Gasification Research at Sotacarbo

Andrea Porcu

SOTACARBO
SUSTAINABLE ENERGY RESEARCH CENTRE

Grande Miniera di Serbariu – 09013 Carbonia, ITALY

Outline

- Company profile
- CRADA (Sotacarbo-NETL agreement)
- Research facilities
- Experimental results
- Experimental results vs simulations
- Future work
- Conclusions

Company profile

Sotacarbo: Società Tecnologie Avanzate Low Carbon

Shareholders:
- ENEA (50%)
- Regional Government of Sardinia (50%)

Estabilished: 1987

energy from biomass

CO_2 capture

CO_2 utilization

CO_2 storage

energy efficiency

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CRADA

Cooperative Research and Development Agreement (CRADA)

Signed in 2018

Italian Team

Sotacarbo S.p.A.

- Andrea Porcu
- Mauro Mureddu
- Federica Dessì
- Alberto Pettinau

USA Team

NETL

- Mehrdad Shahnam
- Yupeng Xu
- Liqiang Lu
- William Rogers
- Jeff Dietiker
- Jia Yu

DOE-HQ

- Bhima Sastri

Research facilities

Demo-scale fixed-bed up-draft gasifier

- up to 5 MW_{th} using coal as fuel
- up to 1.2 MW_{th} using biomass as fuel
- up to 360 kg/h of biomass
- more than 2000 h of experimental test

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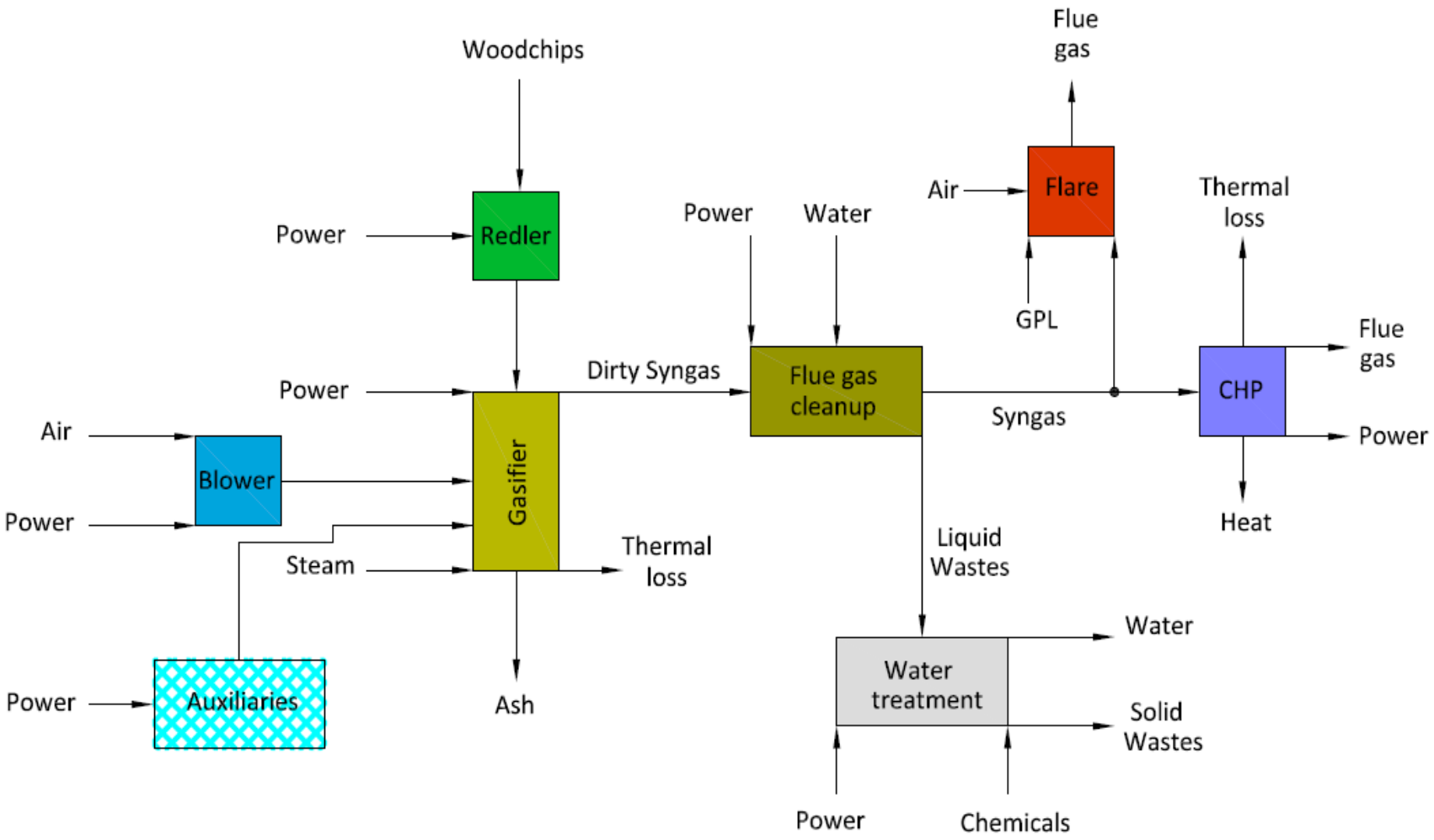
Research facilities



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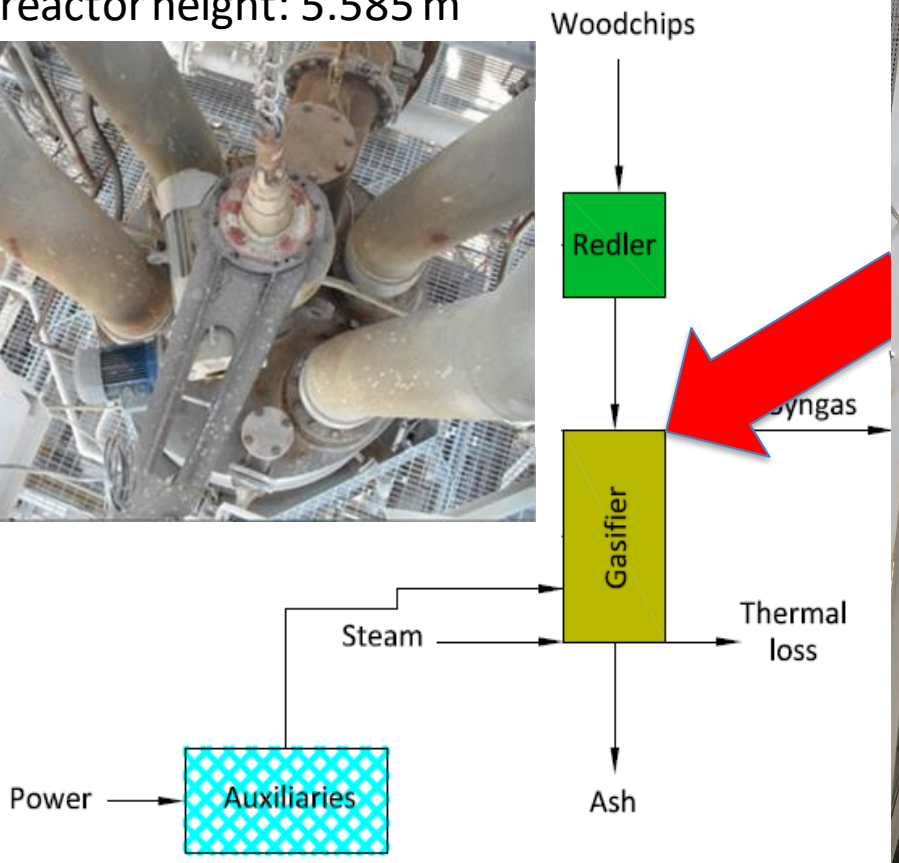
Research facilities

