ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Status of the gasification plants in Italy and the main experimental results carried out in ENEA

Antonio Molino - ENEA

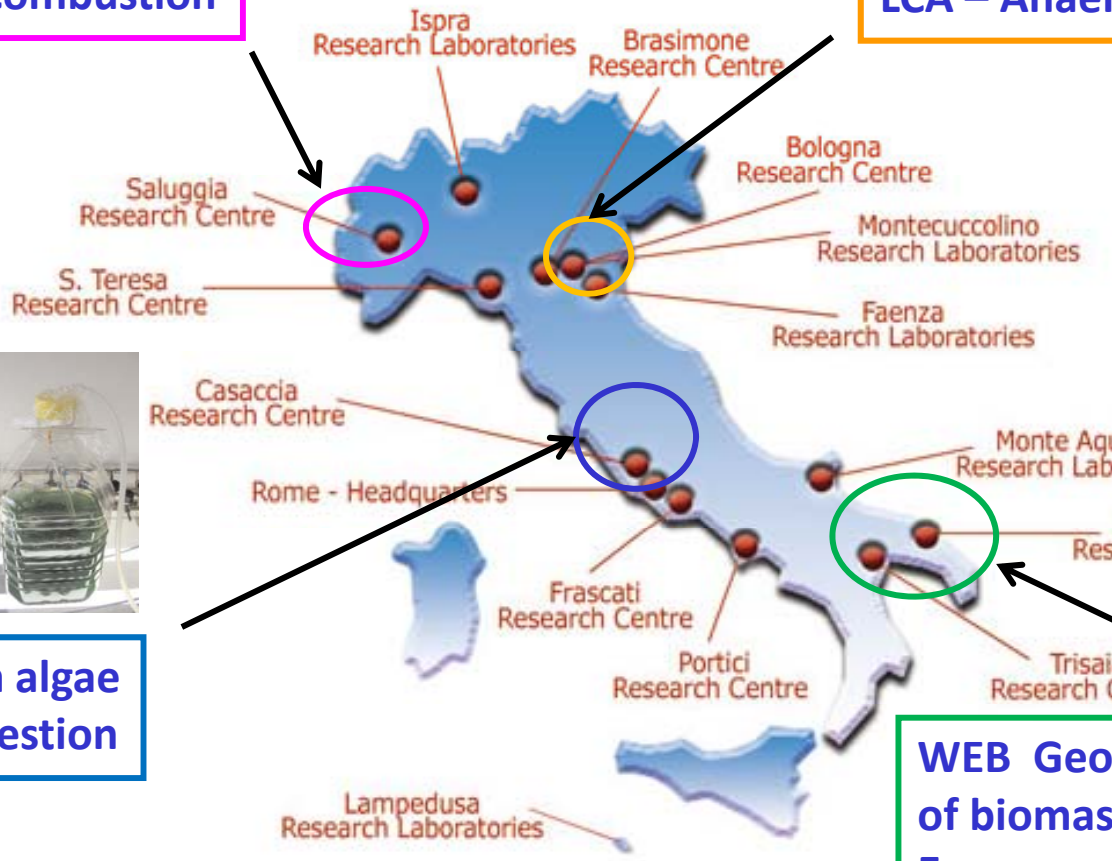
Task 33: Thermal Gasification of Biomass
1st Semi-Annual Task Meeting, 2012

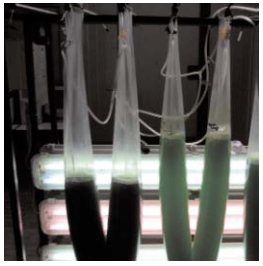
Istanbul, Turkey
Tue, April 17 to Thu, April 19

National Distribution of the ENEA's activity regarding the biomass

Biomass combustion

LCA – Anaerobic Digestion





Biodiesel from algae
Anaerobic Digestion

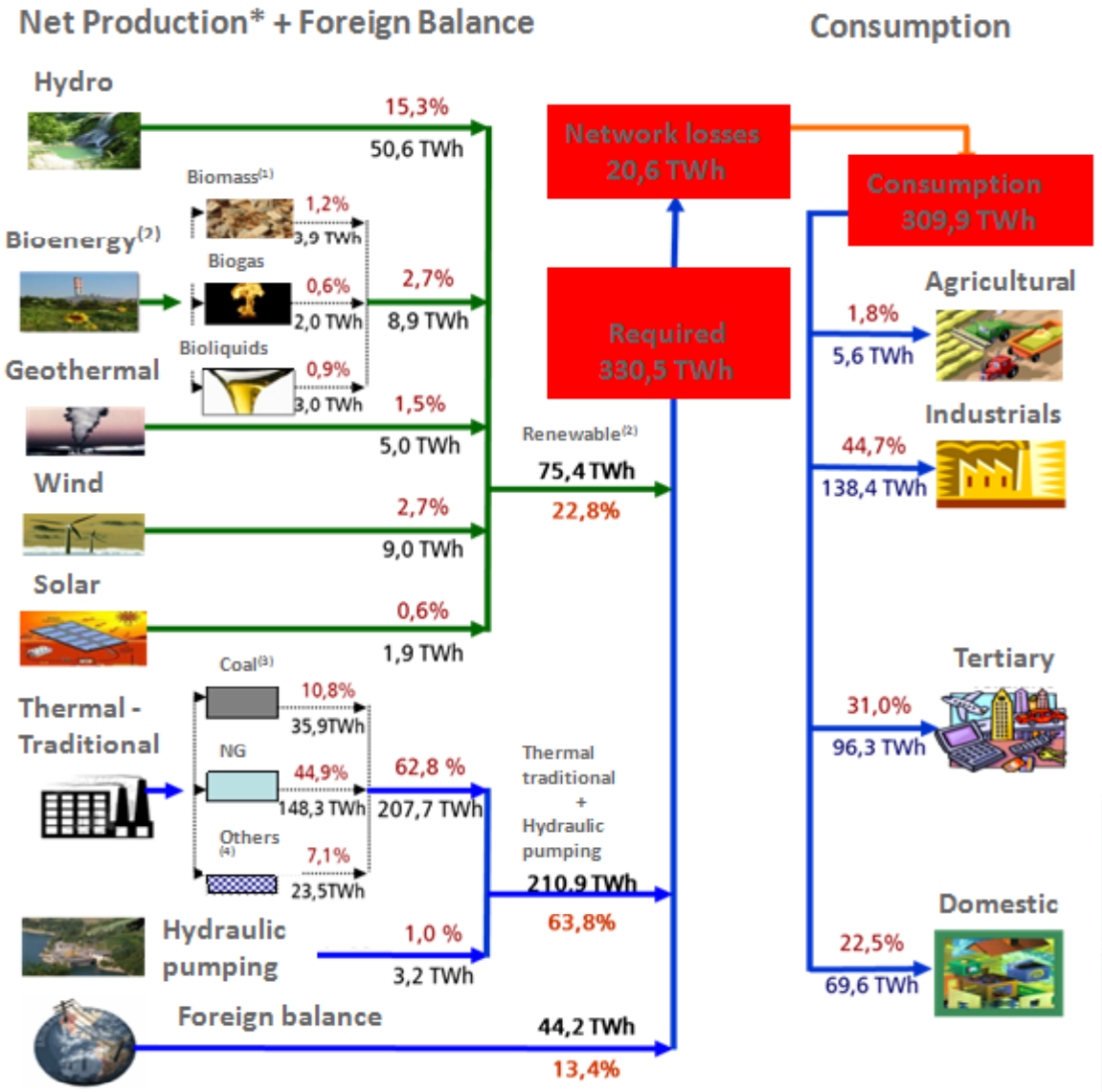
WEB Geographic Information System of biomass
Energy crops
Thermochemical processes
Biofuels of 2nd generation

The development of renewable energy plants

National Electricity balance Year 2010

National demand electricity is **330,5 TWh**, composed by:

- The **44,9%** thermoelectric plants fuelled with **Natural gas**;
- The **22,8%** is the production from **Renewable Sources**;
- The **13,4%** is represented by the **Foreign Balance**.
- The **10,8%** is the production from thermoelectric plants fuelled with **Coal** .



