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► **To cite this version:**

A Missaoui, B Sarh, T Boushaki, K Shway, P Gillon, et al.. Experimental study of combustion syngas released from gasification of agriculture waste in a downdraft gasifier. 27th International Colloquium On the Dynamics of Explosion and Reactive Systems (ICDERS), Jul 2019, Beijing, China. hal-03295457

HAL Id: hal-03295457

<https://hal.science/hal-03295457v1>

Submitted on 22 Jul 2021

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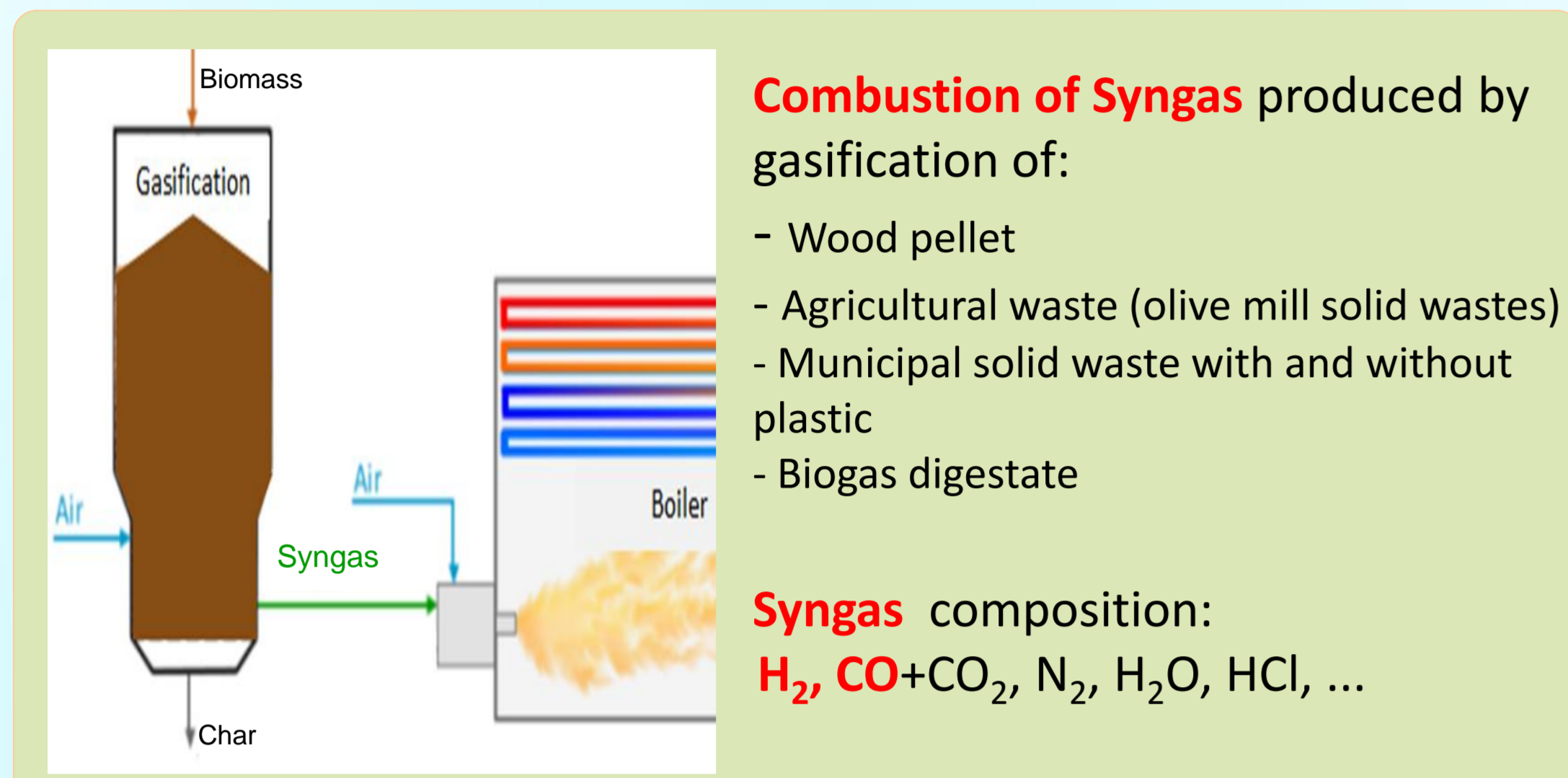
Experimental study of combustion syngas released from gasification of agriculture waste in a downdraft gasifier

