BiOxySorb: Economic low carbon power production and emissions control for future and flexible biomass co-fired power stations

Project Overview

by

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Outline

1. Introduction to the BiOxySorb Project
2. Background:
    - Oxy-fuel Combustion
    - Biomass Co-Combustion
    - Dry Sorbent Injection
3. BiOxySorb Work Packages & Combustion Test Facilities
4. BiOxySorb Publications
5. Summary

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BiOxySorb – Introduction

BiOxySorb:

Economic low carbon power production and emissions control for future and flexible biomass co-fired power stations

Project dates:

- Project start: 01/07/2013
- Duration: 36+6 months
- End date: 12/2016

BiOxySorb – Introduction

Strong consortium with industrial partners from all sectors affected by the investigated technologies:

• USTUTT (IFK):	Academic research institute	-	Germany
• CIUDEN:	Public R&D institute	-	Spain
• Uniper:	Utility	-	UK
• Lhoist:	Producer of sorbents	-	Belgium
• GBS:	Boiler manufacturer	-	Spain

BiOxySorb – Introduction

<u>Project objectives:</u>

- Coal-fired power plants need to reduce carbon intensity:
  - Biomass co-combustion
  - Oxy-fuel combustion
  - Biomass co-combustion in oxy-fuel (negative C-balance!)
- New biomasses come into the market: 2nd generation biomass
- Flexible, low cost emission control required → Dry sorbents
- How can systems be integrated and how do they perform?

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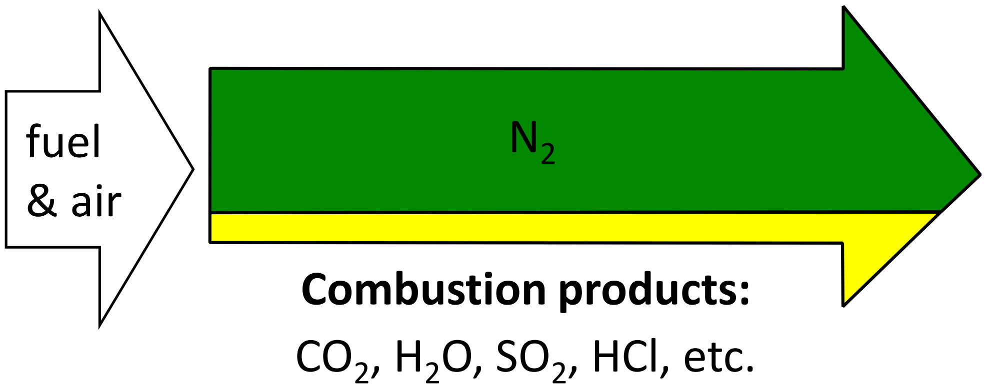
Background: Air vs. Oxy-Fuel

- **<u>Air-fired</u> combustion:**



Background: Air vs. Oxy-Fuel

- **<u>Oxy-fuel</u> combustion:**

fuel
& O_2

Combustion products:
CO_2, H_2O, SO_2, HCl, etc.

<u>**Exclusion of airborne N_2:**</u>

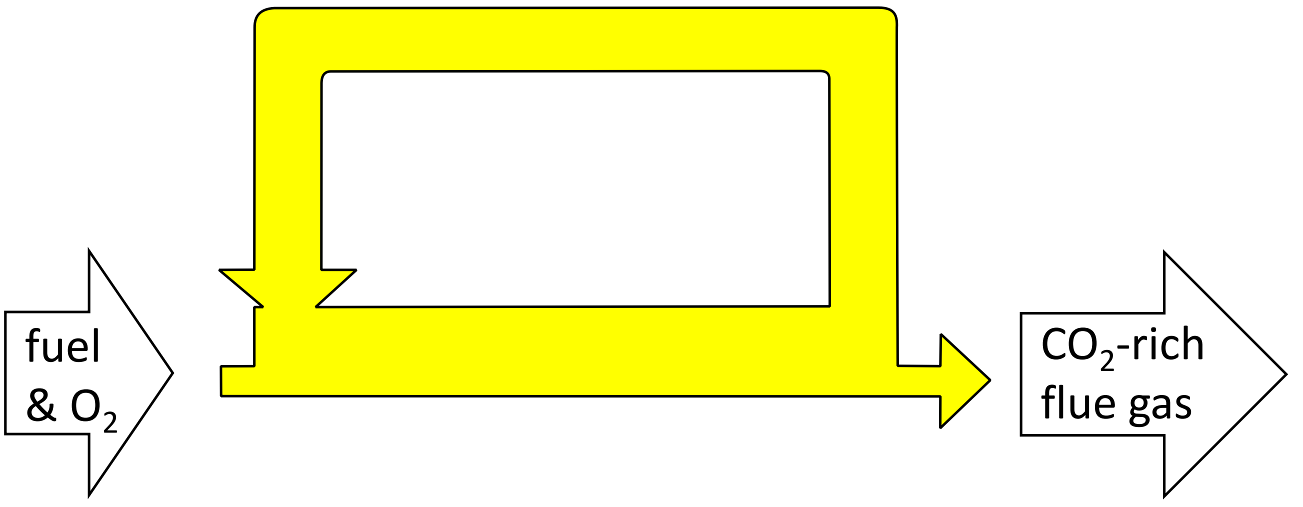
- Generation of CO_2 rich gas for **sequestration/utilization**
- **Increase of acid gas** concentrations (factor 4-5) *(when not removed)*

<u>“Process-borne” impurities:</u>

- CO, NO_x
- Little impacted by absence of N_2
- Concentration changes highly dependent on process conditions

