POLYCITY WORKSHOP ON

BIOMASS IN URBAN COMMUNITIES

ALTERNATIVE CONFIGURATIONS FOR THE INTEGRATED BIOMASS GASIFICATION PLANT OF CERDANYOLA DEL VALLÈS

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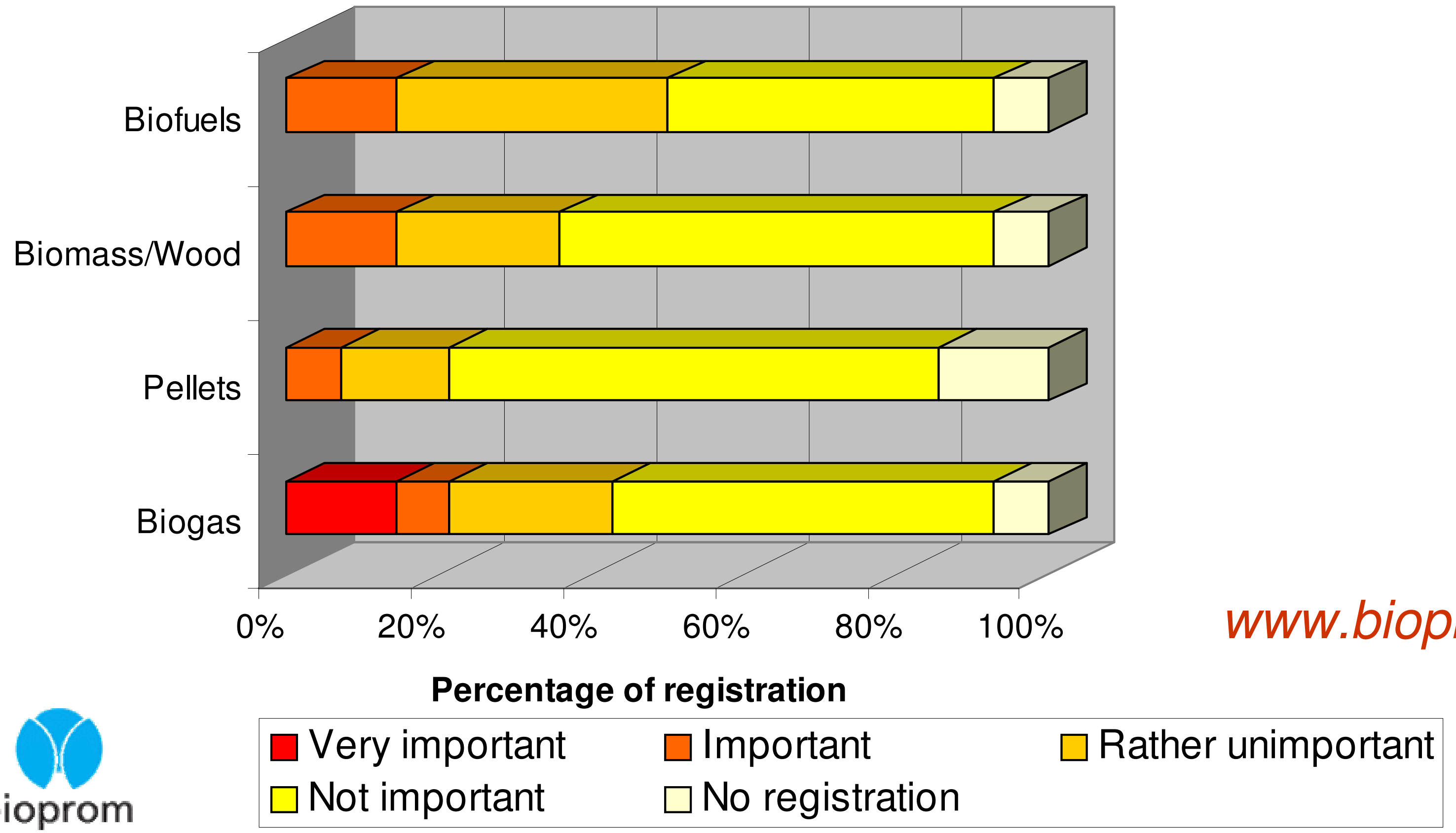
1 INTRODUCTION

Biomass is expected to play an important role in the future global energy infrastructure for the generation of power and heat, but also for the production of fuels and chemicals (*O_2 rich oxidising stream*).

Current role for Bioenergy in urban areas

(Results of the ***Bioprom Project*** *questionnaire in Spain)*



www.bioprom.net

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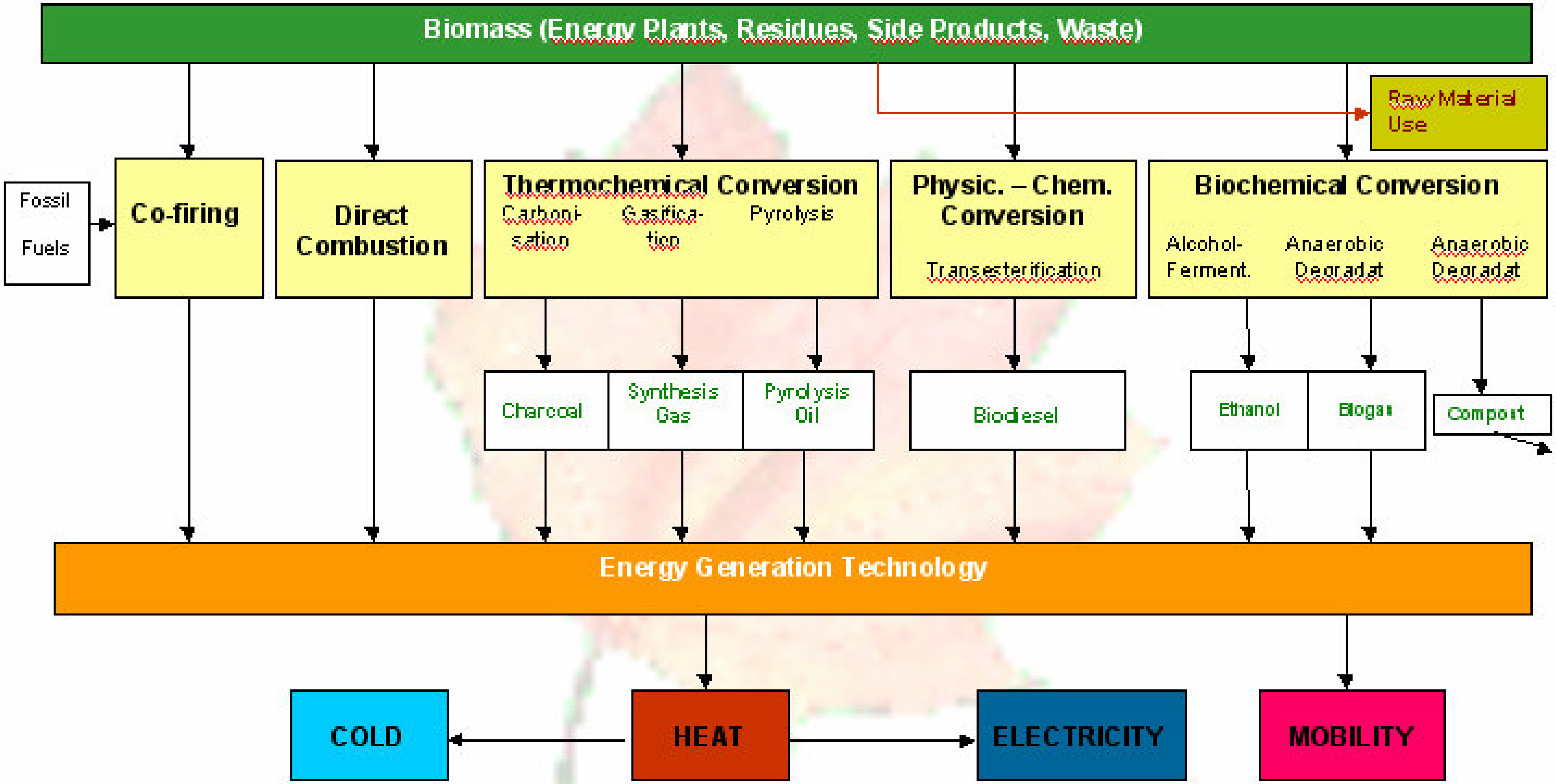
2 BIOMASS CONVERSION TECHNOLOGIES