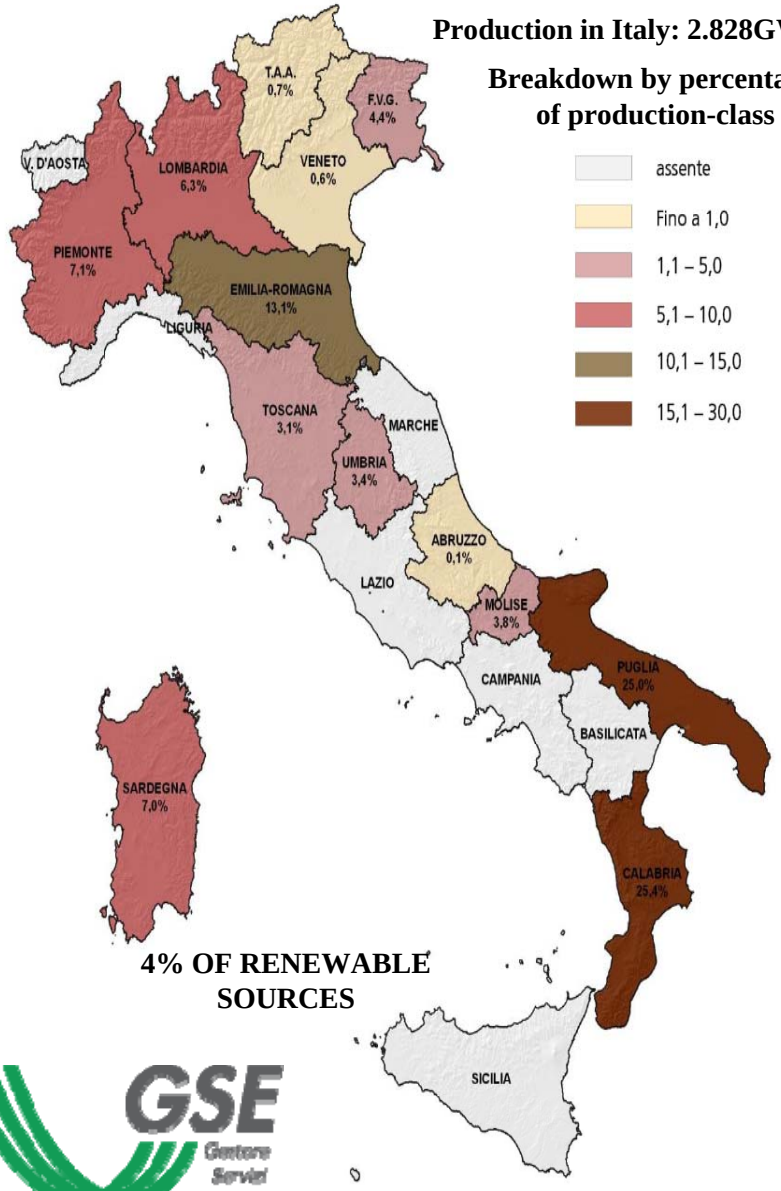
Source: GSE National Manager of the Energy Services

NATIONAL ENERGY POTENTIAL:
Current Status of biomass gasification power plants

ONLY SOLID BIOMASS

Production in Italy: 2.828GWh

Breakdown by percentage of production-class



4% OF RENEWABLE SOURCES

GSE Gestore Servizi Energetici

Source: GSE National Manager of the Energy Services

BIOMASS GASIFICATION PLANT THAT ARE OPERATIONAL IN ITALY

PLANT	POWER (kWe)	MANUFACTURER OF THE SYSTEM	CHARACTERISTICS OF THE PLANT
Belluno(BL)	1000	GAS-1000 MODEL	The plant is fed with 8500t/a of wood
Parma	1000		The plant produces 7.5GWhee 15GWht and it is powered with 9000 t/a of kenaf
Gadesco Pieve(CR)	960	Agroenergia	The pyrogasificator is fed with chopped or chipped vegetable biomass
Alessandria	640		The system is experimental and the process has been developed by poliTO; the plant is fed with 4100 t/a of biomass from forest
Vigevano(PV)	500	Modello GAS-500	The plant produces 3.75GWhe and 7.5 GWht and it is powered with 4100 t/a of wood chips
Caluso(TO)	400	Autogas Nord	The plant is fed with residues of agricultural production, forest biomass, leaves, waste of food industry
Oltrepo Pavese(PV)	300	Bio&Watt	The plant uses an endothermic motor
Castel San Pietro(BO)	250	Bio&Watt	The pyrogasificator is fed with waste prunings, corn stalks, wood chips of poplar
Orzinuovi(BS)	250	Bio&Watt	The pyrogasificator is powered by biomass from forests
Verbania	250	CoVer Energy	The plant is classified as experimental

Gasification is a technology that has great potential in terms of efficiency of conversion of biomass into electricity.
During 2010 requests for qualification that have come to the GSE concern another 20 plants under construction with a total power over 20MWe

Combustion is by far the predominant energy conversion technology

Final consumption

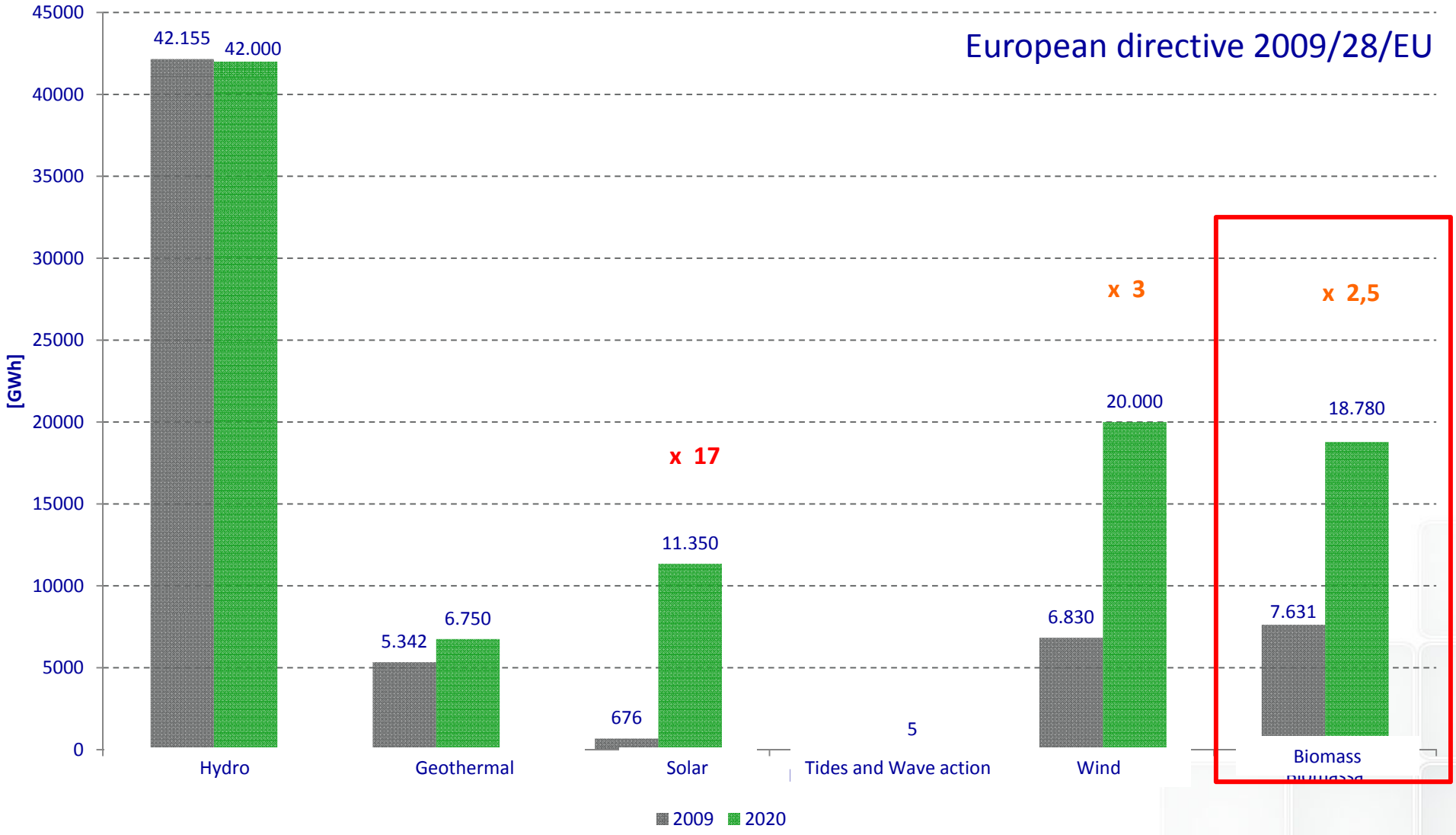
Statistical data for 2008 and estimates to 2020

European directive 2009/28/EU

	2008			2020			
	Consumption from Renewable Energy Sources RES	Gross Final Consumption (GFC)	RES/ Consumption	Consumption from RES	Gross final consumption GFC	RES / Consumption	
	[MTOE]	[MTOE]	[%]	[MTOE]	[MTOE]	[%]	
Electricity	**5,03**	30,40	16,53%	**8,50**	32,23	26,39%	x 1,7
Heat	**3,24**	58,53	5,53%	**10,46**	61,19	17,09%	x 3,2
Transports	**0,72**	42,62	1,70%	**2,53**	39,63	6,38%	x 3,5
Transfers from other states	**-**	-	-	**1,13**	-	-	
Gross final consumption	**8,99**	**131,55**	**6,83%**	**22,62**	**133,04**	**17,00%**	End consumption
Transport for the 10% target	**0,34**	**39,00**	**0,87%**	**3,44**	**33,97**	**10,13%**	

