Promising sustainable feedstocks for transport biofuels respecting food competition

by

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Generally accepted rules on the role of energy inputs for plant production **including food or fuel production**

- More energy input to the production systems, more energy output or more food or fuel production, but non analogical and to a certain point.
- If water or a fertile unit is limited to a minimum amount, energy output or food production will be limited to that factor regardless if other energy inputs are given in abundance
- Poor developing Societies without access to energy inputs can not develop their food production beyond a subsistence level, even thought for them a minimum energy input could assure multiple energy output (or more food)
- The development of a society beyond the subsistence level requires more energy for jobs creation and so, to gain more money for better living standards.

- Energy in general creates new jobs, but R.E.S create more. So, in many countries there is a golden opportunity for the creation of new sustainable jobs and so to reduce their unemployment and poverty.
- Further to that with each **direct new job** created there is an economic multiplier induced 5 **indirect jobs** (U.S. Dep/nt of energy)[1]
- Especially biomass based Energy offers ~60% of the energy cost to the feedstocks producers creating more jobs than any other RES

No upper limits for the always growing biofuels Demand

World Bioenergy	MTOE/y
2010	570
2020	680
Longer Term	800
Potential Max	5.650

2008 bioethanol production

U.S. : 34 M.tones/y

Brazil: 24 M.tones/y

E.U.: 2.78 M.tones/year

(8% of U.S.)

2009 U.E. biofuels production

7.877 Biodiesel + Ethanol

(~19% of U.S.)

- The recent (2/2010) U.S. National targets for biofuel is: the year 2022 the bioethanol production to meet or to exceed the **136.8 M.m^3/y with ~80M.m3/y from advanced biofuels**
- So, we expect Biofuels in U.S. to soar in near future and the big question is what are going to do in E.U., and in the rest of the world.

The Consequences from the bioenergy expansion

1. Competition between food and fuel for land use (ex.: if all corn of U.S. used for ethanol could displace only 12% of the U.S. gasoline).

Table 2. World land availability and Estimations

Total arable lands:		3,316 billion ha
Present utilized land:		1,300 billion ha
Total irrigated land:		0.70 billion ha
Estimated land needed ~2075		
	➢ for 9 billion people:	~1.80 billion ha
	➢ surplus land for energy	>750 million ha

Source: EUBIA Biomass Industry Day, Biomass Conference, Valencia 2008

2. Environmental problems

Biofuel	GHG Reduction, %
1. Sugarcane ethanol in Brazil	86 – 90%
2. Corn ethanol in U.S.	10 – 30%
3. Biodiesel in Europe	45%

Other environmental problems

1. Consequences from monoculture
2. Water Competition
3. Soil and Water pollution
4. Soil erosion

3. Cost Problems

	Typical feedstock for bioethanol production	Production Costs (€/m^3)	Bioethanol Production Million m^3	
			2006	2008
Brazil	sugarcane	170	17.8	24
U.S.A	grain maize	260	18.4	34
E.U	cereals and sugar beet	450	1.6	2.78
China	grain maize, wheat	310	1.4 (2005)	1.90
Australia	sugarcane, wheat	270	0.1	?
Thailand	sugarcane, cassava	210	0.3	0.34
Germany	cereals and sugar + imports	450		
Sweden	grain, cellulose	?		

4. Social problems

- The today ethanol production comes mainly from food crops. So, the energy prices influence food prices (as a psychological fear for the to day situation)

- The sugarcane ethanol in Brazil creates often workers abuse problems

- The Palm oil and Jatropha for biodiesel production creates often social problems to the local farmers and workers abuse.

The European measures to avoid the feedstocks problems

E. Union regulation, supports the use of feedstock **not designated for food** and respecting the **new sustainability criteria,** saving initially at least 35% of CO2, and up to 2017 more than 50%, with the existing installations (<1/4/2013), and more than 60%, for the new installations.