Background: Air vs. Oxy-Fuel

- **Oxy-fuel combustion:**



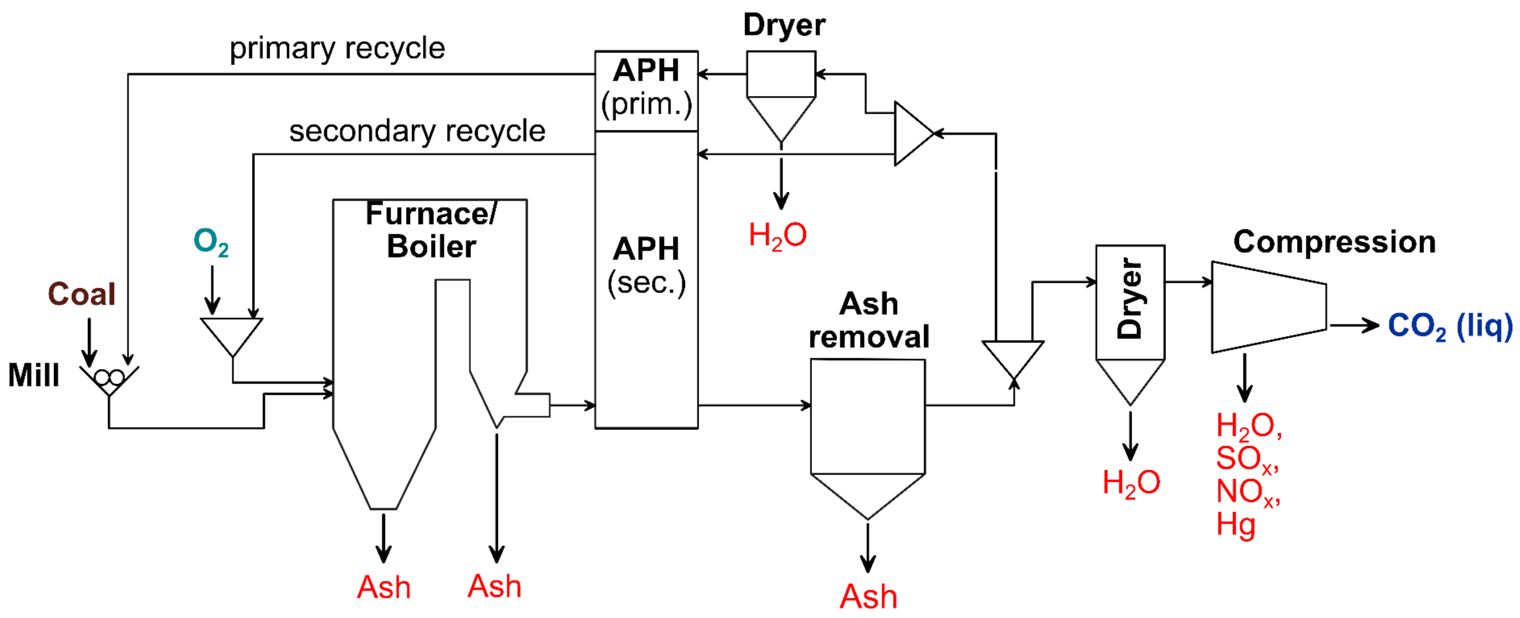
Flue gas recirculation to control:

- Temperatures
- Gas flows

➢ HEAT TRANSFER

Background: Oxy-Fuel Combustion

- Practical **oxy-fuel** configuration for <u>low S & Cl fuels</u>



Problems: - Excessive SO_x (& HCl) levels with most coals

- SO_x (& HCl) control within recycle required to reduce corrosion

- Final acid gas removal required before CO_2 liquefaction

Background: Oxy-Fuel Combustion

- **Oxy-fuel combustion: Status**
  - Feasibility proofed at pilot and demo scale (CIUDEN, Vattenfall, Callide Oxy-fuel Project)
  - Most work focussed on mono-combustion of coal
- **Limited experience/Knowledge gaps:**
  - Biomass co-combustion in oxy-fuel conditions
  - Oxy-fuel combustion of 2nd generation biomasses
  - Fate of acid gases (SO_x, HCl) and trace elements (Hg)
  - Economic flue gas cleaning in oxy-fuel operation by DSI

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Background: Biomass Co-Combustion

- **Biomass co-combustion: Status**
  - Widely applied in power plants; Most plants 5-15% co-firing
  - Currently 1st generation biomasses
  - Biomass co-combustion can be retrofitted
- **Benefits of biomass as fuel:**
  - Renewable energy source: <u>Carbon neutral</u>
  - “Clean” fuel: Lower harmful gas emissions (e.g. SO_x, Hg)

Co-combustion under in oxy-fuel plants:

- Lower SO_x, (HCl) and Hg levels in the boiler/flue gas
- <u>Negative carbon balance</u>

Background: Biomass Co-Combustion

- **Second generation biomass: torrefied biomass**
  - Lower moisture content & hydrophobic properties
  - Higher energy density and heating value
  - Easier storage and delivery
  - Easier milling in pulverized coal-fired plants
- **<u>Limited experience/Knowledge gaps:</u>**
  - Co-combustion of 2^{nd} generation biomasses
  - Biomass co-combustion at high thermal shares
  - Milling/co-milling of 2^{nd} generation biomasses
  - Emission behavior, ash qualities, slagging/fouling

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Background: Dry Sorbent Injection (DSI)

Acid gas (SO_2, SO_3, HCl) control by dry sorbents:

- **Earth-alkali based:** e.g. $Ca(OH)_2$, $CaCO_3$
  - $Ca(OH)_2 + \mathbf{SO_2} \rightarrow CaSO_3 + H_2O$ *(low temperature)*
  - $Ca(OH)_2 + \mathbf{SO_2} + {}^1/_2\, O_2 \rightarrow CaSO_4 + H_2O$ *(high temperature)*
  - $CaCO_3 + \mathbf{SO_2} + {}^1/_2\, O_2 \rightarrow CaSO_4$ *(high temperature)*
- **Alkaline based:** e.g. $NaHCO_3$, Trona *(low temperature)*

