}{(1+i)^t} \Big/ \sum_{t=1}^{n} \frac{E_t}{(1+i)^t} \quad (4)$$

where

R_t = annual revenue by considering dispatchability or intermittency of the source energy,

C_t = annual capacity revenues.

$$\text{MLACE} = \left(\sum_{t=1}^{m} \frac{R_t + C_t}{(1+i)^t} + \sum_{t=m+1}^{n} \frac{R_t}{(1+i)^t}\right) \Big/ \sum_{t=1}^{n} \frac{E_t}{(1+i)^t} \quad (5)$$

MLACE, for example, can not consider the time of day during which a plant on the grid can generate power, and its carbon intensity, and other variables. For that reason there venue from the power plant, MLACE considers means of marginal price for the units of the energy production. Profit is the difference between revenue and cost, if the marginal revenue exceeds the marginal cost, then the facility is feasible. The MLCOE and MLACE are useful metrics for this purpose.

For these analyses, the value m that is presenting payback period of the loan. This value can be determined by the given interest rate by solving the following equation;

$$\text{L} = \sum_{t=1}^{m} \frac{P_t}{(1+i)^t} \quad (6)$$

where

L = total loan, and

P_t = annual loan payment.

The solution of Equation (6), m or i can be obtained by using iteration methods. According to market conditions; if the payback period is given, an acceptable value $\boldsymbol{i}$ can be calculated or vice versa. Through these values MLCOE can be estimated, of course, MLCOE must be less than MLACE for a feasible operation.

3. An Example

An illustrative example is presented in this section, the data for 6 MW solar power plant is the following, Table 1:

Table 1. *The Power Plant Data.*

Production hours (h/year)	3487
Electricity production power (MW)	6
Total electricity production (kWh/yr)	20922000
Total cost ($)	9,800,000.00
OPEX ($/year)	310,000.00
Loan share	0.8
Lifetime of the plant (year)	25

By using Equation 6, the loan cannot be paid in 13 years by selling kWh for $ 0.01 with discount rate 0.03.

Table 2. *Loan Payment, $ 0.01 per kWh.*

Return time (years)	13
Interest rate	0.03
Interest rate	0.01
Unit Price ($/KWh)	2,719,860
Income ($)	4,030,000
OPEX ($)	2,195,200
Interest ($)	7,840,000
Principal ($)	1,960,000
Equity payment	-13,305,340
Total ($)	NOT POSSIBLE

Table 3. *Loan Payment, $ 0.057 per kWh.*

Return time (years)	13
Interest rate	0.03
Interest rate	0.057
Unit Price ($/KWh)	15,503,202
Income ($)	4,030,000
OPEX ($)	1,646,400
Interest ($)	7,840,000
Principal ($)	1,960,000
Equity payment	26,802
Total ($)	POSSIBLE

Table 2 presents that the power plant can be functional if there is a loan for 0.03 interest rate for 13 years, if $ 0.057 per kWh. The question is here, that this sale value is acceptable by the market and less than MLACE. This method gives more insight for feasibility of the power plant, then the metrics of LCOE, MLCOE, LACE and MLACE become meaningful. Table 4 presents further information for calculation of these values.

Table 4. *Further data for calculating LCOE, MLCOE, LACE and MLACE.*

Discount Rate	0.03
Marginal sell price per kWh ($)	0.12
Tax Incentives ($per kWh)	0.04
Dispatched hours (%)	60
Payback period (year)	13
Lifetime (year)	25

For LACE AND MLACE calculation, the dispatch percentage is chosen as 60, and marginal sell price is $ 0.12, based on this scenario, see Table 5.

Table 5. *LCOE, MLCOE, LACE and MLACE values.*

LCOE ($ per kWh)	0.055
MLCOE ($ per kWh)	0.048
LACE ($ per kWh)	0.240
MLACE ($ per kWh)	0.193

Table 5 presents MLCOE that gives more encouraging value and however MLACE results in a less encouraging value. These values are all depending on the selected scenarios and controlled by the loan's interest rates and payback periods.

Likewise, MLCOE and MLACE can be extended for water plants as MLCOW and MLACW and for heat plants as MLCOH and MLACH.

4. Conclusions

In this paper, it is shown that the relationship between financing and production that is not often considered in other approaches. The investor can expose to more sound influence of discount rate and payback period through MLOCE and MLACE. MLCOE investigates a realistic relationship between production cost and loan payback period or interest rate. The initial cost of new a project financed by the investors demands appropriate energy price to meet the loans requirement. MLCOE pictures real situation of the finance of a power plant. The policy makers, investors and designers can conceive the actual impact of the payback period and discount rate on the finance of a power plant through these modified metrics. MLACE is quite important for intermittent energy sources, such as solar and wind energy. These metrics can be easily extended for more detailed calculations and scenarios.

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