Bioenergy feedstock should not be produced:

1) in land of high biodiversity,
2) from places of high Carbon stock (Natural forests, Peat lands, Savannas, etc.)
3) without respecting soil, water and air
4) Biofuels should prove to be socially responsible

The U.S. Measures for better feedstocks

- U.S. Government subsidizes farmers to take land out of corn ethanol production and to plant more advantages feedstocks
- According the California Standards, after 2011 corn ethanol will not be used in that state unless Carbon intensity is reduced
- The Environmental Protection Agency had proposed (5/2009) new R.F. standard, including also the carbon footprint from indirect land use changes
- Recently many States require ethanol blends to respect the Federal air quality goals.

THE MOST PROMISSING SUSTAINABLE BIOFUEL FEEDSTOCKS DON'T THREATEN FOOD SECURITY

The main considerations for biofuels production in some European and neighboring countries:

IN FAVOR

- The Unlimited demand for biofuels of the European market respecting the sustainability criteria
- The considerable opportunity to offer permanent jobs in rural areas
- The environmental benefits
- The favorable climatic conditions for some new sustainable feedstocks in south European regions

AGAINST

- The strong competition, in south E.U. and the Arabic countries, for food and feed production and also for water use.
- The small cultivated area per family around Mediterranean
- The dry conditions in the South European and neighboring countries

1. The cellulosic ethanol by biological means

Cellulosic ethanol production is based on biological means of turning cellulose contain of biomass into ethanol, via a complex procedure .

Table 3. Commercial Cellulosic Ethanol Plants in the U.S. *(Operational or under construction the year 2008)* *http//en.wikipedia.org/wiki/Cellulosic_ethanol*

Company	Location	Feedstock
Abengoa Bioenergy	Hugoton, KS	Wheat straw
BlueFire Ethanol	Irvine, CA	Multiple sources
Colusa Biomass Energy Corporation	Sacramento, CA	Waste rise straw
Coskata	Warrenville, Il	Biomass, Agr. And Municipal wastes
DuPont Danisco Cellulosic Ethanol (DDCE)	Vonore, TN	Corn cobs, switchgrass
Fulcrum BioEnergy	Reno. NV	Municipal solid waste
Gulf Coast Energy	Mossy Head, FL	Wood waste
KL Energy Corp.	Upton WY	Wood
Mascoma	Lansing, MI	Wood
POET LLC	Emmetsburg, IA	Corn cobs (95 Ml/y, 2012 & 13Bl/y 2020)
Range Fuels	Treutlen Country, GA	Wood waste
SunOpta	Little Falls, MN	Wood chips
US Envirofuels	Highlands County, FL	Sweet sorghum
Xethanol	Auburndal, FL	Citrus peels

Table 4. European Efforts on Cellulosic Ethanol by biological means

(*Note: The big expectations of the European efforts are oriented to thermochemical means for cellulosic biofuels –BtL*)

Country	Efforts and Achievements
Sweden	A pilot plan has been realized in SEKAB, in the frame of the E.C. NILE project. The NILE target for enzymatic hydrolysis is to reach a yield of up to 75% of the theoretical max. and they have achieved so far more than 60%[8]
Denmark	In 2009 was opened in Kalundborg a bioethanol plant to produce 5.4 M.liters/year, based on straw as feedstock[12]
Germany	BUTALCO Company cooperates with Hohenheim University to develop yeast strains to process both starch and straw together
Spain	Abengoa Company is building a 19 M.liters of cellulosic ethanol based on new and better enzyme mixtures to be developed by Dyadic International.[14]
U.K	BP, associated with British foods (ABF) and DuPont announced a $400 M. investment to process in late 2009, wheat straw and to produce 420 M.liters of cellulosic ethanol[14]

Table 5. The expected Results from Cellulosic Ethanol

Crop	Annual yield (Liters/hectare)	Greenhouse-gas savings (% vs. petrol)[1]	Comments
Miscanthus	7300	37-73	Low-input perennial grass
Switch grass	3100-7600	37-73	Low-input perennial grass.
Eucalyptus	6000-12000[3], [5]	100-200	Plantation needs tropical or sub-tropical conditions. The better results need water. No frost resistant.
Sugar cane	6800-8000[6], [7]	87-96	Long-season annual grass. Only grows in tropical and subtropical climates.
Sweet Sorghum	2500-7000[4], [5]	Same as sugar cane	Low-input annual grass, resistant to dry conditions cultivation from 50° North to 50° South
Corn	3100-4000[6], [7]	10-20	High-input annual crop. Cellulosic technology would allow Stover to be used and increase ethanol yield by 1.100-2.000 liters/ha

