BioMeGaFuel

Bio Methanol Production via Chemical Looping Gasification Coupled with Membrane Reactors

Chemical Looping Gasification of Biogenic residues and wastes for production of renewable syngas

International Worshop on Sustainable & Circular Technologies
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Society

Life

Matter

7th	Top 5	16.000	121/3
Public research institution at global scale	**European institution by number of actions H2020v**	**People**	**Institutes, centres, units**
14.000	5.000	450	700
Articles published per year	**Ongoing projects**	**Protected technologies**	**PhD Thesis defended per year**

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INSTITUTO DE CARBOQUIMICA

COMBUSTION & GASIFICATION GROUP

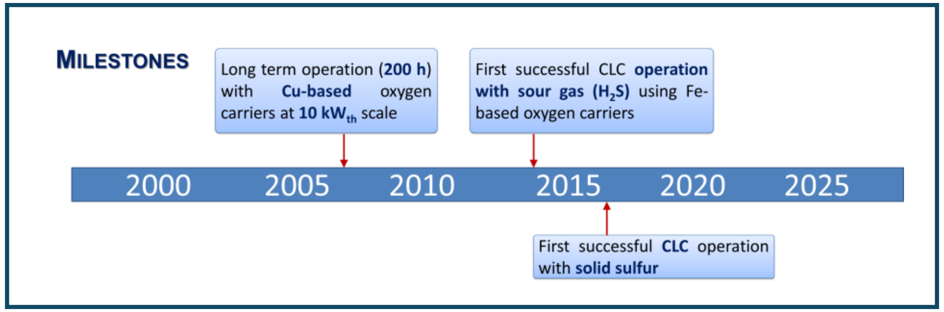
Combustion & Gasification Research Group funded in 1987

COMBUSTION AND GASIFICATION RESEARCH GROUP

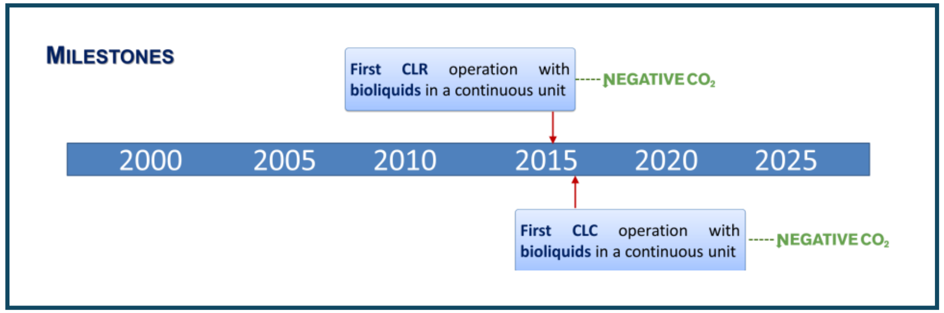
- 9 Permanent position
- 7 PhD students
- 3 Technician

CSIC-ICB milestones on Chemical Looping

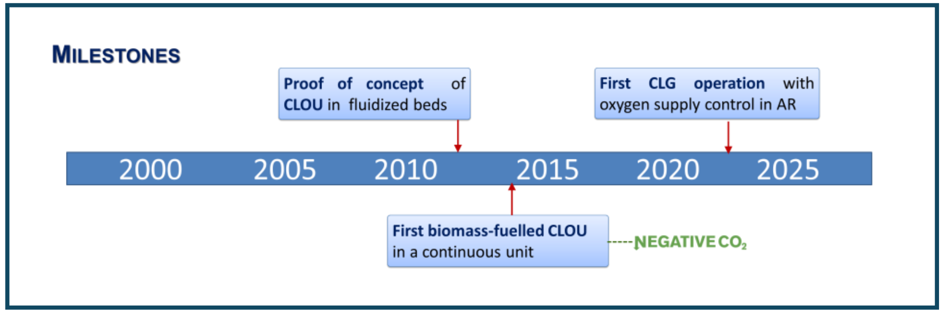
- **2000 h** continuous operation
- Special mention to the use of fuels containing S compounds



