BIOREF

Laboratório Colaborativo para as Biorrefinarias

Gasification - Technology relevance and case study in Portugal

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Forestry and Habitats Online Knowledge Exchange Workshop

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BIOrural

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1 Presentation of BIOREF

BIOREF (Collaborative Laboratory for Biorefineries) is a private and non-profit association aimed to deploy scientific knowledge, technology and innovation in the **development of biorefineries**.

R&I ACTIVITIES

STRATEGIC DOMAINS

Strategic domain	R&I activities
BIOENERGY & RENEWABLE GASES	#1: Biochemical processing of biomass for sustainable aviation fuels #2: Thermochemical processing of biomass for sustainable aviation fuels #3: Thermochemical processing of biomass and wastes for biofuels and renewable fuels #4: CO_2 valorisation into renewable fuels/e-fuels
SUSTAINABLE BIOECONOMY	#5: Algae fractionation into bio-based products #6: Production of bioactive compounds from lignocellulosic materials

1 Presentation of BIOREF (cont.)

- Our associates:

sysadvance

SILICOLIFE

TÉCNICO LISBOA

Ciências ULisboa

a4f algae for future

Universidade do Minho

tratolixo gestão de resíduos urbanos

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HyChem

RAIZ

biotrend experts in bioprocessing

BLC3 CAMPUS DE TECNOLOGIA E INOVAÇÃO

LNEG

1 Presentation of BIOREF (cont.)

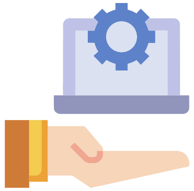
- Our services:

Consulting

Scale-up, Market Studies and Economic, Energy and Environmental Feasibility

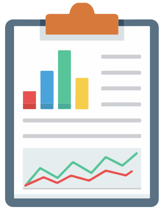
Analysis of New Sustainable Markets

Diversification and Integration of other emerging areas of biomass and biorefineries



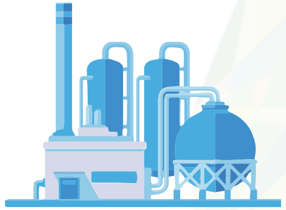
Evaluation, Assistance and Technological Development

Physical, chemical, thermochemical and biological processes



State-of-the-art Studies

In the Technological aspect and in the generation of Value Added Products/Services

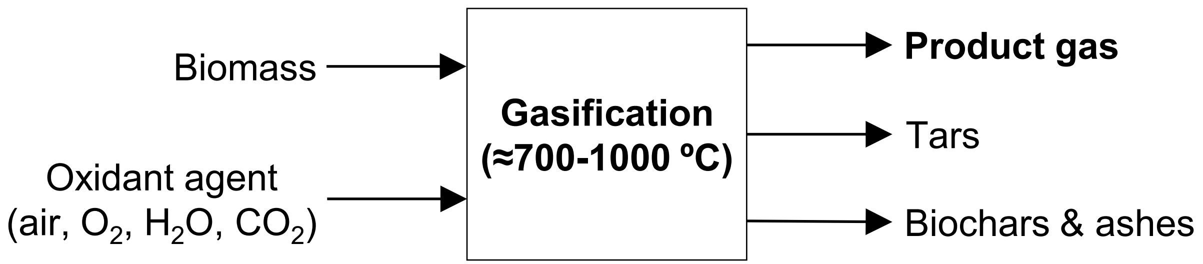


Integration and Stimulation of Biorefineries

Recovery of waste in bioenergy, bioproducts and biofuels in the context of the Circular Economy

2 Gasification concepts and relevance

- Definition: **thermochemical conversion of biomass** using oxidant agents for partial oxidation at high temperature, generating a **product gas for energy applications**.
- General schematic, reactions and products:




Pilot-scale gasifier

Reactions	
Oxidation	**Reduction**
$C + O_2 \rightarrow CO_2$ $2C + O_2 \rightarrow 2CO$	$C + 2H_2 \leftrightarrow CH_4$ (hydrogasification) $CO + H_2O \leftrightarrow CO + H_2$ (water-gas shift) $C + CO_2 \leftrightarrow 2CO$ (Boudouard)


Tar


Char & ash

2 Gasification concepts and relevance (cont.)

- Product properties and applications:

Product	Properties	Applications
Product gas	• High CO content (5-26 vol.%). • High H_2 content (13-27 vol.%). • Significant lower heating value (7-16 MJ/m^3).	• Energy generation (thermal and electric). • Renewable gases (biomethane and hydrogen). • Liquid biofuels (methanol, ethanol, dimethyl ether, Fischer-Tropsch diesel and gasoline).
Biochar	• High carbon and ash contents.	• Catalysts. • Construction materials. • Remediation of effluents.
Tar	• Mixture of liquid hydrocarbons (e.g., naphtalene, benzene, toluene).	• Recovery of chemical products. • Liquid fuels (through regeneration). • Recirculation to the gasifier.

