"ATTRACTIVE MARKET SECTORS FOR FURTHER DEVELOPMENT OF CO-COMBUSTION TECHNOLOGY"

DELIVERABLE 5.4, TASK 5.3

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Economic low carbon power Production and Emissions Control for Future and Flexible Biomass Co-fired Power Stations

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1.- Company presentation

Design, construction, erection and commissioning of steam generators, mainly boilers for power plants and industrial sector.

- Electric power generation plants:

  Conventional fuels.

  Biomass.

  Solid urban wastes.

- Steam Boilers:

  Conventional fuels.

  Biomass.

  Solid Urban wastes incinerators.

  Recovery. (HRSG)

- Thermal equipment:

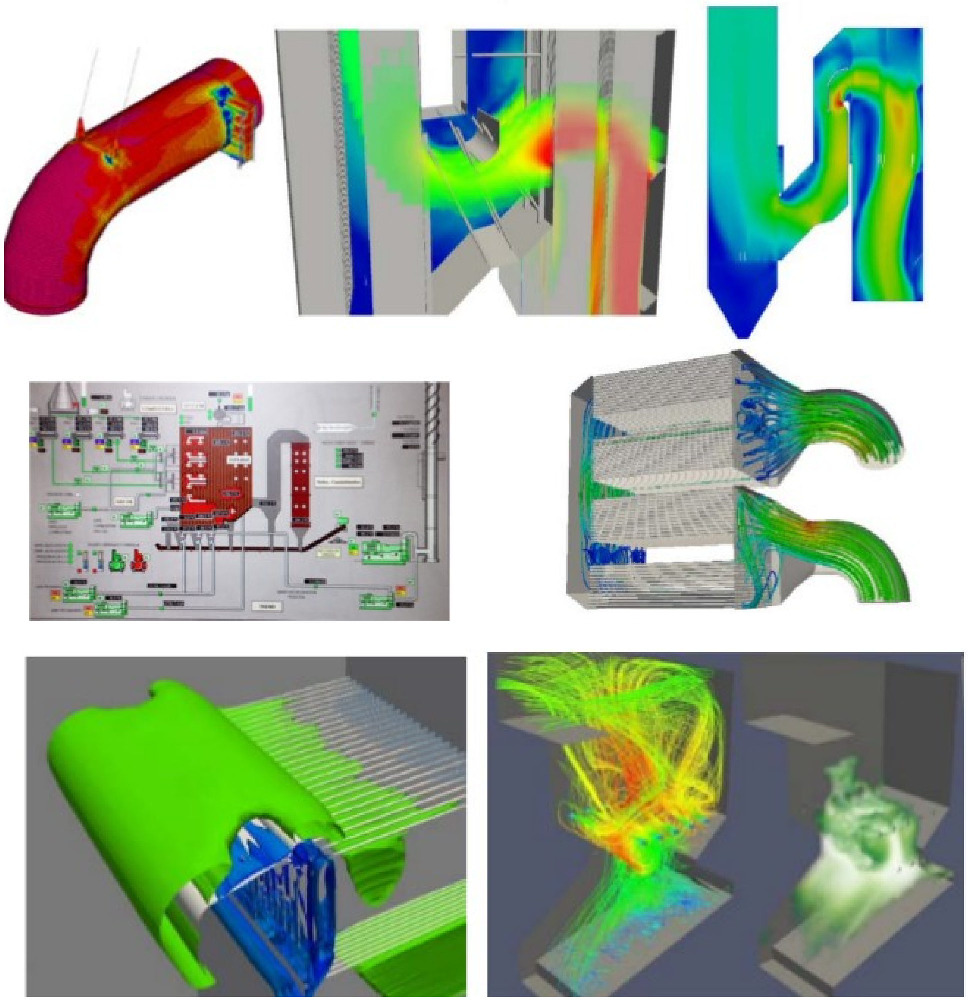
  Shell and tube heat exchangers.

  Condensers.

  Steam acumulators

- Piping, supports and stress on pipes and ducts.
- Metal structures.

