MEDITERRANEAN COMPARATIVE ADVANTAGES FOR BIOMASS FEEDSTOCK PRODUCTION AND IN-FIELD PROCESSES FOR ENERGY GENERATION

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The reorientation of the world economy from the use of fossil row materials to renewable biomass feedstock

The transit from an economy that is based to-day mostly on fossil sources , to a sustainable economy based to the renewable biomass feedstock, is considered a huge effort of the to-day research globally.

But bio-energy and other bio-products, produced to-day from biomass sources (lignin, cellulose, sugars, plant oils and animal grasses), are in direct or indirect competition with food and animal feed.

Under this problem the researchers have to change their work towards other directions to produce biomass feedstock for alternative uses, as they are:

-the combine food/feed production with biomass feedstock production,

-the valorization of marginal land for biomass feedstock production,

-the use of the land under water for biomass feedstock production,

-the use of solid and liquid wastes as biomass feedstock,

-the use of agricultural and forest residues as biomass feedstock,

-the development of the so called bio-products and bio-energy of next generation,

-the alternative uses of plant oils and animal grasses that are characterized not for human/animal consumption.

The world population is in continuous growthαι and is estimated the year 2050, to reach 9 trillion, and in the same time the fossil sources became more expensive.

So, the growing demand of food/feed and alternative uses of biomass dictates the use of any organic feedstock, for the production more cleaver and sustainable products, under the target to reach finally the zero organic wastes.

A few years ago is under development a systematic effort to build the so called bio-reffineries for the holistic production of bio-fuels, bio-chemical products, food and feed, using ALL the chemical products of the biomass.
The result of this effort is the application of the green technology for a variety of products, for a market covering already trillion US dollars globally[5]. (the global market of the bio-synthetic the year 2010 reached in economic value $ 2,1 billion, and is predicted the year 2016 to reach $ 3,8 billion).

The key of success for the research is:

-First of all the selection of the appropriate biomass source(sustainable and low cost),

-Second the valorization of all the chemical products of biomass source(cellulose, hemi-cellulose, lignin, sugars, oils and proteins) to their maximum value.

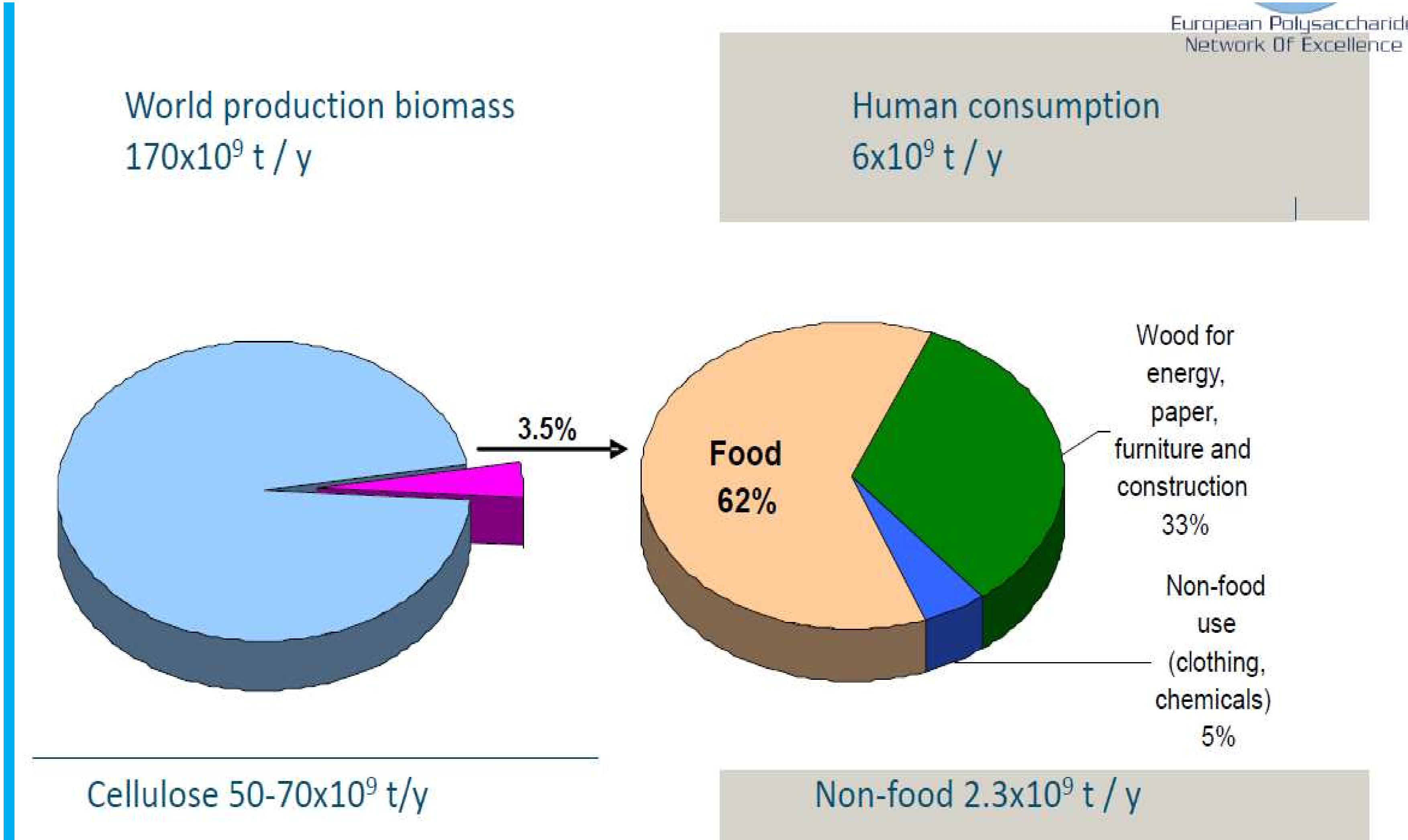


Fig. 1 The % of bio-products from biomass produced globally.
Source: European Polysaccharides Network of Excellence

The IEA predictions for the evolution of the PRIMER ENERGY demand globally.

