LAMNET Workshop

Biomass Opportunities in Venezuela

Modern Bio-energy Schemes for Industrial Developing Countries

European Biomass Industry Association

Dott. Giuliano Grassi

EUBIA Secretary General
eubia@eubia.org
www.eubia.org

Presentation outline

1. Introduction
2. Biomass: definition, resources and utilisation
3. Technology overview and case studies:
   - Solid biofuels
   - Sweet sorghum integrated scheme
   - Small scale ethanol and power production: Haiti / Santo Domingo example
   - ECHI-T: large bio-ethanol project from Sweet Sorghum in China and Italy
   - Technologies for CHP from biomass resources
   - Large CC ethanol fuel power plant
   - Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum
   - Integration of Bioenergy with Petrochemical Complex

A biomass-for-energy definition

- Organic material derived from forestry & agricultural operations, including :
- forestry residues,
- dry agricultural residues (e.g. straw),
- energy crops (e.g. sweet sorghum, miscanthus or short rotation coppice),
- wet or semi-dry agricultural residues (e.g. animal slurries or chicken litter)
- uncontaminated wood processing residues.

Main bioenergy drivers

- **Renewable source of energy**
- **Depletion of fossil fuel resources**
  (~ 50% of recoverable petroleum already consumed)
- **Decrease energy dependency**
- **Favour regional development**
  (rural, stable employment opportunities)
- Biomass resources are **abundant and available** almost anywhere (water constraints however)
- Environment friendly and **CO_2 neutral**

Biomass resources

Worldwide biomass resources

- Worldwide biomass stock: ~ 370 B TOE/a

- World biomass production:
  - Terrestrial: ~ 80 B TOE/a
  - Acquatic: ~ 20 B TOE/a

- Estimation of biomass residues potential (2100):
  - min: ~ 2.1 B TOE/a
  - med: ~ 6.6 B TOE/a
  - max: ~ 28.3 B TOE/a

- Total Energy consumption (2000): ~ 9.9 B TOE/a

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

Biomass resources

European biomass resources

• Current consumption (EU-15; 2001):
- Primary energy: ~ 1486 M TOE/a
- Biomass: ~ 57 M TOE/a *(3.8%)*

• EU guideline regarding biomass use:
- for 2010 ~ 135 M TOE/a
- for 2020 ~ 200 M TOE/a

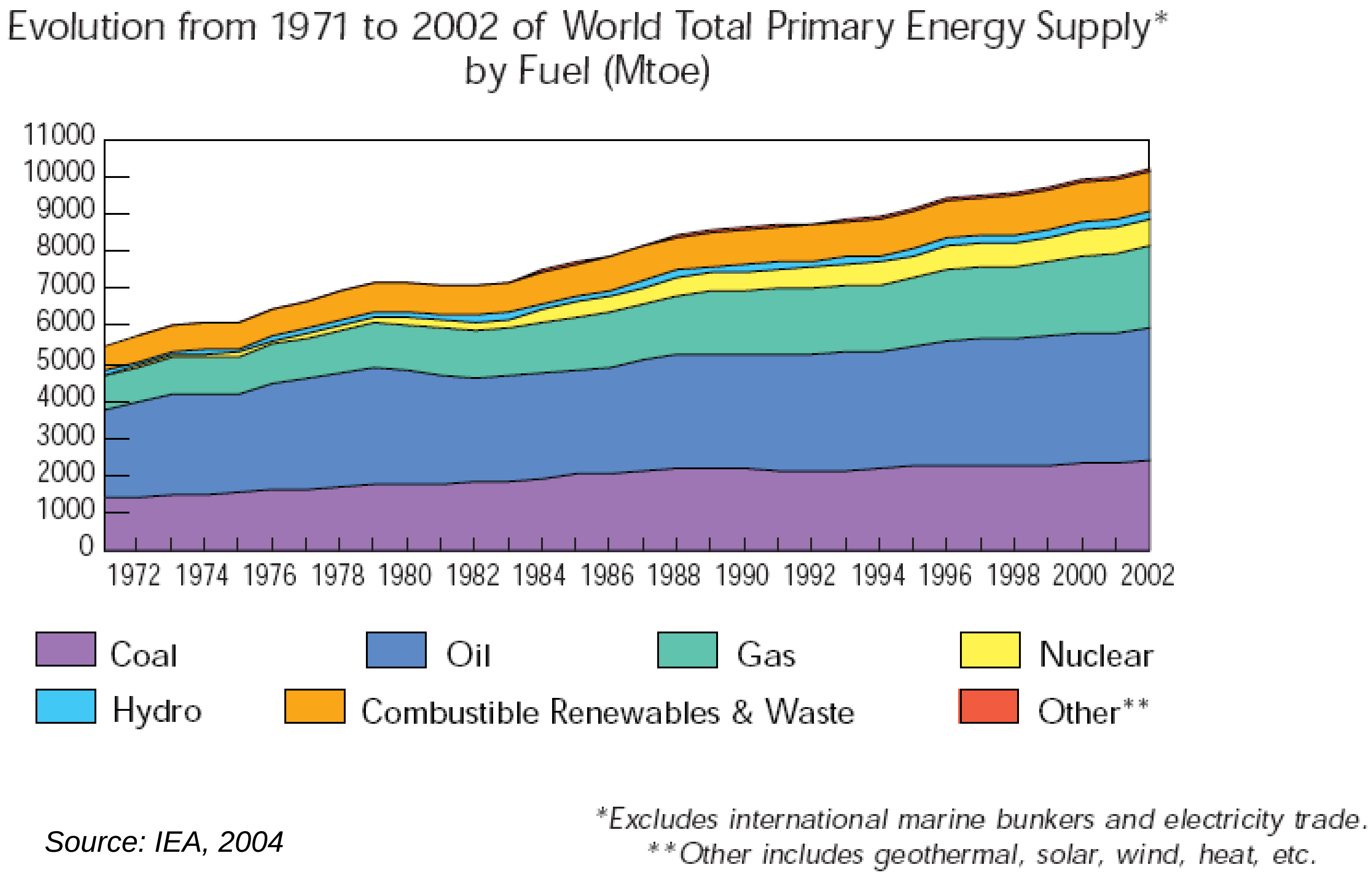
• Biomass potential (2050)
- UE-15 ~ 500 M TOE/a
- UE-25 ~ 600 M TOE/a

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

Estimated time duration of resources

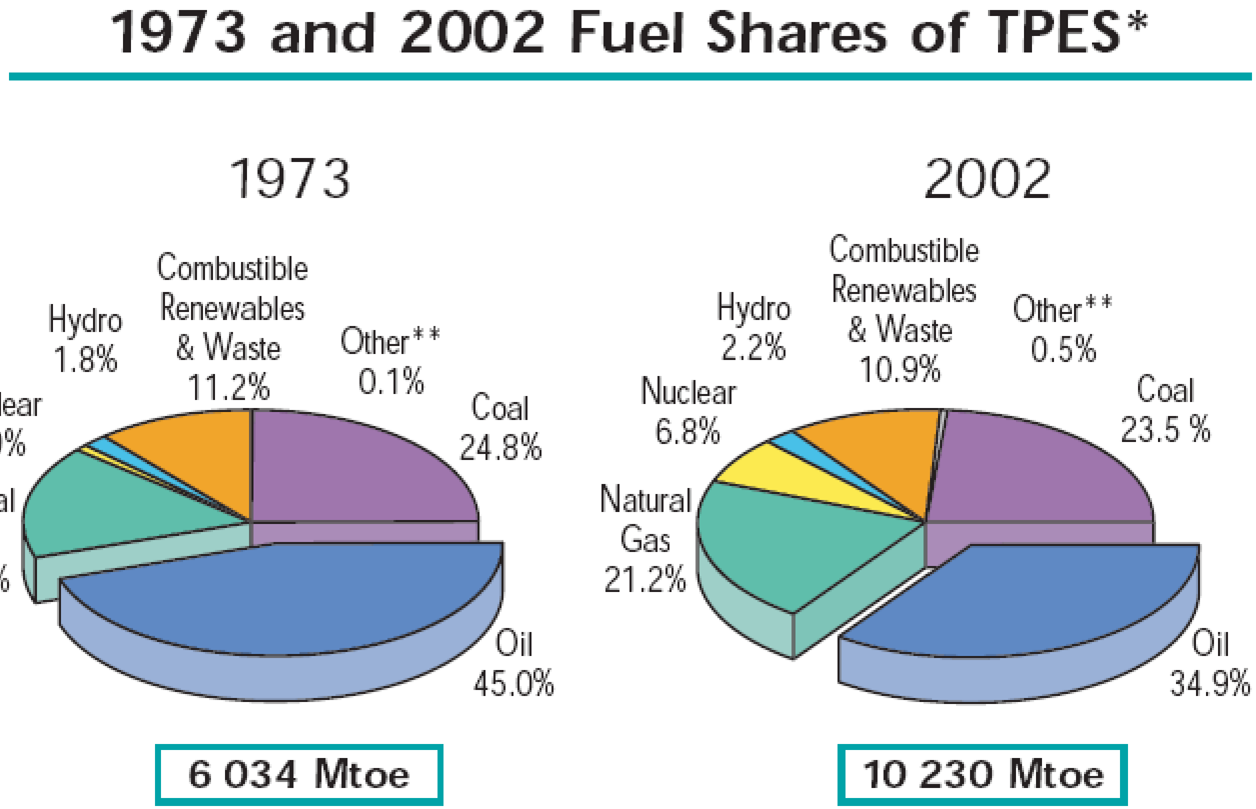
Fossil energy • Oil • Coal • Gas	 40 years 180 years 50 years
Fission energy	27 000 years
Fast breeder (efficiency=60%)	110 000 000 years
Fusion energy • Lithium (cycle D-T; efficiency=30%) • Deuterium (cycle D-T; efficiency=30%)	 2 000 000 years 2 500 000 years
Renewable energies: Biomass, hydro, wind, solar, geothermal…	 Non exaustable