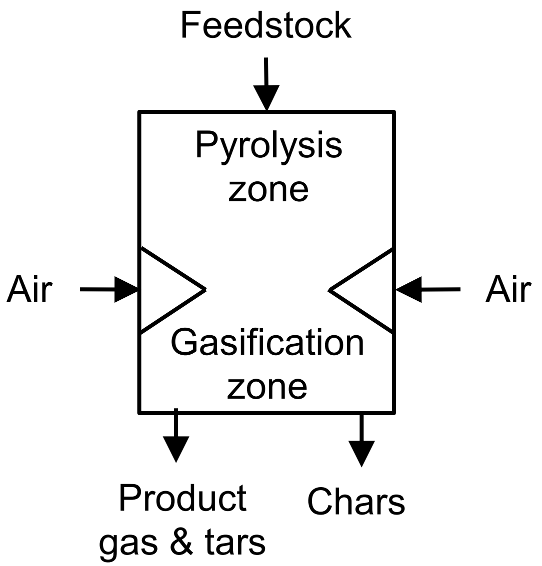
(Basu, 2013; Molino et al., 2018)

2 Gasification concepts and relevance (cont.)

- Reactor configurations:

Fixed-bed downdraft

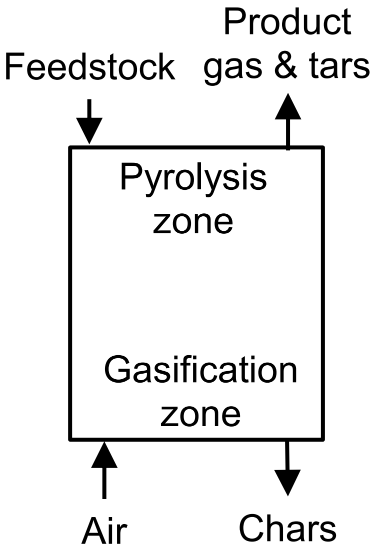
(10 kW - 1 MW)



Characteristics:
- less tars;
- lower startup time;
- small-scale implementation;
- demanding requirements for feedstocks.

Fixed-bed updraft

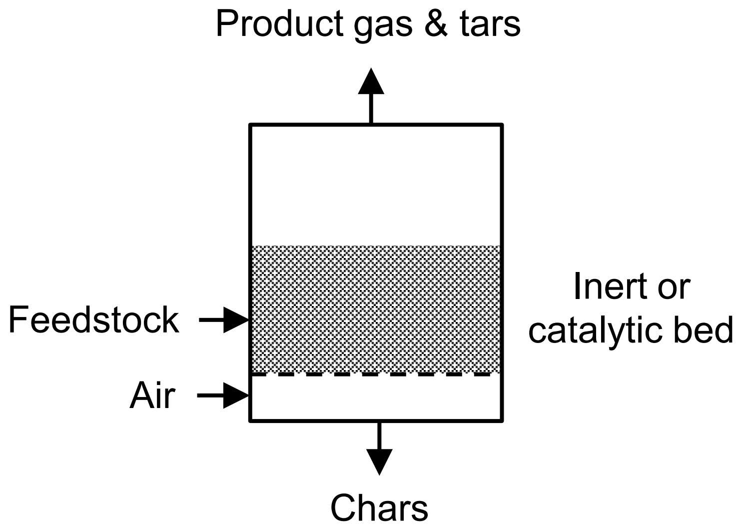
(1 MW - 30 MW)



Characteristics:
- admits wetter feedstocks;
- high tar amounts;
- reduced process flexibility.

