Bioenergy Expansion Worldwide and the Mediterranean Potential for Sustainable and Low Cost Biomass for Energy

Invited presentation by:
Dr. Spyros Kyritsis
President of the Greek Agricultural Academy

**JatroMed First International Workshop on Energy Crops in Mediterranean Region (ECMR-1)
Opportunities and Challenges**

**Hotel Semiramis, November 15, 2013
CDRT, Marrakech-Morocco**

I. Bioenergy expansion worldwide and the future tasks.

Biomass is any organic material which has stored sunlight in the form of chemical energy.

Biomass as a fuel it may include, organic wastes, agricultural residues, and many other byproducts from a variety of agricultural processes.

The world total primary energy supply is expected [15] to increase from 50 Ej today to 160 Ej in 2050, with more than 62% of this to be used for generation of heat and power.

By 2010, there was 35GW of globally installed bioenergy capacity.

From all the Renewable energies Bioenergy is the largest source of energy, providing more than 10% of global primary energy supply [15] .

Bioenergy is the only mean to produce **renewable hydrocarbons**, and the only of the RES where the cost of the **feedstock represent more than 60% of the final energy cost.**

The International Energy Agency estimations for bioenergy demand rise the today consumption three times more the year 2030.

The big majority of bioenergy use is in developing countries, used for cooking and heating, as the 2010 the 41% of the world population relied on wood or other biomass sources to cook and heat their homes.

In the developed countries, the biomass consumption for heat and power is expected to reach 3 times more in 2050.

Biomass, as a renewable source, is also used to replace several industrial bio-products made from fossils. Such a use is exponentially growing in our days, and all products made from fossil fuels (plastics, and others) will be replaced progressively from products made from biomass feedstock.

Even if today they are different cheaper uses of fossil *sources*, the reorientation of the world economy, **from fossil sources to biomass renewable products and energy**, presents many advantages, as they are:

- Environmental considerations
- Energy security
- Socio-economic advantages (direct and indirect job creation etc.)

The uses of total primer energy consumption worldwide

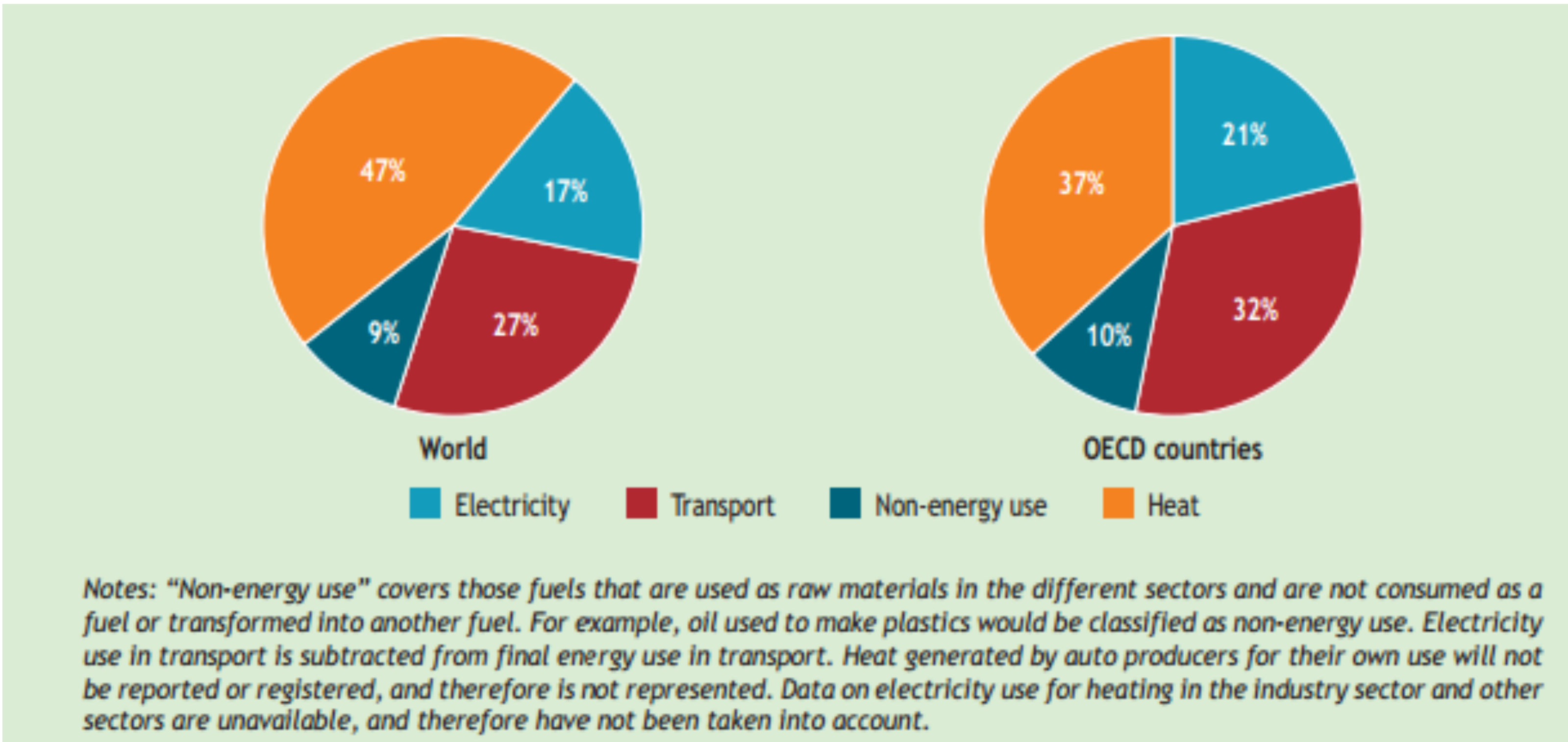


Figure 1. Shares of the world final energy consumption in % for Electricity, Transport, Heat, and Non-Energy uses (figure: OECD study).