- **500 h** continuous operation

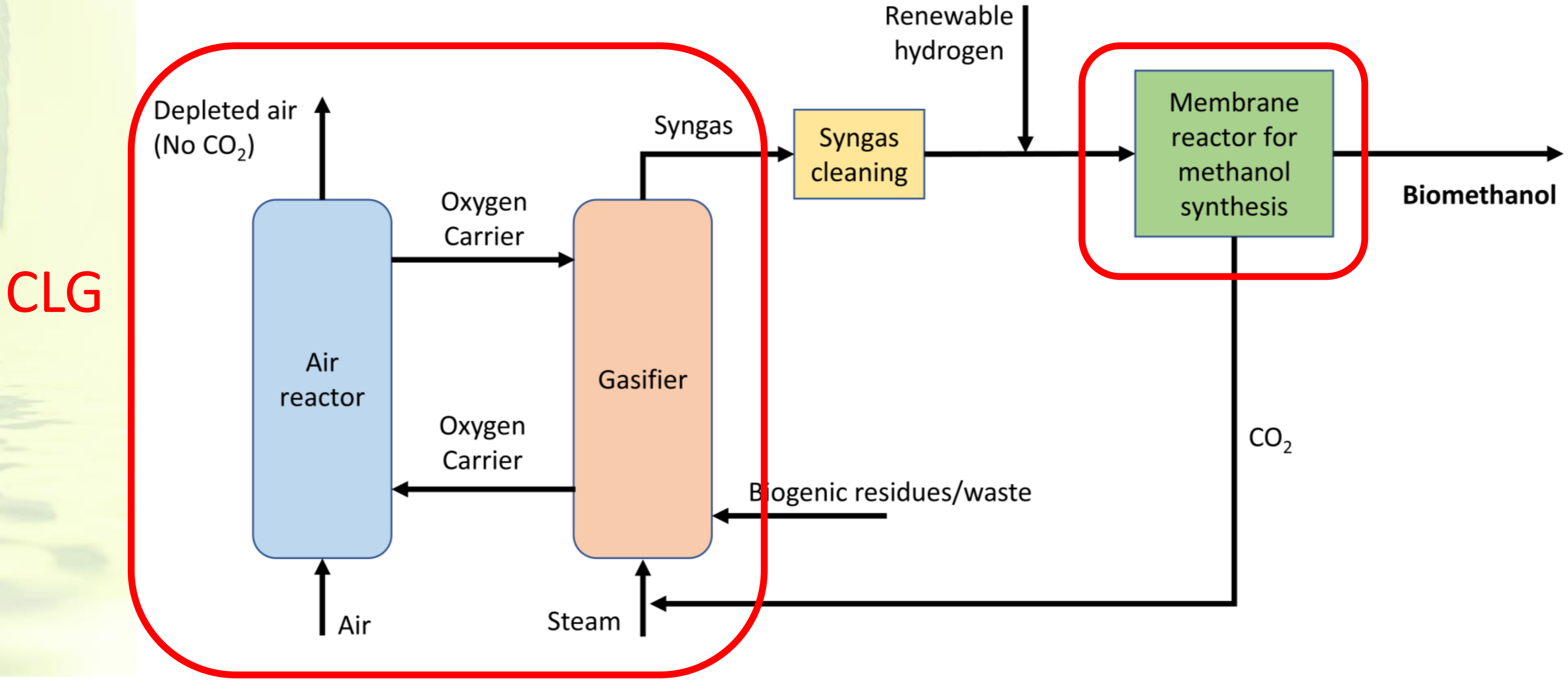


- **+2000 h** continuous operation Combustion and Gasification



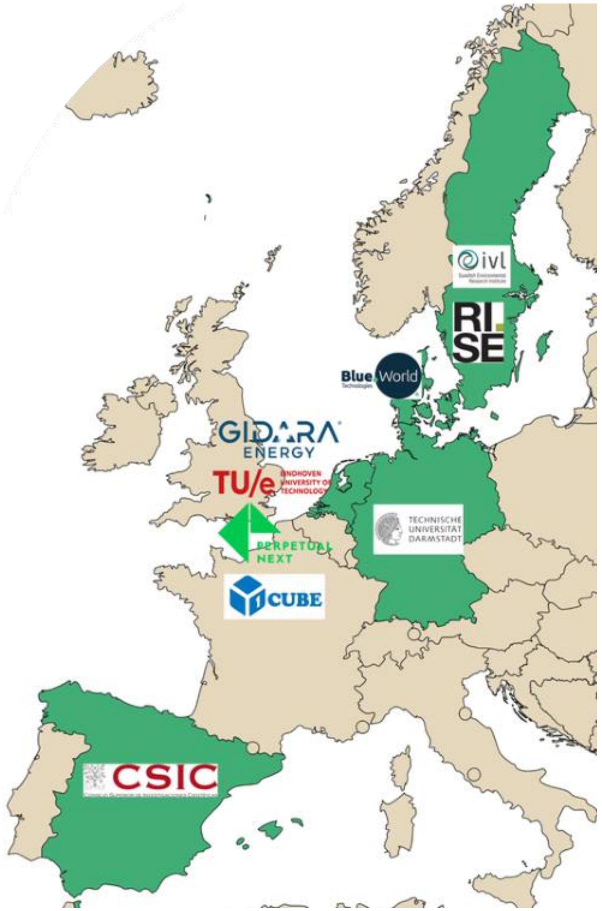
Bio-MeGaFuel concept

Develop a novel **efficient**, and scalable process to convert **low-value biogenic residues** and organic waste to **biomethanol** through chemical looping gasification coupled with membrane reactors



Participants and Consortium Synergies

- The Bio-MeGaFuel project has an expert consortium. It consists of **9 partners from 5 countries** and includes:
  - **Three Research Institutes**: RISE Research Institutes of Sweden, IVL Swedish Environmental Research Institute, and The Spanish National Research Council
  - **Two Universities:** The Technical University of Darmstadt and Eindhoven University of Technology
  - **Four Companies**: GIDARA Energy, Perpetual Next, 1Cube and Blue World Technologies



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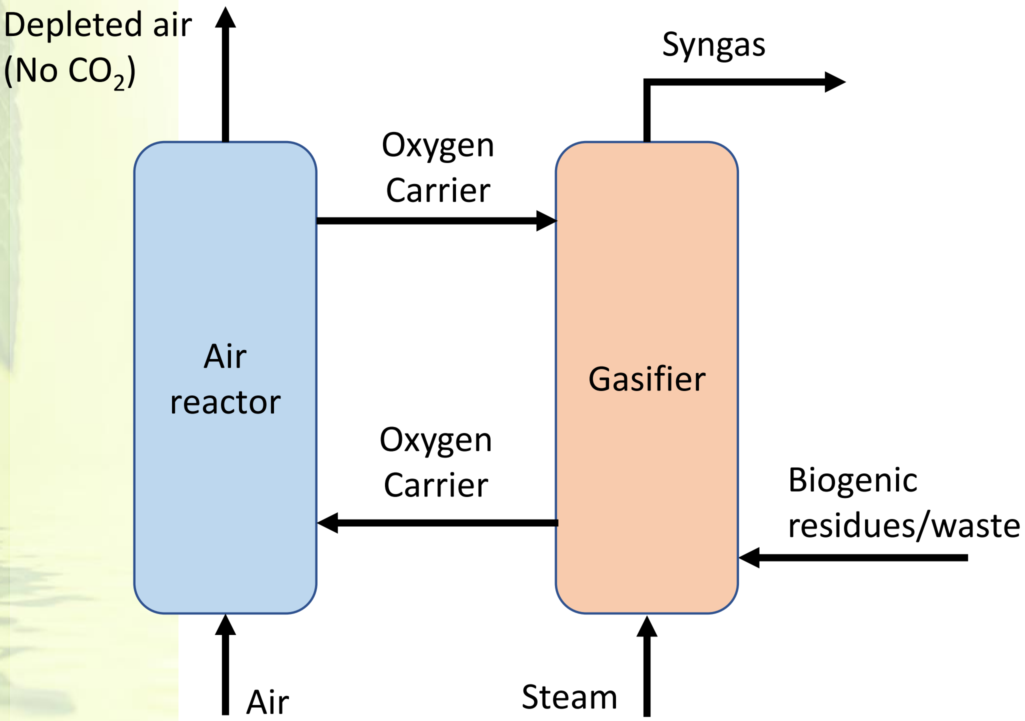
Chemical Looping Gasification



