Fluidized bed applications in EDF Group
- Industrial scale
- Pilot scale

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CHANGER L'ÉNERGIE ENSEMBLE

Industrial scale :
integration of FBC projects in EDF generation portfolio

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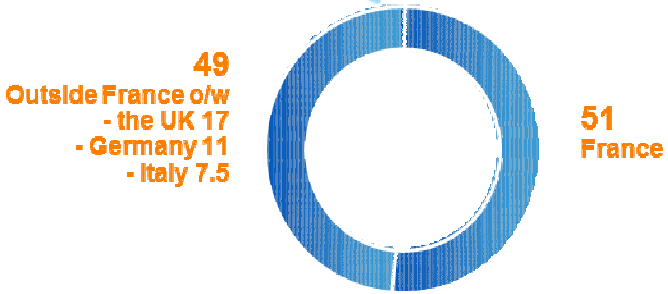
EDF at a glance: Key figures

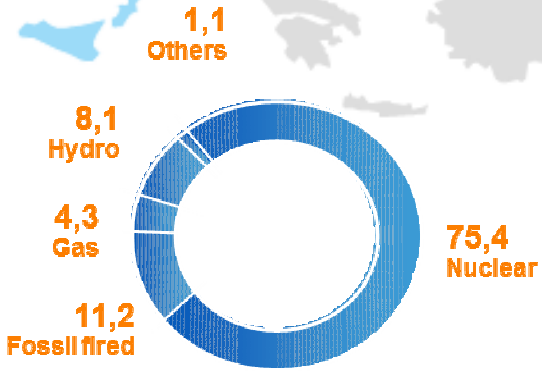
- **618.5 TWh** of energy generated worldwide
- **38 million** customers worldwide
- **170 000** employees worldwide
- **€ 66.3 billion** in sales – **49 %** outside France
- **117 g** of CO2 per kWh generated

- Electricity: **covering the entire chain**, from generation to transmission, distribution and supply.
- **Solidly anchored in Europe**: France, the UK, Italy, etc.
- Industrial operations in **Asia** and **United States**
- Natural gas: a major player

2009 sales in %



2009 Group generation mix in %



Total : 618,5 TWh

Biomass activities at EDF R&D

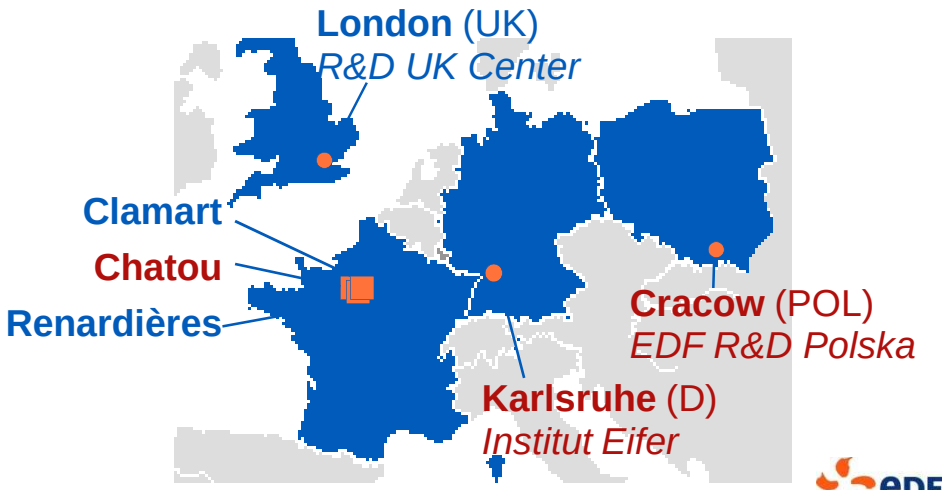
Mission

- **Contribution to the improvement** of EDF Group performance
- Help EDF Group with the development of **new businesses**

Teams located in 3 EDF R&D centers

- Chatou, close to Paris, France
  - Biomass combustion for CHP and power-only applications
  - Co-combustion (CHP, Power-only)
  - Gasification : CHP, BioSNG and 2G biodiesel

  Biomass prospective and technology survey activity (maturity)
- Karlsruhe, Germany
  - Biomass feedstock and pretreatment
  - Biogas
  - Biomass combustion (Small Scale)
- Kracow, Poland
  - Co-combustion