Worldwide bioenergy use



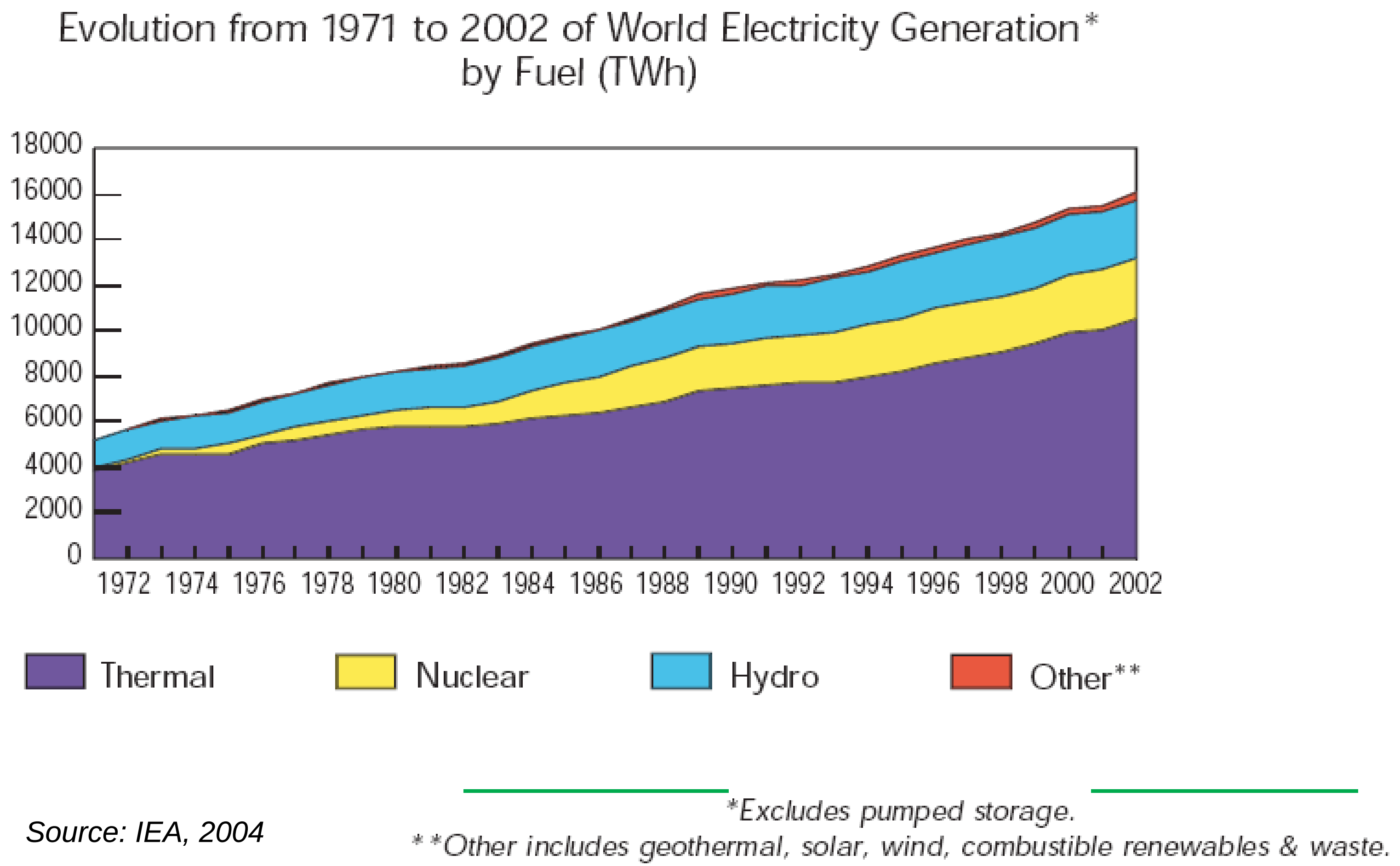
Source: IEA, 2004

Worldwide bioenergy use



Source: IEA, 2004

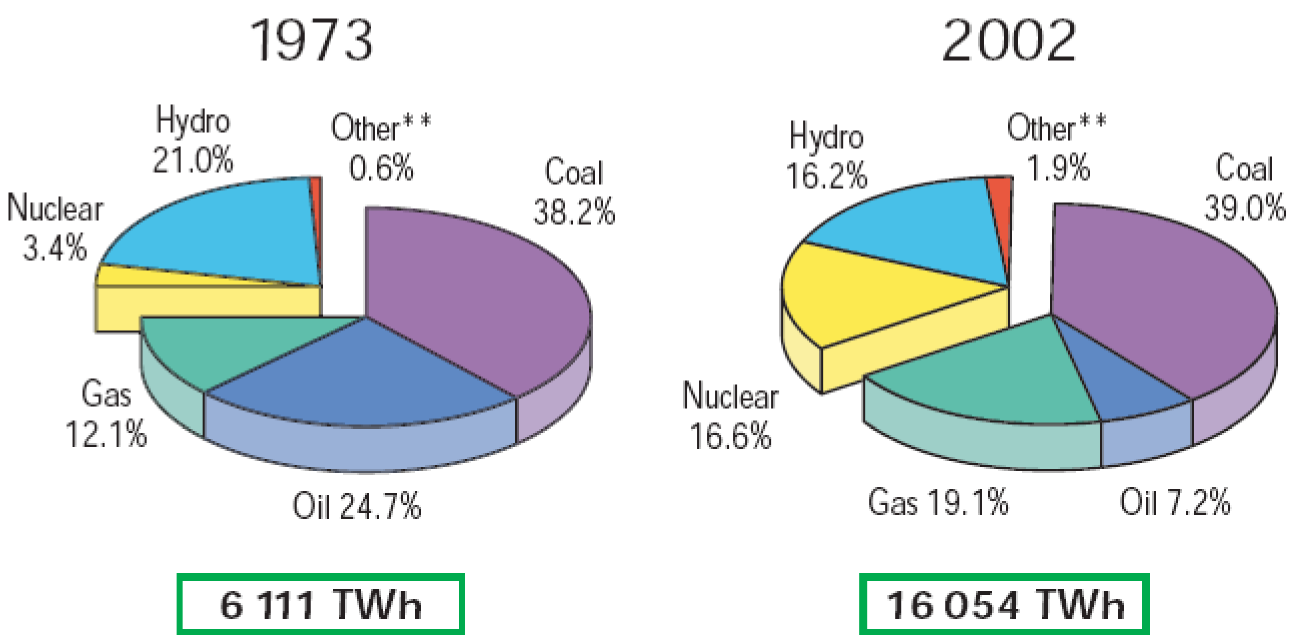
Electricity Generation by fuel



Source: IEA, 2004

Electricity Generation by fuel

1973 and 2002 Fuel Shares of Electricity Generation*

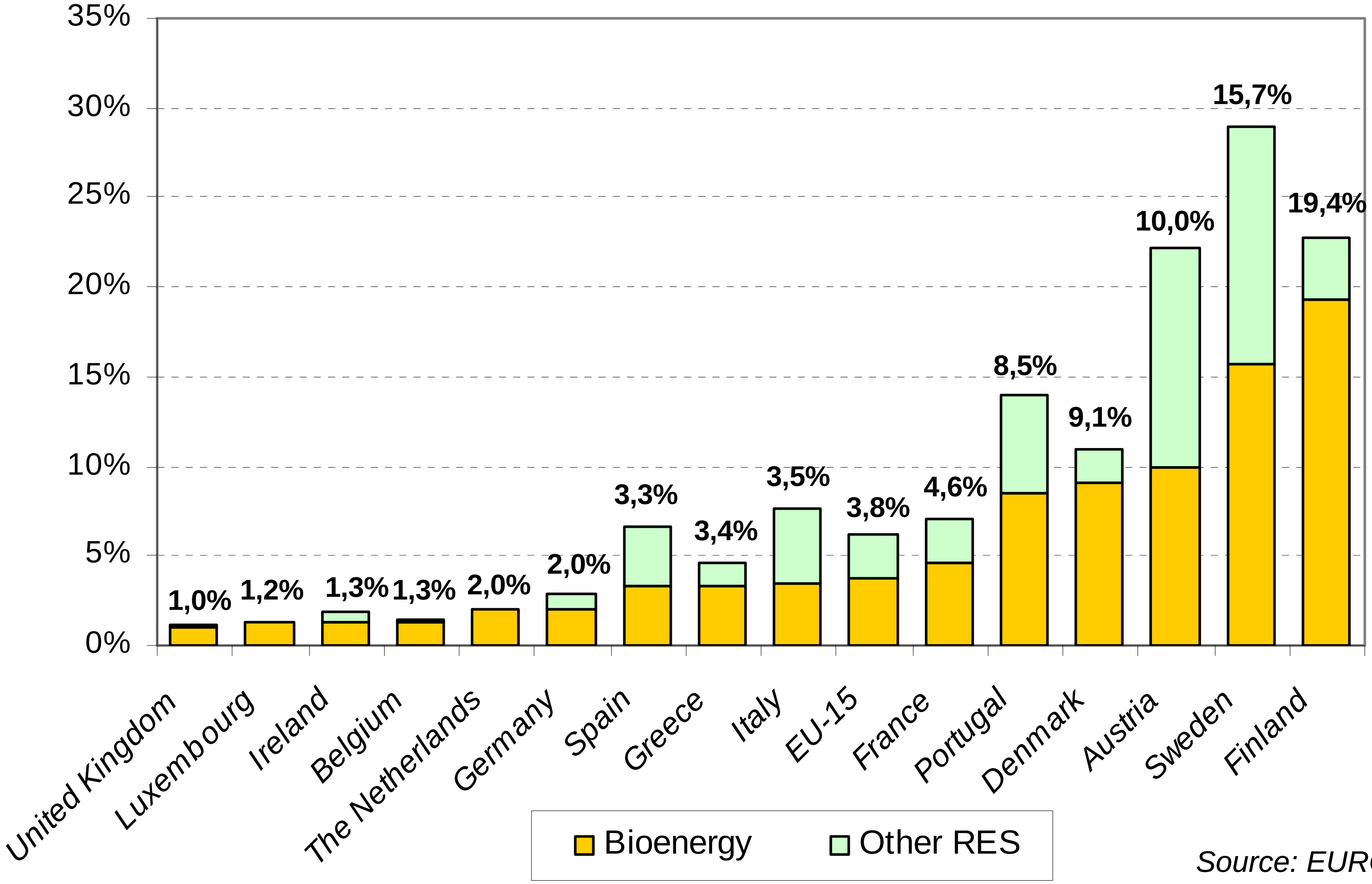


Source: IEA, 2004

**Excludes pumped storage.*
***Other includes geothermal, solar, wind, combustible renewables & waste.*

European bioenergy use

RES and bioenergy shares on total Gross Inland Consumption
(EU-15 ; indicated percentages relate to bioenergy only)



Source: EUROSTAT, 2001

Biomass potential contribution by 2020 (MTOE/y)

Market	2020
Heat	100
Power	57
Transport	
• Vegetable oil (4 mio ha)	5
• Bioethanol (5 mio ha)	15
• Biomethanol (1.2 mio ha)	10
• Biohydrogen / Biosyngas (10 mio ha)	30
TOTAL	217

Bioenergy *vs.* other RE

Advantages

- Sufficient competitiveness of biomass as energy resource in comparison with hydrocarbon
- High potentiality (large areas of crop-land - marginal land - semiarid land)
- Possibility to penetrate all energy market (heat - power - transport - chemicals)
- Possibility of bioenergy systems at very small scale (few KW) - or very large scale (hundred of MW)
- Significant environmental benefits (CO_2 neutrality)
- positive effects on employment in rural areas for the biomass resource production

Disadvantages

- Need of supplying expensive energy feedstock
- Optimisation of bioenergy activity requires very deep knowledge of wide sectoral competence
- Need to adopt horizontal and vertical integration of sub-systems to improve the economic basis of bioenergy complexes
- Water, soil, climatic, environmental constraints limiting the biomass productivity and the type of plants

Basic steps for integrated bio-energy systems planning

1. Resources	**2. Pre-treatment**	**3. Conversion**	**4. Utilisation**
dedicated crop production & waste recovery	Harvesting, storage, transport, recovery	Biochemical or thermochemical	Heat, power, CHP, transport fuels

Biomass productivity present and future in the EU

	Present productivity odt/ha/y	Future productivity odt/ha/y	European regions concerned
Agricultural crops			
• Sweet sorghum	25	35	South
• Miscanthus and similar crops	20	30	South
• Jerusalem artichoke	20	25	South
• Jerusalem artichoke (tubers)	10	14	South
Trees			
• Eucalyptus	10-15	17	South
• Poplar	12	16	North - West
• Willow	10	15	South
• Black locust	5	8	North – West
• Conifers	5-6	8-10	North – West
Aquatic	10-15	20-30	South
Algae	40-60	85-90	North & south

Source: EC, 1992

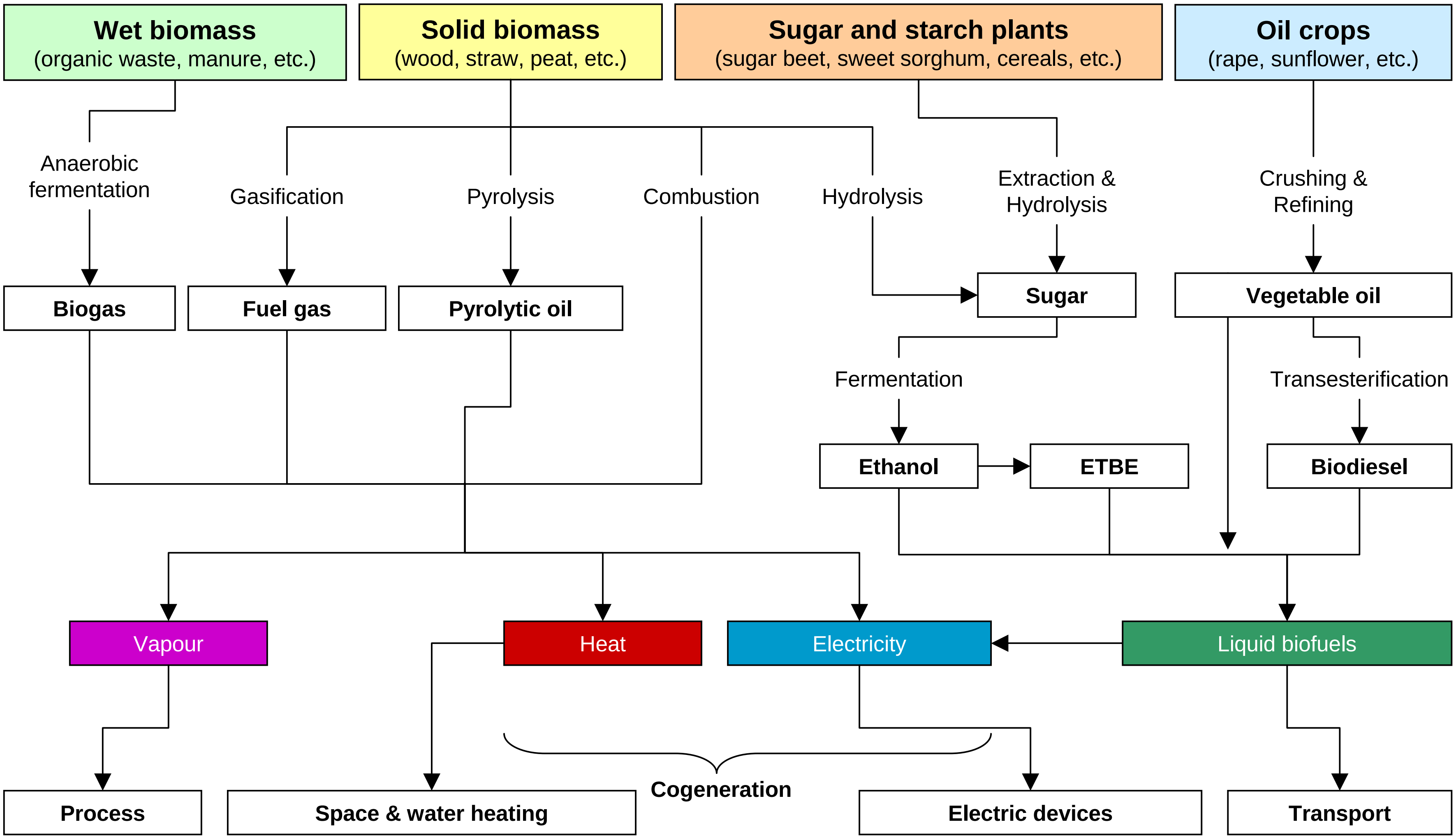
Biomass production costs in the EU

	SRF euros / dry ton		C4 crops euros / dry ton	
	1992	Future*	1992	Future*
Biomass	10	7	42	30
Harvesting	20	15	5	4
Storage	5	4	-	-
Transport	5	4	18	12
TOTAL	40	30	65	46

Future: when commercial production started*

Source: EC, 1992

Main bioenergy routes



Bioenergy : a wide and complex sector

Biomass Production

- Fertiliser distributing machines
- Seeding machines
- Planting Machines
- Harvesting machines
- Transport
- Drying Machines
- Chipping
- Transporter Feeding Machines
- Storage
- Pelletisation & briquetting techn.
- Comminution Pulverising machines
- Cane crushing Machines
- Fluidised bed drying Machines
- Pelletisation Briquetting machines
- Sugar extraction machines + concentration

Conversion & Up-grading

- Biomass powered Combustors
- Fluidised–Bed Combustors boilers
- Anaerobic digestion (biogas)
- Atmospheric gasification
- Pressurised gasification
- Flash-pyrolysis
- Plasma-chemical conversion
- Bio-hydrogen technology
- Bio-gas purification
- Biomass derived gas purification
- Hydrogen purification
- Bio-crude-oil improvement
- BCO hydro treatment
- Hydrogen from BCO technology
- ETBE production technology
- Methanol synthesis
- Fast ferm. technology
- Charcoal technology

Utilisation

- Heating stoves
- Power prod. by gas turbines fuelled with biomass powder
- Power gen. by advanced steam-cycles or indirect GT cycles
- Power generation by turbines combined-cycles
- Power gen. by diesel fuelled with bio-crude-oil
- Use of bioethanol for cogeneration
- Use of bioethanol for gasoline reformulation
- Bioethanol cooking stoves
- Integration of bioenergy with petroleum refineries
- Bioethanol direct use in fuel-cell generators
- Stirling generators
- Emissions control technology
- Electronics tech. for system efficiency improv.
- Advanced electr. generators technology
- Improvement (efficiency & reliability) of end-use tech.: stoves, refrigerators, freezers, water purification, light, electric motor
- Sea-water desalination tech.
- Biogas cogeneration tech.