1.- Company presentation



- Services y aftersales:
  - Combustion specialized consulting.
  - Boiler transformation to other fuels.
  - Boilers revamping y transformations.
  - Fault diagnosis
  - Energy plant process automation: combustion and boilers in general. Logics definitions and integration.
  - Energy efficiency.
  - Co-combustion.
- Finite element calculations, studies and simulations (stress and heat transfer)
- CFD (Computational Fluid Dynamic) simulations (flux distribution, heat exchange, chemical reactions, particle transport etc.)

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2.- Report introduction and scope

- This report is part of the task 5.3 of the BiOxySorb project, **Gestamp Biomass Solutions,** as partner of the project and boiler technological provider, will reflect its conclusions and suggestions for a market sector development of the oxi-co-combustion technology according to own and observed project experiences and results.
- Current advanced combustion typologies will be detailed involving co-combustion and oxi-combustion processes.
- BiOxysorb experience from a boiler provider point of view and analysis of information will provide the conclusions of the suggested sectors for further development of the oxy-co-combustion technology.

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3.- Current advanced combustion technologies

- Environmental impacts of thermal/power generation from fossil fuels have prompted intense development and research activity of improvements focused either in the fuel nature or in the combustion process.

Objectives → Reduce the environmental impact of the thermal/electric generation from the combustion

Objectives → Improve processes performances.

- **Concerning the fuel:** Sustainable means of generating power with an increase of the fraction of renewable energy in the national energy supplies (struggled to compete with fossil energy due to their high costs and technical risks in spite of governmental supports).

- **Concerning combustion process:** Improvements assumed in the past years.One of the most promising technologies are the oxi-fueled combustion technologies (amendable technology for a variety of applications)

3.- Current advanced combustion technologies

- **Co-combustion technology**

Reasonably attractive option for the utilization of biomass for the generation of power or heat, using the extensive infrastructure associated with the existing fossil-fuel based power systems with relatively modest additional investments for a significant CO_2 reduction.

Involves all of the commercially significant solid fossil fuels, including lignites, sub-bituminous coals, bituminous coals, anthracites, and petroleum coke, being co-fired with a very wide range of biomass materials, including herbaceous and woody materials, wet and dry agricultural residues and energy crops.

Operational risks

Reduction in plant availability and flexibility in operation.

Increase in maintenance and replacement costs associated with biomass handling/firing equipment and with the boiler plant.

Technical risks

Fuel preparation, processing and handling issues.

Flame stability/burnout (plant operation, control or emissions levels)

Ash related issues (slagging, fouling or corrosion)

Emissions and environmental impacts.

3.- Current advanced combustion technologies

- **Co-combustion technology**

The great majority of biomass co-firing worldwide is carried out in large pulverized coal power boilers.

Typologies
- Direct co-combustion.
- Indirect co-combustion.
- Parallel co-combustion.

The **torrefaction** of biofuels has open a new approach to consider in the co-combustion processes, as the torrified product has better properties in terms of calorific values, hydrophobic nature, energy density and grindability properties.

Development in technology and process conditions, process expensive and energy inefficient, infeasible for industrial scale co-combustion.

→ Improvements in the process shows promising results to consider a near-future application in industrial-scale power or thermal generation.

Applicability: Most of the applications related with the industrial-scale thermal production, either for power generation or utility services.

3.- Current advanced combustion technologies

- **Oxy-combustion technology**

The oxy-fuel combustion systems are considered a next-step of the air-fuel combustion systems.

- Increase the efficiency of the combustion processes (reduction of flue gas heat losses)
- Lower emissions levels (specific burners designs)
- Improvement in the temperature stability (more stable combustion)

Alternative approach to post-combustion capture for carbon capture and storage for coal-fired systems (CCS).

Diverse systems typology depending on the oxygen injection or the combustion system.

Key aspects

- NO_x generation reduction.
- Flue gases volume reduction.
- More efficient flue gases treatment systems (lower volume, higher pollutant concentrations)
- Higher flame temperatures.

3.- Current advanced combustion technologies

- **Oxy-combustion technology**

Typical applications included industrial heat applications where higher temperatures are needed and otherwise unfeasible to achieve with traditional air-combustion processes.