R&D MAIN SCOPE OF WORK

Identify and understand the best technologies

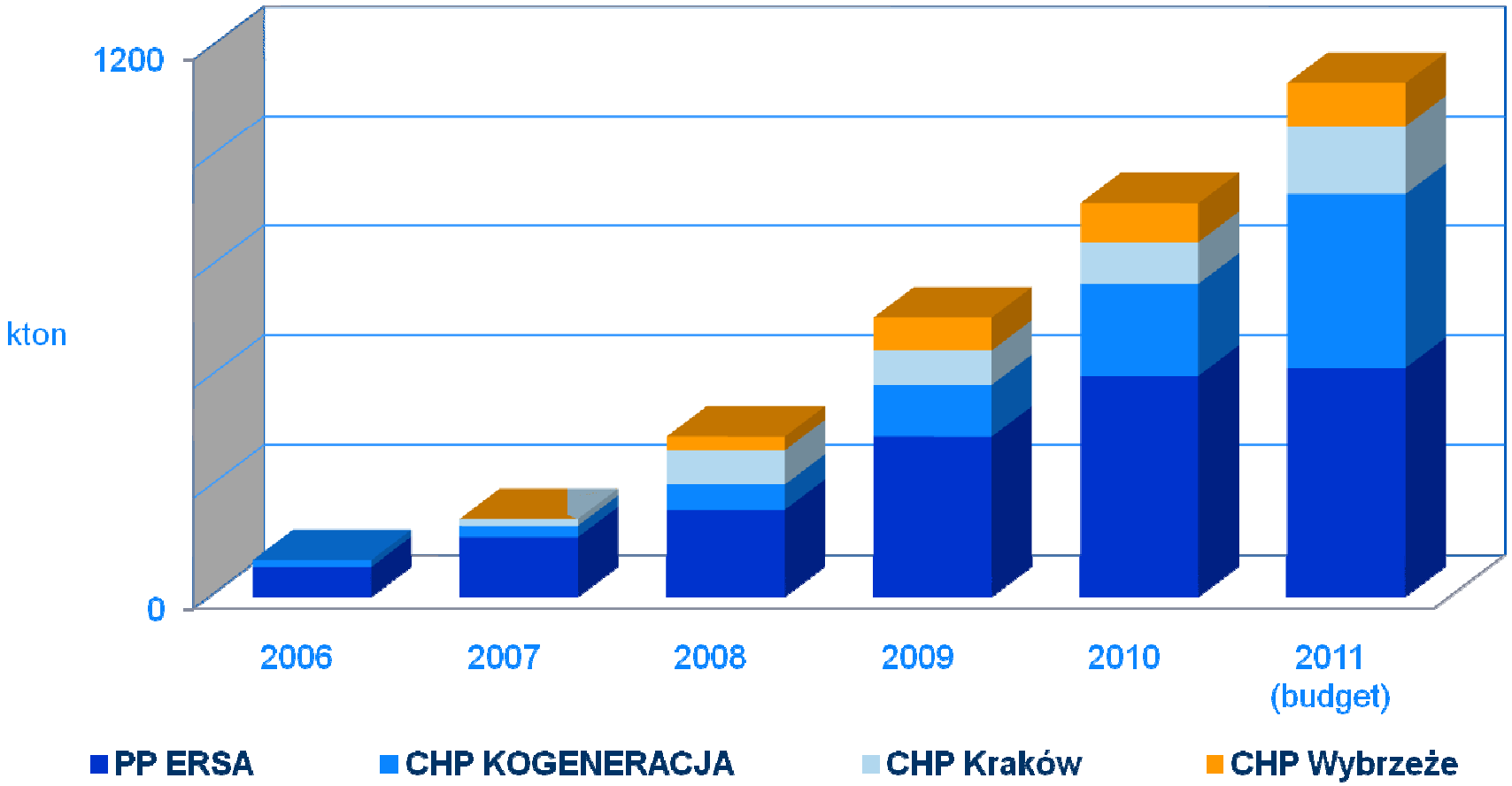
- Power generation and CHP (co-firing, combustion and gasification)
- Bio-SNG
- 2G biofuels (thermochemical and biochemical paths)

Knowledge build up & tools development

- Library of unitary operations models (Aspen Plus®)
- Biomass CHP projects development tool (BioCogen tool)
- Guides for Biomass CHP acceptance tests

Support the EDF Group biomass projects

Biomass consumption in EDF Polska companies



=> More than 14 different kinds of biomass burnt (65% domestic)

* Own data

EDF Polska companies in Poland

- Power Plant
- Combined Heat & Power Plants
- Heat Plant
- Services

- Respect for individuals
- Environmental responsibility
- Striving for excellence
- Commitment to the community
- The necessity of integrity

cergia

EC Wybrzeże

Elektrociepłownia SA Zielona Góra

ENERGOKRAK Sp. z o.o.