Solid bio-fuels (1)

Resources

- Lignocellulosics
- Starch
- Sugar

Pre treatment

- Chipping
- Pelleting
- Briquetting

Utilisation

- Stoves
- Boilers

↓

- Heat
- CHP

Solid bio-fuels (2)

Resources

Woodchips

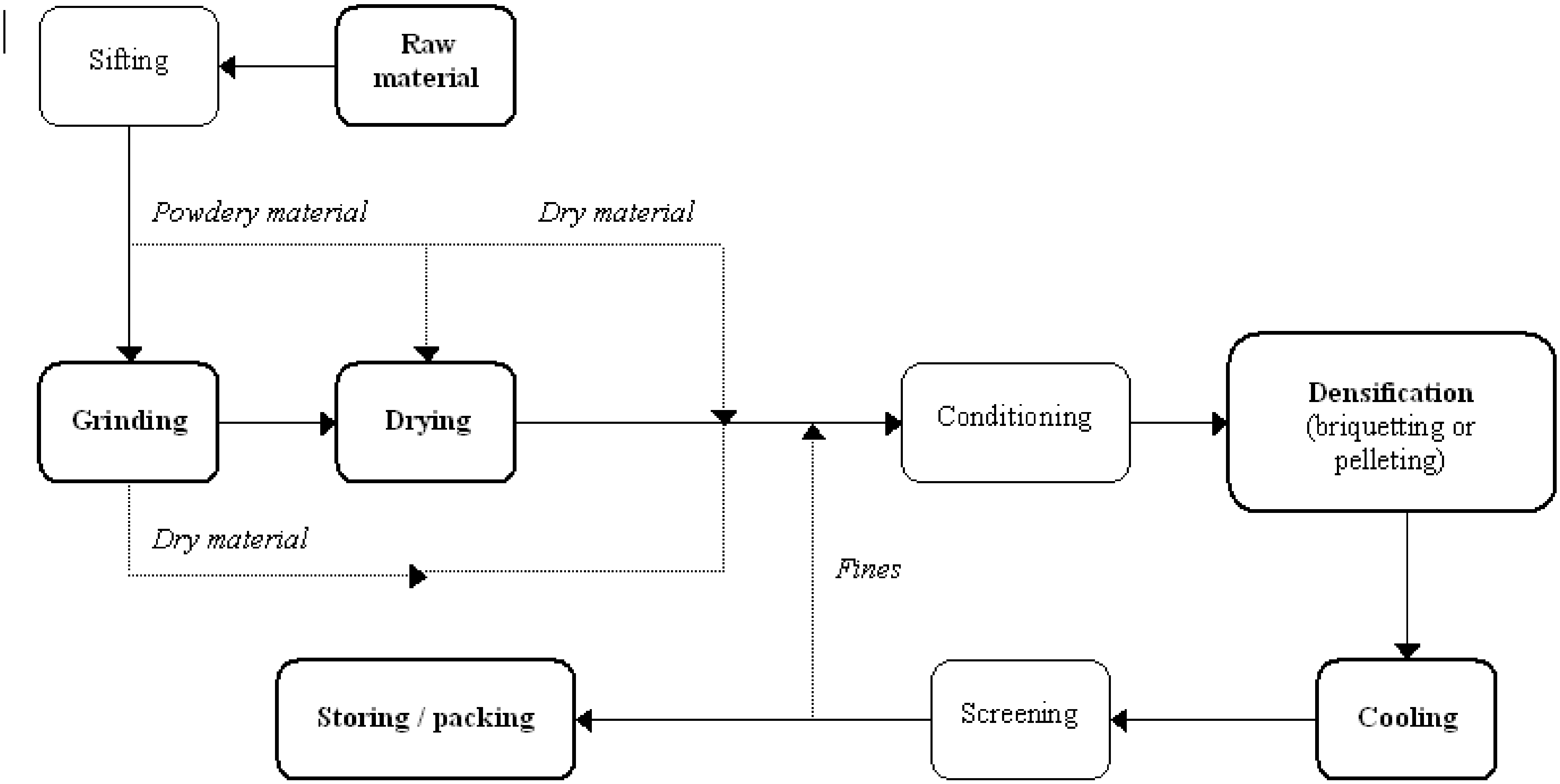
Sawdust

Straw

Others…

Solid bio-fuels (3)

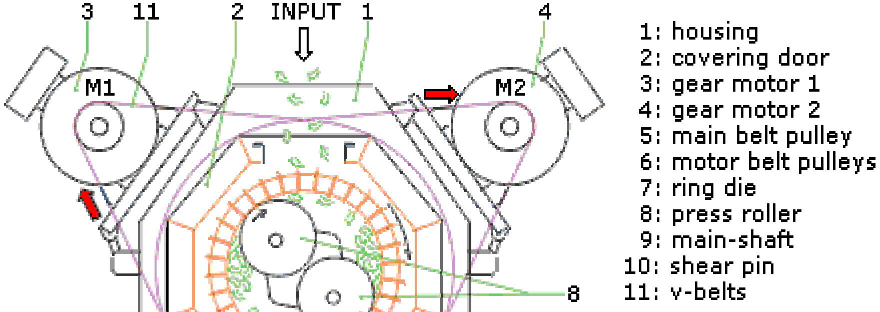
Basic steps of densification processes



Solid bio-fuels (4)

Pelleting equipment

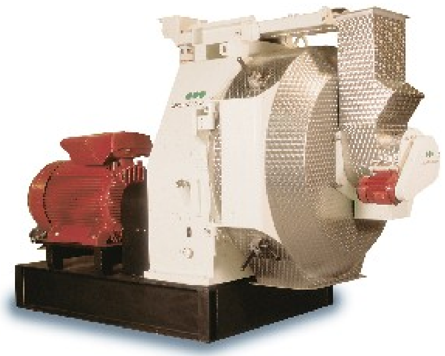
Flat die (left) and ring die (right)



Source: Amandus Kahl; Salmatec; Larus Impianti

Solid bio-fuels (5)

Pelleting equipment

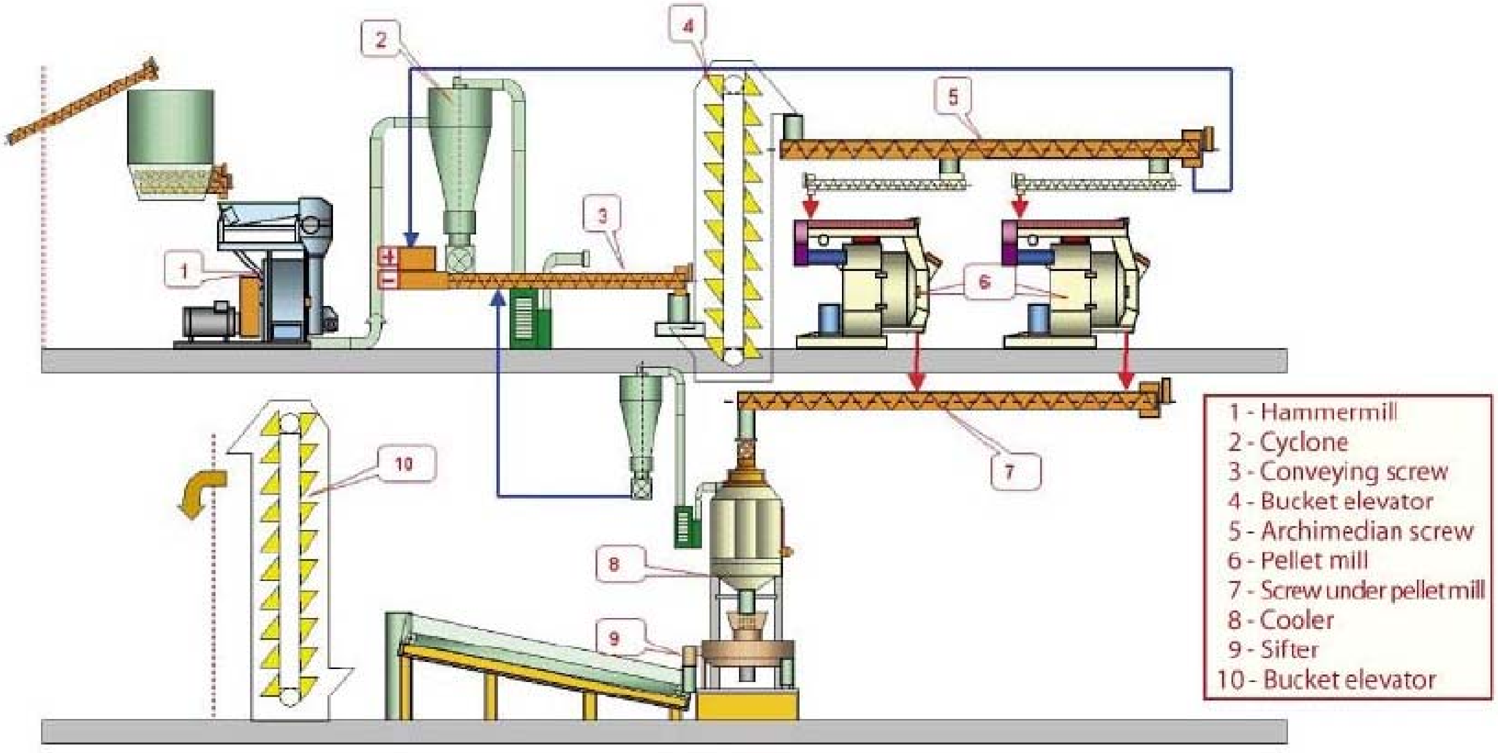


Pellet mill type PMV	Pellet mill type PM	Die press area		Max. Power	
Belt driven	**Gear based**	**cm2**	**In2**	**kW**	**HP**
PMV2		620	96	30	40
PMV515W		2555	396	110	150
	PM615W	3016	468	160	220
	PM615XW	3581	555	160	220
PMV717W		4178	648	200	275
PMV717XW		5498	852	200	275
	PM717W	4178	648	250	350
	PM717XW	5498	852	250	350
	PM30	4459	691	315	425
PMV919W		5432	842	560	800
PMV919XW		7147	1108	560	800
PMV919TW		8577	1329	560	800
	PM919W	5432	842	560	800
	PM919XW	7147	1108	560	800
	PM919TW	8577	1329	560	800
	PM1219W	11400	1767	560	800
	PM1219XW	14313	2290	560	800

Source: Sprout Matador

Solid bio-fuels (6)

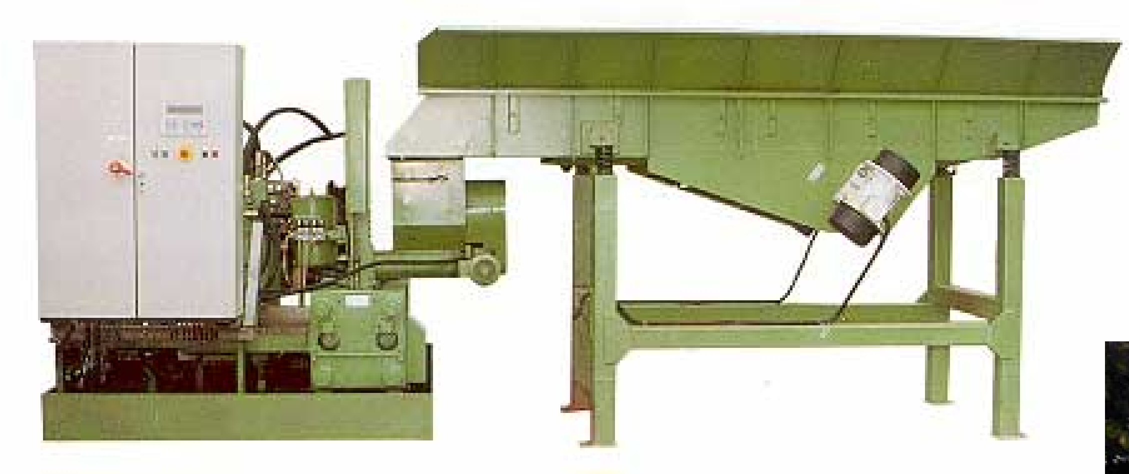
Pelleting plant scheme (10-12 t/h)



Source: Promill Stolz

Solid bio-fuels (7)

Briquetting equipment



Solid bio-fuels (8)

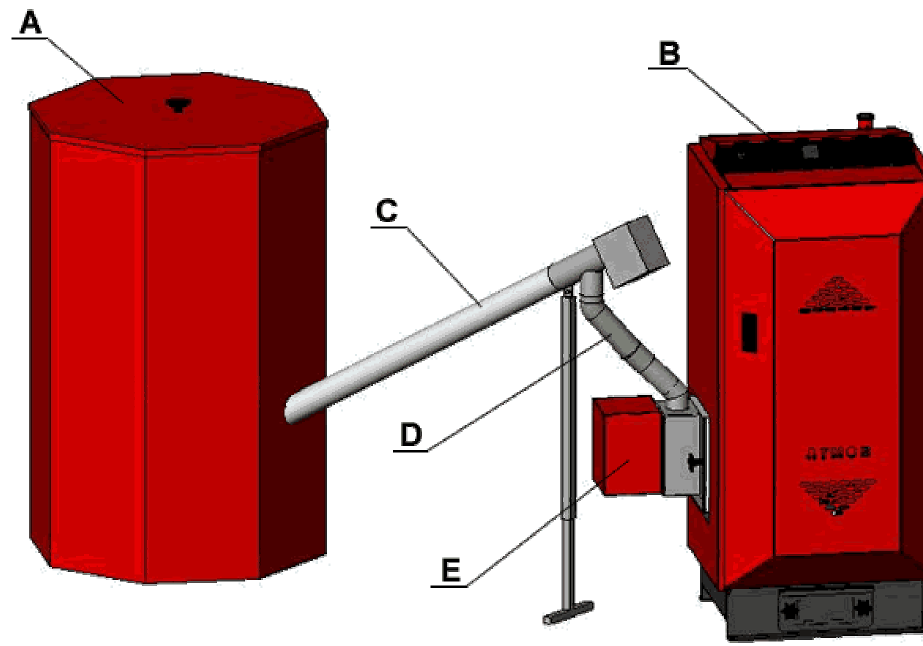
Comparison between briquettes and pellets