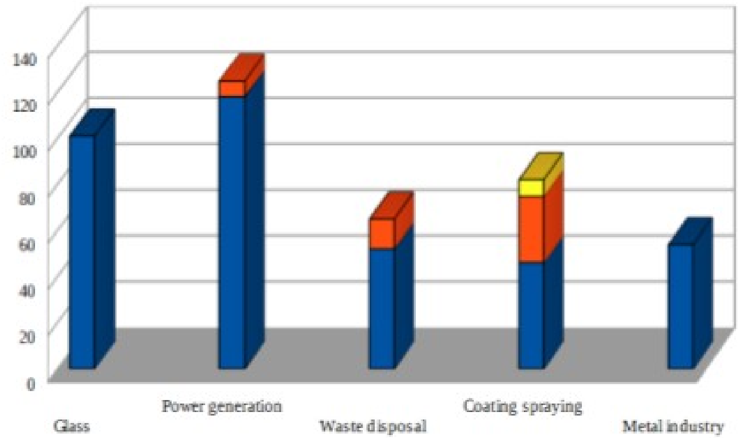
Traditional applications

Glass industry: Increase of the thermal efficiency of processes with an additional increment on the temperatures.

Waste disposal: Increase of thermal destruction thanks to the increase of flame temperature an of flue gases treatment systems. (lower flue gases volume)

Metal industry: Better performances in heat treatment due to higher flame temperatures.

Glass/coating industry: Surface treatments are highly temperature demanding.



3.- Current advanced combustion technologies

- **Oxy-combustion technology**

Most of the current experience for power generation has been developed in different scale test with promising results with several combustion technologies (pulverized coal, fluidized beds or gas-turbine) in relation with **carbon capture and storage** (CCS).

Characteristics comparable to the air-firing combustion despite change of oxidant.

- NO_x emissions from oxy-combustion are significantly lower (65%).
- Steam generation and heat transfer in furnace and convection pass slightly change.
- Flue gas volume exiting boiler reduces by 70%.
- Flue gas treatments easiers (required before exhaust or CO_2 reuse/sequestration)

- **Oxy-co-combustion technology**

Logical path in order to analyze the potential synergies which could be established between co-combustion and oxi-combustion technologies.

"Comprehensive understanding on how direct biomass co-combustion under air and oxy-fuel conditions can be implemented together with efficient low cost emission control techniques in the different markets where traditionally co-combustion and oxi-combustion processes has been performing."

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4.- Project experience

The **BiOxySorb** project has provided interesting feedback and an extensive database of results which supports the issues named in the bibliography and experiences in coal power plants retrofitting.

- **Milling system:**

  Existing **ball milling systems** were analyzed for several proposed bio-fuel/coal mixes at different fuel shares in the project large-scale test facility at CIUDEN.

  Satisfactory results for low bio-fuel/coal shares, impacting in an increase of the milling time as the ratios increases ("dumping" effect). Technically the mills shall support the preparation of the fuels for the co-combustion processes.

  For better milling performance, additional biomass pretreatment is advised or an increase on the torrified degree.

Fuel	HI	Milling time
Bituminous coal	50	23
Biomass pellets	21	73
Torrified biomass wood chips	35	35
Coal/biomass pellets mixture 95/5	42	
Coal/biomass pellets mixture 90/10	41	
Coal/biomass pellets mixture 80/20	37	
Coal/biomass pellets mixture 70/30	34	
Coal/torrified biomass mixture 80/20	32,5	
Coal/torrified biomass mixture 70/30	31,5	
Coal/torrified biomass mixture 60/40	30	

4.- Project experience

- **Fouling probability:**

To analyze inf the selected bio-fuel with the selected fuel shares may represent an impact on the fouling probability of the existent boiler where the large-scale tests were going to be performed, some calculations were performed about the ash melting temperatures of the mixtures biofuel/coal according to theoretical models.

It was not expected to observe severe fouling troubles according to calculations for most of the operational fuel shares despite the fouling probability may reach dangerous values in higher boiler thermal fuel shares (70% coal, 30% biofuel).

Test fuel shares was not expected to generate noticeable fouling effects.

4.- Project experience

- **Gas abatement:**

According to the results that the **Lhoist** group has concluded in their report, SO_2 removal performance were in agreement with the expected predictions, prior the water economizer (300-350ºC) and before the bag-filter (200ºC).

Results in the injections inside the furnace were far from the targets.

Comparing firing modes, the oxy-mode provided better sorbent performance compared to equivalent air-mode combustion, attributed to SO_2 concentration 4 to 5 times higher than in Air-mode (as it was expected according to the consulted bibliography).

