

Estimate of Biofuel's Potential in Tunisia

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Abstract

Tunisia presents an over-drawn national energy balance because of an important decrease of natural gaz and crude oil resources. This explains the appeal to the development of the biofuels sectors as the case of several developing countries.

The works consists in the bio-fuels potential's estimation in our country. The realized inquiry is based on several informations provided by the different organisms of the country and a resultant series of hypotheses of various materials. It allows to determinate the theoretical potential which was estimated at 54,17 % of the energy need and the real poten-

tial which was estimated at 1,2 %. This real potential is determined by identifying the vegetable resources as sugar and the oleaginous plants especially the jatropha favoured by its aptitude of adaptation to the tunisian conditions, choosing the technology of rotation, irrigating by treated waste water and recovering of used vegetable oil. The ligocellulosic form, not very possible because of its extreme cost, will be the

object of subsequent study.

Keywords: Estimation, Potential, Biofuels, Oleaginous plants, Rotation, Used vegetable oil, treated waste water.

1. Introduction

The development of alternative energies, in particular the energy of the biomass, aims at satisfying certain objectives whose principal ones consist in replacing the oil which is considered a fossil hydrocarbon dearly paid and occasionally available, and fighting against pollution and the global warming. Certain countries are engaged in the promotion of renewable energies and more particularly of the biofuels. The development of these types is based on the valorisation of the cellulose biomass resulting from agriculture and the forest, and that of some under products of alimentary industry.

Following the oil crises of the Seventies, the biofuels were perceived in many countries as a realistic solution although partial with the problem of the dependence to the oil resources. The oil counterblow of 1986 and the too high production cost of the biofuels slowed down their development [1]. The context is become again today more favourable because it is based at least on three points:

- The public opinion pressure in favour of the fight against the intensification of the effect of greenhouse and research of the solutions to reduce the emissions of CO₂, principal gas for purpose of greenhouse [2] in particular in the field of transport constitute a significant factor.

The field of transport knew an enormous expansion during XXe century. The growth in request is mainly allotted to the road transport, and more recently to air transport. Oil remains, then, the primary energy most consumed in the world releasing a great quantity of the greenhouse. On the contrary, the bio-energetics seems to be neutral in CO₂ because the CO₂ released during combustion was collected beforehand by the plant at the time of its growth, the assessment of CO₂ being null [3].

Indeed, the average content carbon dioxide made only grow during the nineteenth century with an annual increase of about 0,8 ppm [4] to exceed 360 ppm [5]. In the same way, the methane concentration has almost triplet. Protoxide of nitrogen, less in relative value, have undergoes also an exponential increase. Largely new compounds made their appearance, such CFCs [5]. All these consequences are due only to one third from what results from the combustion of coal and hydrocarbons annually burnt [4]. The emergency is thus today to reduce the emissions of these gases for purpose of greenhouse. [6]

- the security of the supply of energy, at short and long terms, remains the second point, since the majority of the oil-producing countries are regarded as rather unstable (East Means, West Africa). For this reason, the biofuels seem an interesting option.

- Lastly, the third point is the rise continues courses of oil since the beginning of the years 2000 which involves a renewed interest for the biofuels whose production cost was until recently still very high compared to oil fuel [7]. The tripling of the real prices of oil during these last years had another consequence [8] in opposite of the prices fall of the agricultural products. This difference of the prices explains the farmer's interest for the marketing of these products like fuels.

Nowadays, bioethanol is identified like the important bio-fuel. It is produced starting from the vegetable biomass which consumes CO₂ thanks to photosynthesis. Its use makes it possible to avoid the emission from 50 to 80% of CO₂ compared to the equivalent of fossil origin. [9] In parallel, the biodiesel appears as being a new energy-generating product having favourable characteristics since it is renewable, biodegradable and to emanations of CO₂ definitely lower than that of fossil energies. The raw materials currently most used are vegetable oils or they are used in mixture in all proportions with the gas oil and do not require any modification of the vehicles starting from a minimum rate of incorporation equalizes to 2%. [10]

The production of the biofuels in the world is primarily carried by three great areas: the United States, Brazil and Europe which represent the mature markets. [11]

It is the use of ethanol, primarily produced and consumed in the United States and Brazil, first and second producers of soya, which is largely majority compared to the consumption of methyl vegetable oil esters, which remain still a European specificity since the European market of the fuels is marked by an increasing domination of the gas oil consumption. Concerning ethanol, it is imported, is not generally used directly but it is transformed into ethyl-thirdly-butyl-ether ETBE which is, itself, mixed with the gasoline.