	Briquettes	Pellets
Appearance		
Raw material	Dry and grinded wood or agricultural residues. Raw material can be more coarse than for pelleting, due to the larger dimensions of final product	Dry and grinded wood or agricultural residues
Shape	Cylindrical (generally Ø 80 to 90 mm) or parallelepiped (150*70*60 mm)	Cylindrical (generally Ø 6 to 12 mm, with a length 4 to 5 times the Ø)
Structure	Relatively friable, fragile	Stable, hard, without dust
Bulk density	600 – 700 kg-m3	600 – 700 kg-m3
Aspect	Mostly "rough"	"Smooth"
Transport	Unit, palet	Bulk, bags, big bags
Handling	Manual use	Manual or automatic use

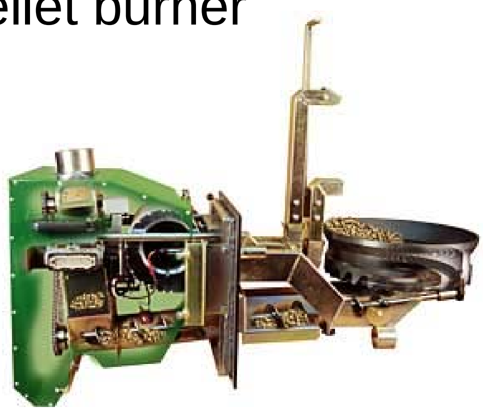
Heat production

Pellet stoves

Pellet boilers



Pellet burner

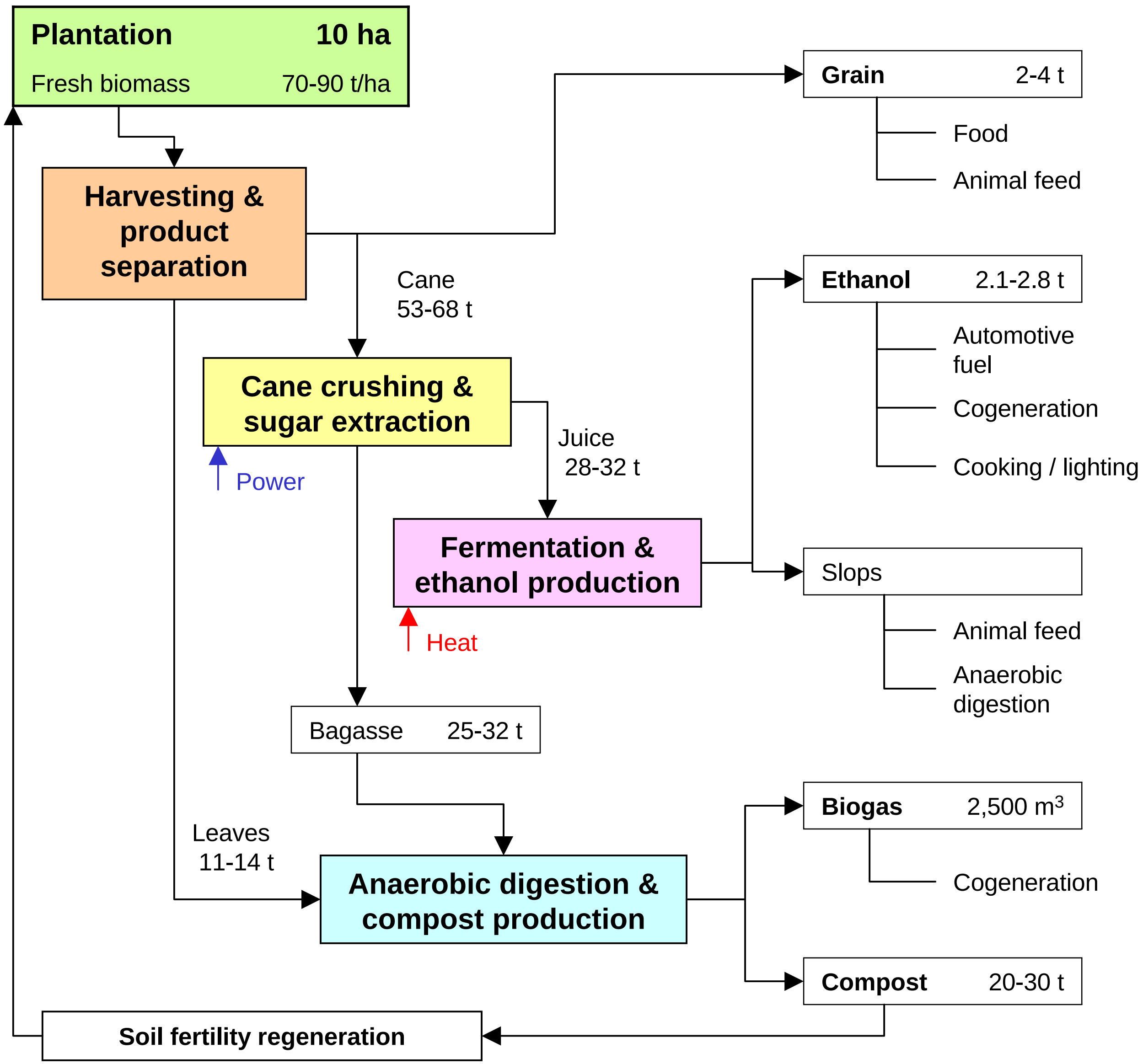


Improvement of the economics through integrated biomass processing

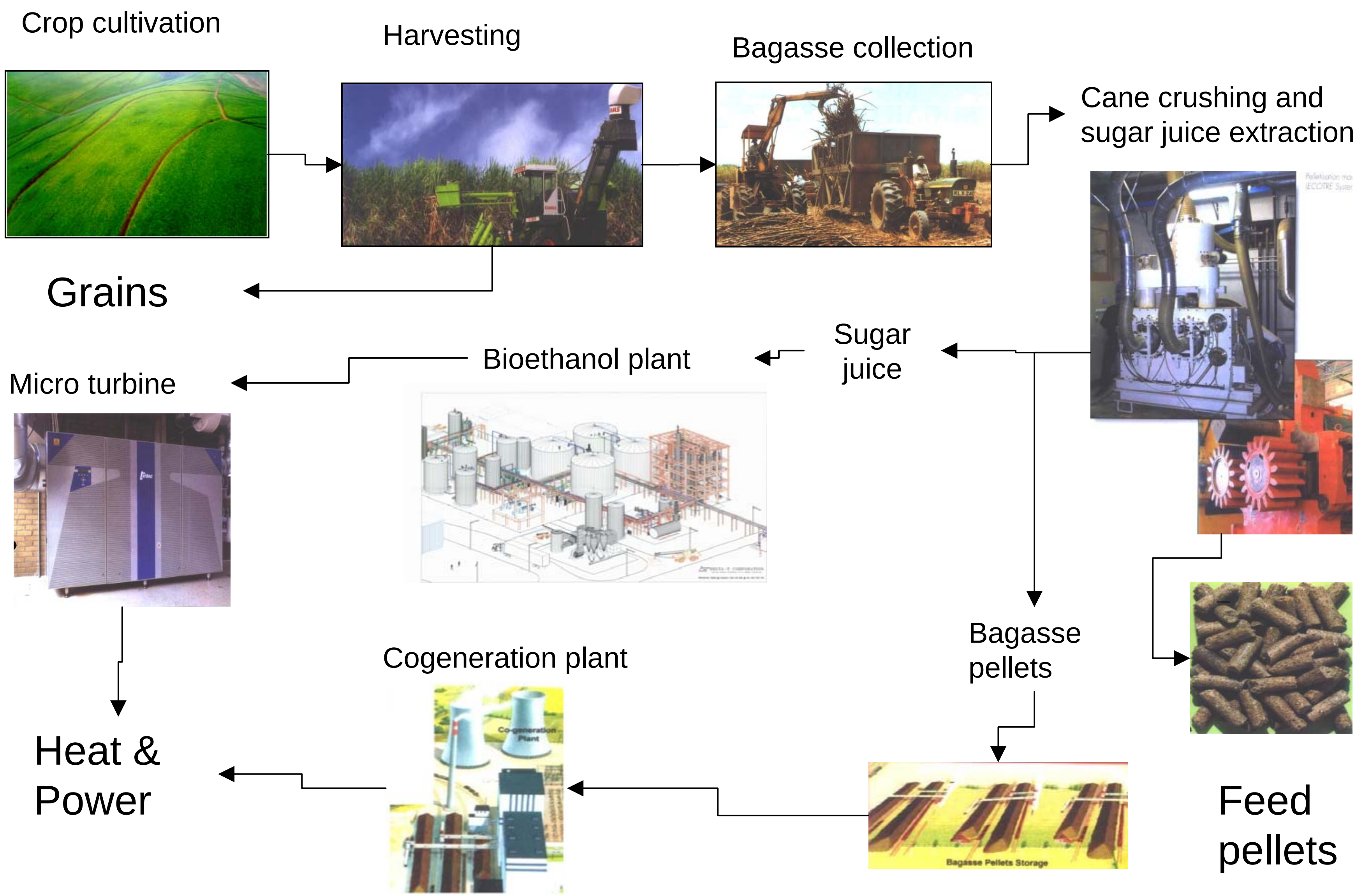
List of typical integrated projects:

1. Sweet sorghum integrated scheme
2. Small scale ethanol and power production:
   Haiti / Santo Domingo example
3. ECHI-T:
   - large bio-ethanol project from Sweet Sorghum in China and Italy
   - potential project in Romania under discussion
4. Technologies for CHP from biomass resources
5. Multi fuel fired CHP plant
6. Large CC ethanol-fuelled power plant
7. Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation
8. Large Scale Integration of Bioenergy with Petrochemical Complex

Sweet sorghum integrated scheme

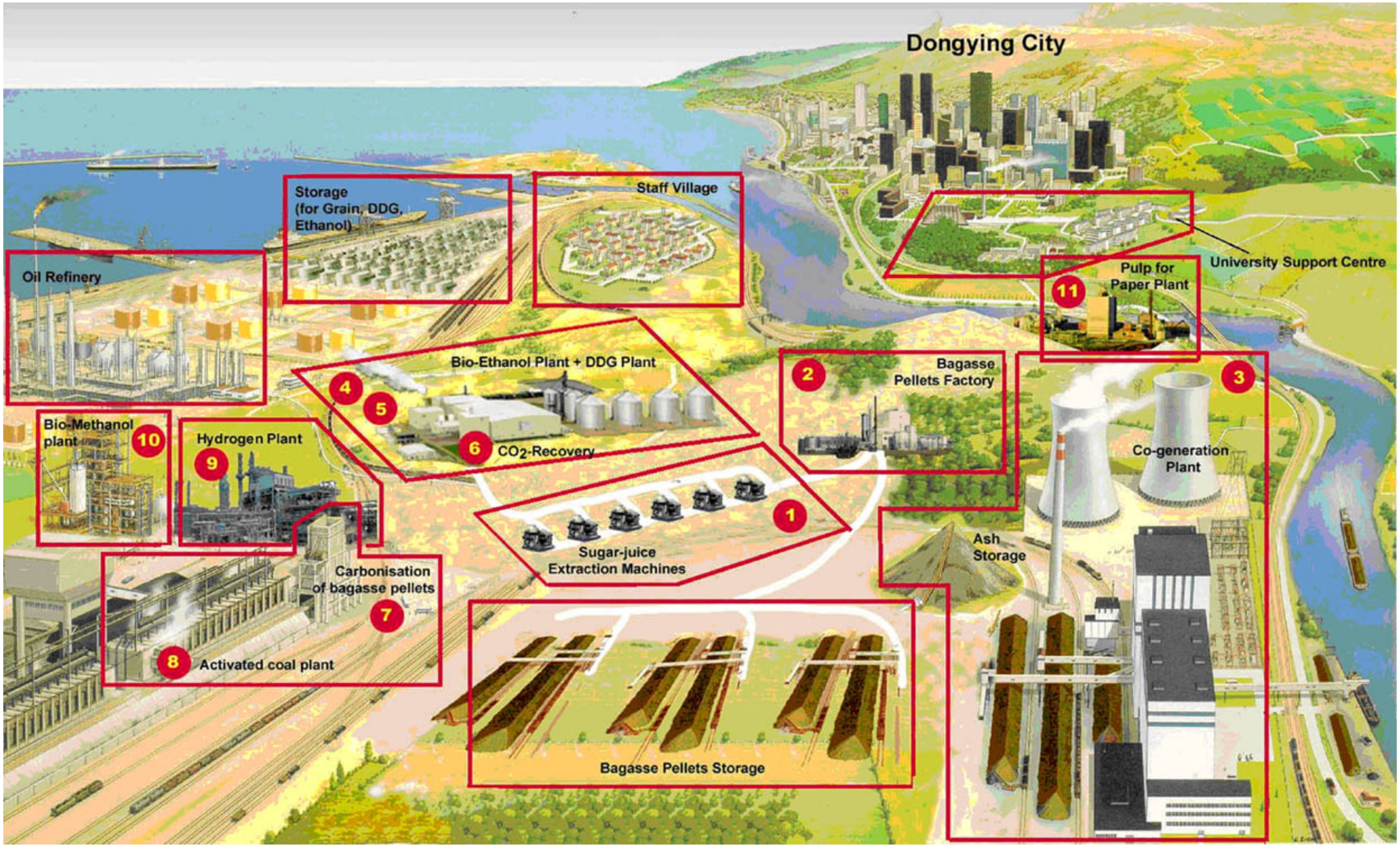


Sweet sorghum integrated complex – Haiti Santo / Domingo



ECHI-T (1)

Large bio-ethanol project from Sweet Sorghum in China and Italy



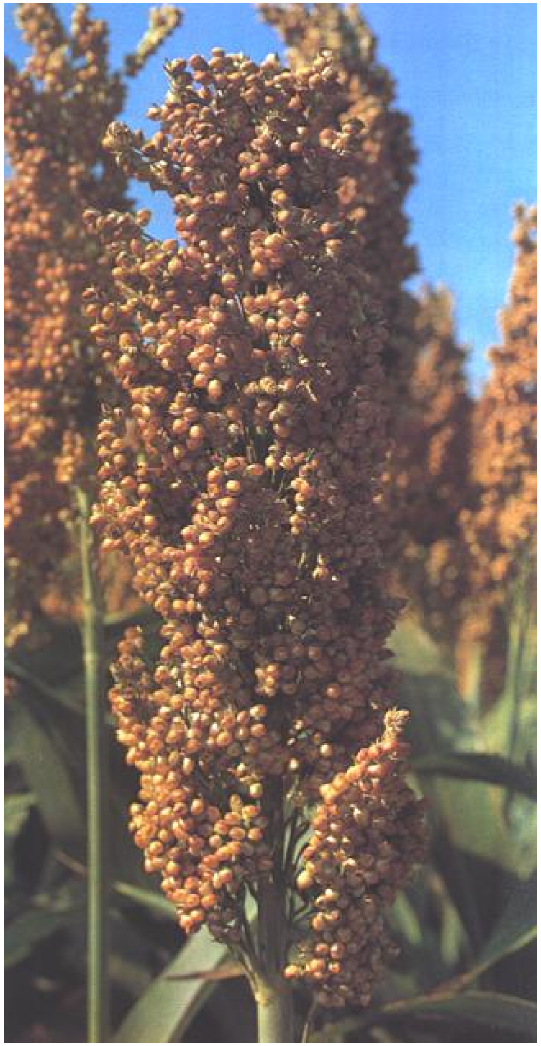
ECHI-T (2)

Why sweet sorghum (*sorghum bicolor*)?