Much higher CO_2 concentration (oxy-combustion) did not have any negative impact on the sorbent performances.

Sorbant by-product exceed the limitations of the EN450 standards relative to ash valorization in cement industry (sulphur and free calcium content).

➡ Alternative valorization of sorbent by-product should be found.

4.- Project experience

- **Large scale test boiler operation**

Large-scale tests in the 20MWth pulverized coal boiler placed in CIUDEN facilities (Ponferrada, Spain) were successfully performed of direct co-combustion and direct oxi-co-combustion.

The selected fuel (saw dust) was pneumatically transported and injected directly into the flame of one of the four existent horizontal swirl burners, at a maximum of 36%$_w$ fuel share of the burner (9%$_w$ of the total fuel fed to the boiler, nearly 6,5% total thermal input basis).

Noticeable stability in the boiler behavior during the tests, negligible changes in the process data of either flue gas and water cycle circuits in the operation test time, minor changes in the operation values in oxy-combustion mode in order to reduce inline ignition risks.

No changes either in the CO(<50ppm) and NO_X emissions levels compared with traditional fuel combustion.

➡ Results undoubtedly encourage to continue with additional biofuel/coal fuel shares in the rest of the burners.

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5.- Potential further development

BiOxySorb Project has provided sustainable results that support co-combustion and oxi-combustion technologies are current and feasible technologies.

Oxi-co-combustion process has been revealed as a stable process which joins the benefits of both combustion processes sharing some known limitations.

- **Oxy-co-combustion processes as alternative to traditional oxy-combustion processes**

  Oxi-co-combustion process can be potentially performed in all the traditional processes where oxi-combustion was performed such as metal or glass industries in order to reduce the fossil fuel consumption.

  ➡ Additional investigation shall be performed to analyze the chemical impact of the gaseous products derived from the bio-fuel combustion in the product characteristics.

- **Potential new uses of ashes from oxy-co-combustion**

  Ashes analyses from oxy-co-combustion processes in large-scale tests has shown the ashes composition does not fit with the traditionally used in cement industries.

  It is suggested an alternative study of the valorization possibilities of these ashes.

5.- Potential further development

- **Systems integration for commercial-scale oxi-co-combustion applicability**

After the tests in small and large scale facilities the next steps of this technologies would be heading to commercial-scale tests to generate an experimental database of experiences for further improvements.

This would require prior additional investigation on a logical transition process which absorb the existing reluctances that may arise for this technologies.

➡ Analyze both technically and economically the integration of the required secondary systems into a commercial scale facility and deriving in a comparative exercise of production improvement margins in order to provide a realistic plant profitability estimation.

Fuel preparation system

Second generation biomasses shows better milling behavior but the commercial-scale supply is not entirely ensured.

For a commercial-scale co-combustion process adequate and flexible fuel preparation systems should be developed:

- Mixed crushing systems, able to handle fossil and biofuel fuels, either simultaneously or staged.
- Integration of torrefaction sub-systems in the facility in order to provide a grindable biofuel.

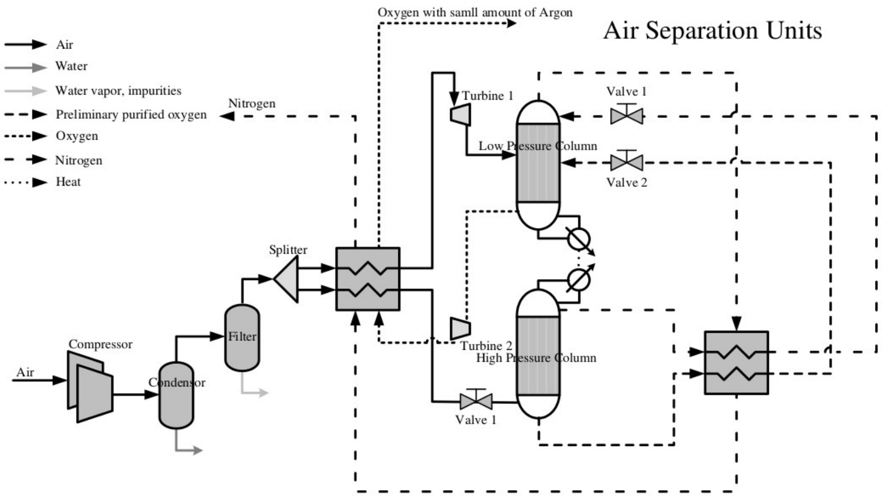
5.- Potential further development

- **Systems integration for commercial-scale oxi-co-combustion applicability**

Oxidant preparation system

Most of the production costs comes from the process reactive/consumables, optimization investigation should be focused on the on-site generation, as costs are reduced if the generation process inputs can be extracted total or partially from the main process.