Many other countries consider the launching of national programs in favour of the biofuels such as China, India, Malaysia, Colombia and Thailand. These developing countries are quite naturally in favourable position for the production of raw materials useful for the biofuel's manufacture, in particular those whose sugar sector is traditionally significant, which is not the case of Tunisia.

In Tunisia, a main effort of research is provided in order to exploit the natural vegetable richness of the country with an aim of being integrated in the way of durable energy production. Indeed, the energy balance is overdrawn during the last years.

In 2006, an aggravation of 83% of the energy deficit is showed and passed from 530 to 986 Ktep between 2005 and 2006. Indeed the primary energy resources showed a strong fall of 5% due to the conjugation of a significant decline in the natural gas resources of 5,6% and one strong decrease in the crude oil's production of 4,2%. In the other hand, the primary request for energy developed of 1,3%. This evolution of

demand is drawn by the increase of 2,3% from consumption in petroleum products against a stagnation from natural gas (+0,5%).

This quantity available out of the crude oil undergoes a process of refining and is integrated into the quantity of the petroleum products which marks a fluctuation around 2200 Ktep (energy control Agency) while the total of final consumption into 2006 including the petroleum products is about 4058Ktep. The natural gas, thermal and hydraulic electricity consumption is equal to 5892 Ktep.

This work consists to estimate the potential of the biofuels resulting from the agricultural products in Tunisia and to study the prospects of this new form of energy. A future scenario is traced by detailing the surfaces used, the nature of the cultures chosen, and the strategies to be followed.

2. Methodology of the research

The working method adopted consists to collect useful information, being able to characterize the sector of agriculture, starting from the specialized organizations in order to determine the theoretical and real biofuels potentials in terms of biodiesel and bioethanol. It is about an investigation where the stake is to avoid the food constraint on the one hand, since Tunisian agriculture is mainly exploited by alimentary industries, and engagement, on the other hand, in other perspectives which appear by the integration of the new industrial crops and the product valorisation to knowing the re-use of treated water and frying oil.

Specialized Organizations

- General direction of agricultural engineering and exploitation of water (INGREF),
- General direction of agricultural production, the general inspection of the agricultural studies in the ministry for agriculture and the hydraulic resources,
- The national institute of agronomic research of Tunisia (INRAT)
- General direction of trade international of ministry of trade and the craft industry,
- The Department of the Environment and the durable development,
- The ministry for industry, energy and SME,
- The national institute of statistics (INS),
- The national office of oil (ONH).

Principal Objectives:

The investigation aimed like principal objectives to determine:

- The distribution of the arable lands
- The description of the agricultural activities on the field crops, the truck farming, fruit-bearing arboriculture and the irrigated cultures.

- Energy cultures existing or being able to be integrated
- Quantity of treated worn water and its re-use
- Quantities of frying oils imported and worn
- The various developer organizations.

2.1. Agricultural grounds and activities

In 2005, the total surface of the farms rises to 5.392 million ha including 120 400ha (2,2% of the surface) of forest grounds and non agricultural grounds. The useful agricultural surface is estimated at 5,271 million ha of which 4,884 million ha (93%) are arable. The surface of the arable lands is distributed between the cultivated grounds (4,213 million ha) and 671000ha fallows it.

TABLE: Surfaces of the cultures in 2004-2005

Designation	Surfaces in 2004-2005	%
Cereals	1610	37%
Léguminous plants	77	2%
Fodder	384	9%
Market gardening	162	4%
Industrial crops and other cultures	23	1%
Trees	2155	49%
Surfaces of cultures	4411	100%

Unit: 1000ha

The distribution of the cultures surfaces shows the existence of three areas:

- The areas with dominant trees (2,155 million hectares of which the 2/3 are covered by the olive-trees)
- Areas with dominant cereal (1,643 million ha in 2006)
- Composite areas

TABLE: Distribution of the olive-growing surfaces by great area in 2004-2005

Areas	Olive-trees into full (thousand ha)	Olive-trees with other trees species	Total (thousand ha)
North	215	14	229
Center	943	205	1148
South	268	40	308
Total	1426	259	1685

So the insertion of the industrial crops like the sunflower and colza is possible sight their importance from agronomic point of view since these oleaginous cultures allow the spreading out of work in the farm and intervene like head of rotation, and energy point of view.