everen Grupa EDF

ZESPÓŁ ELEKTROCIEPŁOWNI WROCŁAWSKICH KOGENERACJA SA

PEC

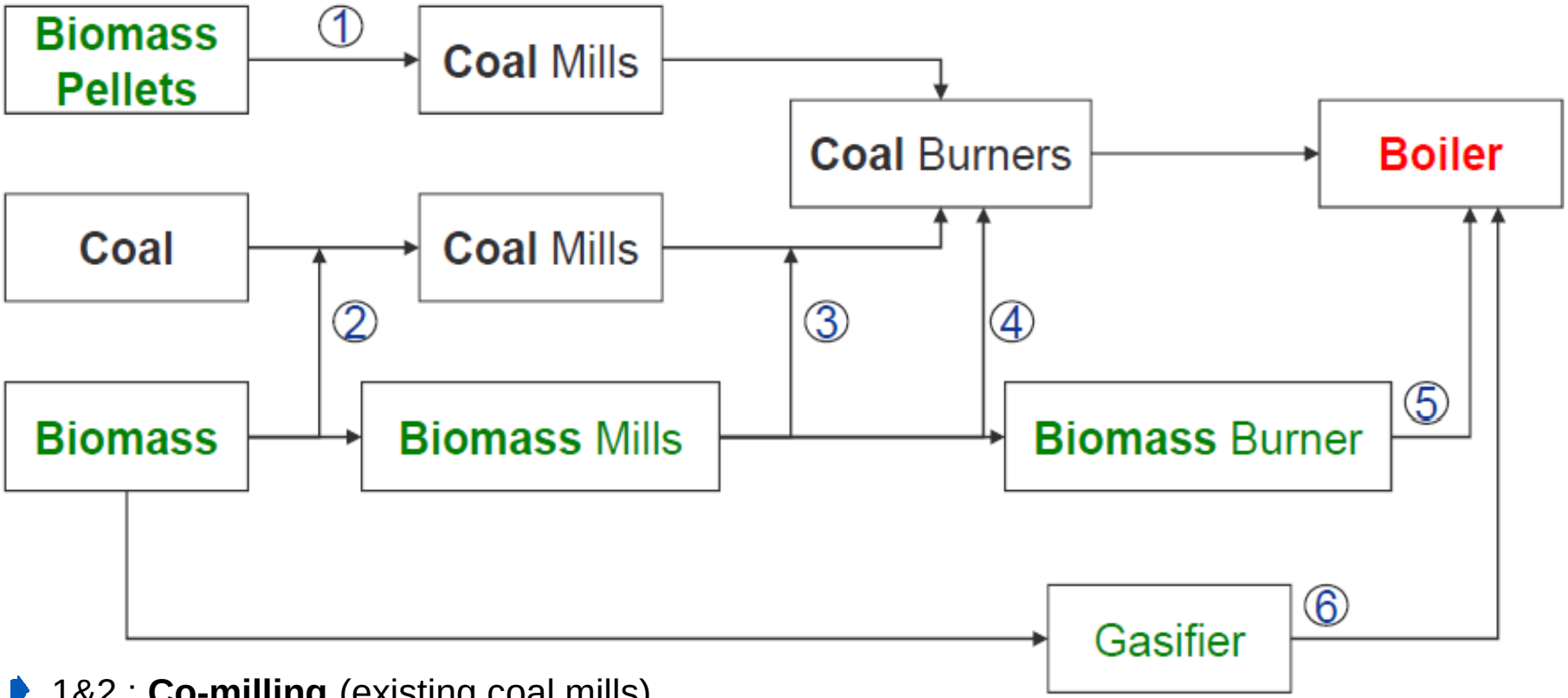
ER

EC KRAKÓW Grupa EDF

Kinds of biomass burnt by EDF Polska

- Types of biomass (legal division)
  - Wooden origin
  - Energy crops
  - Agricultural by-products
  - Food industry by-products
- Feedstock types by moisture content
  - Dry, W < 15% (pellets, briquettes, rape residues, bran)
  - Wet, W > 15% (sawdust, woodchips, corn straw)
- Feedstock shapes
  - Unprocessed, most often as by-products of the main process (sawdust, rape residues, straw, bran)
  - Processed, dedicated for power generation purposes (pellets)
- Main Parameters: NCV, Humidity [%], Ash [%], Chlorine [%], Density

Ways of burning biomass – direct firing, indirect, parallel



- 1&2 : **Co-milling** (existing coal mills)
- 3&4 : **Direct injection** (dedicated biomass mills) – existing burners or “no burner”
- 5 : Direct injection as 3&4 but with dedicated new burners (biomass or combined)
- 6 : **Indirect injection** by adding a gasifier (flexibility / ash separation)
- Other : **Parallel injection** by BFB or CFB conversion or implementation