- reactor inner diameter: 1.3 m
- reactor height: 5.585 m



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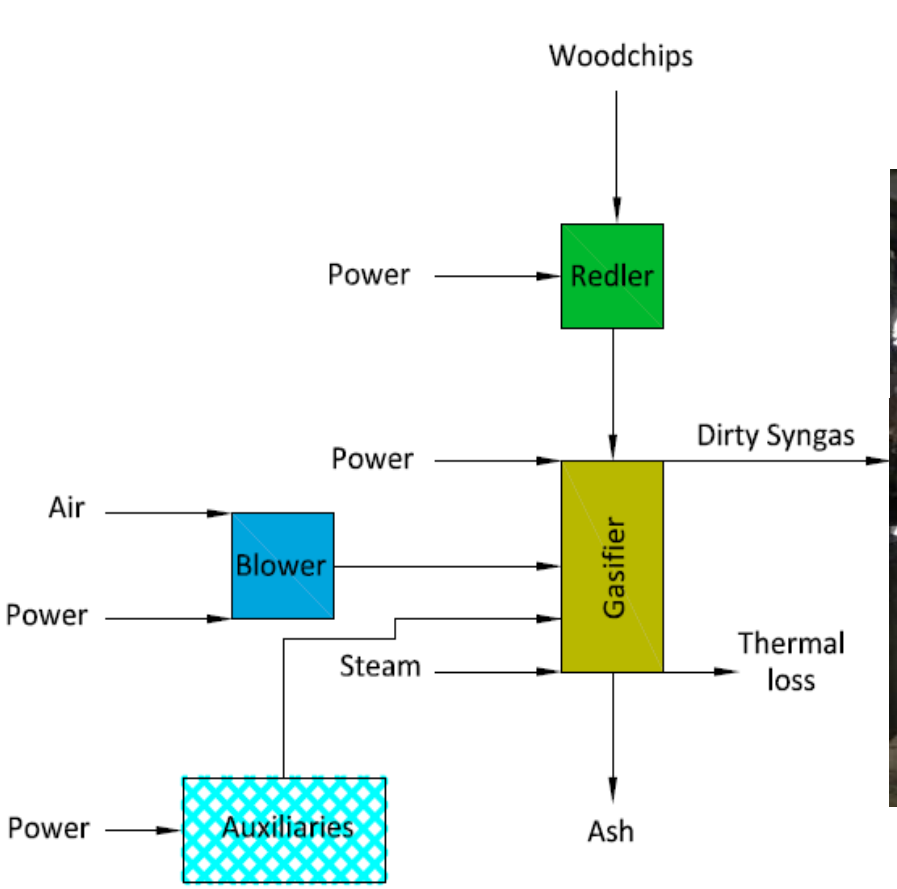
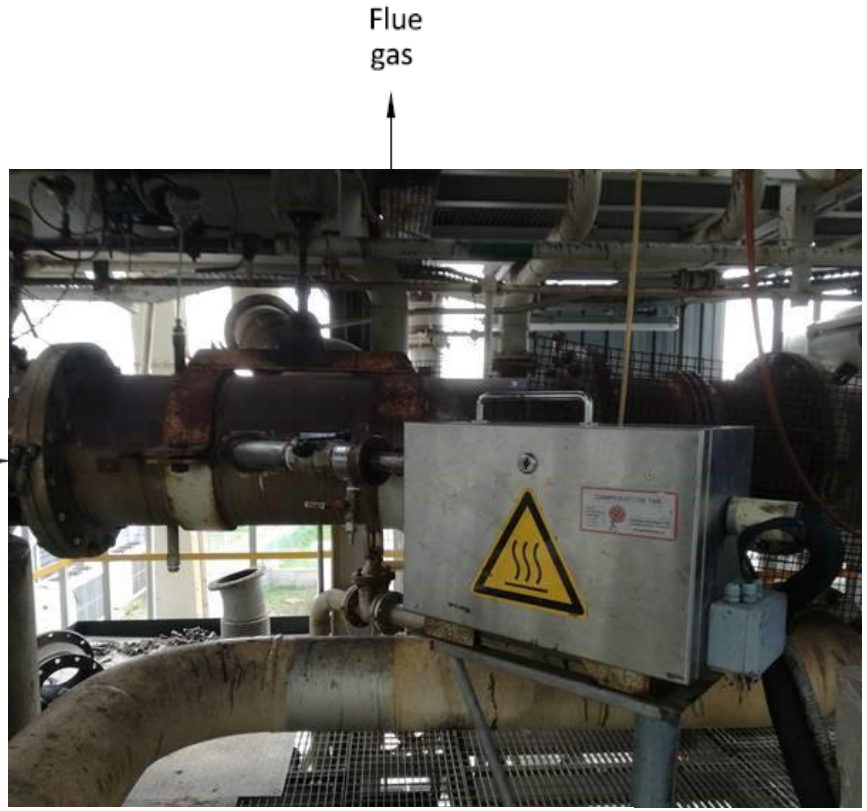
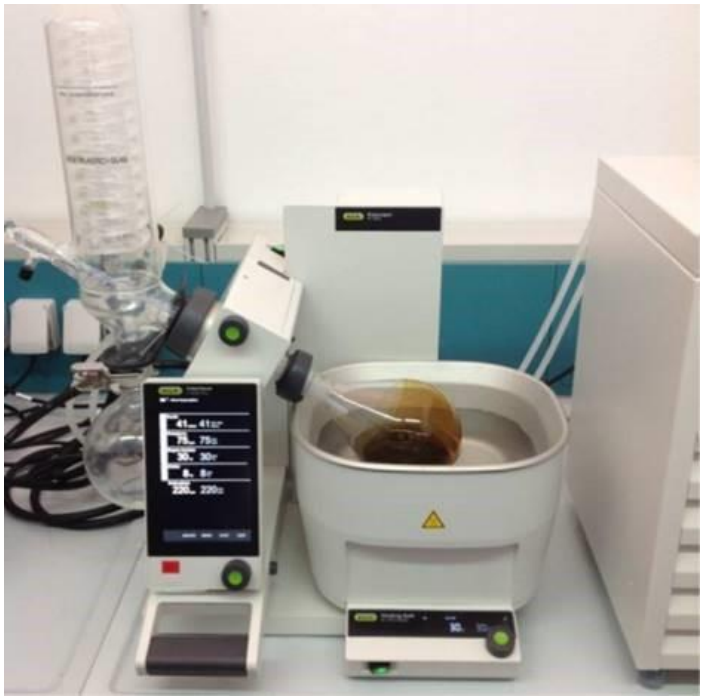
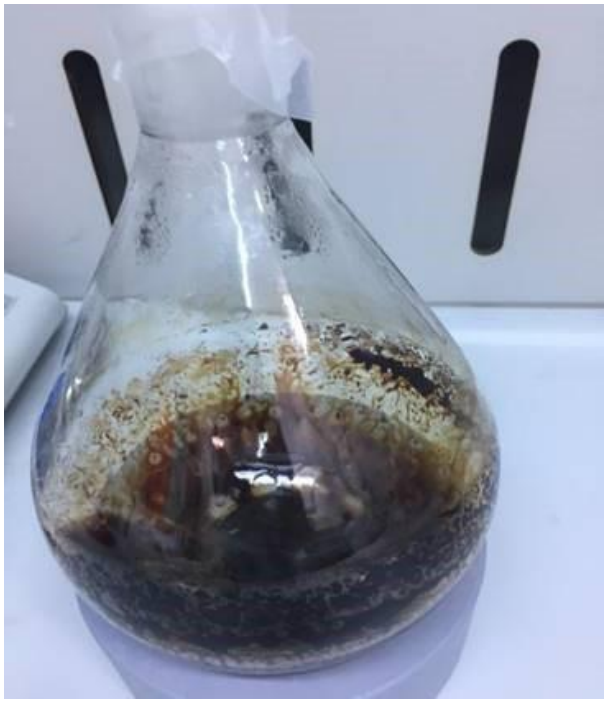
Research facilities





Research facilities





TAR concentration: 60-100 g/Nm^3

Research facilities

FABER

New pilot bubbling fluidized-bed gasifier

- up to 400 kW_{th}
- up to 100 kg/h of biomass
- olivine size 200 µm - 400 µm

Olivine composition

MgO	47.5-50.0%
SiO_2	39-42%
CaO	max 0.4%
Fe_2O_3	8.0-10.5%
Loss on ignition	0.20%

