

Thermochemical Conversion Technologies

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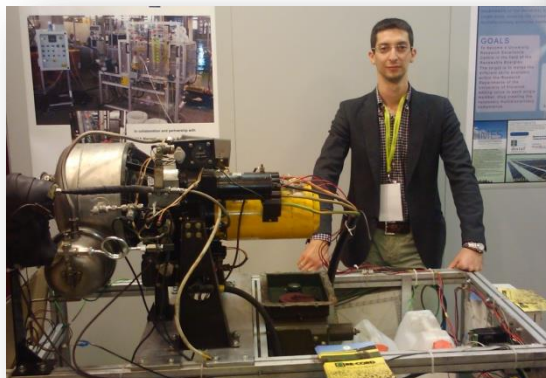


Summary

- RE-CORD / CREAR
- Thermochemical conversion processes
- Gasification
 - ⇒ Cooperation with IIS
- Norms
 - ⇒ Raccomandazione CTI
 - ⇒ GAST project
- Examples of plants
- Conclusions



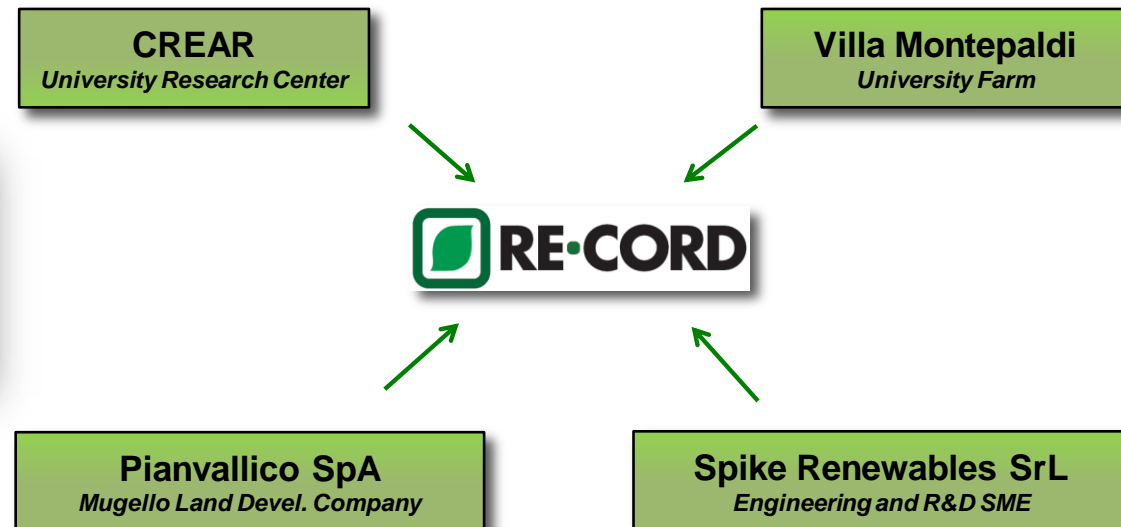
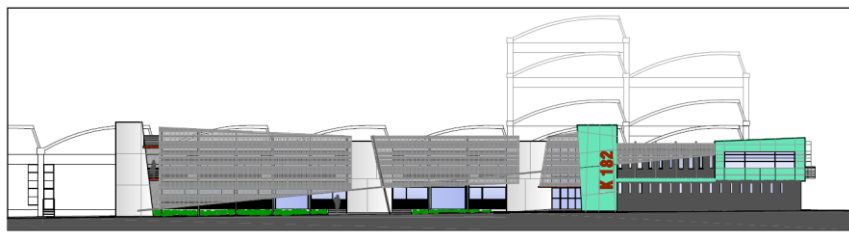
Our group...



➤ RE-CORD – Renewable Energy Consortium for R&D

- **Chemical laboratory fully** dedicated to Bioenergy/Biofuels and Renewables (**Pianvallico** area)
- Various equipments for **Biomass energy conversion**, and **Solar** and **Wind** energy assessments
- **1 ha fenced experimental area** at the **Villa Montepaldi** Farm (300 ha University farm)
- **Preliminary and detailed engineering skills** through **Spike** Renewables SrL
- Academic **R&D skills** through **CREAR**/Dept. of Energy Engineering/Dept.s of Agriculture
- Various Renewable Pilot Plants

RE-CORD MEMBERS



Some National & International Networks

- **Internat. Energy Agency – Bioenergy: Country representant T39**
 - ⇒ T39, Liquid Biofuels, jointly with M&G Group (formerly: T34-Biomass Pyrolysis)
- **EU Biofuel Technology Platform**
 - ⇒ WG4-Sustainability
- **Italian Biofuel Technology Platform**
 - ⇒ WG2 – Conversion
- **ISES-Italia**
 - ⇒ Ital.sect. of Int.Solar Energy Society-Board of Dir.
- **DBFZ**
 - ⇒ German Biomass Res.Center-RAC (Chair of Research Advisory Council)
- **THERMALNET** (Intelligent Energy for Europe)
- **Coordination of EC-R&D&D and IT-MATT projects**
- **Support to EC and Ministries for proposal evaluation and proj.monitoring**
- **International Master Course IMES on Bioenergy and Environment**
 - ⇒ **The 1st Italian Master on Bioenergy (established in 2002)**
 - ⇒ Jointly developed with Univ.Nova de Lisboa, Aston Univ. and three US Universities in the framework of an EU DG Education project