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RenewValue Project



Combustion of Syngas produced by gasification of:

- Wood pellet
- Agricultural waste (olive mill solid wastes)
- Municipal solid waste with and without plastic
- Biogas digestate

Syngas composition:
 $H_2, CO+CO_2, N_2, H_2O, HCl, \dots$

▶ European project: **ERANETMED2-72-169**

▶ **Subject:** Local sustainable renewable energy supply for vulnerable communities in arid and semi-arid Mediterranean zones (MENA)

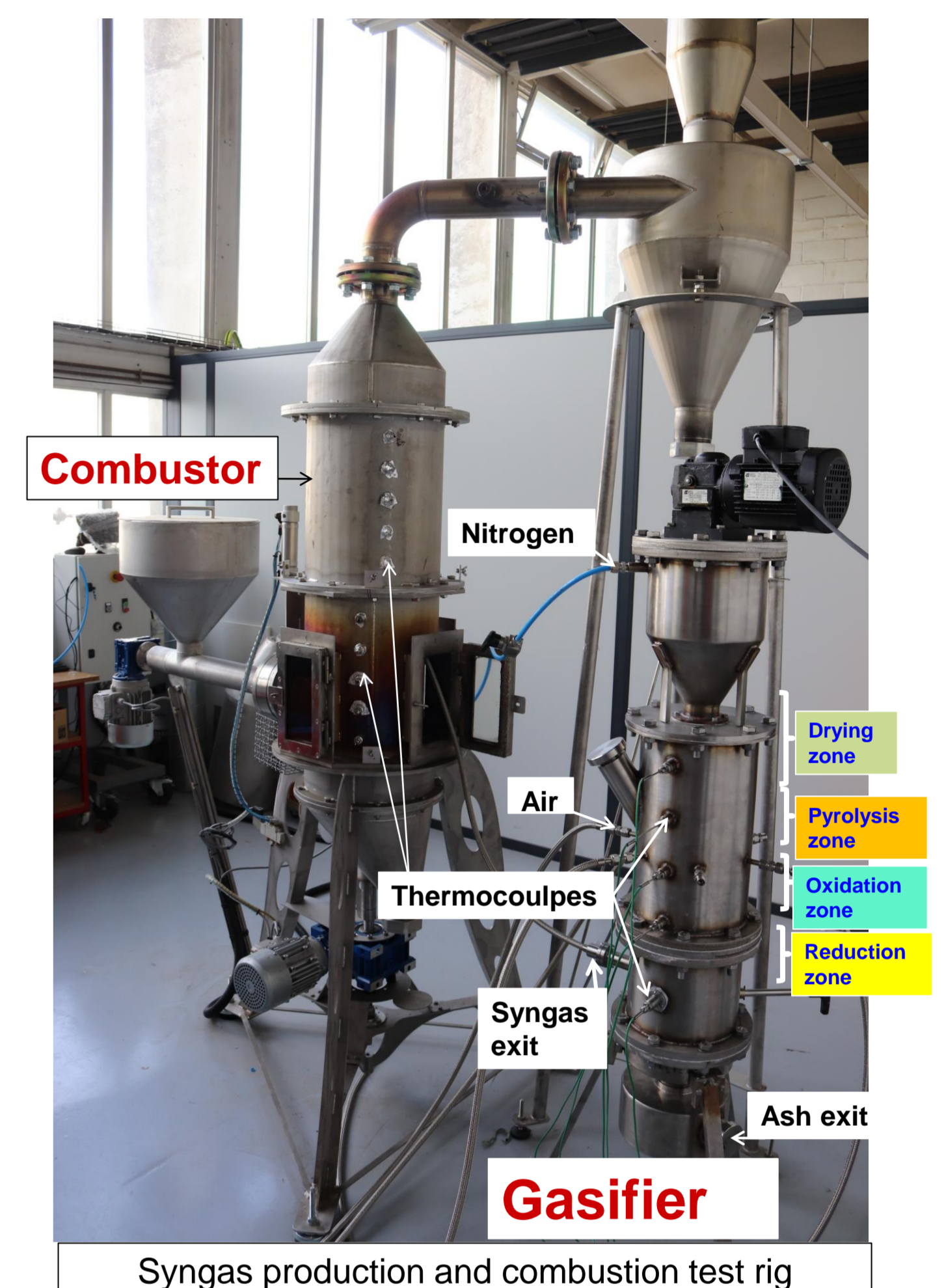
Experimental device

The syngas produced by gasification of olive waste particles in a small pilot scale 5 kWth downdraft fixed bed gasifier, was burnt from a burner inserted in a combustor.