Source (except those indicated): Nature 444 (December 7, 2006): 673-676. (1) Savings of GHG emissions assuming no land use change (using existing crop lands). Modified

Cellulosic Ethanol Cost

- The cost of cellulosic ethanol was double (2006) than from corn especially because of high cost of enzymes (>10 times more than for corn ethanol)
- The U.S. Dept. of Energy estimates a cost reduction by 2012 to \$0.28/liter

Conclusion

Besides the today achievements 1) on the feedstocks productivity and especially the use of organic wastes as feedstock 2) on the Industrial transformation to ethanol and on the expectations that cellulosic ethanol can reduce GHG emission by 85% (Argone Lab, Univ. of Chicago), there is a concern on the time needed to succeed an ethanol cost compared to sugarcane ethanol in Brazil.

Feedstock productivity in South Europe is higher than in the rest of Europe

2. The emerging importance of Sweet Sorghum for Fuel , Food , and Feed.

S.S Characteristics:

1. S.S. is a C4 plant producing grain and sugar in the stalks
2. Efficient convertor of solar energy, with low [23] inputs.
3. Low water inputs (~200 m3/ton), 1/3 of Sugar cane and ½ of Corn [25]

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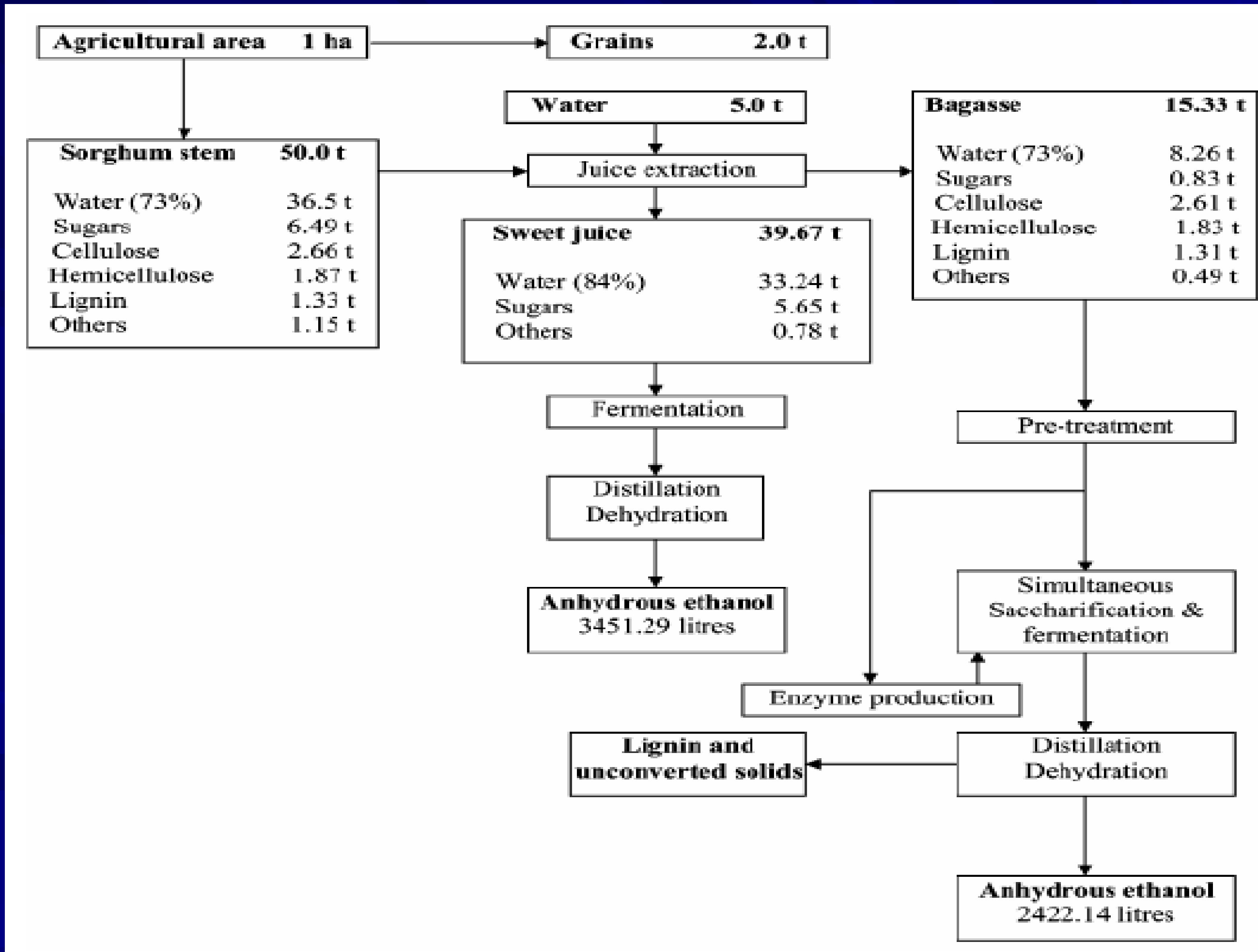
4. It requires only 50 Kg of N/ha,[20],[31] and can extract nitrogen left by previous crops, or from N fixing plants
5. Growing period is shorter (3-5 months) [23],[25] than that of sugarcane (10-12 months) or seed-crops (4-5 months).
6. Bagasse for C.H.P.,for animal feed or cellulosic ethanol.
7. The crop gives good results even in poor, or salty soil.
8. The crop in parallel to juice from stalks, produce also seeds designated for food, feed or for grain ethanol.

