titan
microwave biogas cracking

Direct biogas conversion to green H_2 and carbon materials by scalable microwave heated catalytic reactor for soil amendment and silicon carbide production

The electric decade Workshop – Jan 17th, 2024

Coordinator: Prof. David Farrusseng, CNRS

Duration: 48 month

Starting date: Sept 2022

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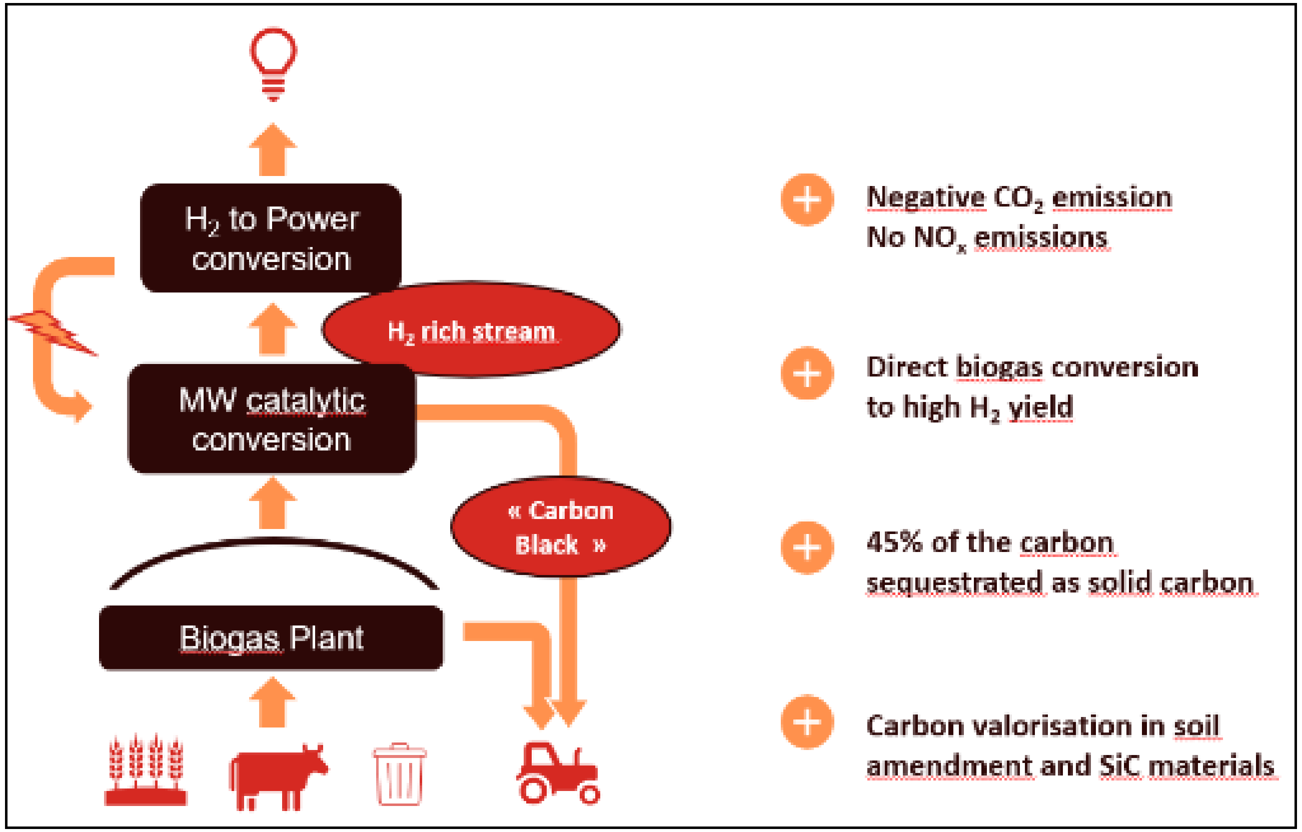
Titan objectives

TITAN develops an innovative microwave heated catalytic reactor which directly converts biogas into H_2 without emission of greenhouse gases.

TITAN aims at H_2 yield at competitive cost due to low CAPEX, affordable to European biogas industry thanks to major expenditure reductions and global process efficiency.



The co-produced carbon material may be used for soil amendment nearby delocalised biogas plants, allowing long term carbon sequestration and a sustainable circular economy.