The impact of Energy to the Environment

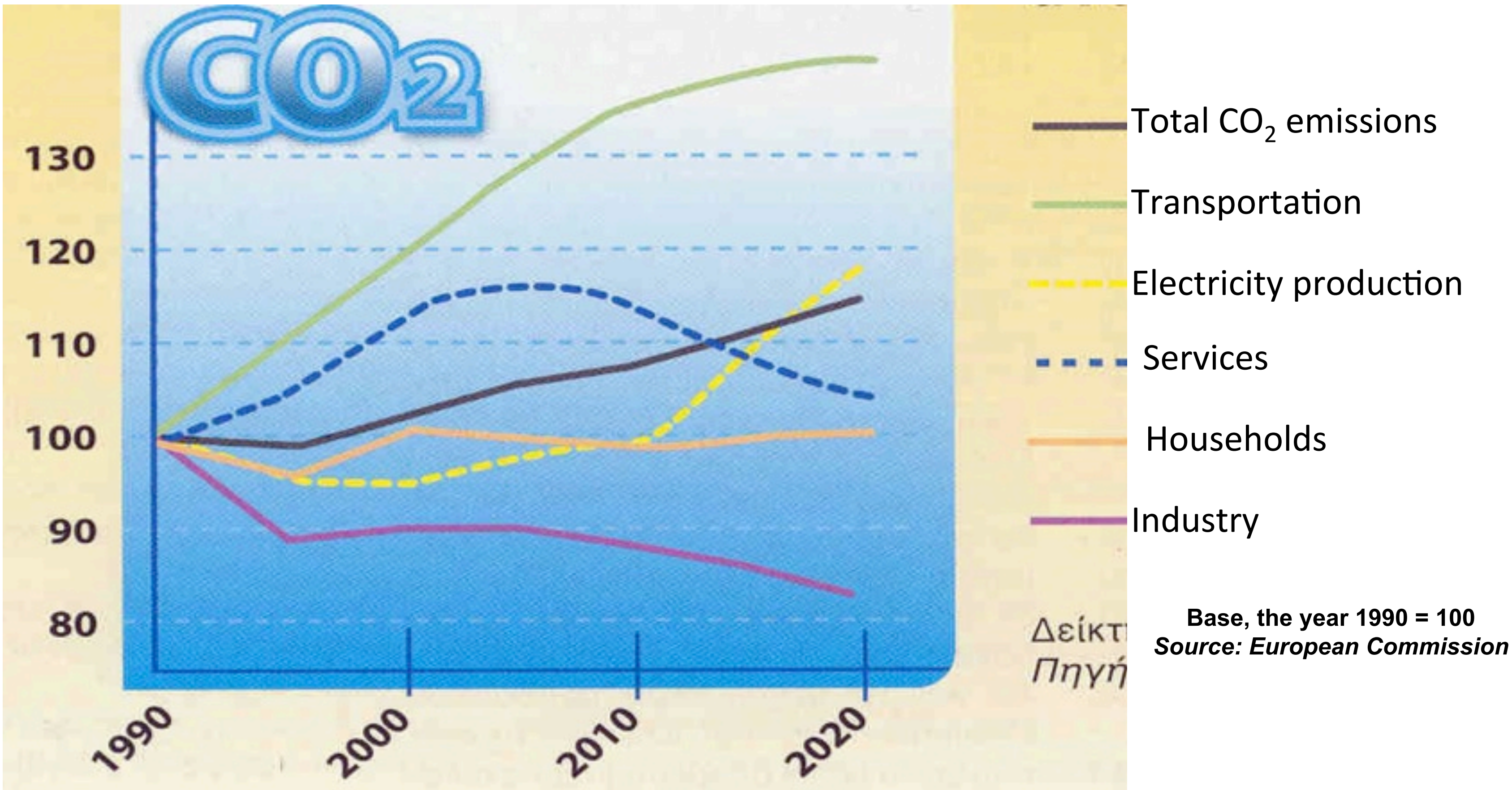


Figure 2. CO_2 emissions by sector, actual and predictions

Worldwide Biofuels demand today and predicted in the near future

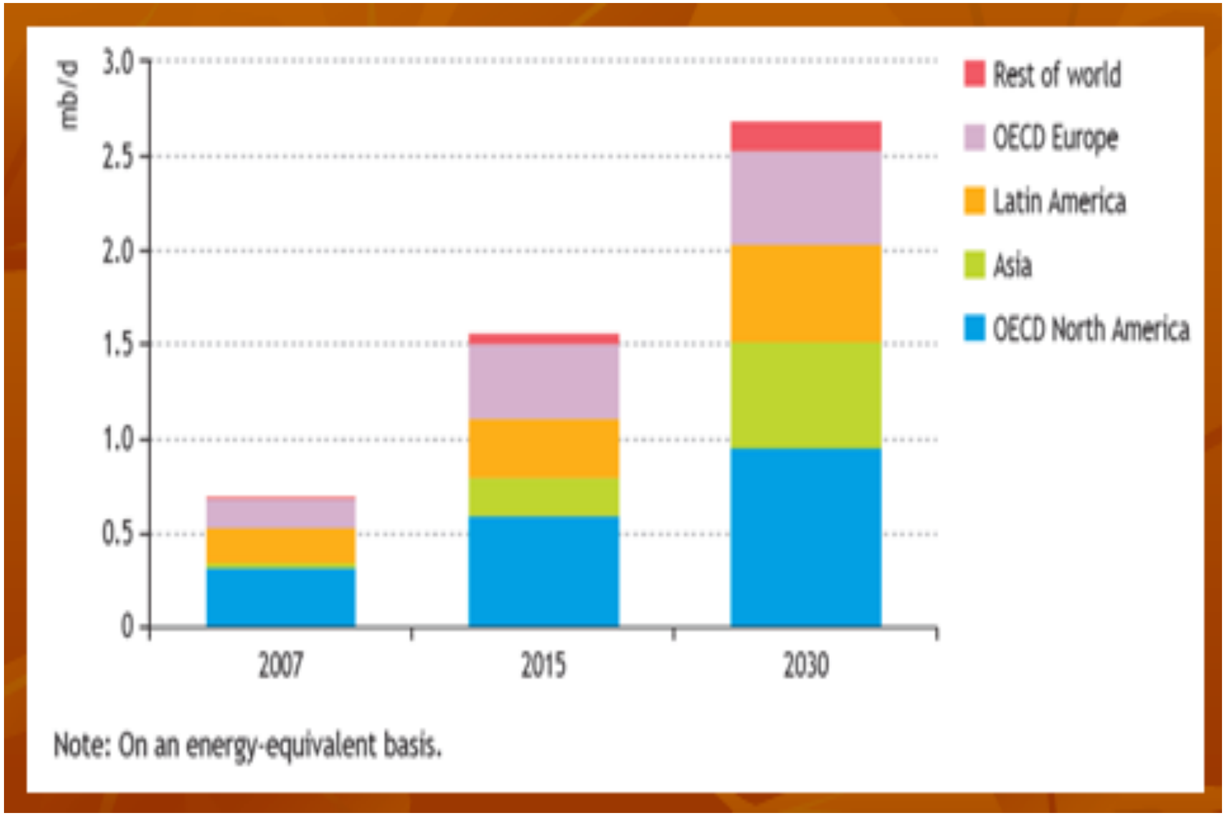


Figure 3. The predicted demand of bio-fuels globally [1]

The IEA' scenarios of the future total energy consumption and the coresponding environmental impact

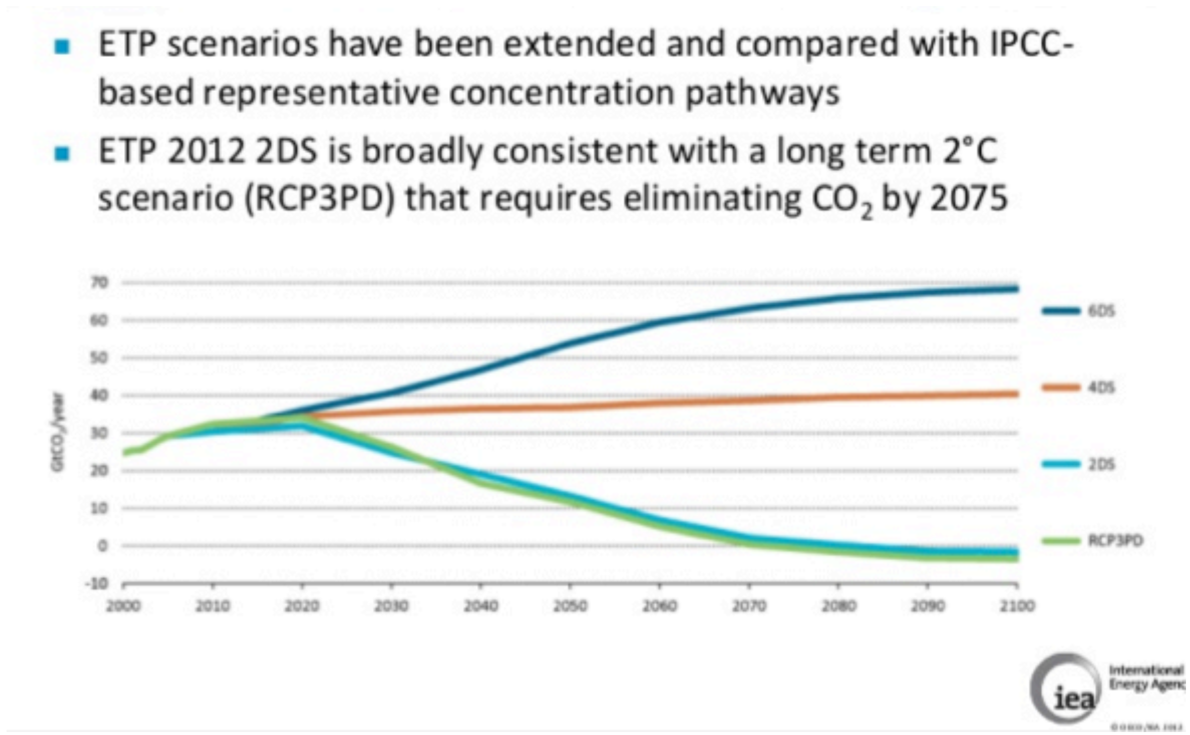


Figure 4. The 3 IEA scenarios for CO2 abetment up to 2050
(Picture from ETP 2012) [7]

