Techno-economic performance and feasibility of biomass energy system: Tunisian case study

TROUDI FATHI[1,*], JOUINI HOUDA[1], AND ABDELKADER MAMI[1]

[1] University Tunis El Manar, Laboratory LAPER, 2092 Tunis, Tunisia.
[*] troudi.fathi@gmail.com

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Rural electrification by the main grid entails large investments and losses. For this, the use of a decentralized energy system such as biomass is very interesting. The main objective of this article is to assess the technico-economic performance of the biomass energy electrical system designed for the electrification of a remote rural area by presenting a Tunisian residential case study located in a north-eastern region. Thus, a mathematical programming model has been developed, whose input is the different economic costs of electricity generation, to determine the optimal radius to grow, thereby reducing the cost of megawatt-hours and thus maximizing the PI profit index. The economic efficiency of the biomass energy system is proven by results under operating conditions specified in the study such as the number of consumers and the price of the biomass energy system indicated by Is. The preliminary study of the energy consumption in the case study makes it possible to highlight the impact of energy consumption and the specific investment Is on the profit index PI. Also, the best electricity production and the corresponding specific investment are determined by technical and economic research to ensure a reasonable price per MWh. This proves that a single specific investment specified $Is = 1,200,000\$$ making it possible to obtain a positive PI profit index provided that the price per MWh will be $55\$/MWh$.

keywords: *Biomass energy, Specific investment, Optimal radius, Profit index*

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1. INTRODUCTION

Faced to challenge and the depletion of traditional resources renewable energy is all the more usable for generating electrical energy. Biomass generation systems offer an optimal solution for satisfying village energy demands to minimize the annual cost [1]. Some developing countries can only provide 13% of their electricity consumption in the European Union [2], and thermochemical systems offer an adequate solution to provide electricity in these areas[19].Biomass energy can be considered as a renewable energy source that is exploitable for electrical energy and heat production. The global installed capacity in the world exceeds. The Biomass source is an optimal solution for supplying isolated sites with electrical energy. Two methodologies are used to generate biomass energy: the first one is the direct combustion of organic elements (waste of plant or animal origin) the second is the combustion by methanation in the case of certain substances which are not directly burned but which are fermented to be transformed into Biogas close to natural gas [3].TThis kind of energy has several advantages such as the raw materials that are renewable and can be produced indefinitely by using it reasonably and durably, Rapid biodegradation of combustion residues, availability of the biomass product everywhere (plant residues, animal residues .....), and the possibility of a co-energy transformation (electricity, heat). Nevertheless, this energy has few drawbacks: like energy efficiency is quite low, Biomass energy production requires the exploitable land occupation and therefore the agricultural production is reduced, an excessive release of CO_2 which exceeds the plants' absorption capacity (photosynthesis) water and soil pollution and the impacts of the biomass resource transfers on production costs and among other things the cost of KWh produced. To ensure a balance between the biomass energy produced and its selling price while respecting the environmental constraints [2], several works have been done for this purpose, especially for isolated sites, which focuses mainly on the modeling and economic study of a biomass plant. Mr. Mahadevan and al [1] have proposed an economic model biomass electric power generation while presenting the sale profit estimation of KWh. They presented the technical and operational parameters and the economic objectives associated with the proposed investment. The authors did not present a technical study of the electric power distribution and the study of the energy consumption to appropriate the production system output.Elisa Moretti and the all [2] presented the performance of a boiler at Biomass (100 kW) in the commercial building case study, they presented an environmental assessment of the BHC (Biomass Heating and Cooling) energy system then he presented the CO_2 emission assessment criterion and the size limits of the particles released by collecting the samples while obeying the UNI Standard technical agreement in 2010-2009. Mr. Muharrem and al [4] have established an energy analysis of an organic cycle unit (ORC) in a plant manufacturing biomass-based forest product. This analysis was performed to implement the effect of condenser pressure on energy and exergy efficiency. The authors tested the adopted model on two different operating conditions according to the criterion of energy and exergy efficiency.

Also, Muharrem et al. have proven by experimental studies the effect of condenser pressure on the energy and exergy efficiency of the ORC unit. However, this study did not focus on the economic study.Md Rezwanul Karim and al [5] presented a three-dimensional numerical 3D model of Biomass combustion and the difficulties of implantation while presenting the Biomass element physical characteristic influences, the geometric model as well. The article did not present the types of Biomass energy exploitation and the energy efficiency of the Biomass system.