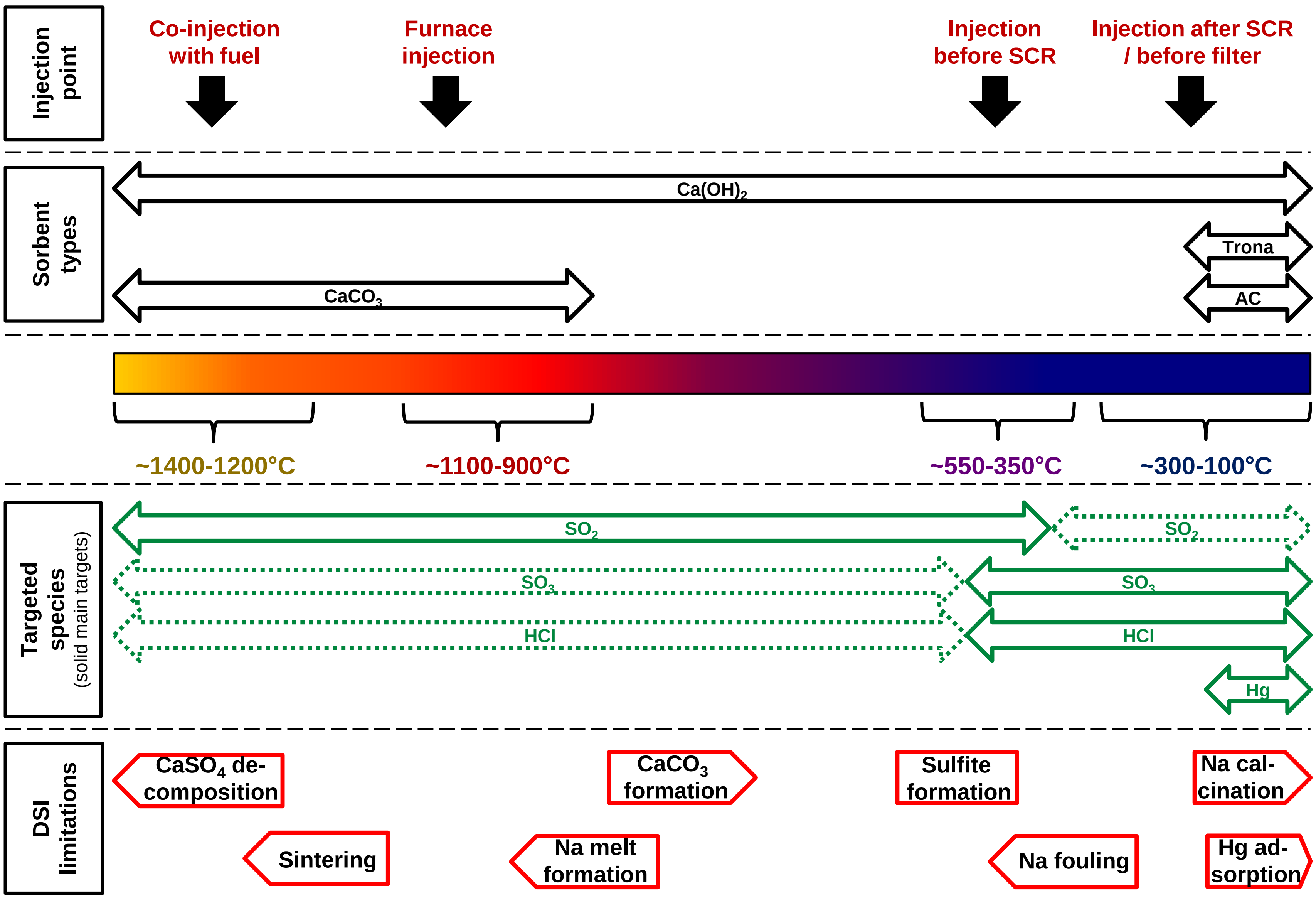
Hg control by dry sorbents:

- **Activated carbon, mineral based sorbents** *(low temperature)*

Performance depends on:

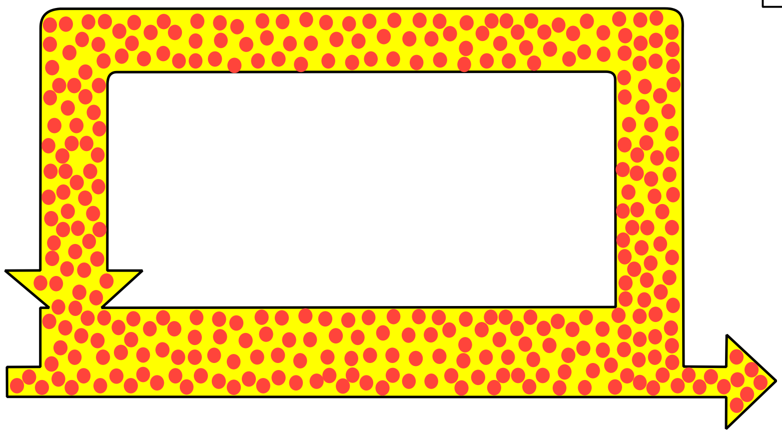
- **Sorbent reactivity** (e.g. porosity, active surface etc.)
- **Process conditions** (e.g. temperature, dispersion etc.)

Background: DSI in BiOxySorb



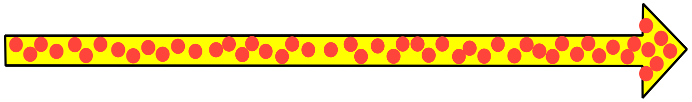
Background: DSI in Oxy-Fuel

- Recycle combustion:



Acid gases (SO_2, HCl):

- No recycle:

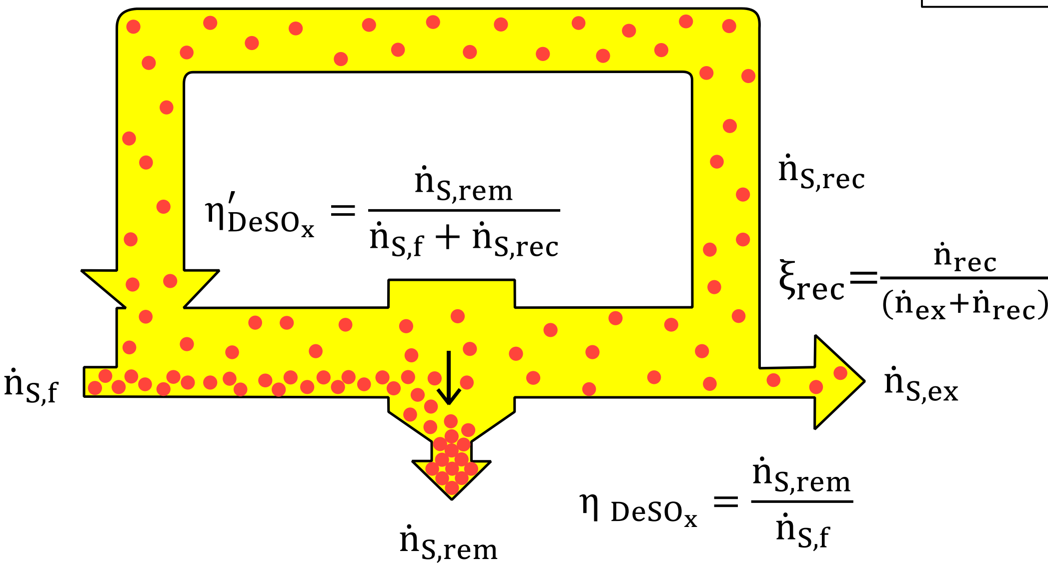


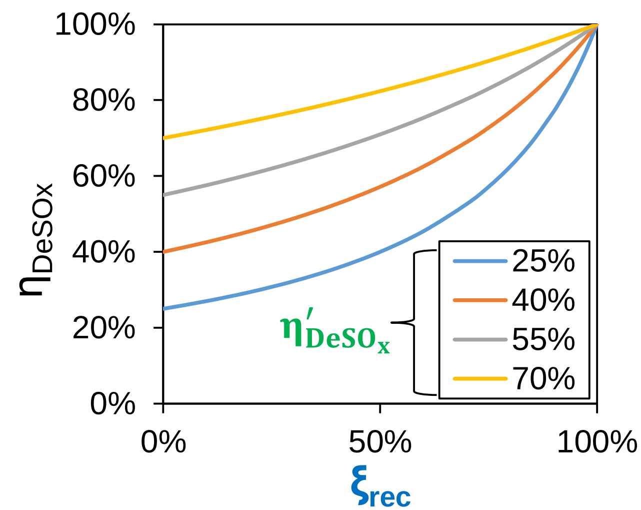
- Recycle combustion does not alter gas concentrations

Background: DSI in Oxy-Fuel

- Recycle combustion:

Acid gases (SO_2, HCl):





<u>Effect of flue gas recirculation on acid gas removal:</u>

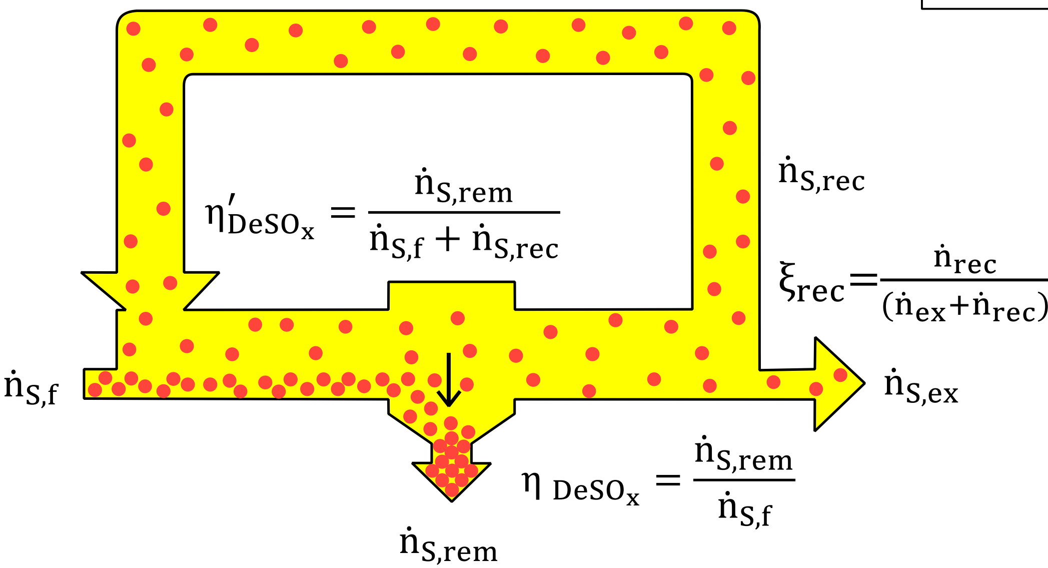
(based on mass balances)

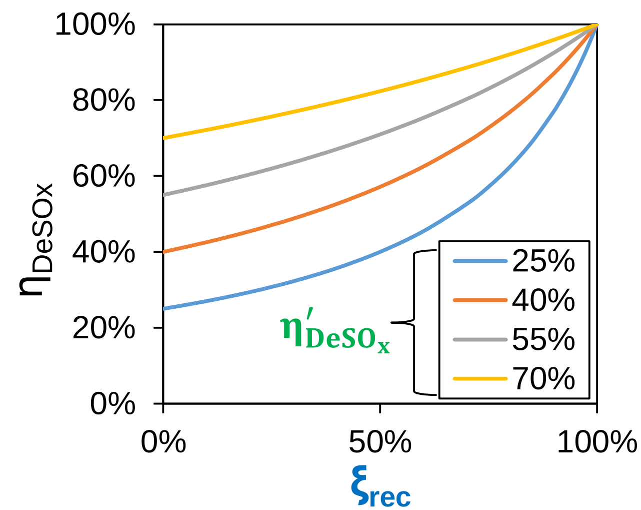
$$\eta_{DeSO_x} = \frac{\eta'_{DeSO_x}}{1 - \left(1 - \eta'_{DeSO_x}\right)\xi_{rec}}$$

Background: DSI in Oxy-Fuel

- Recycle combustion:

Acid gases (SO_2, HCl):