3 GASIFICATION CONCEPT

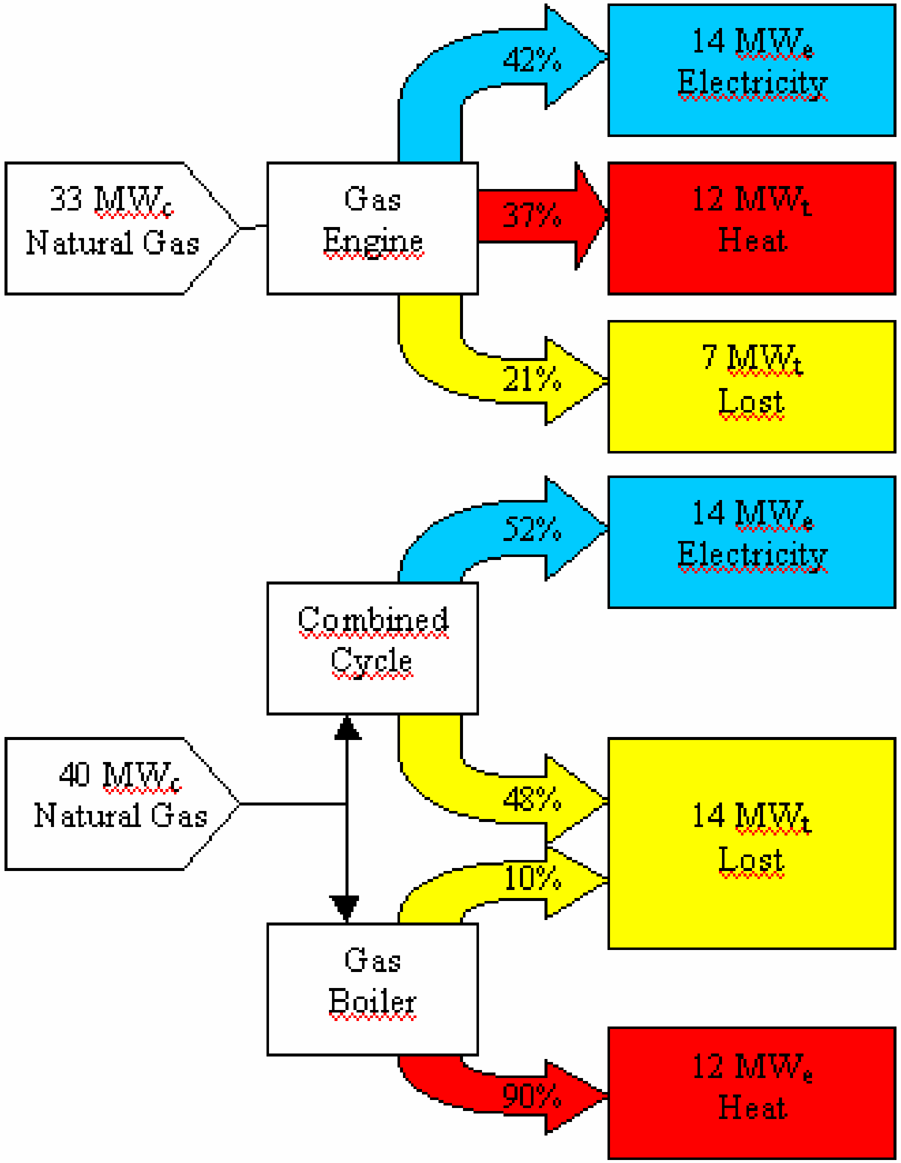
- The gasification process is one of the thermochemical conversions that can be used to transform the chemical energy contained in a solid fuel (like biomass) into thermal energy and electricity.

- The product of the gasification process is the so called “Synthesis gas” that is a mixture of CO, H_2 and other gases.

- The gasification process takes place at high temperature and needs a supply of oxidant lower than required for a combustion process.

- Application of the produced gas:
  - Fuel
  - Raw material for chemicals

4 COGENERATION CONCEPT



Cogeneration

(Combined Heat & Power, CHP)

17.5 % of PRIMARY ENERGY SAVING

0.202 tCO_2 / MWh Natural gas

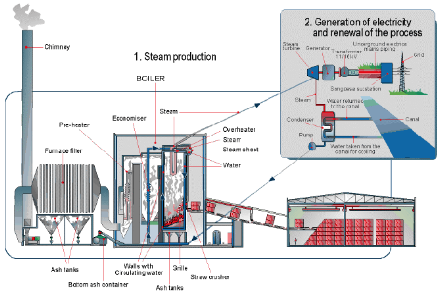
6500 h/year of operation

9191 tCO_2 / year avoided

5 POWER FROM BIOMASS: DEVELOPMENT STATUS (I)

CONCEPTS WITH COMBUSTION

Steam based power generation → Mature technology



25 MWe Biomass Power Plant
Sangüesa (Navarra, Spain)

Organic Rankine Cycle → Demonstration

Schaunhauser Park
(Ostfildern, Stuttgart, Germany)