Mr. Łukasz Dragun [6] presented the contribution of biomass combustion in the electrical energy and heat production and also presented the problems encountered and related to the biomass combustion contribution. Thus, he presented the biofuel sharing histograms, the water production and electric power wind in Poland 2011-2013, and the growth of biofuels demand either for cooling in the summer either for the warming up to winter and the guidelines of good exploitation of natural resources bio-fuel. However, at the same moment as introducing the investment rate, the author did not present a scientific analysis of the output of electrical energy from biofuels as well as the energy cost.

In this context, this paper is focused on the proof study including the electrical energy production based on biomass energy using a technique of direct combustion of organic plant elements as well as adopted models, for the electrical energy the production and secondly the techno-economic feasibility of such an installation by estimating the production total cost and optimizing the Biomass system profitability. Mr. Batidzirai and the all [7] presented a monitoring and technical assistance economic and environmental methodology for the mobilization and exploitation of agricultural residues for large scale energy applications in South Africa. The work presents an economic study while taking into consideration the different criteria of durability constraints to calculate the Biomass cost operated for conversion into electrical energy. In this article, the authors did not present a solution for the increase of the energy efficiency of the Biomass system and they did not present the auxiliary solution which is the coal. Furthermore, they did not mention a solution for increasing CO_2 in the environment and they did not present the criterion of the suggested size of the CO_2 particles [8].

We present for this situation study the energy utilization and makes it conceivable to feature the effect of his impact on the particular speculation Is on the benefit record PI. Thus this paper is divided into three parts: the first part interested in the presentation of Biomass energy types namely biomass energy by anaerobic digestion and biomass energy by direct combustion of organic elements. The second part presents a techno-economic study of a plant-based on biomass energy by direct plant residues combustion by presenting the different plant production phases, treatment, and combustion of plant elements. The third part will be devoted to a case study presenting the influence of the consumer numbers, the price of MWh, and the specific investment I_s on the profitability of the system.

2. BIOMASS ENERGY

The biomass energy process is ensured by two transformation types, such as the biological transformation by anaerobic digestion based on anaerobic digestion by fermentation and the thermochemical transformation that is formed by combustion pyrolysis and gasification. The supplied biomass energy drives a steam turbine that drives a generator to produce electricity.

A. Biological transformation by anaerobic digestion

Organic substance is naturally transformed by the biological process of anaerobic digestion in which microorganisms decompose in the absence of oxygen. This process produces biogas rich in energy with a methane content ranging from 55/100 to 75/100 and a carbon dioxide content of 25/100 to 45/100. The biogas value produces a 6-7 KWh/dry tone from the methane content. Anaerobic digestion is considered renewable because the produced biogas can offset fossil fuel consumption .[6] . The procedure for generating energy from biomass by anaerobic digestion is carried out by several steps following the block diagram of Fig. 1.

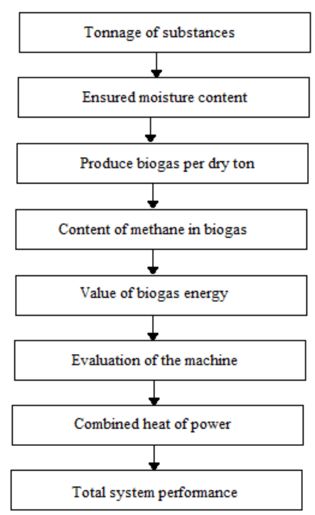

Fig. 1. Synoptic diagram of biomass energy by anaerobic digestion.

The methane volume contained in the produced biogas depends on the substance type undergoing anaerobic digestion. The following table illustrates the energy production of the different substances as well as the different parameters estimated. [7].

B. Thermochemical transformation by combustion

The sequences of the thermochemical transformation process are mainly the organic element drying, the element pyrolysis

Table 1. Theoretical estimation of energy production from anaerobic digestion of substances.

