# Ignition and combustion characteristics of biomass derived fast pyrolysis bio-oil in a combustion research unit

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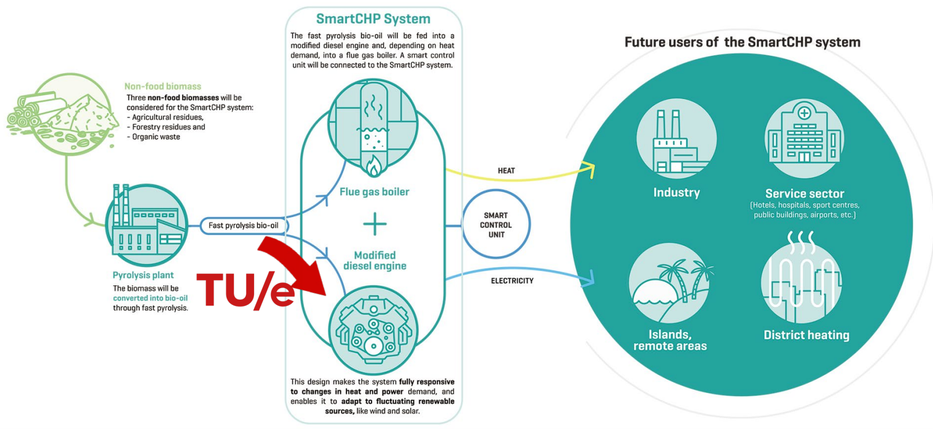
## SmartCHP: aim and impact

- The EU research project SmartCHP will develop a novel, flexible small scale **cogeneration unit** to produce heat and electricity from **sustainable biomass**.
- The main technical novelty is the use of **fast pyrolysis bio-oil (FPBO)** from lignocellulosic biomass in a **converted diesel engine**.
- This will help boost the use of renewables in the electricity and heating & cooling sectors, contributing to the **2030 climate and energy targets**.

With a market potential of **€4 billion**, and an estimated **85 to 95% reduction in GHG emissions** compared to fossil fuels, the installation of the SmartCHP technology in Europe can help mitigate **climate change** by introducing more **renewables** while bringing **new jobs**.

## SmartCHP process




**Challenge: how to apply FPBO in a diesel engine.**

| | | |
|---|---|---|
| *Status quo* | FPBO < 30%: | FPBO+alcohol+(biodiesel, etc.) [1-2] |
| *SmartCHP target* | FPBO ≥ 70%: | FPBO+alcohol; FPBO+Beraid |

## Diesel vs FPBO

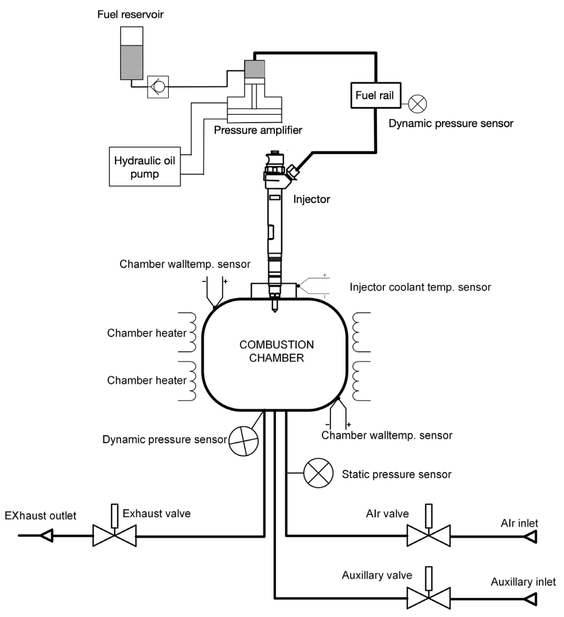
| Property | Diesel | FPBO* |
|---|---|---|
| LHV (mJ/kg) | 42.6 | 16.4 |
| Density (kg/L) | 0.82 | 1.17 |
| C (wt%) | 85.0 | 42.8 |
| H (wt%) | 12.6 | 7.8 |
| O (wt%) | - | 49.2 |
| Water (wt%) | - | 24.1 |
| Solid (wt%) | - | 0.04 |
| Viscosity (cSt at 40 ℃) | 2.7 | 21.0 |
| Cetane number | 54.8 | - |

* Data from wood-based FPBO [3].

