Perspectives of modern bioenergy in the World and in the E.U.

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Context

Several issues relate to the valorisation of biomass resources :

- Agricultural policies and food production
  (global and structural food overproduction in EU)
- Need of energy sources
  (indispensable for economic development)
- Water availability
  (emerging problem)
- Desertification
  (+6 million ha/year around the world)
- Market liberalisation and globalisation

Introduction

Why is biomass so interesting?

1. Renewable resource available virtually anywhere
2. Considerable potential (residues and plantation in the long term)
3. Capacity to penetrate all energy markets (heating, power & transport) as well as the basic chemicals market
4. Important related advantages:
   - net CO_2-neutrality;
   - decrease noxious gas emissions (SO_2,etc.);
   - favour employment in rural areas;
   - contributes to the fight against desertification.

Biomass and Renewable Energy

	Biomass Contribution	Biomass Contribution
	Total Renewable Energy (Hydro + wind + solar + geothermal)	Total Primary Energy
E.U. - 25 (2005)	~ 90MTOE	~ 90 MTOE
	~ 140 MTOE	~ 1,5 BiTOE
WORLD (2005)	0,63 BiTOE	~ 0,63 BiTOE
	1,01 BiTOE	~10,1 BiTOE/y

*** Source EC Trends to 2030 / EC Energy to 2020**

Estimation of world future role of bioenergy

Projections of future potential	Contribution (M Toe / year)*	
Oranisation	**2025**(year)	**2050**(year)
Shell (1996)	2,030*	4,750*
IPCC(1996)	1,720	6,700
Greenpeace(1993)	2,720	4,320
Johansson et al. (1993)	3,470	4,920
WEC (1993)	1,400	3,000
Dessus et al. (1992)	3,220	-
Lashof and Tirpak (1991)	3,100	5,130
Fisher and Schrttenholzer (2001)	8,350	10,750
Average	**3,250**	**5,650**

Source: G-8 Initiative – White Paper

European biomass resources

M TOE: Million of Tonnes Oil Equivalent (1 TOE ~ 2,4 t dry biomass)

- **Current consumption** (EU-15; 2001):

- Primary energy: ~ 1486 M TOE/y
- Biomass: ~ 57 M TOE/y

(3.8%)

- **EU guideline regarding biomass use**:

- for 2010 ~ 135 M TOE/y
- for 2020 ~ 200 M TOE/y

- **Biomass potential** (2050)

- UE-15 ~ 500 M TOE/y
- UE-25 ~ 600 M TOE/y

•(EEA estimation 300 MTOE/y for year 2030

Most will depend on agricultural land available for energy crops

Examples of crops photosynthetic efficiency*

Good choise of energy-crops could increase the future Biomass Potential

Global terrestrial biomass efficiency (average):	0.05	%
Sugar cane – Sweet sorghum plantations:	2.5	%
Sugar beet plantations:	2.1	%
North Europe forestry:	0.07-0.26	%
Reeds:	1	%
Eucalyptus:	0.9-1.7	%
Maximum in laboratory experiments:	7	%
Maximum (few hours) sweet sorghum:	27	%

(photosynthetic efficiency = crop energy content / solar radiation energy)*

Future need: increase the biomass availability

In nature there is a wide variability as far as concerns the photosynthetic activity of plants:

- An increase of **1%** in photosynthetic efficiency of one specific crop would provide **~100 MWh/ha.year**
- Most of present biomass crops are food crops or wood industry crops. Only about 1000 species of the total 242,000 so far identified are well known, utilised and developed.
- For expanding the bioenergy activity considerable effort on required new energy crops (expecially C-4 crops).
- Discovery of the full photosyntetic mechanism could have considerable impact on the biomass resources availability and quality.