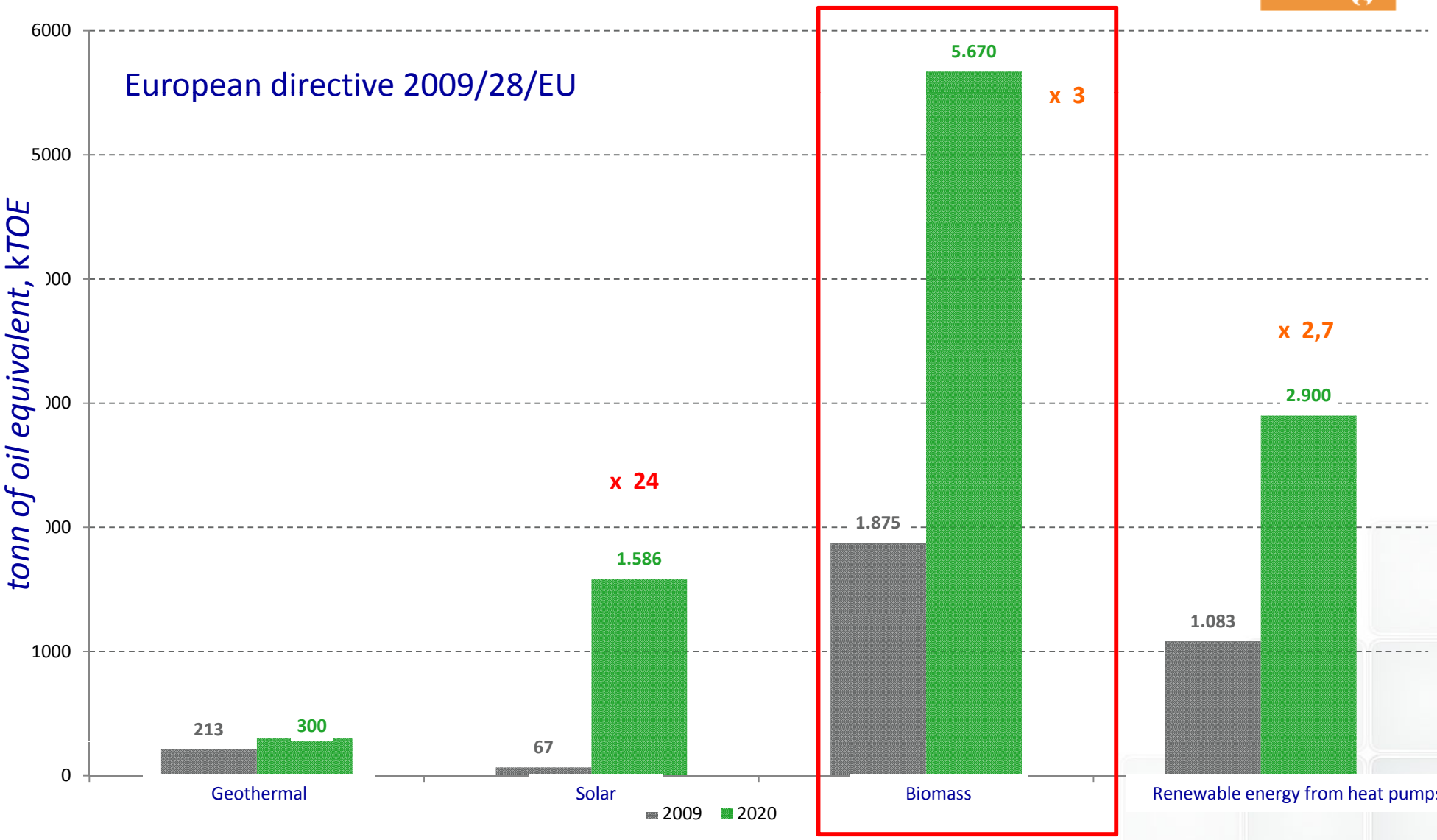
POWER production from renewable energy sources:

statistical data to 2009 and national target to the 2020



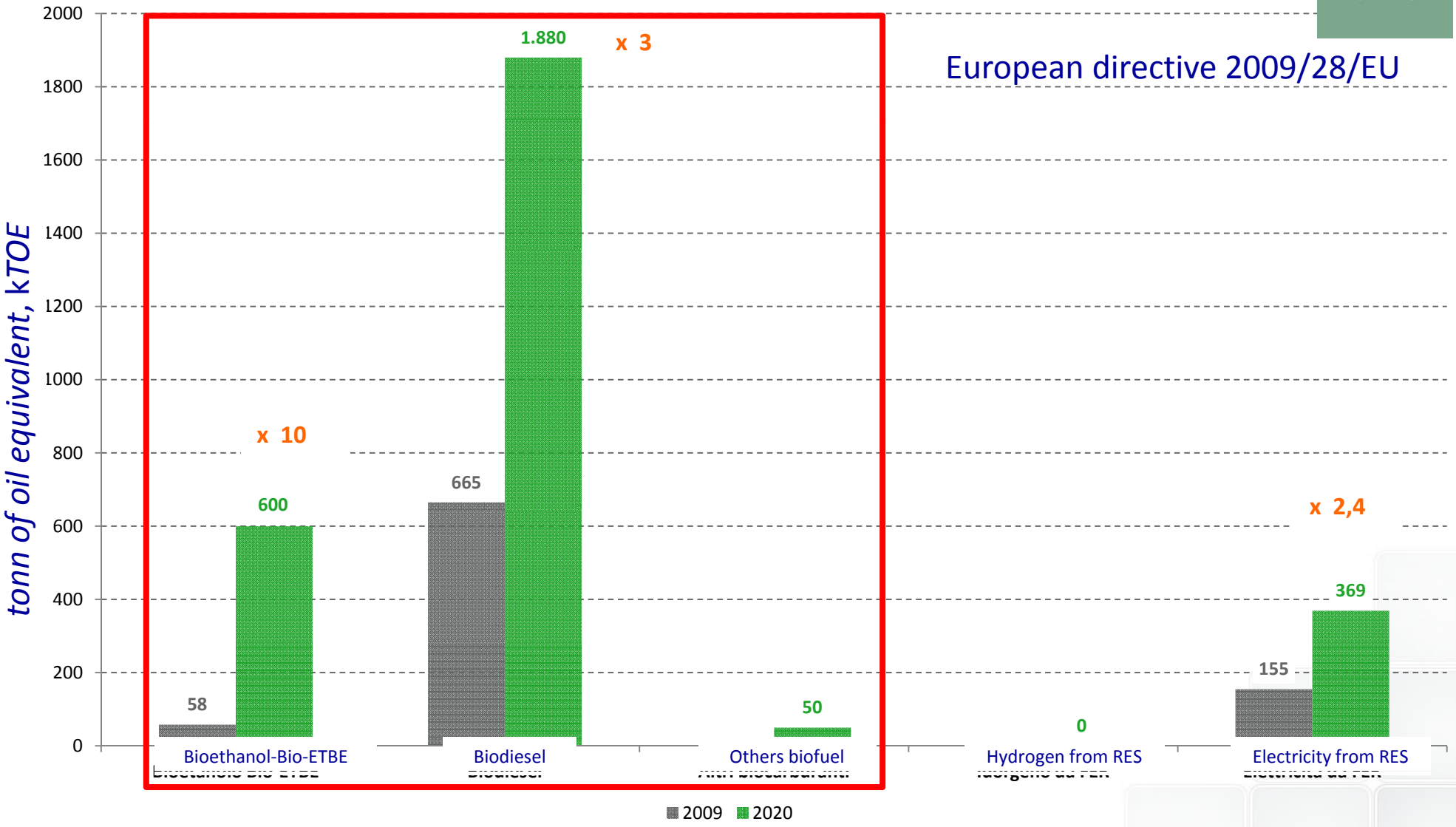
THERMAL production from renewable energy sources:

statistical data to 2009 and national target to the 2020



Energy consumption from renewable energy sources in TRANSPORTS sector:

statistical data to 2009 and national target to the 2020



European directive 2009/28/EU

National incentives for the power production from biomass

Electrical energy:

FIXED RATE of 0.28 €/kWh for plants with size up to 1MWe for 15 years

GREEN CERTIFICATES for plants with size greater than 1MWe; the last year the GC cost was about 87€/MWh depending to the energy market

Thermal energy:

TAX DEDUCTION of 55% of the total cost plant in 10 years for small systems (such as residential)

WHITE CERTIFICATES for the heating networks fuelled by biomass. 1WC is about of 6€/MWh

NATIONAL ENERGY POTENTIAL: FORESTS
Residual Biomass

LIMITATIONS ON POTENTIAL:

- **Forests up 1500m;**
- **Slope roads > 40%;**
- **Accessibility Road;**
- **Protected natural areas.**