Gasifier and burner are made of stainless steel. The gasifier has a height of 0.682 m and an inner diameter of 0.190 m, lined with insulator thickness of 20 mm. The throat diameter is 0.047m. The oxidizing agent is air, regulated via a mass flow controller. The syngas is regulated by high temperature vortex flow meter.

The nozzle exit inner burner diameter is 25 mm. The fuel nozzle consists of a center body fuel injector, a radial air swirler, and a mixing area. The burner is placed in the combustion chamber (Combustor).

For the temperature, 5 type-K thermocouples were used for recording temperature profile at different parts of the gasifier.



Syngas production and combustion test rig

Feedstock materials

The agricultural waste used in this work came from a traditional Moroccan olive oil extraction unit.

the Netzsch (STA 449 F3 Jupiter) thermal analyzer (TG-DTG) coupled with a quadruple (QMS 403D Aeolus) MS was used for thermogravimetric analysis of olive waste. The TG tests were carried out in ambient argon, oxygen and steam to estimate the pyrolysis, combustion and gasification characteristics.

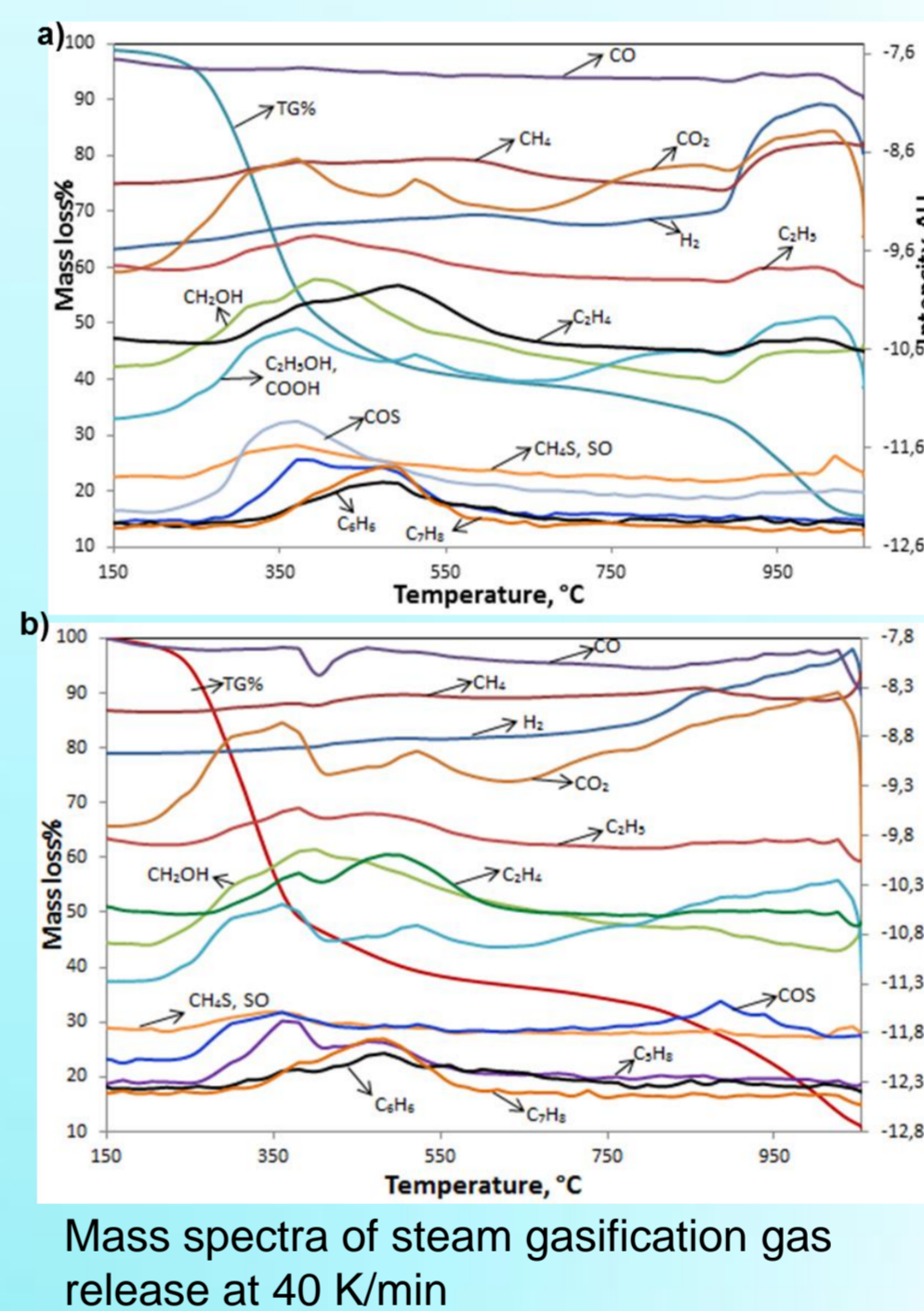
The calorific value was measured using a Parr 1351 adiabatic bomb calorimeter. The high heating value HHVs is $20 \text{ MJ/kg} \pm 2.4\%$.