Stirling engine → In development

New development from SOLO Stirling GmbH

5 POWER FROM BIOMASS: DEVELOPMENT STATUS (II)

GASIFICATION CONCEPTS

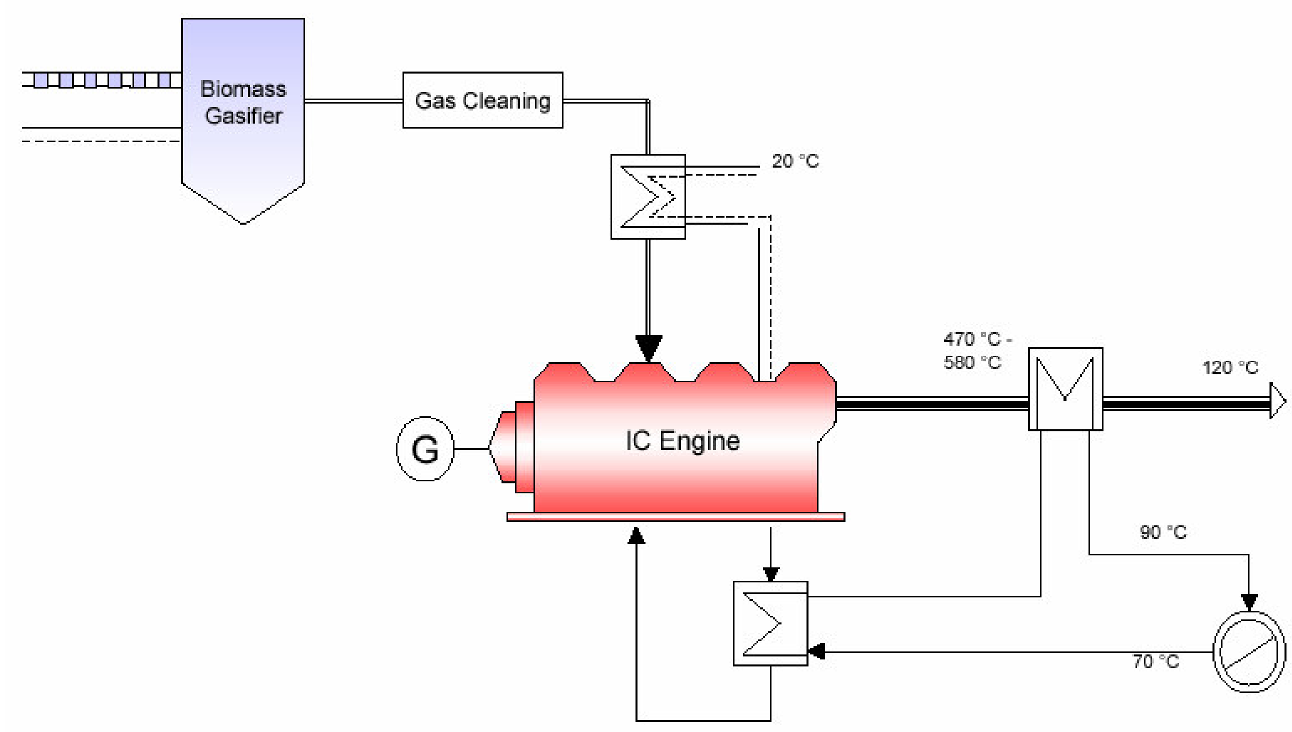
Reciprocating engine and Gas turbines → Demonstration

TAIM-TFG, 600 kW_e (Zaragoza)
ENAMORA-EQTEC, 750 kW_e (Mora d'Ebre)
MOVIALSA, 5.4 MW_e (Ciudad Real)
...

Fuel cells → Trials stage

According to a recent study in Japan (Dowaki et al, Renewable Energy, 32, 80-94,2006) the cost of bio-hydrogen fuel using a gasification process would be 5.75 - 7.86 \$/kg H_2 without subsidies.

6 INTEGRATED BIOMASS COGENERATION PLANT CONCEPT



- Higher electric plant efficiency than steam or ORC biomass combustion technologies specially for small-scale systems.
- Diesel or natural gas engines for less than 1-2 MW_e systems.

7 GASIFICATION WITH MICRO GAS TURBINES

DEVELOPMENT OF A MICRO-TURBINE PLANT TO RUN ON GASIFIER PRODUCER GAS

Contractor:
Biomass Engineering Ltd.

- 30 kWe microturbine (15 kW with syngas) using gas produced in a 80 kW downdraft gasifier operating on clean wood and wood wastes.
- 350 hours of testing.
- Uneconomic operation. Higher capacity micro gas turbines recommended.

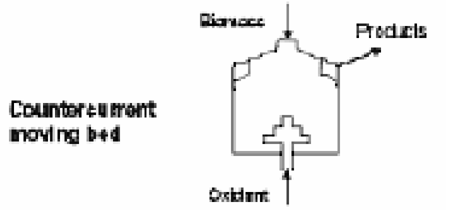
Other initiatives:

→ Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia)

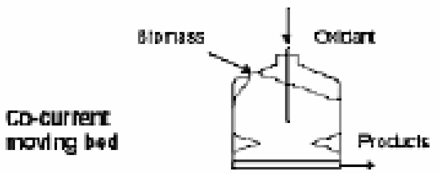
→ Flex-Microturbine Project. Co-funded by NREL/US DOE

8 GASIFICATION: TYPE OF GASIFIER REACTORS (I)

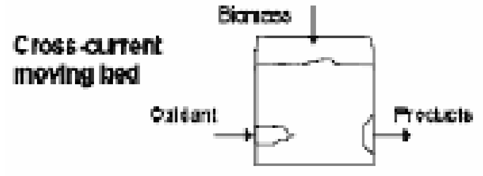
FIXED BED



The solid flows in descendent direction and the gas in ascendant direction (updraft).

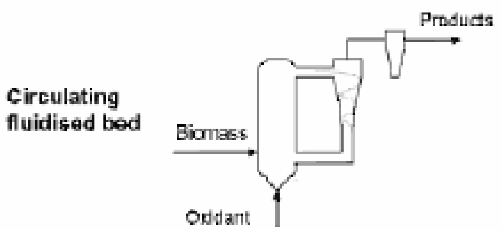


Both the solid and the gas have descendent flow (downdraft).

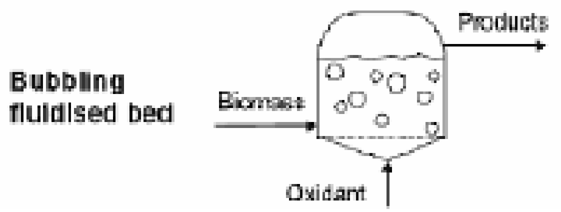


The solid has descendent flow and the gas goes perpendicular to the solid.

FLUIDIZED BED



The inert solid is dragged by the gas flow. Out of the reactor is separated of the gas and it is given back to the reactor.



The gas has low speed. The inert solid remain within the reactor.