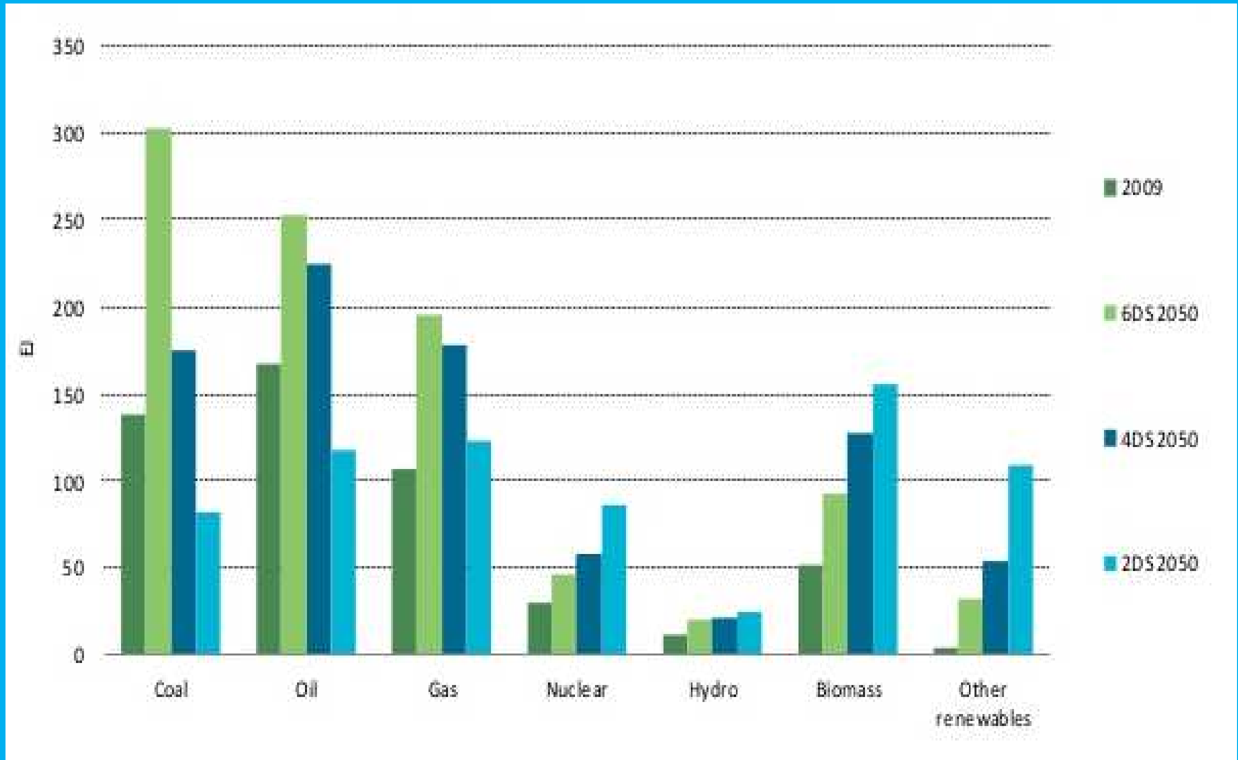


Fig. 2. From the total world demand of primer energy, biomass is predicted (IEA scenario 2DS) to become the bigger demander of energy the year 2050.

(The 2DS scenario of IEA predicts lower CO_2 emissions at 50% the year 2050 and at 100% the year 2075)

Today transport bio-fuels are produced only in arable land and from food/feed.
It was predicted[9]*,the year 2050 transport bio-fuels will cover globally το3%-4% of the 6 billion ha of the today agricultural land in the world level.*
On the other side they are, mainly in the US, Brazil, and EU, scenarios for a continuous important growth of the biomass use for energy, transport fuels and industrial products (see Fig.3). But the policy change to “not use agricultural land and food/feed products for alternative uses” ,makes these scenarios difficult to be realized.

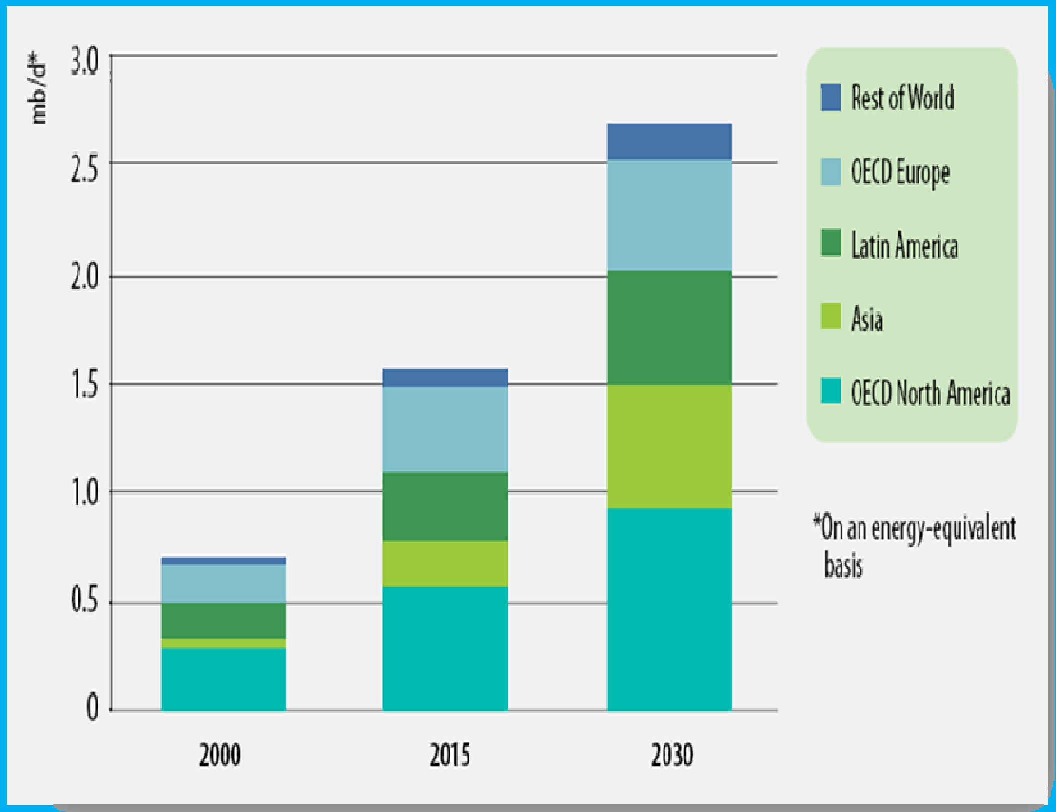


Fig. 3. Predicted transport bio-fuels demand in different regions globally in m. Barrels per day(source : IEA, World Energy Outlook 2009, p.88)