Bubbling fluidised-bed

(3 MW - 200 MW)



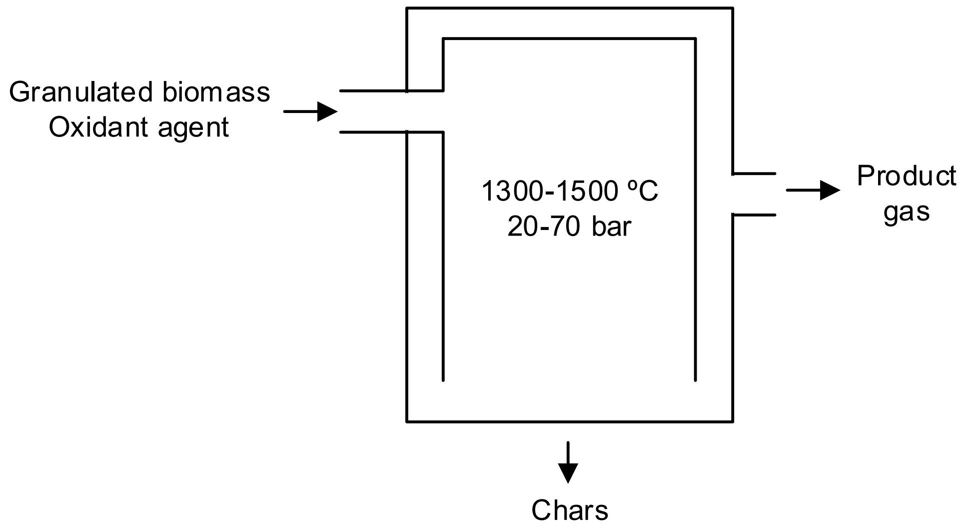
Characteristics:
- greater tolerance to feedstock variability;
- constant temperature;
- implementation at larger scales.

Gasification concepts and relevance (cont.)

- Reactor configurations (cont.):

Entrained flow

(100 MW - 5000 MW)

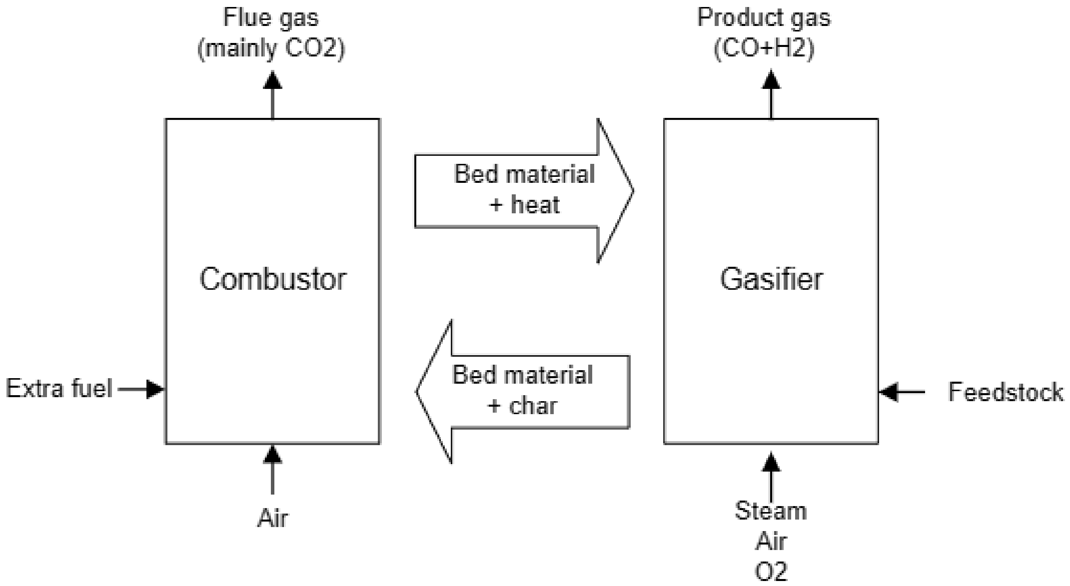


Characteristics:

- minimal tar production;
- high feedstock conversion rates;
- demanding feedstock pre-treatment (grains/powder, ≈250-1000 µm).

Dual fluidised-bed

(200 kW - 200 MW)



Characteristics:

- large-scale implementation;
- separation of CO_2-rich flue gas;
- high H_2 and CO contents in product gas;
- high calorific value (12-20 MJ/Nm^3).