Fig. 6. Mass balance of sweet sorghum ethanol production [27] *(Prasad et al., 2007)*



U.S. Intensive research to replace corn ethanol from S.S. ethanol in Corn Belt (University of Nebraska)

The targets are:

1) To increase the sugar content of S.S juice to a level needed to produce 1000 gal. of ethanol/acre (9m3/ha) under the Corn Belt conditions.
2) Dual ethanol production (sugar + cellulose) to maximize the energy efficiency.

So, working on genes and on better management ,achieved:

a. Low lignin content to S.S. line and hybrids
b. Germination at 10^{o}C soil temperature (42^{o} North)
c. Stress resistance to cold, drought and salt
d. Rotation with Vetch and coproduction of ~ 9t/ha + 50 N units/y

The Oklahoma University succeeded

a. To extend harvest window, managing fast sugar degradation by safety storage
b. To adopt: Harvest, Press, Ferman/on in the field reducing high investment cost.

The 1st commercial distillery installed in India the year 2007. Now S. S, commercial ethanol is already in operation in Texas, Oklahoma, and in Iowa

Fig. 8. Experimental trials with S.S. varieties in Southern Italy 2007 *(Source: Eubia 2009(26))*

- **Experimental trials (Sweet-Sorghum) Southern Italy 2007**

Total fresh weight

Australia seeds: NSS. 104	170t/ha (28000 ha)
Romania seeds: F135/1143	176 t/ha (24000 ha)
Germany seeds: (KWS)	100 t/ha (21,000 ha)

High S.S. grains productivity: ~ 7.5 t/ha.

In sub-tropical/tropical areas, a good combination for co-production of bioethanol is sugarcane and sweet sorghum plantations (11 months of operation for ETOH).

Fig. 9. EUBIA estimations for the cost of Sweet Sorghum ethanol

Assuming that 60% of the ETOH production cost is due to the feedstock (sugar cost) supply, this value is:

$$\frac{50\ €/t}{0.96_1 * 0.93_2 * 0.5_3 * 0.95_4} = 118\ €/t\ ETOH$$

1: Sugar extraction efficienc
2. Fermentation efficiency
3. ETOH/sugar conversion
4: Industrial efficiency

Therefore the anticipated cost of bioethanol from sweet

sorghum is about 200€/t.