OTHER TYPES: Entrained Bed, Rotary kiln, Cyclonic reactor

8 GASIFICATION: TYPE OF GASIFIER REACTORS (II)

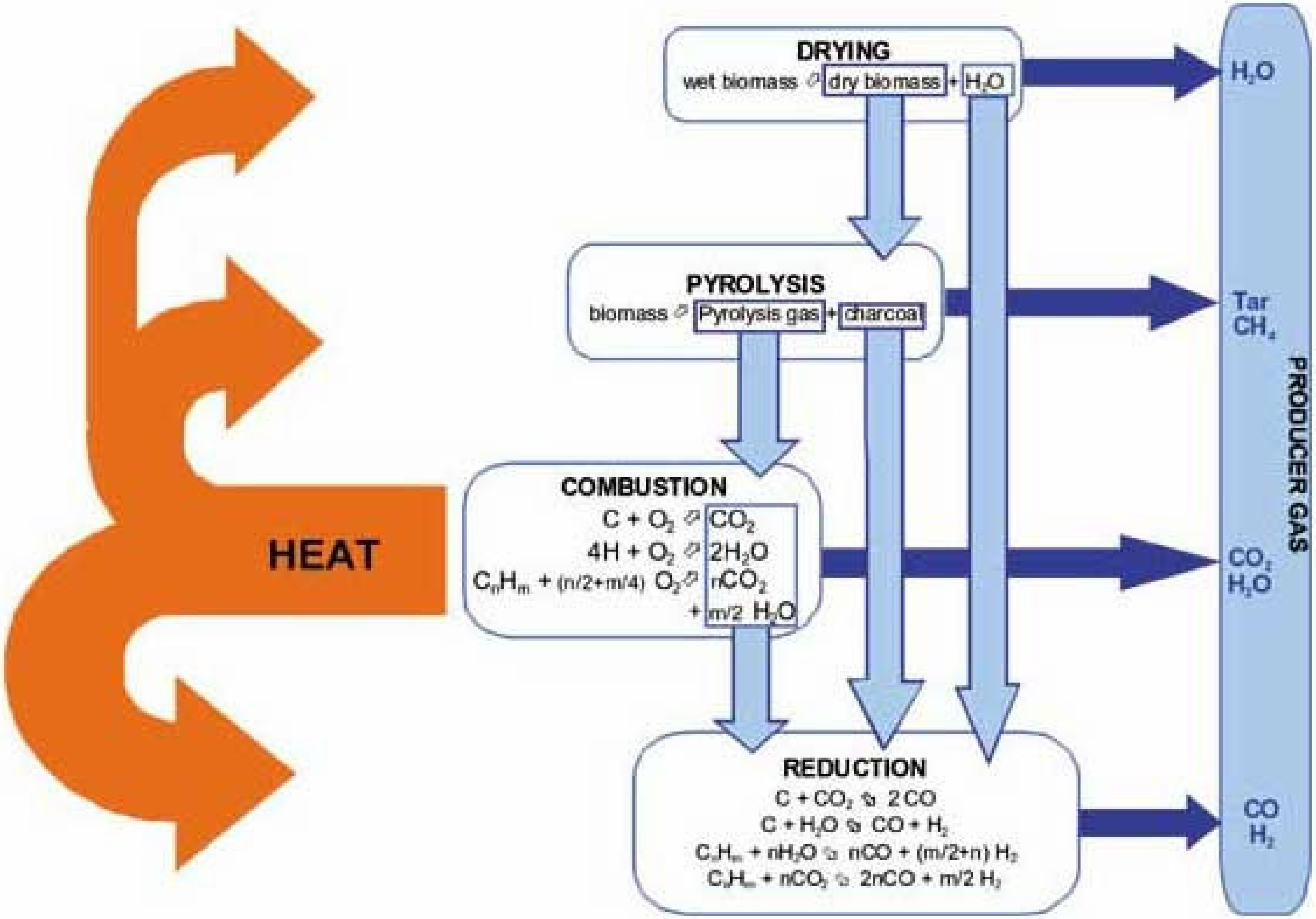
Basic comparasion of the main types of biomass gasifiers

	Fixed bed	Fluid bed
Scale (MWe)	0.1 – 10	1 – 50
Granulometry (mm)	10 - 100	0 - 20
Temperature (ºC)	800 - 1400	750 - 900
Start-up time	Minutes	Hours

9 GASIFICATION PROCESS (I)

Four different processes can be distinguished in gasification:

drying, pyrolysis, oxidation and reduction



9 GASIFICATION PROCESS (II)

Gas composition (% volume)

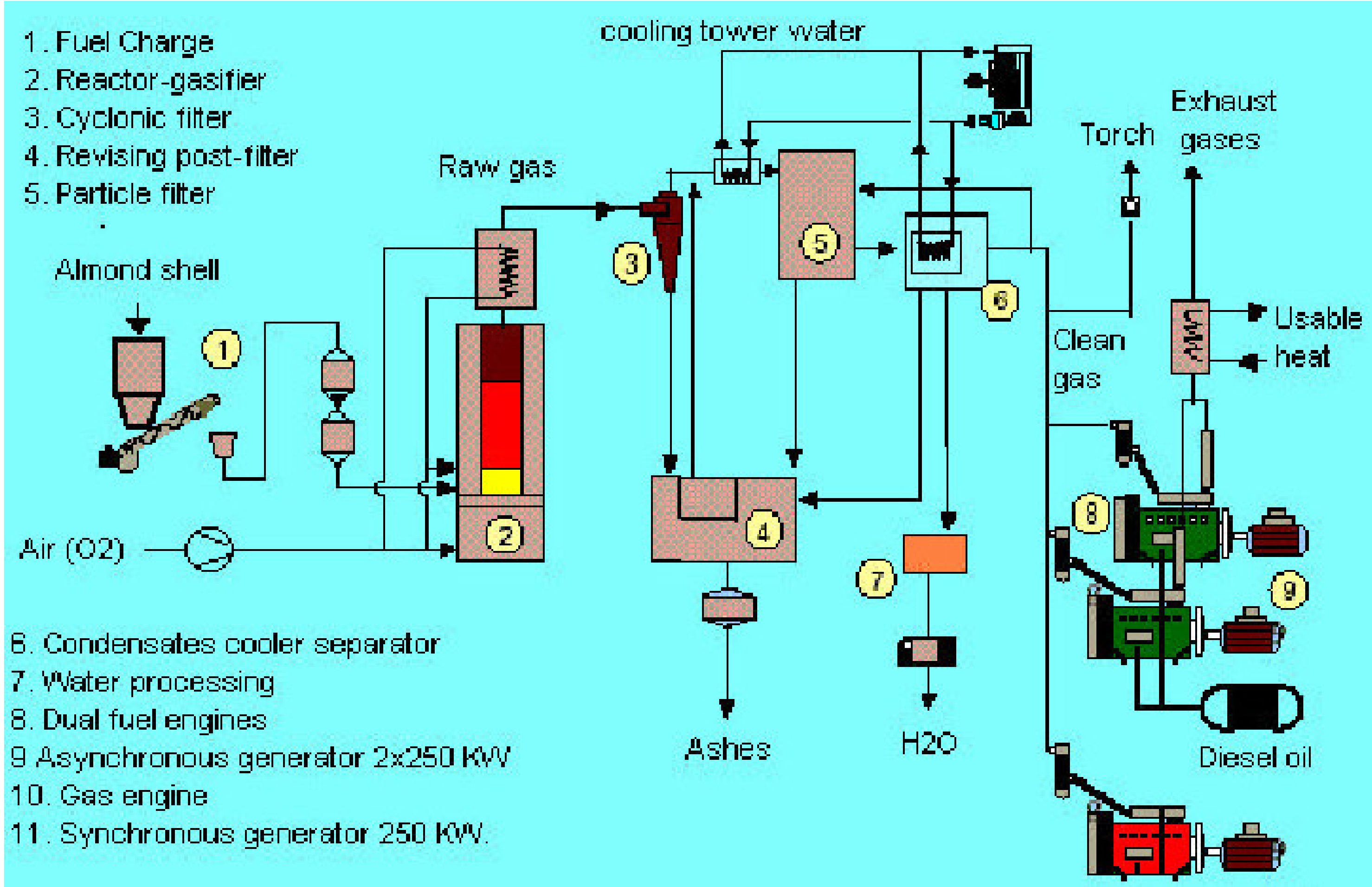
Oxidant Agent	H_2	CO	CO_2	CH_4	N_2	C_2	Use
Air	16	20	12	2	50	-	Fuel
Oxygen	32	48	15	2	3	-	Fuel / Chemicals
Steam	50	20	22	6	-	2	Fuel / Chemicals