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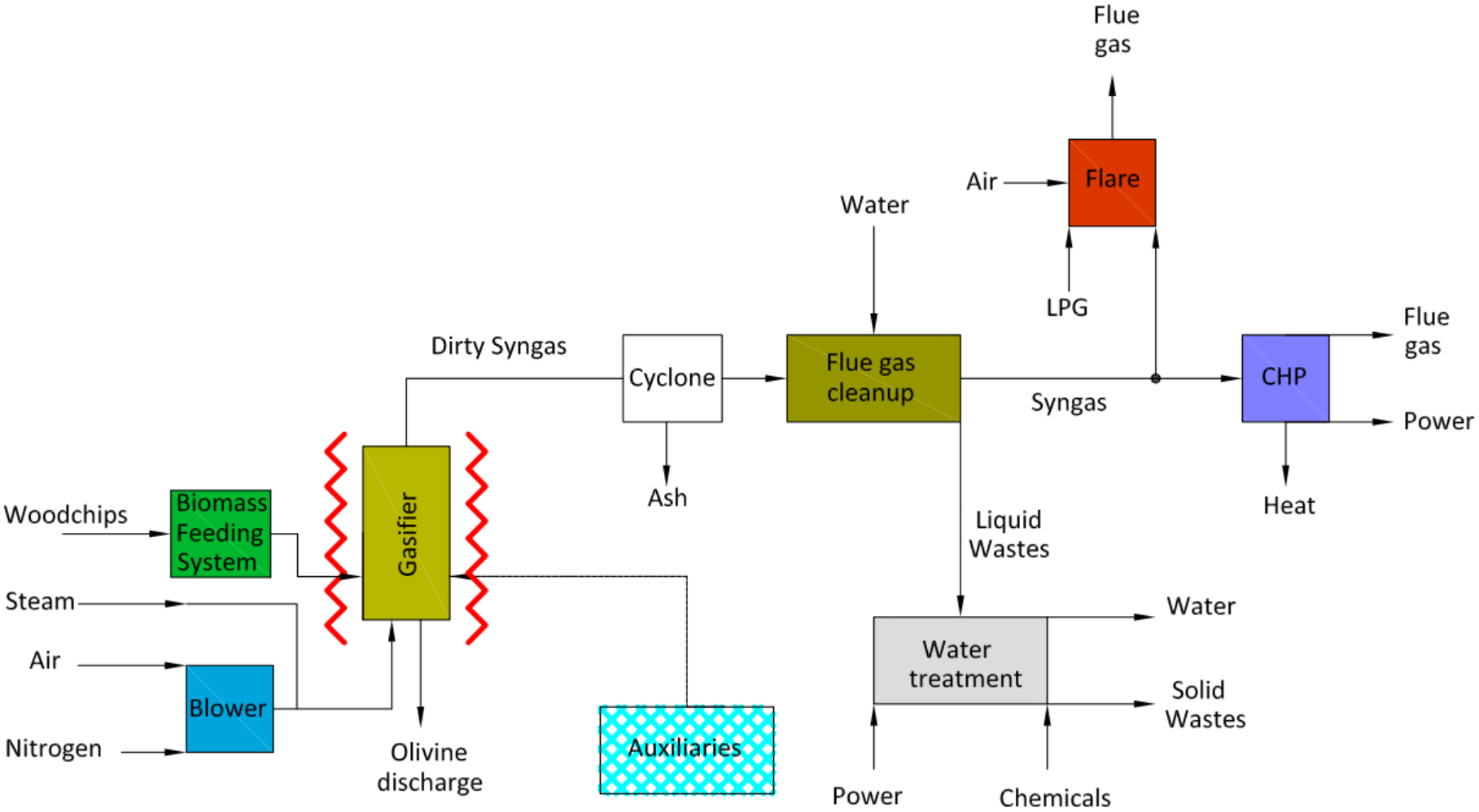
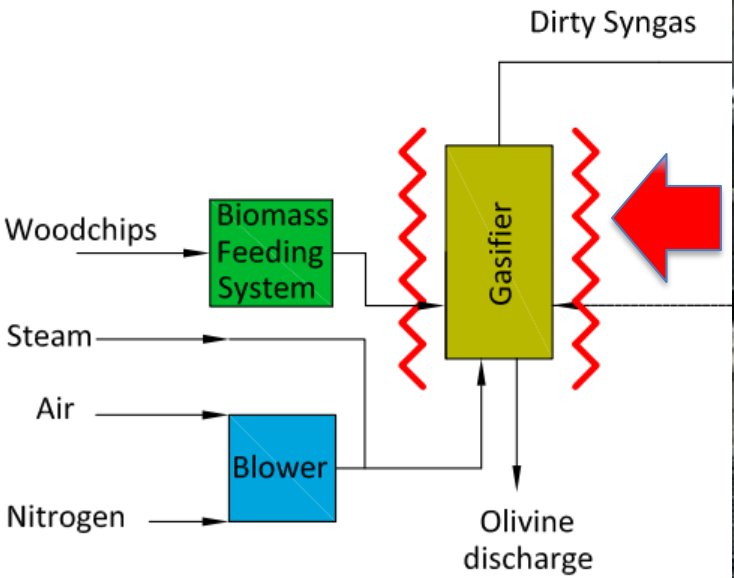
Research facilities