PROJECT STARTED IN 2008
MAJOR CONTRACTORS

- Task A

  Metso Power Oy Finland

  Boiler retrofit K-2 w EC Czechnica to BFB 100% biomass

  Start up of the boiler - June 2010

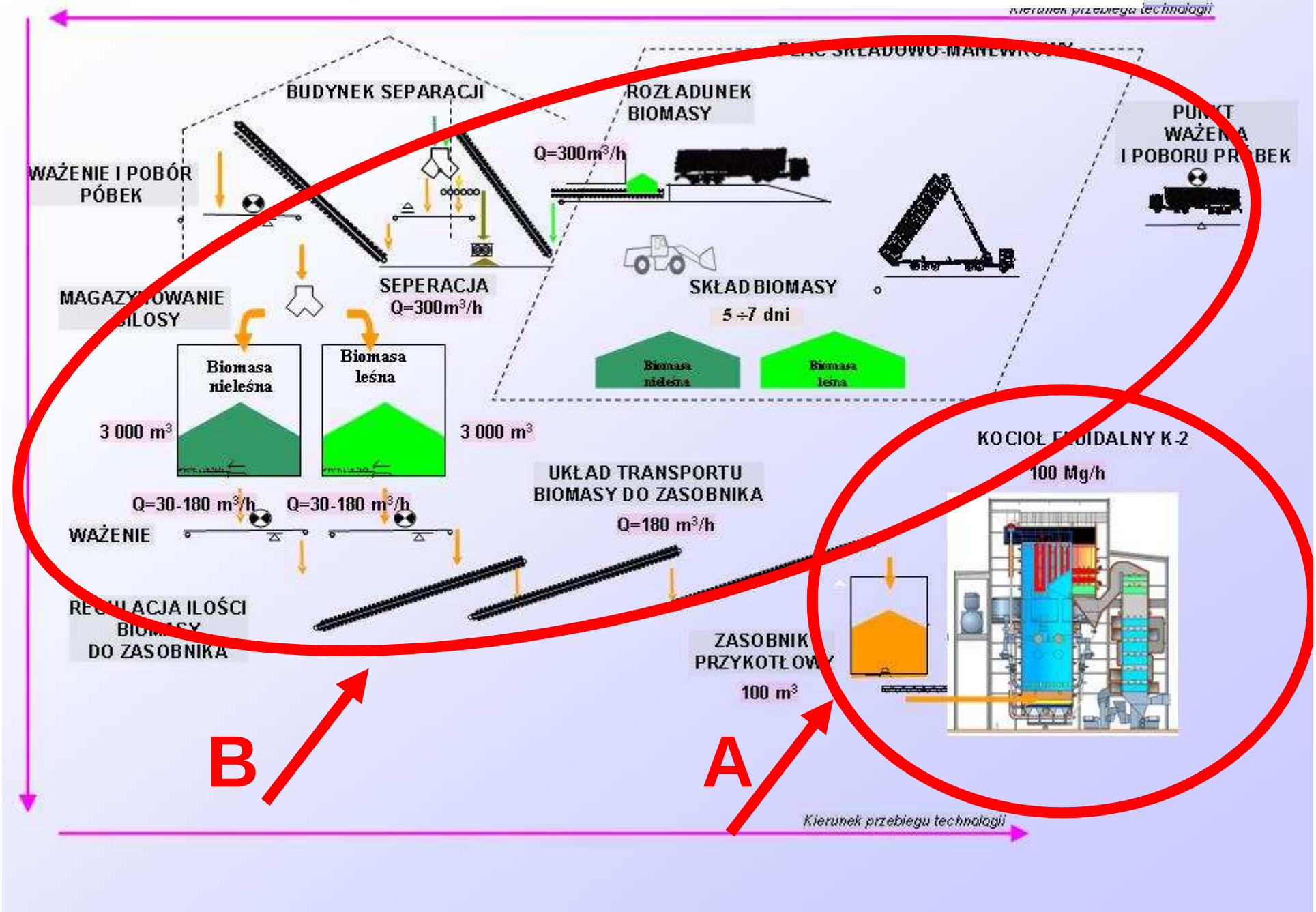
- Task B

  Energomontaż Północ – Bełchatów

  Biomass preparation station

BIOMASS DELIVERY TO THE BOILER – June 2010

Biomass installation in EC Czechnica



Design parameters

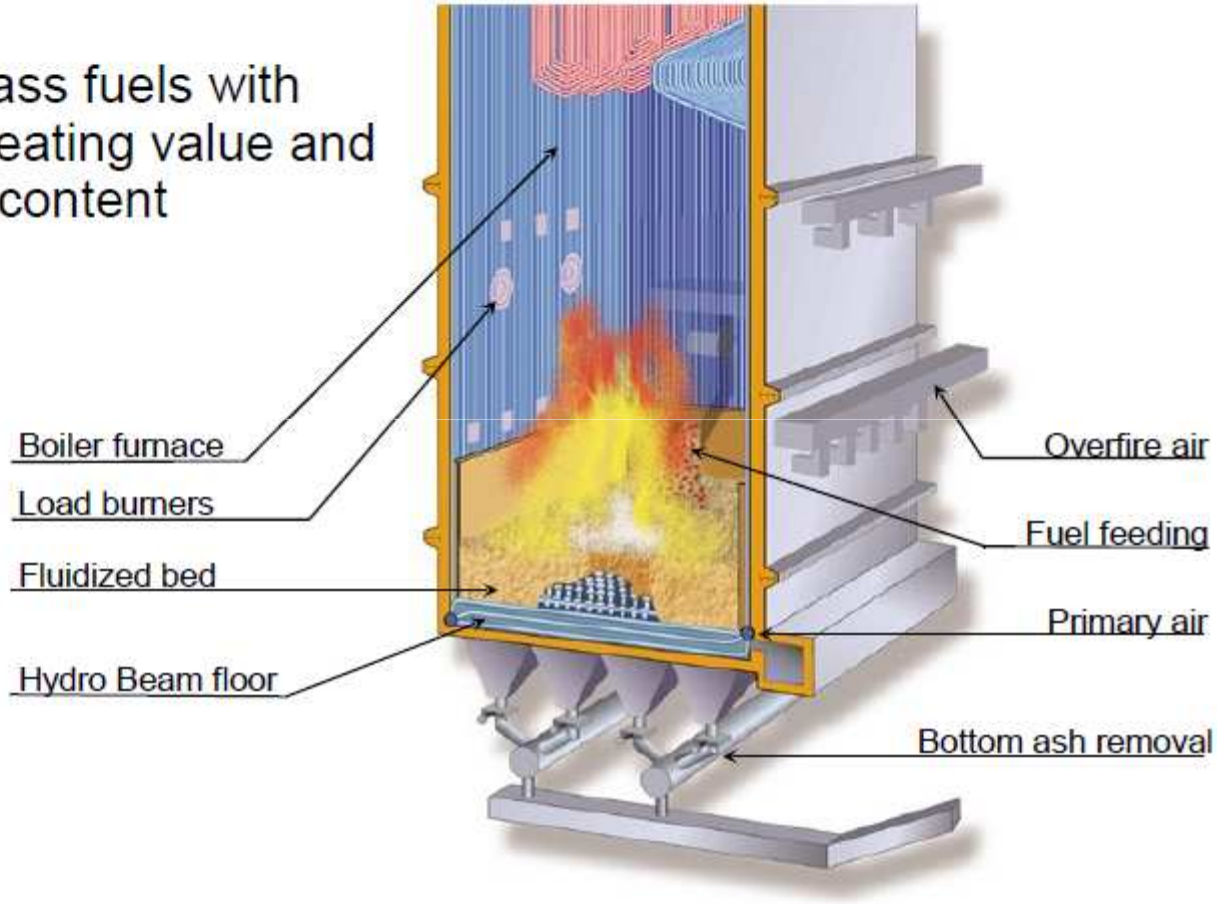
• Biomass type	Agro (corn) & Wood (willow)
• Calorific value	6-13 MJ/kg
• Water content	24-58%
• Density	0,24-0,41 t/m^3
• Biomass consumption	8,8 kg/s ≈ 230 000 t/a
• Silos capacity	2x3000m^3
• Conveyor capacity to feeding silo	180m^3/h
• Biomass particles diameter	max. 63 mm (max 250mm long)
• Feeding silo	1x100m^3
• Steam parameter	100t/h 500°C 7,2 Mpa
• Bed temperature	750°-950 ℃
• NO_x Emission garanty	<300 mg/Nm

STORAGE (Biomass selection)

- 4-5 days max (degradation)
- CO and T measurements located the roof
- Water based antifire system
- odors limitated