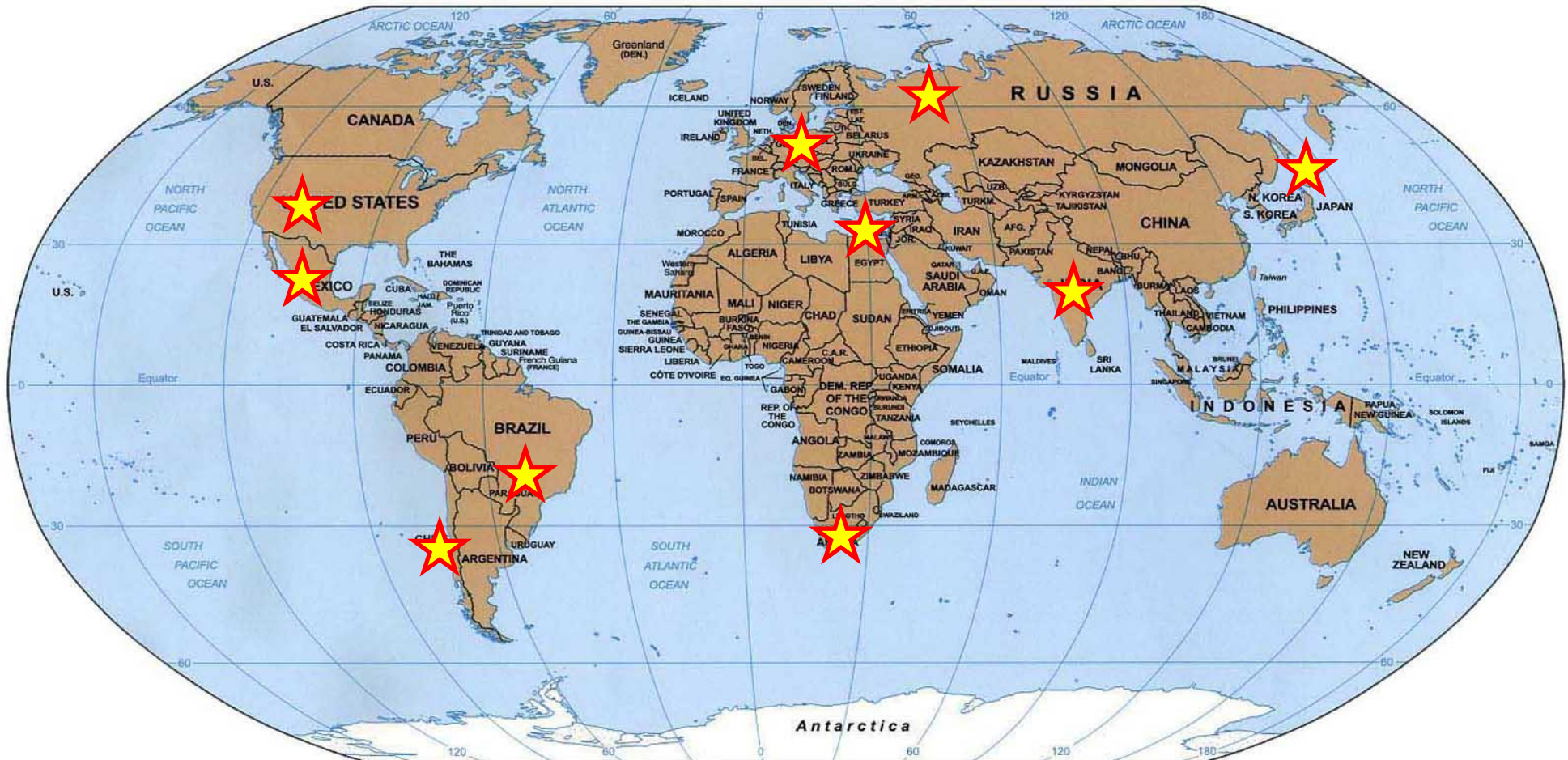
Some industrial partnerships

- **Mossi & Ghisolfi / Chemtex (IT)** → Lignocellulosic ethanol, advanced & aviation biofuels, green chemicals
- **SILO (IT)** → Esterified vegetable oil (from waste cooking oils, fatty acids, etc)
- **Yanmar (Jap)** → Research on bioenergy (gasification, biofuels)
- **NESTE Oy (FI)** → Aviation biofuels
- **Novamont (IT)** → Green chemicals, biofuels
- **Galigani Filtri (IT)** → Design and construction of cold extraction vegetable oil plant
- **VWP (DE)** → Straight vegetable oil engines
- **Riello (IT)** → Test on vegetable oil burners
- **Novaol/Biodiesel producers (IT)** → Innovative microalgae cultivation
- **IBT/Capstone (IT/US)** → Microturbine adaptation to liquid biofuel feeding
- **TURBEC (IT)** → Microturbine minor modifications for external combustion configurations
- **BTG Biomass technology group (NL)** → Biomass pyrolysis, pyrolysis oil test in an adapted microturbine
- **SEA Marconi (IT)** → Design and construction of biomass torrefaction and pyrolysis reactors
- **Mawera - Viessman (A-DE)** → Solid biomass furnace development
- **Fotosintetica & Microbiologica (IT)** → Algae cultivation and biofuel production
- **AlgaeFuels (Chile)** → Algae cultivation and biofuel production

Some Research Partnerships

- **ENEA (IT)** Biomass gasification systems, bioethanol production, steam explosion treatments
- **CNR – Istituto Motori (IT)** Tests and advanced measurements on biofuels spraying and combustion behavior
- **CRA (IT)** Research on lignocellulosic biomass and vegetable oils
- **Indian Institute of Science and Technology (Bangalore - INDIA)** Biomass gasification systems
- **Aston University (Birmingham - UK)** Pyrolysis process and technologies, International Master IMES
- **CSGI Consortium for large interphase systems (IT)** Emulsion of diesel and biofuels for use in prime movers
- **TUG Technical University of Graz (A)** Biomass combustion systems, CFD simulation of biomass combustion
- **Imperial College of London (UK)** Assessment on biofuels market, potential and perspectives
- **IFEU (Heidelberg - DE)** LCA on power production from renewable resources
- **Agronomic department (Florence – UK)** Energy-crop activities
- **VTT (FI)** Biomass pyrolysis
- **DBFZ (DE)** Biomass conversion technologies
- **FCT, Universidad Nova de Lisboa, (PT)** Vegetable oil related activities
- **Boreskov Inst.of Catalysis (Novosibirsk, RU)** Catalytic treatment of biofuels and emission reduction from power
- **University of Bolzano (IT)** Biomass gasification
- **Scuola Superiore S.Anna (IT)** Biomass production, LCA, bioenergy technologies, resource assessment (GIS)
- **Università Politecnica delle Marche (IT)** Biomass gasification

International activities



Short list of pilot plants available at RE-CORD/CREAR

- Intermediate and catalytic **biomass pyrolysis** pilot unit (1.5 kg/h)
- Open-top twin-fire **gasification** unit (up to 100 kg/h, 100 kWe)
- Downdraft Imbert-type **gasification** system (10 kWe)
- Capstone **microgasturbine** converted to biofuels (30 kWe)
- Garret **microgasturbine** converted to raw biofuels (20 kWe, 40 HP)
- **Externally fired biomass/NG gas turbine** system (50-100 kWe)
- **Straight vegetable oil engine-based microCHP** (5 kWe/10 kWth)
- **Straight vegetable oil engine** (7 kWe)
- Pilot **ponds for algae** cultivation (in collaboraiton with DIBA/F&M)
- **Briquetting machine** (100 kg/h)
- **Torrefaction/carbonisation** plant (under construction)
- **Methanation reactor** (under construction)
- Lab-scale **anaerobic digestors**



➤ Briquetting machine

- *100 kg/h compactation system for testing conventional and unconventional feedstocks (e.g. agricultural residues, bioprocess co-products, etc) in pyrolysis and gasification*

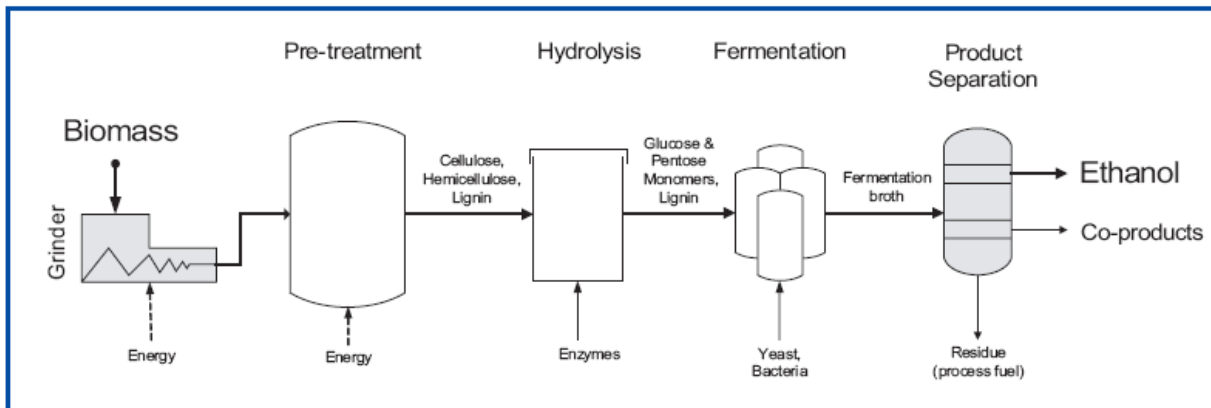




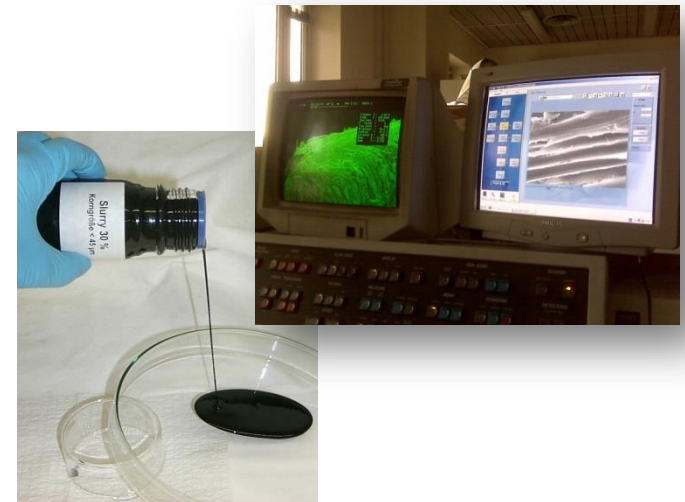
1.5 kg/h pilot pyrolyser
In partnership with SEA-Marconi