Conservative figure: **250 €/t***

*ICRISAT's culculations based on real figures from a small distillery 40 M3/day give a cost of 278 €/m^3 of ethanol

Table 17. The economics of setting up a distillery…

The economics of setting up a distillery…

Distillery capacity	Cost[1] (US$ million)
40 KLPD	9
100 KLPD	28
200 KLPD	38

[1]Includes civil works and excludes facility for germ separation from maize, November 2006.

…and the employment generated by a 40 KLPD unit

Country	Beneficiary farmers	Labor (man days)	Direct staff (man days)
India	5000	40000	100000
Philippines	2500	20000	50000

Source: Rusni Distilleries (P) Ltd.

Summary of Results from Environmental comparison of Sweet Sorghum with other feedstocks and gasoline *(Koppen et all, 2009)*[32]

a. *Energy balance*

- If the crop is used for the production of ethanol (from grain and sugar) and for green electricity (from surplus bagasse), ⇒ **3.5 TOE/ha** can be saved
- If both food from grains and ethanol from the juice are produced, ⇒**2.3TOE/ha** can be saved

b. *Greenhouse gas balance*

The saved gases are depending on yields, production methods, the land cover prior to Sweet Sorghum cultivation, other local conditions, the use of by-products (e.g. bagasse), and the type of fossil energy carriers used.

So, the saved gases in CO2 equivalent are : **1.4 - 20 Kg CO_2/ha**

Conclusion

S. Sorghum even though a new ethanol crop(1st commercial distillery 2007) is proved that disposes a great potential to produce competitive ethanol, to reduce GHG, and a promising crop for food feed and fuel production in parallel or in rotation.

South European and Mediterranean climatic and social conditions are very suitable for S.S. ethanol and feed productions

3. Biogas from anaerobic fermentation, by far the best in sustainability and in land energy productivity

- Biogas or biomethane is obtained via anaerobic fermentation which takes place in closed digesters, continually fed by **waste** from livestock, food industry and from **farming** biomass

- Purified biomethane is used to run CHP engines, to be injected in the natural gas network, and as **a vehicle fuel or for fuel cells**

- The sub-product "digestate" is an organic fertilizer saving around 95% of the nutrients (N, P, K)

- The year 2007 in E.U biomethane production was 5,9 M.toe with 20% growth/year.

