TECHNO-ECONOMIC ASSESSMENT OF VIABILITY OF A PLANT FOR GENERATION OF ELECTRIC ENERGY IN THE AREA OF PARAGOMINAS-PARÁ TROUGHT THE RANKINE CYCLE.

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ABSTRACT. Area of Paragominas has about sixty sawmills in operation that produce great amount of wood residues that could be used for generation of electric energy to lumbermen's benefit. This work has as objective to do a techno-economic viability study for biomass conversion (wood residues) in electric energy in the area of Paragominas-Pa, using the Rankine cycle, verify the profitability of the investment through of the analysis of economic viability and to demonstrate the possibility to supply the demand in the consumption of electric energy and to contribute to avoid a possible lack or rationing that it is already part of the reality of Brazil. It will be analyzed a power plant of 15MW. The economic viability analysis is determined using the method of the internal rate of returrn, the method of the net present value and the method of the discounted payback period as economic evaluation measure. Sensitivity analysis of biomass price shows the economic viability of the project.The constant rise in the petroleum price and the uncertainties about its long term availability is more one reason for researches investments in projects that involve renewable energy.

Key words: Rankine cycle, biomass, techno-economic evaluation, energy

1. Introduction

Brazil counts with conditions privileged for the biomass cultivation, starting from the use of cane of sugar or other varieties of plants for the production of energy that can be in the form of alcohol or biodiesel extracted of vegetables as the soy or dendê. The biomass potential depends basically on two factors: fertile earth and heatstroke, both abundant in Brazil. If just 10% of the degraded area of Amazônia (70 million hectares) it was reforested with dendê (" oil palm "), Brazil would become larger producing of biodiesel of the world. The moment for that project type it is favorable with the entrance in vigor of CDM (Clean Development Mechanism), that to foresee financings for reforestation in the third world, as one of the alternatives to capture the carbon of the atmosphere and to reduce the negative influences of the greenhouse effect. “Recent Work (Berman, 2001)”.

According to the Instituto Superior de Administração e Economia (ISAE) and the Fundação Getúlio Vargas(FGV) of the 28 million cubic meter of wood extracted from Amazônia annually, about 80% are illegal and 50% assist the small sawmills. This situation has been generating serious debates concerning the need of implementing strategies that guarantee the maintainable exploration of the resources forest/woody and the rational development of the activities of the sector, face to the growing of exploration of the wood for countless uses as: generation of electric energy, production of pieces of furniture, naval construction, cellulose obtaining for application in the paper industry, among others. ”Recent work (ISAE/FGV,2003)”.

The use of the biomassa for energy ends provokes emissions of carbonic gas. The advantage in relation to the fossil fuels resides in the fact of those emissions be at maximum equivalent to the amount of carbonic gas captured by the biomass during its growth. The culture and the combustion of the biomassa represent, like this, a neutral balance. Should be considered, also, the perspectives of the Protocol of Quioto, establishing the possibilities of development of Clean Development Mechanisms, in partnership with the developed countries that need to reduce its emissions of carbon. This way, the energetic self-sufficiency of this industrial segment (or even the generation of surpluses for the sale) it can be an important opportunity for investments of foreign capital, through this mechanism, in view of the balance of almost null carbon referring its generation of energy. “ Recent work (Velazquez, 2000)”.

In this context Amazônia comes to be an area with an excellence potential for the generation of electric energy, using wood residues, solving partly, or totally the deficiency of existent electric energy in the area, and this way, to contribute in a significant way for an increase of electric energy in the national energy matrix and to decrease the risks of rationing of electric energy that is already part of the national reality.

The use of wood residues for generation of electric energy using the cycle Rankine or the combined cycle, or the use of both technologies, it is an alternative that can solve the problem of shortage of electric energy in the Amazon area. In particular, this work does a technician-economic study of a Rankine cycle of 15MW of power with the purpose of determining the economic viability of this plant for generation of electric energy to the Paragominas city.