EC Czechnica BFB-100/K-2 : HYBEX BOILER

- For biomass fuels with varying heating value and moisture content



OP-130 retrofit into a BFB-100/K-2

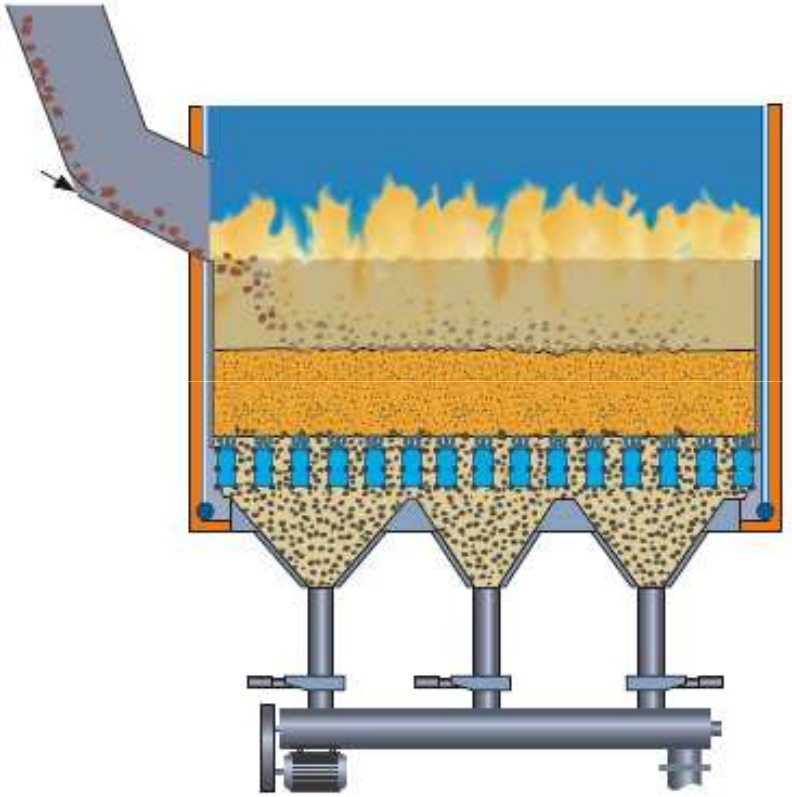
Original walls cut at 70m

Hybex hydro beam floor skid

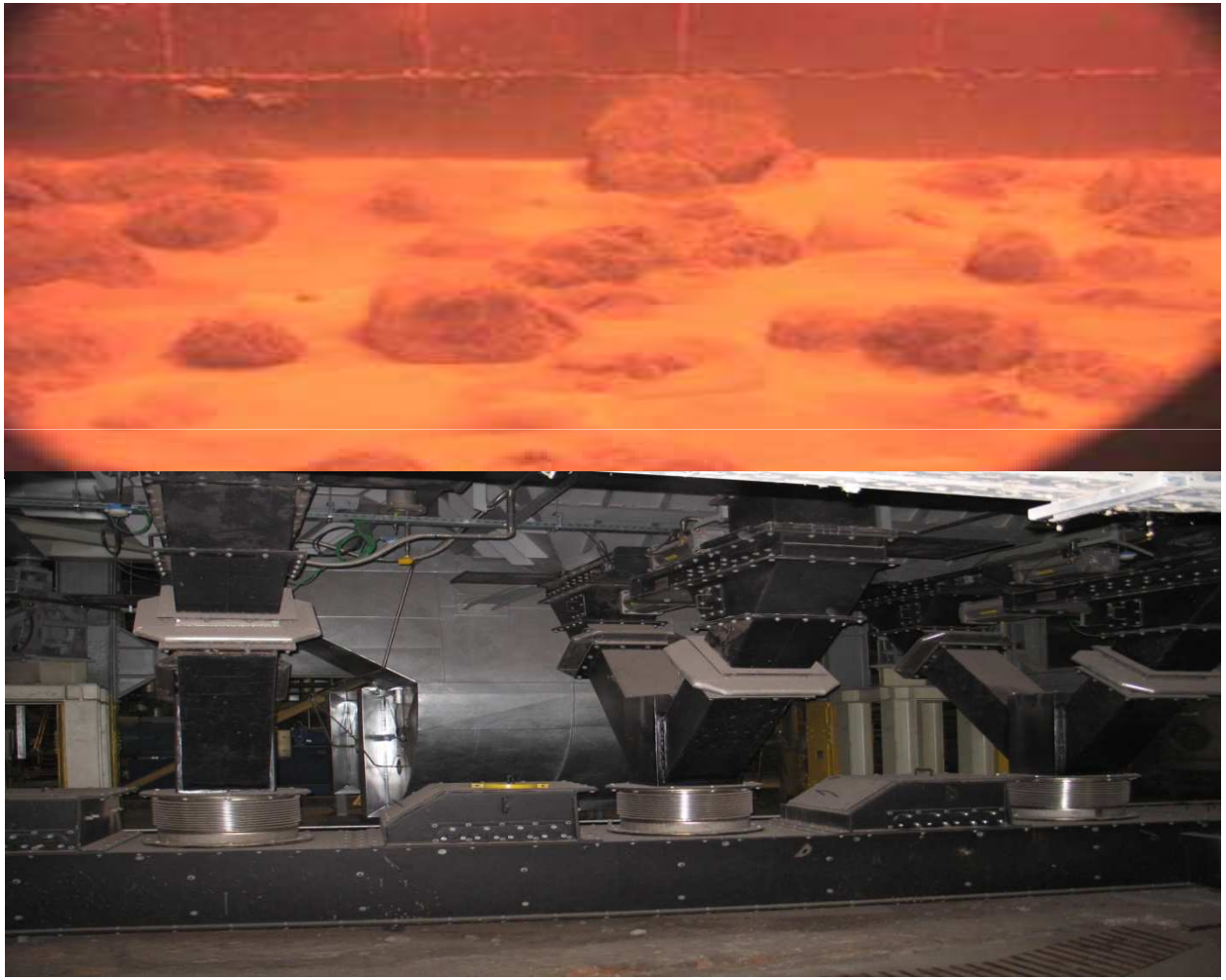
HYBEX TECHNOLOGY

Hydro Beam floor

- Developed for demanding fuels
- Totally water-cooled air beams
- Open bottom design
  - Free area over 30% of cross section
- Excellent removal efficiency
- Patented design



EC Czechnica BFB-100/K-2



OUTLOOK

- Cold start up needs 4h using HFO (Heavy Fuel Oil) as start up fuel
- HFO used when bed temp <700℃
- Some pb with “sandy” wet biomass – low melting point
- More flexible than traditional co-firing (direct firing) with regards to biomass quality. Cheaper biomass.
- Nevertheless, special attention to the calorific value is paid in order to reach the highest power output
- One year feedback report is beeing prepared
- Very good payback levels (<3 years) due to incentives

=> EDF already decided to invest in new BFB projects for next year (100% biomass and co-combustion)

Pilot scale : R&D GAMECO Project Biomass Gasification for Combined Heat and Power (CHP)