The ultimate and proximate analysis are summarized in Table 1.

Thermogravimetry and mass spectrometry results

Thermal analysis of samples were performed at different heating rate over temperature range of $150\text{-}1050^\circ \text{C}$.

Gasification behavior of the sample was conducted in steam atmosphere. During the char gasification process, CO, CO_2 and H_2 gases are released with a small amount of CH_4 (see figure).

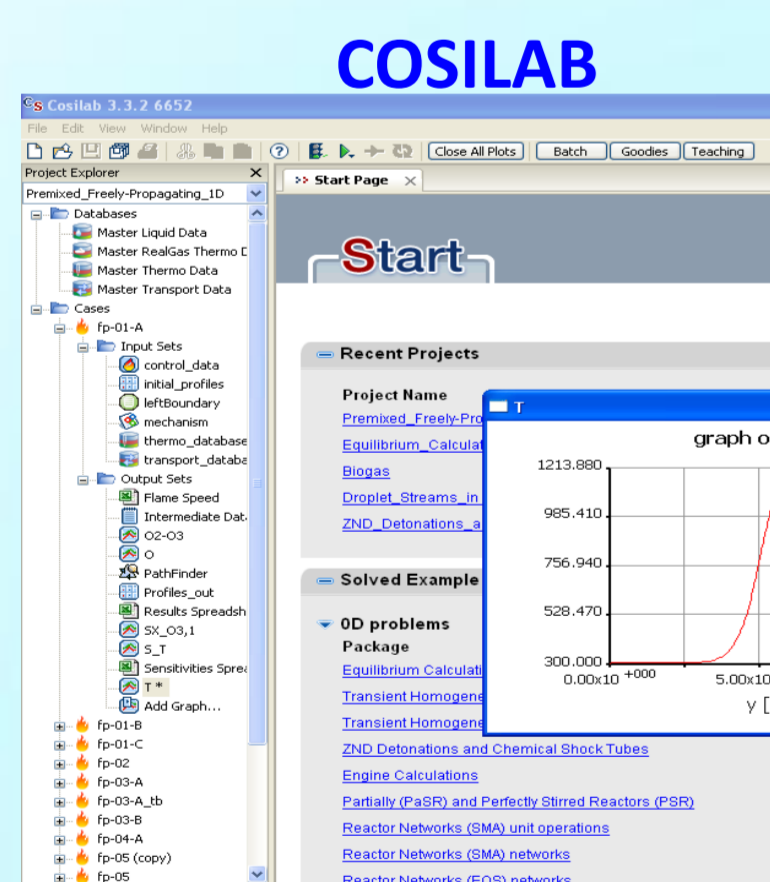


Mass spectra of steam gasification gas release at 40 K/min

| Proximate Analysis (Wt %) | |
|-------------------------------|-------|
| Moisture | 7.5 |
| Volatile Matter | 69.5 |
| Fixed Carbon | 20.2 |
| Ash | 2.8 |
| Ultimate analysis (Wt %, DAF) | |
| Carbon | 50.69 |
| Hydrogen | 6.08 |
| Nitrogen | 1.72 |
| Sulphur | 0 |
| Oxygen | 35.14 |
| HHV (MJ/kg) | |
| | 20.2 |
| Oil content (%) | |
| | 6 |