Production cost of energy crops (trials)			
energy crops	***yeld dt/ha***	***tot cost €/ha***	***biomass cost €/dt***
Sorghum	25-28	850	32
Cardum	10	500	50
Miscanthus	22	650	30
Arundo Donax	30	1100	37
Poplar (SRF)	15	720	48

MISCANTHUS

ARUNDO DONAX

CYNARA CARDUNCULUS

SWEET SORGHUM

CANARY GRASS

STRAW

HEMP

POPLAR

WILLOW

WILLOW

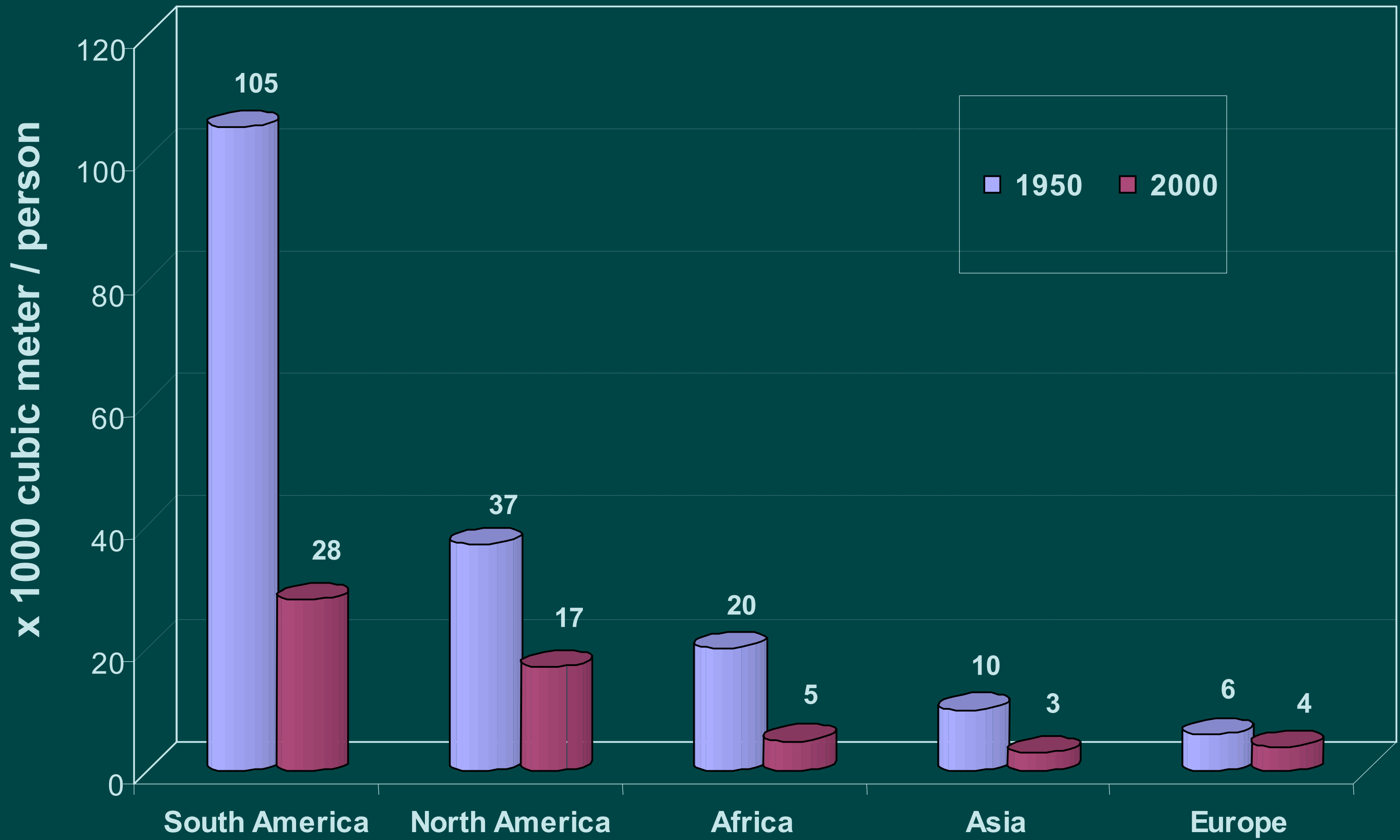
PINE

BIRCH

ROBINIA

Water resources on the globe

Water availability is an important constraint:
(1kg of dry biomass requires 200-1,000 kg of water!
Future choice of water saving crops will be important)



To sum up

1	**Depletion of fossil fuel resources :** ~ 50% of recoverable petroleum already consumed
2	**Biomass** resources are **abundant** and **available** almost anywhere in the EU and worldwide, but with water and good land constraints.
3	The future availability of biomass resources could be increased considerable trough the discovery of the **photosyntetic mechanism**

Which markets for biomass resources?