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EDF
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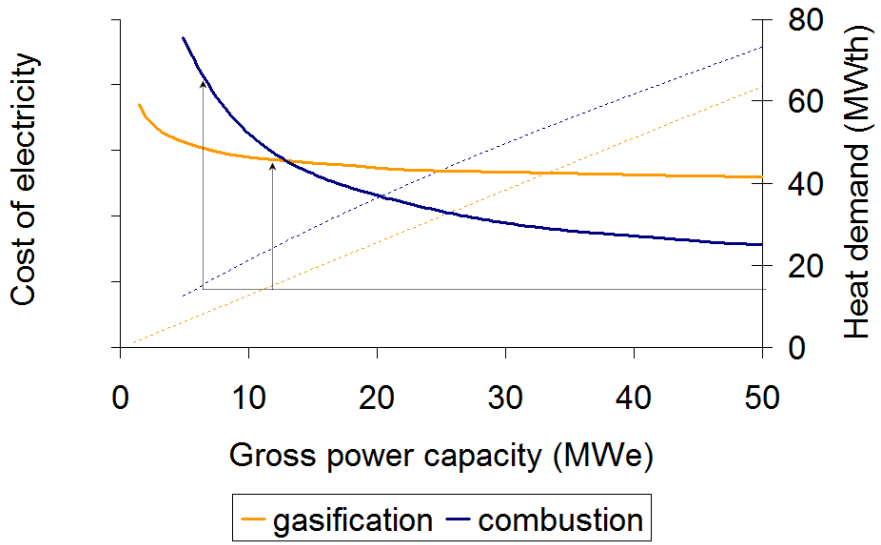
Small-Scale CHP Plant

Biomass Energy Policy in France

- Target of 530 MWe additional production capacity based on biomass CHP before 2012 and 2 300 MWe before 2021
- Public incentive mechanisms
  - Periodic calls for tenders > 12 MWe
  - Bioelectricity feed-in tariff 5 – 12 MWe: 120 – 145 €/MWe

Gasification vs Combustion: Economic Assessment

- Case of a 15 MWth heat demand
  - 12 MWe produced by gasification
  - 6 MWe produced by combustion
  - Combustion electricity production cost 1.5 times higher than gasification
- Biomass Gasification
  - A competitive way for power generation in the medium-size market



Bubbling Fluidized Bed (BFB)

- Highly competitive among the CHP gasification technologies
- Need of further improvements to turn into the reference technology for industrial application in the 1-10 MWe range

Elements of the Process

EQTEC | Gasification Process for CHP Generation

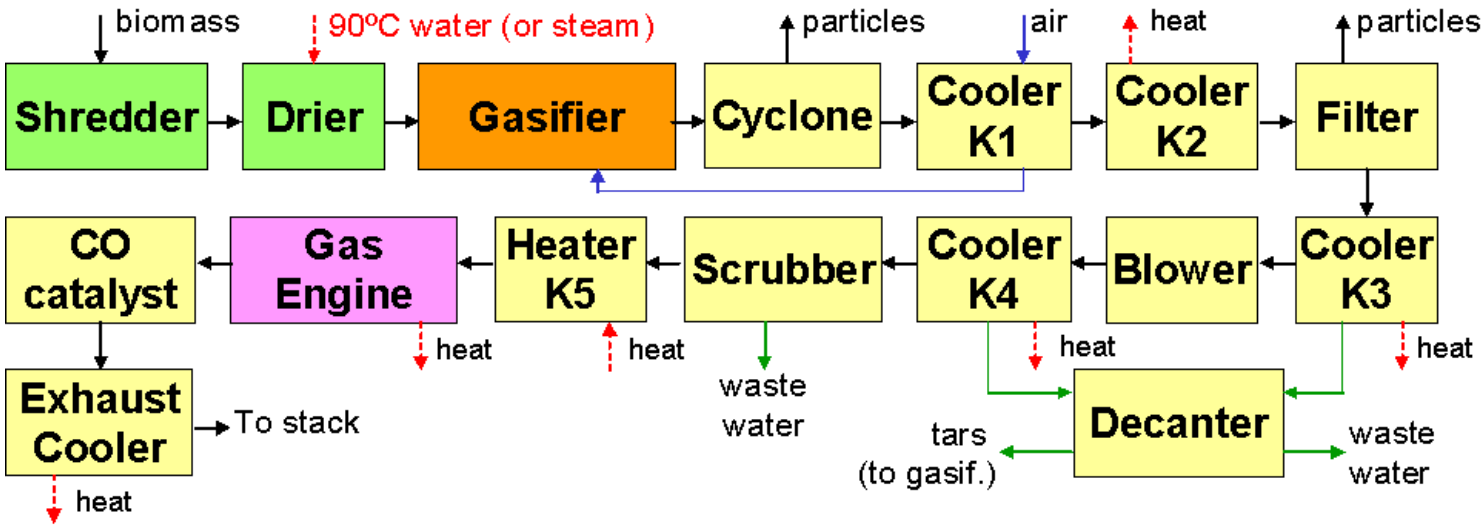
- 3 main parts
  - Gasifier (BFB) reactor – atmospheric pressure, 750 – 900℃
  - Syngas cleaning – filter, scrubber
  - Gas engine plant
- Several references in Europe based on a 1 000 kg/h module – 1.5 MWe