- A high quality non-N_2 diluted syngas is obtained
- Autothermal process
- ASU is not required; improved process economy
- CO_2 concentrated in syngas. Negative CO_2 emissions can be reached if CCS
- Reduced tar formation, less syngas cleaning
- Possibility to obtain pure N_2 at the AR outlet

Chemical Looping Gasification

FUEL REACTOR

- Drying and devolatilization:

  Biomass $\rightarrow$ H_2O + Volatile matter + Char

- Char gasification with H_2O and/or CO_2:

  Char + H_2O $\rightarrow$ H_2 + CO

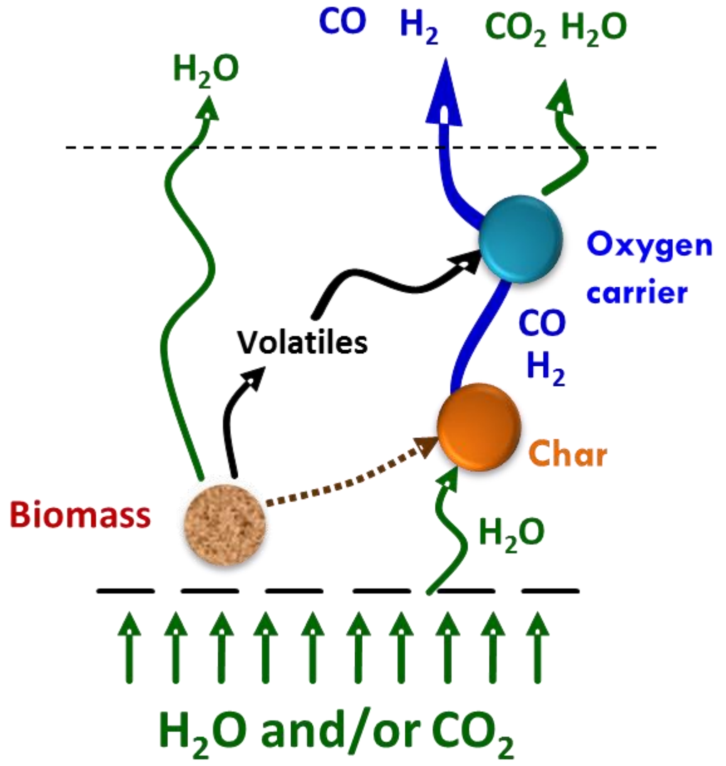
  Char + CO_2 $\rightarrow$ 2 CO

- Oxidation of **SOME** of volatiles and gasification products by the oxygen carrier

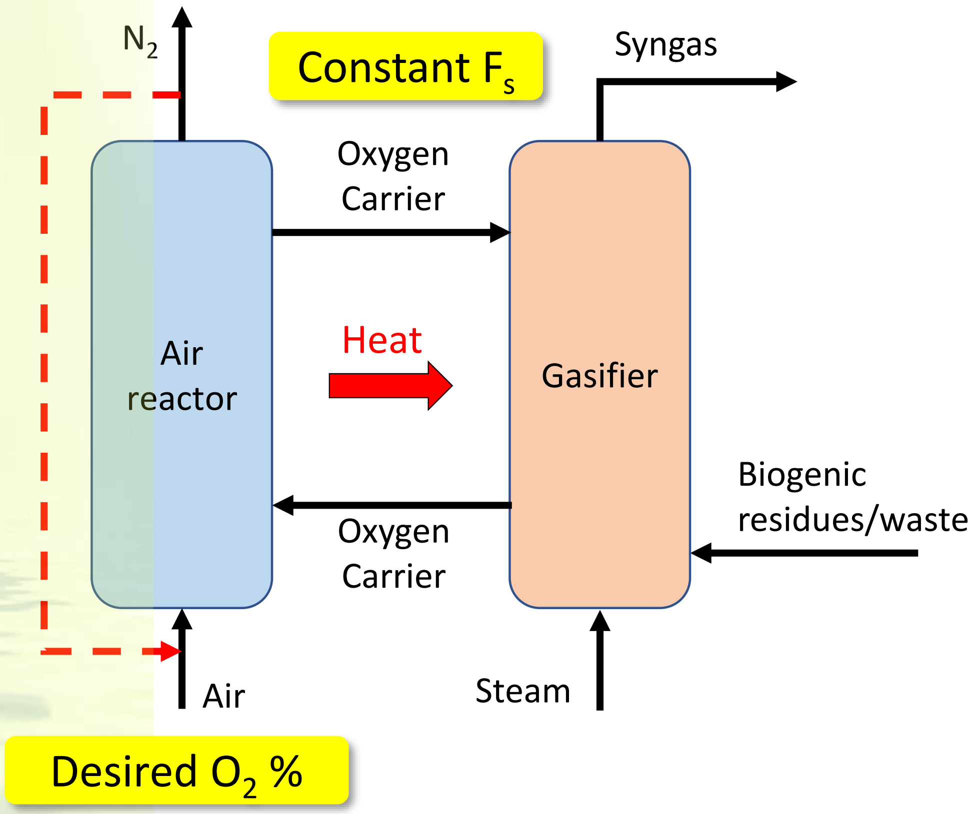
  Volatiles / H_2 + CO $+ Me_xO_y \rightarrow Me_xO_{y-1}$ + H_2O + CO_2

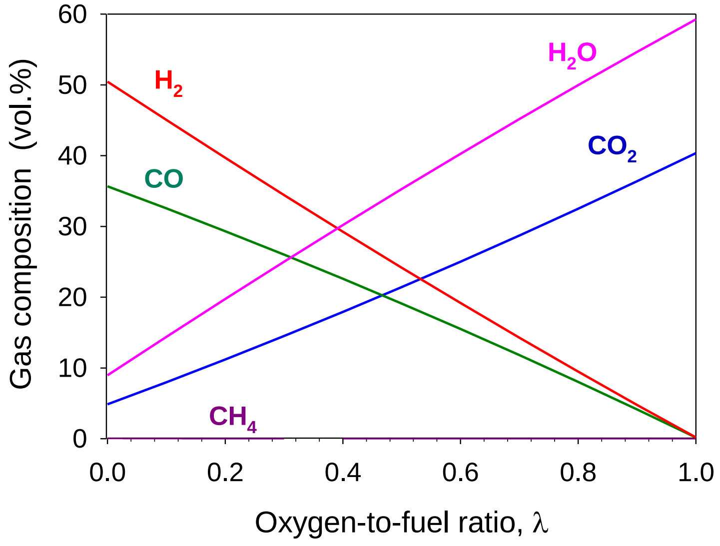
- Water gas shift equilibrium

  CO + H_2O $\rightarrow$ CO_2 + H_2



Control of the oxygen to fuel ratio





BY VARYING THE O_2 FED IN AR

- Allows operation at different ΔT and solid circulation rate (F_s) with any OC.
- Allows production of pure N_2
- Allows higher syngas yield at autothermal conditions