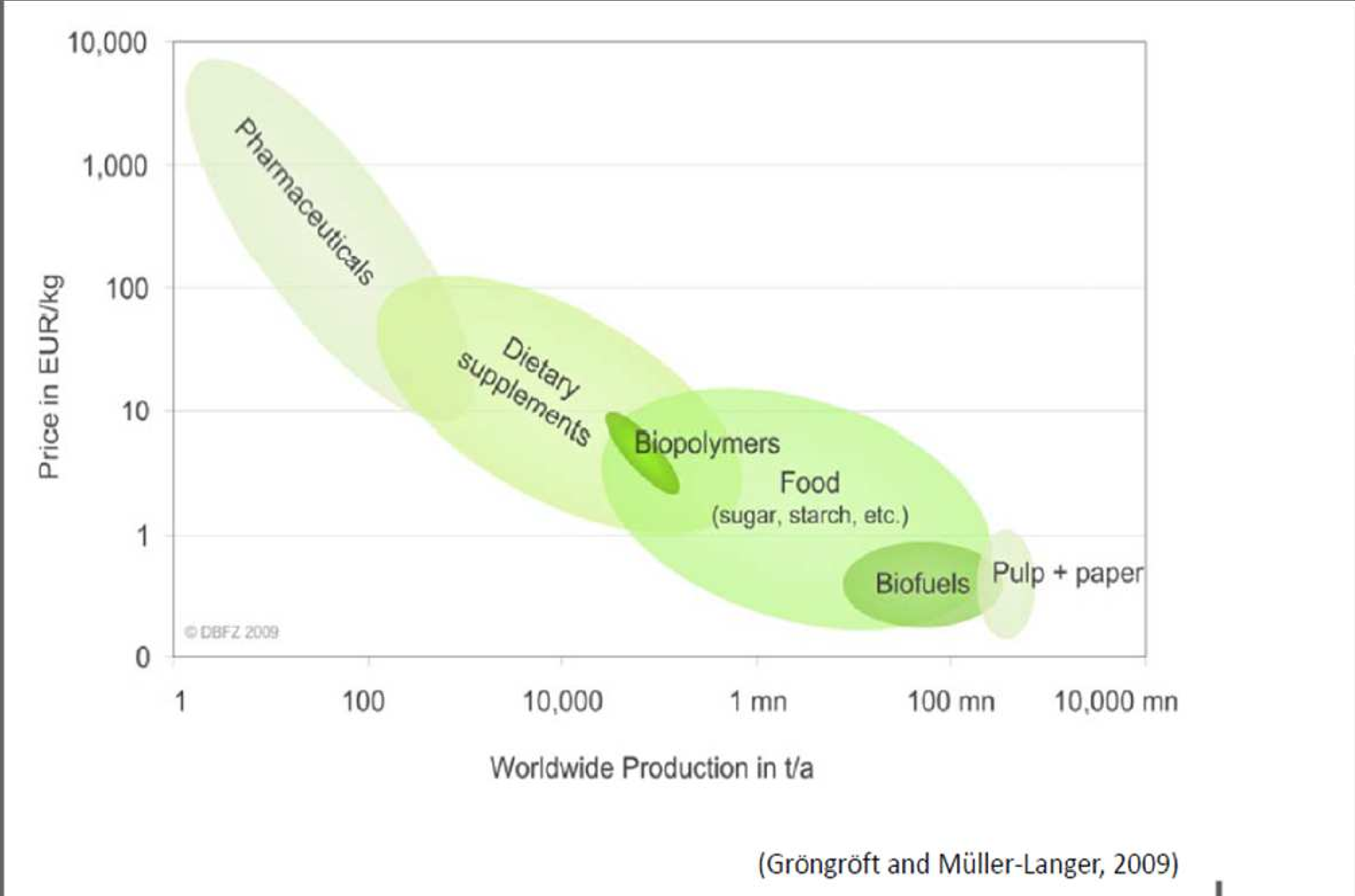


Fig. 4. The world market of Industrial bio-products

Table 1. The cost of different transport bio-fuels, their feedstock cost, their conversion cost, and the revenue from their co-products.

Biofuel	Feedstock	Producing country	Year	Size of plant considered [million l biofuel/yr]	Feedstock costs [$ feedstock / GJ biofuel]	Conversion costs (capex + opex), [$/ GJ biofuel]	Revenue from co-products [$/GJ biofuel]	Total cost [$/GJ biofuel]	Total cost [$/l biofuel]
Conventional bioethanol	sugar-cane	Brazil	2008	250	7.7	7.0	0.0	14.7	0.31
	corn	USA	2008	250	29.4	6.0	0.0	35.4	0.75
	sugar-beet	UK	2008	250	21.6	11.0	8.2	24.4	0.52
	wheat	UK	2008	250	36.2	10.5	6.0	40.7	0.87
	maize	France	2008	250	29.3	10.5	5.0	34.7	0.74
Conventional biodiesel	soybean	US	2008	220	100.6	4.2	55.6	49.2	1.63
	soybean oil	Brazil Argentina	2008	220	22.6	2.7	1.7	23.5	0.78
	rapeseed	UK	2008	220	35.6	4.2	11.3	28.5	0.94
	rapeseed oil	France	2008	220	40.5	2.7	1.7	41.4	1.37
	palm oil	Indonesia / Malaysia	2008	220	25.1	2.7	1.7	26.1	0.86
	tallow	UK	2008	220	13	4	2	15.3	0.51
Lignocellulosic ethanol	cellulosic feedstocks	UK	2015	90	14	14	0	28.0	0.60
			2022	360	14	10	0	23.5	0.50
Syndiesel	cellulosic feedstocks	UK	2015	80	12	17	0	29.5	1.01
			2022	280	12	8	0	20.0	0.69

Source: E4tech (2007)

Sustainability and 2nd Generation transport bio-fuels.

The expected sustainability with the 2nd generation bio-fuels using the cellulose of biomass, faces actually practical problems as they are:

1. The limited productivity of the marginal land to produce cellulosic raw material, if we consider to replace the corn ethanol the fact that, 1ha of land cultivated with corn can produce 4.7 m^3 ethanol and 3.26 t animal feed , instead of the biomass cultivated in1ha of marginal land, producing only 1.12 m^3 bio-fuel and limited feed for animals.

2. The high investment demand and finally the high cost of the 2nd generation bio-fuels, as they are cellulosic-ethanol and BtL (wood-diesel).

So, the research has to solve the difficult problem of the production of the future biomass, as it is : production in large quantities, with sustainability and in low production cost.

The today situation in bioenergy and the reality in Mediterranean countries.

The world research community succeeded to develop several technologies to give energy solutions with the disposed biomass feedstock.

They are technologies suitable for **large biomass processing units to energy**, presenting the advantage of the low cost processing, thanks to scale economy. Examples these technologies are:

-the district heating and the power production with pellets or other forms of biomass feedstock burning or co-burning with coal. These technologies have been developed recently with success for the environment , and energy efficiency, but they need large amount of biomass feedstock, often transferred from one continental to another [from Canada, Brazil, S.E. USA, or from Russia, to E.U. (to Belgium, to U.K. etc.)],

-the bio-ethanol production in Brazil using sugar cane, or using corn in the USA and cereals/ sugar beets in Europe and elsewhere,

-bio-gas production in large anaerobic fermentation units, using municipal and industrial wastes mainly ,

- the bio-ethanol or BtL production of the next generation transport fuels in very large installations in USA, and recently in EU. These technologies, having the target to solve the problem of sustainability, presents actually the big disadvantage of the huge investment and the need for large amount of biomass feedstock.