2.2. Energy cultures

- The corn

According to the general direction of the agricultural studies, this culture can be introduced into irrigated areas. The studies showed an output of irrigation of about 5000 m³/ha allowing an output of production of 70q/ha.

- The sugar beet

Indeed, this culture knew two periods:

- The first hard one of the year 1961 at the year 1983 which was accompanied by the establishment of the Tunisian sugar company.
- The second period between 1983 and 2000 during which new areas of western north were introduced in the irrigation process and the installation of the sugar Tunisian complex.

Outputs about 43t/ha in irrigated and 28t/ha in dryness are reached. These outputs reached values raised about 120t/ha.

- The colza

The acreage in colza has undergoes a regression during the last years; it reaches 180ha only during 2001, the best output is reached at the year 1991-1992; it is equal to 19 q/ha.

- The sunflower

The acreage increases during the last years of 4500ha in 1990 until reaching 11730ha into 2006. As for the productions, they pass from 4769 tons in 1995 to 7383 tons in 1996. The values fluctuate around 10000 tons in the last few years.

- The Jatropha

The tests carried out in full field are set up at Kondar, Medenine, Kaalat Andalous and the regional station of Souhil Wadi in Nabeul. The goal was to give an idea on the behaviour of this species under pedoclimatic conditions marked by a sandy ground and a bioclimatic semi arid superior and also to specify the requirements out of water for this species while varying the quantities of water brought in irrigation.

The results obtained revealed a strong variability between the sources studied with regard to the growth in height in seedbed and plantation at the time of the installation of the test. In seedbed, the average height of the seedlings after one month of sowing is of 15,4cm and after two months of sowing, it is 22,9cm. In this study the performance norms are about 0,5t/ha, they can reach 15 t/ha [12].

2.3. Treated worn water

The purification of worn water and its use in irrigation is an attractive option, in particular in the arid and semi arid regions, because it presents a source of water and additional manures renewable and reliable.

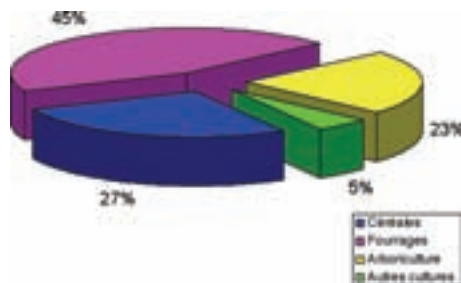
In 2005, the volume of treated worn water is 201 million m³ per year coming from 74 stations of purification of the ONAS.

This volume currently accounts for 5% of the total resources. Only 20% of the total volume of the treated effluents are intended for agriculture and are mobilized starting from the stations of pumping for the irrigation, the remainder of volume is poured in the natural environment.

TABLE: New irrigated perimeters

Areas	Surfaces in ha
Semmana	150
Sidi Ahmed	174
Ouljet El Khodher	30
Jerba Aghim	51
Siliana	80

The surfaces of the irrigated cultures on the level of partner 2001-2002 rises with 7455ha distributed as follows:



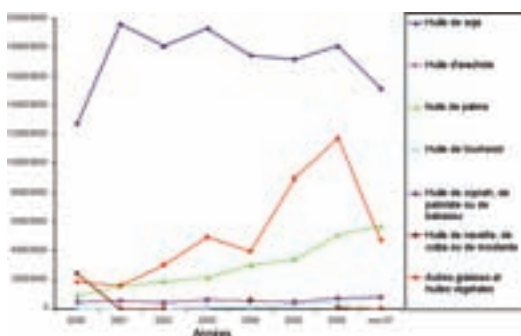
Surfaces of the irrigated cultures in 2002

2.4. Frying Oils

The recovery of worn frying oils as well represents an advantageous factor for its weak price as for its participation in the protection of the environment. This way is very promising. Indeed a significant, but not quantified quantity of worn vegetable oil is rejected directly into the sewers accentuating the worn waters pollution.

It is necessary to recall that during the year 2004 the consumption of the Tunisian vegetable oil market was about 165 000 tons of refined subsidized soya oil and about 5 000 tons of vegetable not subsidized corn and sunflower oil distributed by the National office of Oil (ONH). The apparent consumption of olive oil was only 30 000 tons during the same year.

According to the general direction of trade international, the soya oil occupies a significant place in terms of imported quantity.



Evolution of the vegetable oil imports 2000-2007

2.5. The developer organizations

The technology of production of the biofuels primarily the biodiesel is regarded as being a simple technology being able to be comparable easily by Tunisian industry.