Table 1: Proximate and ultimate analysis for the biomass sample

Combustion characteristics _ calculations



- ✓ Laminar flame velocities (S_L)
- ✓ Flame temperatures (T_f)
- ✓ Chemical species distributions
- ✓ Pollutant emissions (NO, CO, \dots)
- ✓ Pathways of chemical reactions

Reference case CH_4 -air

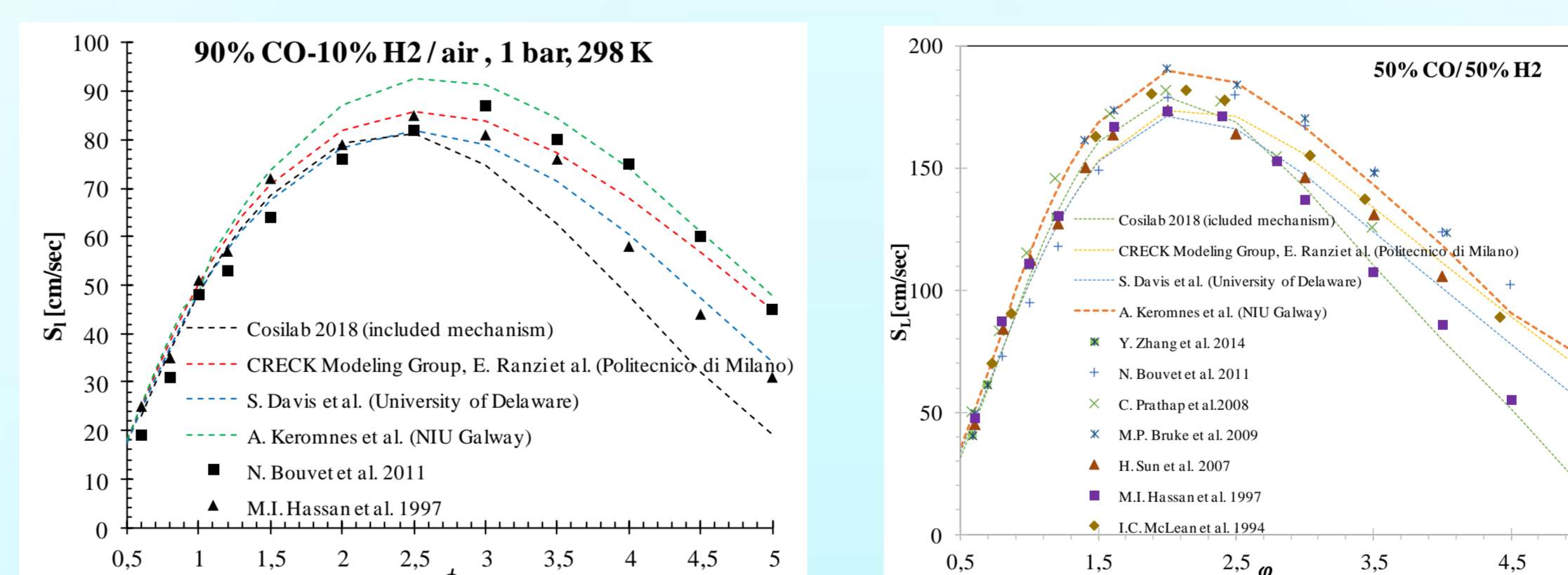
Biogas flame Syngas flame

COSILAB: Combustion Simulation Laboratory. Numerical simulation tool for laminar combustion problems 0D, 1D and recently 2D. Here, calculations of flame 1D (RUN 1DL)