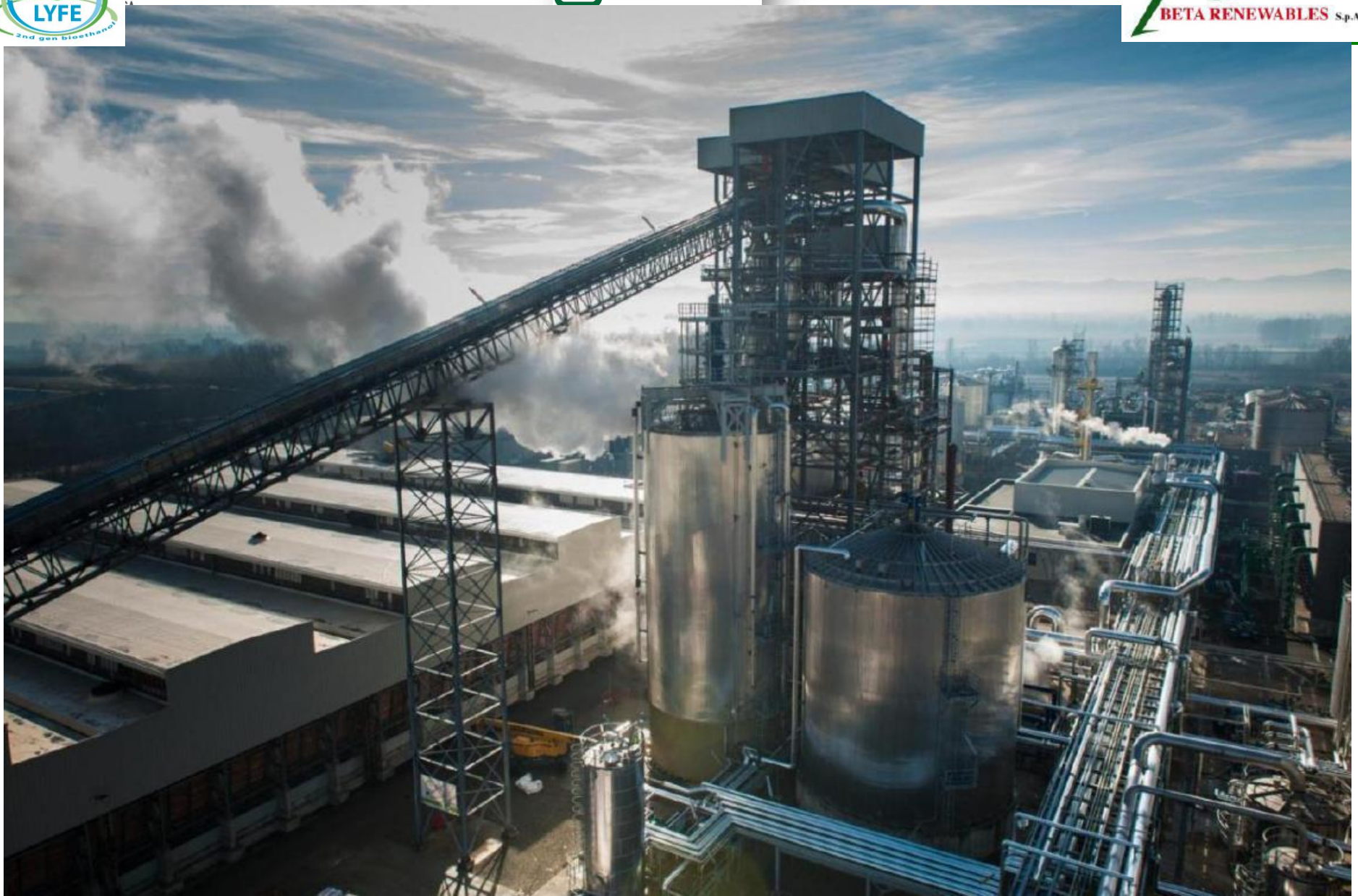
➤ Pyrolysis - Advanced biofuels

- *Development of pyrolysis and torrefaction systems*
- *Pyrolysis of innovative (2° gen) feedstocks: microalgae, lignin*
- *Torrefaction and Pyrolysis of lignocellulosic feedstocks, either dedicated or residual biomass*
- *Lignocellulosic ethanol chain*



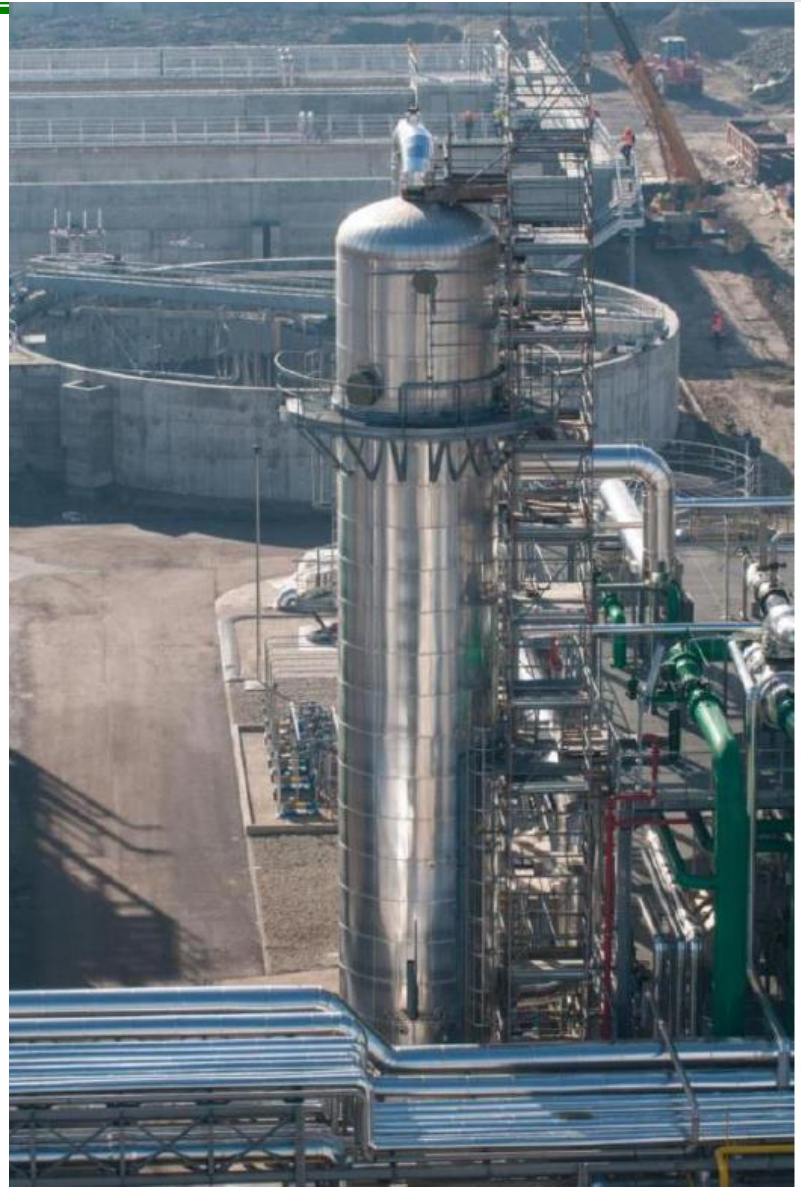
Lignocellulosic ethanol chain scheme (Source:IEA)



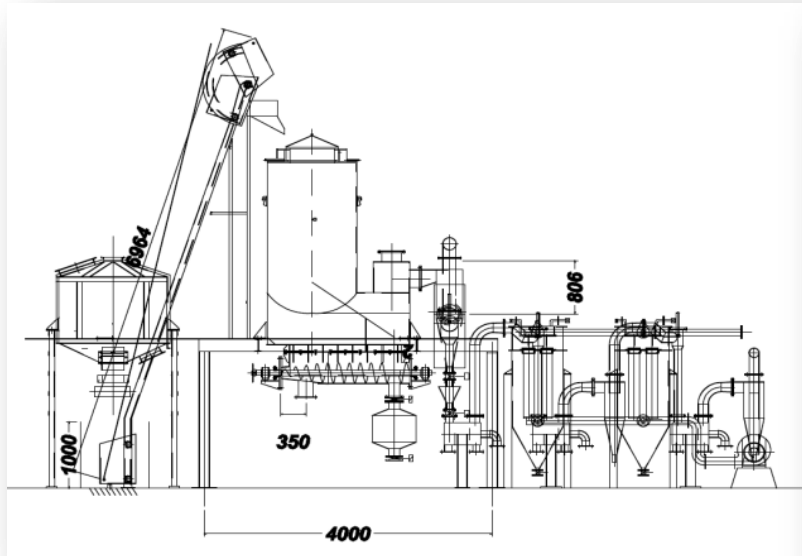












Gasification & Anaerobic Digestion

- *Development and test of small scale gasification systems (in collaboration with IIS-Bangalore)*
- *Thermochemical conversion to upgraded biofuels (e.g. thermochemical methanation)*
- *Upgrading of biogas (from anaerobic digestion) or producer gas to bio-methane/SNG*





➤ Laboratory fully dedicated to Renewable Energy/Biomass

INSTRUMENTS AND ANALYTICAL LABORATORY RE-CORD

RE-CORD system provides the skills and resources (laboratories and equipments) of its members, creating a critical mass capable to develop research and activities of primary-level science and technology.