On the other hand they are family size installations, using mainly agricultural residues, and farm wastes, presenting the big advantage of the low cost of biomass feedstock in relation with the low cost of the feedstock transportation. These technologies suitable for the majority of the Mediterranean farmers (small farms, low investment required) are producing Energy in low cost used in the farm , they create supplementary jobs ,and finally offer this way supplementary income to the farmers and to their families. Examples of such installations are:

-**the small-scale biomass heating systems, using agricultural or forest residues**.
These technologies are today in continuous amelioration by the research (especially concerning their low emissions and their high efficiency), offering to the farmers the needed heat at home and maybe in the farm. The appropriate management in gathering, transportation, loading, and storage of the residues, can gives spectacular reduction of their final cost.

-**the family size anaerobic installations for CHP in-the field.**
The farmer can ferments his farm wastes or even cultivated plant species using them in mixture with the wastes. By that technology the farmer enjoys: economy by heating water and space heating-cooling, supplementary income from the electricity selling to the grid network, economy from the savings in irrigation water and fertilizers, a better environment, and new jobs for his family and maybe not only .

Fig**.5. On the Farm** installation of a Bio-Gas production unit, using for fermentation cultivated Ficus –Indica and the Wastes of the farm. By using the CHP technology the farmer can cover his needs for Heating-Cooling and he can sell the produced Electricity to the Greed.

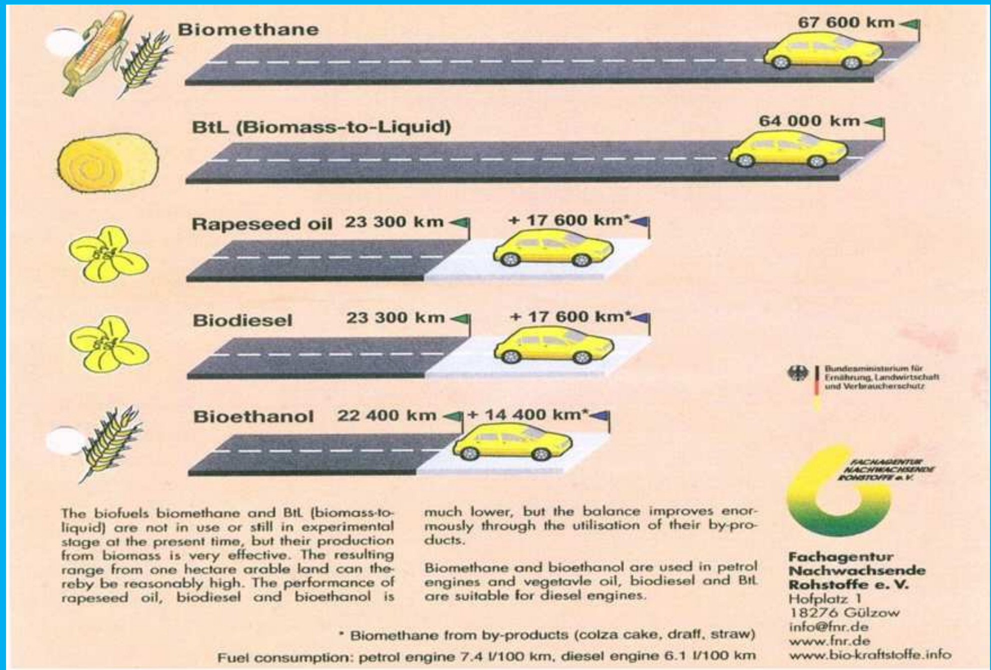


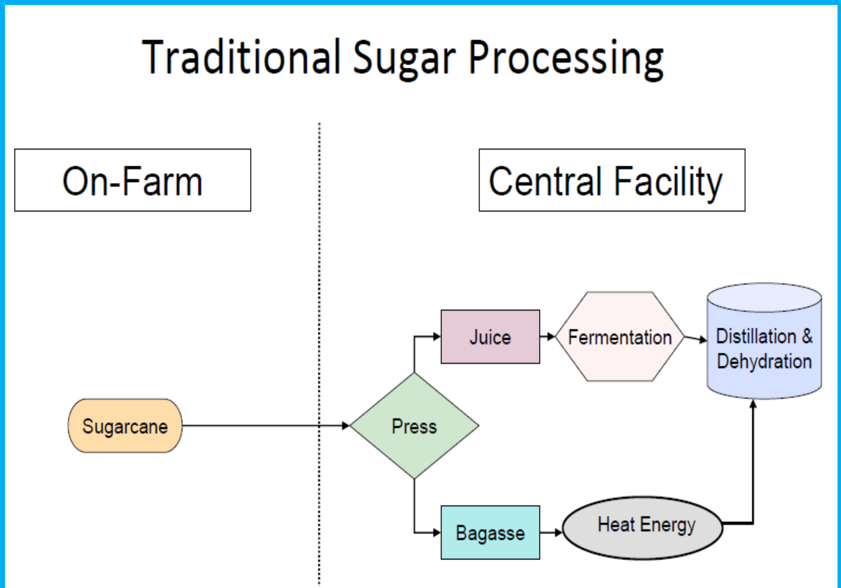
Fig.6. Energy produced from 1 ha of land cultivated with different biomass plants.

-Bio-methane is 8 times more productive in energy from corn ethanol (R.Simson et al. Ren. Energy World magazine, March 2010).

- The compressed bio-methane is environmentally friendlier from more than 70 different bio-fuels (JRC).

-The technology "In-Field Processing of Sweet sorghum to ethanol", it has to be examined carefully for further development and expansion. This technology present the advantages of low cost and more sustainable bio-ethanol production, and better social results[11,10].

The example of the Sweet Sorghum Ethanol Association (SSEA) in the US for "ethanol production **on the Farm",** has to be considered for adoption, not only for ethanol production in Mediterranean countries, but to be adopted for a variety of other bio-energy technologies



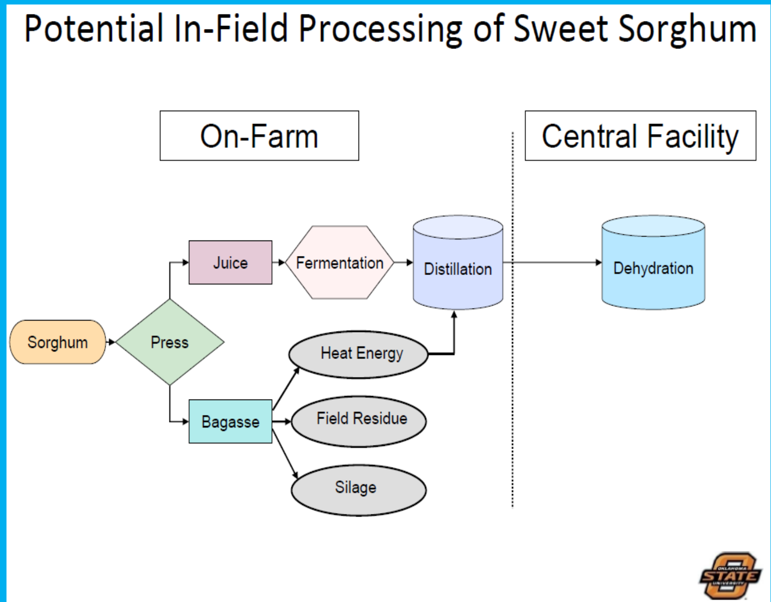


Fig.7. Schematic presentation of the differences between the **Traditional and In-Field Processing** of sugar plants to produce ethanol.