Process Efficiency

- 30 % for electricity power output
- Up to 43 % for heat power output

Biomass Specifications

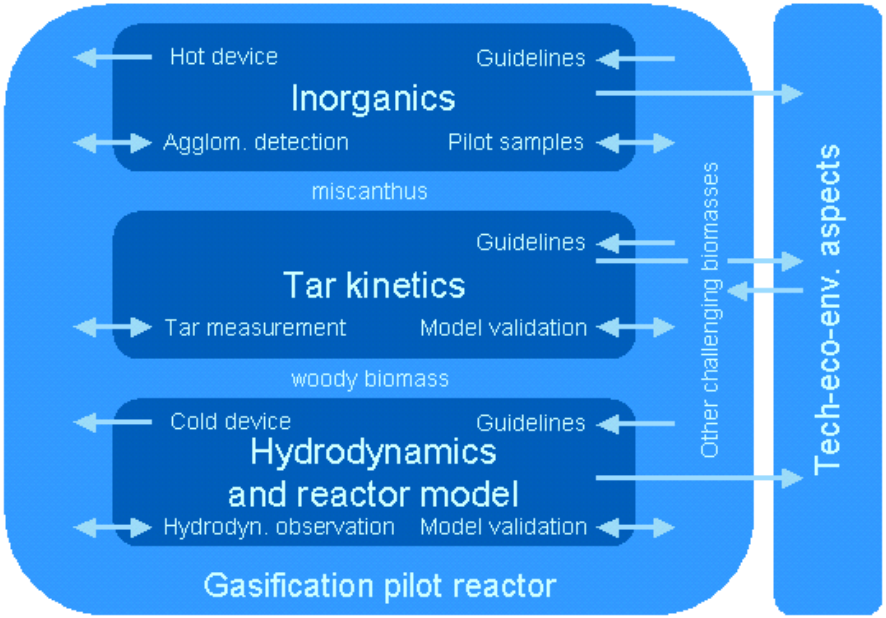
- Particle size from 2 to 15 mm
- Moisture content < 20 wt%
- Ash content < 10 wt%

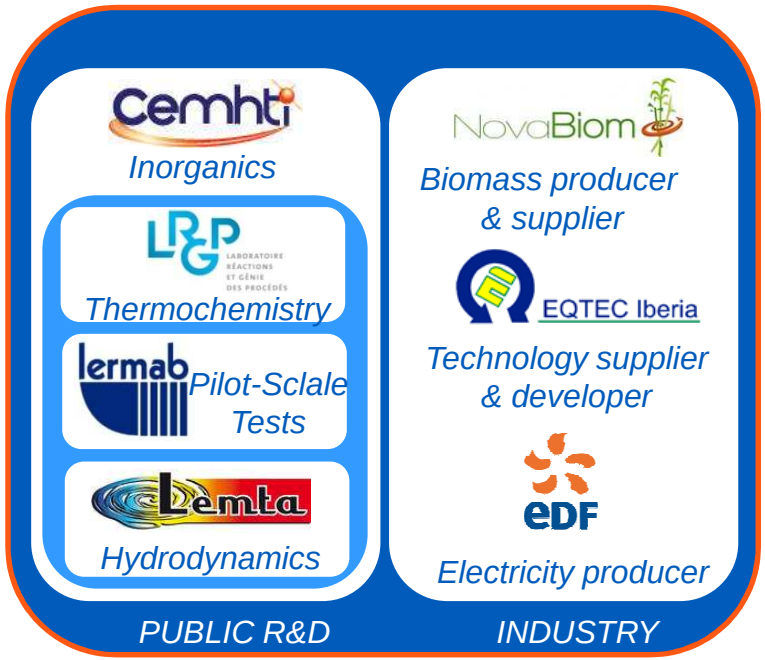


GAMECO Project | 2011 - 2014

Air-Blown BFB Biomass Gasifier

- Project funded by the French National Research Agency (ANR-10-BIOE-001)
- Aims at improving an air-blown Bubbling Fluidized Bed (BFB) biomass gasifier
  - Optimization of its design, operation and up-scaling
  - Increase in feedstock flexibility
  - Deeper understanding and control of biomass BFB gasification key issues
    - Agglomeration
    - Tar production
    - Hydrodynamics





GAMECO Project | 2011 - 2014

Technical and Scientific Challenges

- Predict and control BFB **agglomeration** risks
  - Understanding of bed material and inorganics interations
  - Lab-scale experiments in static and dynamic conditions
  - Reproduction of agglomeration (bed material and inorganics) and sample analysis

- Minimise **tar content** in the syngas
  - Understanding of tar gas-phase (freeboard) and heterogeneous conversion (over bed material and char)
  - Lab-scale experiments on model compounds
  - Detailed radical and semi-detailed kinetic models development
  - Model validation within the pilot reactor test campaigns

- Enlarge **biomass size** and **shape** flexibility
  - Understanding of bed material and biomass mixing, segregation and attrition
  - Lab-scale experiments in a cold device
  - Process modelling

- Study of the most promising **biomass feedstock** in France
  - Characterization of biomass feedstock adapted to BFB gasification
  - Technico-economic tools and life cycle assessment