Oxi-combustion processes requires expensive reactives and in some of the current installations is provided by thirds, but in a commercial-scale facility the reactive should be generated as part of the main process.



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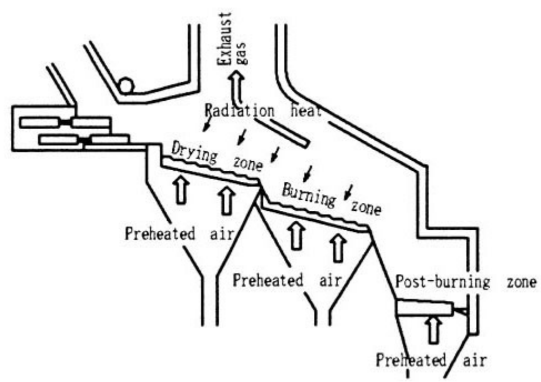
5.- Potential further development

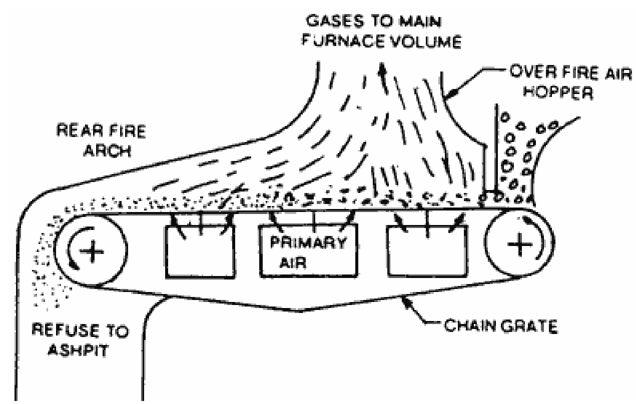
- **Applicability of oxy-combustion for grate technologies**

Grate technologies, either in application for biomass combustion or residues incineration processes, are sensible to NO_x generation whether the temperatures are not carefully controlled. In this kind of combustion equipment

High flame temperature is one of the main precursors of the NO_X formation mechanisms together with the Nitrogen concentration, and despite the relatively elevated Nitrogen composition of the fuels fed in these facilities the main source of nitrogen is the injected under grate oxidizer, which is principally air.

The observed stability of oxi-co-combustion process tests offers an alternative to consider in the classical grate technology combustion processes, where the under fire oxidizer would be composed of a pure oxygen-flue gases mixture.





5.- Potential further development

- **Applicability of oxy-combustion for grate technologies**

This improvement would provide a substantial reduction in the generation of nitrous compound in high alkali fuels as a result of a reduction of the presence of gaseous Nitrogen in the grate with an additional combustion improvement as a result of the high temperature combustion.

Potential improvements

- Higher flame temperature with the derived combustion efficiency.
- Lower nitrous oxides generation.
- More efficient pollutant abatement with the reduction of the flue gases volume

5.- Potential further development

- **Analysis of potential synergies between waste-to-energy technologies and oxy-combustion processes**

Waste-to-energy (WTE) technologies have experienced a huge development as the solid municipal wastes treatment (MSW) is a frequent problem to the society both in short-term and mid-term.

Some of these waste-to-energy technologies are focused in the residues valorization by the conversion into a stabilized fuel ("residue-derived-fuel", RDF) and/or the thermal treatment with a heat or energy generation

Potential improvements

- Higher flame temperatures during the combustion reaction helping to the thermal destruction of the contained components of the MSW/RDF.
- Reduction of the flue gases volume, so that flue gases treatment systems achieves better performances,helping to reduce equipment and reactives consumption in use.

European Commission

Research Fund for Coal & Steel

Gestamp Biomass Solutions

THANKS FOR YOUR ATTENTION

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