- Annual C4 plant
- High photosynthetic efficiency (about 2-3%)
- Low fertilizer and pesticides requirements
- drought resistance, thus low irrigation requirements
- Suitable to different climatic and soil conditions (pH 5.0-8.5)
- Wide range of derived products
- High productivity (25 to 45 dry ton biomass / ha)

Average productivity:

• Grains:	5 ton/ha
• Bagasse (dry):	15 ton/ha
• Sugar:	7 ton /ha
• Leaves:	1.9 ton/ha
• Roots:	2.5 ton/ha



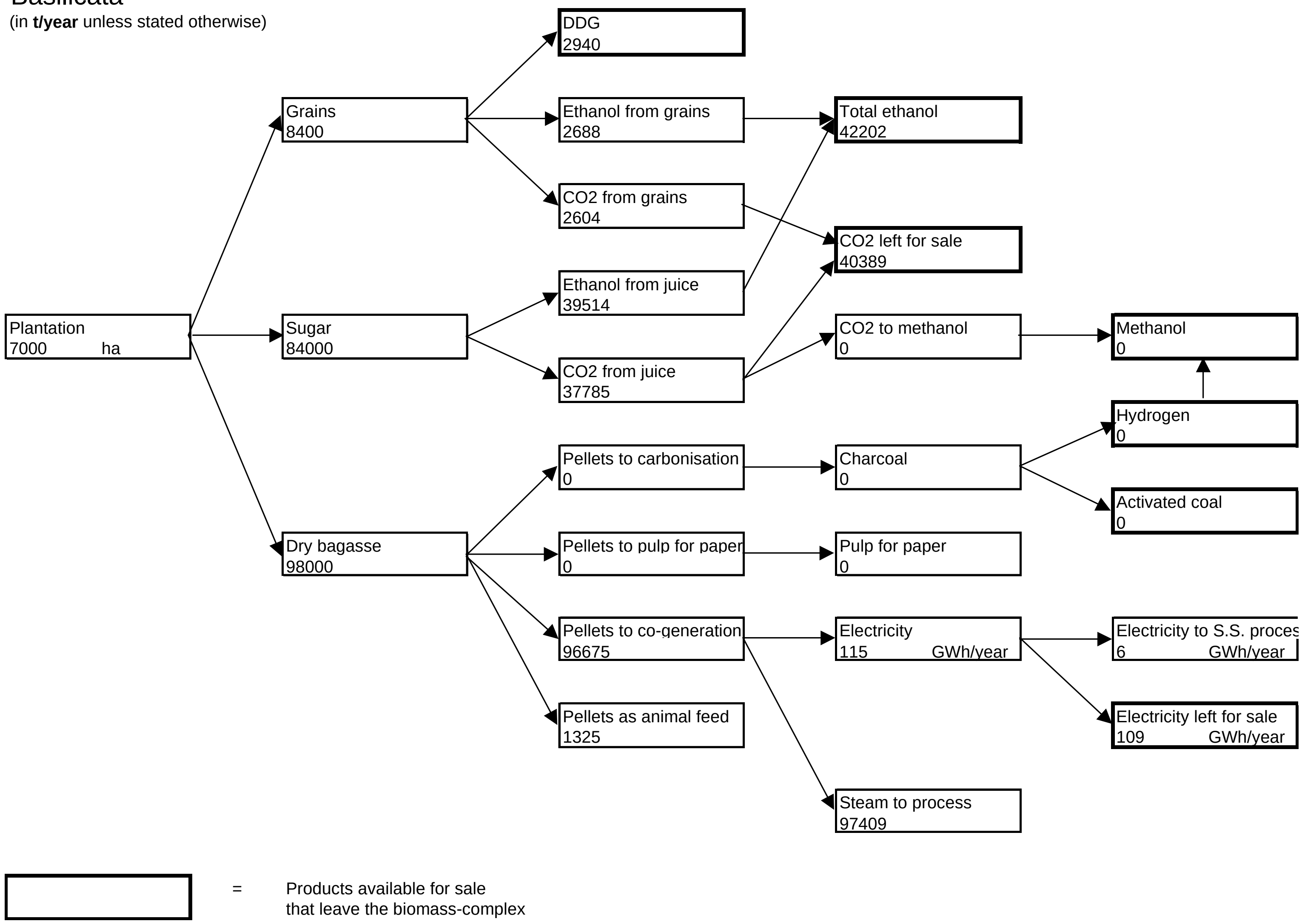
ECHI-T (3)

Project overview

- Sweet Sorghum variety selections, and evaluation of productivity
- Possible configuration (lay-out) and preliminary characteristics of the three complexes
- Available commercial technologies
- Prelim. main characteristics and dimensions
- Prelim. investment costs
- Logistics needed by the integrated complexes
- Costs associated to the Sweet Sorghum production
- Co-product values
- Techno-economic assessment in China and Italy

ECHI-T (4)

Schedule of quantities produced:
Basilicata
(in **t/year** unless stated otherwise)



ECHI-T (5)

Sweet sorghum cultivation periods

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Basilicata								■	■			
Dongying									■	■		
Huhot harvesting										■	■	
Huhot other	■	■								■	■	■

Sweet sorghum yields

Site	***Basilicata***	***Dongying***	***Huhot***
Variety	*Chinese 1, At623xRoma*	*M-81E*	*Tianpin 2*
Grain yield (t/ha)	*5*	*5.25*	*6*
Fresh stem yield (t/ha)	*70*	*75*	*60*
Sugar yield (t/ha)	*7*	*7.65*	*7.2*
Brix (%)	*16*	*17*	*20*
Bagasse yield (t dm/ha)	*17*	*15*	*10.2*
Size (ha)	*7,000*	*19,000*	*20,000*
Harvesting	*Aug., Sep., 2 months*	*Sep., Oct., 2 months*	*Oct., Nov., 2 months*

ECHI-T (6)

Products

Cultivated area and Feedstock				
	Basilicata	Dongying	Huhot (1x10)	Huhot (10 units)
Plantation (ha)	7,000	19,000	2,000	20,000
Grains (t/y)	8,400	99,750	12,000	120,000
Sugar (t/y)	84,000	145,350	14,400	144,000
Bagasse (t/y)	98,000	285,000	20,400	204,000
Product:	Basilicata	Dongying	Huhot (1x10)	Huhot (10 units)
Grains as animal feed				
DDG	2,940 t/y	34,913 t/y	4,200 t/y	42,000 t/y
Ethanol from sugar juice/grains	42,202 t/y	101,688 t/y	10,614 t/y	106,140 t/y
CO_2	40,389 t/y	97,638 t/y	10,197 t/y	101,970 t/y
Bagasse pellets as animal feed	1,325 t/y	101,056 t/y	11,548 t/y	115,480 t/y
Electricity	106 GWh/y *9.5 SS proc* *93 for sale*	176 GWh/y *90 refin* *35 SS proc* *73 for sale* *22 from grid*	- 3.5 GWh/y	- 35 GWh/y
Heat	Process *66-1 t/h*	Process *116-16 t/h*	Process *10-2 t/h*	Process -

ECHI-T (7)

Technologies

Technology	Supplier	Capacity per unit		Investment per unit (Euro)	
Harvesting	CLAAS Ventor		84 t/h		130,000
Extraction	Brazilian		50 t/h		135,600
Pelletisation	various		7 t/h (in) - 4 t/h (out)		672,000
Ethanol/DDG	Delta-T	Ethanol prod. from juice and grain – t/y		Basilicata:	96,383,800
		Basilicata:	42,202	Dongying:	137,663,000
		Dongying:	101,688	Huhot *(1x10)*:	30,855,500
		Huhot *(1x10)*:	10,614		
		DDG production – t/y			
		Basilicata:	2,940		
		Dongying:	34,913		
		Huhot *(1x10)*:	4,200		
		CO_2 prod. from juice and grain – t/y			
		Basilicata:	40,389		
		Dongying:	97,638		
		Huhot *(1x10)*:	10,197		
Co-generation	Siemens	Basilicata:	16.6 Mwel,	Basilicata:	30,000,000
		Dongying:	28.2 Mwel	Dongying:	50,000,000
		Huhot *(1x10)*: 10,614 10.26 steam flow t/h		Huhot *(1x10)*:	3-5,000,000

ECHI-T (8)

Conclusion

- The scheme is technically feasible and in some situtations also economically feasible (Romania project)
- In the future, bio-methanol production in parallel to ethanol should be a recommended target (0.7 kg biomethanol / 1 kg bioethanol) to delay the CO2 emissions to the atmosphere
- Integration with other crops to extend bioethanol production time, to reduce investments and to increase the availability of bio-pellets
- Integrated juice extraction and pelletisation would be an advantage (under investigation now)
- Hydrogen massive production from biomass can be commercially implemented from now utilising less efficient technologies but economically approaching the marginal cost of hydrogen production from natural gas (@ 7$/MMBTU)

Technologies for CHP from biomass resources (1)

Demonstration technologies:
those based on advanced gasification/turbines, flash pyrolysis plants, Diesel, which still present some risks but could become commercial in a near future.

Commercial technologies:
already well established, offering garantee of high performances and good efficiency, time-life, reliability, and noxious emissions control.

Commercial technologies can be further divided in three categories:

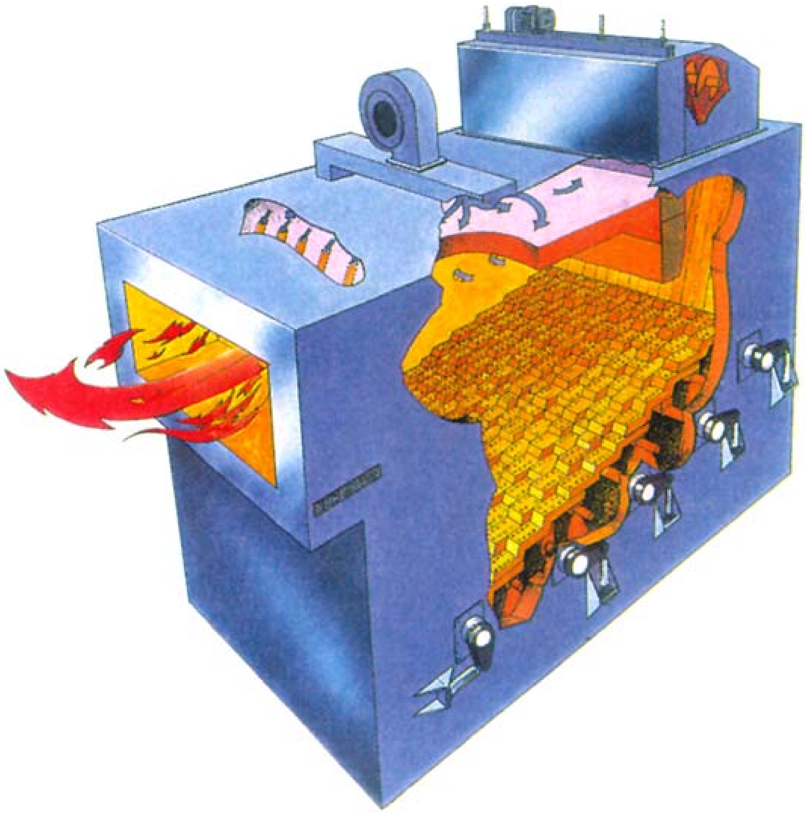
1. small capacity cogeneration plants. Examples:
   Energidalen-Energiproject AB / Sweden (500 kWe, 2000 kWth)
   Martezo down-draft gasifier (100 - 400 kWe, 200 - 800 kWth)

2. medium capacity cogeneration plants (ranging from 5 to 20 Mwe)

3. large capacity cogeneration plants (more than 20 Mwe)

Technologies for CHP from biomass resources (2)

Combustion chamber with movable grid system

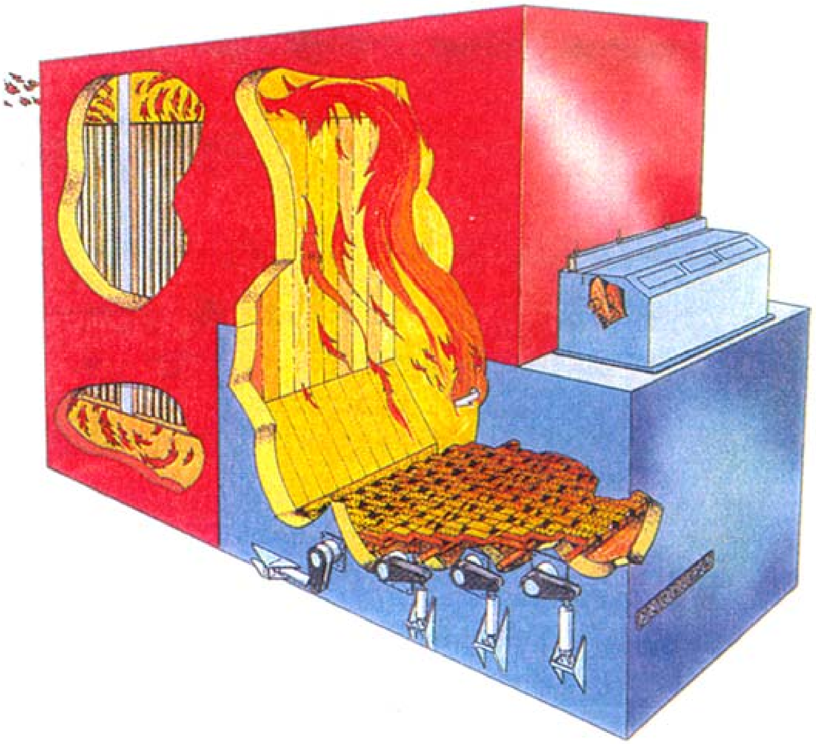


Combustion chamber type TRF with movable grid system.