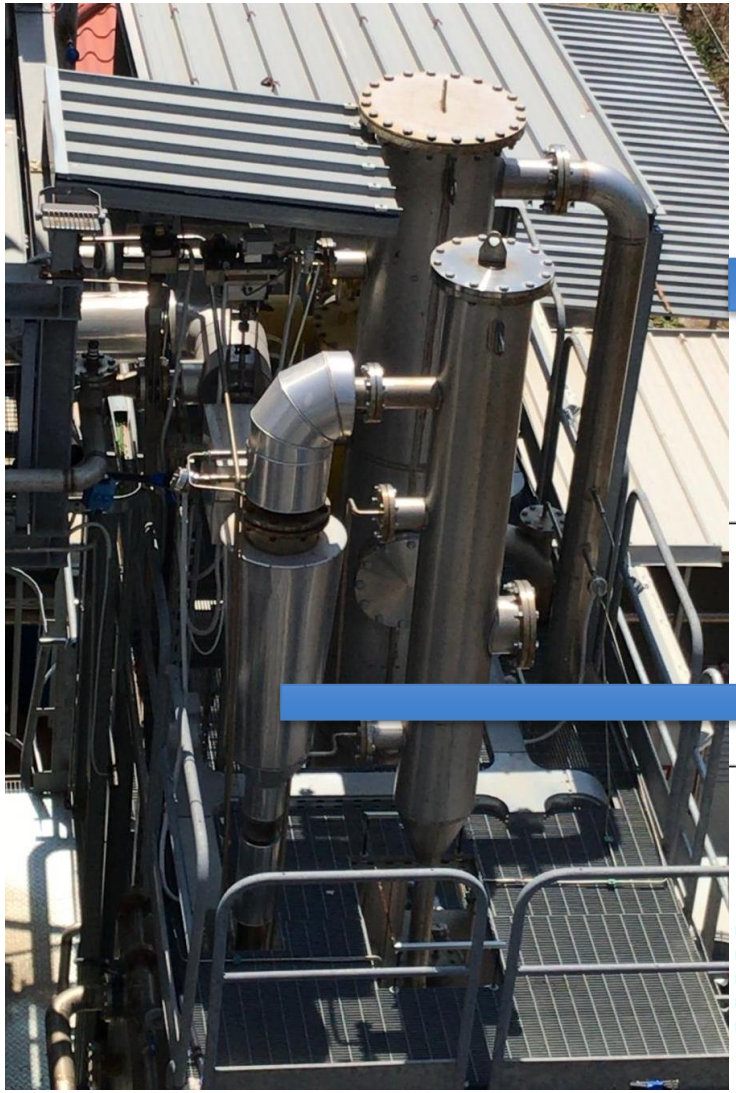


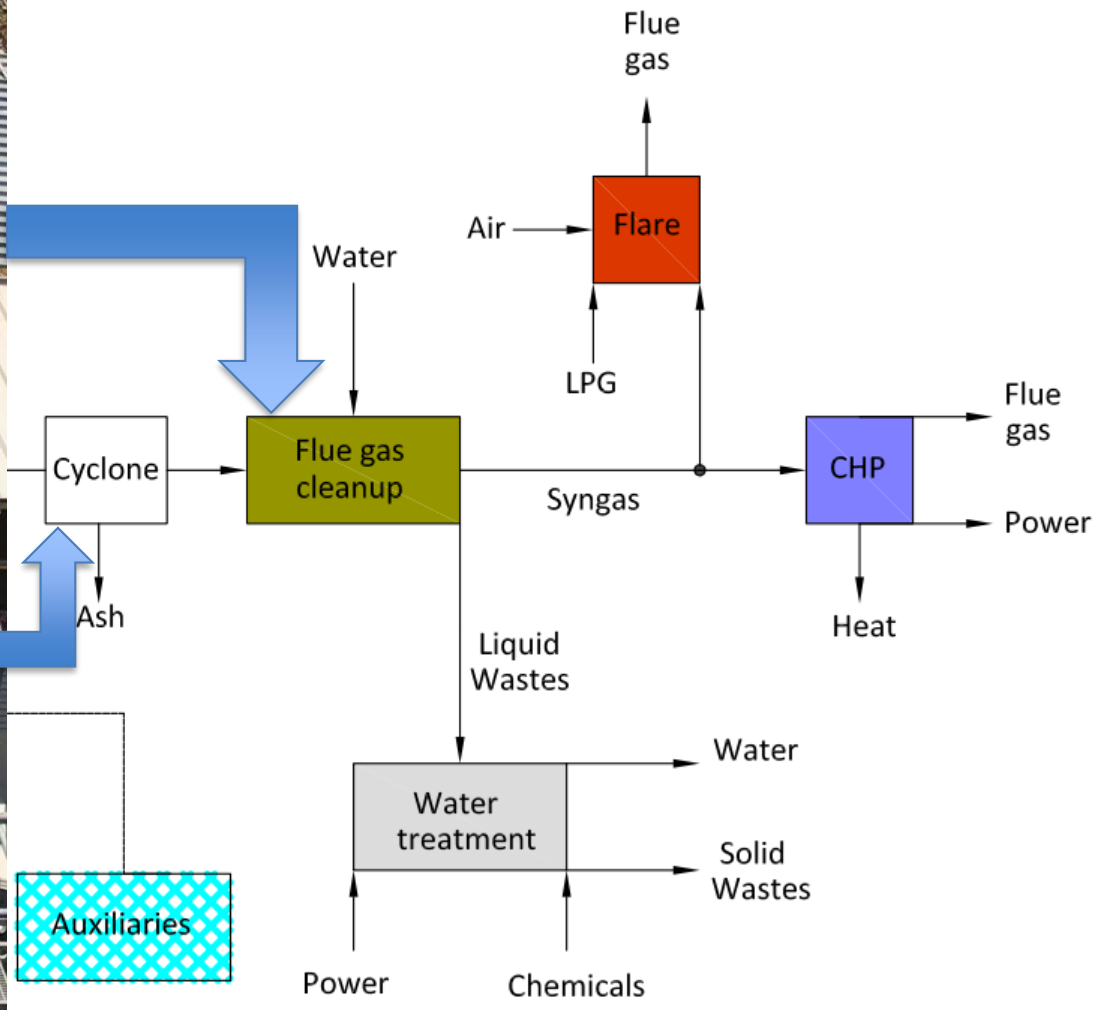
Research facilities

- Incoloy 800 H reactor
- reactor inner diameter: 0.489 m
- reactor height: 5.733 m

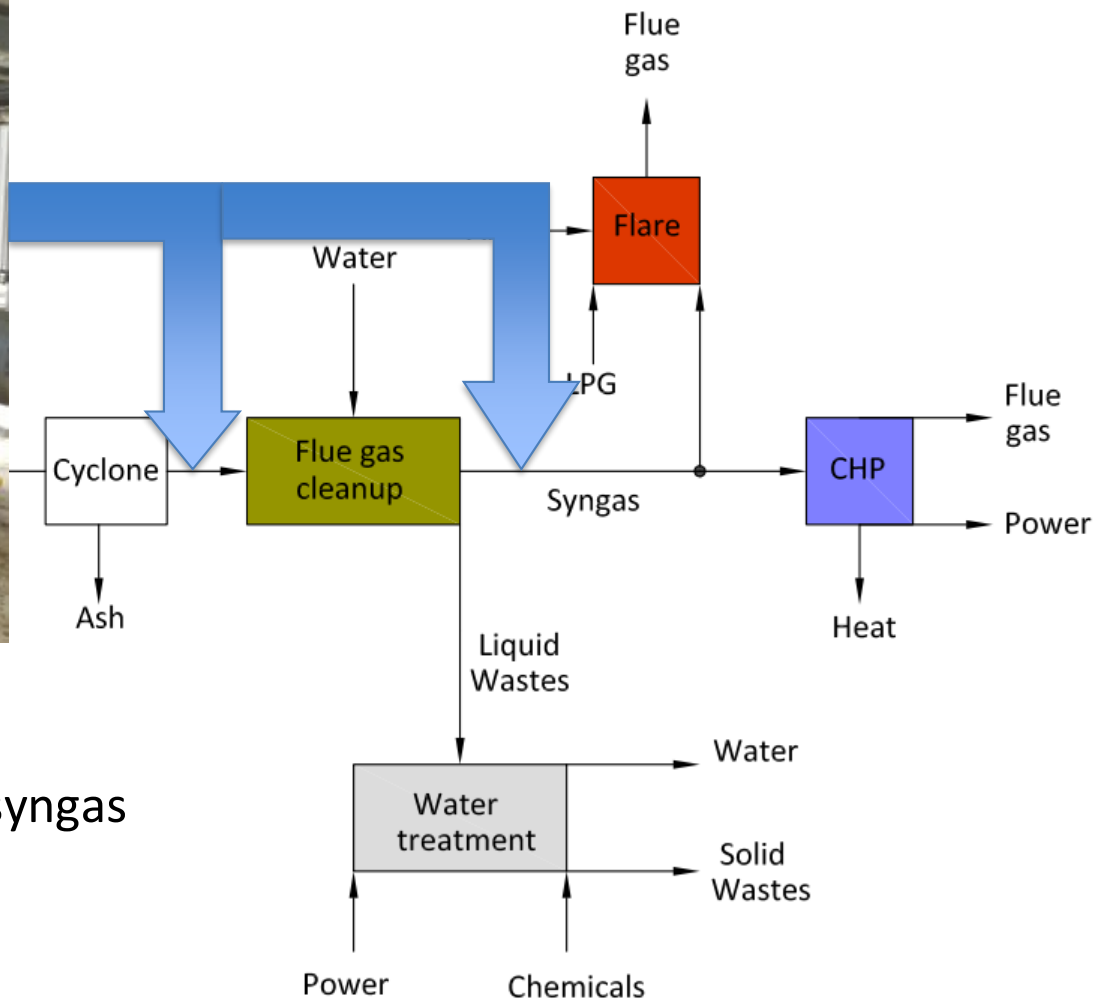


Research facilities





Research facilities



TAR concentration in the raw syngas
1-4 g/Nm^3

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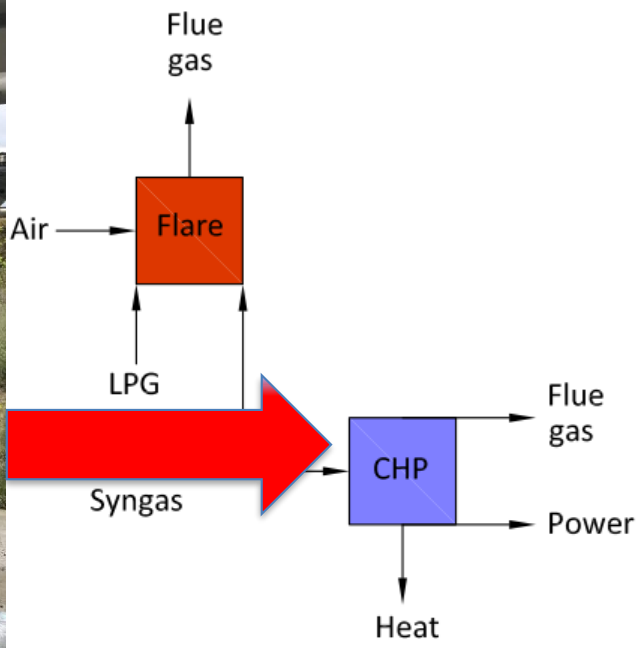
Research facilities