WOOD FOREST

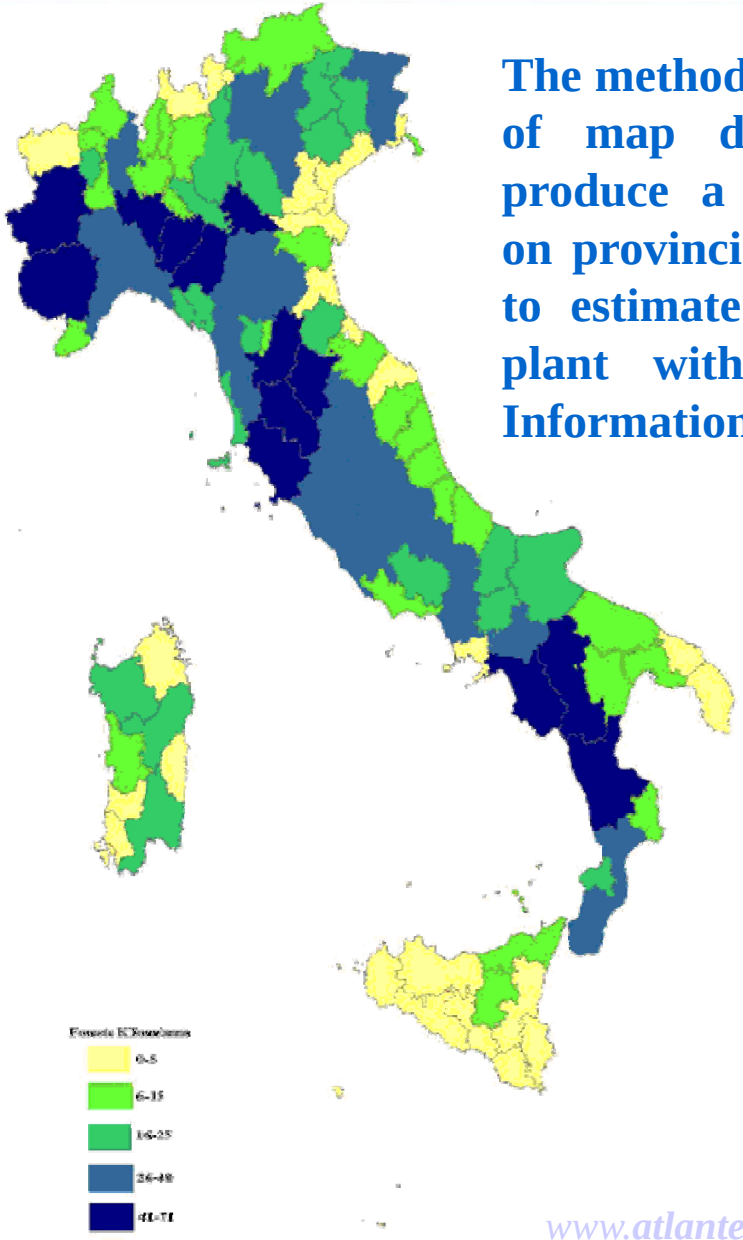
↓

2180 ktonn

↓

~1 MTOE

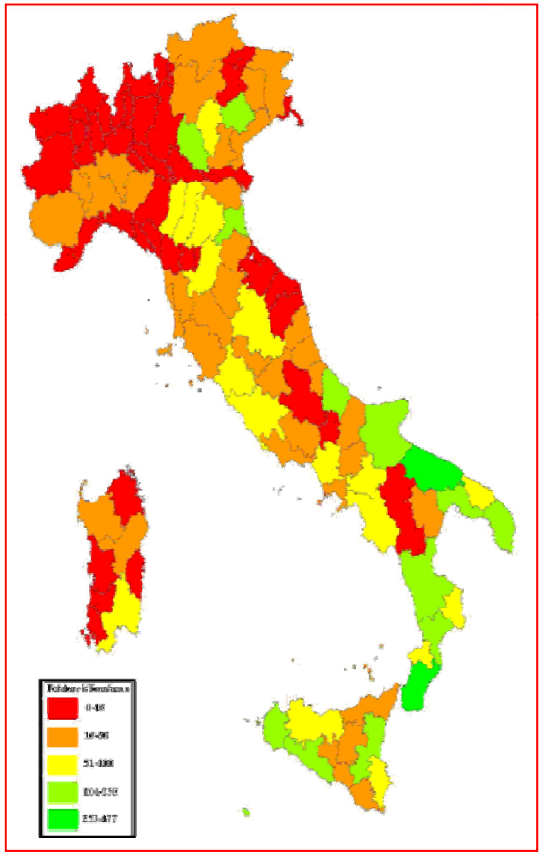
CONSIDERING ONLY THE ROUTINE MAINTENANCE OF FORESTS



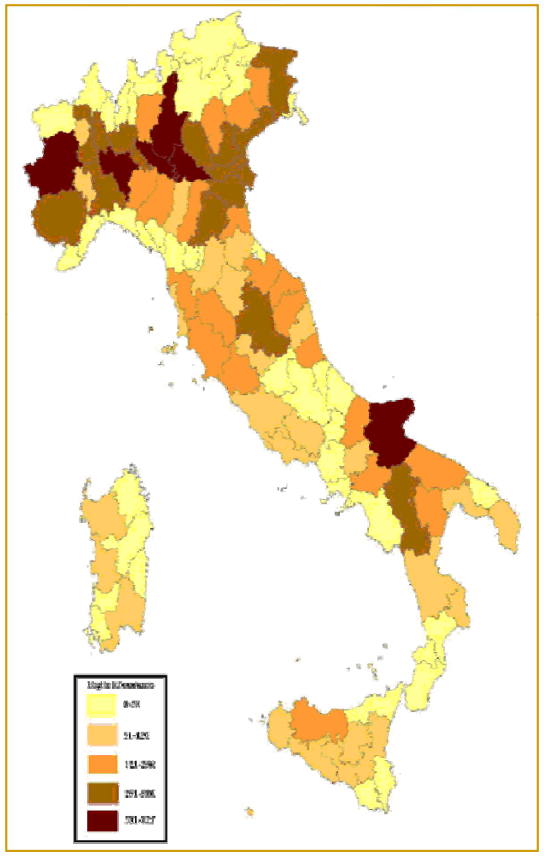
The methodology is based on the use of map data and inventory to produce a geographically detailed on provincial scale that we can use to estimate the size of the power plant with a WEB Geographic Information System.

www.atlantebiomasse.enea.it/

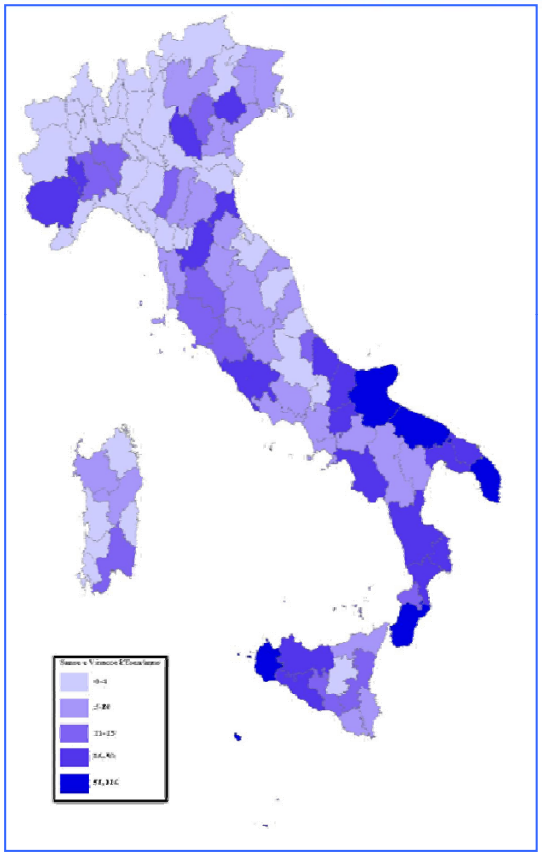
NATIONAL ENERGY POTENTIAL:
Agroindustrial residual Biomass



PRUNING: 4.900ktonn
2MTOE

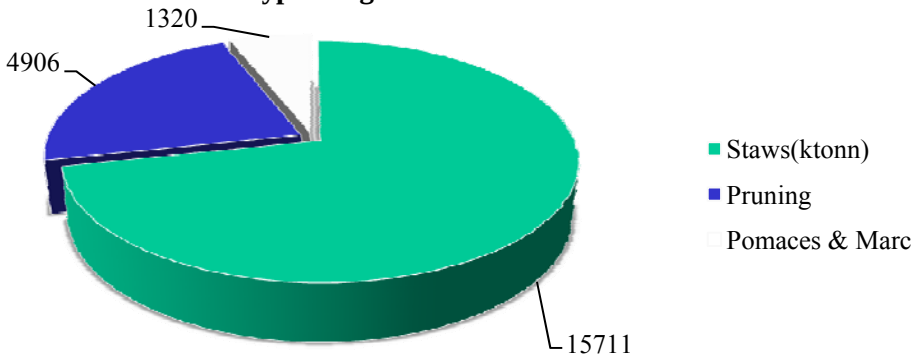


STRAWS: 15.700ktonn
6MTOE



POMACES & MARC: 1.320ktonn
1MTOE

Distribution of different type of agro-industrial biomass



AGROINDUSTRIAL BIOMASS:
22.000 ktonn 9 MTOE

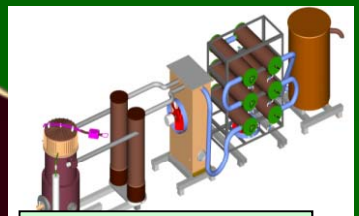
TOTAL BIOMASS 10MTOE ⟺ 53 TWh

Italian electrical consumption 330 TWh (from Terna 2010)