- Unit of triturating

A unit of triturating of a capacity of 20 tons/day was installed in the locality of Ben Béchir in Jendouba by a sponsor deprived in partnership with the ONH (20%), with the French company Sofiproteol (20%). The investment amounted to approximately 1 million DT.

- The Plasticizers General Company (SGP)

The SGP is a company with the capital of 3 300 000 DT, which has in the harbour zone of Radès of a manufacturing unit plasticizers, raw material returning in the manufacture of compound PVC Its production facility is based on a technology acquired near an Italian company, the company Industrie Generali installed in the suburbs of the town of Milan.

This Italian company used its installation of manufacture of plasticizers for the manufacture of the biodiesel intended in mixture for 30% for the gas oil. The SGP lays out the same equipment used by the company Industrie Generali with the help of some modifications. This company is able to launch the manufacture of the biodiesel to height of approximately 7000 tons per year.

3. Results and discussion

The total of final consumption in 2006 including the consumption of the petroleum products (4058 Ktep), the natural gas consumption and that of thermal and hydraulic electricity is equal to 5892 Ktep. This number will be considered the national requirement in primary energy for following calculations.

A series of assumptions will be fixed:

- A rate of oil extraction starting from the oleaginous cultures equal to 99%.
- An output of sugar starch hydrolysis starting from the starch-based cultures equal à .70%.
- Exploitation of the total quantity of the olive oil estimated at 180 000 tonnes/an according to the national office of oil.
- The replacement of trees by cultures at energy ends (sunflower, colza, Jatropha)
- The recourse to the average of the outputs of production during one decade period to take account of the variation of the climatic conditions.
- A rate of recovery of worn frying oils equal to 90%.
- Exploitation of fallow covering the 13% of the agricultural surface for colza culture.

The case of bioethanol

Calculation is done in the following way:

The average of the outputs of production * acreage = produced Quantity of each culture.

Produced quantity * rate of extraction (70%) = Quantity of sugar extracted.

Knowing that **1 ton of sugar ----- > 0,51 ton of ethanol**

According to the article published by the French ministry of the Economy, of Finances and Industry.

Quantity of sugar * 0,51 = Quantity of ethanol.

The case of biodiesel

Calculation is done in the following way:

The average output of production * acreage = produced Quantity of each culture.

Produced quantity * rate of extraction (99%) = Quantity of extracted oil.

Knowing that **1 ton of oil + 100kg methanol = 1 ton of biodiesel + 100kg glycerine.**

Consequently, we will have the quantity produced in biodiesel.

Oil quantity ----- > Bbiodiesel Quantity.

3.1. Estimate of the theoretical potential

The quantity of sugar extracted will be then comparable with the proportion of the sugar contained in the grains of cereals. At corn, the content of sugar reaches 65%, whereas at the barley, it is about 60%, and for the triticale, it can reach 64%.

TABLE: Theoretical bioethanol potential

Cultures	R _{moy} (t/ha)	Surfaces (ha)	Production (tons)	Q _{extracted sugar} (tons)	Q _{bioethanol} (tons)
Common wheat	17	134000	2278000	1036490	52860,9
Durum wheat	13,5	785000	10597500	4821862,5	2459150
Barley	8	520000	4160000	1747200	891072
triticale	16	3200	51200	22937,6	11698,2

The colza contains 40% of oil. The sunflower is cultivated especially for its seeds which provide oil of which the percentage varies from 25 to 46%. Let us fix a rate equal to 46% in our calculations. As for the jatropha, the content of oil can go up to 50%. Let us respect these contents in our calculations. Concerning the other cultures (leguminous, market gardening, trees), they will be replaced by oleaginous cultures according to their regional distribution as follows:

	Surfacescultivées au Nord (ha)	Surfaces cultivées au Centre (ha)	Surfaces cultivées au Sud (ha)
léguminous	67144	37730	60830
market gardenings	73710	70956	17496
trees	42100	638100	101500
	Colza	Sunflower	Jatropha

TABLE: Theoretical potential of biodiesel

Cultures	R _{moy} (t/ha)	Surfaces (ha)	Production (tons)	Q _{extracted oil} (tons)	Q _{biodiesel} (tons)
Sunflower	0,84	9660	8114,4	3695,3	3695,3
Olive-trees	0,72	1685000	1221625	180000	180000
North	1,12	182954	204910	204910,4	204910,4
Center	0,84	746786	627300	244647,1	244647,1
South	0,5	179826	179826,5	88114,9	88114,9
fallows	1,12	671000	751520	293092,8	293092,8
Fodder	1,12	384000	430080	170311,68	170311,68

The theoretical potential also holds account annual imports which vary from one year to another according to the national need. In our case, we will take the average of the quantities imported out of frying oil and colza and sunflower seeds during the period 2000-2007. The seeds will undergo a stage of trituration, will enter the food circuit as frying oil and will be finally recovered with a theoretical rate equal to 90%.