The main characteristics of the technology In-Field Processing of Sweet sorghum for ethanol production [10]

-Investment cost for ethanol processing: **$ 0.264/lit, instead of $ 2.64/lit** in a central industry,

-the final production cost of ethanol : **$ 0.132/lit, instead of > $ 0.35/lit** from a central industry,

-In-Field ethanol has around **8 times less CO_2 emissions** in comparison to the today corn ethanol CO_2 emissions,

- the gains in income/ha are more than 7 fold/ha compared to the gains/ha from the today corn ethanol.

Some encouraging research results for the production of sustainable and low cost biomass feedstock.

a. Biomass production from algae in land covered with water.

For this kind of biomass is estimated [1] that the total world market, in a few years time will grow 43% annually. A growth able to lead the world market volume from $271 million that was the year 2010 to $1.6 billion the year 2015.

b. Agricultural and Forest residues can be a low cost biomass feedstock.

To that biomass source ,**gathering, transportation, and loading** ,together account for around 50% of feedstock costs. In each of the processing steps, costs can be reduced by 20% through improved baling practices (i.e., larger and denser bales), achieved by using specialized field pressing equipment that increases bale density by 30%. In addition, **storage costs** (some 25% of total costs) can be reduced by up to 90%, if bales are stored outside rather than inside, and appropriately protected (by plastic tunnels, for example). The capital cost of **storage barns** is a large part of current storage costs in the today practice.

c. Some plant species and new hybrids able to give promising biomass feedstock , especially under Mediterranean environment .

With the term of promising biomass feedstock, we are giving importance on the environmental/social sustainability, the low cost, and to not compete with food and feed production. With these plant species and hybrids we can produce either cellulose and lignin for energy and transport fuels, or animal feed, or other industrial bio-products.

The referred bellow plants have been proved that are able, under dry and warm environment to produce biomass with:

1. environmental and social sustainability,
2. low production cost,
3. not competing with food and animal feed.

1.**Agave sp**.

Some Agave sp. have huge sustainability and energy advantages as they are produced in marginal, not arable lands ,under rain fed conditions, and not competed with food/feed. At the same time agave saves 2.5 times more CO_2 than corn bio-ethanol (agave-ethanol CO_2 emissions are 35 g/MJ of energy produced).

According to Arturo Valez Jimenez (an agave Mexican specialist), Agave sp. don't require watering or fertilizing and they can absorb CO_2 during the night and use in the photosynthesis during the day. The collected CO_2 is concentrated around the enzyme RuBisCO, increasing photosynthesis efficiency

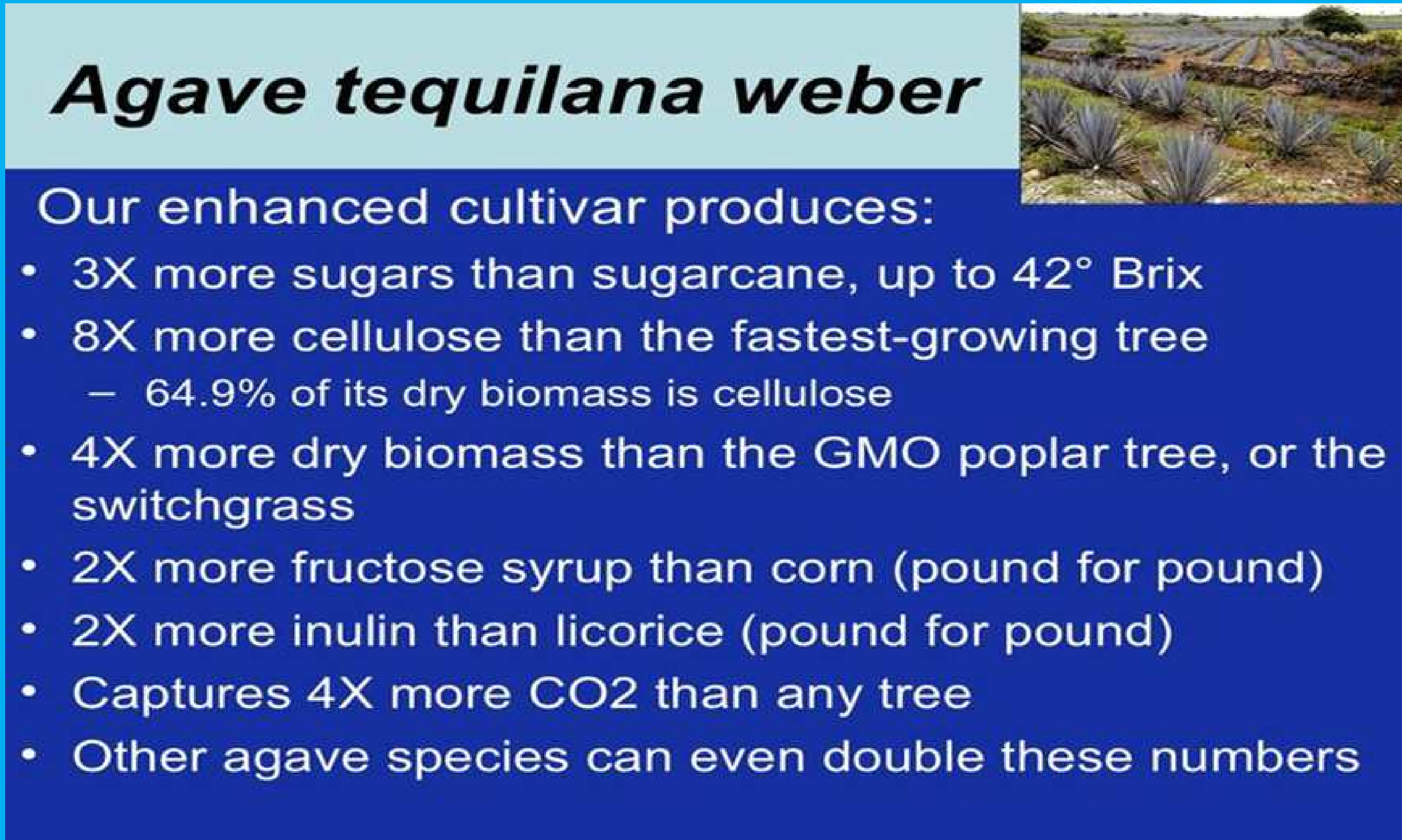


Fig.8. Energy, Chemical bio-products, and Sustainability facts from Agave tequilana

2. Opuntia Ficus-Indica sp.

Opundia ficus-indica (or nopal) is a species of cactus that can be grown for the vegetable nopales in extreme drought conditions, with no irrigation, no fertilizers, and in marginal lands.

