Cost- Benefit Estimation For Alternative Renewable Biofuel From Algae in Comparison with Traditional fuel Source

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Abstract

In the face of the problem of depletion of natural resources, and preservation of environmental and ecological balance. the measuring tools of environmental and social accounting, stand in front of challenge in finding method to measure the change in cost of production that used new methods in produce a new resource of energy, which is friendly to the environment and eliminated the pollution. One of this alternative renewable resources is Algal. as promising sources of clean energy products and a CO2 capturing from air. but the requirements of the complex processes used into convert the Algae to biofuels, create cost structure not competitive with the traditional fuels. So, in this paper it will built a theoretical cost structure ,and aggregate cost elements by using accounting terminology with interaction with terminology chemical engineering, biology and economics field, to calculate cost by equations, and design software program (MS-DOS program) to evaluate the production cost, and the potential economic viability of algae in producing fuel instead of producing it from conventional sources.

Key words: cost-benefit model, operation costs, capital costs, productivity, Algal-Biofuel

الخلاصة

لمواجهة مشكلة استنزاف الموارد الطبيعية وللحفاظ على التوازن البيئي والايكولوجي , تقف ادوات قياس المحاسبة البيئية والاجتماعية امام تحدي لايجاد طريقة لقياس التغير في تكلفة الانتاج التي تستخدم اساليب جديده في انتاج موارد جديدة للطاقة تكون صديقة للبيئة وتساهم في القضاء على التلوث. واحدى هذه المصادر المتجددة هي الطحالب. التي عدت مصدرا واعدا لانتاج الطاقة النظيفة ولامتصاص ثاني اوكسيد الكاربون من الجو. لكن متطلبات العمليات المعقدة المستخدمة في تحويل الطحالب الى وقود حيوي خلق هيكل تكاليف غير قادر على المنافسة مع الوقود التقليدي . لذا سنعمل في هذا البحث على البناء النظري لهيكل التكاليف المطلوب, وتجميع عناصر الكلفة الاجمالية لهذا البناء النظري باستخدام المصطلحات المحاسبية مع التفاعل مع مصطلحات حقل الهندسة الكيمياوية والبايولوجية والاقتصادية لحساب التكلفة وفق معادلات وبرنامج وتقييم تكاليف الانتاج ومعرفة الجدوى الاقتصادية المحتملة من استخدام هذا البديل في انتاج الوقود بدلا من انتاجة من المصادر التقليدية

Notation used

No	parameter	symbol	Unit
1	Total capital cost	TCAP.C	$
2	Arial productivity	AR.P	g/l.d
3	Annual productivity	AN.P	Ton/year
4	Annual productivity	AN.P1	kg/year
5	Annual (N) cost	AN.C	$/y
6	Annual (P) cost	AN.P.C	$/y
7	Annual CO2 cost	AN.CO.C	$/y
8	Annual fresh water cost	AN.FW.C	$/y
9	Annual labour cost	AN.L.C	$/y
10	Annual power cost	AN.PO.C	$/y
11	Total cost	TOTAL.C	$
12	Operation cost	OperationC	$
13	X=unit cost before harvesting	X	$/kg
14	Y=unit cost after harvesting	Y	$/kg
15	Z=unit cost before+ after harvesting	Z	$/kg
16	Number of hectares	No. ha	-
17	Biodiesel productivity	BP	gallon/ye
18	Biodiesel productivity	BP1	barrel/ye
19	Gross annual revenue	GA.R	$/ y
20	Benefit	benefit	$/ y
21	Contribution of nitride to total operation cost	J1	%
22	Contribution of phosphors to total operation cost	J2	%
23	Contribution of CO2 to total operation cost	J3	%
24	Contribution of labour to total operation cost	J4	%
25	Contribution of power to total operation cost	J5	%
26	Contribution of water to total operation cost	J6	%
27	Contribution of indirect costs to total operation cost	J7	%
28	Total pond volume	TPV	Ha
29	Used nitride from culture media	NUC	g/l
29	Total Pond Area	TPA	ha
30	Cost of Site preparation	C.SIP	$/ha
31	Cost of Culture system	C.CLS	$/ha
32	Engineering fee	ENGF	$/ha
33	Contingency	COG	$/ha
34	Cost of Land	C. Land	$/ha
35	Total growth days	TGD	Day
36	Proportion of down time	PDW	%
37	Pr-+oportion of pond harvesting	PPH	%
38	Cost of nitride	CNI	$/kg
39	Cost of phosphors	CPHt	$/kg
40	Harvesting efficiency	HE	%
41	Pond depth	PD	M
42	Pond length	PL	M
43	Pond width	PW	M
44	No of ponds	NOP	-
45	Used nitride from culture media	UNCM	g/l
46	Proportion of medium recycled	PMR	%
47	Algae doubling time	TD	Day
48	NaNo3 concentration in medium	NCM	g/L
49	Used phosphors from culture media	UPCM	g/L
50	NaH2PO4.1 H2O concentration	PCM	g/L
51	Volumetric productivity	VP	g/l.d
52	Co2 cost	CO2.C	$/L
53	Co2 required for different ph	Co2Nph	L/d
54	Fresh water cost	FW.C	$/m^3
55	Average days of evaporation	ADE	D
56	Rate of evaporation	RE	M
57	Labour cost supervisor	LCS	$/ha.y
58	Labour cost senior technision	LCST	$/ha.y
59	Labour cost technision-day term	LCTD	$/ha.y
60	Labour cost technision-shift term	LCTS	$/ha.y
61	Power cost	PO.C	$/kw.hr
62	Power usage	POU	Kw/ha.d
63	Harvesting system cost annually	AHC	$
64	Lipid yield	L.Y	%
65	Price of Gallon	Price .G	$

1. Introduction

The world has realized that the basic cause of the energy crisis is not just scarcity but also the lack of knowledge and the limitation of nature, it is necessary for the world to engage in research to push for alternative fuels and to develop new sources of energy which are renewable and inexhaustible .The problem of Petroleum shortages and the climate implications proven reserves to have driven research and business ventures into algae-based fuels (IEAWEO, 2007). Although efforts to produce renewable energy on an industrial scale have been started in many alternative renewable energy sources like solar, wind, corn, and so on, but produce oil from algae, is one of the most promising sources of alternative energy. According to the historical generation of biofuels industry, revolutions happened in biofuels energy industry characterizing algal biofuel production as a third revolution (IEA Bioenergy, 2008), (http://www.altprofits.comref/report/biofuels) as shown in fig 1.