Main analytical chemistry laboratory equipment

Strumentazione

- Atomic Absorption
- HPLC and GC-MS
- Ion chromatography
- Portable Micro GC
- CHNS
- TGA
- Viscometer
- Hydrometer
- Karl Fischer and Electrochemical analysis Instrumentation
- Chemical fume hood
- Biohazard Hood
- Calorimeter
- Ash melting furnace
- Ultrapure Water System
- Vacuum Filtration System
- Hydrogen Generator
- Centrifuge
- Muffle furnace
- Moisture Analyzer

Possible applications

- Determination of metals contamination on food, beverages, land. Quality control of industrial products, paints, ceramics, glass. Environmental Analysis (Particulate matter, sewage sludge), clinic analysis...
- Analysis of liquid fuels, biological molecules, quality control on chemical products and pharmaceutical organic pollution analysis
- Analysis of water, separation of amino acid mixtures
- Analysis of soils, solid chemical or biological materials
- Recognition of substances, thermal decomposition of organic molecules, polymers and inorganic species study

Main instruments solar and wind laboratory

- Pyrheliometer for direct solar radiation
- Verification and testing photovoltaic systems and three-phase multipurpose tool
- Anemometry tower (30 m)

Other instruments

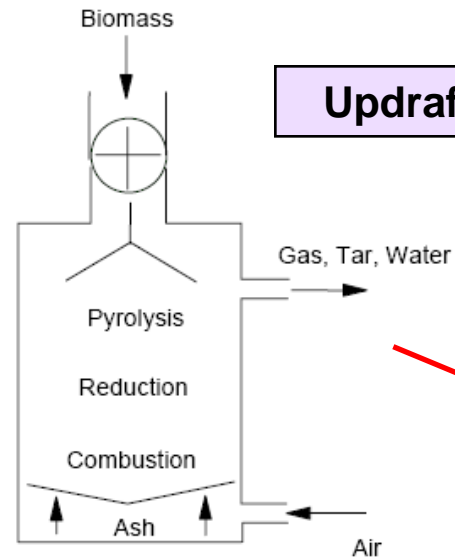
- Gaseous emissions analysis tool
- Analysis of flows in pipes
- Doppler effect 2D-3D speed measuring tool

Pilot and demo plants

- Several bio-fueled microturbines
- Cogeneration / liquid fuel engines
- Gasifier
- Pyrolyzer / torrefaction roaster

In addition: NDIR/Electrochem.Producer Gas Analyzer, Portable MicroGC Gas Analyzer, Portable Tar sampling collection system

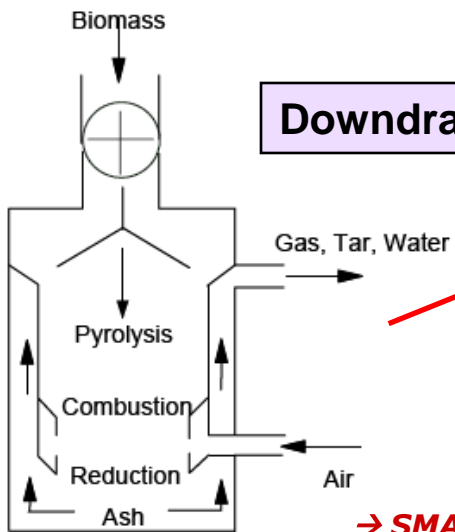
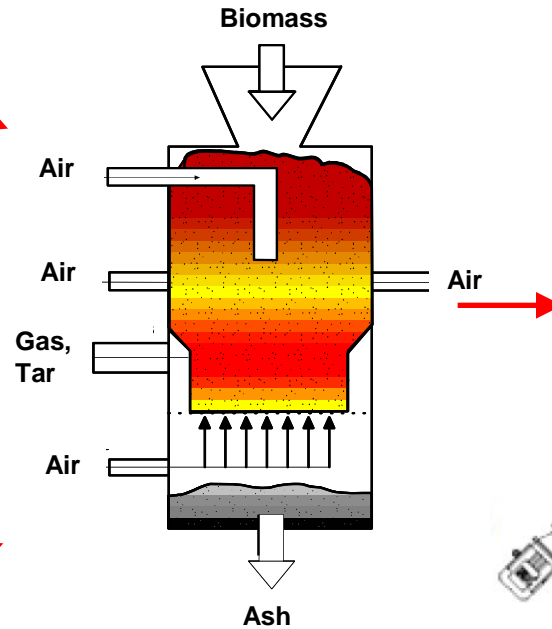
Main types of Fixed Bed Gasifiers