Biogas production in m³/t fresh matter

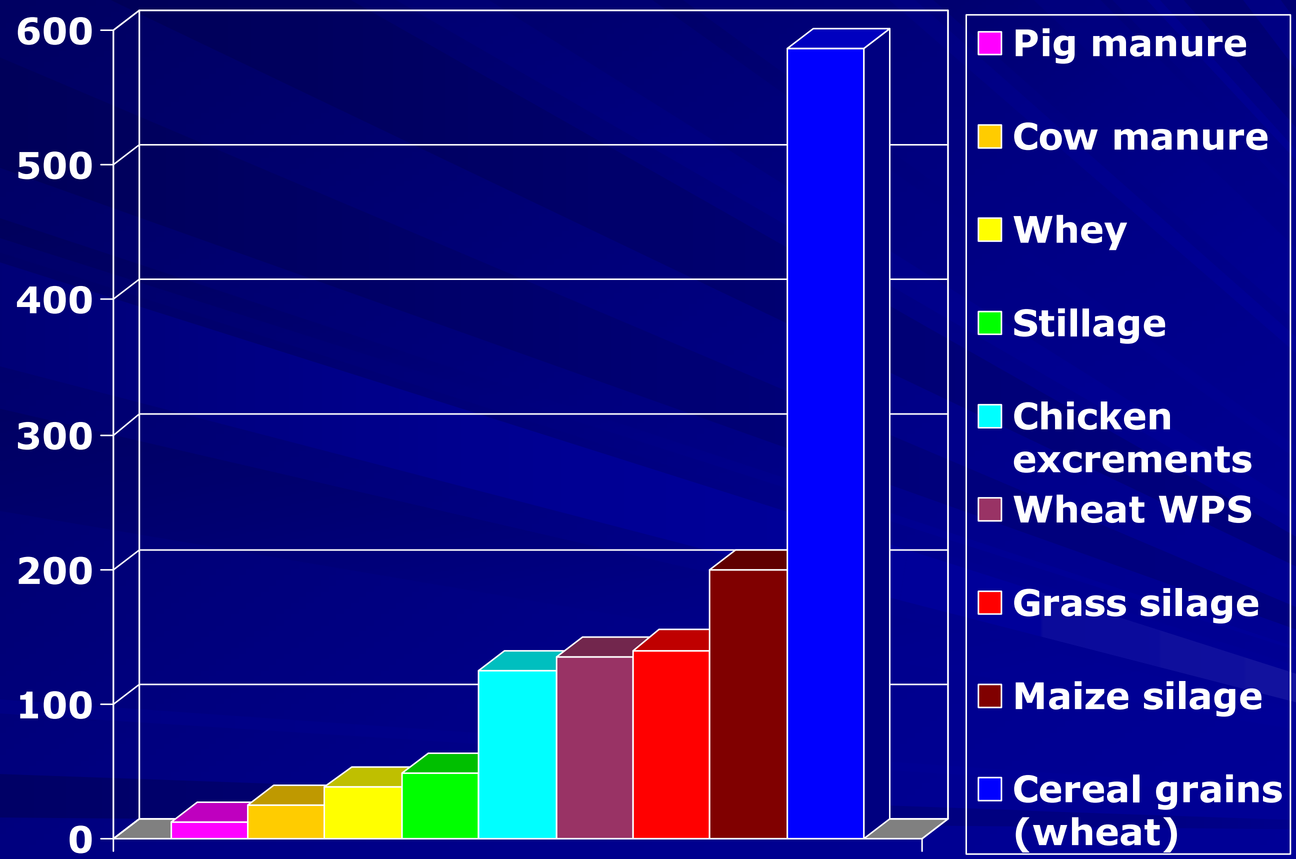
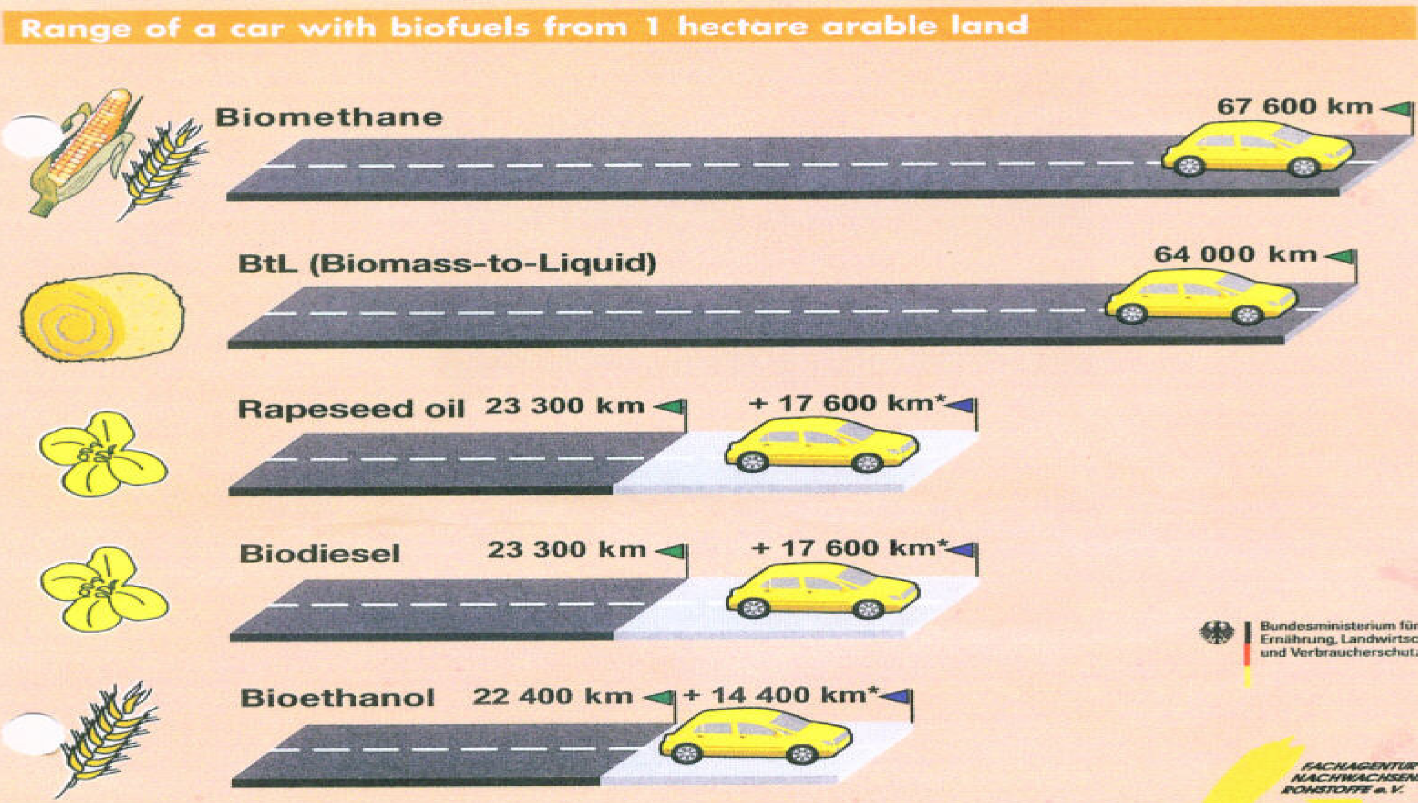