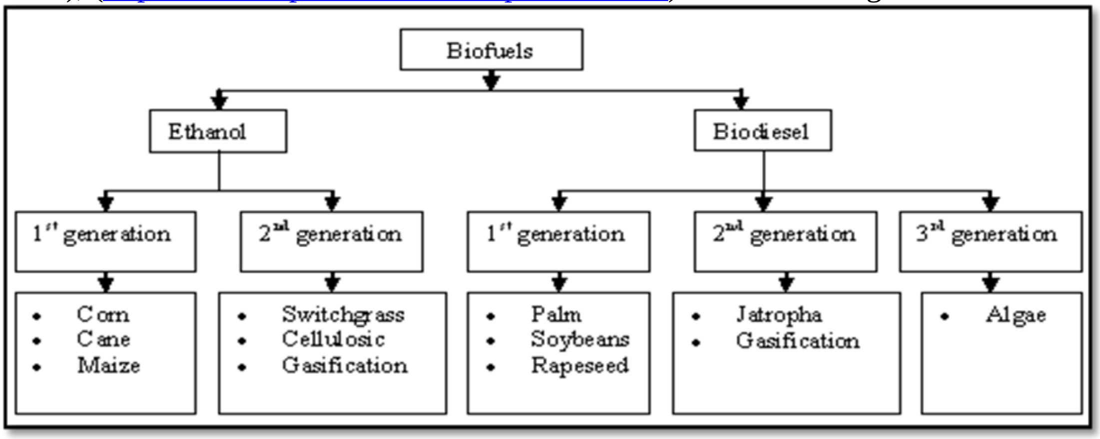


Figure.1 Structure of generation biofuels industry revolutions

Because of the viability of the 1st and 2nd generation biofuels production is however questionable and conflict with either food supply or the fact that may not be enough land to grow the necessary amount of feedstock's. So as an alternative to corn, sugar cane, many believes that algae is set to eclipse all other biofuel feedstock's as the cheapest, easiest, and most environmentally friendly way to produce liquid fuel. Because of this revolution the promise of sustainable energy production from algae has generated tremendous interest in recent years (Antoni.D.*et al*, 2007) (Srivastava .A, 2000). It considered as a viable alternative biofuel feedstock. This does not came easily, it need more subject and huge systems in order to cultivate and convert algae into a biofuel. For this the subject need to offer briefly in order to give it reserves.

Algae can be referred to as plant- like organisms that are usually photosynthetic and aquatic, but do not have true roots, stems, leaves, vascular tissue and have simple reproductive structures. They are distributed worldwide in the sea, in freshwater and in wastewater, most are microscopic, but some are quite large, e.g. some marine seaweeds that can exceed 50 m in length (http:WWW.oilgae.com/algae/algae.htm, introduction to algae &types of algae). Algae are the most diverse organisms in the world (www, algaebase.org), it divided into two categories distinction between them as list in Table 1.

Table 1. Distinction between macro and micro algae

Macro algae	Microalgae
1- Commonly called "seaweeds" 2-Properly called "sea plants" 3-Big enough to tie on ropes 4-Many can be chopped down to "mini"size Like: 1-Green algae 2-Brown algae (Kelp) 3-Red algae	1-Too small to see with naked eye 2-Best grown in slurry systems 3-Some grown in open system 4-Must be enclosed for pure cultures Like: a-Blue green algae (usually benthic) b-Diatoms (major phytoplankton group, can be benthic) c-Din flagellates (major phytoplankton group) d-Others, including raphidophytes

Microalgae have many different species with widely varying compositions and live as single cells or colonies without any specialization. Although this makes their cultivation easier and more controllable, their small size makes subsequent harvesting more complicated. Macroalgae are less versatile, there are far fewer options of species to cultivate and there is only one main viable technology for producing renewable energy: anaerobic digestion to produce biogas. Both groups will be considered, but there is more research, Practical experience, more fuel options from microalgae, for this it take a bigger share in most research (GBEP, 2009). Biologists have categorized, Microalgae in a variety of classes, mainly distinguished by their pigmentation, lifecycle and basic cellular structure, but the most four important are diatoms (Bacillariophyceae) , green algae (Chlorophyceae) ,blue-green algae (Cyanophyceae), golden algae (Chrysophyceae)
(NREL, 1998).There are more than (30000) to (100000) kind of strain of algae, each kind includes many species (Nichols, J), but Researchs focused on Microalgae for mass-production of oil, the preference toward microalgae is due to its less complex structure, fast growth rate, and high oil content (for some species),and some types of algae comprise more than 50 percent oil, as shown in Table 3. (Chisti, Y.2007).

Table3. Oil Content of some Microalgae

Microalgae	Oil Content (%dry wt)
Botryococcus braunii	25-75
Chlorella sp	28-32
Crypthecodinum cohnii	20
Cylindrotheca sp	16-37
Dunaliella primolecta	23
Isochrysis sp	25-33
Monallanthus salina	>20
Nannochloris sp	20-35
Nannochloropsis sp	31-68
Neochloris oleoabundans	35-54
Nitzschia sp	45-47
Phaeodactylum tricornutum	20-30
Schizochytrium sp	50-77
Tetraselmis sueica	15-23

Above all, the average acre of algae grown today for pharmaceutical industries can produce 500 gallons (19000 liters) of biodiesel each year in comparison to an average acre of corn produces 429 gallons (1600 liters) of ethanol per year, and an acre of soybeans yield just 70 gallons (265 liters) of biodiesel per year. From previous the essence issues is economics and cost - benefit oil production from Algae.