	% dry	Biogas $m^3/t.dry$	% CH_4	Power kWh /t.dry
Liquid cattle manure	6-11	100-800	60	6
Solid cattle manure	25-30	600-800	60	6
Chicken manure	10-29	270-450	60	6
Liquid pig manure	3-10	300-800	65	6.5
Solid pig manure	20-25	270-450	60	6
Cutting of herbs	37	700-800	54	5.4

by combustion, and the oxidation phase to obtain the gas of combustion. Presuming the full combustion of fuel elements the combustion gas essentially contains CO_2, HO_2, SO_2, N_2 and O_2. Which are the main chemical elements of the fuel. The flow rate of the combustion gas is calculated as follows.

$$GCV = 0.3491.X_C + 1.1783.X_H + 0,1005.X_S + 0.0151.X_N + 0.1034.X_O + 0.0211.X_{ash}[MJ/kg]. \quad (1)$$

knowledge of the fuel constituents. [15]. The calorific value of the fuel is given by the following equation:

$$NCV = GCV(1-\frac{w}{100}) - 2.444\frac{w}{100} - 2.444.\frac{h}{100}.8.936.(1-\frac{w}{100})MJ/kg \quad (2)$$

Where : The difference in enthalpy between the gaseous and liquid phase of water. knowing that the coefficient is equal to 2.444. w : moisture content of the fuel wt%=6 wt% (db) for biomass fuel wood and w= 5.5 wt% (db) for combustible herbaceous biomass). [15]. h : hydrogen concentration in wt% (db).

Oxygen contributes to the oxidation of the other fuel elements so the amount of air required is given by:

$$\overline{mo}[\frac{kgO_2}{kg.fuel}] = (X_{C1}.[\frac{M_O}{M_C}] + [\frac{X_H}{4}].[\frac{M_O}{M_S}] - X_O).(1 - X_{HO}) \quad (3)$$

molecular mass of the element $M_i[\frac{kg}{kmole}]$ ($M_C = 12.01115$), ($M_H = 1.00797$), ($M_{O_2} = 31.9988$). ($X_{HO} = 12.01115$) mass fraction de (H_2O) in the wet ashes of the fuel. λ : Quotient of excess air. The mass of (N_2) air is given by the follow equation:

$$\overline{mo}[\frac{kgO2}{kg.fuel}] = (X_{C1}.[\frac{M_O}{M_C}] + [\frac{X_H}{4}].[\frac{M_O}{M_S}] - X_O).(1 - X_{HO}) \quad (4)$$

The mass of the combustion gas is given by the following equation:

$$\overline{m_{GC}}[\frac{kg.gas.fuel}{kg.fuel}] = \overline{m_O} + 1 \quad (5)$$

The mass specifications of the combustion gas are given by follow equations (8):

$$\begin{cases} \ddot{m_{CO}} = X_C\frac{M_{CO}}{M_C}.(1 - X_{HO}) \\ \ddot{m_{CO}} = X_H\frac{M_{HO}}{M_H}.(1 - X_{HO}) + X_{HO} \\ \ddot{m_{SO}} = X_C\frac{M_{SO}}{M_S}.(1 - X_{HO}) \\ \ddot{m_N} = M_N + X_N.(1 - X_{HO}) \\ \ddot{m_O} = m_O.(\lambda - 1) \end{cases} \quad (6)$$

Where ($M_{CO} = 44.00995$) , ($M_{HO} = 18.01534$), ($M_H = 2.01594$), ($M_{SO} = 64.0628$). Mass fractions of fuel gas elements (X_{SO}), (X_{CO}), (X_{HO}),(X_N) and (X_N) will be determined by the normalization of the fuel gas mass. The volume fraction of the fuel gas is determined by converting the mass fractions to volume fractions according to the following formula:

$$\frac{\frac{X_i}{M_i}}{\sum\frac{X_i}{M_i}} \quad (7)$$

Where:

$$\frac{X_i}{M_i} = \frac{X_{CO}}{M_{CO}} + \frac{X_{HO}}{M_{HO}} + \frac{X_{SO}}{M_{SO}} + \frac{X_O}{M_O} + \frac{X_N}{M_N} \quad (8)$$

P_0 Pressure under normal conditions ($P_0 = 101325Pa$). T_0 Temperature under normal conditions (T_0=273.17 °K) R_u Universal gas constant ($R_u = 831432J/moleK$) The density of the air is given by (9) :

$$\rho_{air}\left[\frac{kg}{N.m^3}\right] = \frac{P_0}{M.\frac{R_u}{M_{air}}.T_0} \quad (9)$$

The molecular mass of the air is:

$$\ddot{m} = m_{GC}.\ddot{m}_f[\frac{kg}{h}] \quad (10)$$

Where $\ddot{m}[\frac{kg.fuel}{h}]$ is the Fuel consumption rate without wet ash.