- Heat and Cool production
- Power production
- Biofuels production for transport
- Industrial commodities

Stabilisation of humid Biomass

Is still missing a wide strategy on this important issue:

Pellets can be considered the most interesting commodity for stabilisation of biodegradable biomass and for modern bioenergy production and for promoting international trading.

<u>Example of interesting new pelletisation machines</u>

- Micro pelletisation machines (for farmers or cooperatives)
- Mobile pelletisation machines (for dispersed residues)
- Multi stages pelletisation machine (for very humid biomass)

2.1 Heat and Cool production

- **Solid biomass**

- Chips: local markets
- Briquettes: local markets
- Pellets: most suitable biofuel for heat / cool production*

- **Liquid biofuels**

- Biodiesel: good biofuel but expensive
- Biocrudeoil: expensive and problems of stability

- **Gasous biofuels**

- Low Heating Value: low quality biofuel
- Medium H.V. : expensive
- Biogas : good properties and reasonable cost (waste disposal product)

* the use of pellets is already competitive in most of countries in comparison to conventional fuels, even in comparison to Natural gas (spot market price 8$/MM Btu)

2.2 Power production

- **Small power generators (few kWe to 1MWe)**

- Small engines or micro gas turbines fuelled by biodiesel or bioethanol are today commerciallyavailable but with the following constraints:

  - **Limited timelife operation**
  - **Use of expensive biofuels**

-Small power generators using solid biomass are not available commercially. The potential world market is huge : actual business of conventional dispersed generators is ~ 50 billions $ / year.

-Intensive R&D and Demonstration activity is under way (around the world) on Gasifiers-Engines power generators, sterling generators, steam engine. System but not yet a commercially proven technology.

Small Power Generator (Martezo France)

• Large power generators (2 MWe t 500MWe)

- Solid biomass generator (steam condensing); capacity some MWe to some tens of Mwe; hel ~ 29%; specific investment ~ 2,000 € / Kwe

Biomass Power Plant (Siemens)

• Large power generators (2 MWe t 500MWe)

- Liquid biomass advanced C.C. power generators;capacity: 50-500 Mwe ; hel ~ 50-57%; specific investment ~ 600-500 € / Kwe; very low NOx,SO2 emissions. Very performant green power generators but using expensive bofuels (Bio-ethanol, Bio-methanol, Bio-diesel)!