3 X 40 kW_e IVECO dual fuel engines

Research facilities

Bench-scale bubbling fluidized-bed gasifier

- up to 100 g/h of biomass
- reactor inner diameter: 26 mm
- reactor freeboard inner diameter: 54 mm
- reactor height: 800 mm
- olivine size 125 µm - 212 µm

Olivine composition

MgO	39-44%
SiO_2	42-45%
Al_2O_3	0.3-3.5%
CaO	1.5-3.5%
$FeO+Fe_2O_3$	6-9%
Loss on ignition	0.1-2.0%

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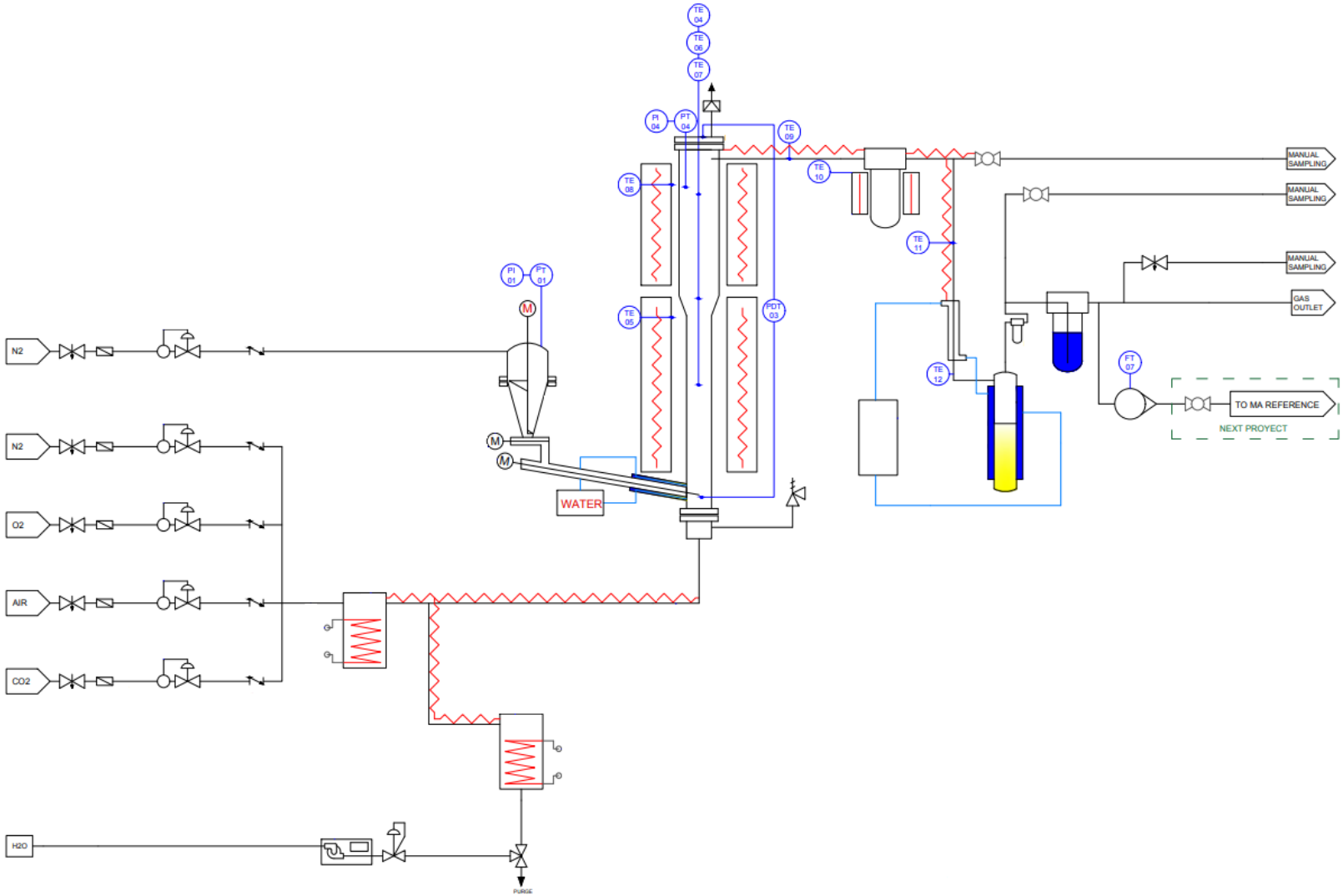
Research facilities



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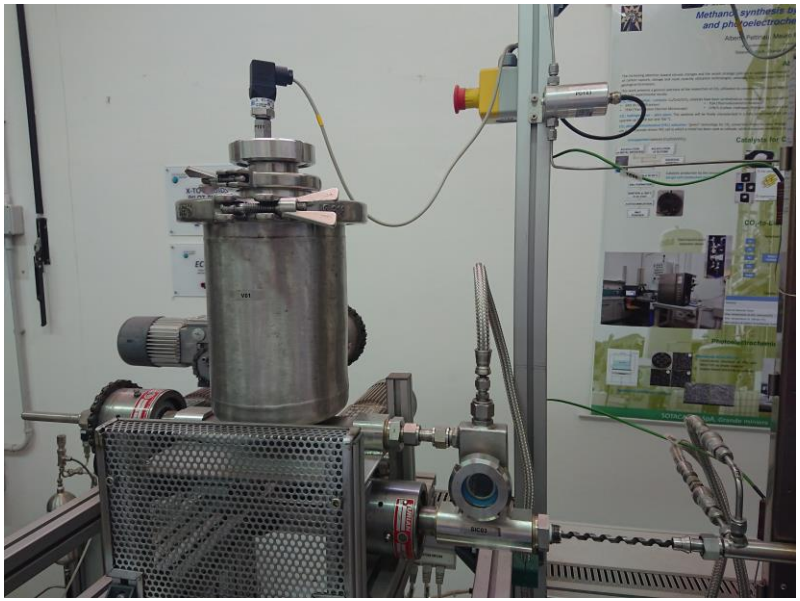
Research facilities



Biomass size 0.5 - 2.5 mm

Sample Name	Moisture %	Volatile %	Ash %	Fixed Carbon %	Volatile Dry %	Ash Dry %	Total C %	H %	N %	S %	O %
Cypress	10.06	67.39	2.37	20.18	74.92	2.63	49.80	6.25	0.44	n.a.	43.51

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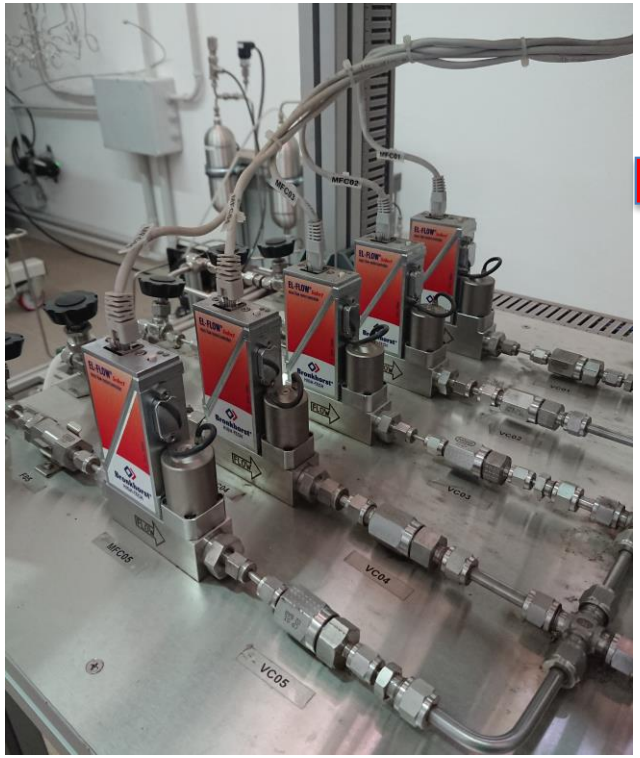
Research facilities