Table 6. Examples of feed-in tariffs in Europe (€ cents/kWh)

Examples of feed-in tariffs in Europe (c€/kWh)[9]

Country	Austria	Germany	France	Italy	Spain	Netherlands
Sewage sludge	5,93	6.16 - 7.11*	7,5	18	10,75 - 15,89	7,9
Landfill	4,03	6.16 - 9*	7,5	18	10,75 - 15,89	7,9
Agriculture 100 KW	16,93	11,67 - 30,67**	9*	22 - 28*	10,75 - 15,89	7,9
Agriculture 500 KW	13,98	9,46 - 25,46**		22 - 28*	10,75 - 15,89	7,9
Agriculture 1000 KW	12,38	8,51 - 17,51**	7,5*	22 - 28*	10,75 - 15,89	7,9
Condition	Plant efficiency of at least 60% (CHP).	Electricity generated from biogas with-drawn from a gas network is eligible only if it is from CHP generation	Plant size smaller than 12 MWe Higher tariffs for overseas territory	Plants smaller than 1 MWe can choose between the guar-anteed feed-in tariff and the green certificate system	Main fuel is bio-fuel or biogas from anaerobic digestion of agricultural and livestock wastes, bio-degradable industrial waste and sewage sludge or landfill gas	If the subsidies applied for exceed the funds available, subsidies are granted in the order of the date of submission of the application
Guaranteed years	10 (+2)*	20	15	15	15	12
	* reduced feed-in-tariff for the 11th and 12th year	*technology bonus of 1-2 € ct/kWh possible **depending on additional bonuses like co-digestion, use of manure, energy crops, effi-ciency, air quality, etc.	*plus additional bonuses	*depending on source of energy; maximum tariff at the moment is 22c€, 28 are planned		

Biofuels in comparison



Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

The biofuels biomethane and BtL (biomass-to-liquid) are not in use or still in experimental stage at the present time, but their production from biomass is very effective. The resulting range from one hectare arable land can thereby be reasonably high. The performance of rapeseed oil, biodiesel and bioethanol is much lower, but the balance improves enormously through the utilisation of their by-products.

Biomethane and bioethanol are used in petrol engines and vegetavle oil, biodiesel and BtL are suitable for diesel engines.