2. Status

The Paragominas city is the largest wood producer of the State of Pará. The municipal district got to possess 300 wood companies in the decade of 80 that went being extinct so that wood offer was decreasing, now there is 68 wood companies in activity in the municipal district. ”Recent work (Plano de Desenvolvimento do APL de Móveis de Paragominas-Pa, 2005)”.

Being still Paragominas city possessor of some dozens of sawmills which generate great amounts of biomassa (wood residues) without any specific end, it was verified that, these residues are usually stoked at open sky and they are generally just burned with the purpose of eliminate them or use them for embankment, contributing, this way, the burns of these residues, for pollution of the areas around the sawmills, besides the contribution for increasing the greenhouse effect. In a generating plant of electric energy, using the biomassa as fuel, these residues would be taken advantage of being used in a noble way, because would contribute for decreasing the atmospheric pollution, besides the generation of electric energy could be consumed by the industries and sawmills, the surplus of energy it could be bought by the concessionary and distributed the domestic consumer.

3. Conversion Technologies of biomass in electricity

The technologies for the primary conversion of biomass for electricity production are direct combustion, gasification, and pyrolysis. Direct combustion involves the oxidation of biomass with excess air, giving hot flue gases which are used to produce steam in the heat exchange sections of boilers. The steam is used to produce electricity in a Rankine cycle; usually, only electricity is produced in a condensing steam cycle, while electricity and steam are cogenerated in an extracting steam cycle. In air-based gasification cycles, biomass is partially oxidized by substoichiometric amounts of oxygen, normally with steam present, to provide energy for thermal conversion of the remaining biomass to gases and organic vapors. For power production the cleaned gasification product gases will be fed directly to a boiler or to the combustion section of an industrial or aeroderivative turbine. In indirect gasification cycles an external heat source, instead of oxygen, is used to provide the energy for high-temperature steam gasification of the organic fraction of biomass to vapors and gases. In pyrolysis processes, indirect heating is also used to convert biomass to a mixture of gases and organic vapors. Pyrolysis is defined as the thermal destruction of organic materials in the absence of oxygen. ”Recent work Craig et al. (1996)”.

4. Methodology

The methodology proposal to reach the objectives part of the need of knowing the reality of the area in what tells respect the availability of residues and necessity of the companies about electric energy. To do a research to estimate the amount residues of wood produced in the area of Paragominas-Pa for a posterior study of viability techniques and economic for its conversion in energy, always taking in consideration the maximum efficiency of the biomassa when being transformed in fuel and the smallest possible cost for that the project be economically viable.

For determination of the amount of biomassa (wood residues) produced in the area of Paragominas a specific questionnaire it was applied to the lumbermen. Were just consulted the companies that belong to the lumbermen's union, being out of this research at least twenty or thirty companies that generate tons of residues of wood that certainty also would be used for generation of electric energy. Considering that the residues generation corresponds, at least, 50% of the processed wood and the specific mass of the drought wood is of $725 Kg/m^3$, it is considered a daily production of 470 tons of residues of wood for the consulted sawmills, therefore, taking in consideration the companies that were out of the research, this residues amount could double. However, in this work only will be considered the amount of biomassa generated by the researched sawmills.

5. Economic Measures

The economic measures can be used to compare alternative investments of project.” Recent work (Short, 1995)”.

5.1 Net Present Value (NPV)

The net present value of project is one way of examining costs (cash out flows) and revenue (cash inflow) together. “Recent work (Palm and Qayum, 1985)”.The Eq. (1) bellow can express the net present value.

$$NPV = \sum_{n=0}^{N} \frac{F_n}{(1+d)^n}$$

n	= analysis year
NPV	= net present value
F_n	= net cash flow in year n
N	= analysis period
d	= annual discount rate

5.2 Internal Rate of Return (IRR)

The internal rate of return (IRR) for an investment that has a series of future cash flows (F_0,F_1,...F_n) is the rate that sets the NPV of the cash flow equal to zero. The IRR can be expressed by Eq. (2) bellow:

$$0 = NPV = \sum_{n=0}^{N} \left[F_n \div (1+d)^n \right]$$

NPV = net present value of the capital investiment
F_n = cash flows received at time n
d = rate that equates the present value of positive and negative cash flows when used as a discount rate