Nitrogen for the feeding system
Nitrogen
Air
Oxygen
Carbon dioxide

Gilson pump
Volumetric flow rate 0-5 ml/min
Working pressure 0-100 bar

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Research facilities

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Research facilities

Metallic filter

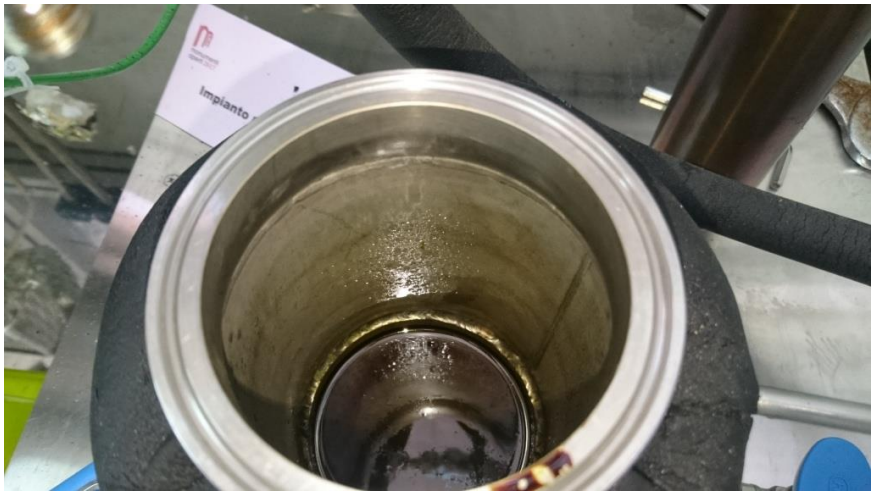
Working pressure: ≤ 0.5 barg

Temperature: up to 450°C

Mesh: 100 µm

Condenser

Estimated TAR concentration: 1-2 g/Nm^3



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Coalescing filter

Pressure: ≤ 0.5 barg

Temperature: atmospheric

Mesh: 0.1 µm

Bubbler water column

Pressure: ≤ 0.5 barg

Temperature: atmospheric

Filled with water

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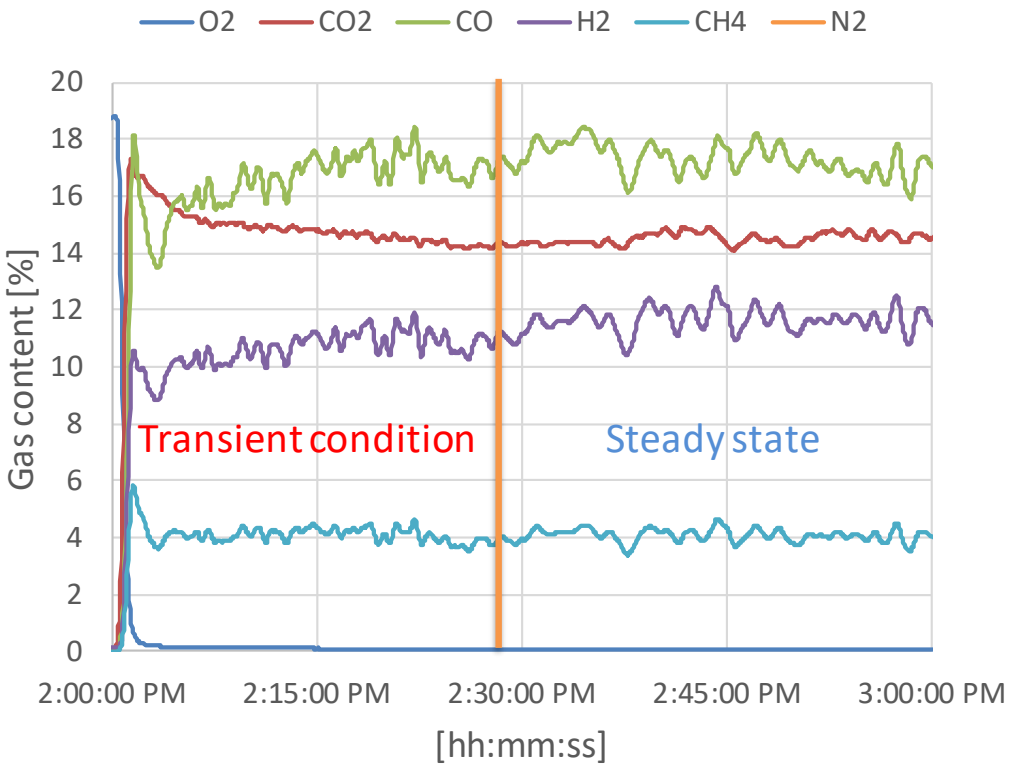
Experimental results

Biomass gasification test



-Biomass flow rate: 100 g/h

-Air flow rate: 1.8 Nl/min @ 350°C

-Olivine loaded: 35 ml → 56.4 g

-Reactor temperature: 850°C

-Condenser temperature: 7°C

-Water+TAR into the condenser: 15.40 g

-Elutriates into the metallic filter: 0.85 g

Equivalent ratio = 0.26
Average syngas LHV = 4.2 MJ/kg
Carbon conversion = 0.74

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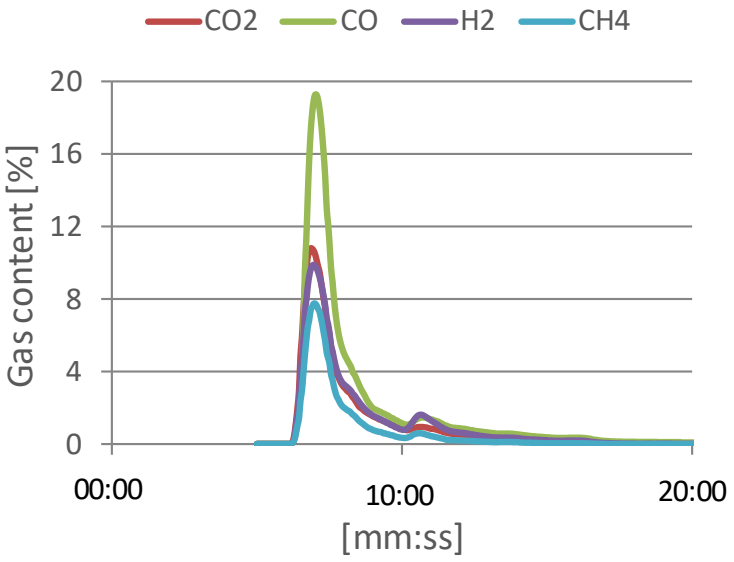
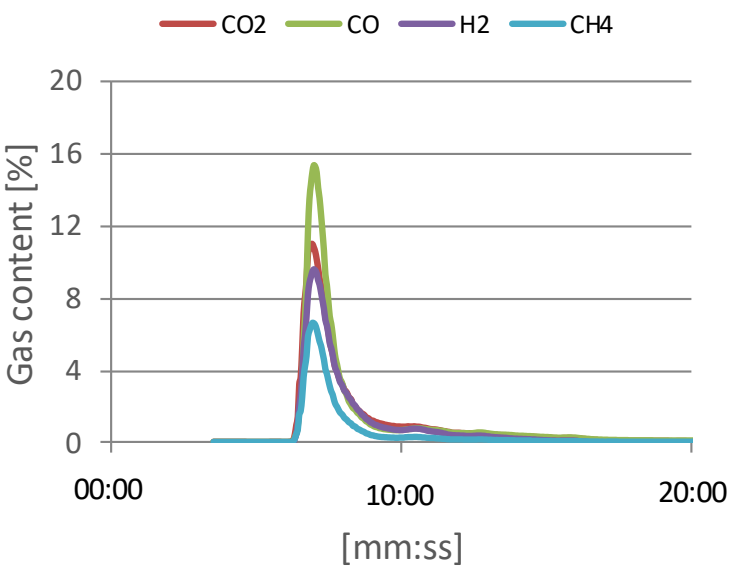
Experimental results