Clara 1 kW CSIC, 20 kW CSIC, 1 MW TUD

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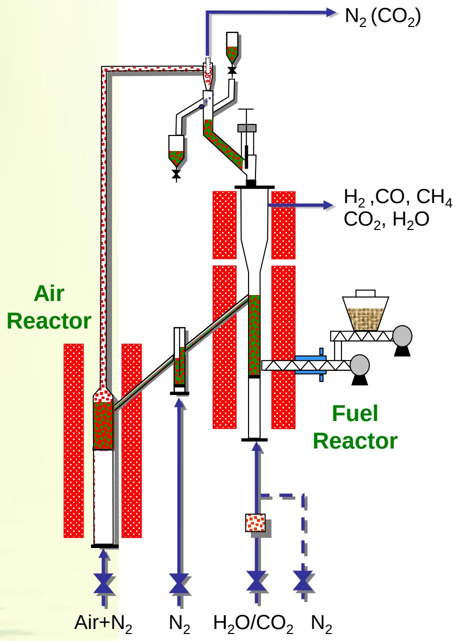
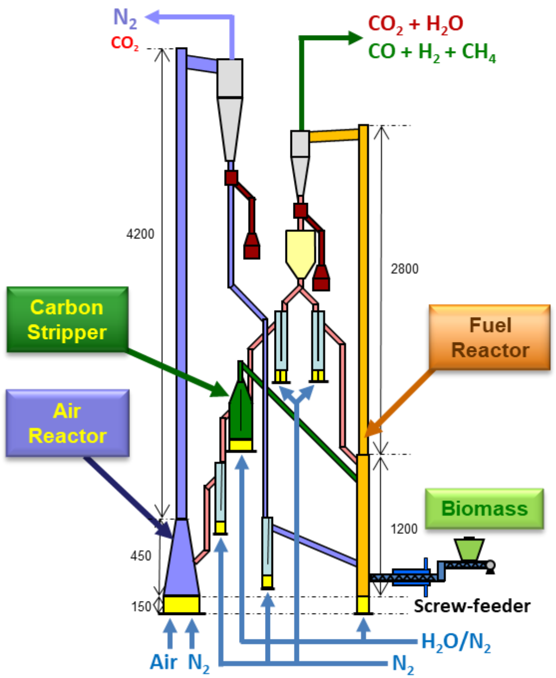
CSIC experience on CLG

1.5 kW_{th} CLG



	FR	AR
Height bottom (m)	0.2	0.1
Diameter bottom (m)	0.05	0.08
Diameterr up (m)	0.08	0.03

20 kW_{th} CLG



	FR	AR	CS
Height (m)	4.0	4.65	0.35
Diameter bottom (m)	0.1	0.3	0.15
Diameterr up (m)	0.08	0.08	--

Projects

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CSIC experience on CLG

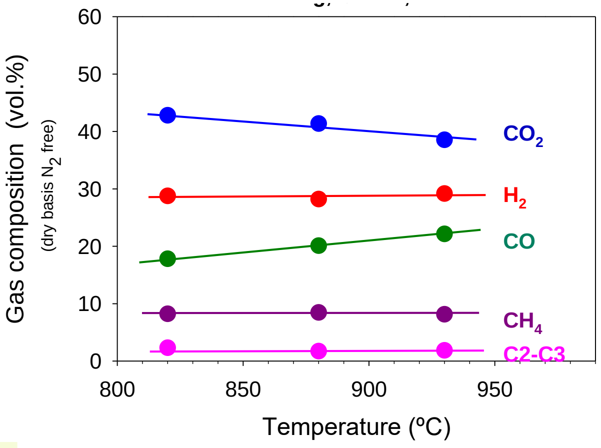
Unit	Oxygen carrier	Biomass	Temperature ºC	Oxygen-to-fuel ratio (λ) mol/mol	Steam-to-fuel ratio $kg/kg_{drybiomass}$	Gasification time at steady state h
1.5 kW_{th}	Ilmenite	Pine wood	820 - 940	0.15 - 0.5	0.05 – 1.1	55
	Fe ore	Pine wood	820 - 940	0.2 – 0.5	0.05 – 0.6	40
	Mn ore	Pine wood	820 - 940	0.2 – 0.4	0.05 – 0.8	50
	LD slag	Pine wood, almond shell, olive stone	820 - 940	0.2 – 0.5	0.05 – 0.8	60
	Fe10Al	Pine wood Olive stone	820 - 940	0.2 – 0.5	0.05 – 0.6	34
	Fe20Al	Pine wood	820 - 940	0.2 – 0.6	0.05 – 0.6	38
	Fe25Al	Pine Wood Olive stone	820 - 940	0.2 – 0.5	0.6	31
	Cu14Al	Pine Wood Olive stone	820 - 940	0.2 – 0.5	0.6	45
20 kW_{th}	Ilmenite	WSP-ad	800 -990	0.1 - 0.4	0.7	40
	Ilmenite	PFR	890 -950	0.2 - 0.4	0.7	20
	Ilmenite	TWSP-ad	850 -965	0.1 - 0.4	0.7	25

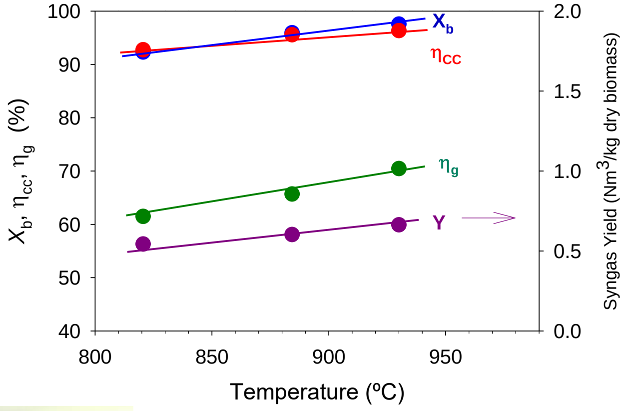
> 400 h of CLG operation **under steady state** conditions.