2 Gasification concepts and relevance (cont.)

- Product gas characteristics:

Reactor	Conditions	Syngas composition (vol.%)				LHV (MJ/m^3)
		H_2	CO	CO_2	CH_4	
Fluidised bed	• Pine sawdust. • 700-900 ºC. • Air-steam.	21-39	35-43	18-20	6-10	7.4-8.6
Updraft	• Woodchips. • 900 ºC. • Air.	18	14	14	2	4,4
Downdraft	• Wooden cubes. • 800-850 ºC. • Air	11-20	17-24	7-11	1-2	4-5
Dual fluidised bed	• Bark. • 850ºC. • Steam.	45	23	18	8	10.6
Entrained flow	• Corn cobs. • Oxygen.	25-28	34-36	26-35	2-5	7.7-9.4

(Molino et al., 2018; Hanchate et al., 2021; Kremling et al., 2017; Hsi et al., 2008; Dogru & Erdem, 2020)

2 Gasification concepts and relevance (cont.)

Gasification pros and cons (compared to combustion)	
Pros	**Cons**
• Lower emissions of pollutants (NO_x, SO_2, dioxins and furans). • Implementation at smaller scales (<100 kW). • Higher energy efficiency during syngas combustion. • Flexibility of gas applications (energy and fuels). • Autothermal operation is possible. • Possible valorisation of by-products (chars and tars).	• Pre-treatment of feedstocks may be demanding. • Lower technological maturity. • Higher precision of oxidant agent injection. • Instability of temperature. • Less silent and odorless process.

(Grande et al., 2021)

2 Gasification concepts and relevance (cont.)

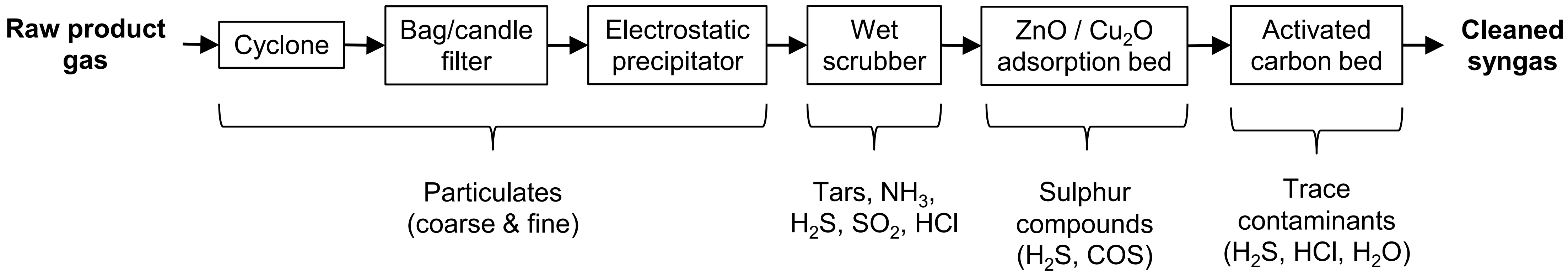
- Contaminants in product gas:

Contaminant	NH_3	H_2S	HCl	HCN	NO_x	SO_2
Concentration (ppmv)	33-7000	33-2500	60-650	100-400	<650	<1500

Cause

- Catalyst poisoning.
- Corrosion.
- Formation of deposits.
- Air pollution & health diseases.

- Configuration example for a gas cleanup system:



(Bari et al., 2000; Recari et al., 2016; Dias, 2008; Tamošiūnas et al., 2023; Liu et al., 2012)

3 Case study in Portugal

- Project HYFUELUP (Hybrid Biomethane Production from Integrated Biomass Conversion):
  - goal: development of an advanced technology to **convert low-grade feedstocks into biomethane using gasification, electrolysis and methanation** (TRL 6-7);
  - period: 11/2022 to 10/2026;
  - funded by Horizon Europe;
  - website: https://hyfuelup.eu/;
  - project consortium:
    - leader: BIOREF Laboratório Colaborativo para as Biorrefinarias
    - contributors: Politécnico de Portalegre, Circle Molecule, KAΠE CRES, Paul Scherrer Institut PSI, University of Stuttgart Germany, Johnson Matthey Inspiring science, enhancing life, Bioplat Biomasa para la Bioeconomía, LNEG, dourogás renovável, AlphaSYNT Swiss SynFuels