Dry Biomass pyrolysis test



Wet Biomass pyrolysis test



	Dry Biomass	Wet Biomass
Average Gas yield	66%	65%
Average Char yield	17%	13%
Average Tar yield	17%	22%

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Experimental results vs Simulation

Mettler Toledo TGA/DSC 3+ thermogravimeter

TG
- T_p: peak temperature (DTG profile)
- W_r: residual weight
- α_t: conversion degree

DSC
- H_r: heat of reaction

	Pyrolysis
Pressure	1 atm
Atmosphere	100 % N_2
Flow rate (ml/min)	100
Heating rate (°C/min)	5, 10, 20, 30
Max. temperature (°C)	800

Kinetic analysis

$$\frac{d\alpha}{dt} = k(T)\, f(\alpha) \qquad \alpha = \frac{(m_i - m_\alpha)}{(m_i - m_f)}$$

Model-free isoconversional kinetic study

Flynn-Wall-Ozawa (FWO), *ASTM E1641*

$$ln\beta_i = -1.052\,\frac{E_\alpha}{RT_{\alpha,i}} - 5.331 + ln\left(\frac{A_\alpha\, E_\alpha}{R\; g(\alpha)}\right)$$

Kissinger-Akahira-Sunose (KAS), *ASTM E2890*

$$ln\left(\frac{\beta_i}{T_{\alpha,i}^2}\right) = ln\left(\frac{A_\alpha R}{E_\alpha\; g(\alpha)}\right) - \frac{E_\alpha}{RT_{\alpha,i}}$$

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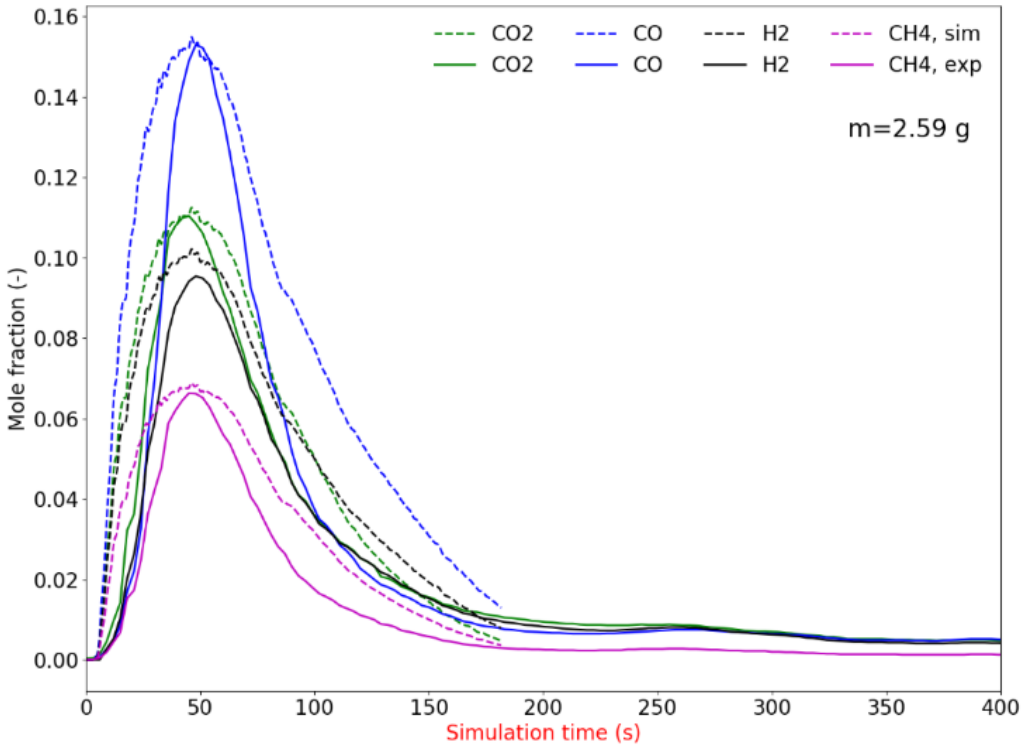
Experimental results vs Simulation



Good agreement is observed between simulation and experimental results

Sample	E_a	n	A
Cypress	212.18 kJ/mol	7.2	2E+19 1/s

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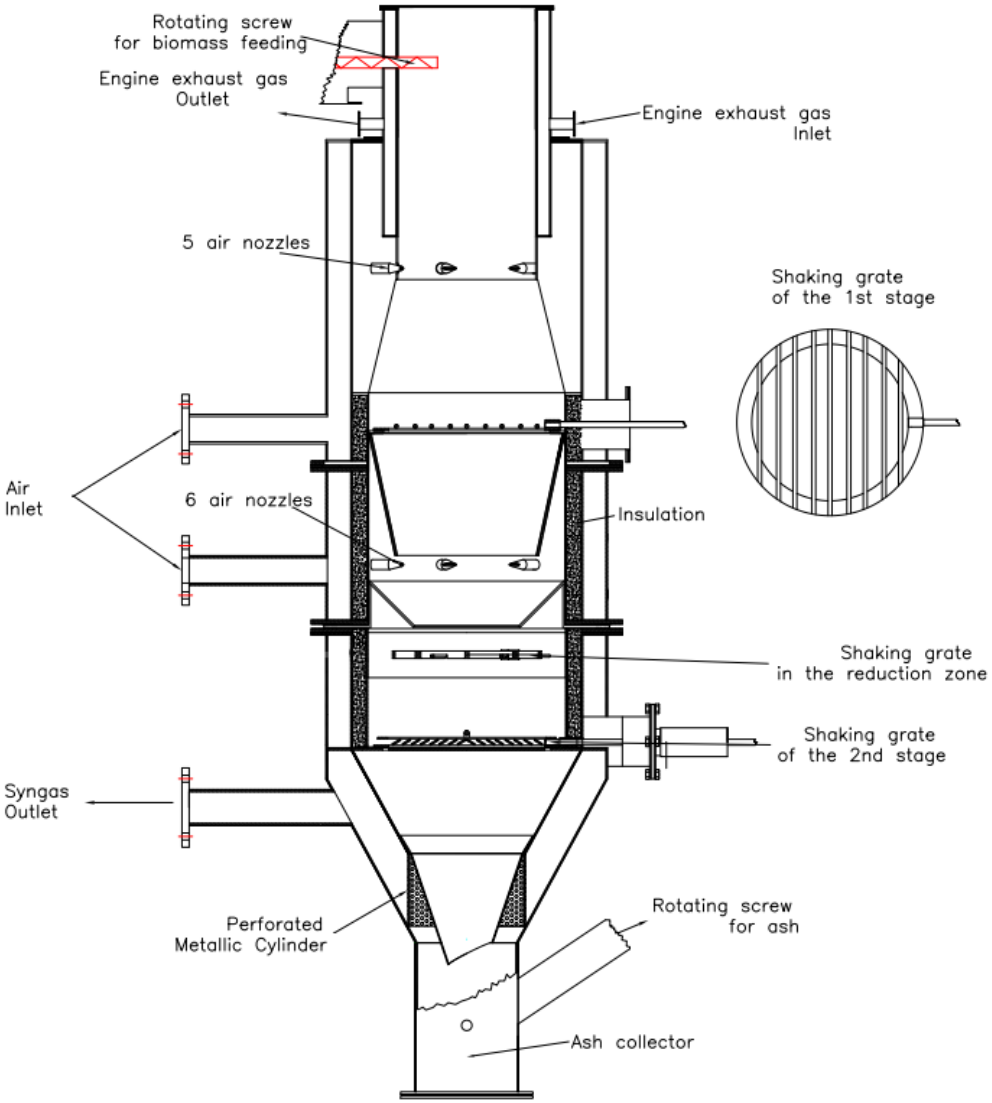
Future work