The volume flow rate of the fuel gas is expressed by the following equation:

$$\ddot{V} = \frac{\ddot{m_{GC}}}{\rho_{GC}}\left[\frac{N.m^3}{h}\right] \quad (11)$$

The mass flow of air :

$$m_{air} = m\ddot{_{fuel}}.\ddot{m_{air}}\frac{kg}{h}\left[\frac{N.m^3}{h}\right] \quad (12)$$

The volume flow of air:

$$V_{air} = \frac{m_{air}}{\rho_{air}} \left[\frac{N.m^3}{h} \right] \quad (13)$$

The energy produced by N.C.V will be calculated by the energy supplied by the combustible gas, it is indispensable to introduce the enthalpy of the five specified gases according to the following expression:(14)

$$h(T) = T.(a_1 + \frac{a_2}{2}.T + \frac{a_4}{4}.T^3 + \frac{a_5}{5}.T^4 + \frac{a_6}{6}.T^5).\frac{R_u}{M_t} \left[\frac{J}{kg.i} \right] \quad (14)$$

The coefficients are divided into two sets for each specified gas, one for the use of temperatures below 1000°K and the other for temperatures above 1000°K.

Lost energy due to imbricated coal is given by (7):

$$\overline{E_c} \left[\frac{kJ}{kg \cdot fuel(waf)} \right] = 34910 \cdot \bar{m}_c \left[\frac{kC}{kg \cdot fuel(waf)} \right] \quad (15)$$

Where 34910 is the calorific value of C given by equation (15) the general energy balance becomes (J/h). In the same way the gas enthalpy is given by (16):

$$Ncv.\ddot{m}_F + [h_F.T_f + h_F.T_{Amb}].\ddot{m}_F + [h_{Air}.T_{Air} + h_F.T_{Amb}] = [h_{FG}.T_{FG} + h_{FG}.T_{Amb}].\ddot{m}_{FG} + \sum Qi + \sum \overline{E_i}.\ddot{m}_F \quad (16)$$

Where Ncv : the net calorific value of the fuel (h_F) fuel enthalpy (h_{Air}) the enthalpy of the air

To find the combustion temperature, the temperature of the gas flow is adjusted until the left side of equation (17) is equal to the right side. In the case of no losses and no pre-heating, the general energy balance will be simplified to the following equation:

$$N_{cv} \cdot F = \{h_{FG}(T_{FG} - T_{Amb})\} \cdot FG \quad (17)$$

3. OPTIMIZATION OF THE BIOMASS ENERGY COST

Revenue from the sale of energy from a biomass source is:

$$CF = IN - OUT \quad (18)$$

Where **IN** is the income and the **OUT** is the spending cost.

A. The total cost of expenditure

A.1. Cost manipulation

The manipulation cost is described by the following equation:

$$C_b = \pi.R^2.C_{bs}(\$/year) \quad (19)$$

A.2. Transport cost

Represents the transport cost of forest residues for combustion:

$$C_t = \frac{2}{3}.\pi.R^2.C_{ts}(\$/year) \quad (20)$$

A.3. Cultivation cost

This cost is based on the employee's number according to the following equation:

$$C_w = C_{ws}.n_u(\$/year) \quad (21)$$

A.4. Maintenance and repair costs

It is proportional to the total investment cost:

$$C_r = I.K_r(\$/year) \quad (22)$$

B. Cost of sale

The total cost of the different expenses will be expressed according to the following equation:

$$Out = C_b + C_t + C_w + C_r \quad (23)$$

Once the combustion is carried out, the electrical and thermal produced energy will be developed in the following section and are expressed respectively by E_e and E_t.

$$PI = \frac{NPV}{I} = \frac{E_e.p_e + E_t.p_t - (C_b + C_t + C_w + C_r.f_a - I)}{I} \quad (24)$$