www.atlantebiomasse.enea.it/

ENEA's technological platform for the biomass gasification

compressed air
criogenic gases
hydrogen storage



Fixed bed
P= 30-80 kWe

Interconnected fluidized bed gasifier
1 MW_t

Countercurrent fixed-bed gasifier
150 kW_t

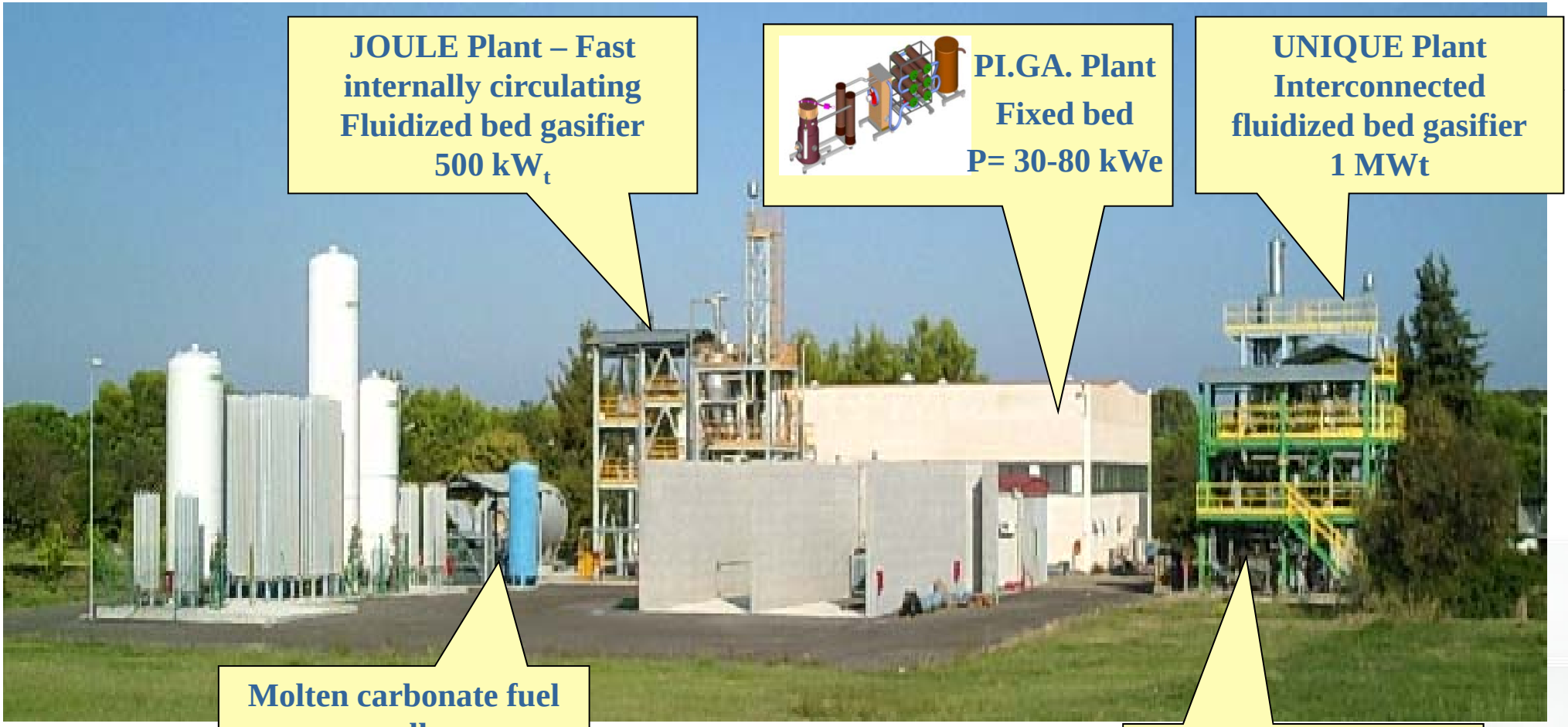
Molten carbonate fuel cell
125 kW_e

JOULE Plant – Fast internally circulating Fluidized bed gasifier
500 kW_t

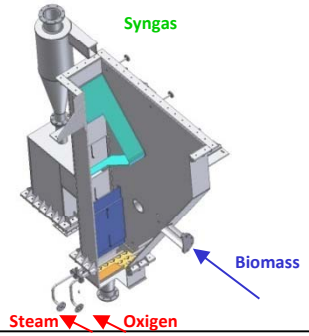
Started: 2008
Finished: 2010

ENEA Trisaia from many years is working in the field of energy conversion of biomass and thermochemical processes and it is equipped with different technologies for the gasification and facility for the power generation.

Current state of the technological platform for the ENEA biomass gasification



The Gasification Technologies In ENEA Trisaia Research Center

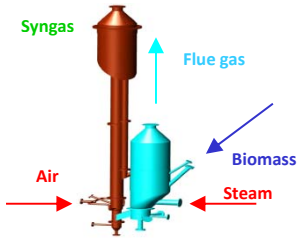


Fluidized bed gasifier with internal recirculation

Enriched Air/Steam 1MWth

Suitable for the power generation both with ICE and fuel cells

SYNGAS COMPOSITION	
Specie	*%Vol.*
H_2	32
CO	17
CH_4	6.2
N_2	0.9
CO_2	20.9
H_2O	32

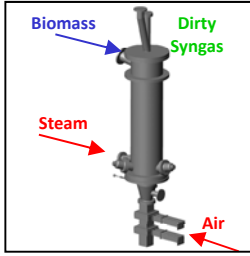


Internally Circulating Fluidized Bed technologies

Air/Steam 500kWth

Suitable for the power production both with MCI and fuel cells, or for biofuel production from Fischer Tropsch process

SYNGAS COMPOSITION	
Specie	*%Vol.*
H_2	34.1
CO	25.1
CH_4	10.4
N_2	9.6
CO_2	20.8

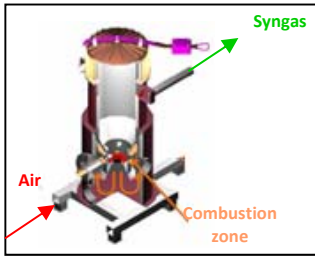


Fixed bed updraft

Air/Steam 150kWth

Suitable for the power generation with ICE only if there's a good syngas cleaning

SYNGAS COMPOSITION	
Specie	*%Vol.*
H_2	20
CO	21
CH_4	4
N_2	40
CO_2	6
H_2O	9



Fixed bed downdraft

Air/Steam 150-450kWth

Suitable for the power generation with ICE

COMPOSIZIONE SYNGAS	
Specie	*%Vol.*
H_2	15
CO	22
CH_4	3
N_2	40
CO_2	20

PI.GA – Downdraft gasifier

Downdraft gasifier of 150-450kWth

Cleaning Section:

The cleaning section is composed of four filtration stages:

- Cyclone
- Scrubber
- Disk filter
- Sawdust filter

Power Generation Section:

The power generation is composed of a Diesel engine modified to Otto cycle with gas feeding, coupled with an alternator.

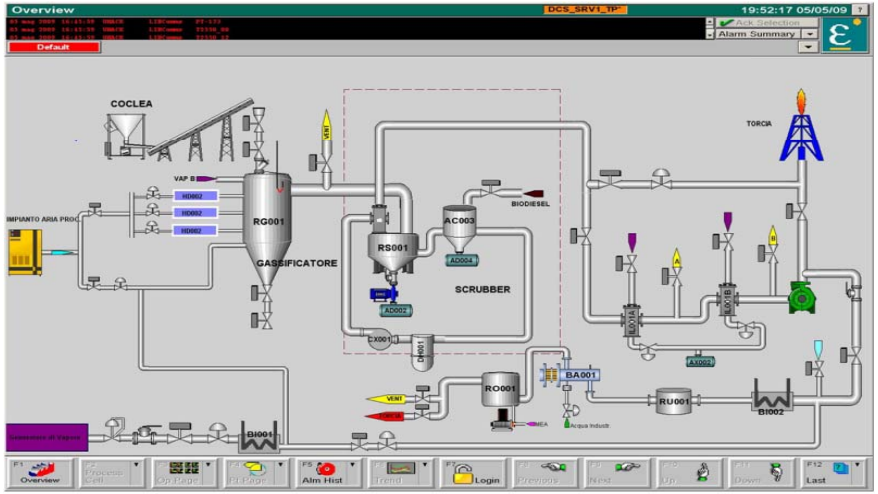
The load generated is dissipated by means of electric resistances and the total power dissipation is approximately 30 kWe with the possibility of adjusting the electric load step of 1 kW

IVECO 82100 2200giri/min 40kWe

	Syngas composition
Carbon dioxide	14,24
Propane	0,78
Ethane	0,17
Hydrogen	12,11
Oxigen	1,70
Nitrogen	48,68
Methane	1,97
Carbon monoxide	20,35
LHV KJ/Nmc	**5407,27**
HHV KJ/Nmc	**5794,34**
D [kg/Nmc]	**1,21**

PRAGA PLANT - Updraft gasifier 150kWth

Funded by the Ministry of University and Research for 5.112.000€ – MIUR Finished: 2009



Tests were carried out using almond shells as feedstock and operating the gasification at the following conditions: ER~0.20, steam/biomass ~0.4, and atmospheric pressure.