- Gas composition depends on many factors:
  Type of biomass, gasifier type, granulometry, etc.

- Other typical values: 2.0 - 2.4 Nm^3/kg of biomass
  5.4 - 5.7 MJ/Nm^3 HHV

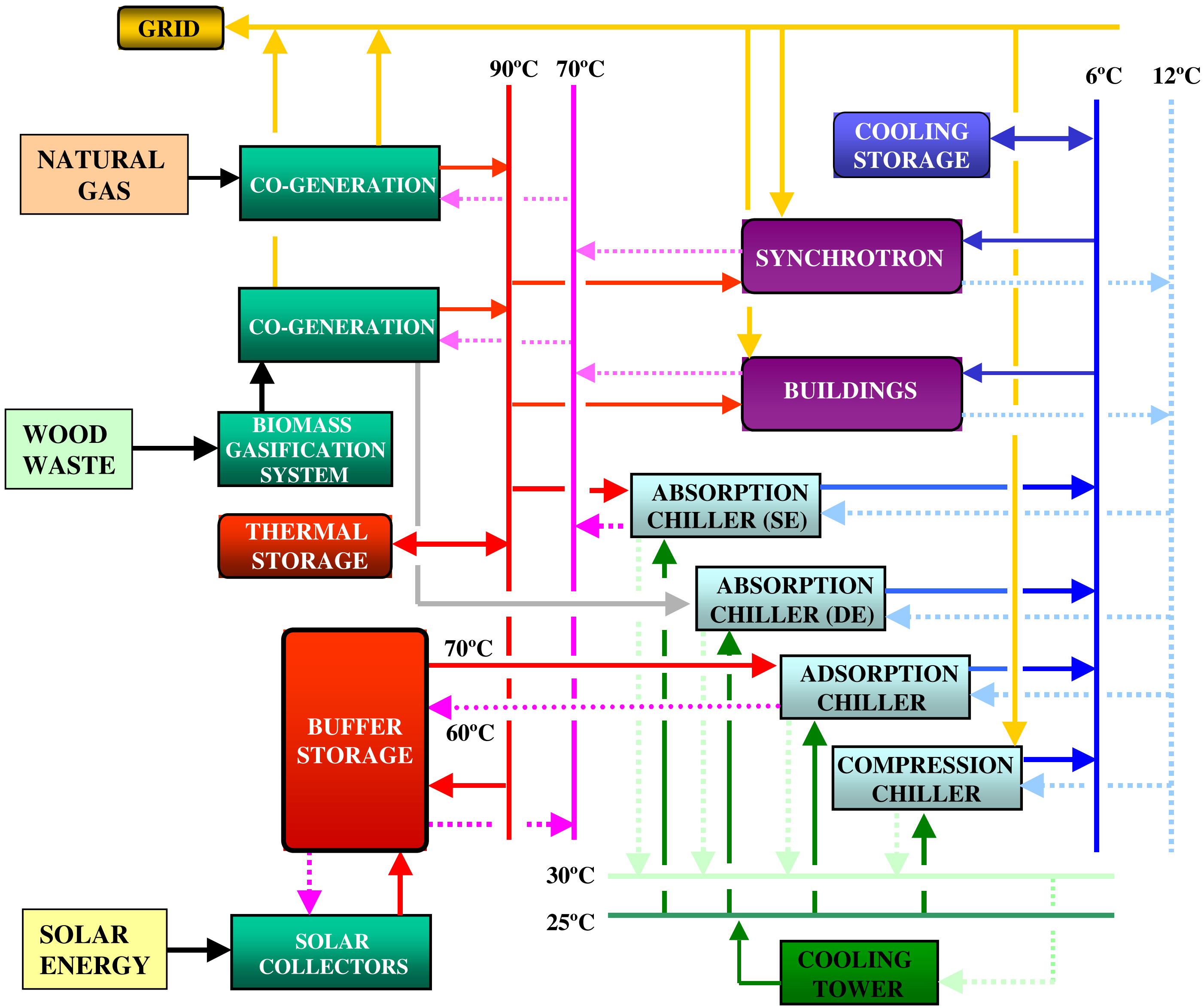
10 BIOMASS GASIFICATION PLANT COMPONENTS

INTEGRATED BIOMASS GASIFICATION PLANT (MORA D'EBRE, SPAIN)