5.3 Discounted Payback Period (DPB)

The discounted payback period is the number of the year necessary to recover the project cost of an investment while accounting for the time value of money. DPB is recommended when risk is an (i.e., significant uncertainties are present) because DPB allows for a quick assessment of the duration during which an investor's capital is at risk. "Recent work (Short, 1995)". DPB is determined by Eq.(3) bellow:

$$UCFR = [d(1 + d)^n]]/[(1 + d)^n – 1)]$$

UCFR = uniform capital recovery factor
d = discount rate
n = analysis year

6. Economic analysis

6.1 Plant cost estimation

Purchased equipment costs PE (€) have been evaluated on the basis of correlations resulting from interpolation of experimental and literature data having the following general expression $PE = aS^b$, where a and b are specific coefficients, while S is a characteristic equipment parameter. In particular, equipment costs have been parameterized in function of the plant net electric power output W_{NE} (MW), the power generated by steam cycle WST (MW), the gas turbine power WGT (KW), the biomass flow rate $M_{G/CC}$ (kg h^{-1}) feeding the gasifier, the steam flow rate produced by heatrecovery steam generator MHRSG (kg h^{-1}). The adopted correlations for purchased equipment costs evaluation are based in Tab. 1. The reliability of such equations has been verified by resorting to a comparison between calculated costs and actual cost data obtained from vendors. "Recent work Caputo et al. (2004)". The monetary values of the table are in Euro that were converted for dollar using the rate of exchange of the month of April 2005, 1€ = 1,34 US$. Substituting W_{NE} = 15MW in tab. 1, the total plant cost is estimeted.

Table 1. The adopted purchased equipment correlation.

Plant sections	PE correlation(€) C/ST
Boiler	$1.340.000 W_{NE}^{0.694}$
Steam turbine	$633.000\ W_{NE}^{0.398}$
Condenser	$398.000\ W_{NE}^{0.333}$
Heat exchanger (cooling water)	$51.500\ W_{NE}^{0.5129}$
Alternator	$138.300\ W_{NE}^{0.6107}$
Fans	$35.300\ W_{NE}^{0.3139}$
Condensate extraction pumps	$9.000\ W_{NE}^{0.4425}$
Feed pumps	$35.000\ W_{NE}^{0.6107}$
Pumps	$28.000\ W_{NE}^{0.5575}$
NOx and SOx removal equipments	$126.000\ W_{NE}^{0.5575}$

C/ST(Combustion/steam). PE (Purchased Equipment). W_{NE} (Net Power -MW).

6.2 Biomass consumption

Is determined trough the Eq. (4), bellow:

$$M = \frac{W_{NE} \times 3600 \times OH}{\eta \times LHV}$$

M = biomass consumption (Ton / day)

W_{NE} = net power (MW)
OH = hours
η = efficiency
LHV = low heating value (KJ Kg^{-1})

6.3 Cost of energy

Is determined by Eq. (5), bellow. “Recente work (Reis, 2003)”.

$$COE = C_{\cos t} + C_{o\&m} + B_{\cos t}$$

COE = cost of energy (US$/MWh)
C_{Cost} = cost of capital (US$/MWh)
$C_{0\&M}$ = operation and maintenance costs (US$/MWh)
B_{cost} = biomass cost (US$/MWh)

6.3.1 Cost of capital

The cost of capital is an important factor in the economic analysis of firm, utilities, and other business entities. The cost of capital has that to be recovered by the investor to warrant his investment. Higher returns attract increased investment, whereas lower returns discourage investment and lead to inadequate supplies and sources of investment capital. “Recent work (Short, 1995)”. The cost of capital is calculated by Eq. (6) bellow.