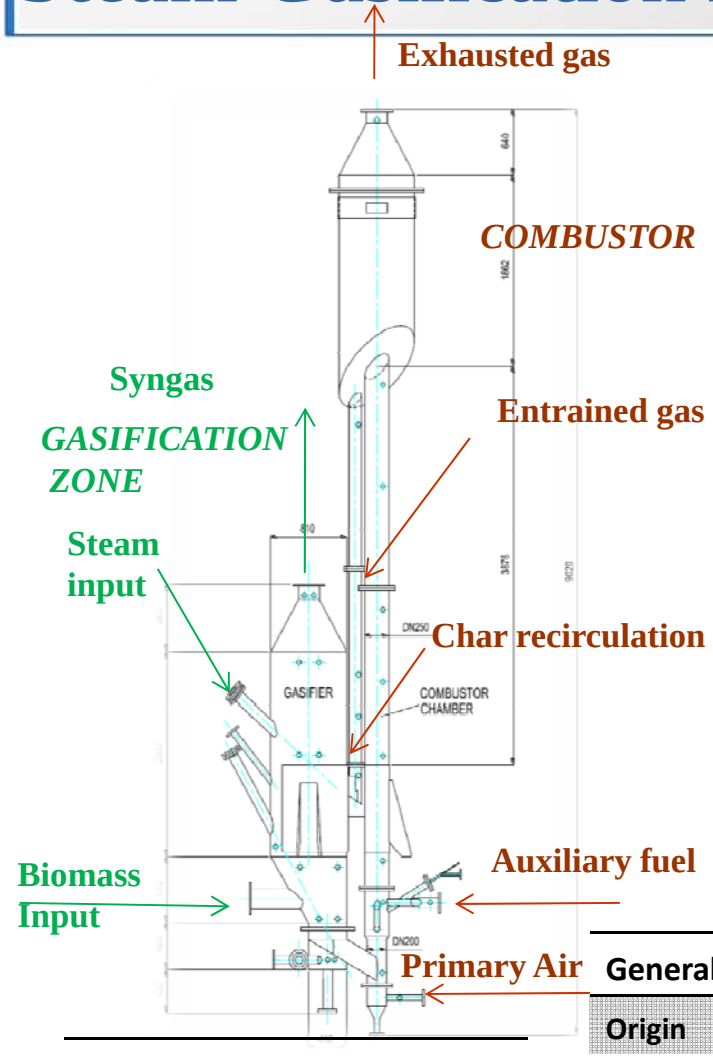
Process Characteristics	
Main feeding	Almond shells
Nominal flow rate	30-40 Kg/h
Gasifying medium	Mix Steam-Air
Nominal power	200 kW_{th}

Gas Components	%vol. dry
H_2	21
CO	22,8
CO_2	13,4
CH_4	~1
C_3H_8	<1
O_2	<1
N_2	41
LHV (kJ/Nm^3_{dry})	5,7

Analitycal Technique	Total Tar content (g/Nm^3_{dry}) [a]		Removal efficiency ($\%_{wt}$)
	Gasifier	Scrubber	
Gravimetric	66.0	0.91 [b]	98.6
Chromatographic [d]	11.4	0.32 [c]	97.4

a) According to the CEN/TS 15439 procedure; standard dev: 5-10%
b) as sum of both tar and biodiesel.
c) calculated as sum of all molecules quantified by chromatographic analysis
d) value referred to only tar molecules detectable at the GCMS instrument.

JOULE PLANT:
Steam Gasification Pilot Plant of 500kWt

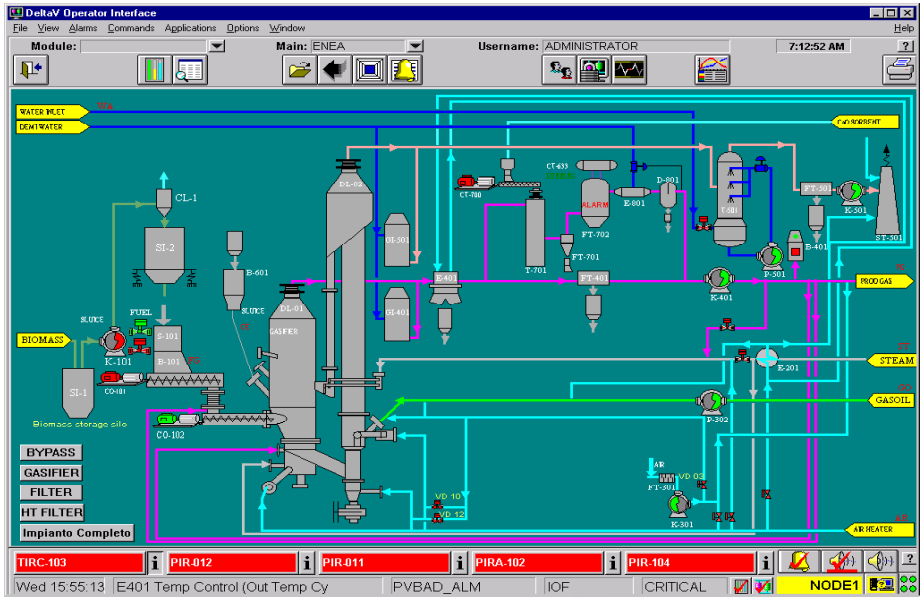


Gasifier developed in collaboration with Vienna University of Technology, University of L'Aquila, Louis Univ
Filter system

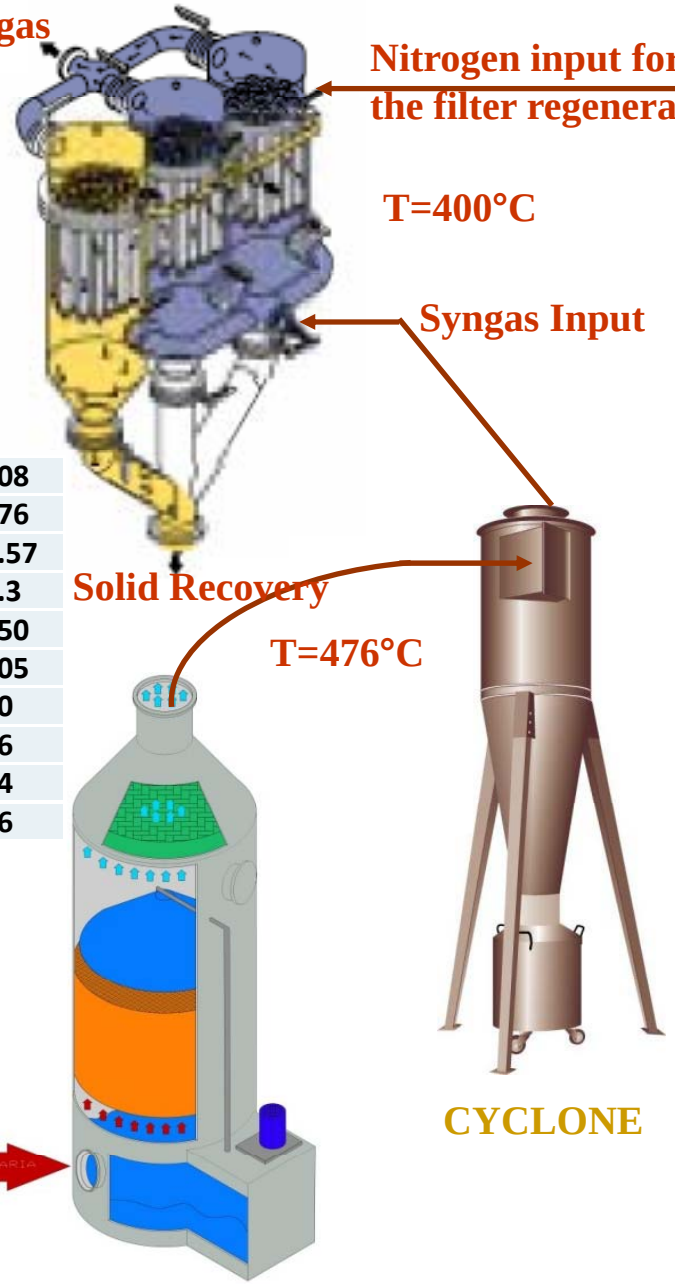
Fast Internally Circulating Fluidized Bed technologies FICFB

Composition	Olivine sand
$\%SiO_2$	41.9
%MgO	49.5
$\%Fe_2O_3$	7.1
$\%Al_2O_3$	1
$\%H_2O+\%CO_2$	0.5

General Features	of the Olivine
Origin	Austria
Density	3400-3500 kg/m3
Bulk Density	2050-1900 kg/m3
Medium Diameter	344 µm
Thermal Expansion	(1100°C) 1.3%
Mohs Hardness	6.5-7
Specific Heat	0.95-1.05 kJ/kg °C