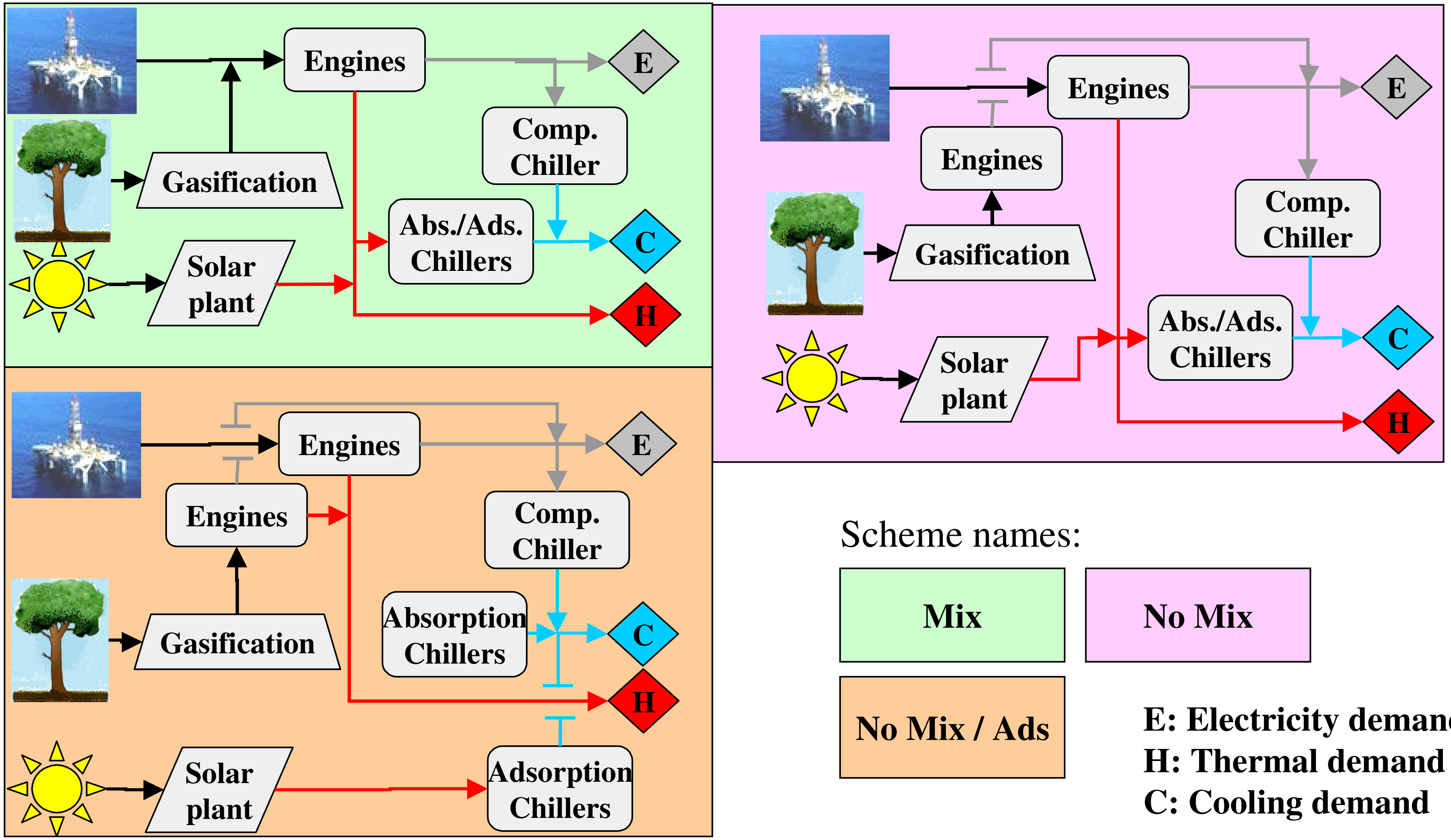
1 kg of Almond Shells (3800 kcal/kg LHV, 4.5 kWh → 1 kWh electricity

11 DISTRICT HEATING AND COOLING – POLYCITY - CERDANYOLA



11 DISTRICT HEATING AND COOLING – POLYCITY - CERDANYOLA

POLYGENERATION OPTIONS



Scheme names:

Mix	No Mix
No Mix / Ads	

E: Electricity demand
H: Thermal demand
C: Cooling demand

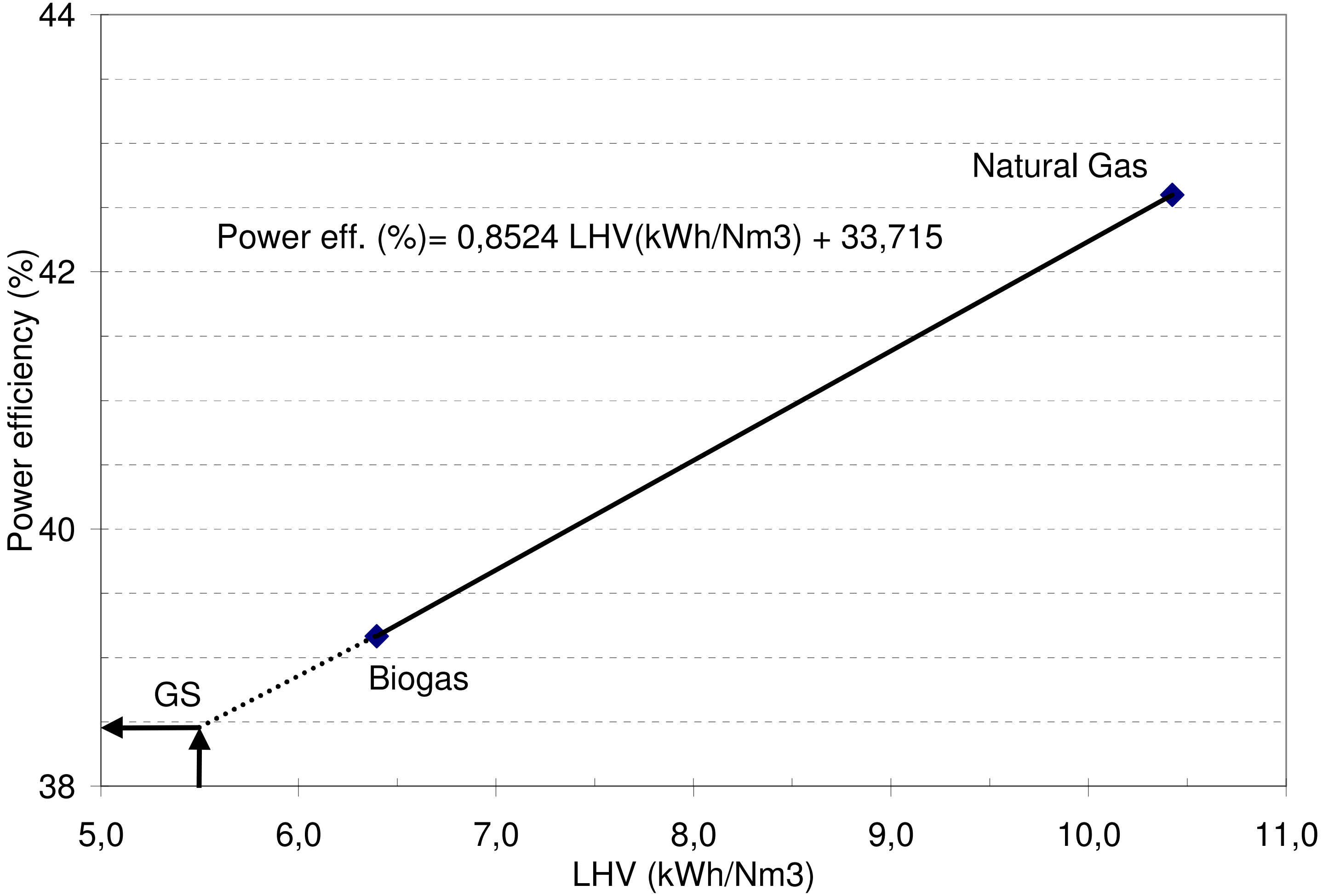
DISTRICT HEATING AND COOLING – POLYCITY - CERDANYOLA

The simulation takes as reference the plant **ENAMORA, Energía Natural de Mora, S.L.** This is an integrated biomass gasification power plant located in Mora la Nova, Catalunya.