C. C. Power Plant (G. E.)

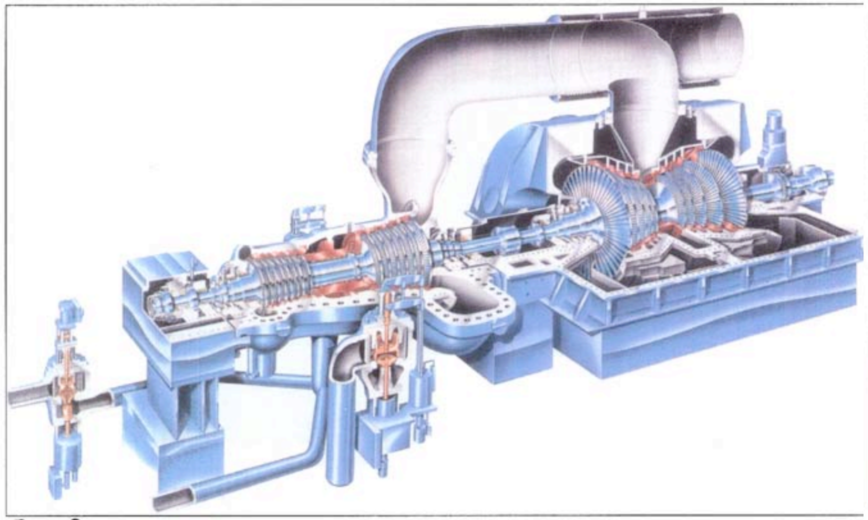


FIG. 2

C. C. (Siemens) Power Plant

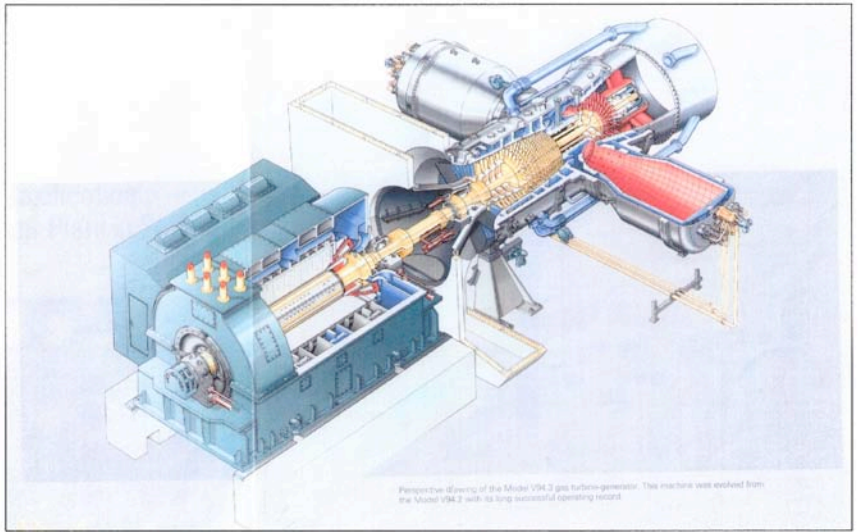


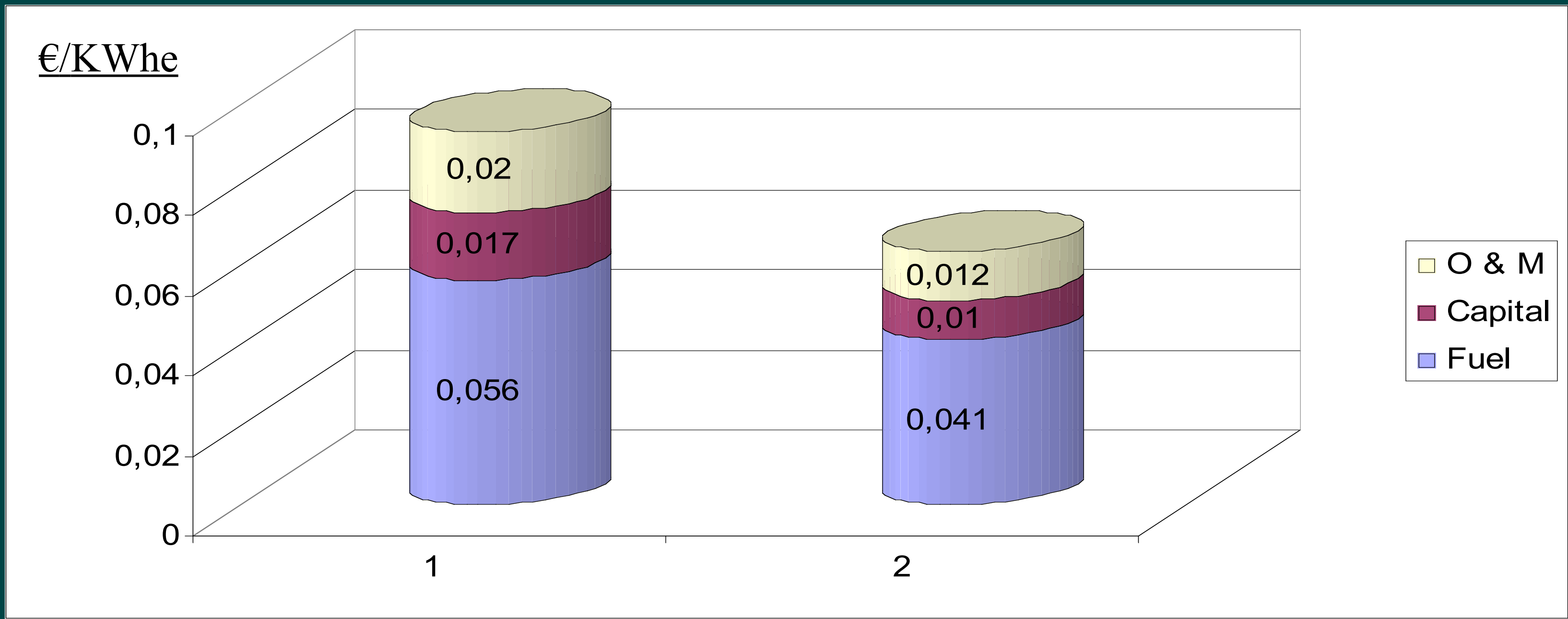
FIG. 1

Green Power Production

<u>25 MWe Biomass Power Plant</u>
(ηe = 30%; Inv. : 1.500 €/KWe;
I = 5%; n = 20 years;
biomass cost=50€/dt)
<u>Total . 0.093€/KWhe</u>