* Biomethane from by-products (colza cake, draff, straw)

Fuel consumption: petrol engine 7.4 l/100 km, diesel engine 6.1 l/100 km

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- According to a study by Rogiel Samson et al (2009), the net energy output of biogas from corn silage is **8 times more** than the energy output of ethanol from corn. (Ren. Energy World 3/2010)
- Compressed biogas (WTW, Well To Wheels) is most climate friendly of more than 70 different fuels and pathways (JRC-E.C)

Conclusion

Biomethane is today the most energy efficient use of land and by far the best environmental solution for biofuel production and use. But still the cost is higher than biofuels from some other sources. .
Under tropical and subtropical climatic conditions the energy productivity of certain feedstocks (maize, sorghum etc.) is at least 30% bigger than under the Central and North European conditions.

4. **Jatropha Curcas** *(Euphorbiaceae)*

- J. Curcas is a poisonous shrub cultivated in Tropical and Subtropical regions[3]. It is resistant to a high degree of aridity, growing almost in deserts (250mm rain/year), in waste lands and almost in any terrain, even on gravelly, sandy and saline soils.

- If planted in hedges productivity can be 0.8 – 1.0 Kg /1m. Seed production can be 0.4 – 5t/ha and even 12t/h (Hohenheim University under better conditions. The seeds contain ~ 34.4% [2] oil of high - quality

Commercialization

India, Africa, Latin America and Philippines are the main regions of Jatropha cultivation.

- **In Myammar** there is a 50,000 ha plantation in a target to reach 700.000ha
- **In Mozambique** where is a potential rain-fed production are activated an Austrian and a Dutch Agencies working with small farmers in poor land. The farmers practice also mixed cultivation with maize, chili pepper, sunflower. Foreign companies use fertile soil without the involvement of local farmers paying them as workers very poorly(5) as they sold their fertile land at a give – away price, resulting a serious social problem
- **In Tanzania** the German R.E. group Prokon has a project with 10,000 ha for oil production and cake for C.H.P

  Already 16 National and International Companies are dealing with J. Curcas cultivation

  A BP company(5) has 172,000 ha and is planning to extend it to 1 Million ha up to 2012 and after that a further 300,000ha/year will be installed. They try to use land that is not for food production.

- In Central America the company SG biofuels gave[6] impressive results with a new cultivar of J. Curcas the J Max 100. They reported an increase in profitability more than USD 1000/ha or 3 t/ha at USD 0.37/liter.
- In Philippines Jatropha grows on infertile soils and on hillsides not in the same soils as food crops. Average productivity is 4-5 t/ha. They try to develop the mobile refineries to avoid expensive investment of a central plant.

Conclusion

J. Curcas is a new feedstock able to valorize poor soils under dry conditions

Sustainability can be achieved under an appropriate policy.

Some Universities (Hawaii, Hohenheim, California) and many Research Centers (in Guatemala and others) try to find the best cultivars for specific conditions.

The social and climatic conditions in South Med-countries are suitable for good production, but research is still needed to assure production and efforts.

5. Algae feedstock for biofuel

The biomass of algae is suitable to produce bio-oil, bioethanol, biogasolines, biomethanol, biobutanol and biogas.

Algae grow 20-30 times faster than food crops[(10)]. The reported yields are between 47-187 tones/ha.year.

So, algae present huge advantage in sustainability and productivity, but yet (2008) biofuels from algae are very expensive. They also need a cheap source of sterile CO_2.

Commercialization

There are in evolution many R&D efforts in E.U.,U.S, and in other countries on algae biofuels.

The U.S. Defense Agency has the ambitious target (2010) to produce algae in large scale at a cost of $ 0.53/litre that is much less than from the today demo projects.

The companies SAIC and General Atomics will operate in 2011 a production of 189 Million liters/year, with 9.37 m^3/ha.year of oil with a cost competitive to fossil fuels(11)

Conclusion

Given the sustainability and high productivity advantages of algae biofuels and the intensive research undertaken by Universities and Nationals and Private Research Centers, the production cost is estimated to be gradually dropped in near future.

The only remaining concern is the possibility the entire production to be undertaken by big companies without the farmers participation.

General Conclusion

The better Productivity and Sustainability of the new feedstocks and their ability to be produced either in Infertile soil or for dual purpose Food and Fuel, moreover the fact that investments and markets are without frontier, an appropriate policy is needed by E.U and countries to face many of their energy , economic and social problems.

THANK YOU

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