CSIC-ICB experience on CLG –an example-

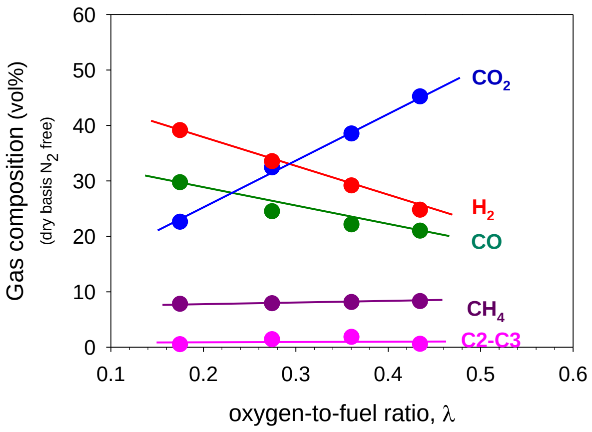
LD slag

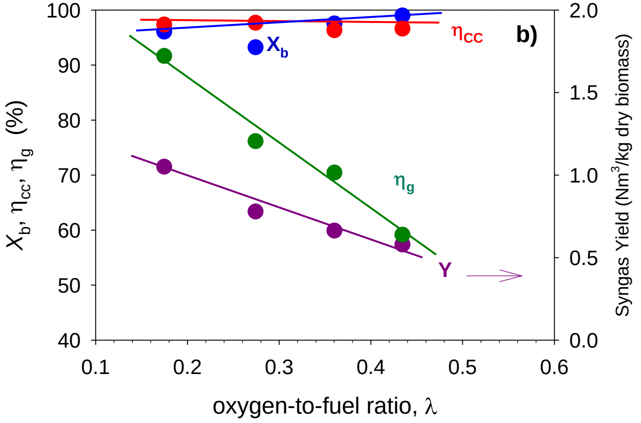
λ=0.36, S/B=0.6



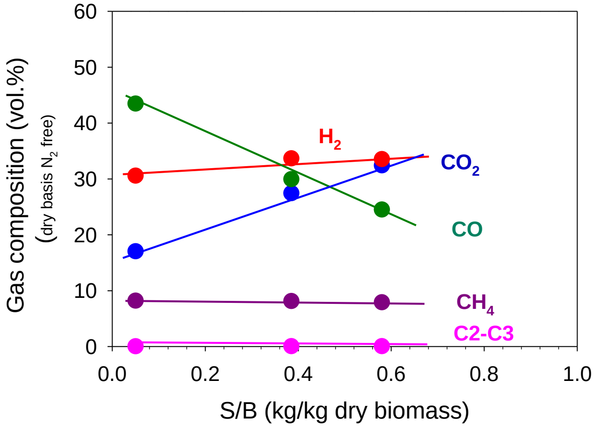


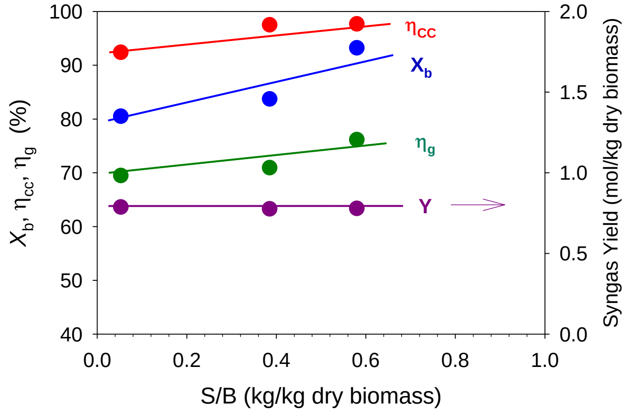
T=930 ºC, S/B=0.6





λ=0.27, T=930 ºC





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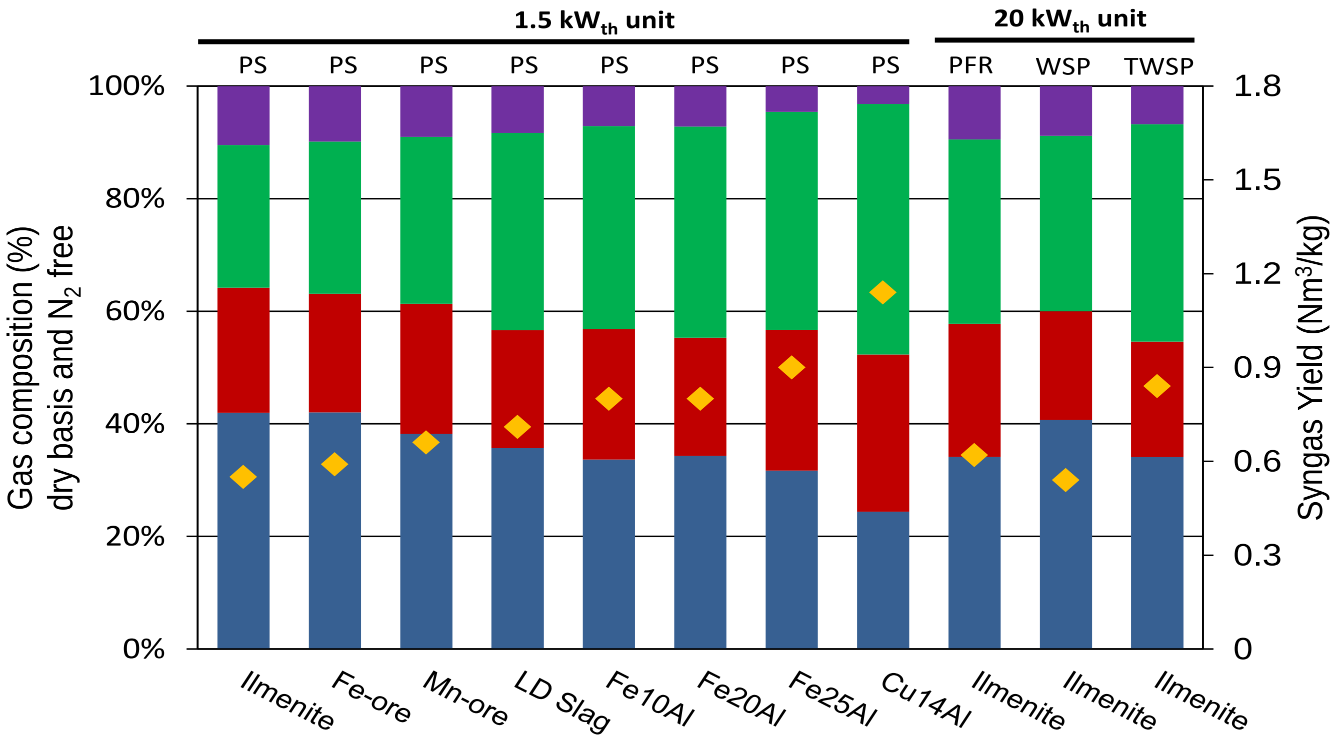
CSIC-ICB experience on CLG