B.1. Electric energy produced

Electric energy produced is

$$E_e = S.\delta.H_b.\eta_e(MWh/year) \quad (25)$$

$$P_e = \frac{E_e}{t}(MW) \quad (26)$$

B.2. Thermal energy produced

The thermal energy produced is:

$$E_t = S.\delta.H_b.\eta t.f_u \{MWh/year\} \quad (27)$$

B.3. Cost of sale of the energy produced

The cost of sale of the energy is described by the following:

$$IN = E_e.p_e + E_t p_t(\$) \quad (28)$$

C. Revenue from the sale of energies

The energy sales revenue is expressed as CF and given by following equation where:

$$IN = E_e.p_e + E_t p_t - (C_b + C_t + C_w + C_r) \quad (29)$$

C.1. Cost of revenue

The NPV cost of income depends on the usual lifetime of the plant and the discount rate to be determined by:

$$NPV = CF.f_a - I \quad (30)$$

Where

$$f_a = \frac{(1+i)^{v-1}}{i.(1+i)^v} \quad (31)$$

C.2. Profit index

The PI Profit Index is determined as follows:

$$PI = \frac{NPV}{I} = \frac{(E_e.p_e + E_t.p_t - (C_b - C_t + C_w + C_t + C_r)).f_a - I}{I} \quad (32)$$

C.3. Specific investment

The electrical energy production is essential during the investment of the Biomass energy production project; for this we define the specific investment Is as follows:

$$I_s = \frac{I}{P_e} \quad (33)$$

Investment I described by:

$$I = I_s.P_e = \frac{E_e}{t} = \frac{\pi.R^2.\delta.H_b.\eta_e}{t} \quad (34)$$

D. The radius R_0 calculation of the optimal surface

The optimal radius to cultivate and which allows having the maximum profit index of the biomass energy indeed to be able to estimate the costs of biomass production, the index of profit of an installation is given by:

$$PI = \frac{f_a.t}{I_s}.p_e + \frac{f_u.t}{\eta_e.I_s}.\eta_t.p_t - \frac{f_a.t}{H_b.\eta_e.I_s}.C_{bs} - \frac{2}{3}.\frac{f_a.t}{H_b.\eta_e.I_s}.R.C_{ts} - \frac{f_a.t.n_u.C_{ws}}{\pi.R^2.\delta.H_b.\eta_e.I_s} - K_r.f_a - 1 \quad (35)$$

$$PI = \gamma - \beta.R - \frac{\alpha}{R^2}$$

$$\frac{dPI}{dR} = 0 \Rightarrow R_0 = \sqrt[3]{\frac{3.C_{ws}.n_u}{\pi.\delta.C_{ts}}} \quad (36)$$

The optimized energy produced is written according to the optimum radius as follows:

$$E_{e0} = \pi.R_0^2.\delta.H_b.\iota_e = S_0.\delta.H_b.\eta_e$$

$$P_{e0} = \frac{E_{e0}}{t} = \frac{S_0.\delta.H_b.\eta_e}{t} \quad (37)$$

$$PI_0 = \gamma - \beta.R_0 - \frac{\alpha}{R_0^2}$$

4. CASE STUDY AND REVENUE CALCULATION

To test the profitability of the biomass facility for an isolated site, a real case study of the region Ain Drahem Tunisia. To do this we took the daily consumption of a habitat during the four seasons by the load curves given by Fig. 2 and according to this consumption we looked for the energy consumed.

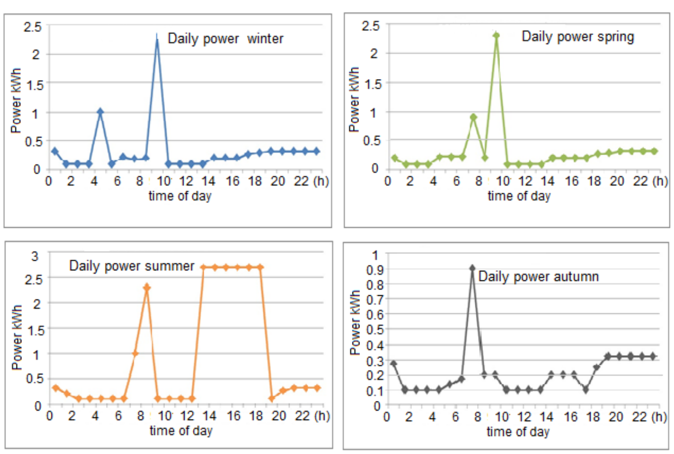

Fig. 2. Consumption of isolated site habitat for each season.