It can be fueled with peat, chips, forest residue, bark and sawdust with a moisture content of 35-60 %

Technologies for CHP from biomass resources (3)

Combustion chamber with movable grid and “sprider stokers” feeding system



Combustion chamber type TRT with movable grid system and sprinder-stockers injectors. It can be fueled with pellets, briquettes, peat, chips with a moisture content up to 35 %.

For a unit of 6 Mwe the typical plant characteristics are:

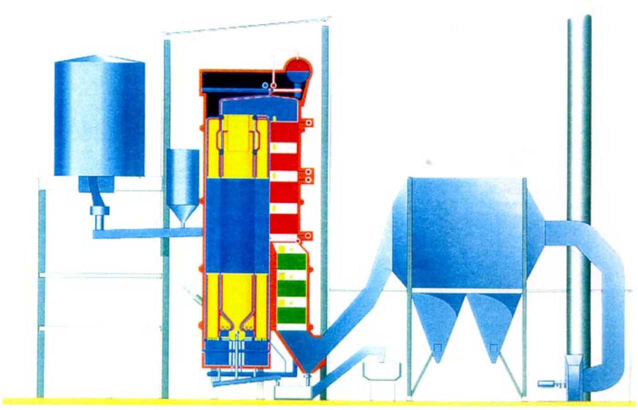
Inlet conditions	40 bar - 480 °C
Net Power	5500 kWe
Power for auxiliaries	500 kWe
Steam mass flow	28 t/h
Inlet heat power	26 MW
Electrical efficiency	21%
Specific investment	1350 $
No_x Emission	< 150 - 200 mg/Nm^3

Technologies for CHP from biomass resources (4)

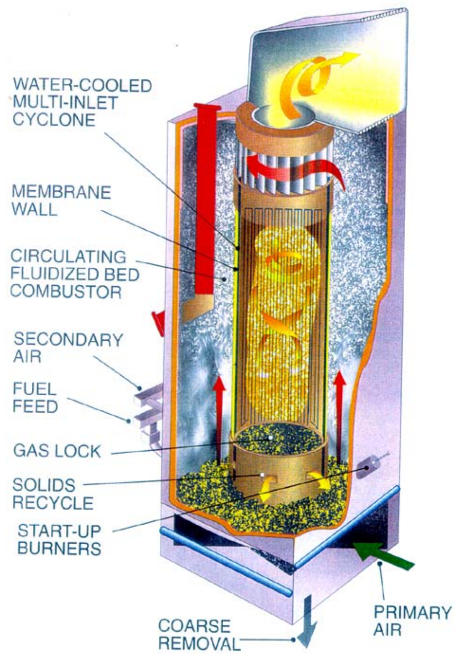
Fluidised bed combustion chamber

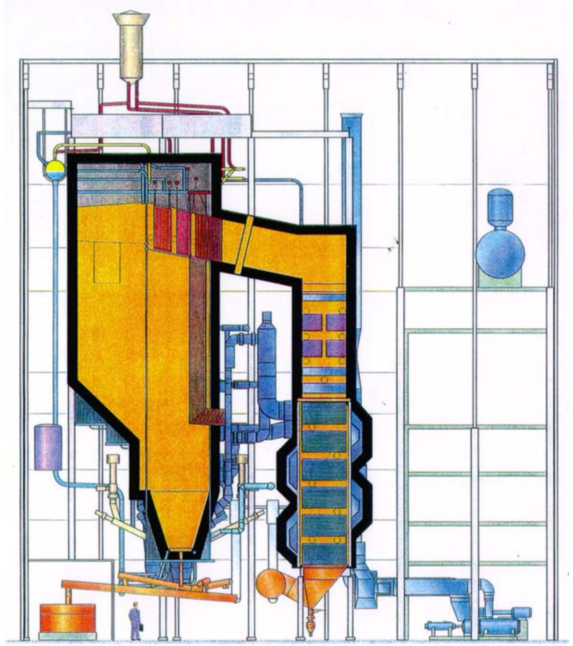
Modern technology and now largely utilised for capacity over 7 MWe and presents 2 main configurations:

1. FBC boiling technology for less demanding and lower capacity



2. FBC re-circulating technology for larger capacity plants





Technologies for CHP from biomass resources (5)

Biomass fluidised bed combustion cogeneration plant (10 MWe)

Example 1:

Cogeneration power plants		
Name	Lomma Energi AB, Sweden	
Power output max	4.3 MW_e	
District heat output max	11.4 MW_{th}	
Design data		
Thermal output	16.2 MW_{th}	
Steam flow	5.6 kg/s	
Steam pressure	61 bar	
Steam temperature	510 °C	
Fuels		
	Paper waste (100% MCR)	Wood waste (100% MCR)
Sulphur	0.02 %	0 %
Ash	< 10 %	2 %
Moisture	10 %	30 %
Lower heating value	19.0 MJ/kg	12.6 MJ/kg
Emissions guarantees		
	Paper waste	Wood waste
NO_x	50 mg/MJ	80 mg/MJ
SO_2	50 mg/MJ	50 mg/MJ
CO	90 mg/MJ	90 mg/MJ
N_2O	35 mg/MJ	35 mg/MJ

Technologies for CHP from biomass resources (6)

Biomass fluidised bed combustion cogeneration plant (10 MWe)

Example 2:

Cogeneration power plants		
Name	Skellefteå Kraft AB, Sweden	
Power output max	32 MW_e	
District heat output max	58 MW_{th}	
Design data		
Thermal output	91 MW_{th}	
Steam flow	37 kg/s	
Steam pressure	141 bar	
Steam temperature	540 °C	
Fuels		
	Wood (100% MCR)	Peat (100% MCR)
Sulphur	0.01 %	0.1 %
Ash	1.3 %	2.5 %
Moisture	50 %	50 %
Lower heating value	8.3 MJ/kg	8.9 MJ/kg
Emissions guarantees		
	Wood	
NO_x	50 mg/MJ	
CO	90 mg/MJ	
N_2O	20 mg/MJ	

Technologies for CHP from biomass resources (7)

Investments

Typical biomass cogeneration system costs:

Installed Power [MW_e]	10
CAPITAL COST	
Turbine Generator	6.000.000
Boiler	7.500.000
Boiler Feed Conveyor	250.000
Truck Dumper	450.000
Front End Loader	450.000
Raw Wood Drag Chain Conveyor	300.000
Raw Biomass Belt Conveyor	200.000
Disc Screen	350.000
Hammermill	300.000
Sized Wood Belt Conveyor	500.000
Storage Silo	1.700.000
Total Capital Cost	**18.000.000**

Total investment and other cost related to the to the 10 MW cogeneration plant

Electric Power Production [MW_e]	10
Thermal Power Production [MW_{th}]	24
Investment (civil works not included) [M$]	18
Working time of the plant [h]	7000
Electric Energy Production [MWh]	70000
Thermal Energy Production [MWh]	170000
Biomass Consumption [t/y]	64.000
Electric Energy Selling Price [$/kWh]	0.130
Thermal Energy Selling Price [$/kWh]	0.02
Biomass Purchase Price [$/kg]	0.05
Annual Fixed Cost [M$/y]	1.8
Life of the plant	20
Total Revenues [M$/y]	9.4
Total Operative Costs [M$/y]	5

Technologies for CHP from biomass resources (8)

Employment and specific investment

Estimated manpower requirements (direct jobs) for the biomass production and for the operation and maintenance of a 10 [Mw_e] plant are shown in the tables here below

Type of Intensive Energy Crop	Cultivated area needed for 1 job [ha]	Manpower needed for the production of 1TOE [hr]
Short Rotation Forestry (*)	~ 60	3.7
Herbaceous crops	~ 120	1.9
Sugar Crop (Sweet-sorghum)(**)	~ 85	1.6
(*) Those data enclose the preparation of planting material, storage, transport. One ton of dry biomass is assumed to have an energy content of ~ 0.43 TOE. Average Labour requirements(1995) for modern production, mechanised harvesting, transport (average distance 20km) and management for sugar cane activity in Brasil (about 25,000 ha/yeld 75 t/ha year): **1 job per 21 ha**.		
(**) Estimated labor requirments for production , harvesting, mechanical sugar juice separation and transport of the products (grains, sugar-juice, bagasse derived from sweet sorghum plantations) to the processing factories and management is: **1 jobs per 30 ha** of plantation.		

Technologies for CHP from biomass resources (9)

Employment (10 MWe)

	Number of Directs Jobs Required			
Activity	**1 MWe**	**5 MWe**	**10 MWe**	**30 MWe**
Reception + pre-treatment of biomass	12	16	20	20
Conversion of biomass (gasification/pyrolysis)	4	8	8	12
Power Generation	4	4	4	8
Total Number of Direct Jobs	20	28	32	44

	SR Forestry crops	Herbaceous Crops	SRF Forestry crops	Herbaceous crops
Production of biomass	47	24	54	28
Reception, pretreatment of biomass	5	5	20	20
Conversion (Gasification/pyrolysis)	-	-	8	8
Electricity generation (four shift)	20	20	4	4
Total number of jobs	72	49	86	60

Technologies for CHP from biomass resources (10)

Employment (10 Mwe plant) in European conditions

8 direct job/MWe if based on forestry crops

5.5 direct jobs/MWe if based on herbaceous crops

Specific investments are estimated as follows:

1. Biomass cogeneration: ~ 200,000 [$/job]
2. Biomass Cogeneration/Bioethanol: ~ 300,000 [$/job]
3. Biomass Cogeneration/Bioethanol - Biomethanol: ~ 270 - 412,000 [$/job]

Multi fuel fired CHP plant (1)

MÅBJERGVÆRKET
Måbjerg, Denmark

1st CHP plant in Denmark using a combination consisting of waste, wood chips, straw and natural gas

Fuel distribution in 1998:

- 550,000 t wastes
- 31,000 t straw
- 26,000 t wood chips
- 3,200 t wood pellets
- 2,000 t different bio-fuels
- 3,7 mio m3 natural gas

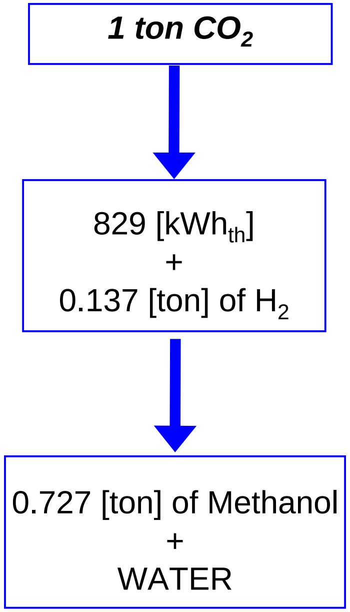
Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (1)

The synthesis of methanol

Methanol (CH_3OH) is synthesized by a catalyzed reaction of carbon monoxide with hydrogen:

$CO + 2H_2 \rightarrow CH_3OH$

Methanol production by CO2 hydrogenation :



Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (2)

Basic chemistry of alcohol fuels

CHEMICAL FORMULAE	
Ethanol	CH_3CH_2OH or (C_2H_5OH)
Methanol	CH_3OH
Ethane	CH_3 CH_3 (or C_2H_6)
Ethyl Tertiary Butyl Ether (ETBE)	$(CH_3)_3COC_2H_3$
Methyl Tertiary Butyl Ether (MTBE)	$(CH_3)_3COCH_3$
Methane	CH_4
Gasoline	C_4 to C_{12}

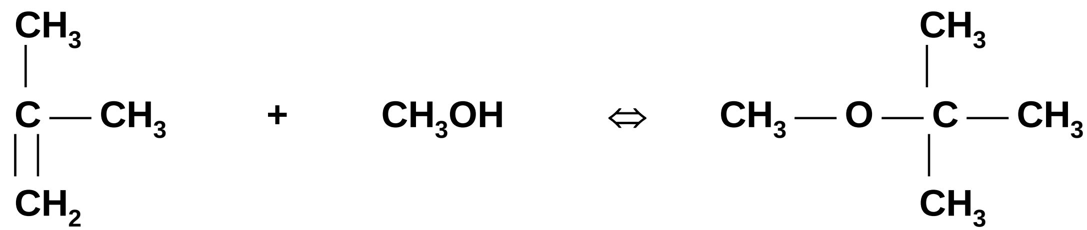
Physiscal Properties of some bio-fuels and gasoline