λ= 0.3, T=930 ºC, S/B=0.6

PS= Pine sawdust
WSP=Wheat Straw pellets
PFR= Pine forest residue
TWSP=Torrified Wheat Straw

- Synthetic oxygen carriers exhibited higher syngas yield than mineral & wastes
- CH_4 (HCs) content affects is the main factor affecting syngas yield.
- Torrefaction improved gasification performance

WP2. Chemical Looping Gasification

BioMeGaFuel

Task 2.1
Biogenic feedstock sourcing

GIDARA ENERGY

Task 2.2
Characterization of selected feedstock

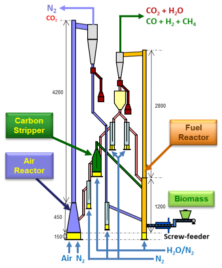
PERPETUAL NEXT

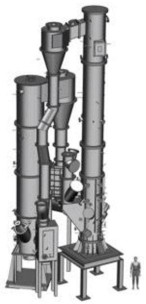
Task 2.3
Pilot testing
HTW® 500 kWth

Technische Universität Darmstadt
EST

Task 2.4
Small scale testing continuous CLG gasification

CSIC





Task 2.5
Pilot testing
CLG 1 MWth

Technische Universität Darmstadt
EST

Task 2.6
Kinetic determination

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GIDARA ENERGY
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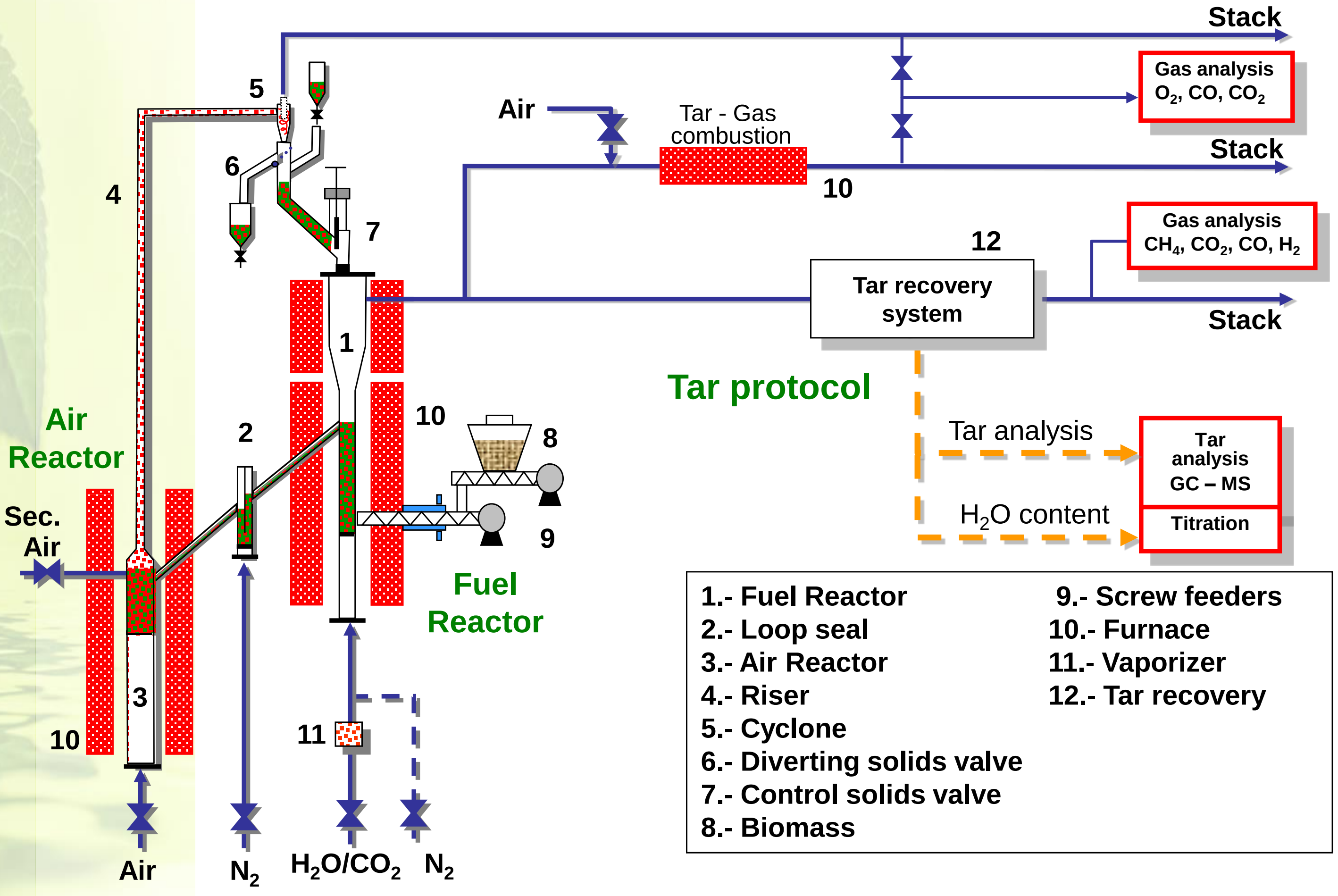
Task 2.7 / 2.8
Modelling and validation of HTW® and CLG-System