2- Background of the research:

All R&D since century ago, from first breakthrough to discover algae, when pond scum (Anabaena cylindrical, a cyan bacterium) collected from a Massachusetts reservoir was found to produce almost pure hydrogen gas (Jackson and Ellms, 1896), and subsequent time, like offered in 1948, when Paul Cook engaged in some of the first research on algae mass culture and cultivation with Stanford Research Institute, and In 1950s, at USA when algae biomass production for wastewater treatment and conversion to methane (Oswald & Golueke, 1960).Then In 1953,were microalgae biofuels mentioned in conjunction with an algae pilot plant operated on a rooftop at MIT (Burlew, 1953).This early basic research and other’s laid the foundations for the applied research in Algae biofuel production, but in 1970 this was strongly initiated after the energy crisis , at 1978 algae were first explored as alternative fuel in USA, the aquatic species program run by the national renewable energy laboratory, researched high oil-output algae for biofuel, after testing more than 3000 types of algae, but the subject studied from the view of chemical, engineering, biological...and ect, even in few cost studies in the early and in latest literature, the calculated cost of product came from the view of economics field, and they are differ in determining the cost of gallon as shown in Table 4, and Figure 2.

Table 4. Summary of microalgae cost analyses published

Author	Year	Product	Productivity (t/acre/y)	Total costs $
Fisher	1935	Food	35	49.5
Oswald&Golueke	1958	Electricity	30	5.85
Benemann et al	1976	Methane	23	7.4
Benemann et al	1977	Methane	20	9.4
Dynatech	1977	Methane	30	13.7
Tahal	1978	Feed	60	184.7
Shelef et al	1977	Feed	60	68.8
Kawaguchi	1977	Health foods	25	1292
Soeder	1977	SCP	36	186.4
Tahal	1977	Spirulina	32.5	98

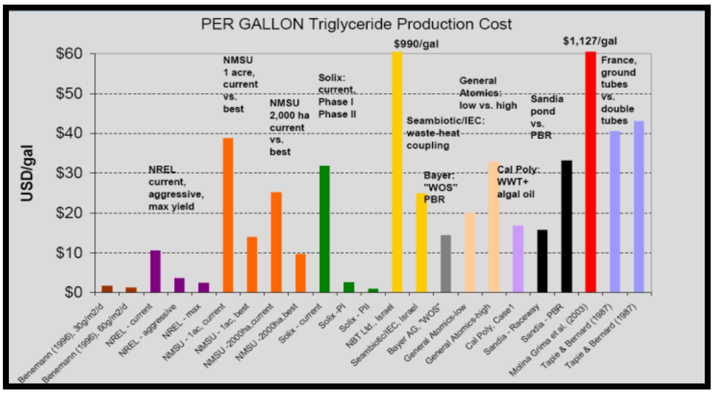


Figure 2. Production cost of gallon algae oil range in different latest studies

But no study came from the view of accounting ,so in this research ,the subject study f rom the view of accounting to calculate the cost of barrel of biofuel of algae and evaluating the parameter such as operation cost, capital cost, and productivity that affect on total cost, comparative with benefit that gain from pricing algae oil versus traditional oil price in order to report whether the oil production from algae economically feasible compared to conventional oil.

3. Algae production systems (Input Materials and Methods)

3-1. Input Materials : The inputs materials for production biofuel from algae are simple, all materials needed are the single-celled organisms that only need sunlight, water (fresh or waste) with (nitrate, phosphate), and carbon dioxide Co_2 to grow; they can quadruple in biomass in just one day. These inputs and materials according to the accounting classification named initial direct cost includes raw materials like:

• Microalgae that grow rapidly and have high oil yield
•Inexpensive land
• Water
• Light
• Favorable temperature
• Nutrients (N, P, CO2)
• Sustainable culturing approach
• Process by (photosynthesis) Microalgae convert sunlight, water and carbon dioxide into biomass contains lipid oils and oxygen.

And add to them labour and direct & indirect industrial expenses to be operation cost. Either the cost of land and equipment used in production classified as capital cost

3-2. Production system (Methods) : Producing biodiesel from algae biomass is not a simple technical process. Algae like any good must pass many stages in order to convert it from plant to Oil. Algae had specific condition make it more complex than other goods. One major concern is to determine the important stages in algae production system,(which help us in determining the various components of total production costs) as shown in Table 5 which Summarized these specific stages.

Table 5. algae production

Cultivations method	Production Stages of Bio-fuel
Open Pond System	Flocculation Mechanical Press Mechanical Oil Drum Dryer Methane Gasification Expulsion
Hybrid System	Liquefaction or Fast Pyrolysis Mechanical Press Microfiltration Green Diesel Hydroprocessing
modular (indoor)Closed Photobioreactor	Methanol Fermentation Sonication
Heterotrophic Fermentation	Solvent Extraction Rotary Dryer Mechanical Press Centrifugation Biodiesel Transesterification
Integrated Cultivation System	Modified Fermentation Supercritical Fluid Extraction Solar Drying Butanol + Hydrogen

Sources: (catie R, elt. 2009)

Where cultivation algae are divided into many categories as below;

1- Cultivation in pond (Whether close pond or open pond).

2- Cultivation in photobioreactor which divided to subsystems in PBR and photobioreactors. And photobioreactors are divided to many categories like;

a- Stirred tank.
b- Bubble column.
c- Flat plate.
d- Tubular reactor (divided to:–Horizontal -Vertical).
e- Air lift.
f- Immobilized.
g- Vertical column.