C_{Cost} = 1000 x W_{NE} x S_{Cost} x UFCR
W_{NE} = net power (MW)
S_{Cost} = specific cost of the plant (US$/KWh)
UCFR = uniform capital recovery factor

6.3.2 Operation and maintenance costs

There is no absolute standard as to which costs are included in O&M costs. For mature technologies, estimation of future O&M costs is generally based on historical performance. For mature conventional fossil fuel system, it is often assumed that annual O&M costs will equal about 1% to 2% of the system’s capital initial costs. However, for for conservation and renewable energy systems that are typically in the early stages of technical and market development , O&M costs are more difficult to estimate. “Recent work (Short, 1995)”. In this work is adopted 1,5% of the system’s capital initial costs based on “Caputo et al.(2004)”. The O&M costs is calculated by Eq.(7) bellow:

$C_{O\&M}$ = 1000 x $F_{O\&M}$ x W_{NE} x S_{Cost}
$F_{O\&M}$ = operation and maintenance fator

6.3.3 Biomass cost

It was determined by Eq. (8), that follows:

$$B_{\cos t} = \frac{B_{price} \times 860}{LHV \times \eta}$$

B_{cost} = biomass cost (US$/MWh)
B_{price} = biomass price (US$/Ton)
LHV =low heating value(KJ Kg^{-1})
η = efficiency (%)

6.4 Administration costs

According to literature data, the operator number has varied in the range 12-36 for project of this nature. “Recent work Caputo et al. (2004)”. In this project is considered 12 employees, representing the cost shown in the cash flow in the end of this paper. The value is considered with 60% of tax.

7.0 Premises considered for calculations

For determination of the parameters above and of the cash flow in this work, is considered the following premises:

- Rankine Cycle Power Plant:15MW
- Standardizing value for April 08, 2005 for generation of energy through biomass: 59,41US$
- Discount Rate: 12% annual

- Income Tax: 33%
- Taxes on the gross revenue: 0,0403
- Biomass price: 25 US$/T (1,7US$/GJ).
- Biomass low heating value(LHV) with an average moisture content of 30%: 14.630KJ/Kg
- Exchange Rate for April 08, 2005: 1€ = 1,34US$
- Hours of annual plant operation: 8048 hours
- Efficiency of the cycle: 25%
- Duration of the plant: 25 years. "Recent work (Short,1995)"
- Operation and maintenance factor : 0,015. "Recent work Caputo et al.(2004)".
- Depreciation: 25 year. "Recen work (Short,1995)".
- Specific mass of the drought wood: 725Kg/m^3. "Recent work (Nogueira & Silva Lora,2003)".
- Available Biomassa: 470 Ton / daily

8.0 Results and discussion

- Total cost of plant is determined throught the table 1: US$ 18.207.954,27.
- Specific cost of the plant: 1.213,86US$/KWh
- Biomass consumption : 355 Ton daily
- Capacity factor: 0,92
- Generated annual energy: 110.687,67 MWh annual
- Cost of energy: 48,01 US$ / MWh
- Anual gross revenue: 6.576.022,65US$.
- Tributes: 265.013,71US$
- Annual net revenue: 6.311.008,94US$

The internal rate of return (IRR) for this project it is 13,12% annual and the net present value (NPV) is US$ 1.377.686,05 Showing this way, the viability of the project. The value of the discounted payback shower the return of the investment starting from 9 years. As the internal rate of return (IRR) as the net present value (NPV) and the discounted payback was determined being used the resources of Microsoft EXCEL 2000.

8.1 Sensitivity analysis: Impact of the biomass cost

Once that cost of the biomass is one of the factors that can turn unviable a project of generation of energy through biomass, it is made an analysis of sensitivity varying the price of the biomass until a value that turns the project unviable economically. See tab.2 and Fig.1.

Table 2 and the Fig.1, show that the project becomes economically unviable starting from 10%, because the NPV it is negative and IRR is smaller than the discount rate of 12% annual.

Table2. Impact of the biomass cost on the project

Biomass. Price	0%	2%	4%	6%	8%	9%	10%	11%
IRR	13,12	12,88	12,64	12,39	12,14	12,02	11,.90	11,77
NPV	1,37	1,07	0,77	0,47	0,17	0,023	-0,12	-0,27

Biomass Price (US$/Ton). IRR(% annual). NPV(MIL. US$).