Opuntia is culltivated today in Mexico and Chile for bio-gas production. The main features of the bio-gas of nopal are the absence of sulfuric acid and the rapid generation of bio-gas with short retention times (5-10 times faster than animal manure).

Fig. 9. A plantation of Opundia Ficus –Indica in marginal land (Morocco 2013).

According to Dr. R. Morales (head of ELqui Global Energy centre in Chile), one ha of Opuntia produces 17,500 m3 of bio-gas, or the equivalent in energy 10,000 lit of diesel.

The bio-gas produced is the same molecule of natural gas, containing CH4 (75%), CO_2 (24%) and 1% of other minor gasses. The calorific value of bio-gas from nopal is 7,000 Kcal/m3.

3. Switchgrass (Panicum virgatum) for bio-based products and Energy/Fuels

Switchgrass (Panicum virgatum) *is a perennial native warm-season grass, that is a leading biomass crop in the United States. Initially was grown in the USA as a hay and forage crop.*

Switchgrass is productive and sustainable on rain-fed marginal land .

Breeding and genetics research has been conducted at a limited number of locations by USDA, university scientists, and private companies, like NexSteppe, in USA.

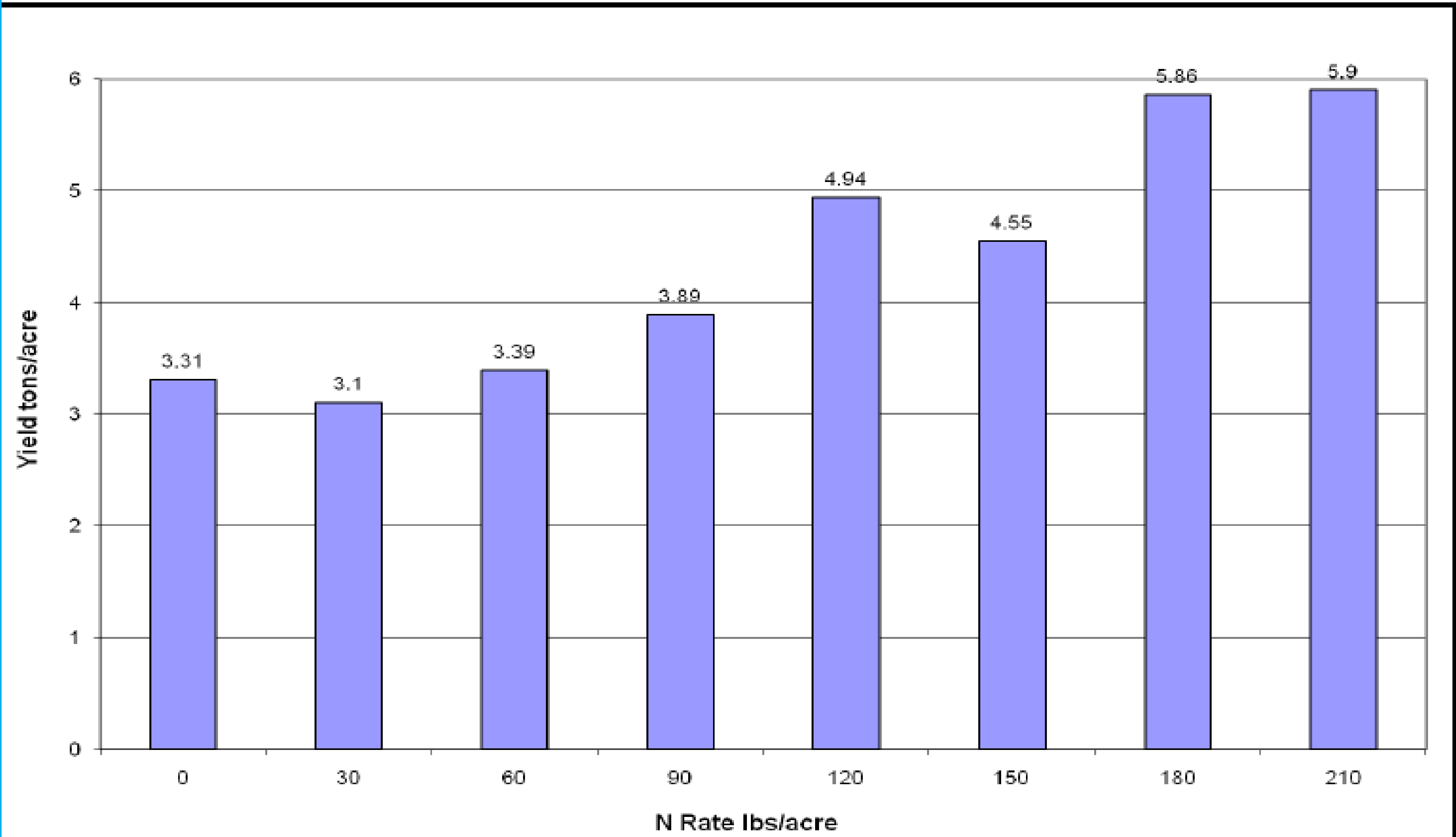
Switch grass is well suited to marginal cropland and is an energetically and economically feasible and sustainable biomass energy crop, with currently available technology.

Switch grass sequesters as much carbon into its root system as it does above ground, which means that processes using switch grass can produce carbon negative bio-fuels, bio-power, and bio-based products.

Switch grass provides a high quality biomass with low moisture, low ash, and high calorific value.

Fig. 10. Switch grass plantation in its third year (photo NexSteppe)

Fig. 11. Results on Switch grass yield based on Nitrogen application.
(according a research of Oklahoma State University)