1. Bioenergy for the Transport Sector in the different scenarios

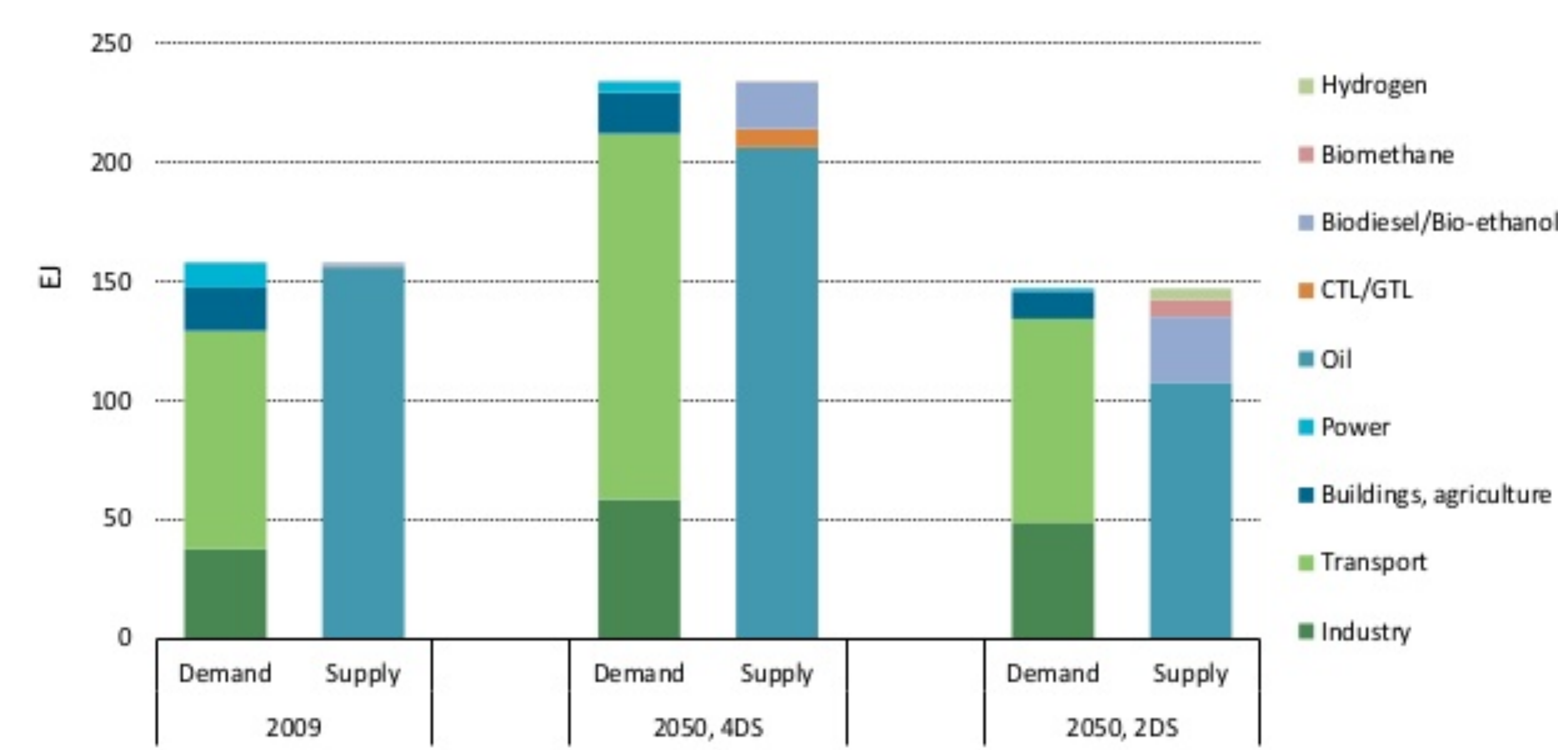


Figure 5. Liquid fuel demand, in the 2D Scenario of IEA, will be stabilized at today's level, largely due to efficiency improvements and electrification in the transport sector. (Fig. IEA) [7]

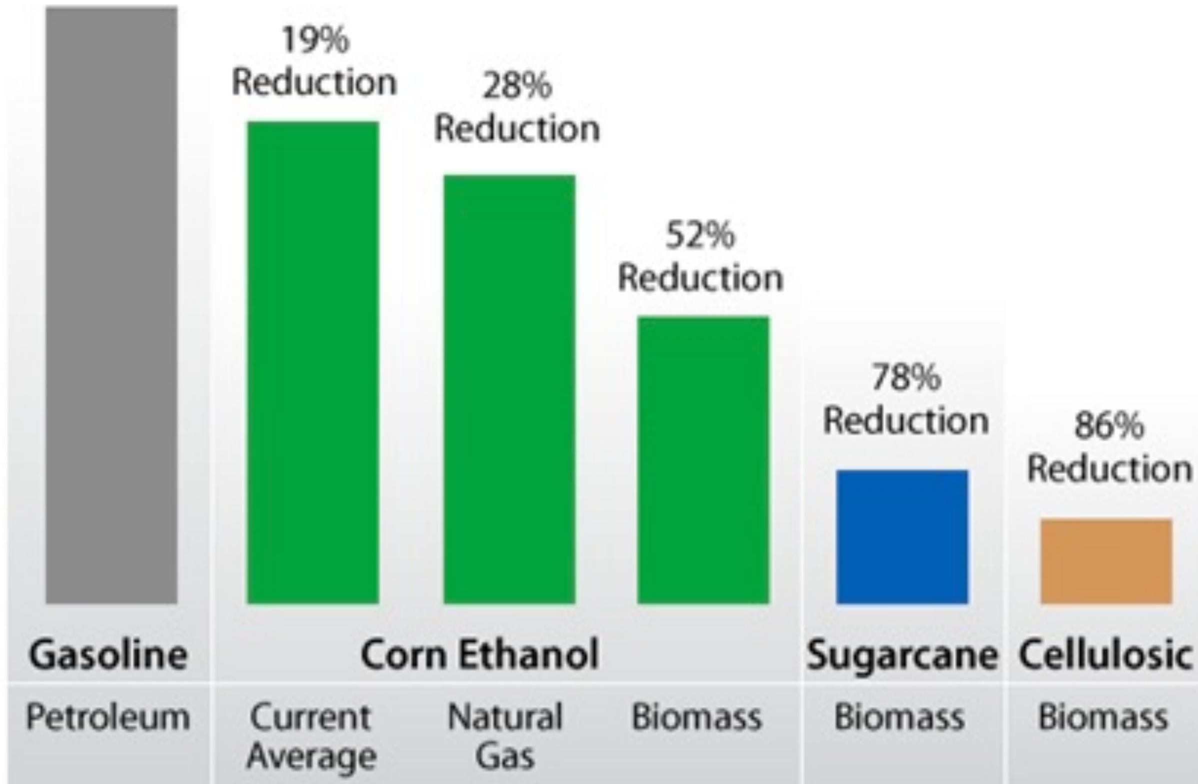


Figure 6. Greenhouse Gas Emissions of Transportation Fuels and the expectations from the 2nd generation biofuels. (By Type of Energy Used for Processing)

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)

Fig. 7 Biofuels common cost of production

2. Bioenergy for electricity production

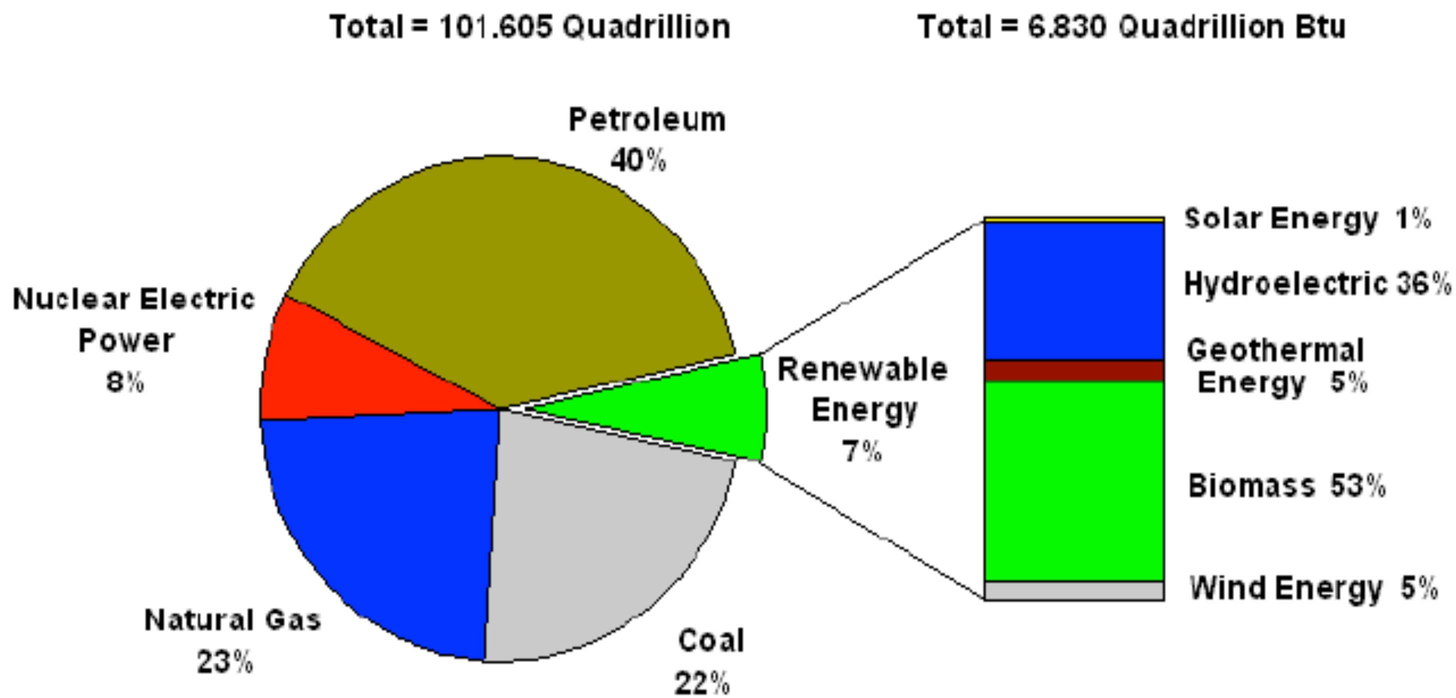


Figure 8 . Worldwide primer energy used for power production, and the Renewables sources contribution[5]