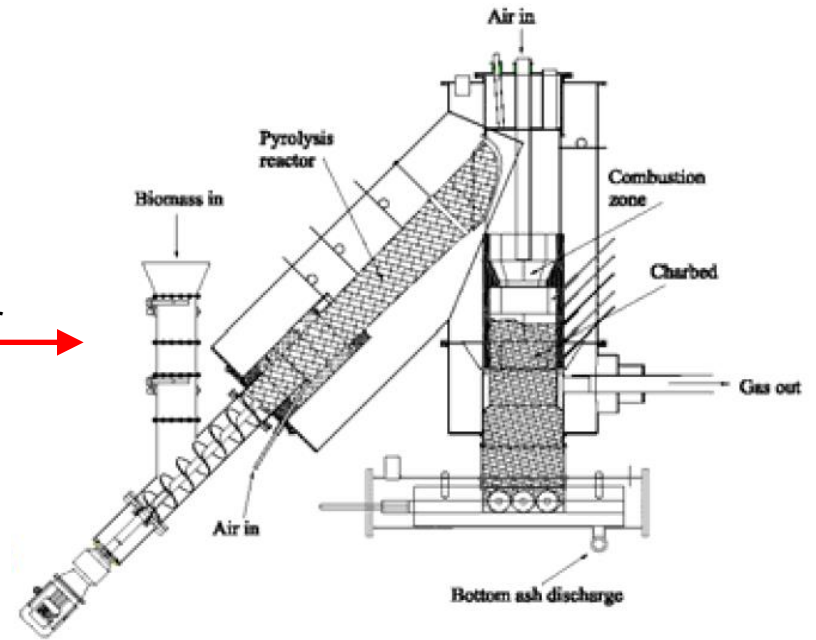
Updraft

Open-top Double Fire

Two/Three Stage



Downdraft

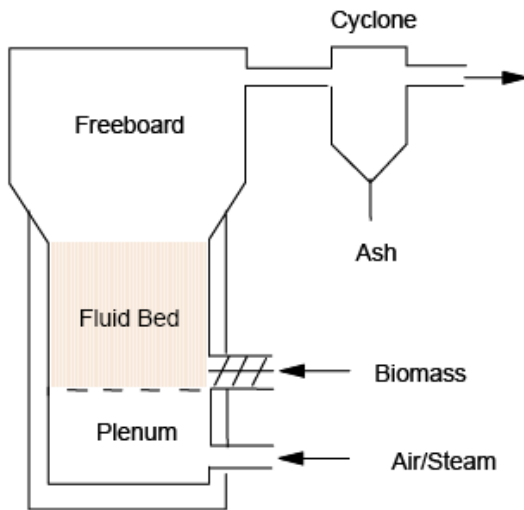


Source: H.Hofbauer, Wien University, 2007

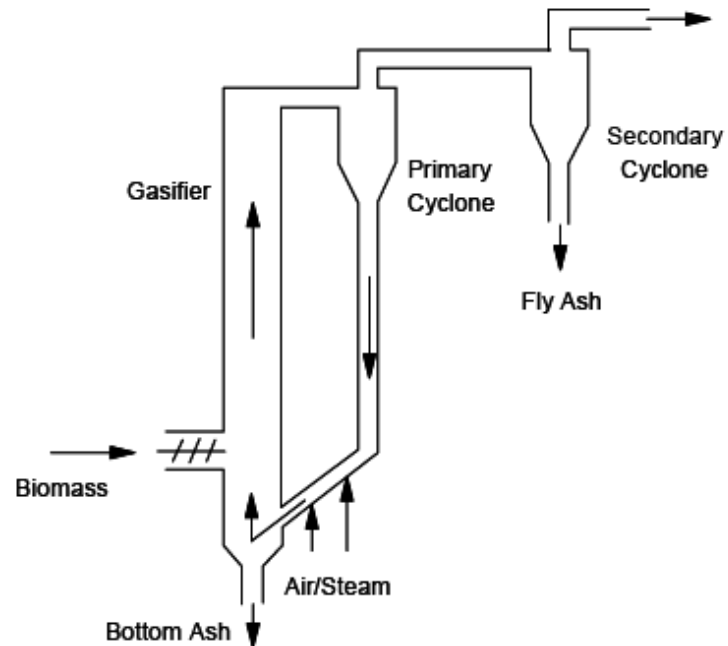
→ SMALL SCALE CHP/POWER PLANTS, OR HEAT GENERATION SYSTEMS

Main types of Fluidised Bed Gasifiers

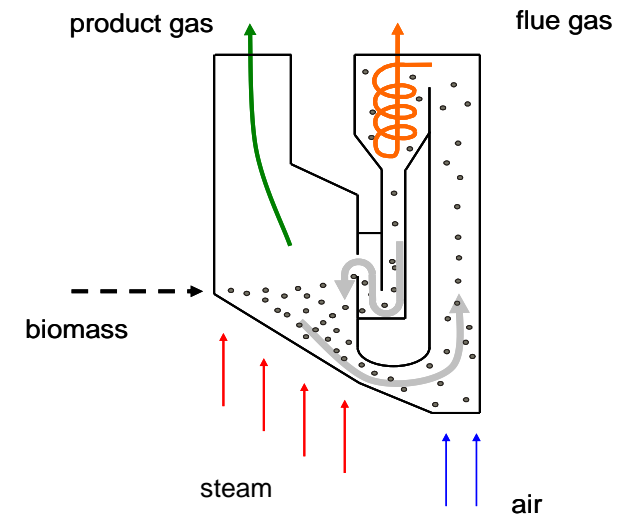
Bubbling fluidised bed gasifier



Circulating fluidised bed gasifier

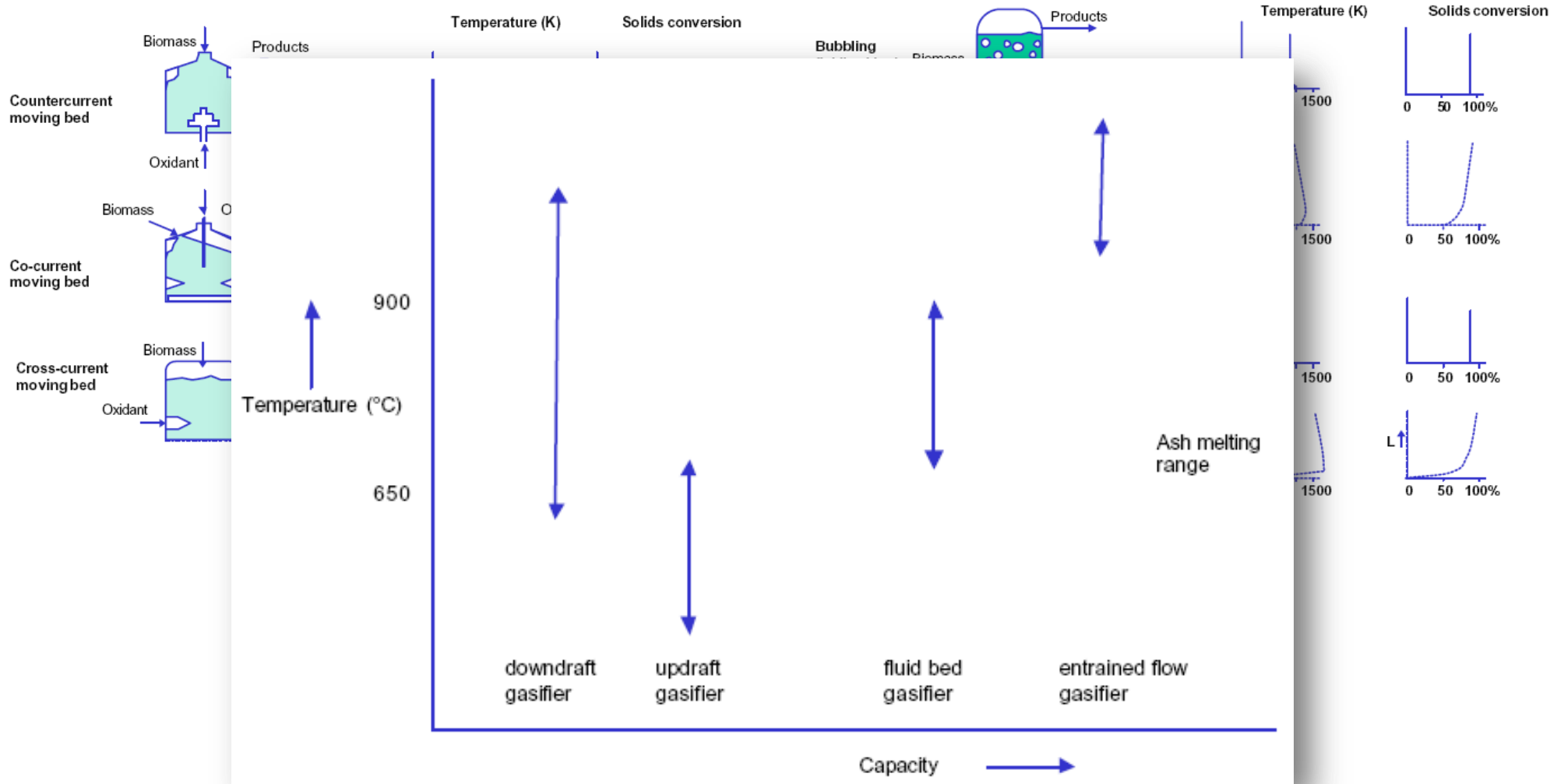


Dual fluidised bed gasifier

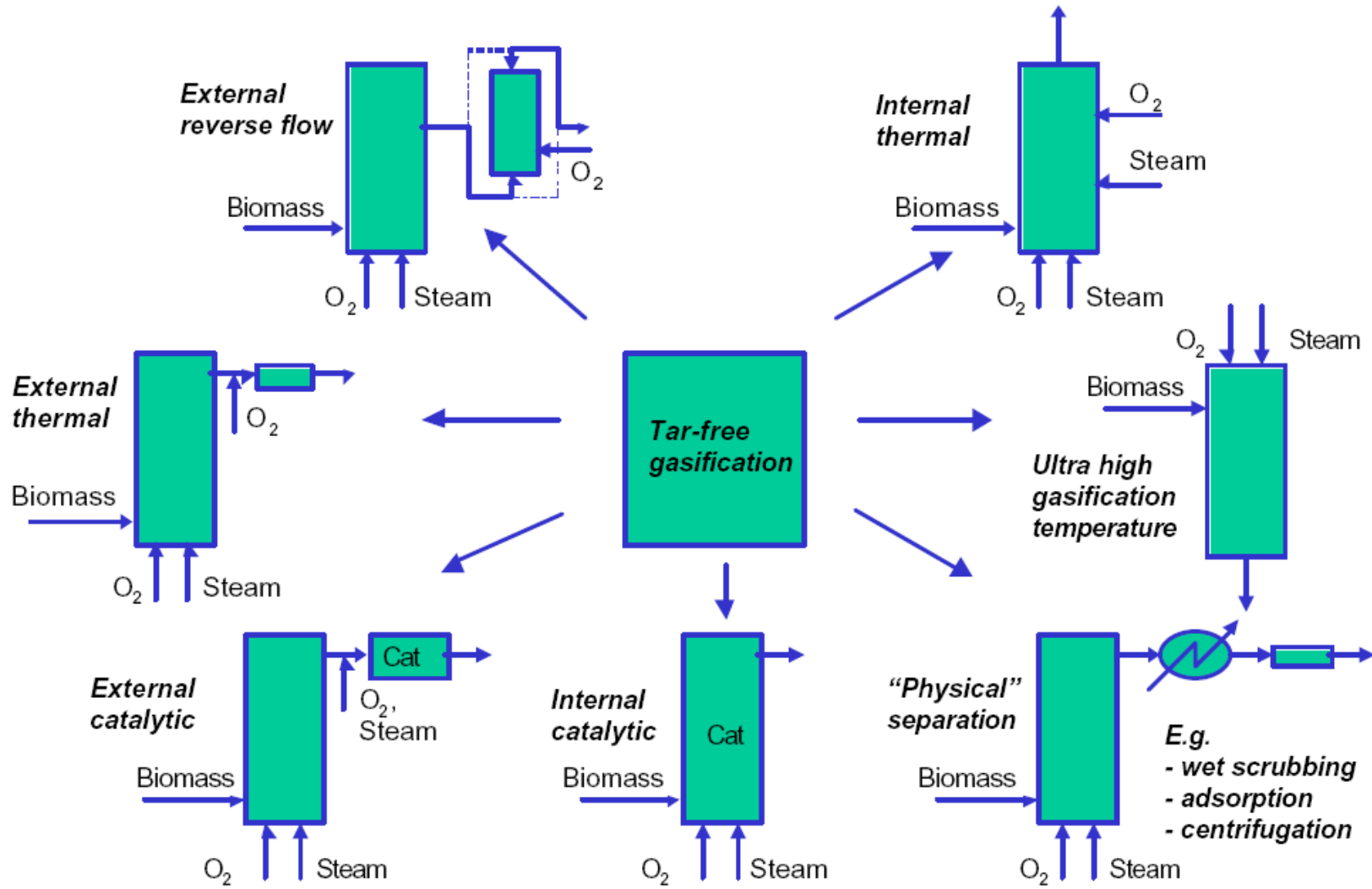