3- Cultivation in Sewage waste water.

4- Marin environmental.

5- CO_2 capture.

6- Desert.

But some, who had active research, and laboratory experiences, had some conversions about algae fuel, this issues title as assumption like: **a**- The present cost of algae production from open ponds is too high to make fuel production economically viable. **b**- The photo bioreactors (PBRs) are too expensive. **c**- The energy inputs into the algae production process are very high. d- Some algae don't need sunlight, and can produce oil in a fermented process. These issues and the complex processing requirements, create a cost structure that's not competitive with the traditional fuels .But the largest issue concerning the development of algae into biofuel is the capital cost for a pond or PBR process and this for it self need separate research to measure it.

4.Developing Cost Equation Model and Calculating the Cost oduction

The more complementary and complex approach for evaluating the cost of a particular biofuel algal produce is to setup the whole process, determine the approximate production costs and assess which factors are the most effected on the final product cost. So depending on the prior studies which addressed key issues as biological, engineering, and economics parameters in development production system to microalgae-fuel like, Productivity (Arial & Annual productivity), Space required, Water losses, O_2 inhibition, Process control, Capital/operating cost ....etc (Benemann.J, 2008), we will design assumptions for all parameters. take in consideration uncertainties involved in designing such model, uncompleted, unavailable important information and data about the subject ,because of it under research and developed. Also we use Sensitivity analysis in order to determined which parameters are most likely to have the largest impact on production costs. As we mention previously , this model is not exhaustive as it does not include some factors such as the costs of drying and further processing of the biofuel, the cost of packaging and marketing nor the cost of capital of this stage because of the lack of data about it, so the focus will be on calculating the operation cost for the final product, depending on assumption and input data listed in Table 6 , to develop the equation as listed below :

Details	Equation	No
Total capital cost	TCAP.C=TPA×(C.SIP+C.CLS+ENG.F+COG+C.LAND)	1
Arial productivity at various levels of (Ph).	AR.P=VP× (PD×1000)	2
Annual productivity at various levels of (Ph)	AN.P=VP×TGD×(TPV×1000)×(1-PDW)×PPH×HE/ 1000000	3
The annual extra volume of culture media to replete the amount of lost	AEV=TPV×PPH×TGD× (1-HE)	4
The nutrients added to make up for it take up by cells	NARC=NUC×PPH×TGD(TPV×1000)	5
The amount of nutrients added to the medium	NAHC=NUC×TGD×PMR×(TPV×1000)×(1-PPH)	6
The amount of nutrients required for making up the extra culture media	NPE=AEV×NCM	7
The amount of nutrients added per year.	NGN=NARC+NAHC+NPE/1000	8
Total annual cost for co2	$TC_{different\ ph}$ =COC×$CN_{different\ ph}$×(TPV×1000)×(1-PDW)	9
Annual cost for total fresh water added	TFWC=TPA×ARE×AR	10
Labour cost	TLC=LCS+LCST+LCTD+LCTS	11
Annual power (Electricity) cost	APOC=24×POC×POU×TGD×TPHA×(1-PDW)	12
Cost before harvesting	PUPH=(TCAC/12)+ANC+APC+TFWC+Asco+TLC+ TPOC/AVP_{ph} ×1000	13
Cost after harvesting	PHPH=(TCAC/12)+ANC+APC+TFWC+Asco+TLC +TPOC + AHC/AVP_{ph}×1000 AHC=From Table :Harvesting days/year=140 day :VH=TPV×PPH×TGD×(1-PDW)	14
Rate of production lipids	BP=(((fcl*Pa)/ρcl)*length*width*No of ponds)/3.75/45 Pa=Arial productivity (kg/m2.y) : fcl=dry mass microalgae lipid fraction: ρcl=lipid density(kg/l)	15
Indirect costs	(Insurance=TCAC×2%)(Depreciation=TCAC×10%) (Maintenance = TCAC× 3%)(Others = TCAC ×1%)	16
Oil yield (gallon & barrel)	Operation($/ton)=operation/AVP : Noha=PL*w*pnum/10000: tpap = PL * PW * PNUM: oilpp = (tpap * oilp)/37.85/3.9: oilppb=oilpp/45	17
Revenue	R= (oilppb * price)/AVP Oilppb= oil yield : AVP=annual productivity	18
benefit	B=Revenue-operationX OperationX=operation cost ($/ton)	19

Table 6. Assumption and Input data of biofuel cost process

	Case	Abbreviation	Value	Units
1	Cost of Site preparation	C.SIP	16000	$/ha
2	Cost of Culture system	C.CLS	240000	$/ha
3	Engineering fee	EF	38400	$/ha
4	Contingency	COG	12800	$/ha
5	Cost of Land	C.LAND	1000	$/ha
6	Land / Area(ha)	LAND/Areal	100, 200, 300, 400, 500	
7	Total growth days	TGD	330	day
8	Proportion of down time	PDW	15%	%
9	Proportion of pond harvesting	PPH	50%	%
10	Cost of nitride	ANC	1	$/kg
11	Cost of phosphuors	APC	1.5	$/kg
12	Harvesting efficiency	HE	90%	%
13	Pond depth	PD	0.2	M
14	Pond length	PL	530	M
15	Pond width	PW	12	M
16	No of ponds	No.P	157,314,471,628,785	-
17	Used nitride from culture media	NUC	0.0075	g/l
18	Proportion of medium recycled	PMR	90%	%
19	Algae doubling time	td	<2	day
20	NaNo3 concentration in medium	NCM	0.075	g/l
21	Used phosphors from culture media	PUC	0.0003	g/l
22	NaH2PO4.1 H2O concentration	PCM	0.005	g/l
23	Volumetric productivity	VP	0.078	g/l.d
24	Co2 cost	COC	0.068	$/l
25	Co2 required for different ph	CNph	0.35	l/d
26	Fresh water cost	FWC	0.05	$/m^3
27	Average days of evaporation	ADE	330	D
28	Rate of evaporation	RE	0.03	M
29	Average rainy days	ARD	25	D
30	Average rain	AR	0.1	m.d^{-1}
31	Labour cost supervisor	LCS	2058.33	$/ha.y
32	Labour cost senior technision	LCST	2816.66	$/ha.y
33	Labour cost technision-day term	LCTD	6933.33	$/ha.y
34	Labour cost technision-shift term	LCTS	3900	$/ha.y
35	Power cost	POC	0.15	$/ha.y
36	Power usage	POU	65	$/kw.hr
37	Harvesting system cost annually	AHC	From Table.2 (.35)	$
38	Oil lipid	oilp	(5-60) Taken (30)	$
39	Price /barrel of Oil	price	150	$