The different standard parameters needed for the simulations are given by Table 2.

A. Case study for standard values

According to the standard values given in the parameter tables

$$PI = -0.3281 - 57.10^{-4}.R - \frac{13.1392}{R^2} \quad (38)$$

We proceed to the representation of PI=f(R) for standard values (IS=210000 $) Then we calculate the optimal radius given

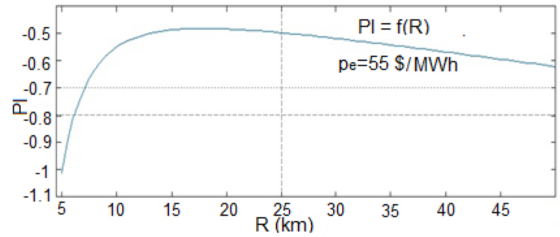

Fig. 3. Curve PI = f(R) for $p_e = 55(\$/MWh)$.

by the following equation:

$$R_0 = \sqrt[3]{\frac{3.C_{ws}.n_u}{\pi.\delta.C_{ts}}} = \sqrt[3]{\frac{3*3000*12}{\pi*200*0.3}} = 17.894km \quad (39)$$

The specific investment is (Is=2100 000$)

$$PI = -0.3281 - 57.10^{-4}.R_0 - \frac{13.1392}{R_0^2} = -0.4820 \quad (40)$$

It is clear that for such an investment and the price (pe=55$/kWh) the system is not profitable. In the following we vary the consumer number (N= 40000,N=48000, N=52000 and N=56000) then we will calculate the radius of surfaces to be cultivated for each consumer numbers and The profits reveals. The monthly consumption of habitats is presented in Fig. 4. For

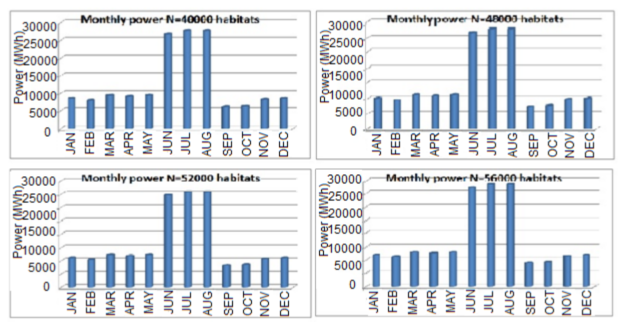

Fig. 4. Monthly consumption.

the specific investment and electric energy price, Table 3 presented electric energy Ee (MWh), surface Sc (Km^2), radius (Km), and profit index PI.

The electrical energy consumed annually is ($E_{e3} = 202683$) MWh, the corresponding radius is ($R_c = 18.47.km$) as well as the necessary surface is ($S_{e3} = 1023.652.km^2$) the overall mass of biomass required ($M_{e3} = 20473.t/year$),the profit index is (PI=-0.482), , so the system is not yet profitable. From the results in Table 3, we note that the cultivated radius closest to the optimal radius (R_0) corresponds to several consumer 51200 in (50000-52000), it is the radius that ensures maximum profit, to confirm this result varying the price to ensure a positive profit index.

B. Influence of the change in the price of electrical energy

To confirm the results, we have discussed a second simulation scenario that allows us to vary the price of MWh (40$, 55$, 70$, and 90$) for the same investment rate previously fixed (1200000$

Table 2. Parameter table.

Parameter	Standard value	Minimum value	Maximum value
	Biomass conversion parameter		
Annual usage time $t(h/year)$	7000	4000	8000
Usual life of the plant $V_u(year)$	20	8	24
Electrical efficiency η_e	0.22	0.1	0.4
Electrical efficiency η_t	0.62	0.48	0.72
Thermal utilization factor f_u	0.5	0	1
Annual maintenance factor K_r	0.03	0.02	0.06
	Workforce parameters		
Number of employees n_u	12	2	20
The cultivation specific cost $C_{ws}(\$/year)$	3000	2000	4000
Unit cost of handling biomass $C_{bs}(\$/year)$	50	20	140
Unit cost of transport $C_{ts}(\$/t.year)$	0.3	0.1	0.9
	Biomass parameters		
Dry matter yield $\delta(t/km^2.year)$	200	50	500
Heat value biomass $H_b(MWh/t)$	4.5	3.8	5
	Economic parameters		
Electric energy price $p_e(\$/MWh)$	55	40	140
Thermal energy price $p_t(\$/MWh)$	20	10	60
Discount i	0.1	0.05	0.2

Table 3. The effect of variation in number of habitats N on the profit index PI for Is = 2100000.