## Experimental method

### Combustion research unit (CRU)

| CRU operation condition | |
|---|---|
| Chamber volume [L] | 0.475 |
| Chamber wall temperature, T [ºC] | 300 – 590 |
| Initial chamber pressure, $P_{init}$ [bar] | 10 – 70 |
| Injection pressure, $P_{inj}$ [bar] | 200 – 1000 |
| Injection duration [ms] | 0 – 1.5 |




## Data process & indicator definition

Pressure profile from CRU

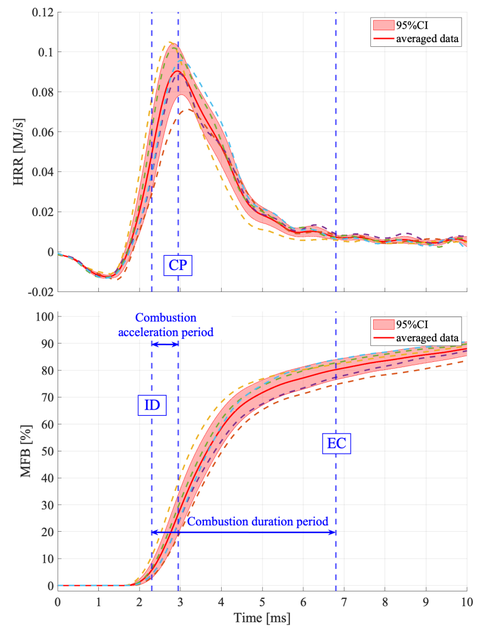
**Derivative** — Speed of sound correction; Heat transfer correction

Heat release rate (**HRR**)

**Integral** — Injection volume; Fuel LHV

Mass fraction burned (**MFB**)

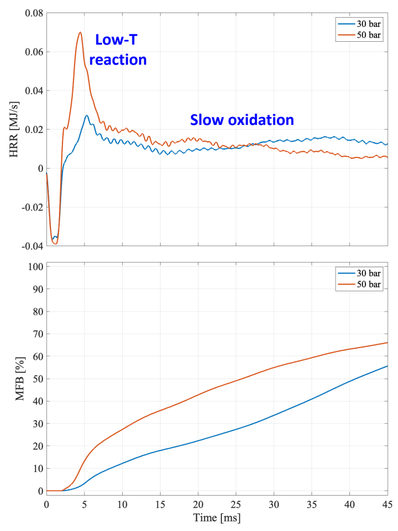
| Indicator | Definition |
|---|---|
| Ignition delay, ID [ms] | 5% MFB |
| Combustion phasing, CP [ms] | Maximum HRR |
| End of combustion, EC [ms] | 80%MFB |
| Combustion acceleration period [ms] | Between ID and CP (CP–ID) |
| Combustion duration period [ms] | Between ID and EC (EC–ID) |