TABLE: Theoretical potential of biodiesel resulting from the imports of vegetable oils and seeds

	Q _{oil/seeds imported} (tons)	Q _{biodiesel} (tons)
Frying oil	274740,145	247266,13
Sunflower seeds	255,9	103,64
Colza seeds	0,19	0,067

So the theoretical potential of the biofuels is equal to **3191,7Ktep** which presents **54,17%** of the national requirement in energy. Thus, it is necessary to cultivate twice all the useful agricultural surface (5,271 million ha) of the Tunisian territory to satisfy our energy needs.

3.2. Estimate of the real potential

The real potential of the biofuels in Tunisia is almost nullified. The only oleaginous culture which exists is the sunflower, and it is completely used for food ends. The sugar cultures do not exist. However, we can consider the exploitation of certain techniques such as farming rotation and the integration of the fallow. Certain factors must, first of all, being put in consideration by estimating this potential at knowing the importance of two agricultural fields which are olive growing and the cereal planting.

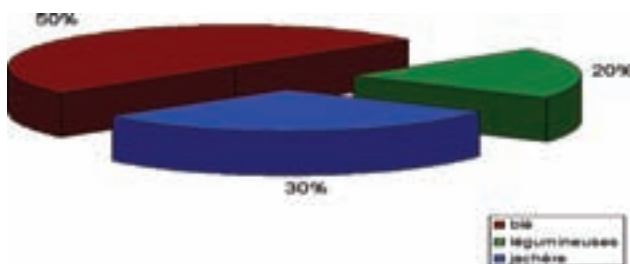
- **Crop growing:** Two thirds of the trees surface are covered by the olive-trees. So it cannot be competed with by the sector of the biofuels for its great food value. Nevertheless, a surface of 259 miles ha is cultivated in partnership with other trees species, which presents an advisability to exploit the majority of the olive surface to carry out mixed planting whose second plants are dedicated to the

sector of the biofuels. We will exploit the olive-growing surface of north (14000ha) cultivated in intensive not to disturb the outputs of productions of the olive-trees.

TABLE: Production of biodiesel starting from the olive-growing surfaces in partnership with the sunflower

Plants	R _{moy} (t/ha)	Surfaces (ha)	Production (tons)	Q _{extracted oil} (tons)	Q _{biodiesel} (tons)
Sunflower	0,84	14000	11760	5355,5	5355,5

- **Cereal cultivation:** Tunisian agriculture is based primarily on the field crops (cereals). Despite, this sector is intended entirely for the human consumption knowing that Tunisia imports in addition to its annual production of cereals (19884 tons in 2007 with an output of 14,7 t/ha which is considered better than last year), of the significant quantities out of durum wheat, common wheat, barley, and corn with a predominance of the common wheat importation.
- **Energy cultivation:** The industrial crops cover the 1% of the total surface of the cultures. This rate can increase knowing that 13 % of the agricultural surfaces constitute the fallow whose introduction supports a farming rotation.
- **The rotation:** Rotation is a technique applied in agriculture. It is about a succession of cultures in a farming system, according to a certain order and on the same piece. As for the rotation, it is about the division of the grounds of a farm in distinct parts, called plates or magpies, devoted each one to a planting given during one farming season.



Distribution of the plants

TABLE: Examples of rotation including colza

Years	Plants	Plants
1 st year	Colza	Colza
2 nd year	Corn	Corn
3 rd year	Rye	field bean
4 th year	Oats	Corn
5 th year	Clover	Oats
6 th year	Corn	Clover

In term of cultivated areas, we will have the following distribution:

Corn	83930ha
Leguminous plants with seeds	33572ha
Planting on fallow	50358ha

TABLE: Production of biofuels based on a rotation

Plants	R _{moy} (t/ha)	Surfaces (ha)	Production (tons)	Q _{extracted oil/sugar} (tons)	Q _{biodiesel or bioethanol} (tons)
Colza	1,12	50358	56400,96	22334,78	22334,78
Sunflower	0,84	50358	42300,72	19263,75	19263,75
Beet	28,9	5000	144500	17432,5	8890,56
Molasses				2621,23	1336,8

- **Frying oils:** This great importance, characterizing the gas oil consumption in Tunisia, directs the exploitation of worn vegetable oils. Let us calculate, then, the quantity of biodiesel produced starting from the vegetable oils imported by supposing a rate of recovery of 10% in the zones with strong density of restoration or the communities.