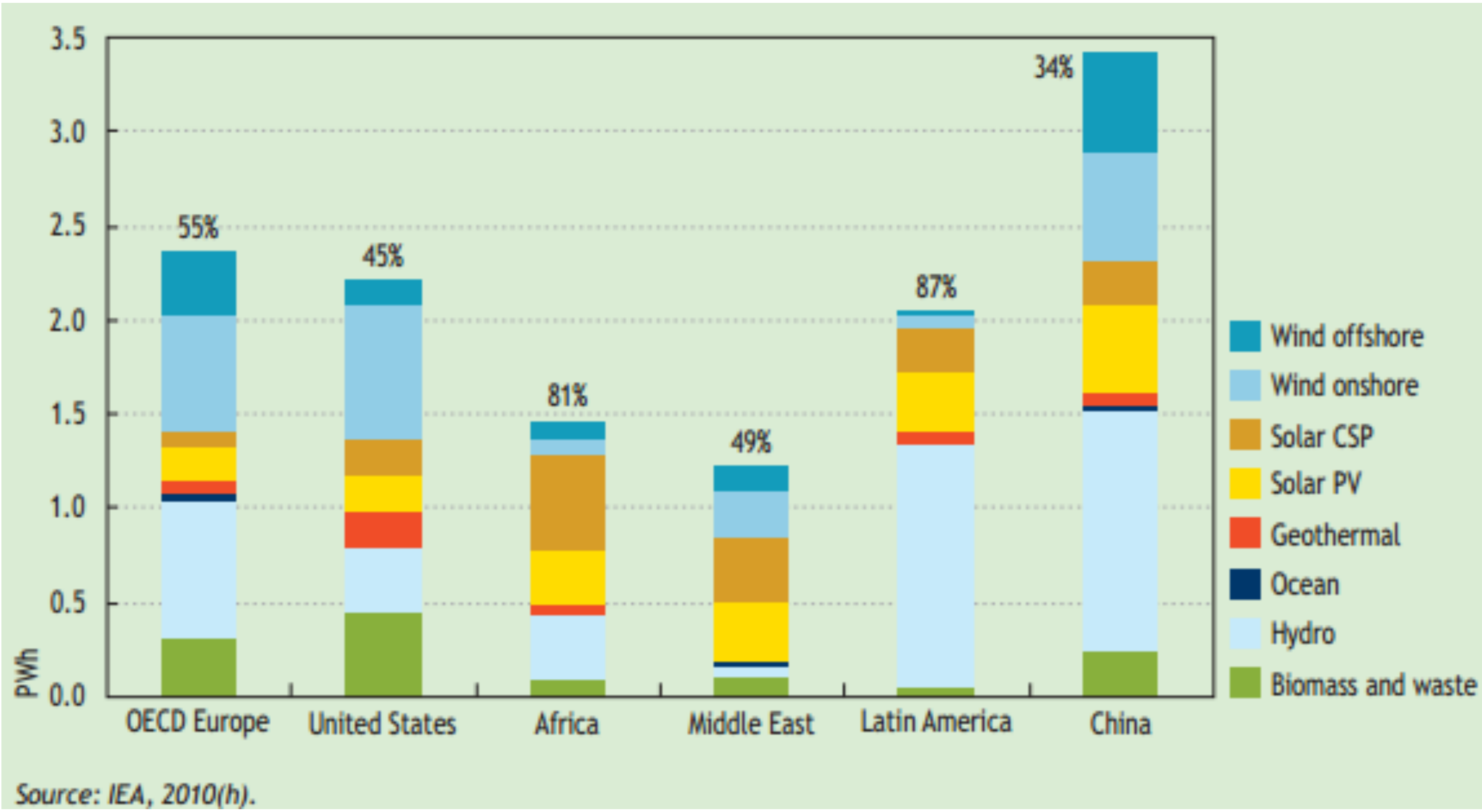


Figure 9. Renewable electricity generation in the BLUE MAP scenario of IEA for key countries and regions in 2050 [8]

3. Bienergy for HEAT production (or Direct biomass combustion)

The Heat production by Bioenergy is the largest primer biomass energy in the world.

In our days, Bioenergy is used for Combined Heat and Power production or for co-firing in existing coal- fired power, or heat plants (the % of biomass in mixture with coal are given in the Bioenergy Technologies).

This sector includes, beside the power generation in industry, the Local Heating systems, as they are :
- the multi-dwelling residential buildings,
- the single-family homes,
- the cooking and space heating, in developing countries (the largest part worldwide).

The annual biomass for heat and power consumption in EU is predicted to grow by 850 TWh by 2020 to a total of 1.650 TWh (doubling of today's level).

The EU Commission's recent report on the sustainability of biomass concluded:

"the most common types of bioenergy for heat and power applications reduce emissions by 55 to 98%, compared to today's fossil fuel mix in EU power generation, even in situations where the biomass is transported internationally (??) [6]".

II. Biomass uses worldwide

From one side the growth of biomass use for energy and bio-products , as well as the continuous growth of the demand for food/feed, and from the other side the priority given (first priority in EU) to the sustainability of biomass products, raised the world concern for the future use of the world biomass sources.

The above two reasons dictated «two new rules” for the future biomass production:

1) Not to use food/feed and the land cultivated for their production for alternative uses (as they are bioenergy and bio-products) ??.

2) The biomass sources have to fulfill the sustainability criteria.

So, bioenergy and other bioproducts have to come from feedstocks produced:

on marginal land, on land covered with water, from the wastes and from the agricultural /forest residues.

At the same time biomass production and processing have to be sustainable.

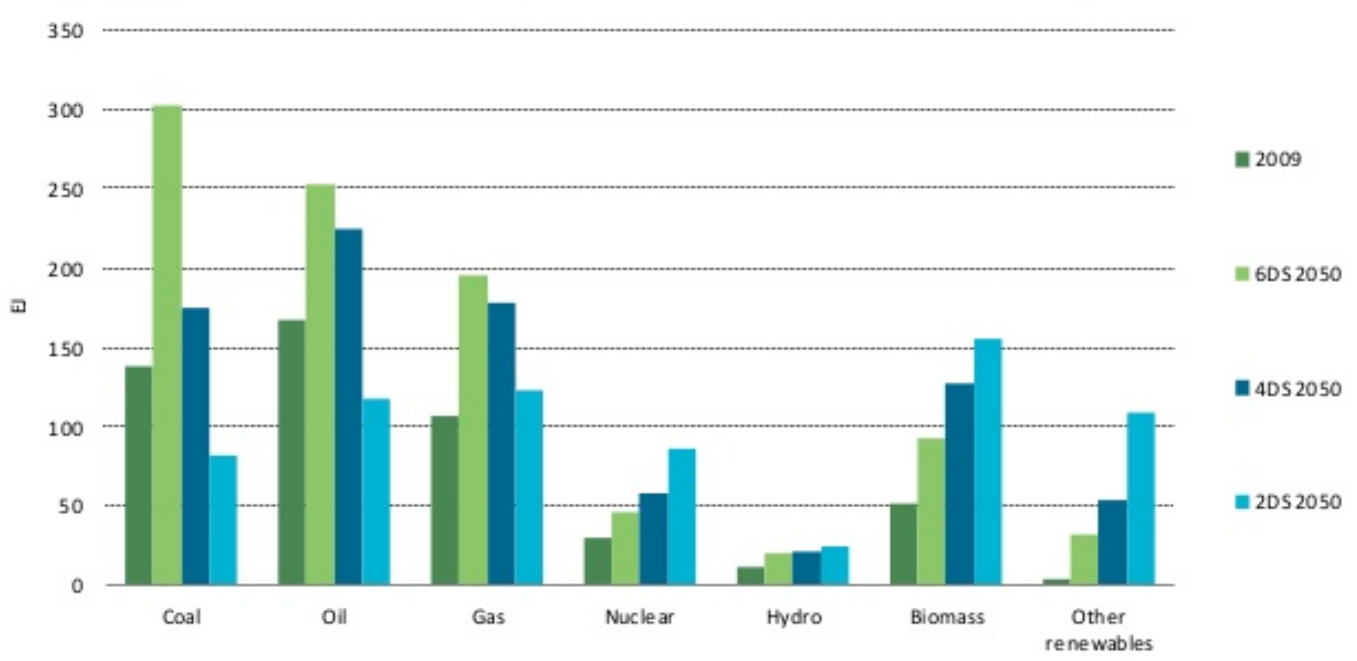
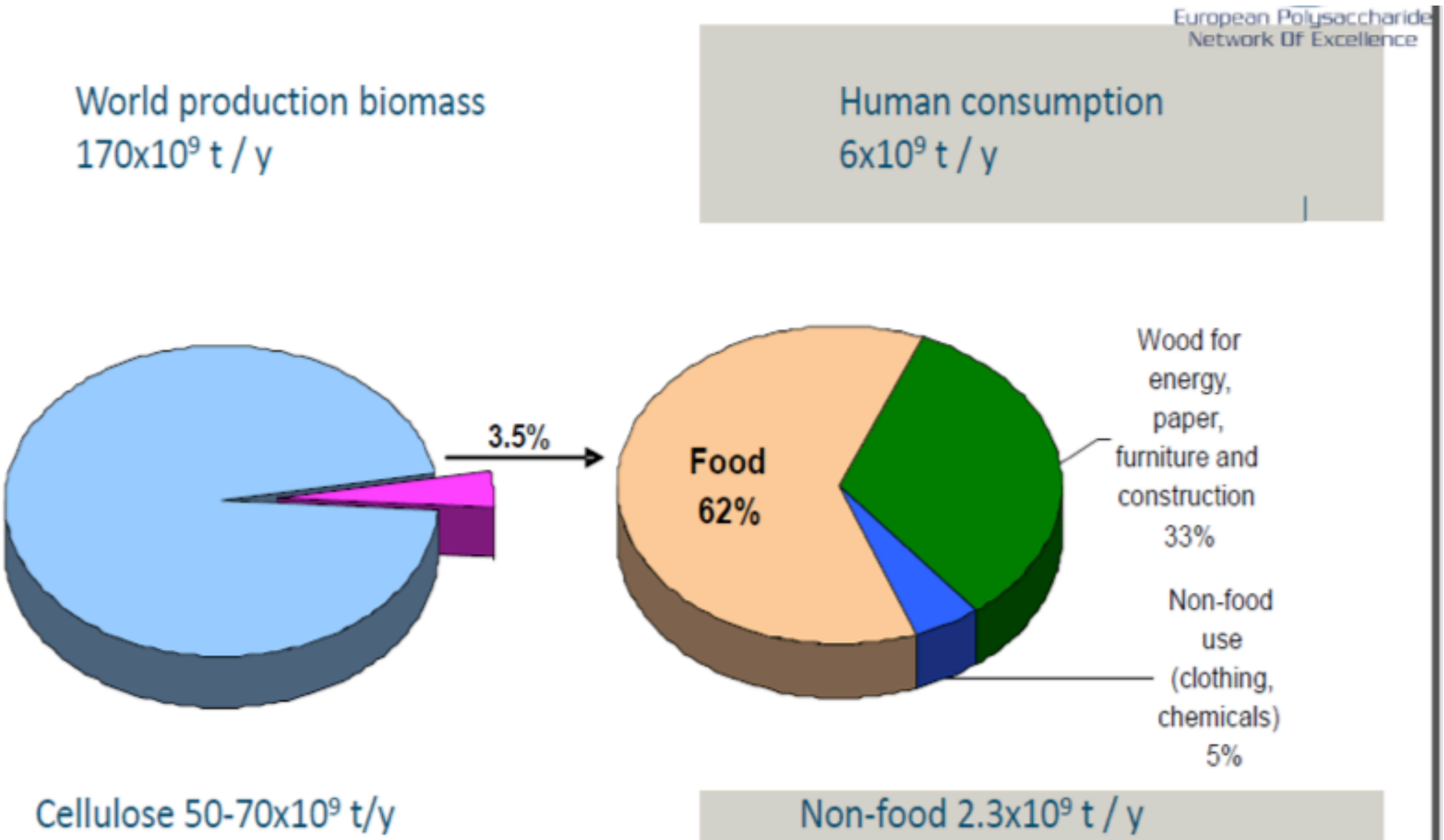