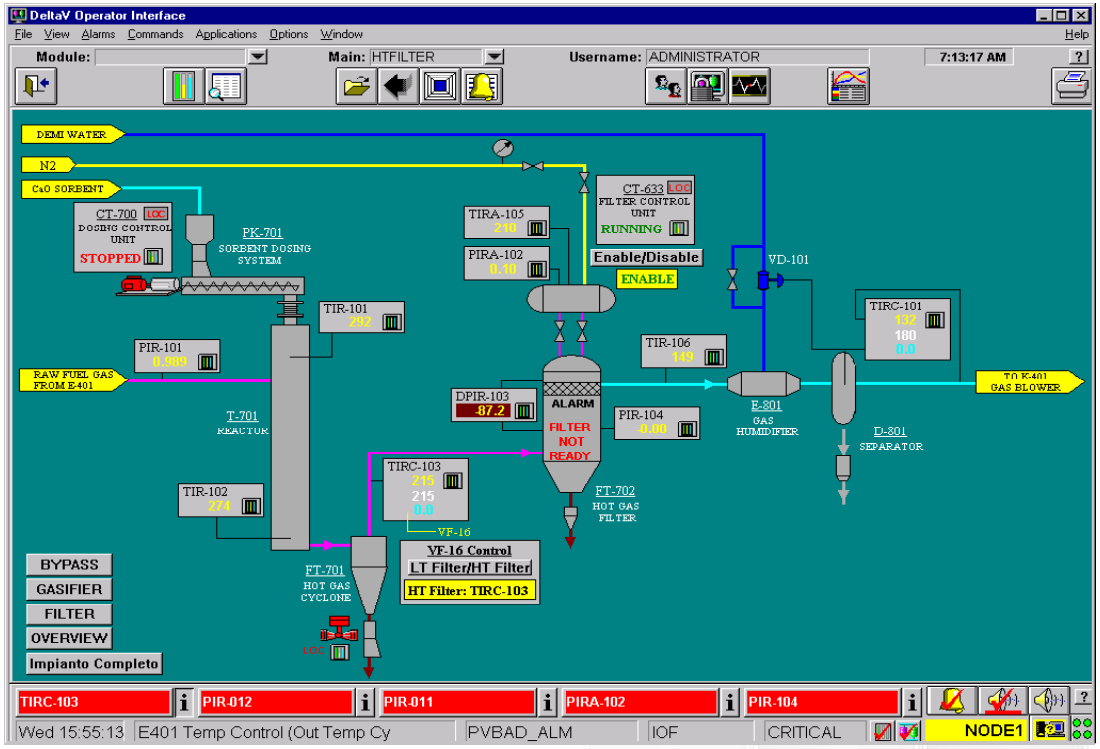


HOT GAS CLEANING : Experimental Results



Tin [°C]	508
Tout [°C]	476
CaO [kg/h]	0.57
Ca/(Cl+S) [molar]	4.3
H_2Sin [ppmv]	250
HClin [ppmv]	105
H_2Sout [ppmv]	40
HClout [ppmv]	36
SR [%]	84
ClR [%]	66

Performance of the Hot gas cleaning section	
Outlet H_2S concentration	~ 40 ppmv
Sulphur removal efficiency	84%
Outlet HCl concentration	~ 30 ppmv
Chlorine removal efficiency	70%
Cyclone removal efficiency (d=2 µm)	95 %
Tars(g/Nm^3)	10
Particle out	2,1 mg/Nm^3



UNIQUE PLANT

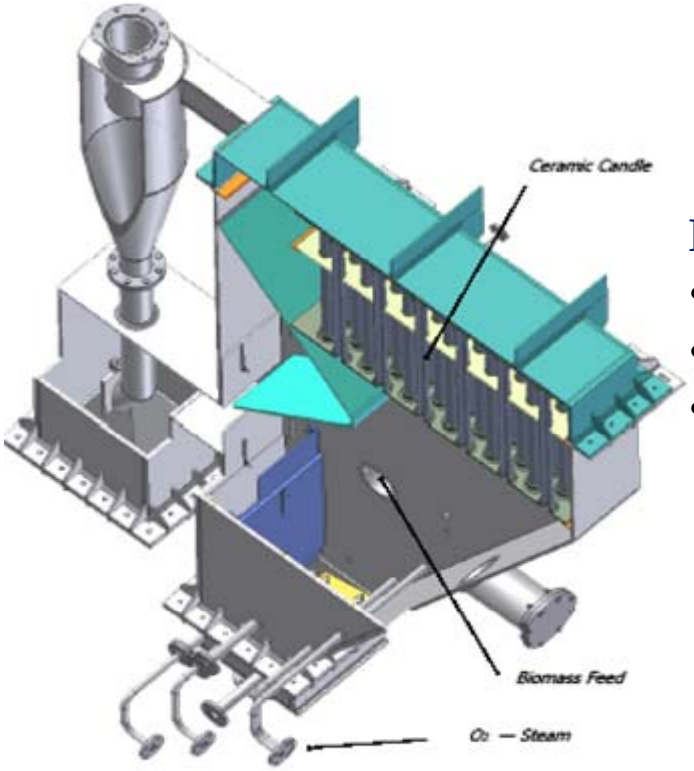
Funded by 7°FP
Finished: 2011
Financing of 3.715.503 €

Fluidized bed gasifier with internal recirculation of 1MWth

Enriched Air/Steam

Patent

RM2008U000022



Main advantages of the UNIQUE plant:

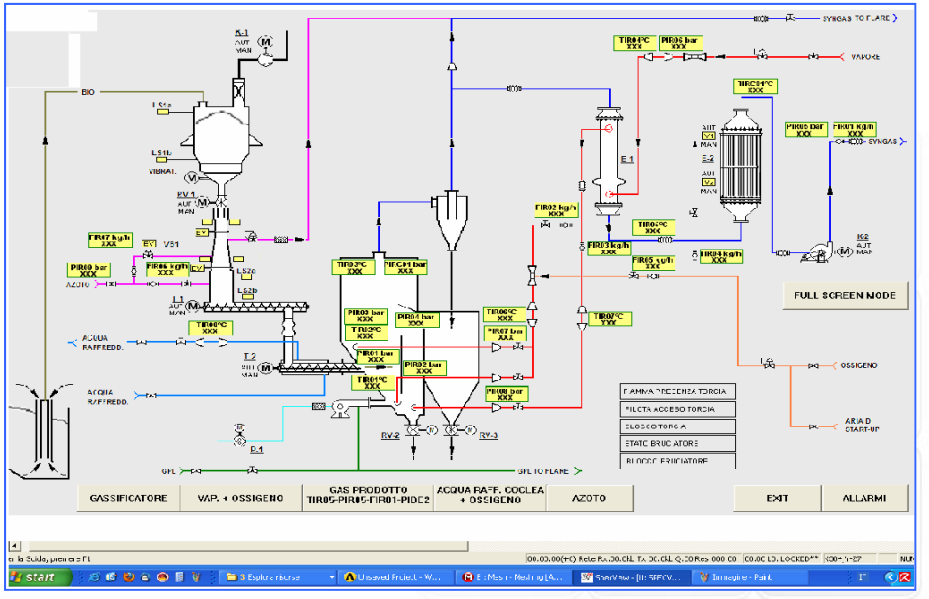
- **Higher hot gas cleaning;**
- **System more compact;**
- **Reducing both the investment costs and the operative costs**

Partners :

UNIVAQ, PALL, ULP, TUV, UPT, CSIC, IEN, ENEA, FZJ, BKG

Syngas composition	
Specie	**%Vol.**
H_2	32
CO	17
CH_4	6.2
N_2	0.9
CO_2	20.9
H_2O	32

Product Stream	
Syngas	**385Nmc/h**

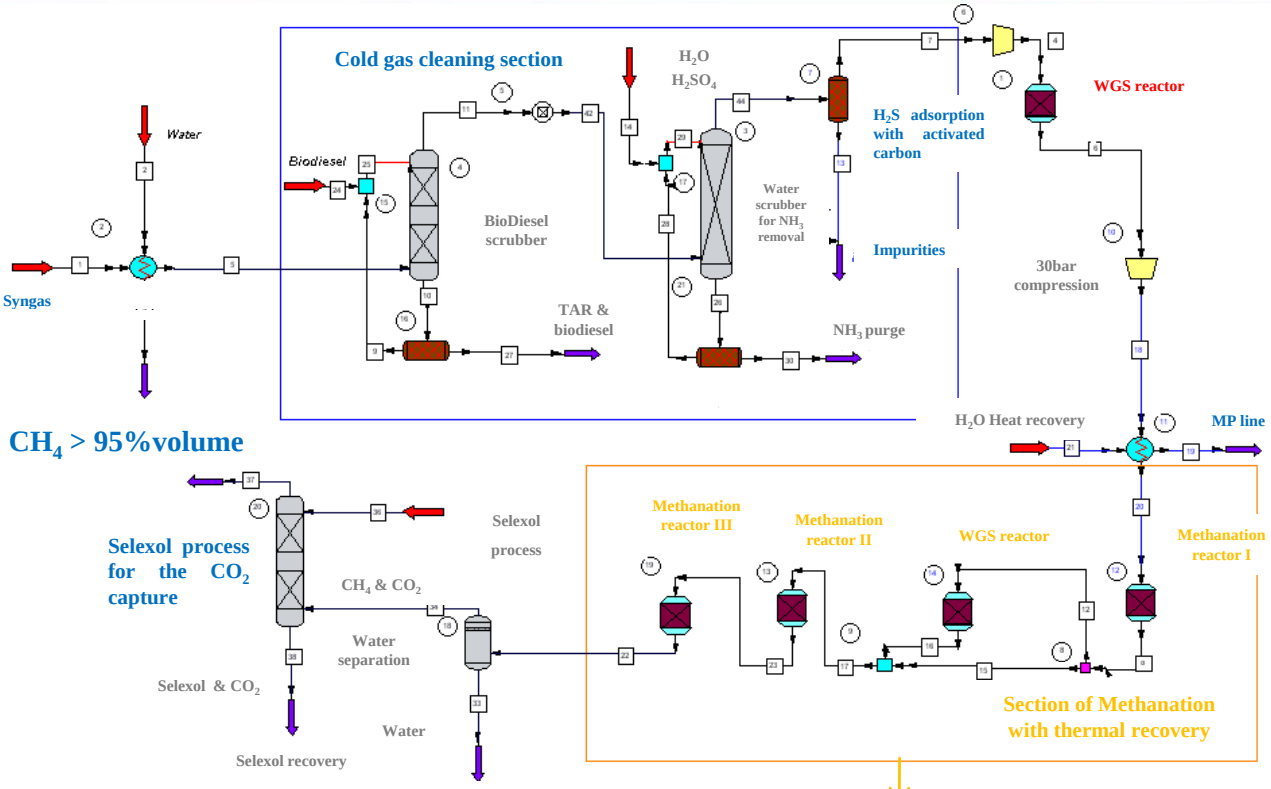


Current activity lines: Production of bio-SNG from syngas

Fluidized Bed of 1MWth

Patent
RM2008U000022

SYNGAS COMPOSITION	
Specie	%Vol.
H_2	32
CO	17
CH_4	6.2
N_2	0.9
CO_2	20.9
H_2O	32



Chemical Yield about of 60-75%

INTERMEDIA STAGES FOR PRODUCTION OF THE SYNTETIC NATURAL GAS

- Cold gas tars cleaning;
- Water scrubber for ammonia absorbing;
- Neutralization of acidic substances by use of low cost sorbents;
- CO-shift reactor for increase the H_2/CO ratio necessary for the methanation stages:

$$CO+3H_2=CH_4+H_2O \quad \Delta H^{\circ}_{Reaz} = -206{,}28 \text{ kJ/mol}$$

- Compression stage for improve the thermodynamic conditions and for obtain a bio-SNG to high pressure suitable for the grid injection;
- Selexol process for CO_2 split-up from the syngas

An example of Synthetic Natural Gas production from lignocellulosic biomass

The ENERPARK Project

The project was funded by Basilicata Region with the EU Structural Funds PO FERS 2007-2013 through which the EU aims to streng then economic and social cohesion of its territory by correcting imbalances between the regions.

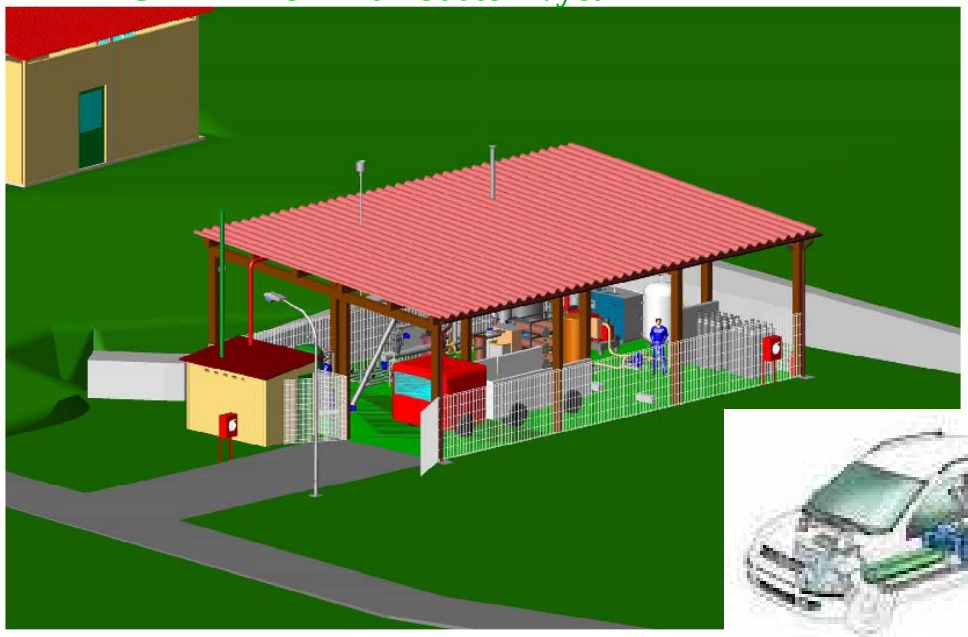
Started: Dicember 2011
Term: 2 Years
Funded: 500k€

The project provides the construction of a gasification plant coupling with a methanation plant for increase the biomethane content in the syngas.
The biomass used for the process derive from the routine maintenance of the Gallipoli Cognato's foresty

PRUNINGS

PLANTS OLD AND DISEASED

ENERGET INPUT max 800tonn/year



A second step of the project provides the use of biomethane for the service cars for the workers in the park

ENERGETIC OUTPUT

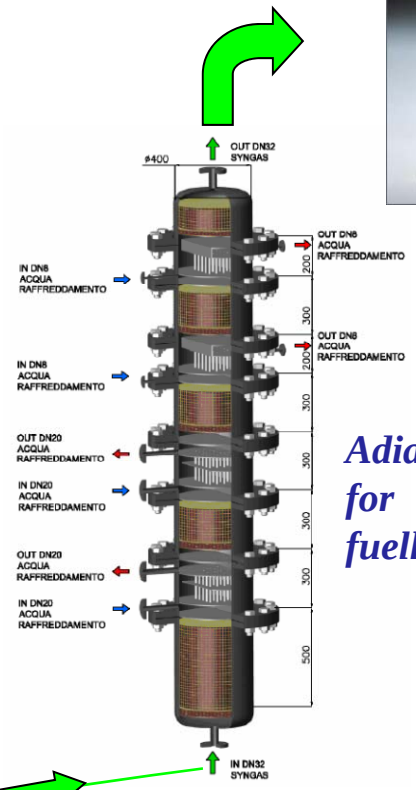
BIOMETHANE for the AUTOMOTIVE sector

Min 300.000km/anno

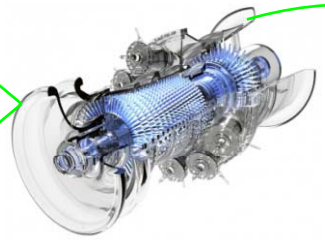
Current activity lines: Supercritical water gasification SCWG

Advantages of the SCWG process:

- **The presence of water in supercritical form promotes the reactions of hydrolysis, facilitating the ability to attack polymeric structures such as reducing the lignin to more easily processable oligomers;**
- **The SCW is a reagent, in fact up to 50% of the hydrogen product comes from the water;**
- **Never pretreatment processes for biomass, indeed its presence facilitates the process;**
- **It promotes the reactions of the water gas shift further enriching hydrogen in the syngas product;**
- **Produces a syngas TARS free;**
- **It can be use also for sewage sludge.**



Adiabatic catalyst stages reactor for liquid biofuels production fuelled by CO_2/H_2



Heat & Power

End-uses of the syngas produced by the process SCW

- **Easily removal of CO_2 into syngas being already pressurized;**
- **Highest hydrogen content in the syngas;**
- **Cleaning of the syngas more efficiently and with lower processing costs**
- **Using the syngas such (H_2/CO_2) in catalytic processes for the production of liquid biofuels;**
- **Economical process also for sewage sludge**

Other project working in ENEA

BRISK - Biofuels Research Infrastructure for Sharing Knowledge

BRISK is funded by the European Commission Seventh Framework Programme (Capacities)

The initiative runs from 1st October 2011 to September 2015. 8.98M€ funded

BRISK aims to develop a European Research Infrastructure for Thermochemical Biomass Conversion, supporting R&D on innovative processes to convert sustainable feedstocks (agricultural/forestry wastes and energy crops) into liquid, gaseous or solid fuels. The specific aim of BRISK is to overcome fragmentation in R&D facilities for thermochemical technologies, by enabling researchers to have access to high-level experimental facilities and services across Europe. The BRISK network will encourage and facilitate cooperative research in the specialised laboratories of project partners. The facilities are also open to researchers outside the project

Industry 2015: HY-Tractor project

Tractor-powered with a Fuel Cell fuelled to syngas

HY-Tractor project is funded by the Ministry of Economic Development
4.51M€ funded

The initiative runs from 1st October 2010 to September 2014.

The project involves the construction of an innovative and ecological sub-surface seeder provided with electrical rather than pneumatic or hydraulic actuators. Electric actuators guarantee for higher level of control, which enable the development of advanced planting techniques, i.e. techniques including the use of GPS.

“The best way to predict the future is to build it”

(Peter Drucker)

Thanks for your attention

Antonio Molino ENEA
antonio.molino@enea.it
+39 0835974736

Main experimental results: Effect of SBR and temperature

Feed: Almond Shell	N° 1	N° 2	N° 3	N° 4
Biomass [kg/h]	57	57	87	92
SBR(steam biomass ratio)	1.7	1.4	1	0.9
Temperature [° C]	795	816	839	835
CO [% vol.]	19.0	20.6	23.6	25.1
CO_2	20.6	20.8	21.6	19.3
H_2	26.0	33.4	32.7	33.1
CH_4	9.2	9.1	9.6	10.4
C_2H_6	0.2	0.2	0.1	0.2
C_3H_8	2.2	2.1	2.4	2.3
N_2	22.8	13.9	9.9	9.6
PCI [MJ/Nm^3]	10.62	11.44	12.21	12.71
Syngas[kg/h](dry basis)	74	55	122	119
Efficiency	45	39	70	72

Experimental tests	N° 1	N° 2	N° 3	N° 4
Biomass[kg/h]	57	57	87	92
Process Temperature [° C]	795	816	839	835
SBR	1.7	1.4	1	0.9
Tar experimental(g/Nm^3)	10.6	11.4	12.7	12.2
PCI [MJ/Nm^3]	10.62	11.44	12.21	12.71
Syngas[kg/h](dry basis)	74	55	122	119

GC-MS Analysis: Tar High Temperature