Note: Barrel=42 gallon (according to us measurement) was the adoption of info@digitaldutch .com

But we noted that any factor can increase the net productivity of the plant on annual biases at little incremental capital or operating cost, is of fundamental importance. The simplest and most important of these are:

- Site selection. A microalgae plant should be located at a site where climatic conditions provide optimal growth conditions for the longest possible period.
- Selection for faster growing, more productive strains optimized for the prevailing climatic conditions is also important. To do this it essential to have a good understanding of those factors which limit growth and productivity, an excellent

example of such studies is given in the paper by Vonshak and coworkers (Richmond et al., 1980; Vonshak et al., 1982, 1983; Vonshak, 1987).

- Culture systems :productivity can also be improved through better culture systems, however the incremental cost of these culture systems in relation to the improvement in productivity must be evaluated carefully.

- The cell concentration of the products is also very important. Increased product concentration not only decreases the effective unit cost of the raw biomass, but it also generally reduces the cost of extraction and purification.

- Harvesting system which represents a significant capital and operation cost component. So the choice of harvesting system also depends on final product desired. It is therefore desirable to select an algae with properties which simplify harvesting i.e. large cell size, high specific gravity in comparison to the medium. The cost of harvesting may be offsite against the cost of achieving higher productivity.

- Algal-biofuel production labour: Labour is required for pond and equipment maintenance, monitoring of the cultures, harvesting, extraction and further processing. So any improvements in the design of the process and automating the operations of the plant which decrease the labour requirement, without unreasonably increasing the capital costs need to be considered carefully as a possible means of reducing production costs.

For commercial production the whole process of culture, harvesting and subsequent downstream processing must be reliable. particularly in case of large open pond systems , open air cultures in use today. These assume a good understanding of the algae and their interaction with the environment. For this the direction towered Closed culture systems, such as the tubular photo bioreactors which are being developed in several parts of the world (Chaumont et al., 1988; Borowitzka & Borowitzka,1988, 1989; Hoshino et al., 1991) are another way to improve reliability since the growth environment can be much more closely monitored and controlled.

4- Discuss the results

The main goal of this research is to measure the cost of barrel of algae-biofuel in comparison with the cost of barrel of traditional oil, so in this paper we gain the result as shown in Table 8 after applying a theoretical approach to evaluate economics & cost–benefit of product biofuel from microalgae.

The results show that the cost of barrel of algae-biofuel is still higher than the cost of barrel of traditional oil, but this result was much better than the result of others like Harmelen (336,525$resp) (Harmelen .T.V, 2006), the cost of barrel between (143.88-151.51$), it can be reduce for commercial purpose if improved the harvesting efficiency and increase the productivity of algae oil content of species. The total cost of algae process is sensitive to culture area and it so much sensitive to the productivity and improving the harvesting efficiency. The operation cost per unit (if productivity $/ton) of biomass is increased with the increasing area until reaches 300 hectare, then it begun to decrease ,this means that the commercial cost be benefit with the increasing the culture area. The benefit and revenue increased until 400 ha and jumped sharply until 500 ha of cultural area, this means that the good benefit confirmed at 500 ha of area. The analysis shows that the operation cost components like water cost are of high major significance. The cost of the biomass is most sensitive due to increases in labour and power costs, whereas nutrient has little impact, which much better from the result of (Phillip Brown) as shown in Figure 4. Once potential contributor to overall operating costs, is the cost of addition of CO_2 to the culture. In open systems at normal pH & pH<9 the transfer efficiency of CO_2 is low, and it is doubtful whether the increased productivity, algal production is intensive to Labour which is required for pond and equipment maintenance, monitoring of the cultures, harvesting, extraction and further processing .Any improvements in the design of the process and automating the operations of the plant which decrease the labour requirement.

Table 7. The Output

Area(ha) Parameters	100	200	300	400	500
Capital cost ($)	3.077E+07	6.154877E+07	9.232316E+07	1.230975E+08	1.538719E+8
Annual productivity (Ton/y)	1966.196	3932.392	5898.587	7864.783	9830.979
Total cost ($)	3.02E+07	6.1E+07	9.08E+07	1.2E+08	1.5E+08
Operation cost ($)	2.785418E+5	5.570837E+05	8.356255E+05	1.114167E+06	1.392709E+6
Biomass cost ($/ton) = operation cost /Annual productivity	137	139	140	139	132
Biomass cost ($/kg) = Operation cost / Annual productivity	0.137	0.139	0.14	0.139	0.13
Cost before harvesting ($/kg)	4.06	2.031767	1.354511	1.015883	0.8127068
Cost after harvesting ($/kg)	6.59	3.297375	2.19825	1.648687	1.31895
Biodiesel productivity (gallon/y) oil yield = 30	202930	405861	608791	811722	1014563
Biodiesel productivity (barrel/y) oil yield=30	4509	9019	13528.7	18038	22547
Biodiesel productivity(barrel/ton)	2.3	2.2	2.3	2.3	2.3
Barrel cost ($/barrel) add 9% of biomass cost as extraction process cost	150	151.51	152.6	151.51	143.88
Gross annual revenue ($/ton)	344	344	344	344	344
Profit ($/ton) (Revenue- Biomass cost)	207	205	204	205	312
Profit (Revenue- Barrel cost)	194	192.49	191.6	192.49	200.12
Cost of gallon ($)	3.57	3.6	3.62	3.6	3.42