Figure 10. Biomass will becomes the largest primary energy carrier by 2050 in the 2DS IEA's scenario [7]

The World Food and Feed concern



Source: Food& Biobased Research, Wageningen, NL

Figure 11. Total biomass production globally and % designated for food.

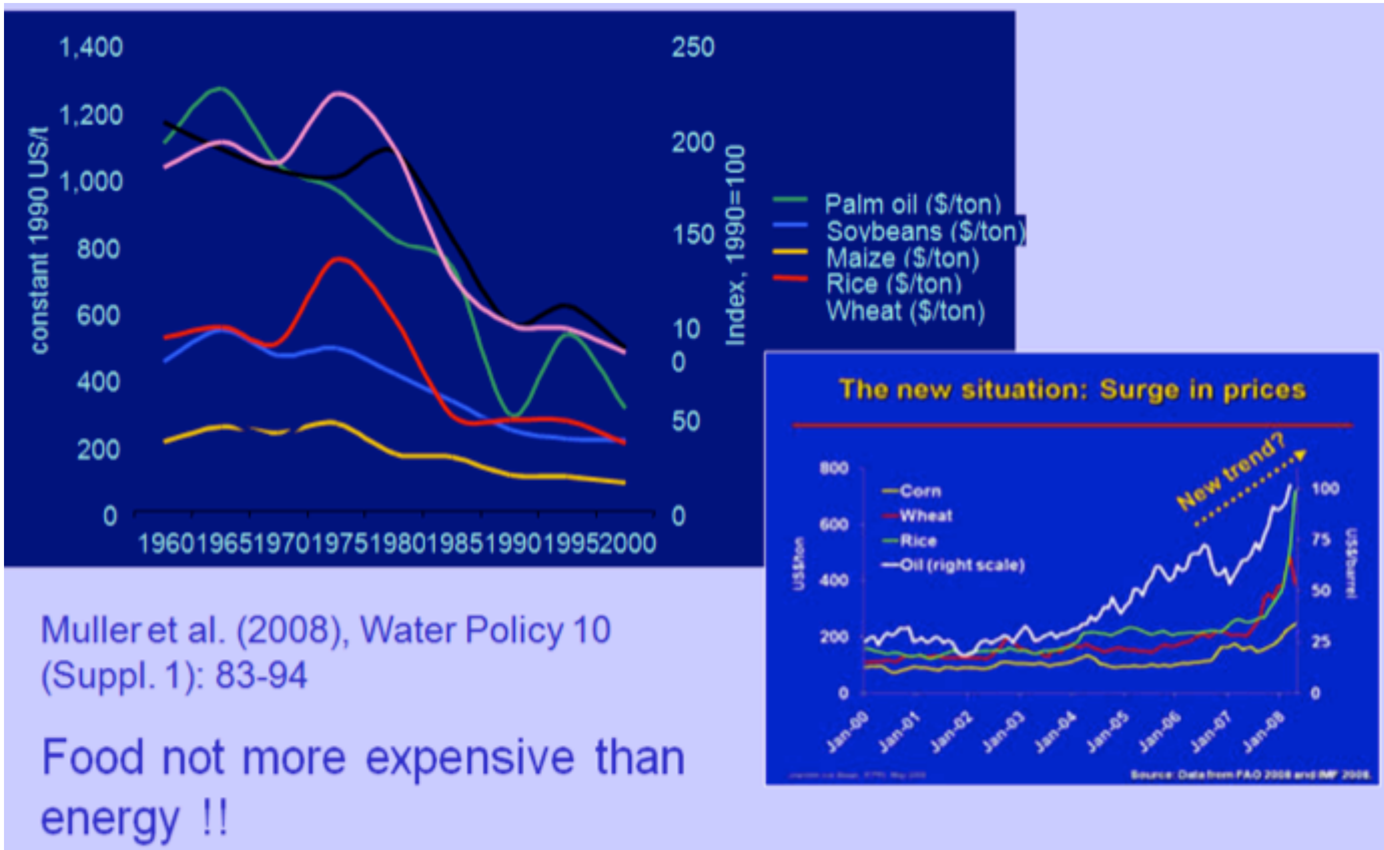


Figure 12. The past and recent evolutions of prices for food/feed, and energy (source: FAO)[9]

The new researchers' obligation.

The world's hopes to solve the problem of biomass sustainability avoiding the use of agricultural land, based on the next generation bio-fuels produced by lignocelluloses, face some practical problems, as they are:

a. The limited productivity of marginal lands to cover the growing demand of biomass feedstock.

Here we should have in mind that to replace corn ethanol coming from 1ha , the corn produces 4.7 m^3 ethanol and 3.26 t feed, but 1ha of marginal land can produce to day only 1.12 m^3 of bio-fuel and restricted feed production.

b. The high cost of investment and finally the high cost of the next generation bio-fuels, like bio-ethanol and BtL (wood-diesel).

To face the above two problems, research has to solve the difficult and complex problem of the future biomass production:

To produce large quantities and low cost biomass, with sustainability and out of fertile agricultural land.

In parallel research has to succeed to a better bioenergy and biorefinery efficiency.

III. Priorities in bio-energy technologies development

Besides the new rules to be followed by the biomass feedstock, today bio-energy technology has also to be sustainable and efficient. To that direction there is a continuous progress worldwide, summarized as follows:

1. Bio-refinery technology development. This relatively new technology for bio-products and bio-energy production uses all the chemicals of biomass, and it has succeeded (LUCINTEL, a US-based market research company)[12] " the global market for synthetic bio-products to reach the value of $ 2.1 billion in 2010, and is expected to reach $ 3.8 billion by 2016".This progress of the technology is expected to continue, especially in the synthesis of bio-products.