## Results and conclusions

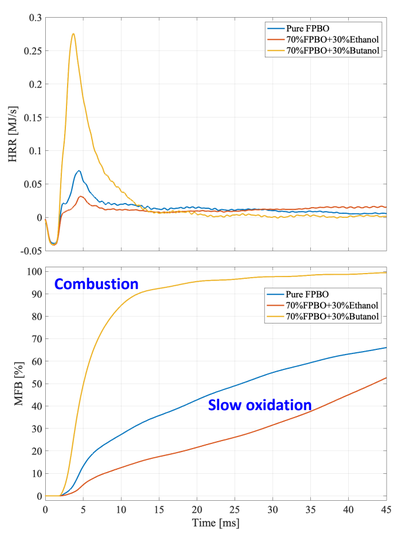
### Pure FPBO

T=590 ºC, $P_{inj}$=1000 bar



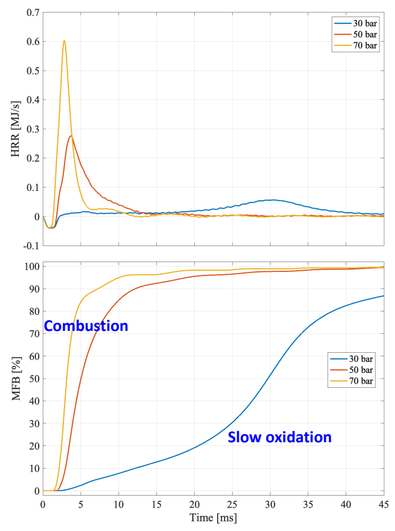

### Effects of alcohol addition

T=590 ºC, $P_{init}$=50 bar, $P_{inj}$=1000 bar



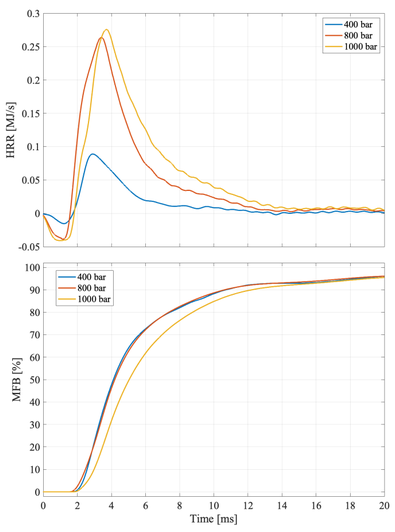

### Effects of $P_{init}$

T=590 ºC, $P_{inj}$=1000 bar



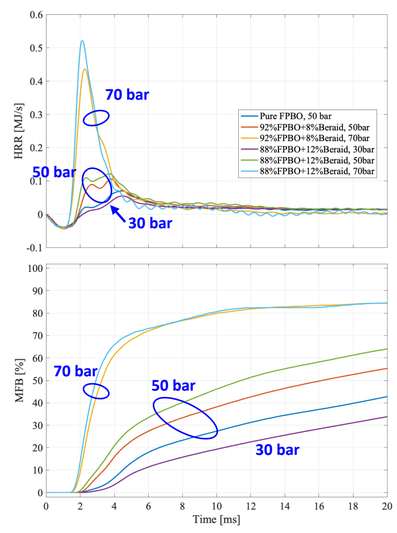

### Effects of $P_{inj}$

T=590 ºC, $P_{init}$=50 bar




### Effects of Beraid addition

T=590 ºC, $P_{inj}$=1000 bar




**FPBO ignitability: between ethanol (CN ~7) and n-butanol (CN 17)**

- Compared with ethanol, adding 30% n-butanol could significantly improve the ignition and combustion processes of FPBO.

**Chamber pressure & injection pressure**

- For 70%FPBO+30%Butanol, higher chamber pressure boosts ignition and combustion processes.
- Once the autoignition succeeds, the intense combustion (maximum HRR) arrivals within around 1 ms.
- Burn duration decreases with higher chamber pressure, while increases with higher injection pressure.

**Ignition improver: Beraid is unqualified for FPBO**

- When adding 12% Beraid to FPBO, the improvement in ignition behavior is very limited.

## References

[1] Y. Wang, *et al*. (2021). Ignition and combustion characteristics of n-butanol and FPBO/n-butanol blends with addition of ignition improver. 10th European Combustion Meeting.

[2] S. Lee, *et al*. (2020). Combustion and emission characteristics of a diesel-powered generator running with N-butanol/coffee ground pyrolysis oil/diesel blended fuel. *Energy*, 206, 118201.

[3] B. Beld, *et al*. (2018). The use of a fast pyrolysis oil–Ethanol blend in diesel engines for CHP applications. *Biomass and bioenergy*, 110, 114-122.

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