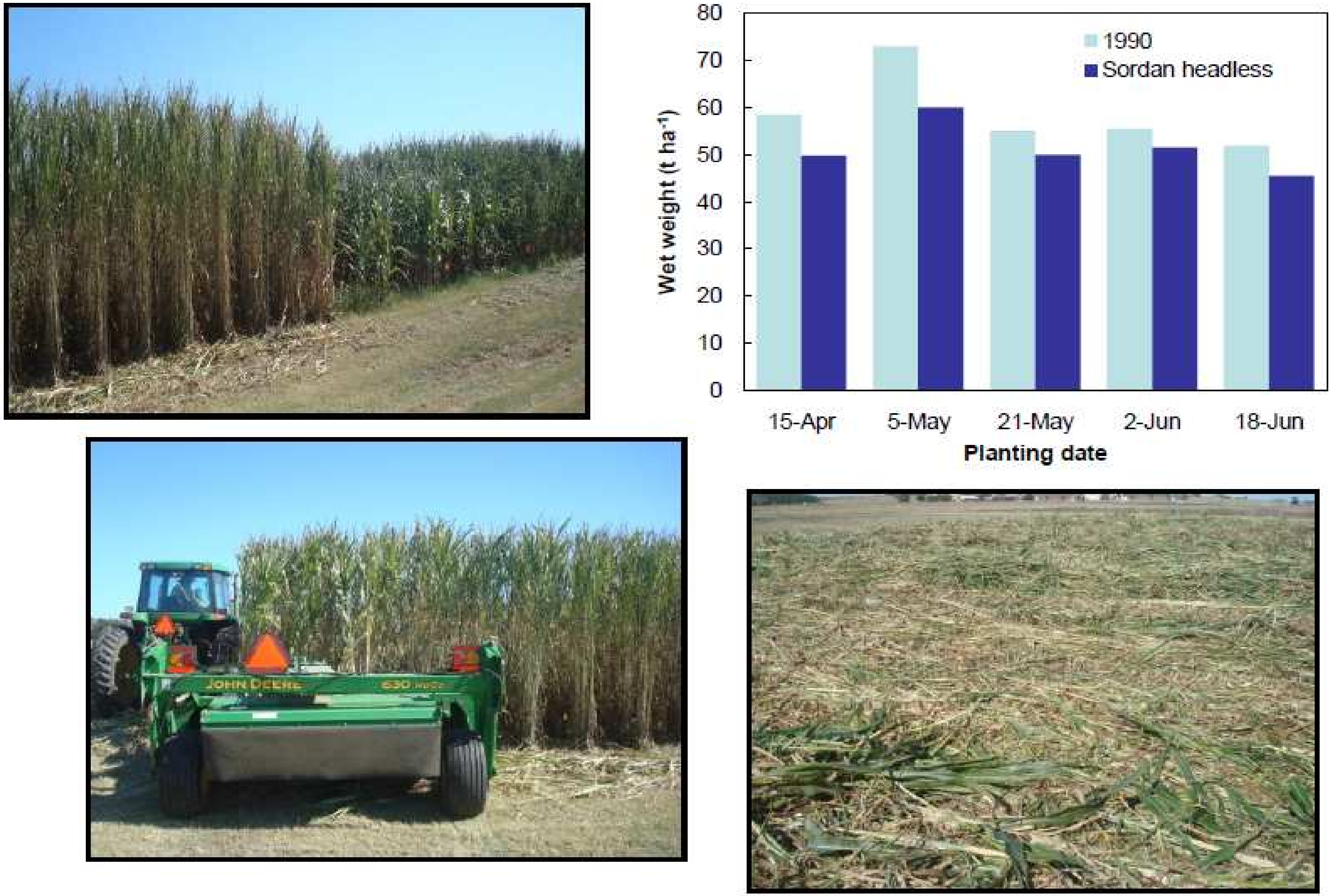


Fig. 12. Research on the High Biomass Sorghum –Planting date in Oklahoma

4. The new Hybrids for high biomass production.

Several specialized in breeding companies (mainly in USA, like Ceres, NexSteppe, McClune Industries, SG bio-fuels in USA, and the Grass and Environment research centre of Beijing), using advanced breeding techniques ,they had developed very promising hybrids of:

1. Sweet sorghum,
2. High biomass sorghum,
3. Switch grass ,
4. Elephant grass,
5. Some other hybrids, producing very promising feedstock for the bio-based industries and fuels/energy.

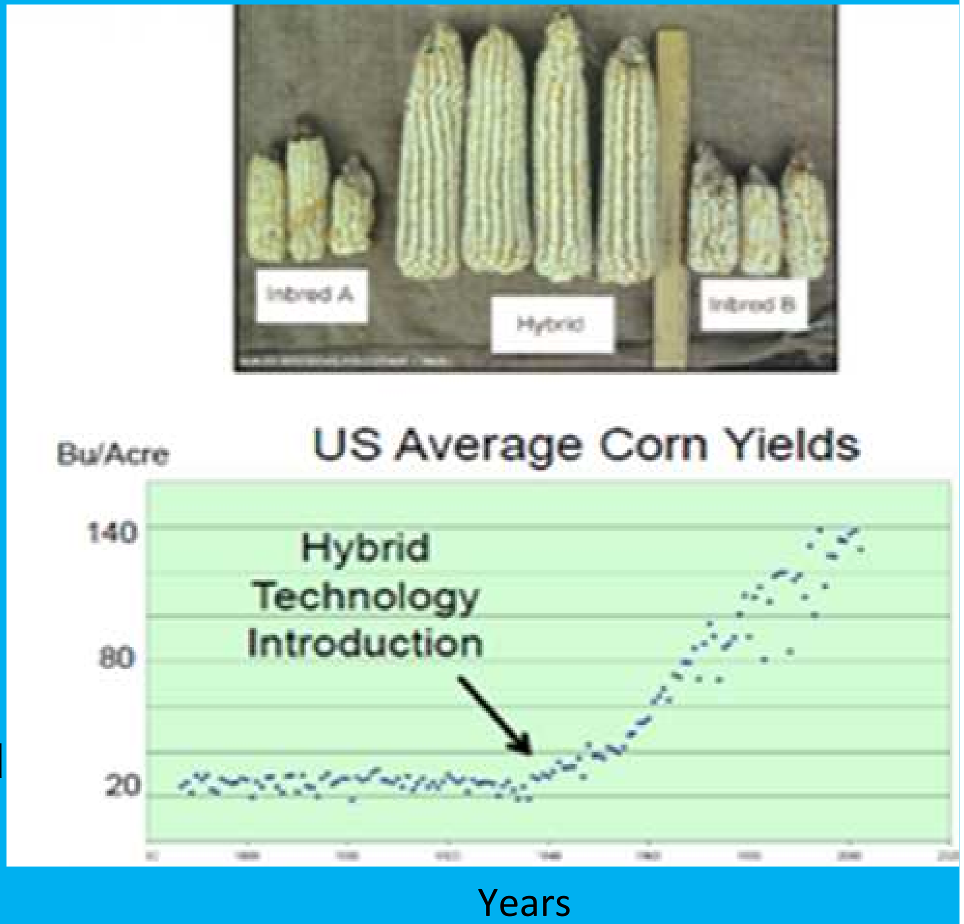


Fig. 13. As it happen with corn amelioration, starting in 1950, the fantastic results achieved today in corn productivity, could be expected also with the new biomass hybrid crops. (fig. from SG biofuels[7])

4.1. Sweet sorghum (Sorghum bicolor L., Moench)

Sweet sorghum was in the past introduced into many countries (USA, India, Romania, Egypt and many other countries), because of the high sugar content in the stalks and the seeds production used for food/feed. Although sweet sorghum was primarily grown to produce syrup, and food/feed, it can also be used today as feedstock for bio-fuel and bio-based chemicals.