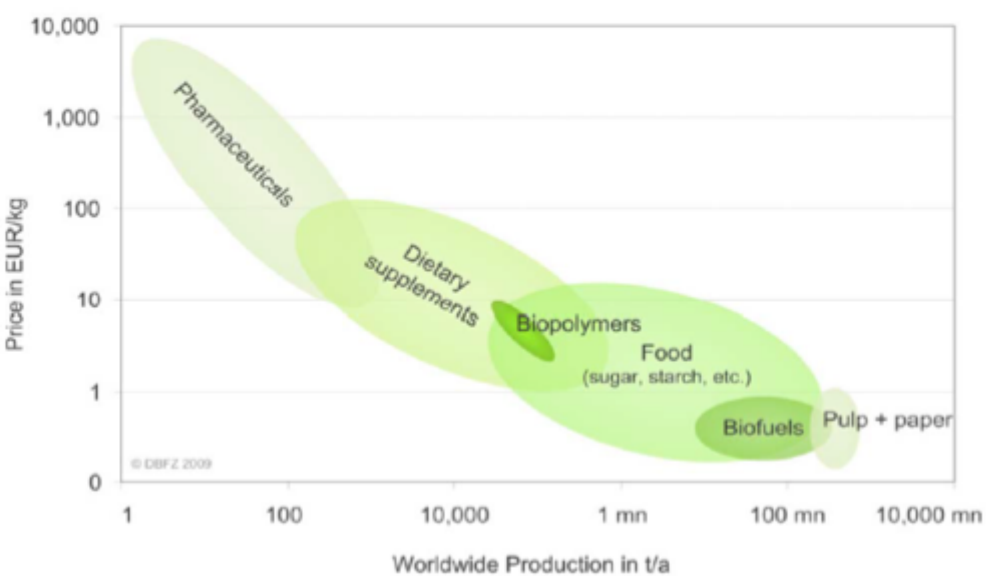


Figure 13. The world market of bio-products

(Gröngröft and Müller-Langer, 2009)

Bio-refineries present an opportunity for the forest industry (especially in several countries like Russia, Canada, Brazil, S-East USA, Scandinavia) to produce higher value products from low cost ,renewable raw materials.

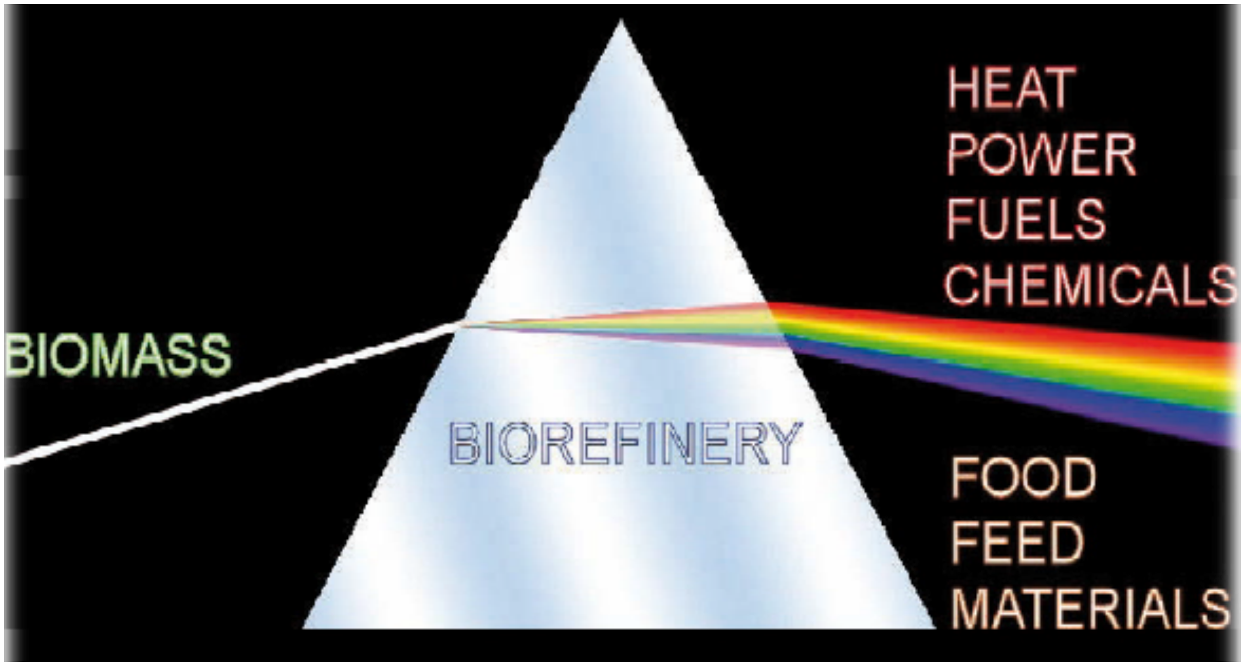


Figure 14. The International Energy Agency (IEA) gave the following definition for biorefinery: "**Biorefinery is the sustainable processing of biomass into a spectrum of *marketable products (food, feed, materials,* chemicals) and energy (fuels, power, heat)".**

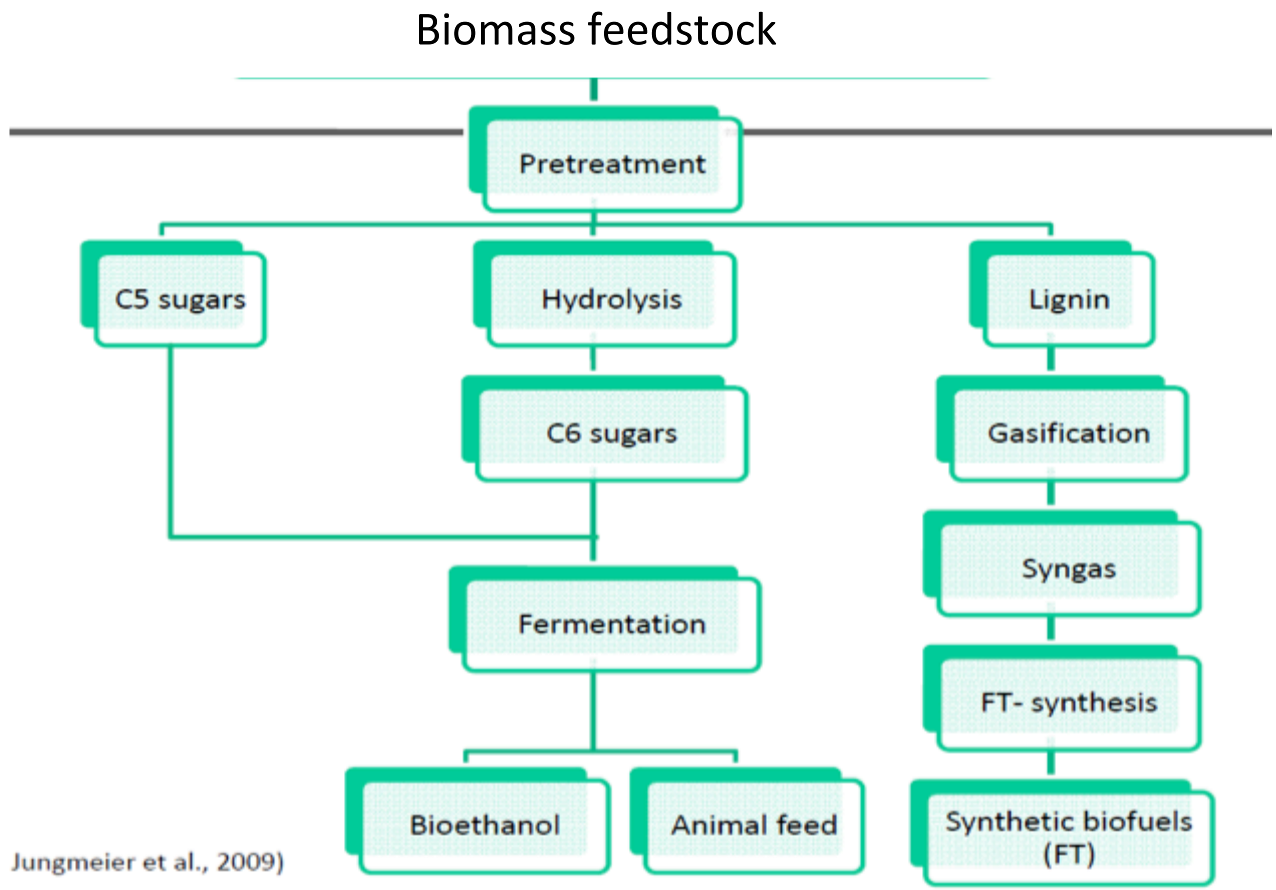


Figure 15. An example of a typical flow of chemicals and their processing in a simple biorefinery for bio-ethanol and food/feed production [10] .

2. Co-firing bioenergy technology is a major application area for biomass in existing coal-fired power and/or heat plants. The possible % of biomass in co-firing depends on what alterations companies are willing to undertake, and what efficiency losses they are willing to accept, and it also varies from plant to plant.
Commonly biomass % used in European industry co-firing applications, are given bellow [11]:

■ Up to 5 % biomass (on an energy basis) is possible in close to all plants without any major investments or losses of efficiency.

■ 5-15 % co-firing is possible in most plants younger than 30 years, but may require upgrading plant equipment such as storage, grinders, feed systems, burners, air blowers, and flue gas cleaning equipment.

■ 30-50 % co-firing has been done in a number of European plants, with the same type of alterations as mentioned above, but with higher requirements on the quality and consistency of the biomass feedstock.