Source: H.Hofbauer, Wien University, 2007

Main types of Gasifiers – Temperatur distribution



Systems to remove or convert tars



Biomass pretreatment

Pretreatment is necessary before feeding the biomass to the system:

- Chipping/Crushing
- Drying
- Densification
 - ✓ Pelletisation
 - ✓ Briquetting
- Torrefaction
- Pyrolysis



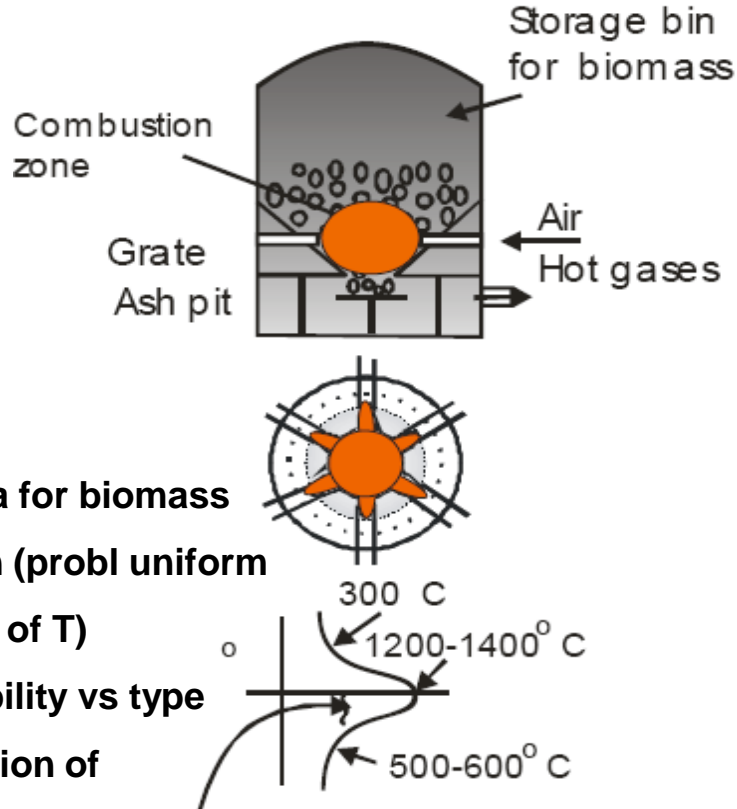
Biomass for small scale gasifiers

- **A good quality (i.e. within spec.s) biomass is needed to ensure stable/reliable operation.**
- **Pretreatment** is then necessary as a **standardisation mean** of biomass at inlet.