In favorable conditions, sweet sorghum varieties can reach more than 4 m tall and produce 50-126 tons /ha of fresh biomass.

Sweet sorghum is drought tolerant, with only 50% of the water needed by corn, and requires less than corn nitrogen fertilizer (or even up to zero in rotation with papilionaceai).

Sweet sorghum has energy efficiency 1:8[6] in comparison to corn efficiency <1:1.8.

Bio-fuels production methods use either gasification or sugars or better fermentation, as its juice contains sucrose, fructose, and glucose which can easily be transforming into ethanol.

The bagasse can be used to feed livestock (if they are domestic animals in the vicinity), or for CHP and the produced heat to be used for the processing, or finally to be used as raw material in a bio-refinery. The vinasse after fermentation is used for feed or as fertilizer.

The ideal for a sweet sorghum producer is to have its own processing facility **in-farm**.

Sweet sorghum is better adapted in **Mediterranean regions**. As an example, one can see the recent results of a comparative research in Germany (N.52º) and in Italy (N.42º)[13], with 6 different varieties of Sweet sorghum (Keller, M81E, Dale, Delta, Bovital and Goliath), where the biomass production and the sugar content were **double** in South Europe .

Sweet sorghum feedstock production can easily be combined with rotation in the same year with papilionaceai (e.i. Vicia velosa), and to produce this way supplementary feed and 50 units of Nitrogen fertilizer.
With the varieties **in use** we can estimate, in Med. regions an ethanol production of > 6 m^3/ha.

Fig.14. Sweet sorghum Harvesting

Fig. 15. Sweet sorghum Harvesting and Jus extraction in the same pass using the Mc Cluny Sor-cane Harvester in large farms..(photo: Mc Cluny Industries)[10]

Fig. 16. Jus extraction and on farm Fermentation in small farms[11].

4.2. The Sweet sorghum hybrids Malibu.

Some companies have succeed to produce hybrids with higher production (i.e. 9m³ of bio-ethanol/ha), targeting to next generation of sustainable feedstock solutions for the bio-based Industries.

NexSteppe Company claims the production of **Malibu sweet sorghum hybrids**, targeting to provide an easily accessible source of fermentable sugars for the production of advanced bio-fuels and bio-based products.

A number of **Malibu's** hybrids are in the market, tailored to face the different conditions in practice, and to provide a wide range of maturities to meet varying customer harvest-window profiles (even a year round production is possible in tropical's).

4.3. Pennisetum purpureum Schumach or Elephant grass (hybrid pennisetum).

The hybrid pennisetum was created and tasted from the Grass and Environment Research center of Beijing, and registered exceptional biomass production, compared to some other species under the same conditions and inputs in water and chemicals, as follows:

-**Swichgrass** biomass production…..............23.33 t/ha/year
(and Cellulosic ethanol 5.15t/ha/year)

-Silverreed biomass production …............... 28.22t/ha/year

-**Giant reed** biomass production …..............47.08t/ha/year

-**Hybrid pennisetum** biomass production… 59.22t/ha/year
(and cellulosic ethanol 13.69 t/ha/year)

4.3. Sorghum sudanense (Piper) Stapf. (The hybrid Palo Alto)

Sorghum sudenense is a graminae produced as fresh fodder, and sillage.
Common name in Australia and USA is Sudan grass and in Sudan its name is Garawi.
The very good productivity in biomass of Sudan grass has been further ameliorated by hybridization. Standing at 6m tall after only four months of growth, NexSteppe's Palo Alto high biomass sorghum hybrids provide a high- yielding, low-cost biomass feedstock for bio-products, bio-gas, and cellulosic bio-fuels.

Palo Alto hybrids was designed to have low moisture levels at maturity, for biomass sorghums significantly lessen the amount of water harvested, thereby reducing the harvest a higher energy density for combustion and transport costs that can be at least 50% of total delivered feedstock cost.

That lower moisture levels provides a higher energy density for combustion.

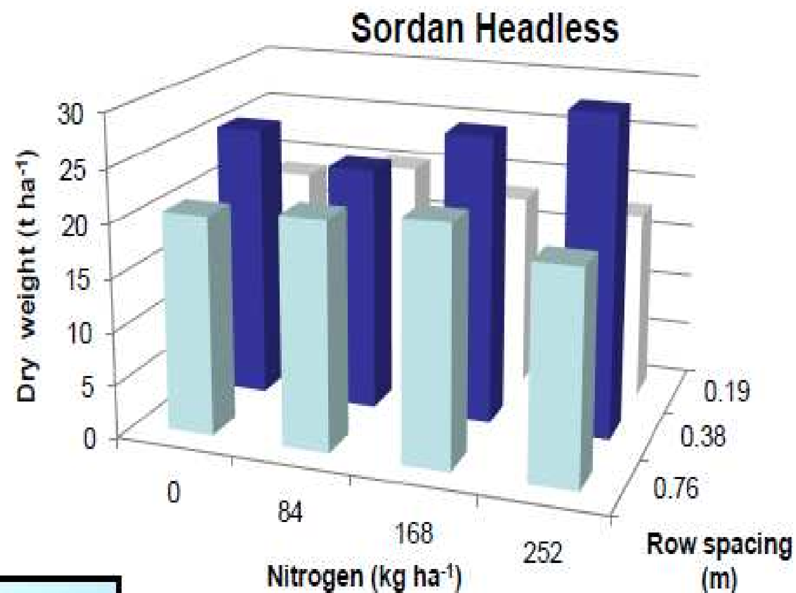


Fig. 17. Oklahoma State University (OKLA) research on Nitrogen and Spacing of High Biomass Sorghum (Photo: OCLA).

Conclusion

The step by step abandonment of fossil products (coal, oil, natural gas), for environmental, growing cost, and exhausting reasons, oblige the world economy to use the renewable row materials of Biomass.

In order to be successful this reorientation of the world economy, it is needed the sustainable and low cost development of a technology, able to valorize to maximum value ALL the organic matter of biomass, offering valuable bio-chemical products to the market.

This Industrial technology of bio-refinery is in development in our days and requires high investment and quantities of sustainable low cost biomass.

The future in bio-economy of the farmers, especially for the small and medium size farmers, is to produce in their marginal land low cost biomass and to apply small scale technologies **In-Field** to produce energy to cover their needs or to offer to the market.

The Mediterranean farmers have the privilege of the warm and sunny climatic conditions in the region, and beside the drought conditions, are very favorable for several productive plant species or hybrids . In parallel they can adopt a small in investment technology to cover their energy needs and to profit of a supplementary income for their family.

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Thanks for your attention

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Sweet Sorghum

High energy crop for ethanol production (15-20% directly fermentable sugar)

Can be grown in temperate climates

Low fertility requirements

Low water requirement: 1/2 corn and 1/3 sugarcan