■ Fully converting an existing coal plant to dedicated biomass combustion often requires changing parts of the boiler, or the entire boiler.

■ The co-firing potential is broadly similar for hard coal and lignite plants, but co-firing in hard coal plants generally requires high-quality biomass (e.g., wood pellets),while lignite plants can, in certain cases, also burn wet fuels (wood chips), or fuels with longer fibers (straw).

Finally biomass co-firing with coal, in large power production units, **is in progress** , but **more progress** is expected in this technology with more % of biomass feedstock in the mixture and better than the today (average 30%) conversion efficiency.

3. Gasification technology for power, CHP, polygeneration and Syngas production ,is in a continuous research effort, especially in the Center and North of the EU.
The liquid fuel expected by Syngas remains expensive, but progress is expected in near future.

4. **The technology for the next generation bio-fuels** is in the hands of large private companies, and marks a continuous advance. But the market demand for ethanol produced from lignocelluloses and for wood diesel, produced via synthesis gas (respecting sustainability, ex. better ILUC), from feedstock produced in marginal lands, still hurts upon the reality of **high production cost** (because of the low productivity of biomass feedstock, and the high investment for the factory).

The high investments from private companies, and the given economic incentives (mainly from USA government), is expected to give better results in the future.

5. **Pellets production technology**, storage and long distance transportation is always expanding (besides the questions on its sustainability) [6], but the humidity poses problems to economic production, safer storage and transportation.

6. **Torrefaction** technology shows progress, especially in Sweden, and can solve the above mentioned problems of pellets.

7. **Small Pellettizing units,** for small producers or farmers, need the attention of researchers. There is a need for equipment, able to pelletize a variety of biomass feedstock. Successful results to this direction will lead to a wider use of agricultural and forest residues and offer more socio-economic advantages to the rural population.

8. **Small and large combustion units** for pellets or other biomass feedstock need researchers' attention, in order to achieve more efficient combustion with less CO_2 emissions.

The introduction of CHP will ameliorate considerably the overall efficiency.

9. Conversion and cost of existing industrial and residential heating, based on fossils.

Bioenergy technology in this sector needs amelioration, either by replacing current coal, gas, and oil heating systems, with a biomass boiler, or through establishing / expanding district heating networks connected to biomass heat plants. Local conditions, such as: the scale of the installation, type of use, climate, and the type of heat (low or high temperatures), determine which of these alternatives is better.

Physically, biomass boilers can be installed in most buildings where there is a water-based heating system, and where there is enough space to store the pellets, but:

1). At present, the cost of converting residential and industrial heating from oil or gas to pellets varies widely, depending on the scale of the installation. For example, systems for residential, multiple dwellings with a heating capacity of around 100 kW can cost from 30,000 to 65,000 Euros.

2). Comparable investments for oil, or gas are much lower, approximately 20,000 to 25,000 Euros and 18,000 to 30,000 Euros respectively, depending on local conditions.

3). For single-family houses, investments range from 10,000 to 16,000 Euros for pellets, compared with 5,000 to 13,000 Euros for oil and 5,000 to 12,000 for gas.

10. Anaerobic fermentation technology (for bio-methane production) is expending rapidly, especially in some European countries (Germany, Austria, Denmark and others). The new technological achievements offer more efficiency and stability.
The problem of the economic competition with fossil energy can be minimized, if the co-produced heat will be used closer to complete.

The fact that this technology manages wastes, protects ground water, produces fuel and recycles nutrients, makes it attractive for further applications.

More research is needed in this technology for lower investment cost (especially for the anaerobic fermentation of the MLWs), and for more sustainable and low cost cultivated feedstock, not in competition with food/feed production, as it happens with the majority of actual cases in Central Europe.

Recent research to this direction in Chile and Mexico with the plant Opuntia ficus indica, used for bio-methane production, gave interesting results, as they are:

-The absence of sulfuric acid and the rapid generation of bio-gas with short retention times (5-10 times faster than animal manure).
-According to Dr. R. Morales (head of ELqui Global Energy centre in Chile), one ha of Opuntia produces 17,500 m^3 of bio-gas, or the equivalent in diesel10,000 lit/ha.

-The bio-gas produced contains CH4 (75%), CO_2 (24%) and 1% of other minor gasses and its calorific value 7,000 Kcal/m3.

11. The technologies "on the farm biomass feedstock proccesing to energy", have to be examined carefully for further development and expention. These technologies present the advantages of low cost and more sustainable energy products, and better social results[2].

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, but to be adopted in a variety of other bio-energy technologies.

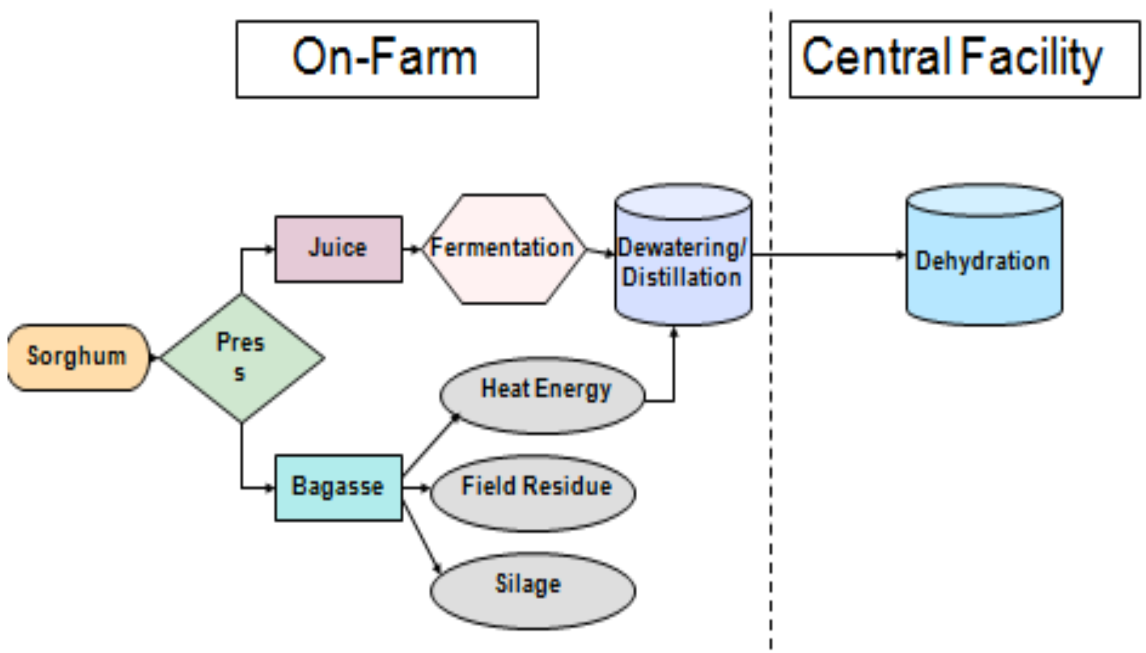


Figure 16. Sweet sorghum processing on- Farm for ethanol production, practiced in the South States of USA. (Fig. by Oklahoma State University) [3,4]

Main characteristics of Sweet sorghum processing on-Farm for ethanol production[2]:
- Investment cost for ethanol processing: $ 0.264/lit, instead of $ 2.64/lit for a central industry ,
-the production cost of ethanol is $ 0.132/lit, instead of > $ 0.35/lit from a central industry,
-on-Farm ethanol has around 8 times less CO2 emissions in comparison to the today corn ethanol
- gains in income/ha (> 7 fold) compared with the gains from the today corn ethanol production.

12. The technology for agricultural residues cost reduction is a need, as the main cost reduction levers are gathering, transportation, and loading of the residues, which 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%. Larger and denser bales increase the amount of energy in each loading or transport operation, reducing the operational cost per energy unit. 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.

13. The new hybrids and plant species for biomass production advances world wide.Hybridism is a new sector of research for better biomass productivity. The sector gave already spectacular results[13,14], especially in hybrids coming from private companies, but more should be expected in near future, by the research expansion to that direction.

Finally Bioenergy is in expansion worldwide having the target: "the transition from an economy based on fossil raw materials (coal, oil, natural gas) to a sustainable world economy, which will be based on the use of **renewable biomass feedstock** for the production of fuels/energy and other chemical products".

The prediction in the different scenarios for the future use of biomass feedstock for energy creates food/feed insecurity in the world.

To secure environmental and social sustainability from the always growing use of biomass sources, the world scientific community and the policy makers are taken several measures, as they are: not to use agricultural products and the land used for their production for "alternatives uses", the progressive use of all the organic materials of biomass (residues, wastes, etc.) and to raise the technology efficiency in bio-products production (energy and other), in order to make biomass use more sustainable today and in the future.

(Recently in EU, trying to avoid uncertainty within European Industry, decided to allow 6% cal. for food/feed based biofuels by 2020 and to establish a separate quota of 2.5% more for advanced biofuels for 2020).

More progress is needed in the near future to assure the expected sustainability of biomass and its expansion use avoiding to influence the security of food/feed.