<u>Biomass –Coal Cofiring (500MWe)</u>
(ηe = 40%; Inv. : 1.200 €/KWe;
I = 5%; n = 30 years)

<u>Total . 0.063€/KWhe</u>



Agro-Pellets Cost = 80 €/t

Biomass-Coal cofiring in large Power Plants

Advantages

•Most economic way to produce “green power”;

•High efficiency:~40%;

•Possible energy contribution from biomass of 20% at present;

•Large potential in the E.U. : ~50,000 MWe and c160.000 MWe world-wide.

•Large supply of agro-forestry biomass (~0.5 Kg dry/KWhe): 180 mio d.t/y with great impact on rural economy;

•Small supplementary investment required:~100€/KWe

•Reduced CO_2 and SO_2 emissions from the power-plant.

Biomass-Coal cofiring in large Power Plants

Constraints & Problems

•20% limits of co-firing with present technology;

•More complex Combustion Chemistry with risks of fouling, slag-sintering depots if correct operation is not adpted;

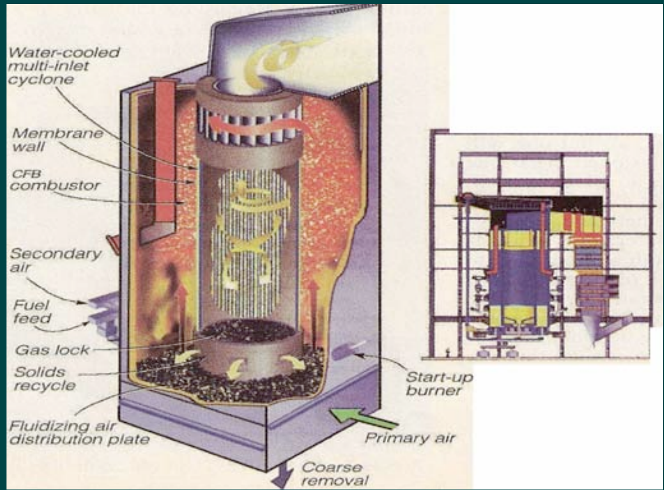
•Need of homogeneous biomass feedstocks supply to not perturbe the boiler operation and plant efficiency;

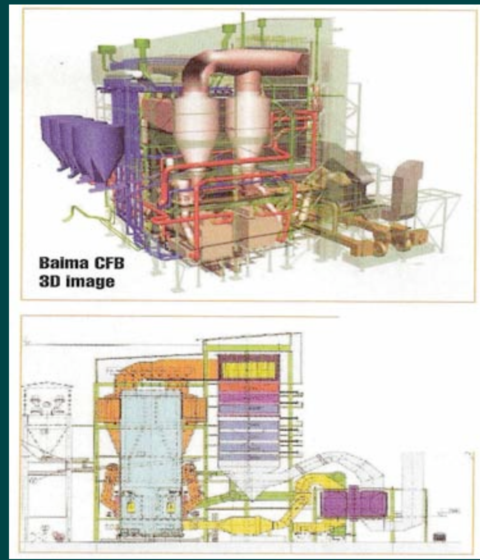
•Back of international standards for the biomass ;

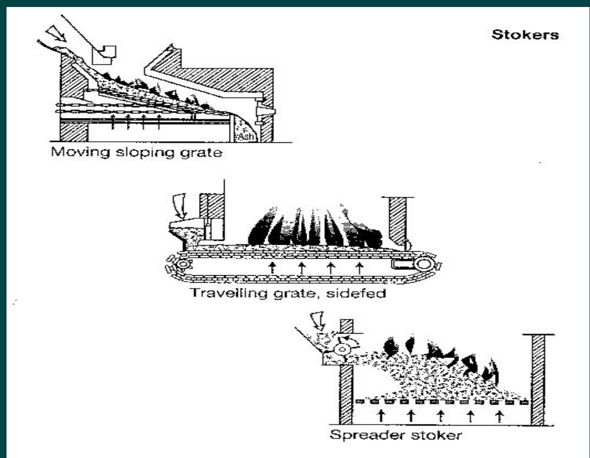
•Infrastructure needed for large-scale biomass supply;