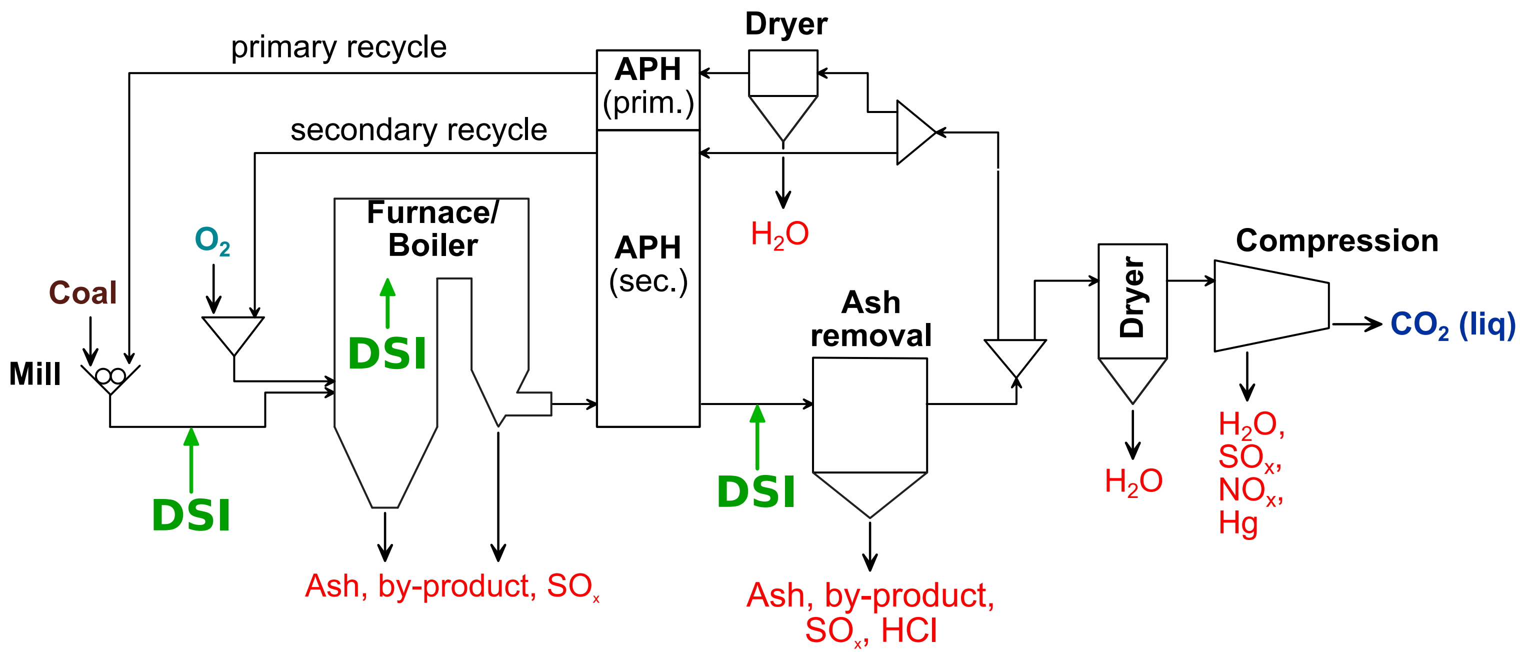


<u>Effect of flue gas recirculation on acid gas removal:</u>

- Practical residence time of impurities is extended (beneficial)
- Acid gas removal lowers initial impurity levels (negative)
- Both effects balance each other to some degree

Background: DSI in Oxy-Fuel

Dry Sorbent Injection (DSI) [e.g. $CaCO_3$ or $Ca(OH)_2$]:



Benefits/drawbacks:

+ Low costs (no scrubber required)
+ No excessive gas cooling
- Dilution of ash

BiOxySorb – Dry Sorbent Injection

- **Sorbents for SO_x, HCl and Hg control: Status**
  - Widely applied for Hg control (USA)
  - Applied for acid gas removal (e.g. wood & MSW fired & FB systems)
  - Few applications for acid gas removal in coal/oil fired systems (USA, China)
- **<u>Limited experience/Knowledge gaps:</u>**
  - Potential of sorbents to increase flexibility of flue gas cleaning systems
  - Performance of sorbents under oxy-fuel condition
  - Integration of sorbent injection in oxy-fuel processes

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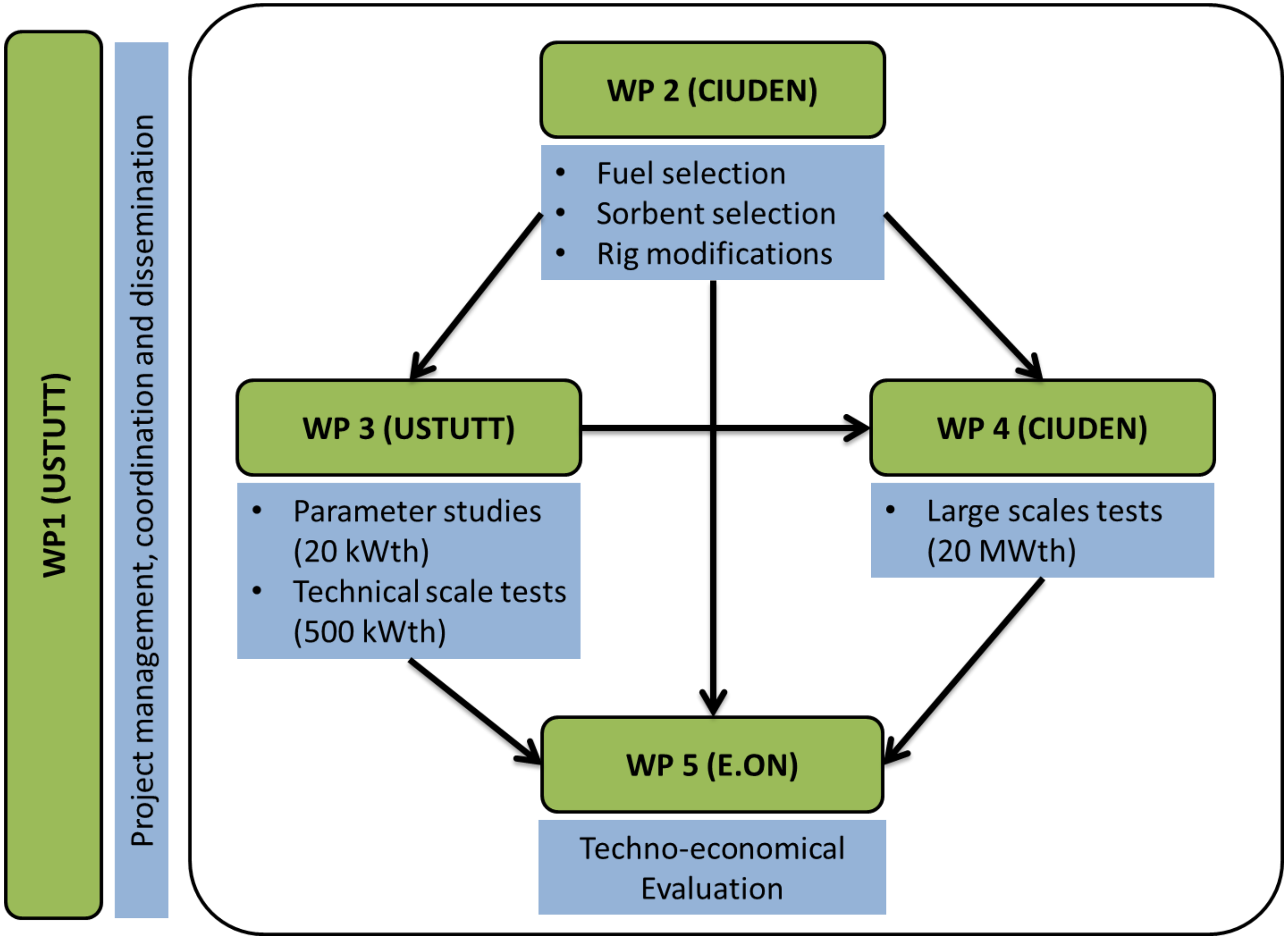
BiOxySorb – Work Packages & Facilities