IV. The Mediterranean potential for sustainable and low cost biomass for energy.

We are going to give bellow, in a brief description, what we thing as promising biomass feedstock, giving importance on their environmental/social sustainability, low cost, and not compete with food and feed production.

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.

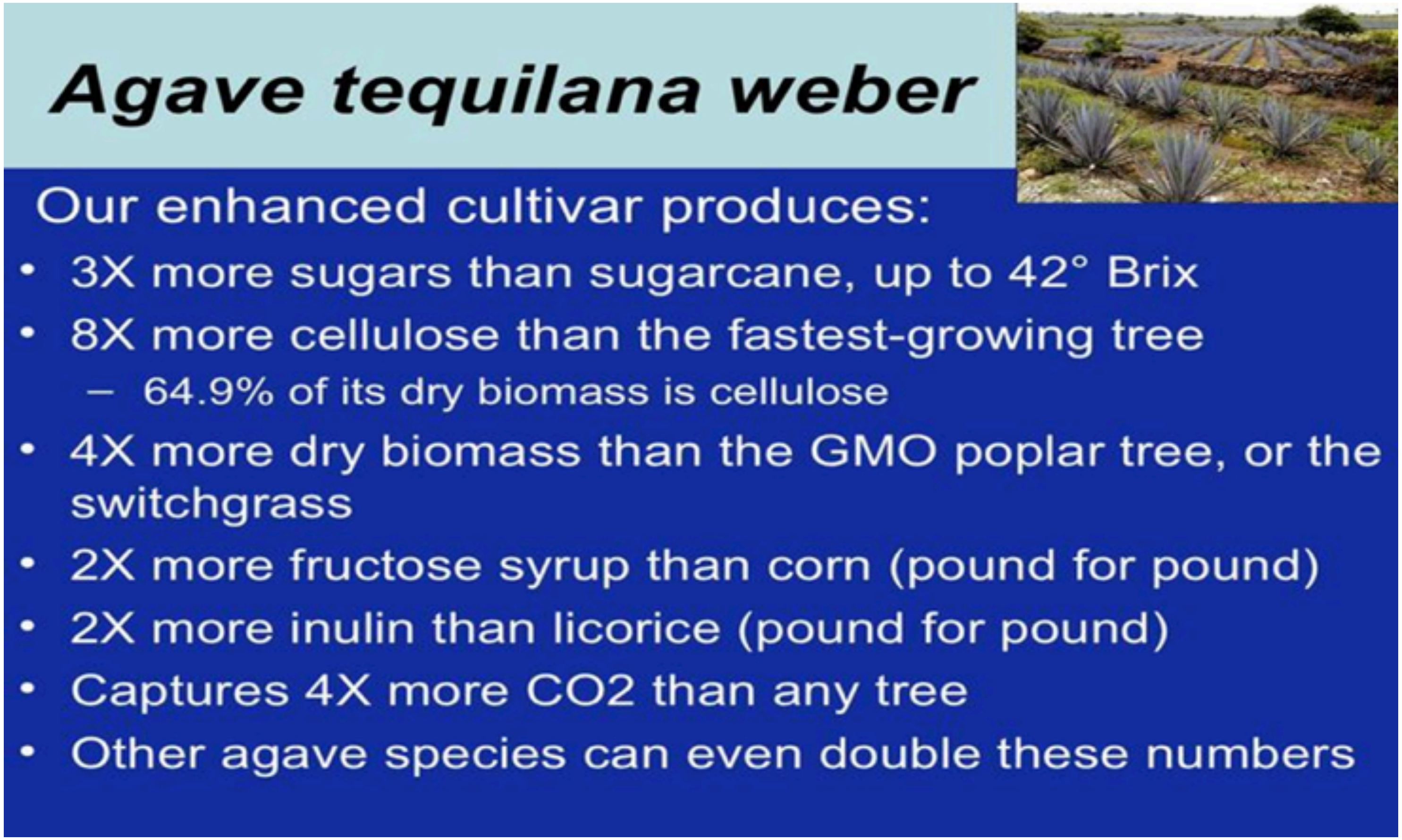


Fig.17. Some Energy and bio-based chemicals that could be extracted from *Agave tequilana*.

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 soils. 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).

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.

Fig.18. Plantation of Opuntia ficus-indica

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.19. Switch grass plantation in its third year

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: Sweet sorghum, High biomass sorghum, Switch grass ,Elephant grass, Jatropha curcas, and other hybrids, producing very promising feedstock for the bio-based industries and fuels/energy.

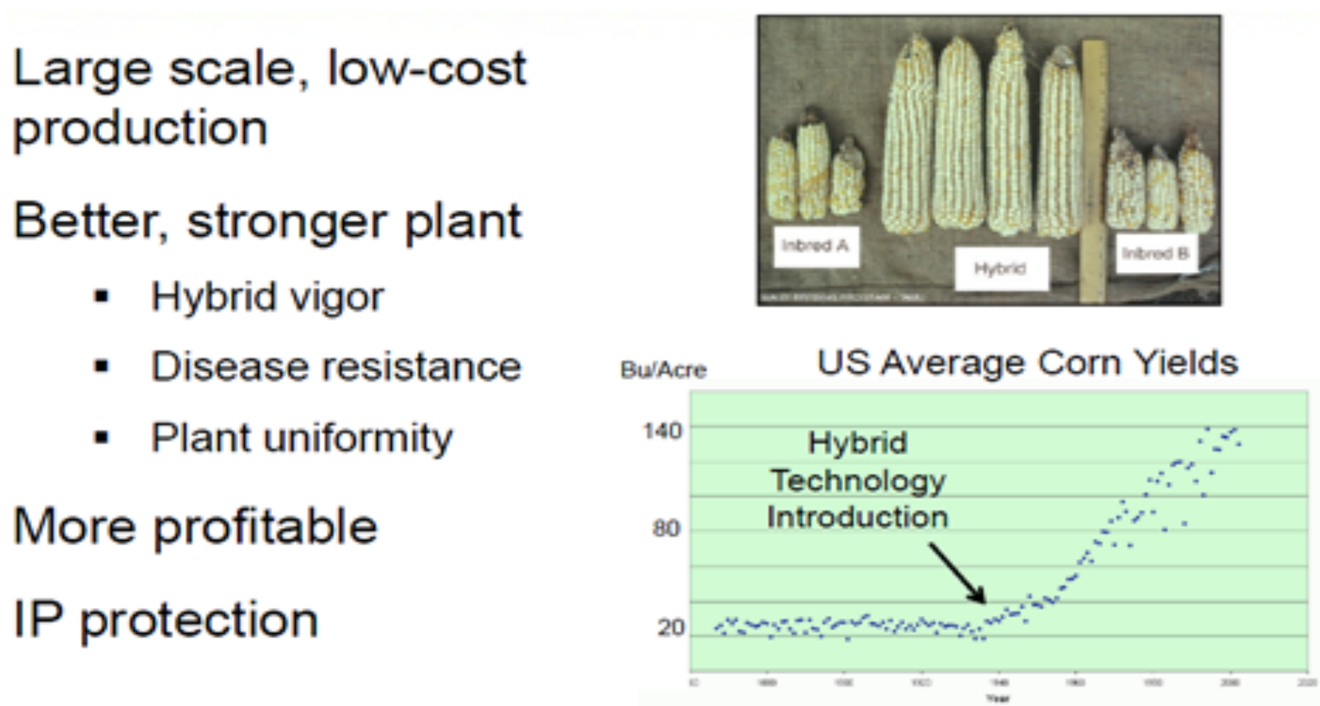


Fig. 20. As it happen with corn amelioration, starting in 1950, the fantastic results achieved in our day in corn productivity, could be expected with the new biomass hybrid crops (fig. from SG biofuels[7])

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 combination in each sweet sorghum farm is to have its own processing facility

Sweet sorghum is better adapted in **Mediterranean regions**. As an example, one can see the recent results of a comparative research in Germany (N.52^{o}) and in Italy (N.42^{o})[16], 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.

4.2. The Sweet sorghum hybrids Malibu.

Some companies have succeed to produce hybrids with higher production (i.e. 9m^3 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. Sorghum sudanense (Piper) Stapf. The hybrid Palo Alto

Sorghum sudenense is a graminae produced as fresh fodder, and sillage.
Synonimes are Vulgare va. sudenense Hitchc. 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 and transport costs that can be at least 50% of total delivered feedstock cost. That lower moisture levels also provides a higher energy density for combustion

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

The hybrid pennisetum was created and tasted from the Grass and Environment Research center of Beijing.

The hybrid pennisetum registered exceptional biomass production in comparison to Swichgrass, Silverreed, and Giant reed, 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)

Conclusion

The world economy is moving to substitute fossil fuels with the renewable sources. From all the renewable sources the only one producing hydrocarbons is biomass, able to substitute all fossils raw materials used for industrial Products and Energy.

Many Mediterranean regions have the privilege to produce low cost and sustainable biomass not in competition with food/feed, but research and demonstration is needed to prove this privilege.

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Thank you for your attention

Spyros KYRITSIS
e-mail: skir@aua.gr