- ✓ Biomass Type: Almond Shells and Olive Pits
- ✓ Biogas production: 2,500 Nm^3/h
- ✓ Biomass Consumption: 900 – 1,200 kg/h
- ✓ Nominal Electrical output: 750 kW
- ✓ Nominal Thermal output: 3,500 kW

Gasification Plant

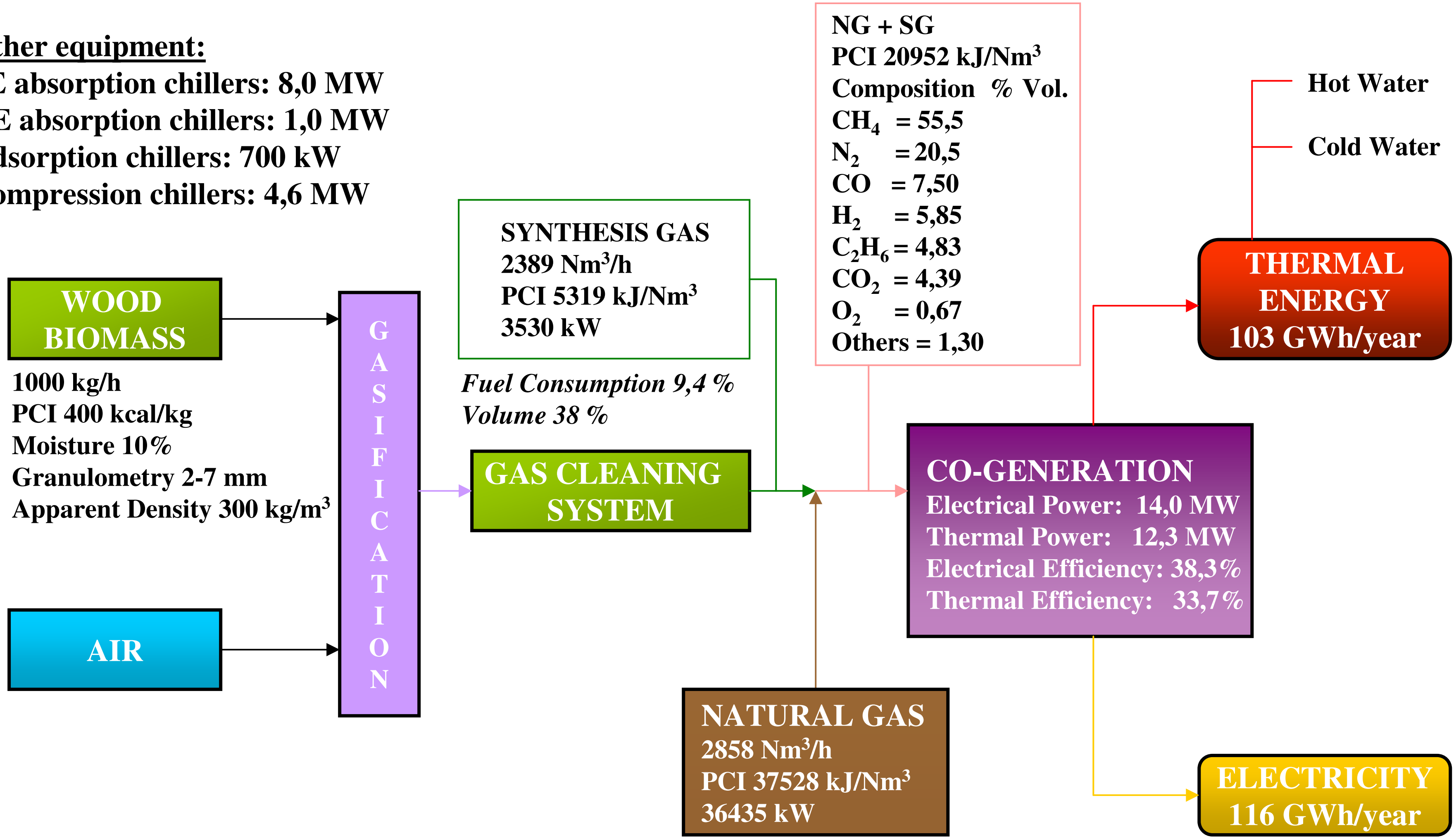
INTEGRATED BIOMASS GASIFICATION PLANT (Mixing of fuel)



INTEGRATED BIOMASS GASIFICATION PLANT (Mixing of fuel)

Other equipment:

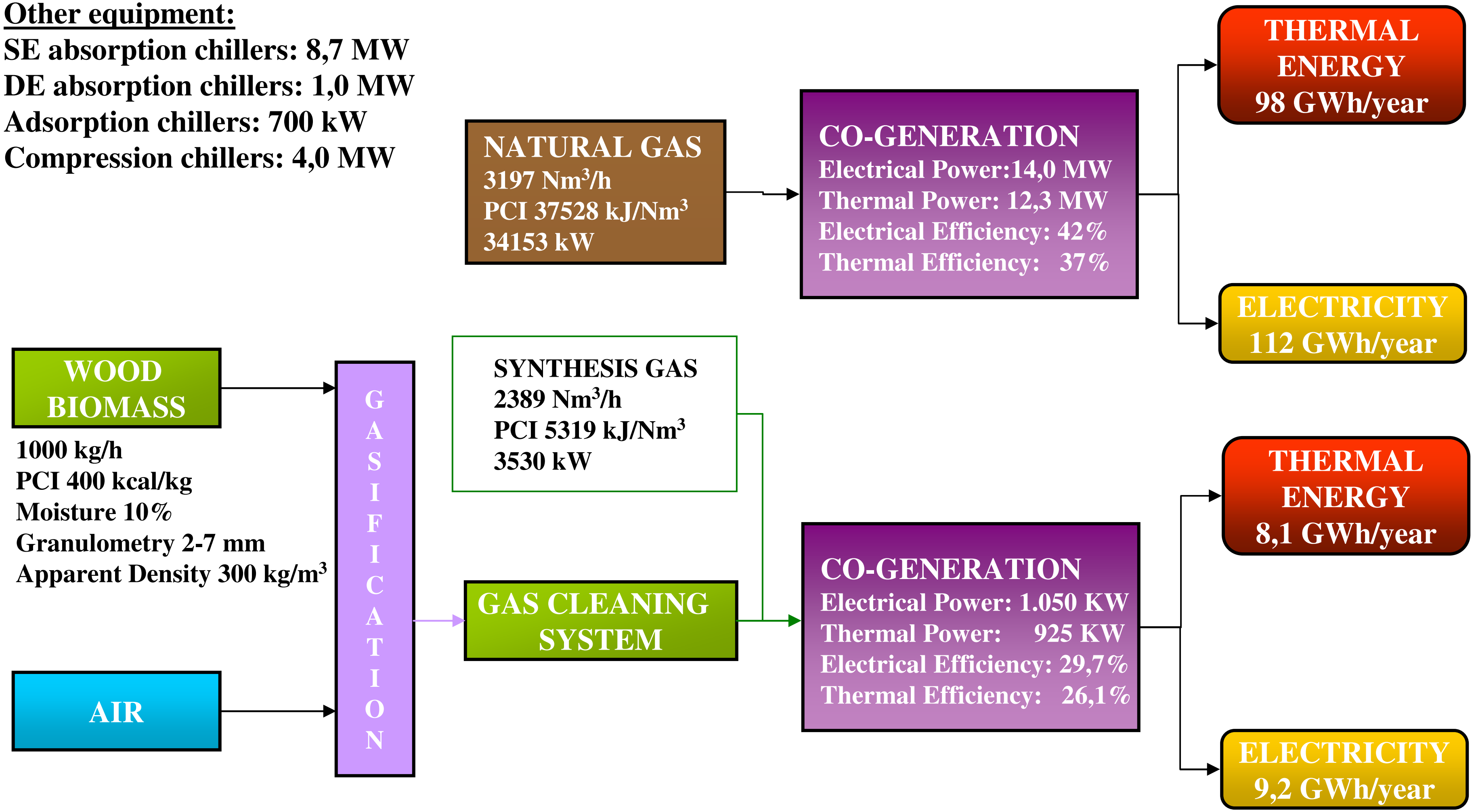
SE absorption chillers: 8,0 MW
DE absorption chillers: 1,0 MW
Adsorption chillers: 700 kW
Compression chillers: 4,6 MW