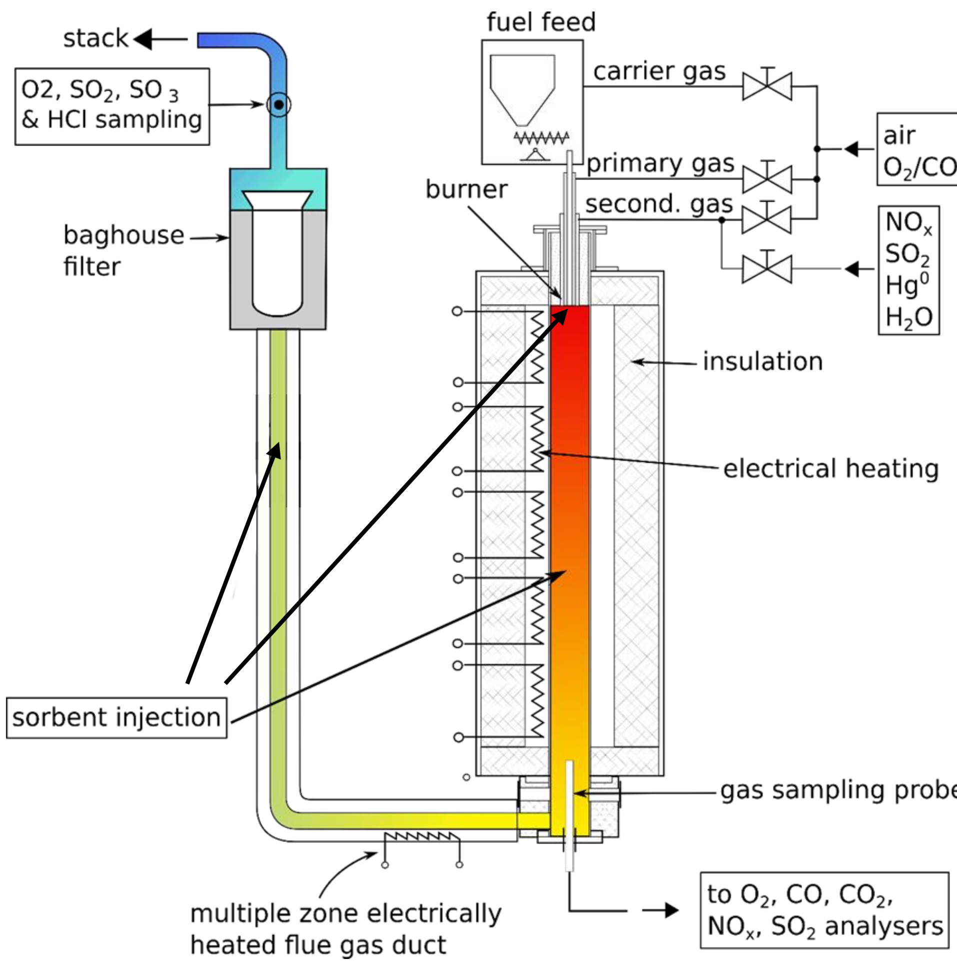
BiOxySorb – Work Packages & Facilities

IFK's 20 kW el. heated facility:

- Air and simulated oxy-fuel operation
- Mono- and co-firing possible
- Very good accessibility for injection and sampling

➢ Highly flexible system

Used for WP3 <u>parametric studies</u> on co-combustion and DSI in air and oxy-fuel mode