GIDARA ENERGY

Task 2.9
Comparison of CLG with HTW® for Methanol synthesis

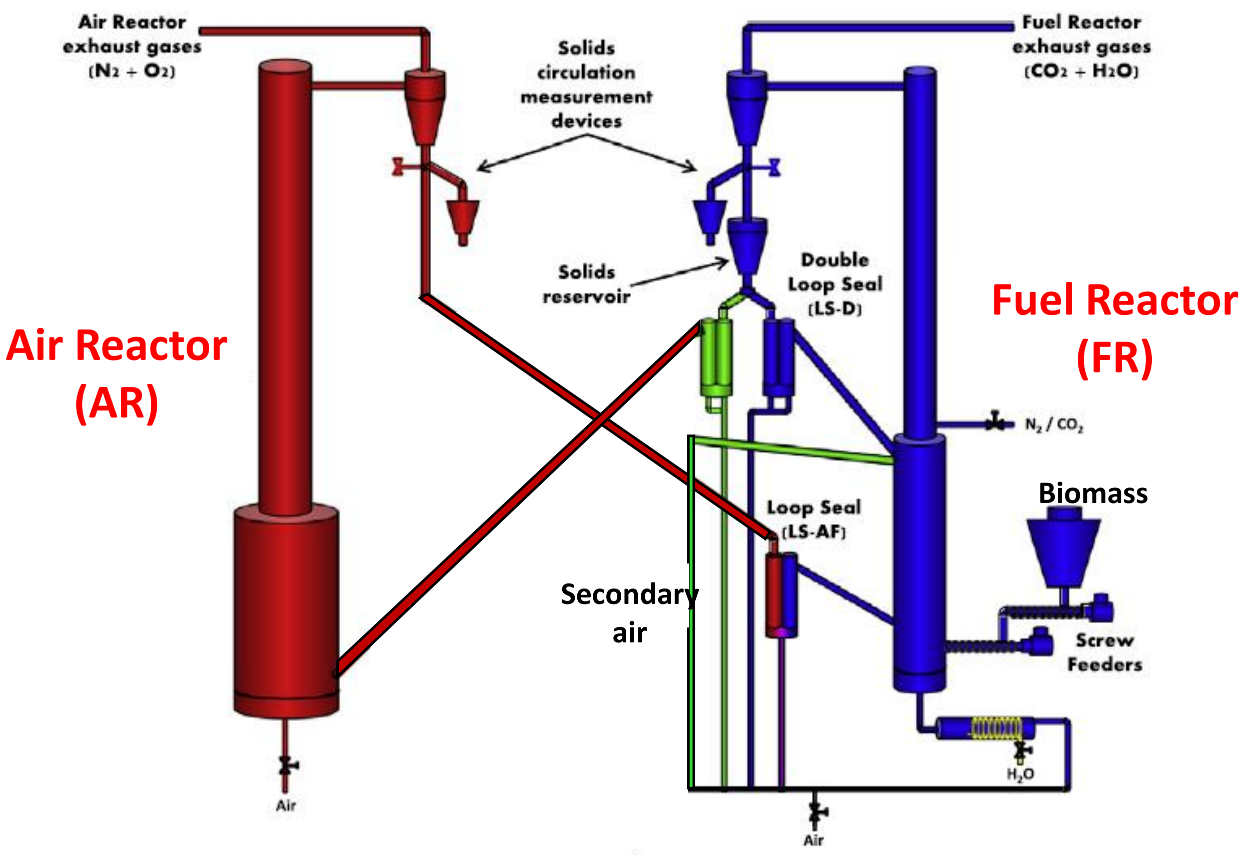
Task 2.4. Small scale continuous CLG gasification tests



1.5 kW_{th} CLG unit at CSIC

- FR: bubbling fluidized bed
- u_g = 0.1-0.2 m/s

Task 2.4. Small scale continuous CLG gasification tests

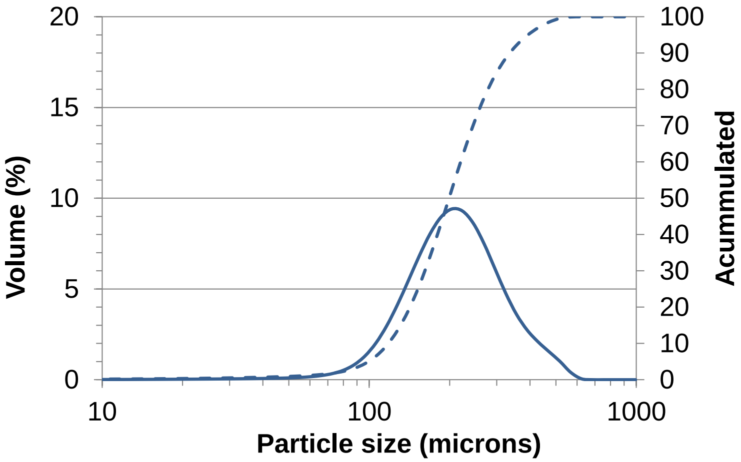


20 kW$_{th}$ CLG unit at CSIC

- FR: turbulent fluidized bed
- ug = 1-4 m/s

Oxygen carrier : Ilmenite

Fresh ilmenite from Titania, Norway.
Calcination: 950 ºC in air for 2 h
Circulated 6 h at 800 ºC in air



Calcined ilmenite

Fe_2TiO_5	54.7 wt.%
Fe_2O_3	11.2 wt.%
TiO_2	28.6 wt.%
Inerts	5.5 wt.%

PROPERTIES

	Calcined ilmenite
Particle size (μm)	100-300
True density (kg/m^3)	4100
$R_{O,ilm}$ (%)	4.0
Porosity (%)	1.2
Crushing strength(N)	2.2
XRD (main species)	Fe_2TiO_5, Fe_2O_3, TiO_2