Physical Properties	Ethanol	Methanol	MTBE	ETBE	Gasoline
Molecular Weight	46.07	32.04	88.15	102.18	n.a
Specific Gravity [kg/dm³] @ 15[°C]	0.794	0.796	0.740		0.72-0.78
Boiling Point [°C]	78	65			27- 225
Pump Octane Number (Neat / Blended)	97 / 111	98 / 115			72 – 76 / na
Latent Heat of vaporisation [kJ/kg]	920	1176			348
Heating Value [kJ/kg]	26700	19920	35270	36030	41840 -44164
Stoichiometric air - fuel weight	9.00	6.45	11.69	12.10	14.7

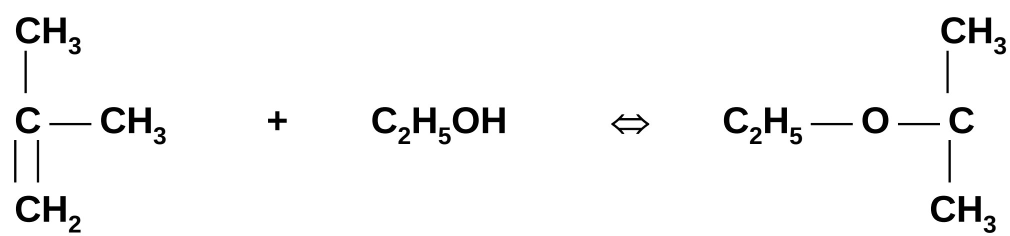
Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (3)

Process chemistry to obtain MTBE and ETBE:

Isobutylene(≅ 64%) **Methanol**(≅ 36% in volume) **MTBE**



Isobutylene **Ethanol** (≅ 48% in volume) **ETBE**



Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (4)

Due to the differences in molecular weight of ETBE and MTBE, and the differences in the reaction stoichiometry, the amounts of alcohol and isobutylene required are quite different in each case. The amounts of reactant required to make 1,000 gallons of the ether are shown in the following relationships:

Ethanol	+	Isobutylene	=	ETBE
1054 kg		1564 kg		2845 kg (Theretical yield)
Methanol	+	Isobutylene	=	MTBE
1017 kg		1786 kg		2803 kg (Theretical yield)

Blending values of Oxygenates in typical unleaded gasoline are :

Oxygenates	*Octane (R+M/2)*	*Reid Vapor Pressur (PSI)*
Methanol	116	61.0
Ethanol	113	21.5
Arconol	98	12.7
Oxinol 50	106	33.5
MTBE	106-110	8.0-9.3
ETBE	109-113	7.0-8.3
N-Butane	92	60.0
Toluene	106	0.5

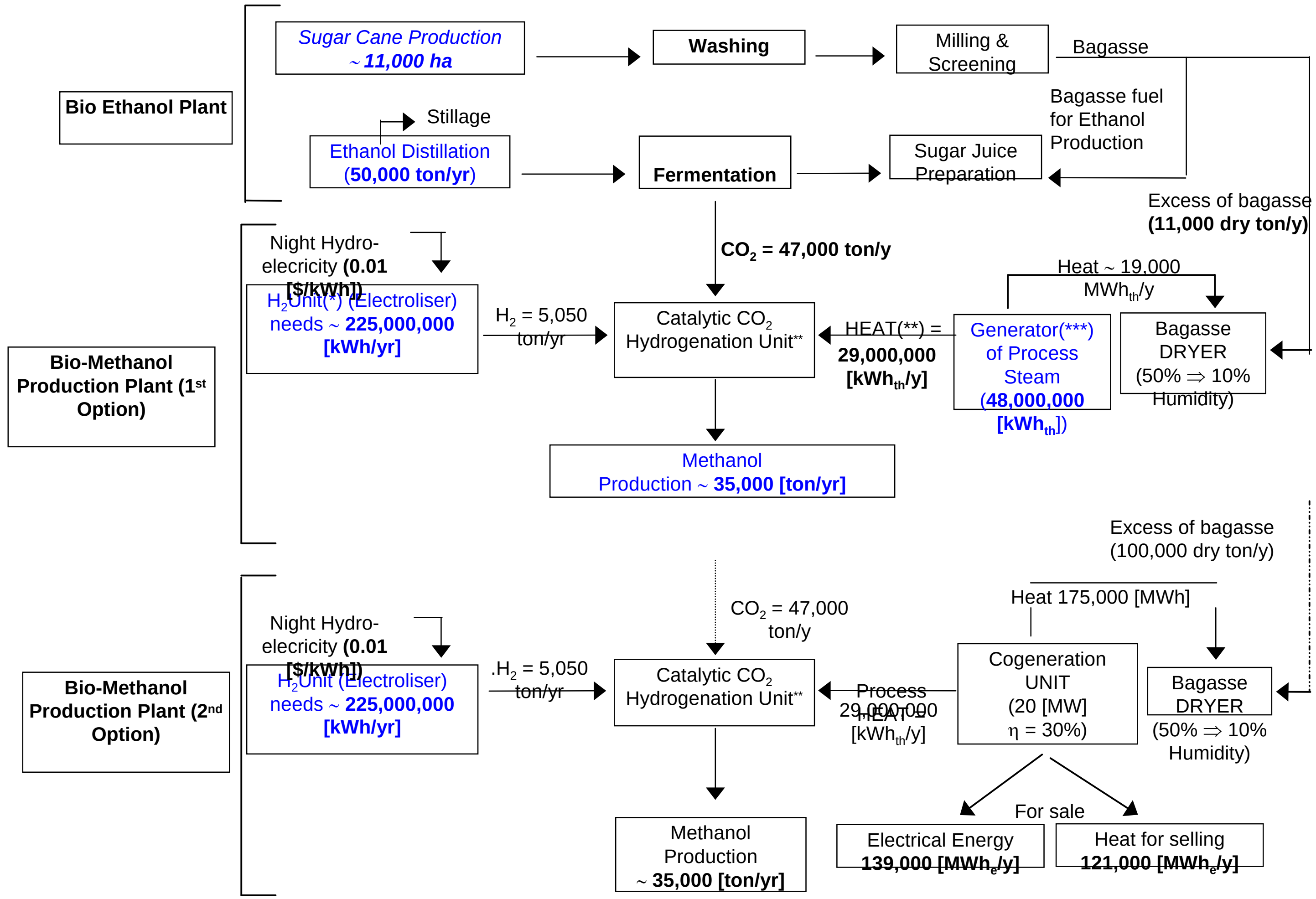
Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (5)

Isobutylene is currently derived from two major sources: steam cracking for ethylene manufacture and fluid cat cracking for FCC gasoline, distillate, etc manufacture. Isobutylene supplies can also be made available by isomerizing surplus N-Butane to isobutane, the dehydrating the isobutane to isobutylene (but with high investment: 250 M$ min.); see Figure below (H2 plant).

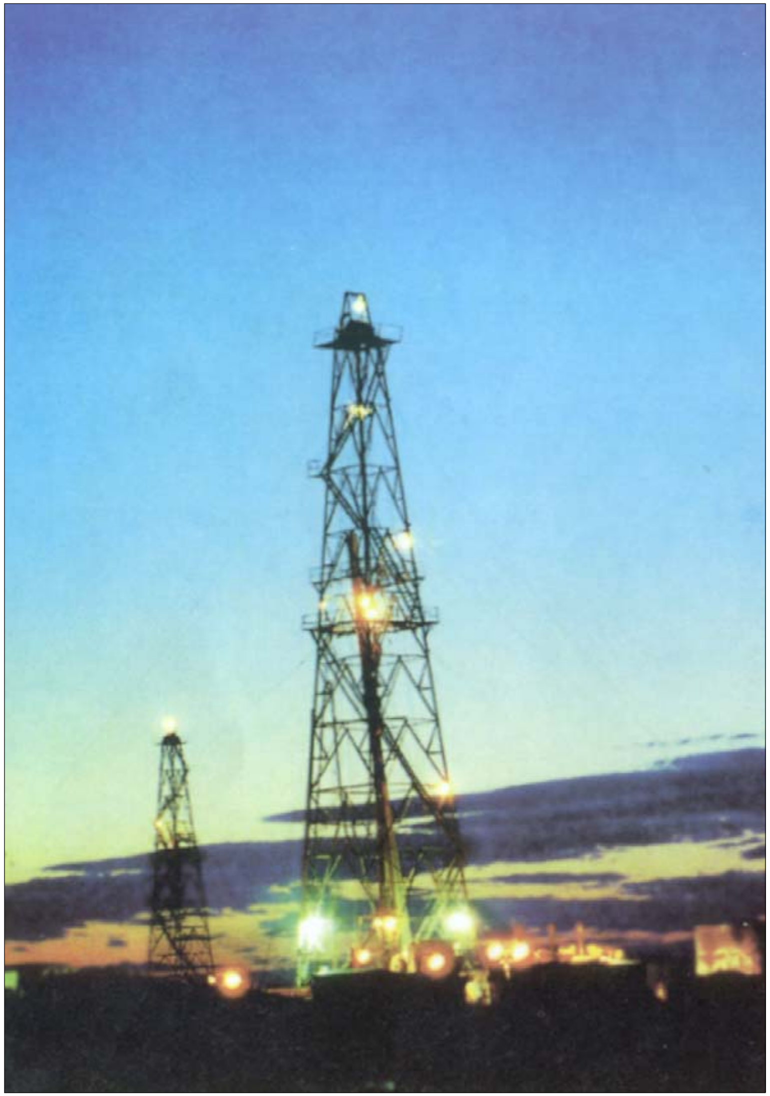
Because the basic process chemistry is the same, ETBE can be manufactured with the same catalytic reaction and essentially the same process unit as MTBE.

Cogeneration plant with simulatneous integrated production of bio-ethanol and bio-methanol from sugar cane or sweet sorghum for gasoline reformulation (6)

Biomethanol production integrated with bioETOH production from sugar cane



Large Scale Integration of Bioenergy with Petrochemical Complex (1)



Large Scale Integration of Bioenergy with Petrochemical Complex (2)

OIL REFINING

Basic refining process of heavy oil into light oil and the conversion of distillation residues, consists of cracking the molecules to increase the hydrogen content and to decrease the carbon content of the derived products with expenses of energy (endothermic process)

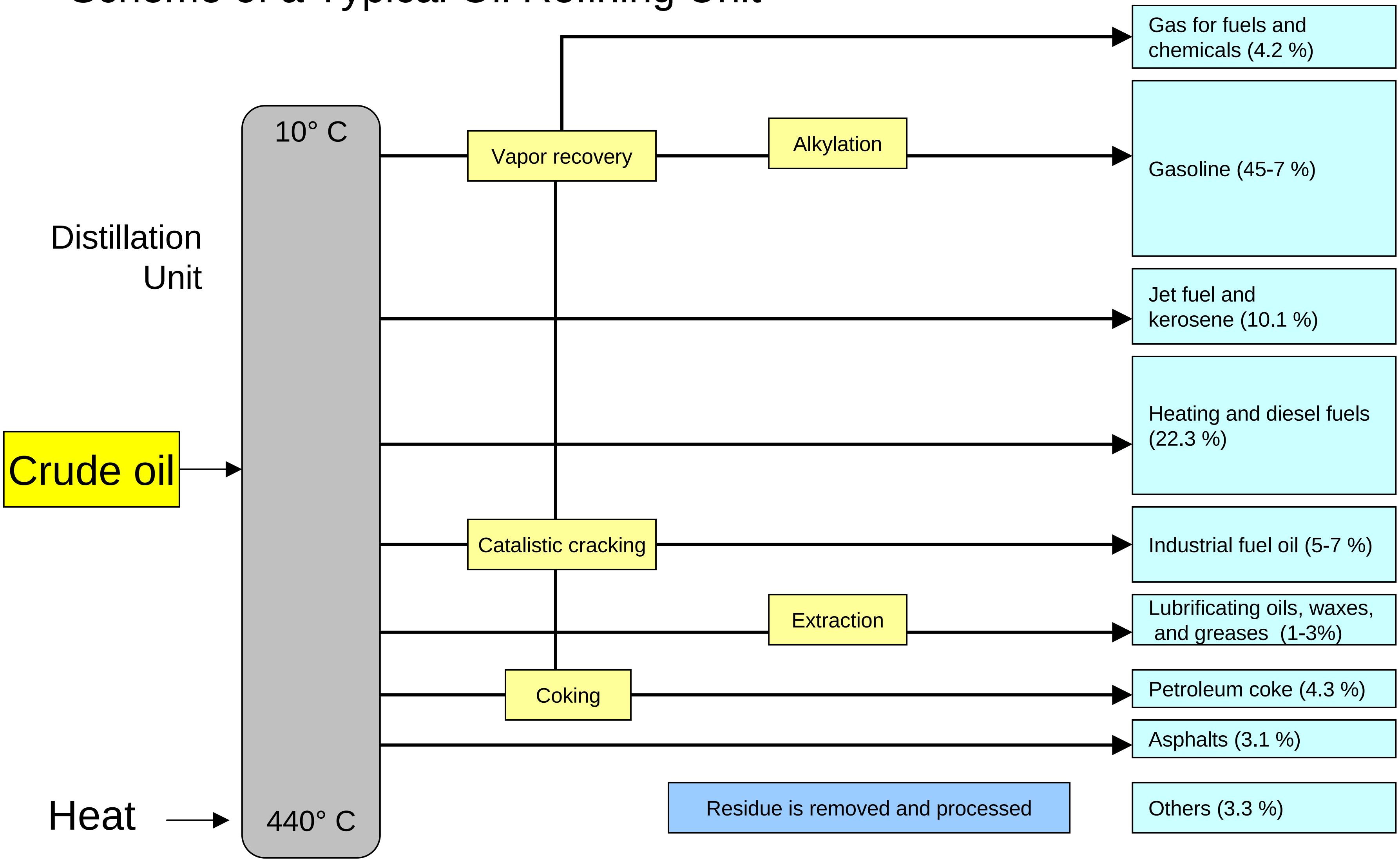
OIL REFINING	H_2 CONTENT (wt)
Heavy – oil	11%
Medium – oil	12%
Gasoline	14%
(Methane)	(25%)

Main "ingredients" for refining processes:

Temperature	Pressure	Hydrogen	Catalyst

Large Scale Integration of Bioenergy with Petrochemical Complex (3)