Number of habitats N	R_C(km)	E_e(MWh)	PI
48000	17.339	187092	-0.4821
50000	17.697	194888	-0.4820
52000	18.391	226683	-0.4820
54000	18.391	210479	-0.4821
56000	18.729	226070	-0.4823

).According to the different profit indices given by the following table.

We note that the biomass system is not profitable for low prices at any considered consumer number, from 80 $ we start to have low profitability of the order of 22 % This is why a third simulation scenario was considered in which the specific investment rate **Is** is varied to ensure the system profitability.

C. Influence of the variation of the specific investment Is

The last case study aims at determining the influence of the investment variation on the profit index, this scenario consists in fact of varying the investment rate Is from a value of $I_s =$ 1200000$ to value $I_s =$ 3000000$ and for each MWh price, the profit index is calculated. In our case study, we present the influence of the specific investment and the sale price pe on the price index PI.

Table 4. The effect of price change and the number of consumers on the profit index PI for the specific investment (2100000$).

p_e($)	N	PI	p_e ($)	N	PI
40	48000	-0.9078	70	48000	-0.0564
	50000	-0.9077		50000	-0.0563
	52000	-0.9077		52000	-0.0563
	54000	-0.9078		54000	-0.0564
	56000	-0.9080		56000	-0.0566
	58000	-0.9082		58000	-0.0569
55	48000	-0.4821	90	48000	0.5111
	50000	-0.4820		50000	0.5113
	52000	-0.4820		52000	0.5113
	54000	-0.4821		54000	0.5112
	56000	-0.0908		56000	0.5110
	58000	-0.4826		58000	0.5107

C.1. First case studied N=48000 consumers

For N=48000 consumers, the curve PI= f(p_e) of the different specific investments announced presented by Fig. 5.

The effect of the alteration of particular investment and the sale price p_e on the price index PI for N=48000 consumers are presented in Table 5.

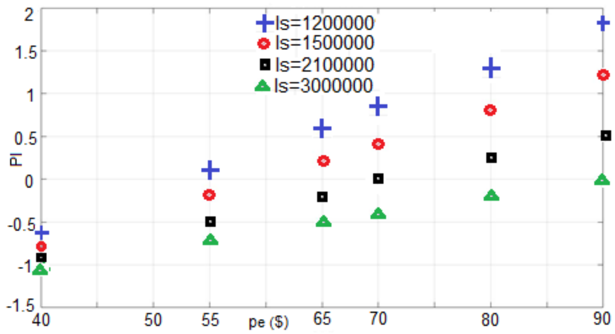

Fig. 5. Curve PI = f(p_e) to different specific investments for N=48000 consumers.

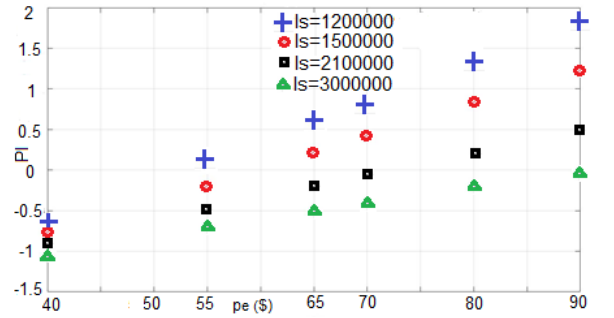

Fig. 6. Curve PI = f(p_e) to different specific investments for N=52000 consumers.

Table 5. The effect of price change and the specific investment on the PI profit index for N=48000 consumers R=17.339 km.

	I_s=1200000$	I_s=1500000$	I_s=2100000$	I_s=3000000$
P_e ($)	PI	PI	PI	PI
40	-0.6471	-0.7688	-0.9078	-1.0121
55	0.0978	-0.1728	-0.4821	-0.7141
70	0.8428	0.4231	-0.0564	-0.4161
90	1.8360	1.2177	0.5111	-0.0188

Table 7. The effect of price change and the specific investment on the PI profit index for N=56000 consumers R=18.729 km.