→ Contractual issues on maintenance / servicing

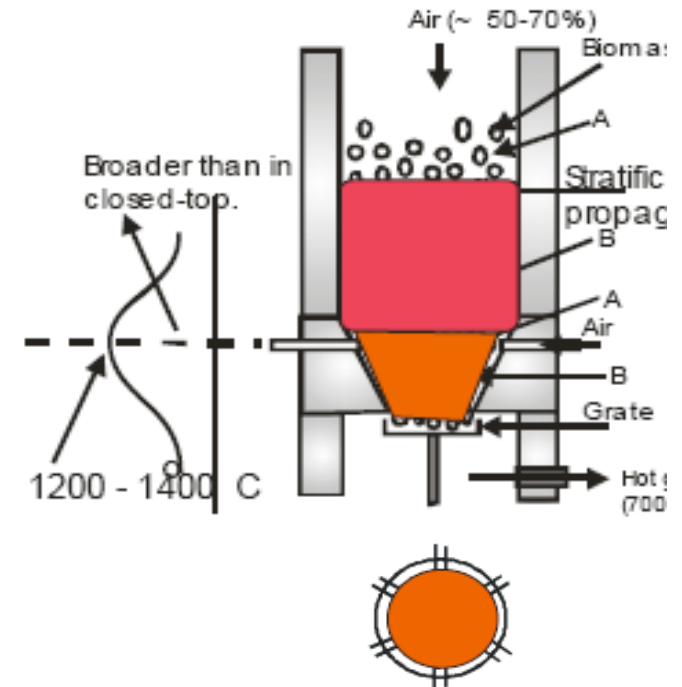


CLOSED TOP THROATED (IMBERT-TYPE) GASIFIERS



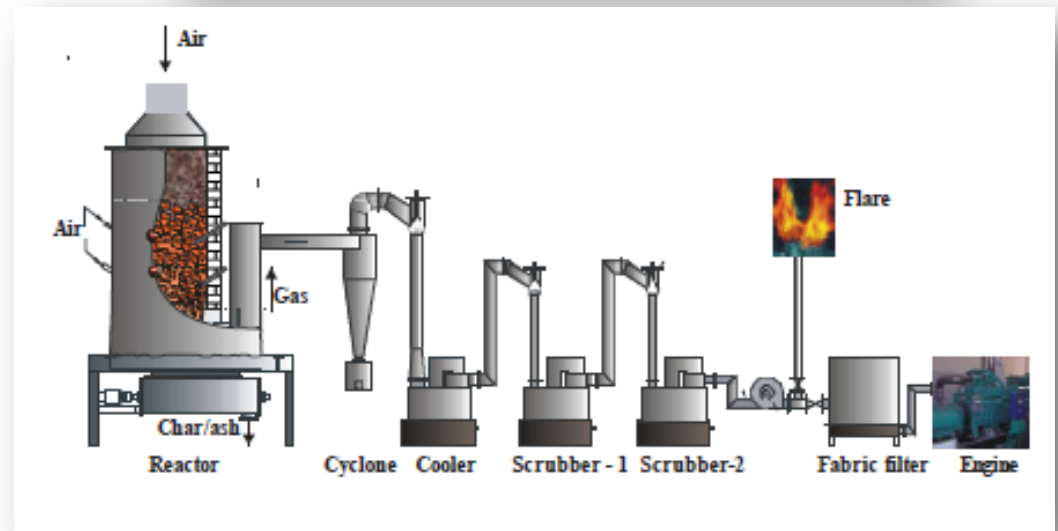
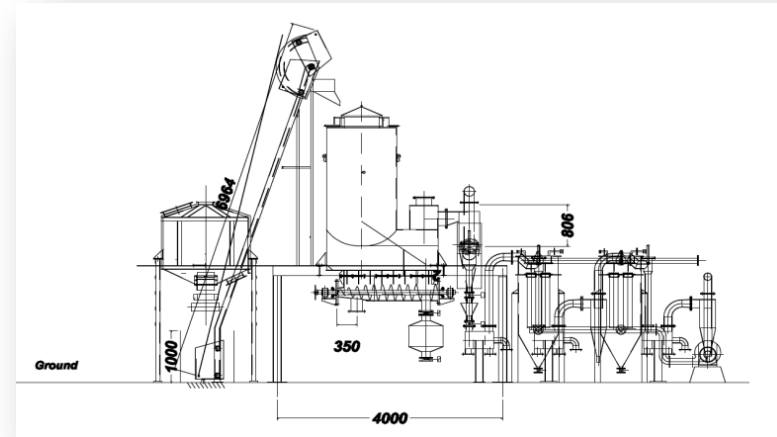
- ✓ Small area for biomass combustion (probl uniform distribution of T)
- ✓ Low flexibility vs type and dimension of feedstock
- ✓ Capacity
- ✓ Limited turn down ratio

OPEN-TOP TWIN-FIRE GASIFIER BY IIS (Bangalore) AT CREAR



- ✓ Larger combustion area
- ✓ Longer resid. Time
- ✓ Greater tar cracking
- ✓ Overcome 500 kg/h
- ✓ Safety

MATT-MNRE: CREAR (+ENEA)/IIS AGROGAS PROJECT

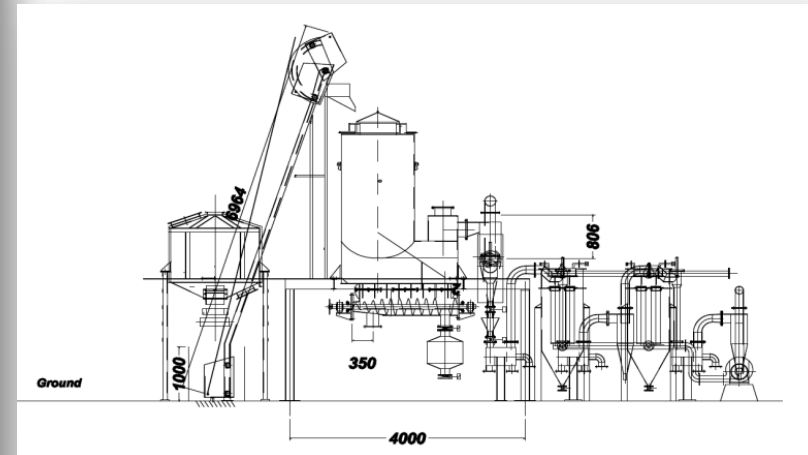


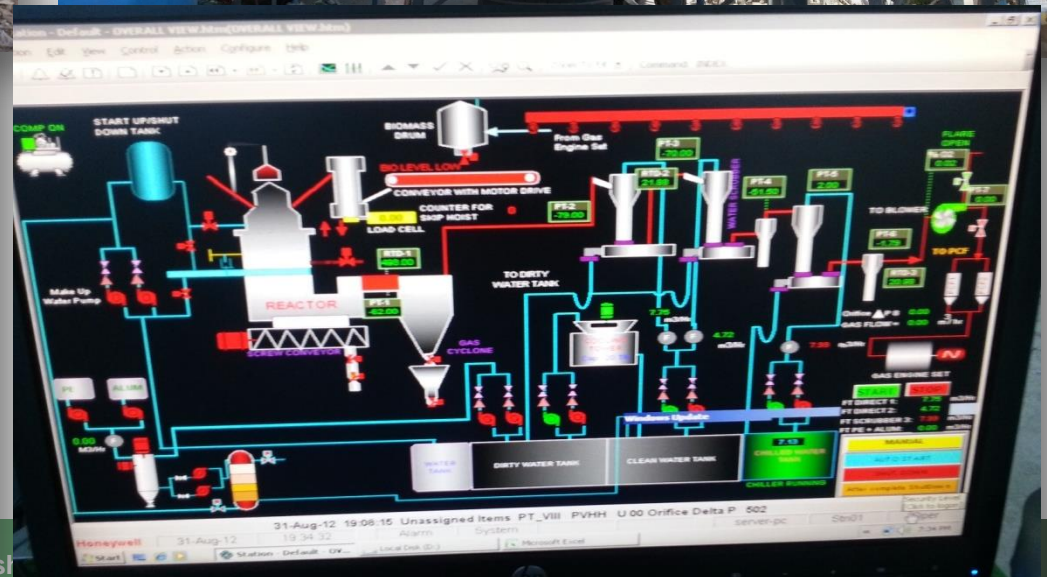
Goals

- ✓ Bring it to EU Standard
- ✓ Demonstration of performances



- 70 kWe gross – 54 kWe net
- Range: up to 2 MWe
- Heat: biomass drying
- Automatic operation
- EU Standard
- ➔ *Performances: demonstrated in Gurgaon (Delhi), May 2012 and Colle Val d'Elsa (Italy), July/Aug 2012*







.....and, the most important thing...

Friendship !



Some market related issues on small scale gasifiers...

Recommendation CTI 13

Plants for **production and use** of gas from **lignocellulosic biomass gasification**

- Classification, essential characteristics, rules for the offer, order, construction and commissioning