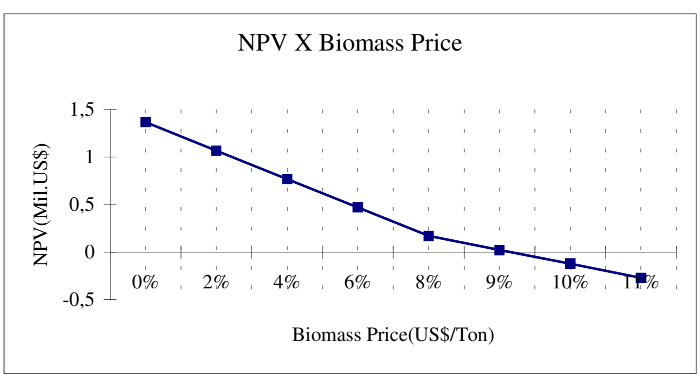

Figure.1. NPV in function of the biomass price variation.

8.2 Sensitivity analysis: Reducing biomas price in 20%

Reducing the biomass price in 20%, it is verified that, although increasing the total investment in up to 24% the project is still economically viable as shows the results of the tab. 3 below. This analysis, is very important, because it shows the direct influence of the biomass price for the accomplishment of a project of this nature.The Fig 2 and Fig 3 show the variation of NPV and IRR respectively in function of the investment, reducing the biomass price in 20%.

Table.3.IRR and VPL in function of the variation of the investment, reducing the biomass price in 20%.

Invest.	-30%	-20%	-10%	0%	10%	20%	22%	23%	24%	25%	27%
IRR	23,11	19,97	17,52	15,54	13,90	12,51	12,26	12,13	12,01	11,89	11,66
NPV	9,85	8,02	6,2	4,38	2,56	0,745	0,381	0,199	0,017	-0,165	-0,529

Investment(MIL.US$). IRR(% annual). NPV(Mil.US$).

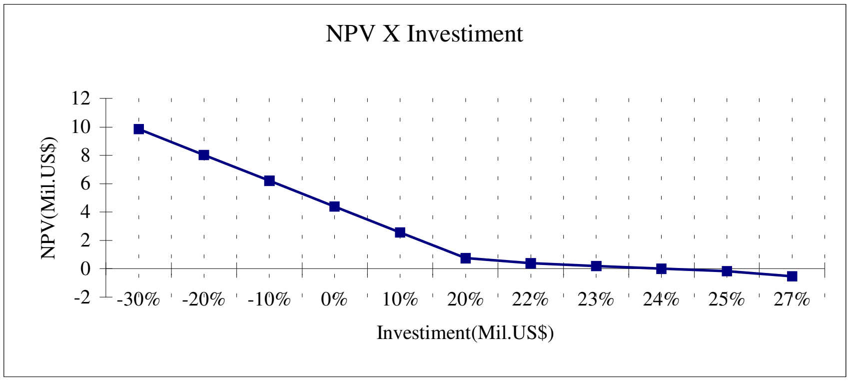

Figure 2.NPV in function of the investment, reducing the biomass price in 20%.

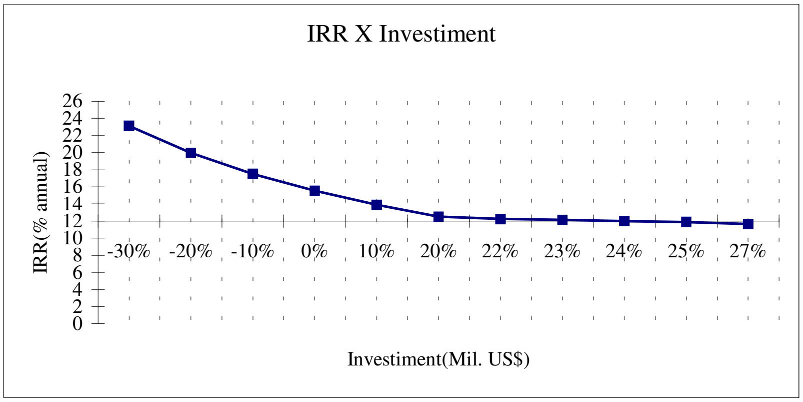

Figure 3.IRR in function of the investment, reducing the biomass price in 20%

8.3 Sensitivity analysis: Impact of the Income Tax

It can be concluded that above 41% of income tax, the project is economically unviable because the internal return rate is less then the discount rate as shows tab. 4.