Table 8. Operation cost driver for various items of cultural areas

Details	100,200,300,400,500(Hectares)
Contribution of nitride to total operation cost	**1.68 %**
Contribution of phosphors to total operation cost	**0.1%**
Contribution of CO2 to total operation cost	**14.5%**
Contribution of labour to total operation cost	**5.6%**
Contribution of power to total operation cost	**23%**
Contribution of water to total operation cost	**17%**

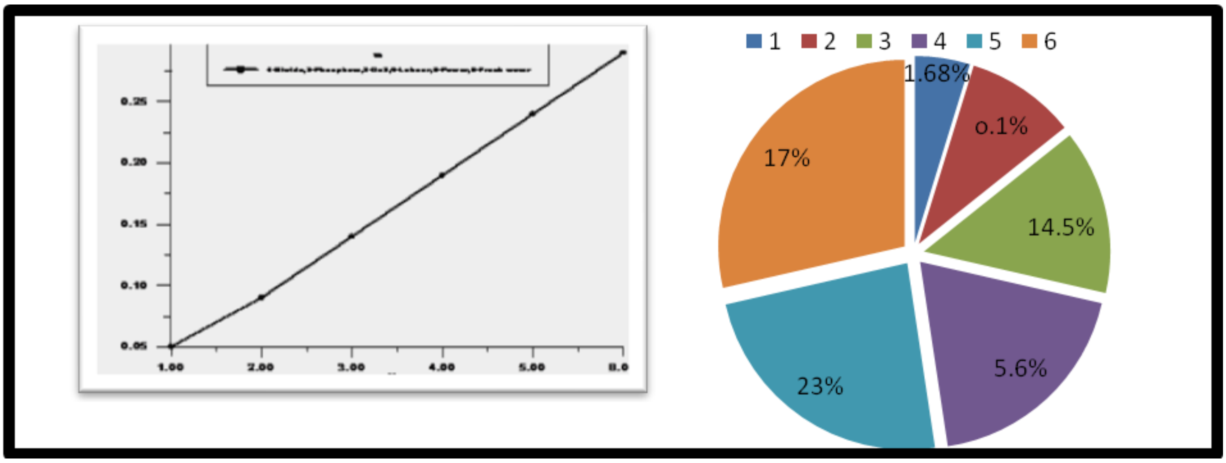
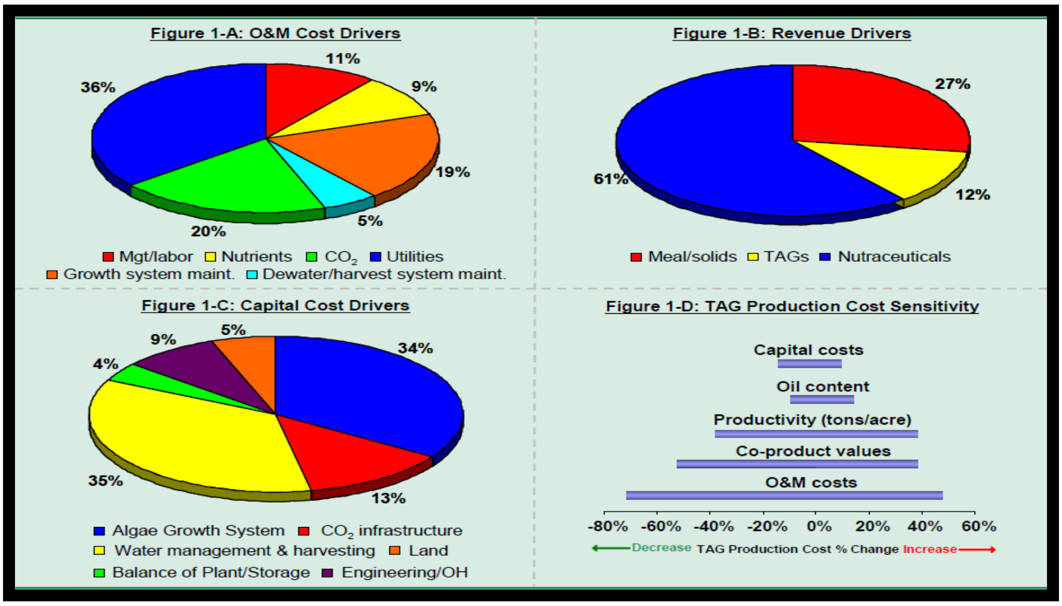


Figure 3. Operation items cost drivers 1- Nitride, 2- Phosphorus, 3- CO2, 4- Labour, 5- Power, 6- Fresh water.



***(Brown. P, 2009)**

Figure 4. Algal biofuels economic drivers.

5- Conclusions and Comparison with the other workers

The applying cost structure model indicated that there was economic feasibility from produced algal-bioful ,although the production cost was high but it was reasonable cost in comparing it with the damage and costs spent to protect the environment from pollution, others conclusion was the cost and revenue sensitive to the productivity and culture area which agree with results of other researchers as shows in Table 9,Figure 5.