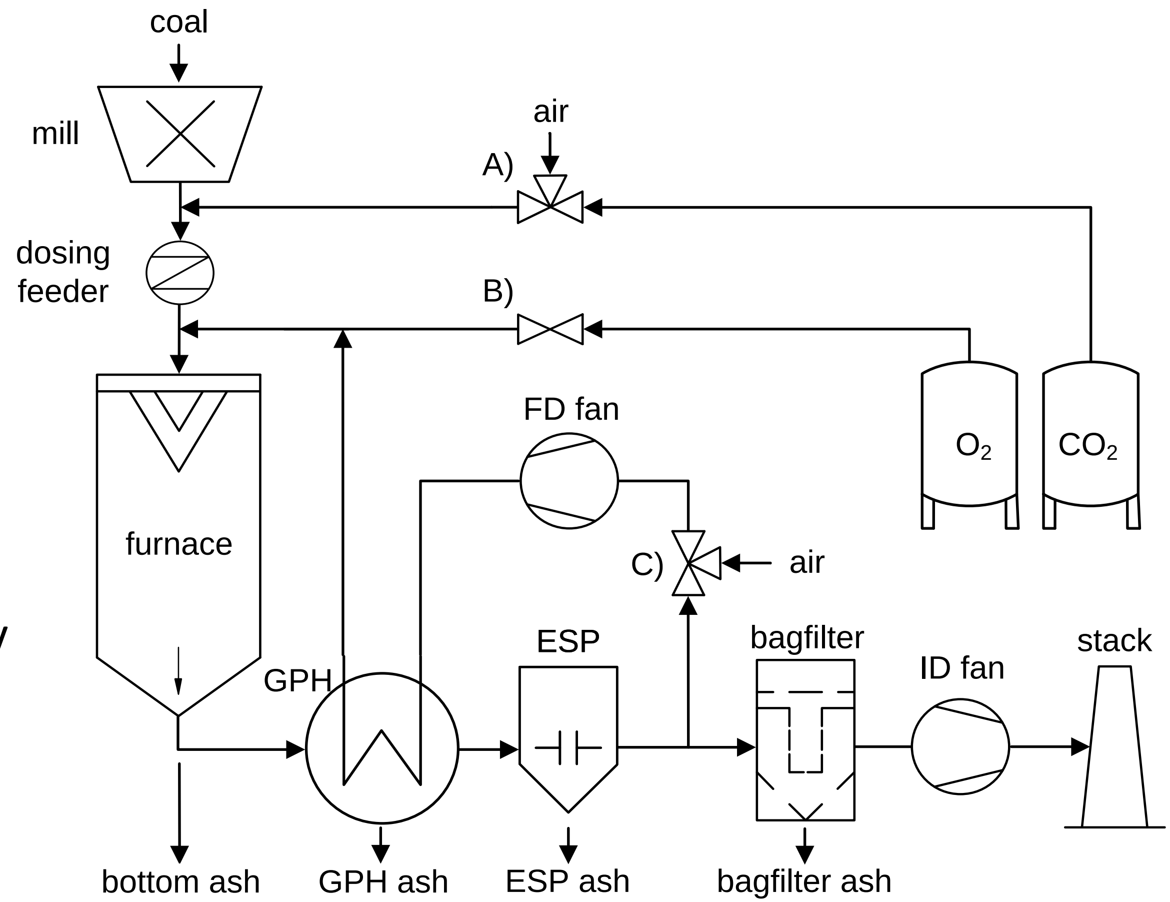


BiOxySorb – Work Packages & Facilities

IFK's 500 kW pilot rig:

- Air and oxy-fuel operation
- Mono- and co-firing
- Good accessibility for injection and sampling
- More realistic system
- 24 hour operation
- ➢ Less flexible & more costly

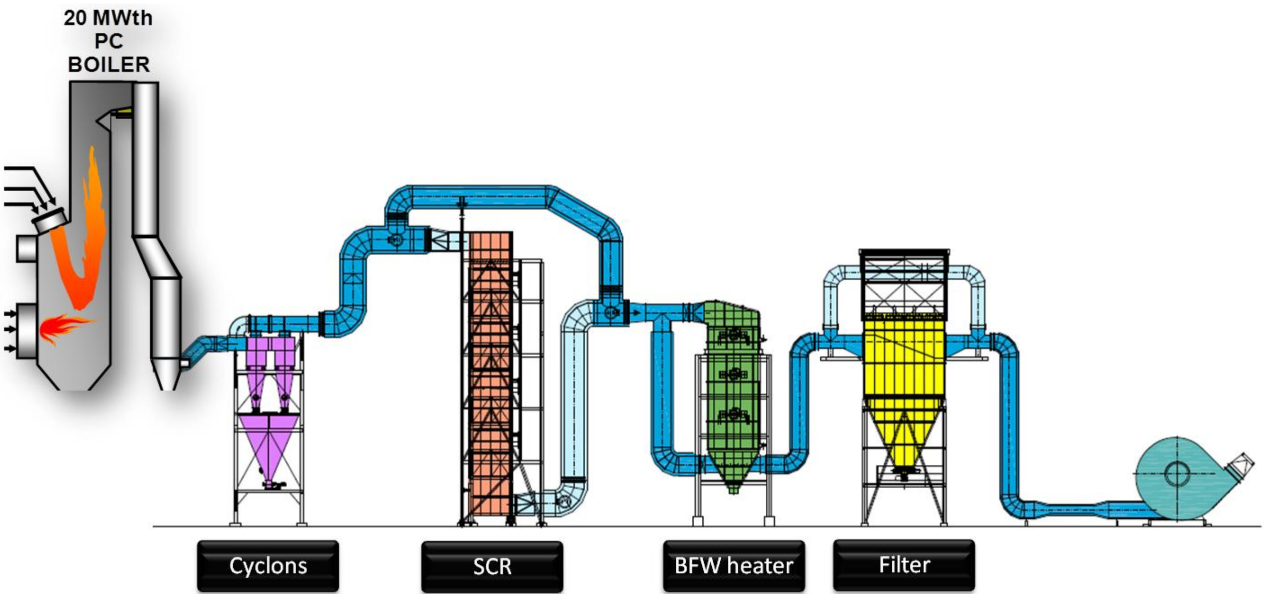
Used for WP3 <u>pilot studies</u> with selected co-combustion and DSI configurations in air and oxy-fuel mode



BiOxySorb – Work Packages & Facilities

CIUDEN's 20 MW demo system:

- Ball mill (co-milling)
- Air and oxy-fuel operation
- Mono- and co-firing
- Good accessibility for injection and sampling
- Realistic: Industrial scale and outline
- 24 hour operation
- ➢ Less flexible & relatively costly



Used for WP4 <u>demonstration tests</u> with selected co-combustion and DSI configurations in air and oxy-fuel mode

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BiOxySorb: Publications

- <u>Poster:</u> **Presentation of the BiOxySorb Project,** *Reinhold Spörl et al. (IFK),* 3rd Oxyfuel Combustion Conference, 9th-13th September 2013, Ponferrada, Spain
- <u>Presentation:</u> **Risk during co-firing oxy-mode**, *Miguel Angel Delgado et al. (CIUDEN)*, 4th IEA CCC Workshop on co-firing Biomass with Coal, 4-6th November 2014, Nittany Lion Inn, State College, Pennsylvania, USA.
- <u>Presentation:</u> **The Impact of Co-combustion on Acid Gas and Mercury Emissions**, *Reinhold Qin et al. (IFK),* 40th International Technical Conference on Clean Coal Fuel Systems 31st May-4th June 2015, Sheraton Hotel, Clearwater, Florida, USA.
- <u>Presentation:</u> **Impact of Co-combustion and Oxy-Fuel Combustion on Flue gas Impurities**, *Reinhold Spörl et al. (IFK),* 5th Oxyfuel Combustion Research Network Meeting, 27th-30th October 2015, Wuhan, China
- <u>Presentation:</u> **Acid Gas Control by Dry Sorbent Injection in Air and Oxy-Fuel Combustion**, *Reinhold Spörl et al. (IFK),* 5th Oxyfuel Combustion Research Network Meeting 27th-30th October 2015, Wuhan, China
- <u>Presentation:</u> **Acid Gas Control by Dry Sorbent Injection in Air and Oxy-Fuel Combustion**, *Reinhold Spörl et al. (IFK),* 33rd Annual International Pittsburgh Coal Conference 8th-12th August 2016, Cape Town, South Africa.