Table 4. Impact of the Income Tax on the project

Incom.Tax	20%	25%	30%	35%	40%	41%
IRR(%an.)	14,9	14,23	13,54	12,84	12,12	11,98

8.4 Sensitivity analysis: Impact on Generation Cost

A plant of generation of energy using national equipment can have a reduction of up to 30% in its total investment. "Recent work (Tolmasquim, 2003)". Based on this information was made a sensitivity analysis reducing the cost of generation in up to 30%.Table 5 shows result of analyses. To the Proportion that reducing the plant price, the project becomes more economically attractiveness as shows the tab. 5.

Table.5. Shows the values of IRR and discounted Payback reducing the value of the Investment in up to 30%.

Investiment Reduction	-10%	-20%	-30%
IRR (% annual)	15,01	17,32	20,25
Payback (year)	7,82	6,44	5,27

9.0 Cash Flow

The cash flow facilitates the visualization of a financial problem involving revenues and expenses that happen in different instants from the time. "Recent work (Casarotto Filho, 2000)".The cash flow that follows shows clearly the financial results of the project. The net present value, the internal rate of return and the discounted payback are shown in color predominant yellow for biomass price 25US$/Ton. The Tab. 6 shows the cash flow of the project.

Table 6. Cash Flow of the project.

YEARS	AG R (1)	TRIBUTES (2) 0,0403 X AGR	ANR (3) (1) – (2)	CO&M (4)	BIOMASS COST (5)	ADM COST (6)
0	----------------	--------------	----------------	--------------	----------------	-----------
1	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
2	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
3	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
4	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
5	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
6	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
25	$6.576.022,65	$265.013,71	$6.311.008,94	$273.119,31	$2.719.754,21	$82.080,00

(Table 6. Continuation)

YEARS	DEPRECIATION (7)	NPBIT (8) (3)-(4)-(5)-(6)	I T (9)	NPAIT (10) (8) – (9)	FINAL BALANCE (10) + (7)
0	--------------	------------	-------------	------------	($18.207.954,27)
1	$728..318,17	$2.507.737,24	$0,00	$2.507.737,24	$3.236.055,42
2	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
3	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
4	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
5	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
6	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
25	$728..318,17	$2.507.737,24	($827.553,29)	$1.680.183,95	$2.408.502,12
26			($827.553,29)	($827.553,29)	($827.553,29)

NPV	$1.377.686,05
IRR	13,12%
PAYBACK(years)	9,48

AGR = Annual gross revenue (US$)
ANR = Annual net revenue (US$)
NPBTI = Net profit before income tax (US$)
NPAIT = Net profit after income tax (US$)
IT = Income tax
FB = Final balance (US$)

10 Conclusion

The Rankine plant is viable economically because the economic measures show that the internal rate of return, the net present value and the time of return of the capital indicate the economic viability of the project. Table 3 shows that reducing the biomass price in 20%, the project has its economic viability increased sensibly because in agreement with the result of the analysis although with an increase of 24% on the total investment of the plant an internal rate return of 12,01% is obtained, that yet is a superior value to the discount rate of 12%. Considering that amazônia is abundant in biomass, the biomass price around 20US$/Ton (1,36US$/GJ) is possible of being practiced. Careful should be taken for that this biomassa be produced in sustainable way, for that the environment, already so attacked, can be preserved. On the other hand the continuous rise of the petroleum price it is an indicative for that be intensified researches investments in renewable energy. At once that Amazônia it is an area rich in biomass, investments in projects of this nature could contribute with energy matrix of Brazil and to reduce the greenhouse effect. As in the amazônia exist many areas of degraded lands, such areas could be used for the cultivation of energy forests without a possible competition with food production, turning projects of this nature every time attractive economically.

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11. Responsability notice.

The authors below mentioned, are the only responsible for the printed material included in this paper.

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