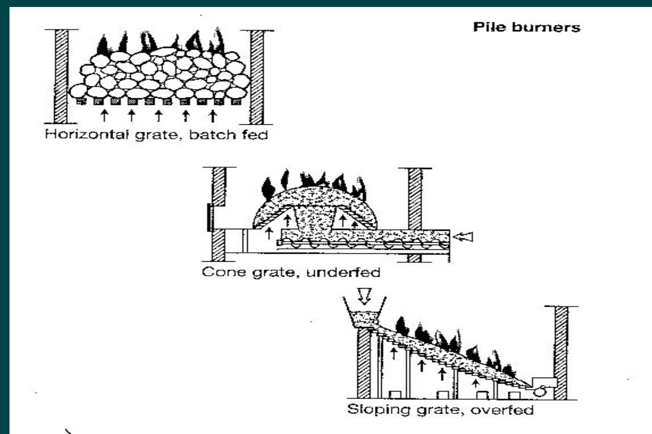
•International trade of biomass no yet established.

Co-firing Power Plants (Examples)









2.3 Biofuels production for transport

Composition (*MTOE) and objectives related to bioenergy in EU

Biomass resource	**1995**	**2000**	**White Paper goals for 2010**
Solid biomass	42,9*	48,4*	102
Gaseous biomass	1,2	1,8	15
Liquid biofuels	**0,4**	**0,9**	**18**
Biodiesel	*0,28*	*0,70*	-
Bioethanol	*0,08*	*0,20*	-
Total	**44,5**	**51,1**	**135**

(*MTOE)

Source: Kopetz, 2003 in Renewable Energy in Europe (EREC) Draft copy January 2004

EU framework for biofuels

European directive 2003/30/CE (May 2003) :

Promotion of the use of biofuels
and other renewable fuels for transport

Minimum proportion of biofuels and other renewable fuels that should be placed on the markets of each member state (in %*) :

By December 31st 2005:	2 %
By December 31st 2010:	5,75 %

**: calculated on the basis of energy content of all petrol and diesel for transport purposes placed on the markets at the corresponding date.*

EU framework for biofuels

EU Directive 2003/30/CE :

Biofuels with the major technical and economic potential:

- Bioethanol (+ bio-ETBE)
- Biodiesel
- Biogas
- Biomethanol (+ bio-MTBE)
- Biodimethylether (DME)
- Synthetic biofuels
- Biohydrogen
- Pure vegetable oil