Min measurements on commercial plants

Characterization and mass flow measurement of inlet biomass

Measurement of T distribution in the reactor

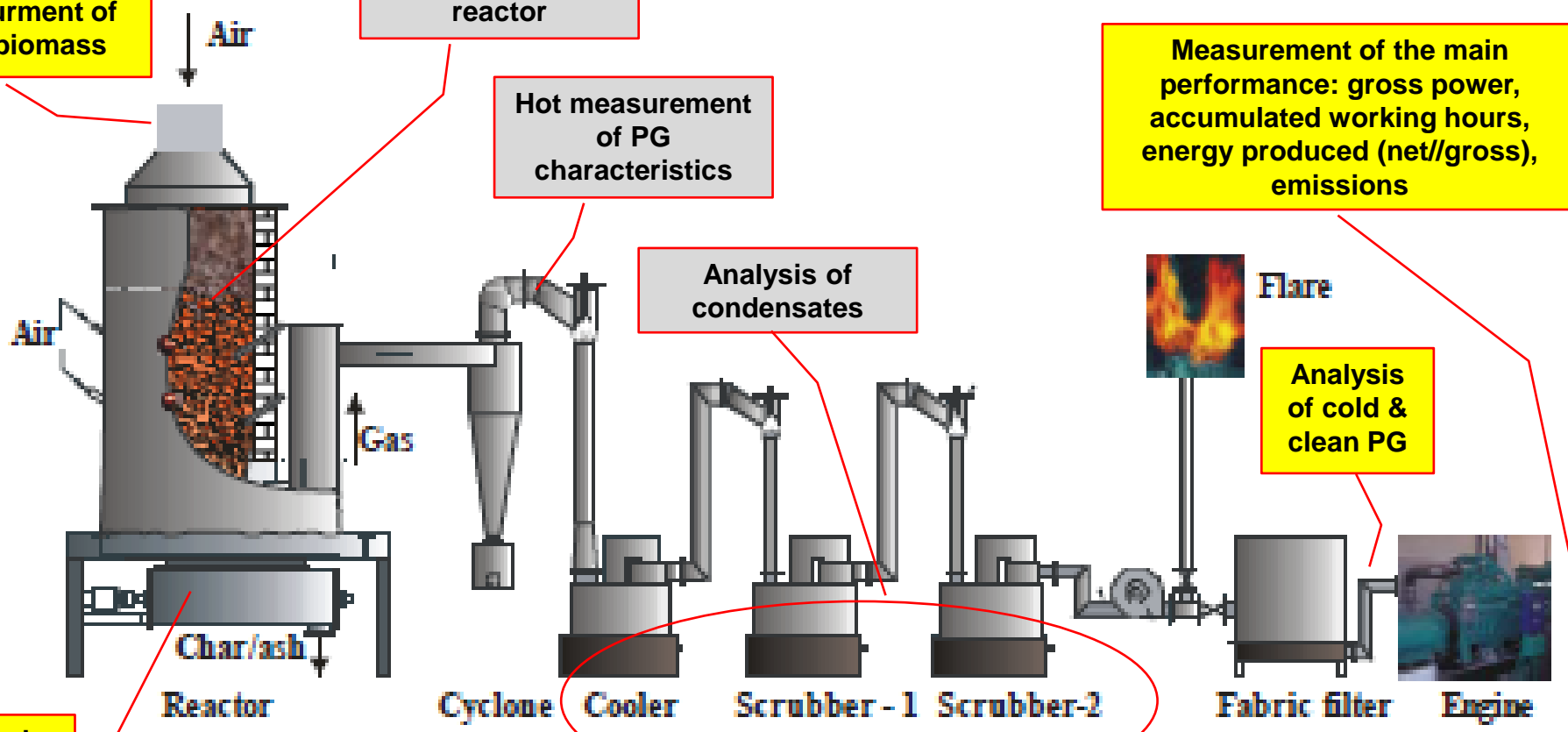
Hot measurement of PG characteristics

Analysis of condensates

Measurement of the main performance: gross power, accumulated working hours, energy produced (net/gross), emissions

Analysis of cold & clean PG

Analysis of ashes



→ Mass & Energy Balance

RE-CORD

- **RE-CORD** can carry out the necessary steps to certify the performance and verify these during lifetime
- On going collaboration with **TÜV-Italia** Gruppo (TÜV-Sud) on certification.



GAST Project

Experiences in biomass GAsification in South-Tyrol: energy and environmental assessment

➤ Scope

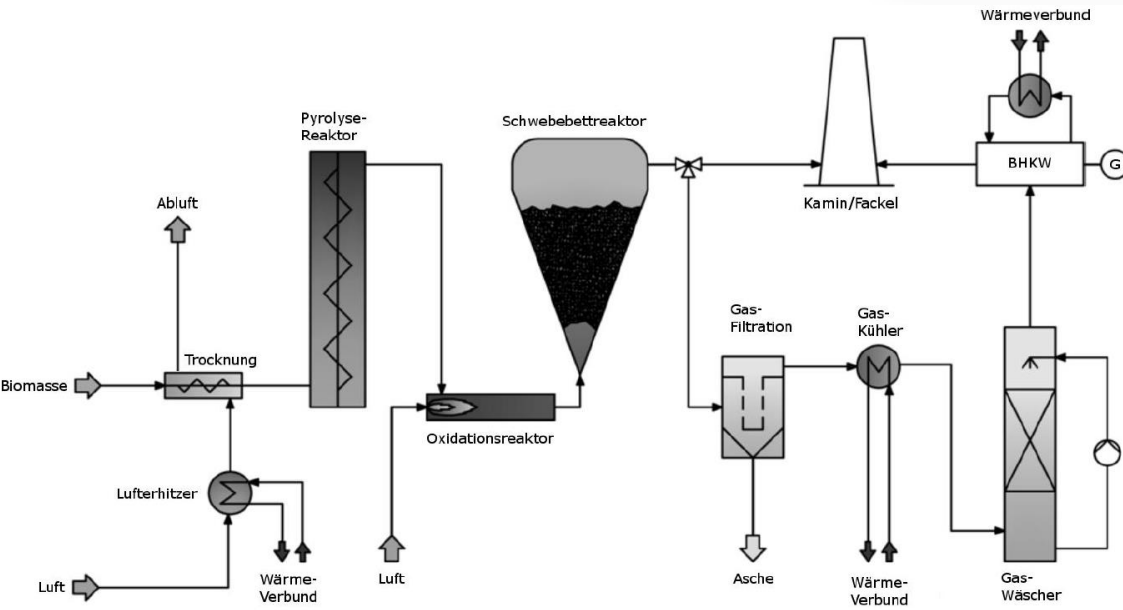
- ⇒ Preliminary screening of small scale biomass-gasification-based cogeneration plants located in South Tyrol
- ⇒ Two or three representative plants selected for the monitoring campaign
- ⇒ Characterisation/Monitoring

➤ Coordinator and Partners

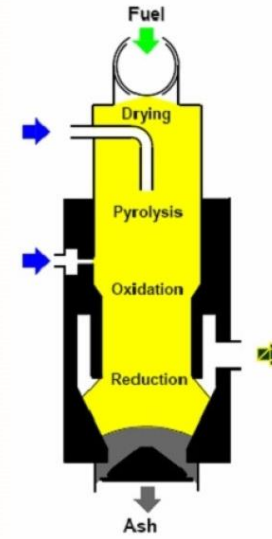
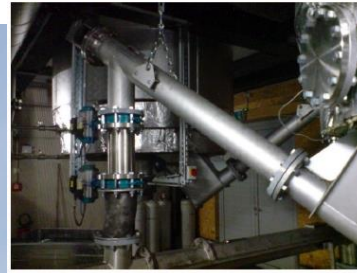
- ⇒ Libera Università di Bolzano (prof Marco Baratieri)
- ⇒ Eco Research Srl
- ⇒ Subcontractors: RE-CORD, TIS Innovation Park



...few examples of gasifiers on the market...



SYNECO



Asche ohne Kohlenstoff



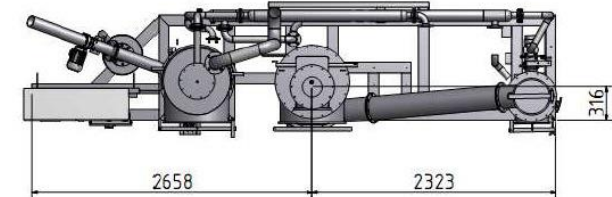
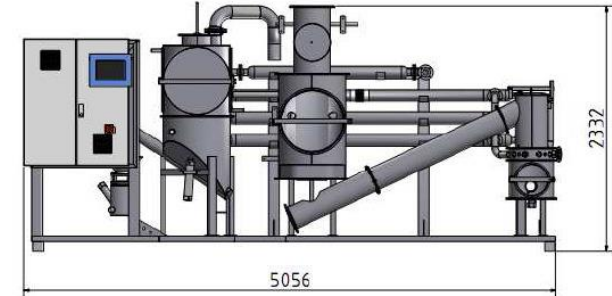
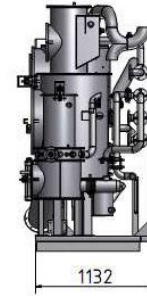
holz energie wegscheid



Terruzzi (Ankur) gasifier



Spanner



RE-CORD: YANMAR project

➤ Scope

- ⇒ Installation and testing of a 40 kWe gasification plant
- ⇒ Japanese technology, various plants installed in Japan (visits during July 2013)
- ⇒ Transfer to EU
- ⇒ Performance analysis
- ⇒ Improvement of some sections / components



Overall market considerations in Italy

- The sector is growing towards industrial/commercial use
- Various manufacturers in the field of small scale plants – Several from Austria and Germany
- CAPEX are significant, particularly at small scale
 - ✓ Order of almost 5-6000 €/kWe
 - ✓ Economic viability very difficult
 - ✓ Incentives needed, not only for CAPEX but also for OPEX (biomass cost)
- That is why standardisation becomes important
- Monitoring is also important for technological assessment & decision makers/environmental agencies at local level
- There is a window of opportunity for transfer and adaptation of know how from India to EU, meeting standards and competing on costs



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Thanks for your
attention !



Ricerche e servizi per le Rinnovabili