INTEGRATED BIOMASS GASIFICATION PLANT (No mixing of fuel)

Other equipment:

SE absorption chillers: 8,7 MW
DE absorption chillers: 1,0 MW
Adsorption chillers: 700 kW
Compression chillers: 4,0 MW



INTEGRATED BIOMASS GASIFICATION PLANT - Comparison Alternatives

Energy MWh/year	**Fuel mixing**	**Dedicated engines**
Total electrical production	124.820	124.834
Biomass electrical production	12.988	9.184
% Renewable electrical energy	**10,4%**	**7,4%**
% Renewable reduction	-	-29,3%
Total thermal production	111.938	111.930
Biomass thermal production	11.441	8.071
Solar thermal production	1.977	1.977
% Renewable thermal energy	**12,0%**	**9,0%**
% Renewable reduction	-	-29,5%
Primary energy from RES	32900	32900
Primary energy consumption	**260.167**	**242.320**
Primary energy consumption reduction	-	6,9%
CO2 emissions (t/year)	**54.225**	**50.693**
CO2 emissions reduction	-	6,5%

DISTRICT HEATING AND COOLING – POLYCITY - CERDANYOLA

Electric tariffs applicable to renwable energy sources in Spain according to RD 436/2004

(Source: IDAE, Hernández, 2005)

Two options for selling power:		**Option a):** Fixed price (regulated tariff) calculated as a % of yearly average tariff (same for every hour)	**Option b):** Free sale onto the organised market plus an incentive and premium (when applicable) calculated as a % of the yearly average tariff: different price for each scheduling period (for each hour)		
		Fixed price=Regulated Tariff c€/kWh	**Premium c€/kWh**	**Market Participation Incentive c€/kWh**	**Total = Premium+Incentive c€/kWh**
SOLAR (b.1.)					
Photovoltaic (b.1.1.)	**≤ 100 kW**	**575%**			
	> 100 kW	**300%**	250%	10%	**260%**
Solar Thermoelectric (b.1.2.)		**300%**	250%	10%	**260%**
WIND (b.2.)					
Onshore Wind power (b.2.1.)	**≤ 5 MW**	**90%**	40%	10%	**50%**
	> 5 MW	**90%**	40%	10%	**50%**
Offshore Wind power (b.2.2.)	**≤ 5 MW**	**90%**	40%	10%	**50%**
	> 5 MW	**90%**	40%	10%	**50%**
GEOTHERMAL (b.3.)					
	< 50 MW	**90%**	40%	10%	**50%**
HYDROPOWER					
(b.4.)	**≤ 10 MW**	**90%**	40%	10%	**50%**
(b.5.)	**> 10 MW and ≤ 25 MW**	**90%**	40%	10%	**50%**
	> 25 MW and ≤ 50 MW	**80%**	30%	10%	**40%**
BIOMASS					
(b.6.)	**Energy crops** (≥ 70%)	**90%**	40%	10%	**50%**
	Agricultural and forestry wastes (≥ 70%)	**90%**	40%	10%	**50%**
(b.7)	**Sludges/biogas** (≥ 70%)	**90%**	40%	10%	**50%**
(b.8)	**Agricultural and forestry industries** (≥ 90%)	**80%**	30%	10%	**40%**

The percentages are applicable to the yearly average tariff (TMR), 7,6588 c€/kW for 2006. The final price is the TMR multiplied by the corresponding percentage.

BIOMASS GASIFICATION PLANT ECONOMIC VIABILITY

			Biomass plant lineal payback		Comparison with conventional case		
Biomass type	**Biomass price €/MWh biomass**	**Biomass cost k€/year**	**subsidy**	**without subsidy**	**Operational annual difference Conventional-Biomass k€**	**L. payback years (with subsidy)**	**L. payback years (without subsidy)**
Forest residues (1)	9,40	291	3,2	3,9	147	5,1	6,9
Forest residues (2) Mechanized withdrawal Max distance: 10 km	15,00	464	5,3	6,4	-26	-	-
Forest residues (2) Manual withdrawal Max distance: 30 km	25,00	773	-	-	-335	-	-
Industrial residues (2) Large crushing machine	0,67	20,7	2,0	2,4	417	1,8	2,4
Industrial residues (2) Small crushing machine	5,51	170	2,5	3,0	268	2,8	3,8

Conventional case investment cost (all cases):	664
Sold energy (power + thermal) k€/year	728
Natural gas cost k€/year (all cases):	438
Biomass plant cost k€ (all cases):	1.684
Biomass plant extra cost k€ (all cases):	1.020

(1) IDAE Promotional paper nº 2 June 2002

(2) "Cogeneración con biomasa, los hechos en cifras", Besel S.A. May 2001

12 CONCLUSIONS

- ☑ The gasification technology can transform the solid biomass into a low calorific value gas to obtain higher power efficiency than biomass combustion technologies.

- ☑ In the framework of the POLYCITY Project a new integrated biomass power plant based on reciprocating engines is included with a biomass treatment capacity of about 1000 kg/h.

- ☑ The performed techno-economic study suggest that the use of a dedicate engine for the produced gas will be a better option that the mix of syngas and natural gas.

ACKNOWLEDGEMENT

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SIXTH FRAMEWORK PROGRAMME

POLYCITY