Design of a new down-draft gasifier

Biomass: Pellet and brewery spent grain

Thermal output: 30 kW_{th}

Wood pellet size: 6 X 6 X 15 mm

Spent grain size: 2 X 2 X 6 mm

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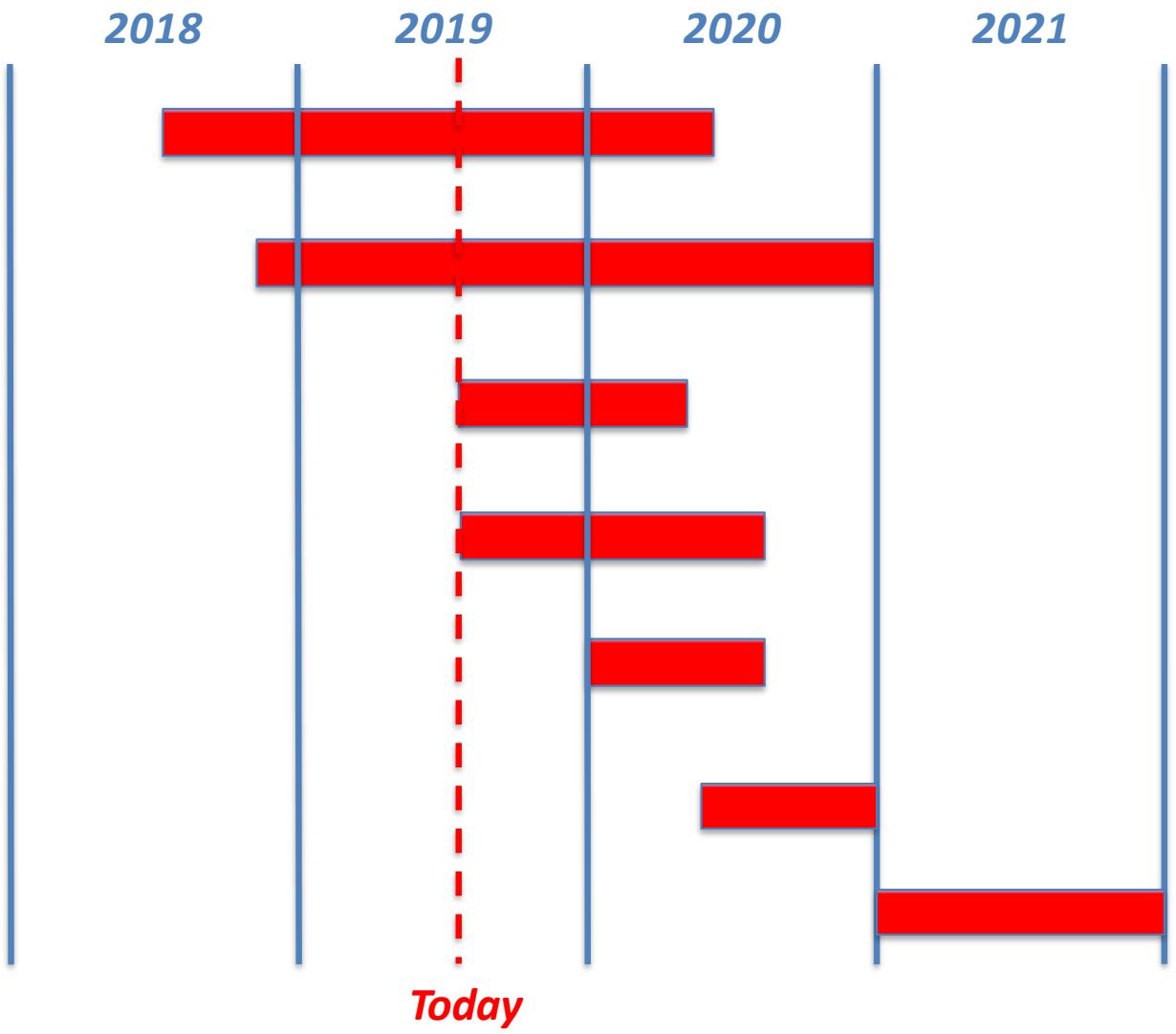
Future work



Model definition
Bench-scale bfb gasifier

Model validation
Bench-scale bfb gasifier

Preliminary design new unit
Down-draft gasifier

Model definition
Down-draft gasifier

Design vs simulation result
Down-draft gasifier

Construction
Down-draft gasifier

New unit tests

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Conclusions

- **Good agreement** between experimental results and MFIX simulation
- **Additional experimental** tests already scheduled using steam
- Few **critical points** still to be solved
- MFIX application for the **design of a new gasification unit**

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8th annual international

Sotacarbo Summer School

on low carbon technologies

8-12 June 2020

In partnership with:

IEA CLEAN COAL CENTRE

GeoNet

ECOBASE
Enhanced oil recovery with storage

ECCSEL

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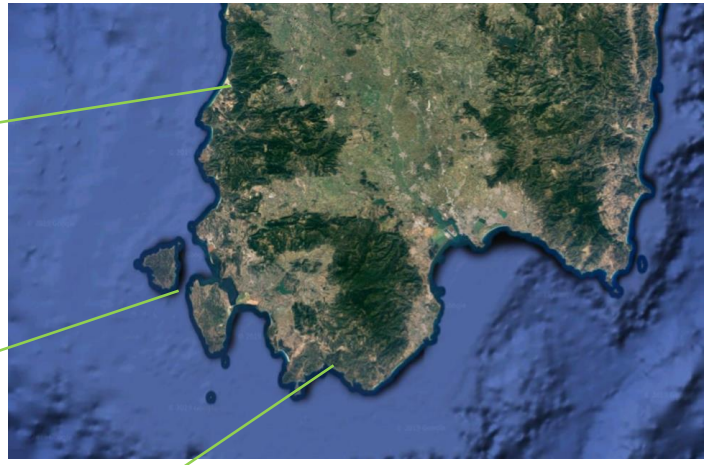
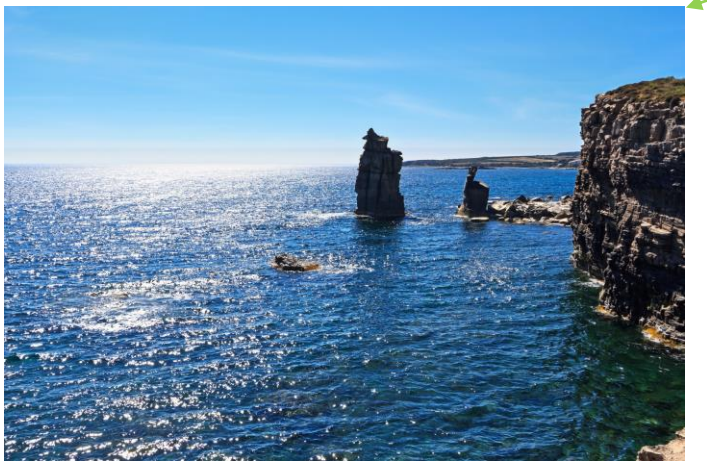
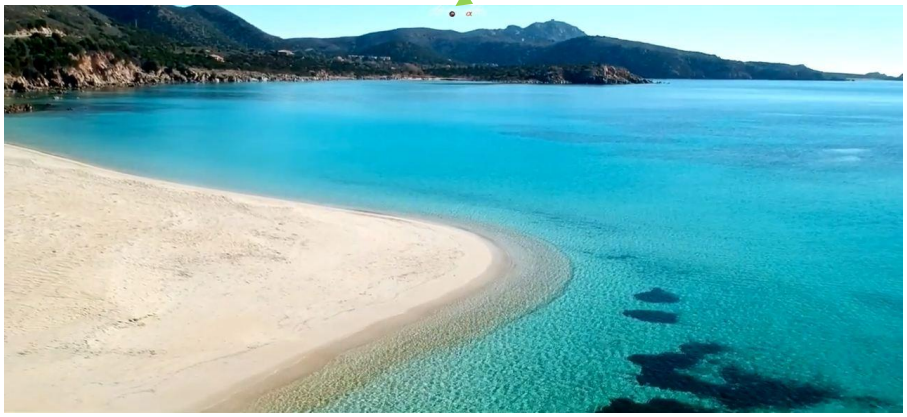
Thanks for your attention!







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