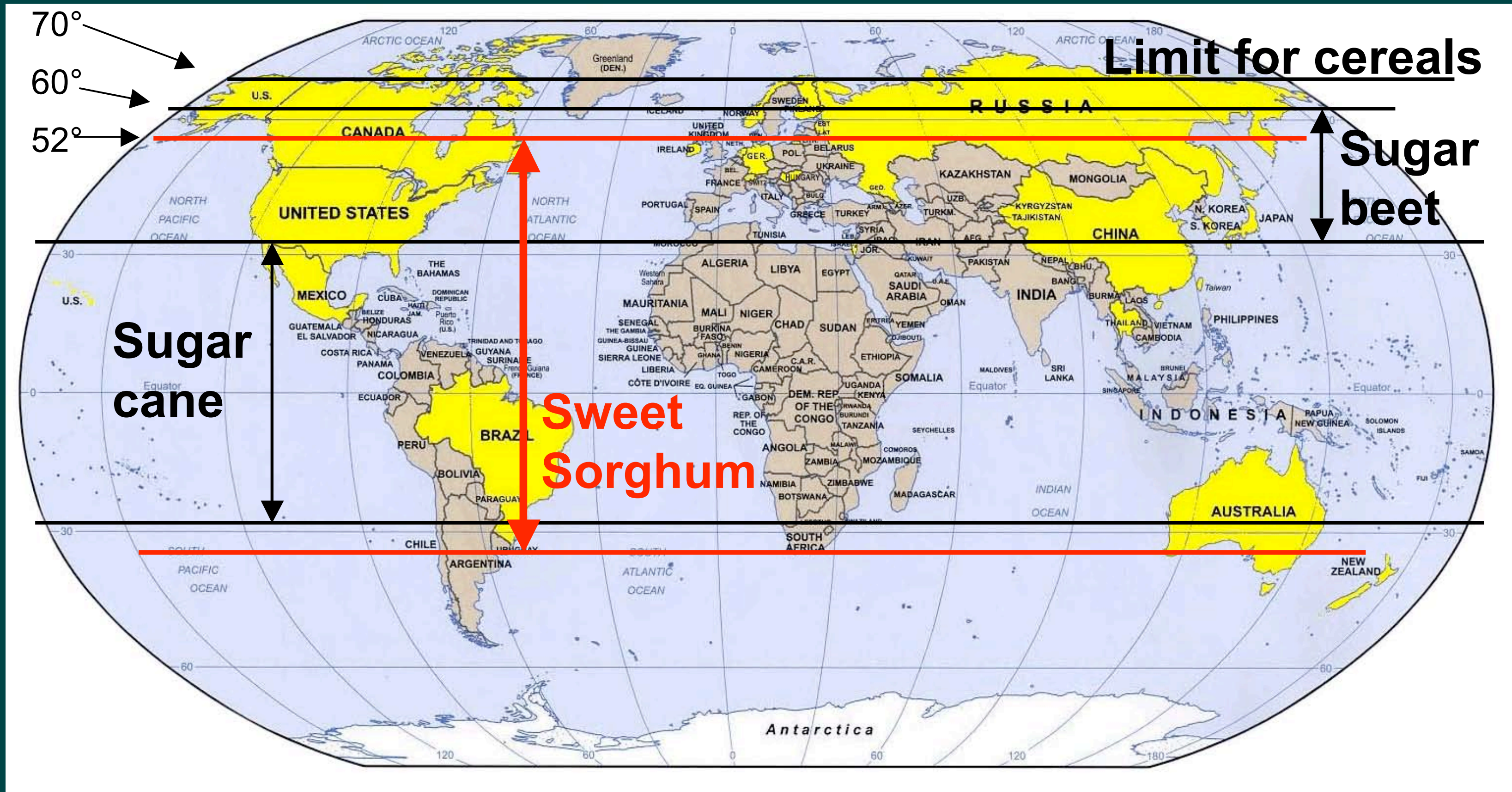
Biofuels with the major technical and economic potential

- For each biofuel: **advantages** and **drawbacks** if compared between them or to other fuels
- The **economic aspect** will be the main driver of the penetration on the market
- Competitiveness will be based on the industrial costs of the end-products (gasoline and diesel fuel); an estimation (oil at 60 $/bbl) is:

~ 450 €/TOE

Potential geographical areas for S. Sorghum

Because of his wide geographical cultivation potential Sweet Sorghum could be the most important energy crop for combined power&biofuel production



World-wide Co production of "Green-Power" & Bioethanol (from sugar cane/sweet sorghum)could have large impact on Development and G.H.G mitigation

Hydrocarbons Quotation

Best Biofuels costs estimations

(W.S. Journal 10.05.2006)

Hydrocarbons	Price	Heating value	Biofuels	Price	Heating value
Crude Oil	70 $/bbl	10,000 Kcal/Kg	Biomass (fresh 50% moisture) (sale value 60$/dry t)	20 $/bbleq	2,050 Kcal/Kg
Natural Gas *** (7$/MMBTU)	38$/ bbleq	12,700 Kcal/Kg	Pelletised Biomass (100 $/t)	29 $/bbleq	4040 Kcal/Kg
Gasoil	86$/ bbleq	10,200 Kcal/Kg	Bioethanol** **Brasil** – 200$/(hydrous)	39 $/bbleq	6,700 Kcal/Kg
Gasoline*	75 $/bbleq	10,500 Kcal/Kg	Bioethanol **EU** sugar beet – 500€/t =120 $/bbleq **EU** sweet sorghum – 250€/t = 60$/bbleq	60-120 $/bbleq	7,000 Kcal/Kg
Methanol (350 $/t)	88 $/bbleq	5,550 Kcal/Kg	Bio-Methanol 340 $/t (with CO2 credit 40€/t)	83 $/bbleq	5,500 Kcal/Kg
Hydrogen (prod. Cost)	100 $/bbleq	30,000 Kcal/Kg	Bio-Hydrogen (~1,900 $/t with CO2 credit) (~ 2,280 $/t without CO2 credit)	86-102 $/bbleq	30,000 Kcal/Kg

Conversion Technologies

Biological conversion

- Anaerobic digestion (biogas production)
- Sugar fermentetion (Bioethanol production)

Thermochemical conversion

- Carbonisation (η_e ~ 52%)
- Pyrolysis (η_e ~ 70%)
- Gassification (η_e ~ 70%)

Pre-treatment

Stabilisation of umid biomass is of great strategic importance for future large-scale exploitation of this renewable resource. A promising technology is now appearing on the market. Several new machines should be developed.