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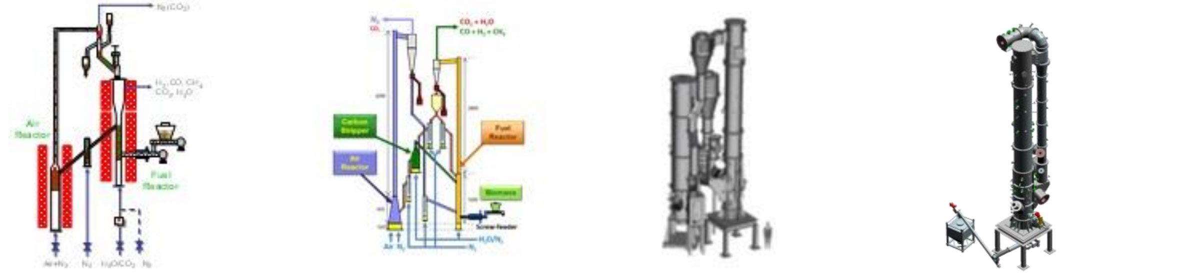
Feedstock selection



		1.5 kW CLG CSIC	20 kW CLG CSIC	1 MW CLG TUD	HTW® TUD
Biogenic residues	Waste Wood Type B	✓	✓	✓	✓
Agricultural residues	Olive pits	✓	✓	?	
	Buckwheat pellets		✓	?	
Woody biomass and forestry residues	Spruce tree tops and branches	✓			
Algae	Microalgae	✓	✓		

Feedstock analysis





ANALYSIS (wt.%)	Waste Wood Type B	Olive pits	Buckwheat pellets	Spruce branches	Microalgae
Moisture	6.8	7.3	9.7	8.0	7.9
Ash	1.7	0.3	2.0	2.5	6.3
Volatiles	74.2	74.9	66.4	72.1	72.9
Fixed carbon	17.3	17.4	21.8	17.5	12.8
C	46.3	46.3	45.0	46.7	44.1
H	5.5	5.5	5.2	5.4	5.7
N	1.1	1.1	0.6	0.4	8.1
S	0	0	<0.1	<0.1	0.7
O(by diff.)	38.5	38.5	38.5	37.0	27.2
LHV (kJ/kg)	16664	17352	16375	16808	17635

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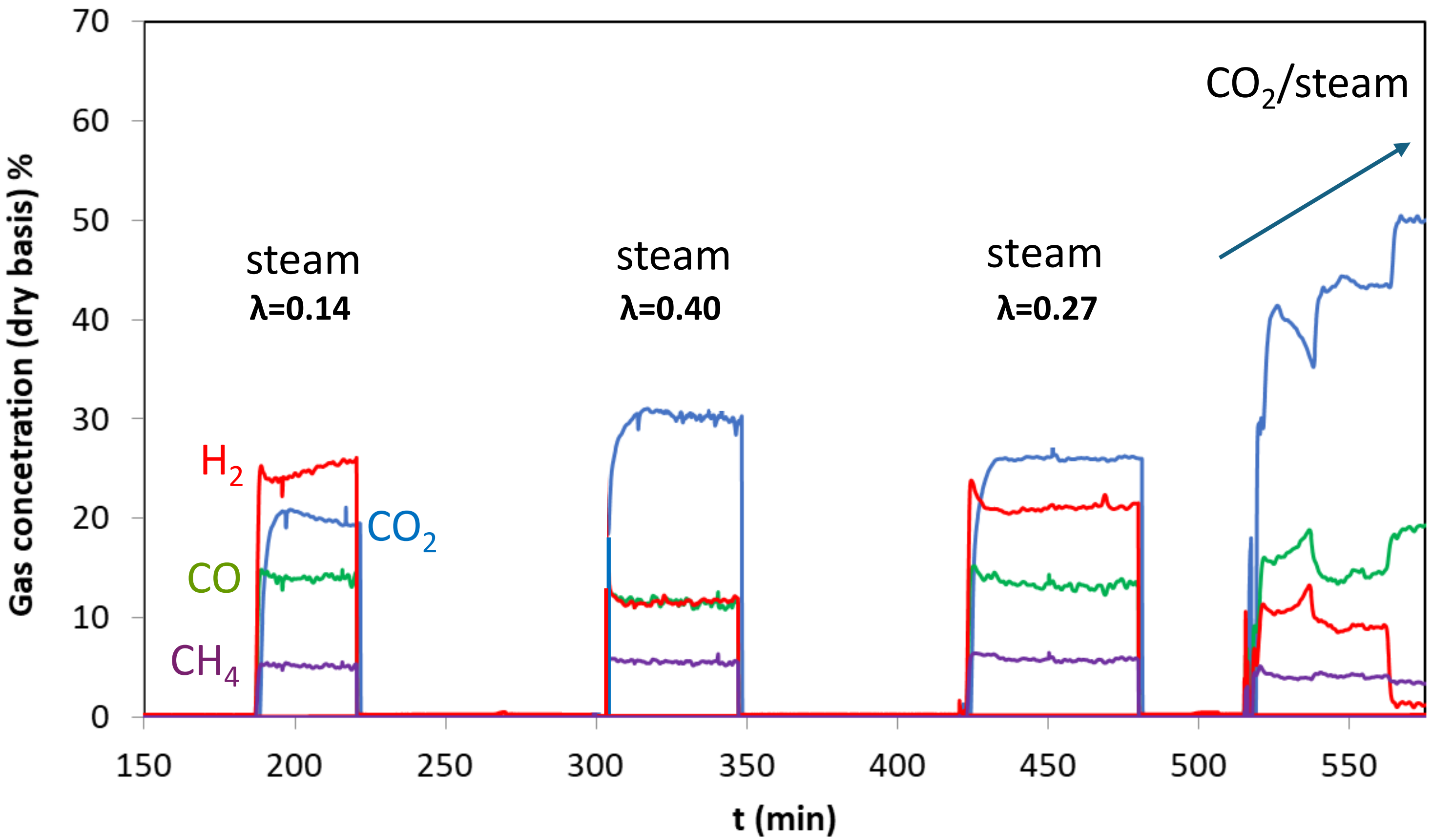
Task 2.4. Small scale continuous CLG gasification tests

Results with Waste Wood Type-B



- Particle size: < 3 mm
- Temperature FR: 875 ˚C
- λ = 0.1- 0.4

THANK YOU
QUESTIONS/COMMENTS

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