Scheme of a Typical Oil Refining Unit



Large Scale Integration of Bioenergy with Petrochemical Complex (4)

HEAVY-OIL PROCESSING

↓

1st STEP

VIS-BREAKING
Thermal processing to obtain
Commercial Heavy-Fuel

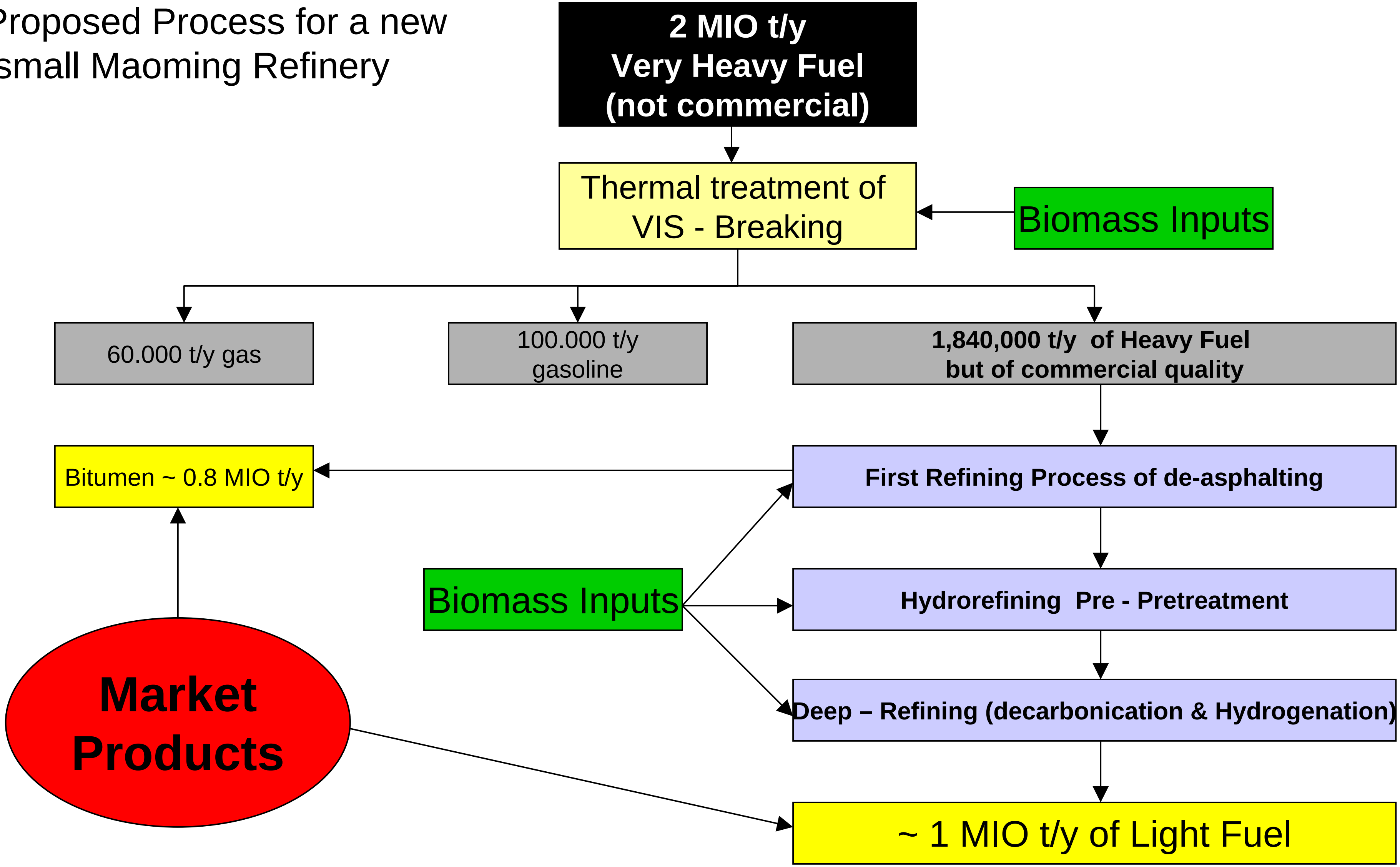
↓

2nd STEP

PRE-TREATMENT & DEEP REFINING
Catalystic Craking at high temperature (450°C)
And hydrogen pressure (15-80 BAR)

Large Scale Integration of Bioenergy with Petrochemical Complex (5)

Proposed Process for a new small Maoming Refinery

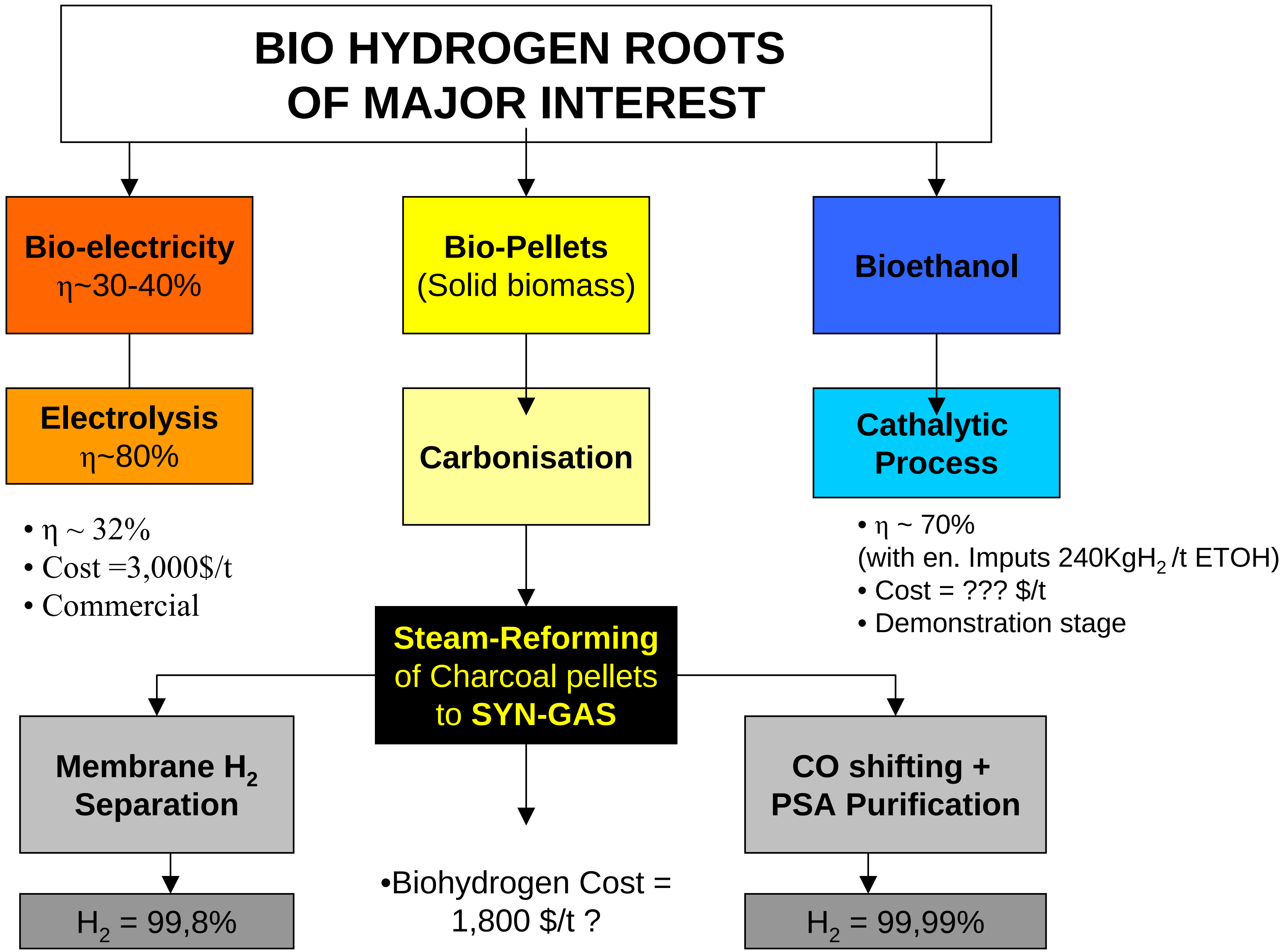


Large Scale Integration of Bioenergy with Petrochemical Complex (6)

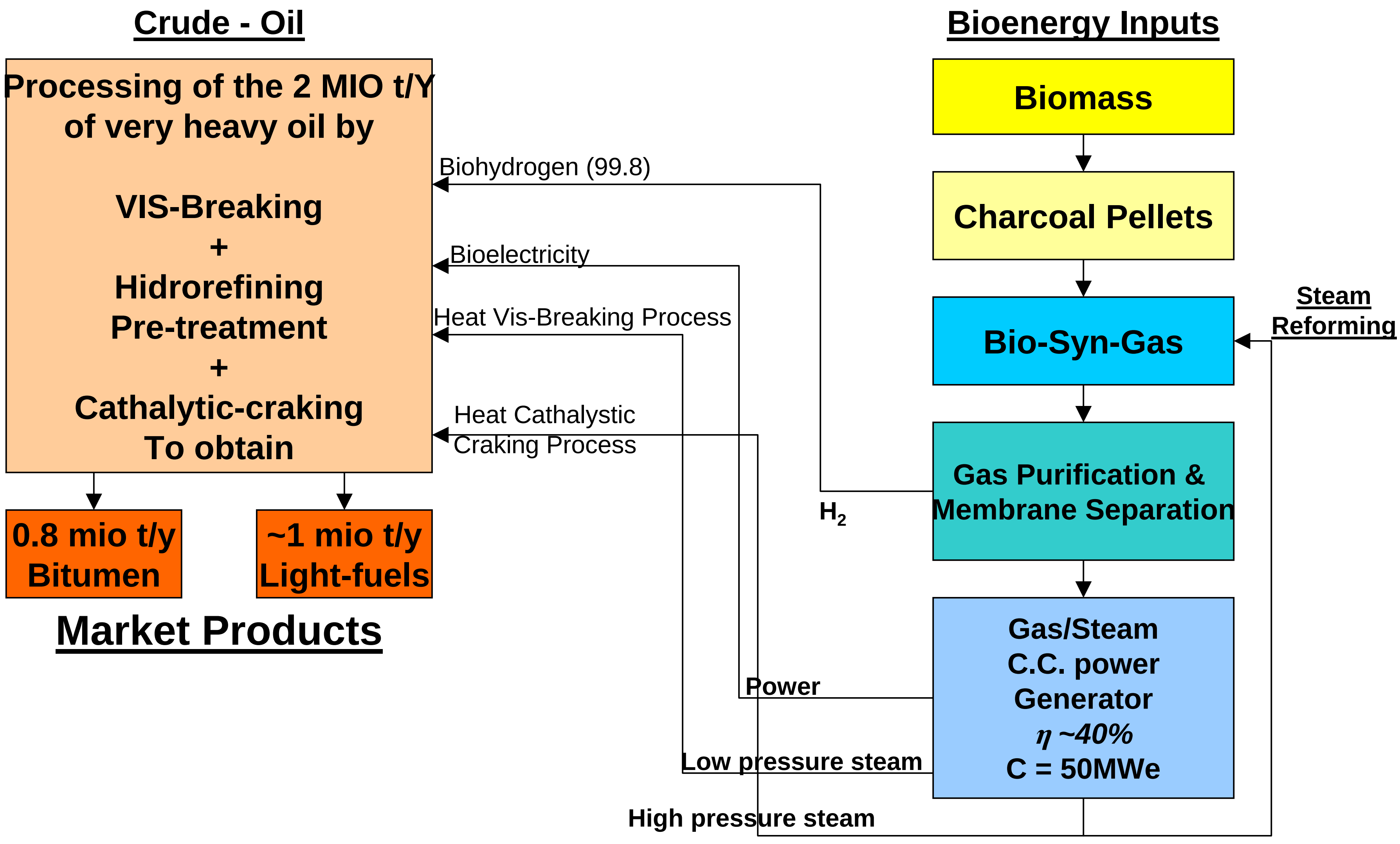
Resources	Feedstock	Quantity for 1 ton H_2
From Biomass resources	Pellets (60$/t)	18.2 t
	Charcoal (120$/t)	7 t
	Bioethanol (250$/t) ●	4.1 t
From Fossil resources	Coal (50$/t)	10.1 t
	Oil (220$/t = 30$ Bbl)	5.1 t
	Nat. gas (150$/1,000 m^3)	6,400 m^3
	Nafta (250$/t)	4.8 t

● With a supplementary heat input

Large Scale Integration of Bioenergy with Petrochemical Complex (7)



Large Scale Integration of Bioenergy with Petrochemical Complex (8)



Large Scale Integration of Bioenergy with Petrochemical Complex (9)

Potential bioenergy Contribution to supply the energy inputs for refining

- Heat (steam)
- Electricity
- Hydrogen

Large amount of energy input is needed (Process η =80%)

- 0.4 MTOE/y
  (Refinery capacity = 2 MTOE/y)
- 2 MTOE/y
  (Refinery capacity = 10 MTOE/y)

Most promising Biomass Resource: → **BIO-PELLETS**

- cost similar to Natural Gas (~ 200$/TOE)
- easily handled, transported, stored

Amount of Biopellets needed per year

- 0.85 mio t/y
  (Refinery capacity = 2 MTOE/y)
- 4.2 mio t/y
  (Refinery capacity = 10 MTOE/y)

Large Scale Integration of Bioenergy with Petrochemical Complex (10)

Major Benefits deriving from the use of Bioenergy for Crude-oil Refining

- Benefits for the oil-importing Country balance of payment, due to the substitution of valuable $ imported hydrocarbons with local competitive biomass energy resources valued in local currency.

- The substitution an utilization of 20% renewable biomass energy resources decrease, of 20% the CO_2 emission into the atmosphere

- The production and supply of biopellets to the refinery generates many diversified jobs and supplementary income for rural population (rural development impact)

European Biomass Industry Association

Dott. **Giuliano Grassi**

EUBIA Secretary General
eubia@eubia.org
www.eubia.org