3 Case study in Portugal (cont.)

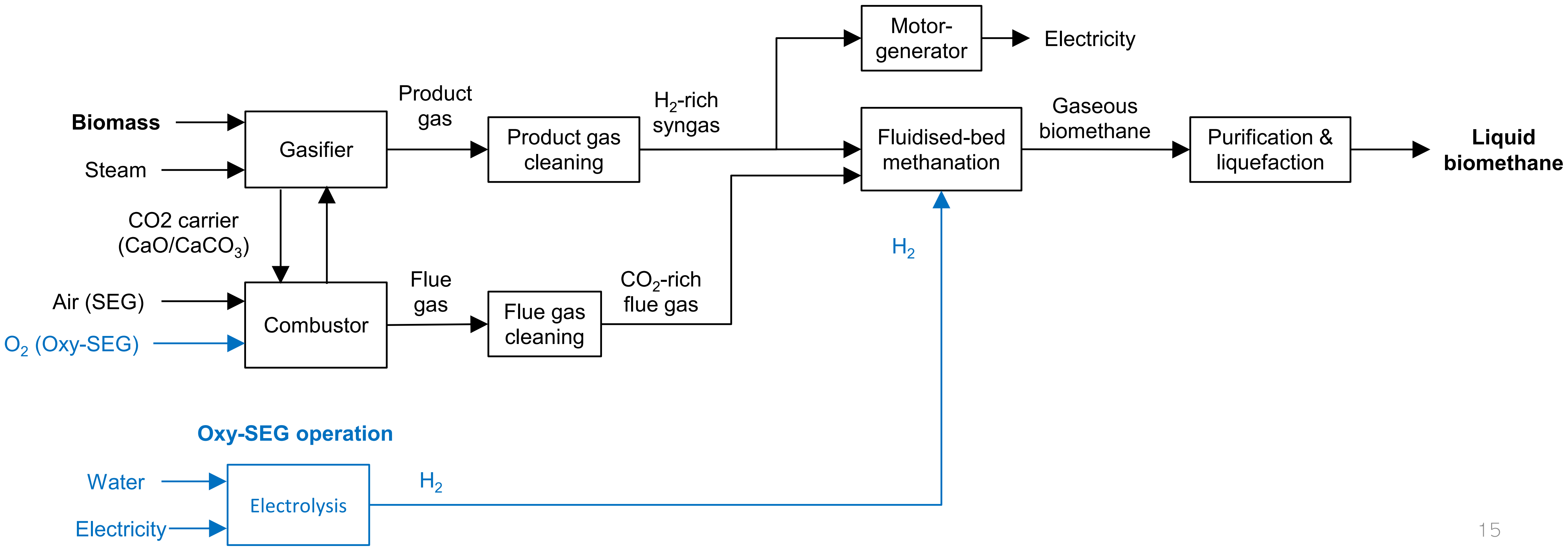
- Project HYFUELUP - key innovations:
  - **diversification of feedstocks** (from crop rotation systems and low-grade wastes (digestate));
  - **hybrid SEG/Oxy-SEG operation** in the same reactor configuration;
  - **flexible H2 addition** for methanation;
  - demonstration of a complete value chain integrating **SEG, catalytic fluidised-bed methanation, and high-temperature electrolysis**;
  - **enhanced carbon conversion efficiency** (65-71 % as HHV);
  - **reduced production of GHG** compared to natural gas (<90 %).

3 Case study in Portugal (cont.)

- Project HYFUELUP - demonstration site:
  - located in **Tondela (Viseu), Portugal**;
  - retrofitting of an existing CFB gasifier;
  - feedstocks: **digestate sludges and lignocellulosic wastes** (1-4 t/h);
  - biomethane production: **50 m^3/h** (or 500 $kW_{th\ LHV}$).

3 Case study in Portugal (cont.)

- Project HYFUELUP - technical aspects:
  - gasifier configuration: **dual fluidised bed** (sorption enhanced gasification, SEG);
  - dual mode of operation (**SEG/Oxy-SEG**), according to H_2:CO ratio in the syngas:



4 Presentation highlights

- Gasification is a **sustainable and flexible process** for valorising residual feedstocks into different added-value products.
- The process contributes to **fulfil the European environmental policies** regarding renewable fuels and GHG abatement.
- **Injection of steam or O_2** enriches syngas composition, but increases process complexity and costs.
- The gas cleanup step is a **critical point** in the process → a thorough planning at affordable cost is required.
- **More projects and investments are required** at a national level.

Laboratório Colaborativo para as Biorrefinarias

Thank you for the attention!

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