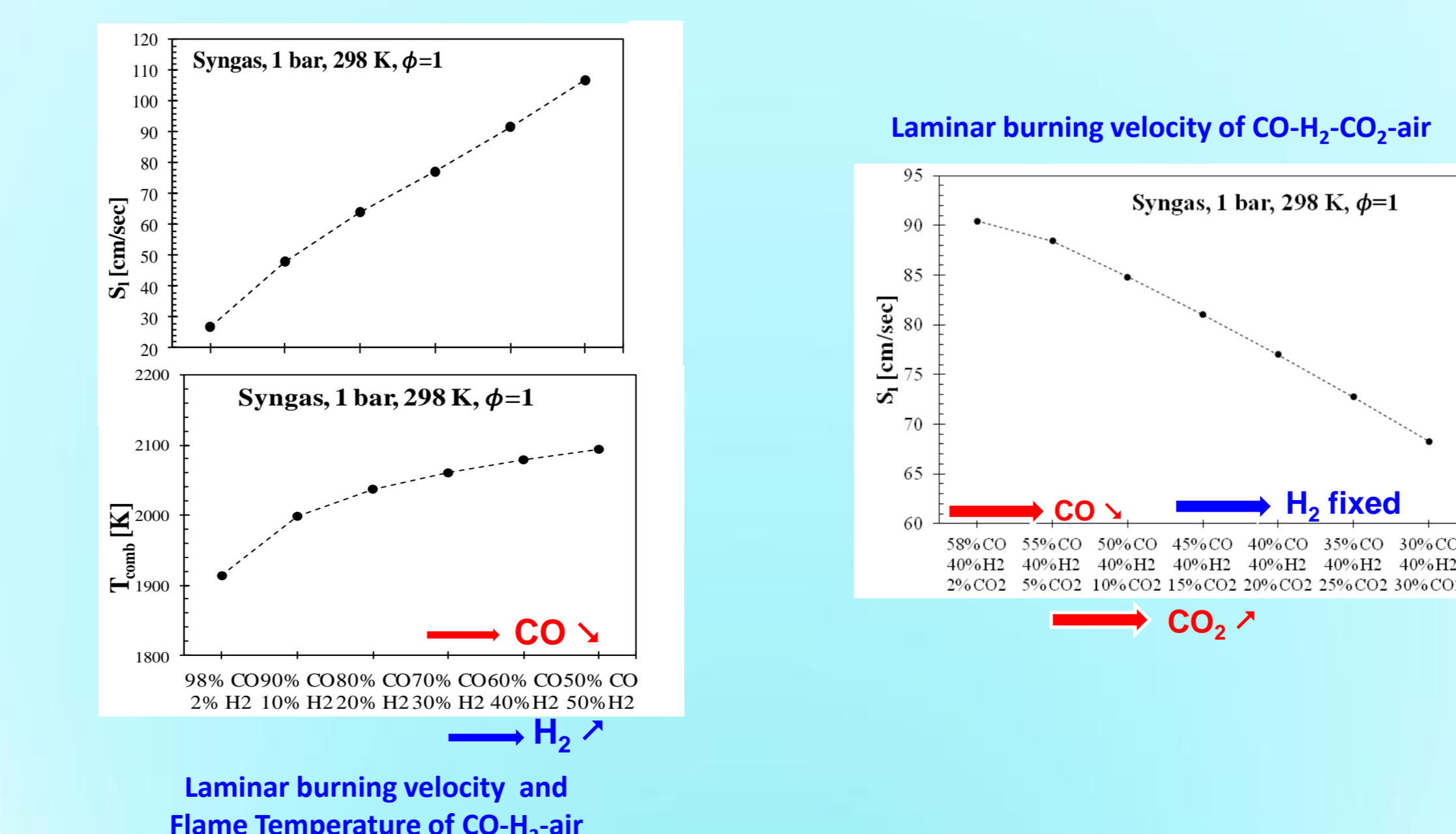
⇒ For different parameters : T, P, X_i, ϕ
 ⇒ With different mechanisms of reactions

Syngas flame calculations

Laminar burning velocity of $CO-H_2$ -air flames: 90/10% and 50/50 % $CO-H_2$



- ✓ Results are compared and validated with experimental results
- ✓ With $+H_2$: S_L max at $\Phi=2.5$ (CH_4 -air: at $\Phi=1.05$)
- ✓ $+H_2 \Rightarrow S_L \uparrow$; $S_{L,max}$: 190 at 50% of H_2 , 90 at 10% H_2 against 38 cm.s^{-1} CH_4 -air
- ✓ $+H_2$: higher reactivity, higher flammability limits, higher velocity, higher T