	I_s=1200000$	I_s=1500000$	I_s=2100000$	I_s=3000000$
P_e ($)	PI	PI	PI	PI
40	-0.6474	-0.7690	-0.9080	-1.0122
55	0.0976	-0.1730	-0.4823	-0.7142
70	0.8425	0.4229	-0.0566	-0.4162
90	1.8357	1.2175	0.5110	-0.0189

C.2. Second case studied N=52000 consumers

We presented in Table 6 the influence of price change and the specific investment on the price index for N= 52000 consumers.

Table 6. The effect of price change and the specific investment on the PI profit index for N=52000 consumers R=18.047 km.

	I_s = 1200000$	I_s = 1500000$	I_s = 2100000$	I_s = 3000000$
P_e ($)	PI	PI	PI	PI
40	-0.6470	-0.7687	-0.9078	-1.0121
55	0.0981	-0.1726	-0.4820	-0.7140
70	0.8430	0.4233	-0.0563	-0.4160
90	1.8363	1.2179	0.5113	-0.0018

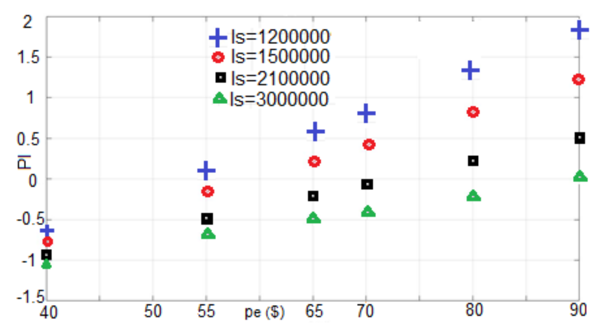

Fig. 7. Curve PI = f(p_e) to different specific investments for N=56000 consumers.

For N=52000 consumers, Fig. 6 represented the curve PI= f(p_e) of the different specific investments announced.

C.3. Third case studied N=56000 consumers

The influence of price change and the specific investment on the price index for N= 56000 consumers is presented in Table 7.

For N=56000 consumers, the curve PI= f(p_e) of the different specific investments announced is represented by the following figure.

5. INTERPRETATION OF THE INFLUENCE OF THE SPECIFIC INVESTMENT IS ON THE PROFIT INDEX

According to the simulation results given by Tables 5, 6, and 7, We note that we obtain the optimistic profit index PI value indicator for a particular investment $I - s = 1200000\$$ and this from a price $p - e = 55\$/MWh$ if we increase the same investment at ($I - s = 1500000\$$) the profit index PI was beneficial for $p - e = 65\$/MWh$. Besides for a specific investment Is=2100000 $ the process is more profitable for all the price pe=80 $/MWh at the process is more profitable for all prices pe proposed. In addition, it is noted that for a specific minimum investment ($I_s = 1200000\$$) and a price $p_e = 55\$/MWh$, the profit index is maximal for several consumer N=52000(PI=0.0981) and this by comparing it with the other profit indices of the other numbers of consumers ((N=48000, PI=0.0978), (N=56000, PI=0.0976)). These results prove the first case study and confirm the choice of the number of consumer N=52000 which ensures a maximum profit with a radius very close to the optimal radius and a minimum specific investment.

6. CONCLUSION

In this article, we have presented the types of biomass energies to harness and ensure the production of electric power and exploit natural resources. As result, the technical parameters of the economic model and their influence on biomass power plants were presented. This preliminary study of the electrical consumption of the case study allowed us to highlight the influence of the quantity of electrical energy consumed as well as the specific investment on the profit index, for this, the quantity of optimal electrical energy produced as well as the corresponding specific investment have been determined by the technico-economic study in order to guarantee a reasonable price per MWh which makes it possible to encourage this type of renewable energy to appropriate exploitable agricultural areas in a forest region of Tunisia. It has been proved that for a specific investment of $Is = 1,200,000\$$ the profit index PI is positive for the price 55$ of the MWh, also for $Is = 1,500,000\$$ PI will only be positive from the price 70$ of the MWh and finally for an investment of $3,000,000\$$ PI will not be positive for the prices of the MWh proposed by the study.

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