Gasification of biomass

Gasification is an endothermic reaction between Carbon and steam or CO2:

- $C + H_2O \rightarrow$ CO + H2
- $C + CO_2 \rightarrow 2CO$

CO + H2 →

2:1	2:1	3:1	1:1	
Methanol	Fischer-Tropsch	Methane	Oxo synthesis	Ethylene
• Formaldehyde •Gasoline •Aromatics •Olefin	• Gasoline • Middle distillates • Waxes		• Aldehyde • Alcohols • Hydrocarbons	• Ethanol • Acetic Acid • Glycol Ether

Unfortunately synthesis-gas contains **tar** (mixture of hydrocarbon compounds) and traces of HCl,HF,NH3 and alkaline metals, their concentration depends on nature of biomass and type of reactor.

Up to now tar gas-cleaning cannot be considered a solved problem !

Gasification of biomass

Following a world-wide survey on gasification of biomass, today there are (R.E. journal):

329 Gasification centers in operation o under implementation

- **163** Operative gasifier units — **60,000** MWth Installed capacity
- **33** New serious projects — **18,000** MWth New additional capacity

Gasification of biomass

- **<u>Traditional Gasification</u>** (atmospheric gasification)

  - Fixed bed Downdraft
    (few kWth-1MWth)

  - Fixed bed Updraft
    (1 MWth-10 MWth)

Most of these gasifiers are at present used for heat production. Few are adapted for power generation even if only one technology (Martezo-France) can be considered commercially interestinting because of is offered with resonable time-life garantee (operation > 10 years) and efficiency ($\eta e \sim 18\%$).

Gasification of biomass

- **Advanced gasification**

  (pressurized and oxygen gasification)

  - Dense fluidised bed
    (1 MWth-50 MWth)
  - Circulating fluidised bed
    (10 MWth-200 MWth)
  - Entrained fluid. bed under pressure
    (100 Wth-500 MWth)

The minimum size required for pressurized gasification systems (for economic reasons) is estimated near to 50 Mwe.

Enviromental Benefits

- Optimised bioenergy closed schemes (biomass production, conversion and utilisation) present energy ratio: (outputs / inputs) ~ 2 or more. Therefore they are neutral from the CO_2 emission into atmosphere and can greately benefit from CO_2-trading
- Biomass resources contain very low amounts of sulfur so SO_2 emissions during cmbustion are very limited
- Particulate and other regulamented emissions i.e Nox, VOC, can be contolled by existing commercial technologies
- Biofuels are of geat interest for all energy markets but in particular for the transport sector and able to decrease the negative enviromental impact of congested urban areas

Conclusion and Recomandation I

- The biomass resources have a considerable potential in a long term

- Biomass is able to penetrate all energy markets: heat/cooling, power generation, transport.

- Bioethanol is the most promising short term biofuel also in term of economic perspectives

- Commercial Bio-hydrogen production from low quality biomass could be carried out now with existing technologies at a competitive cost (~ 2.000 €/ tH2) in comparison to H2 from natural gas price 10 $ / BMBtu) . Bio-H2 could benefit in future of CO_2-credit of **~ 400 €/t.** assuming 40€/ tco2).

Conclusion and Recomandation II

- For future large-scale, exploitation of biomass, integration of bioenergy schemes with coal power plants; large Bioethanol plants; petrochemical complexes and gas-pipeline infrastuctures seems of great interest

- Considerable R&D demonstration program is still needed, i.e.:

  - Identification and development of energy crops
  - Stabilisation of umid biomass resources
  - Conversion process and technologies for biofuels production
  - Advanced power generators also at small capacity (10-500 kWe)
  - Potential wide range of biomass derived industrial commodities

Thank you for your attention

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