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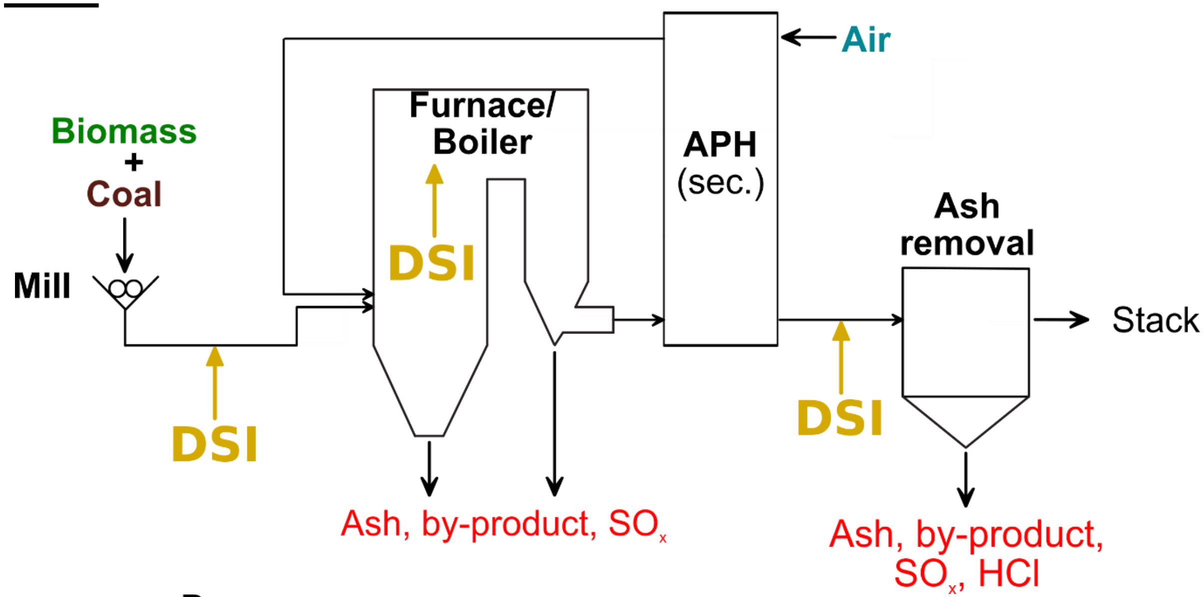
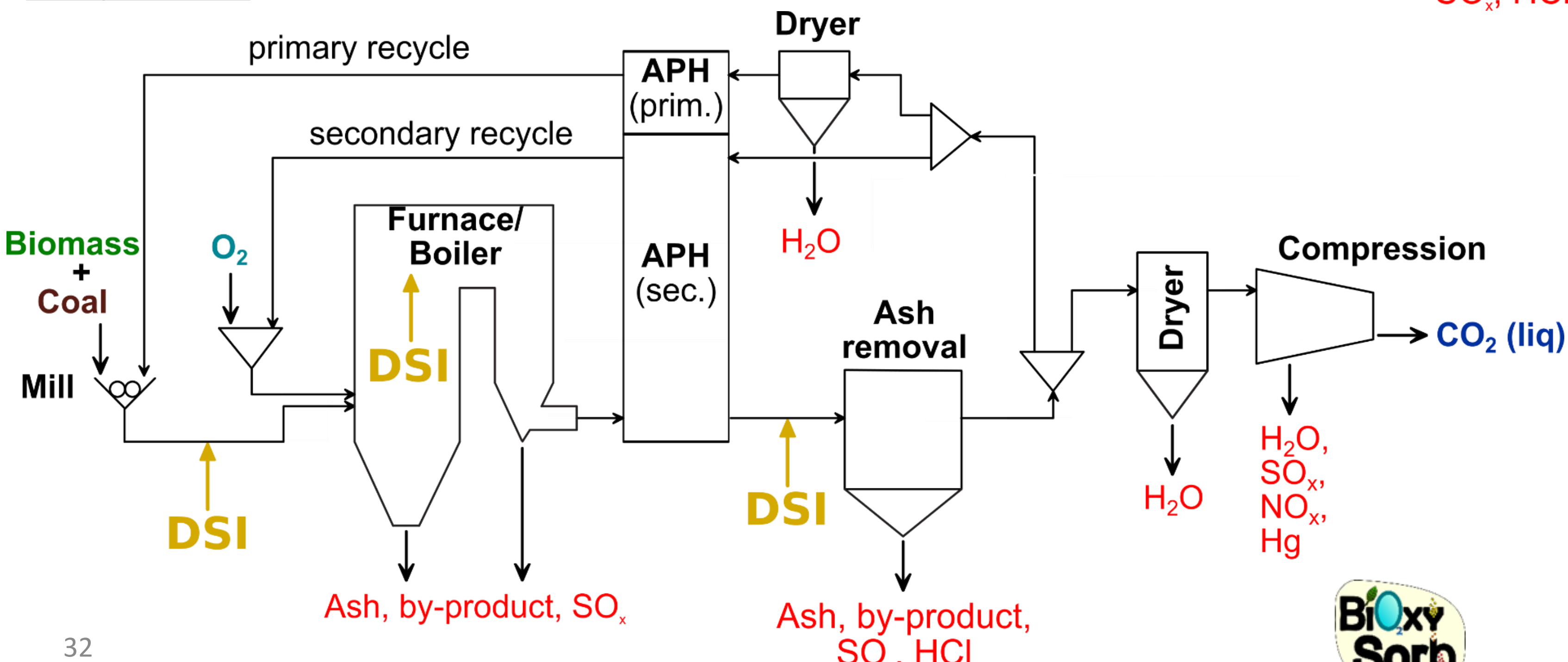
Air:



Oxy-fuel:



Thank you for your attention!

ACKNOWLEDGMENTS

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