Table 9. Comparison between several workers for many algae variable parameters

Algae Type	Culture System	Culture area/volume	Productivity	Cost $/Kg	Reference
Scenedesmus	Raceway	4 ha	20	7	Becker et al. (1980)
Spirulina	Ponds	20 ha	12	5	Rebeller(1982)
Spirulina	Raceway	5 ha	12	12	Rebeller(1982)
Microalgae	Ponds	800 ha	17	0.4	Benemann et al.(1982)
Spirulina	Raceway	10 ha	14	6	Richmond (1983)
Microalgae	Ponds	10000 ha	20	0.3	Regan&Gartside (1983)
Porphyridium	Solar water	34 ha	30	14	Anderson&Eakin(1984)
Cruentum	Heater	-	-	-	Tapie&Bernard (1958)
Microalgae	Tubular reactor	10 ha	16	7	Tapie&Bernard (1958)
Chlorella	Raceway	-	25-30	22	Kawaguchi (1980)
Chlorella	Raceway	-	25-30	23	Kawaguchi (1980
Spirulina	Raceway	5 ha	3.2	22	Jassby (1988)
Dunaliella	Raceway	2 ha	4	10	Mohn&Cordero (1990)
Microalgae	Tank culture	20 m^3		60	Fulks&Main (1991)

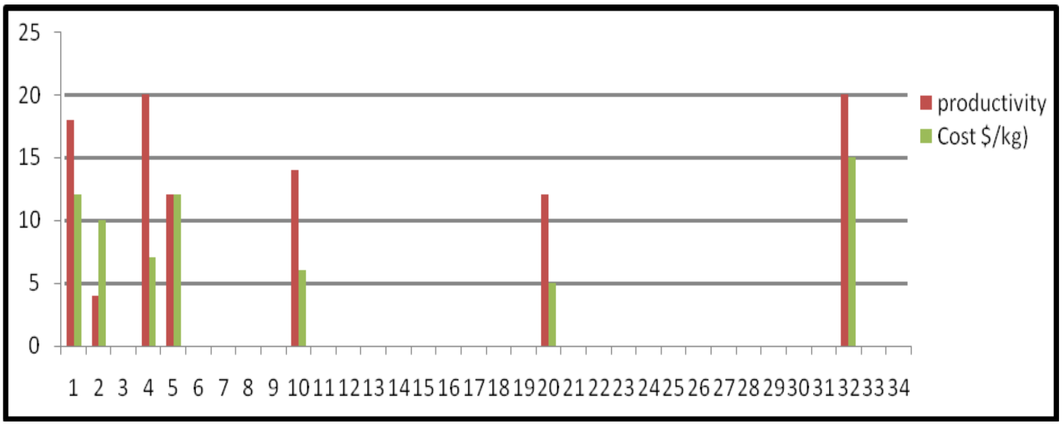


Figure 5. Shows the effect of area size from 1-32 ha on algae productivity and the final production cost ($/kg), the productivity increased while cost rate decreased to lower levels.