TABLE: Production of biodiesel from imported oils

Q imported (tons)	Q recovered (tons)	Q biodiesel (tons)
274740,145	27474,0145	27474,0145

The most significant point for the manufacture of biodiesel rests on the existence of the raw materials and particularly those of vegetable oils. For Tunisia, vegetable oil could come from three sources:

- Colza or other oleaginous seeds like the case of sunflower.
- The recovery of worn oils
- Importing the palm oil particularly starting from Asian countries.

3.3. Future scenarios

The following table summarizes the quantities to be produced out of bioethanol and biodiesel by taking account of the various possibilities. It should be noted that the corn contains 60% of sugar and the grains of soya contain 18% of oil.

TABLE: Summary of the obtained values

Cultures	Surfaces (ha)		outputs (t/ha)		Production (tons)		Q _{ethanol/biodiesel} produced (thousand tons)	
	In dryness	In irrigated	In dryness	In irrigated	In dryness	In irrigated	In dryness	In irrigated
Sugar beet	5000	9000	28-30	43	140-150	387	1,295-1,387	3,580
Corn	1000	500	20-25	70	20-25	35	4,284-5,355	7,5
Colza	40358	10000	1,12	0,35	45,2	3,5	17,9	1,38
Sunflower	40358	10000	0,84	0,25	33,9	8,4	15,44	3,825
Tested Soya	200	50	0,7-0,8	0,30-0,35	0,14-0,16	0,015-0,0175	0,025-0,0285	0,00267-

Concerning the sunflower, colza and corn seeds and oil imports:

	Imported quantity (tons)	Q _{ethanol/biodiesel} produced (tons)
Frying oil	274740,145	27474,0145
Colza seeds	255,9	10,13
Sunflower seeds	0,19	0,0062

These assumptions make it possible to produce a quantity of bioethanol equal to 17,82 miles tons and a quantity of biodiesel equal to 66,06 thousands tons. This quantity is equivalent to **69,4Ktep** what covers **1,2%** of our energy needs.

- **The use of the vegetable residues:** The vegetable residues resulting from the forestry development and agriculture can constitute resources for the biofuels development. However, this lignocellulosic way is not yet well controlled.

Conclusions

In front of the current economic situation of the flamed oil price, all militates with the introduction and the use of biofuels which is a solution with a future.

The introduction of the industrial crops (colza, sunflower, beet sugar, jatropha), the recourse to the technique of rotation, the use of the fallow, the re-use of treated worn water and the recovery of worn oils make it possible to cover only the 1,2% of the national energy need. Nevertheless, these solutions suggested present limits:

Concerning colza, the major advantage is the raising of prices of seed oils which is in favour of its local cultivation. The problem lies in the useful surface which enters in competition with the cereal surfaces. As for the sunflower, although its planting currently exists, the production is entirely directed towards food consumption.

These plants can be started again in the head of a rotation with fallow integration. In our study, only 15 % of the fallow was exploited. Moreover, the recourse to the irrigation allows a better production while the quantity of worn water in the nature is estimated at 80% of the total quantity.

Jatropha, a plant shrub with energetic ends, not very demanding of the arid or semi-arid areas, with fruit rich in oil and able to fight in hard conditions of the desert seems to be a promising solution. However, it still remains on the scale of the experimentation.

In addition, it is necessary to note the importance of the recovery of worn vegetable oils of which the quantity remains to be discussed since the distribution of the edible oils is not well controlled. Despite, a study can be carried and based on the area distribution of the hotels and the possibility to install collection equipment.

The lignocellulosic form can, be also developed starting from the forestry and agricultural residues and the herbaceous or little lignified plants which are without use and can be collected for energy ends.

Thus, the development of these alternative solutions is based on the agricultural management and, in the other hand, the synergy between the applied agricultural and desired energetic policies. The coordination between the various services of the state are still essential. However, Tunisia, in charge to feed 10225.4 thousands resident persons and 5473.7 not residents, prefers to develop other types of energy such as the wind power, solar energy, wood energy and biogas.

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