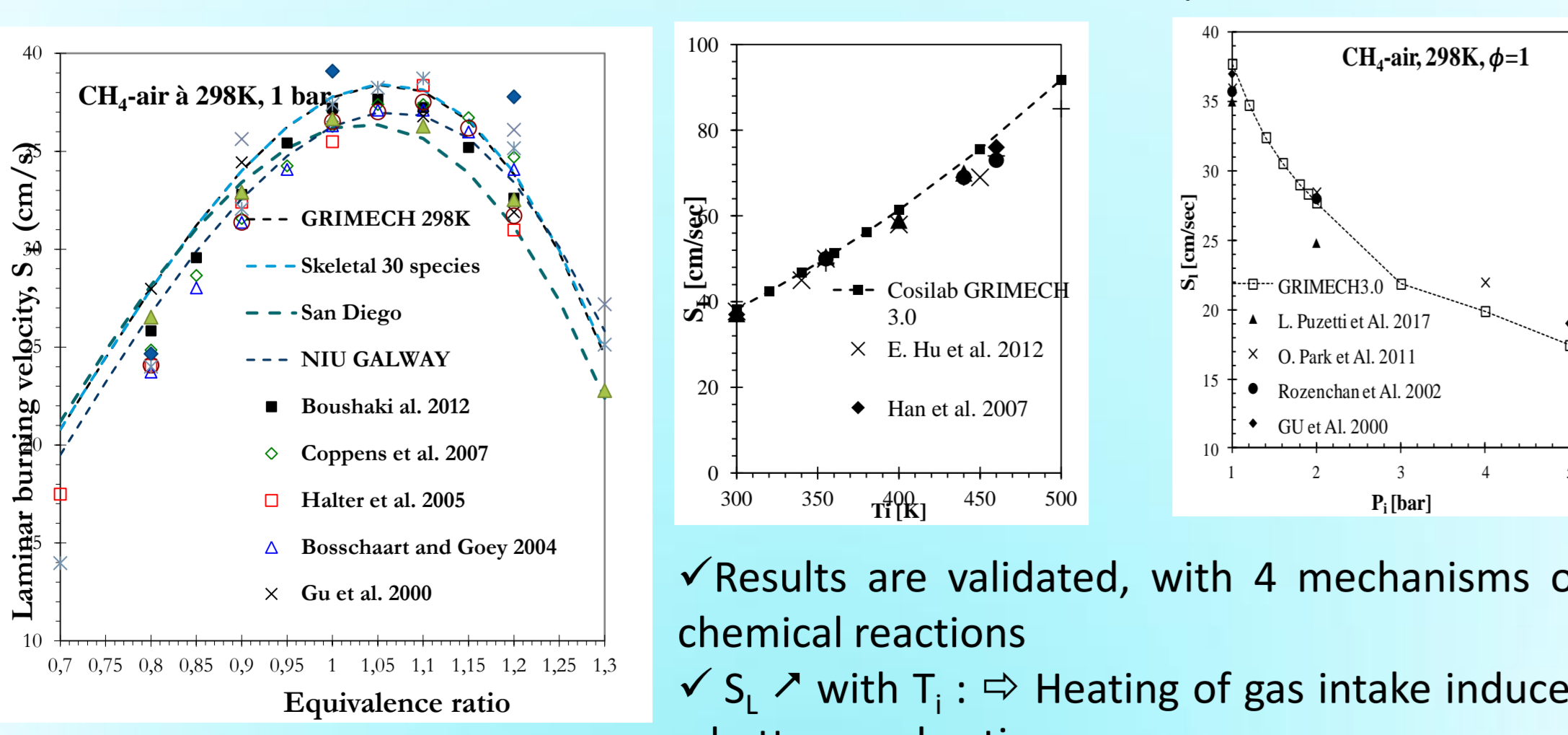
Next steps

- Tests with different biomass (pellet wood, olive waste, municipal solid waste)
- Investigate the operating conditions
 - Influence of air flow rate
 - Influence of temperature on gas production and composition : H_2+CO content and H_2/CO ratio
 - Influence of air equivalent ratio
- Analyze the product obtained (syngas, tar...)
- Investigation on syngas flames

Case of CH_4 -air flame

Laminar burning velocity with equivalence ratio: CH_4 -air, at 298 K, 1 bar

Laminar burning velocity with initial temperature and pressure : CH_4 -air, 1 bar, $\Phi=1$



- ✓ Results are validated, with 4 mechanisms of chemical reactions
- ✓ $S_L \uparrow$ with T_i : \Rightarrow Heating of gas intake induces a better combustion
- ✓ $S_L \searrow$ with P_i