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Programming of modeling process

```
50 INPUT "SPREP =Site Preparation($/ha)** ="; SPREP
   INPUT "CSYS =Culture System ($/ha)******* ="; CSYS
   INPUT "ENGF =Engineering Fee ($/ha)****** ="; ENGF
   INPUT "CONTING =Contingency ($/ha)** ="; CONTING
   INPUT "Land =Land ($/ha) ************* ="; LAND
   INPUT "TGD=Total growth days*********** ="; TGD
   INPUT "PDW= Proportion of down Time*** ="; PDW
   INPUT "PPH= Proportion of Pond Harvesting* ="; PPH
   INPUT "Ncost=cost of nitride/kg ********* ="; Ncost
   INPUT "Pcost=cost of phosphorate/kg ***** ="; Pcost
   INPUT "HE=Harvesting Efficiency (%)******** ="; HE
   INPUT "ODEPTH=Pond Operating Depth (m)* ="; ODEPTH
   INPUT "LENGTH=Pond Operating LENGTH (m)* ="; LENGTH
   INPUT "WIDTH=Pond Operating width (m)**** ="; W
   INPUT "PNUM= No of ponds ************* ="; PNUM
   INPUT " NUC=Used Nutriedes from culture media* ="; NUC
   INPUT "PMR=Proportion of medium recycled**** ="; PMR
   INPUT "td =Algae Doubling Time < 2 days******** * ="; td
   INPUT "NCM=NaNo3 concentration in medium*** ="; NCM
   INPUT " PUC=Used phosphorus rate from culture media* ="; PUC
   INPUT " PCM=NaH2PO4 .1H20 Concentration******** ="; PCM
   INPUP"VP=Volumetric productivity of different (ph)(g/L.day)* =";VP
   INPUT "CC=CO2 Cost                    ******** *** ="; CC
   INPUT "CN ph=CO2 required fore different PH** ="; CNph
   INPUT "FWC = Fresh water cost ($/m3) ******** ="; FWC
   INPUT "ADE=Average days of evaporation (day** ="; ADE
   INPUT "EV=Rate of evaporation (m) ************ ="; EV
   INPUT "LCS =Labour cost supervisor *********** ="; LCS
   INPUT "LCST=Labour cost senior technician ***** ="; LCST
   INPUT "LCTD=labour cost technician-day term ** ="; LCTD
   INPUT "LCTS=labour cost technician-shift term  * ="; LCTS
   INPUT "POC=Power Cost  ******************** ="; POC
   INPUT "POU=Power Usage   ****************** ="; POU
   INPUT "AHC=Harvesting system cost ($)/Table*** ="; AHC1
   INPUT"fcl=Dry mass microalgae lipid content fraction* =";fcl
   INPUT"dcl=Density of lipids usable for conversion to biodiesel(kg/L* =";dCL
   INPUT "price ($)          ********************** ="; price
   REM  *********     Total Capital Cost     **************
   TPHA = LENGTH * W * PNUM / 10000
   TPV = ODEPTH * LENGTH * W * PNUM
   TPA = LENGTH * W * PNUM
   TCAP = TPHA * (SPREP + CSYS + ENGF + CONTING + LAND)
   REM ***********     Arial Productivity     ****************
  AP = VP * (ODEPTH * 1000)
  REM ****    Biodiesel productivity/year...(gallon& barrel)     *****
  PA=(AP*360)/1000
  PCL1=(fcl*PA)/dcl
  PCL=(PCL1*TPA)/3.75*10
  PCLL=PCL/45
  REM ******      Annual Productivity           **************
  x = 1 - PDW
 AVP = (VP * TGD * TPV * 1000 * x * PPH * HE) / 1000000
 AVP1 = AVP * 1000
 REM  ************     AN cost       ********************
 AEV = TPV * PPH * TGD * (1 - HE)
 NARC = NUC * PPH * TGD * (TPV * 1000)
 NAHC = NUC * TGD * PMR * (TPV * 1000) * (1 - PPH)
 NPE = AEV * NCM
 NGN = (NARC + NAHC + NPE) / 1000
```

```
 ANcost = NGN * Ncost
 REM *******    APcost      ***********************
 PARC = PUC * PPH * TGD * (TPV * 1000)
 PAHC = PUC * TGD * PMR * (TPV * 1000) * (1 - PPH)
 PPE = AEV * PCM
 PGp = (PARC + PAHC + PPE) / 1000
 APcost = PGp * Pcost
REM ****************************** CO2 Cost ***********************************
TC = CC * CNph * (TPV * 1000) * (1 - PDW)
REM ****************************** Fresh water Cost ****************************
X11 = ADE * EV
TPV1 = X11 * TPA
TPV2 = TPV - TPV1
TFWA1 = TPV2 * FWC
TFWA = -TFWA1
REM ****************************** Labour Cost *********************************
Noha=length*w*pnum/10000
LCS1=LCS*Noha
LCST1=LCST*Noha
LCTD1=LCTD*Noha
LCTS1=LCTS*Noha
TLC = LCS1 + LCST1 + LCTD1 + LCTS1
REM *****         Power Cost        ************
TPOC = 24 * POC * POU * TGD * TPHA * (1 - PDW)
REM *******      Cost before Harvesting      ***********
PUPH = ((TCAP / 12) + ANcost + APcost + TC + TFWA + TLC + TPOC) / (AVP * 1000)
PUPH1 = TCAP + ANcost + APcost + TC + TFWA + TLC + TPOC
cbefore = (ANcost + APcost + TC + TFWA + TLC + TPOC) / (AVP * 1000)
cbefore1 = ANcost + APcost + TC + TFWA + TLC + TPOC
REM ****************************** Cost After Harvesting ************************
AHC=AHC1*TPV*140
 PHPH = ((TCAP / 12) + ANcost + APcost + TC + TFWA + TLC + TPOC + AHC) / (AVP * 1000)
PHPH1 = TCAP + ANcost + APcost + TC + TFWA + TLC + TPOC + AHC
cafter = (ANcost + APcost + TC + TFWA + TLC + TPOC + AHC) / (AVP * 1000)
cafter1 = ANcost + APcost + TC + TFWA + TLC + TPOC + AHC
REM ****************************** Total Cost before+ After Harvesting ************
Insurance = TCAP * .02
depreiation = TCAP * .1
maintanence = TCAP * .03
Others = TCAP * .01
indirectcosts = insurance + depreiation + maintanence + others
 x = (PUPH / AVP)*1000
Y = (PHPH / AVP)*1000
Z = ((PUPH + PHPH) / AVP)*1000
TOTAL=PHPH1+indirectcosts
OPERATION=cafter1+indirectcosts
 j1= (ANcost/operation)*100
j2= (APcost/operation)*100
j3= (TC/operation)*100
j4= (TLC/operation)*100
j5= (TPOC/operation)*100
j6= (TFWA/operation)*100
REM .................OIL YIELD / {GALLON/BARREL} ************************************
Noha=length*w*pnum/10000
REM      *************tpap = LENGTH * W * PNUM
REM      ****** oilpp = (tpap * oilp)/37.85/Noha*2.5
REM     ********************** oilppb=oilpp/45
```

```
 Revenue= PCL * price
 Benefit=Revenue-operation
REM $$$$$$$$$$$$$$$$$$      OUTPUT      $$$$$$$$$$$$$$$$$$$$$$
PRINT "TCAP=TOTAL CAPITAL COST ($)                ******* ="; TCAP
PRINT "AVP=ANNUAL PRODUCTIVITY *(Ton/year)******* ="; AVP
PRINT "ANcost=Annual (N) cost ($/y)         *********** ="; ANcost
PRINT "APcost=Annual (P) cost ($/y)                  ***** ="; APcost
PRINT "TC=Total Annual cost for co2 ($/y)            ********* ="; TC
PRINT "TFWA=Total Fresh water added by rain ($/y)  **** ="; TFWA
PRINT "TLC= Total labour cost ($/y)                  ********** ="; TLC
PRINT "TPOC=Total power cost for ponds operation ($/y)* ="; TPOC
print"TOTAL ($)                                         ********* =";TOTAL
PRINT"operation ($)                                      ****** =";operation
PRINT "X ($/unit)                                         *********** ="; x
PRINT "Y ($/unit)                                        ************ ="; Y
print "Noha= number of hectars                     ********** =";Noha
print"PCL=biodiesel productivity(gallon/year)     ************ =";PCL
Print "PCLL=biodiesel productivity (barrel/year) *********** =";PCLL
PRINT "Gross annual revenue ($/y)        ************** ="; Revenue
print"benefit ($/y)                              *************** =";benefit
print"j1= contribution  of nutride cost to total operation cost(%)* =";j1
print"j2= contribution  of phosphours cost to total operation cost(%)* =";j2
print"j3= contribution  of co2 cost to total operation cost(%)   ** =";j3
print"j4= contribution  of labour cost to total operation cost(%)* =";j4
print"j5= contribution  of power cost to total operation cost(%)* =";j5
print"j6= contribution  of water cost to total operation cost(%) * =";j6
GOTO 50
```