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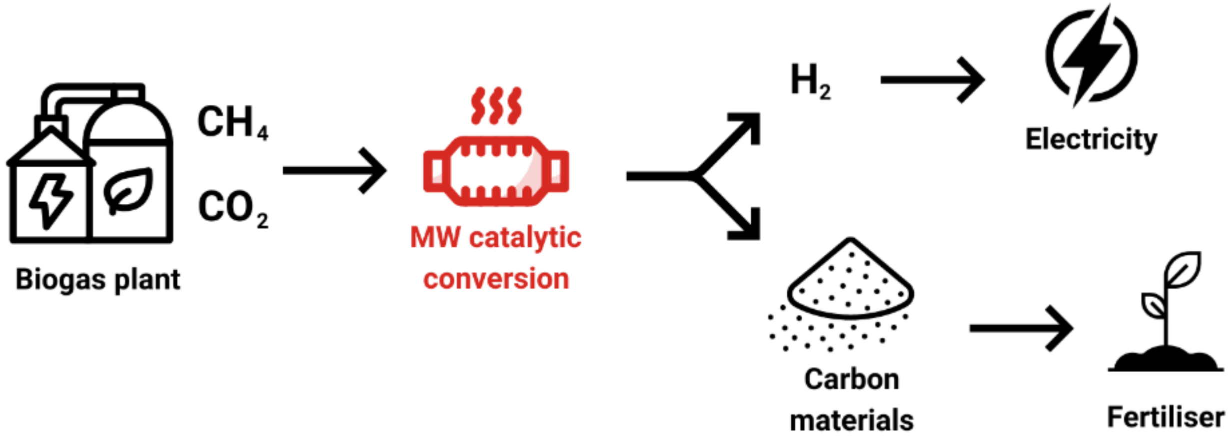
Titan at a glance

- Direct conversion of biogas by simultaneous CH_4 cracking and CO_2 dry reforming shall allow boosting H_2 yield (+30%) with the use of a post-processing WGS reactor;
- High biogas conversion (>90%) via a Microwave heated fluidised bed catalytic technology (non-plasma);
- CAPEX compatible with current biogas plant investment level, thanks to the design of scalable Microwave heated reactors – and a modular approach;
- Smart process intensification that avoids costly upstream gas separation processes and downstream gas recycling – small/large biogas plants;
- An electricity self-sufficiency process by use of available H_2 to power solutions.



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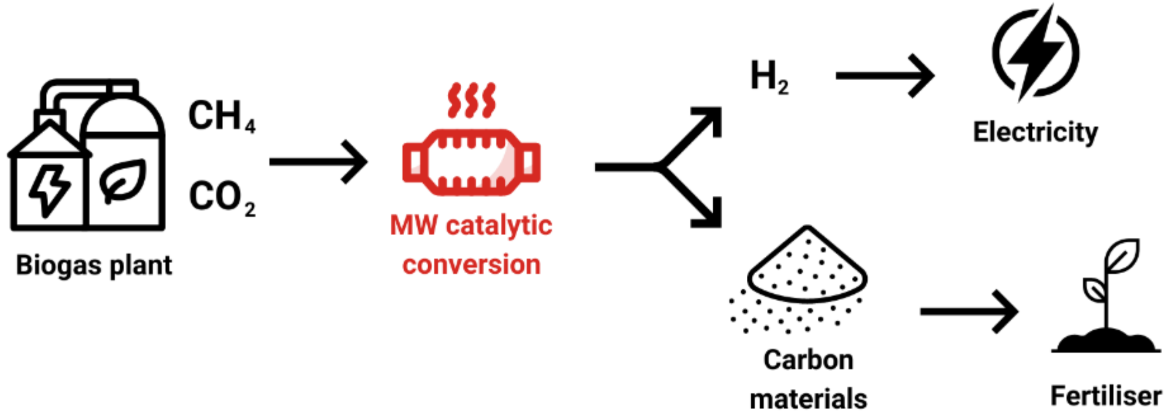
TITAN impact against climate change

- Demonstrating a carbon (GHG) negative emission solution that contributes to the decarbonisation of agriculture sector;
- Accelerating carbon capture in agriculture by soil amendment using novel “biochar” from biogas - Circular economy
- Use of abundant, non-toxic catalysts that allows for the direct utilisation of the carbon materials for local soil amendment by possible integration with on-site fertiliser production at biogas plants, thereby enabling easier handling;



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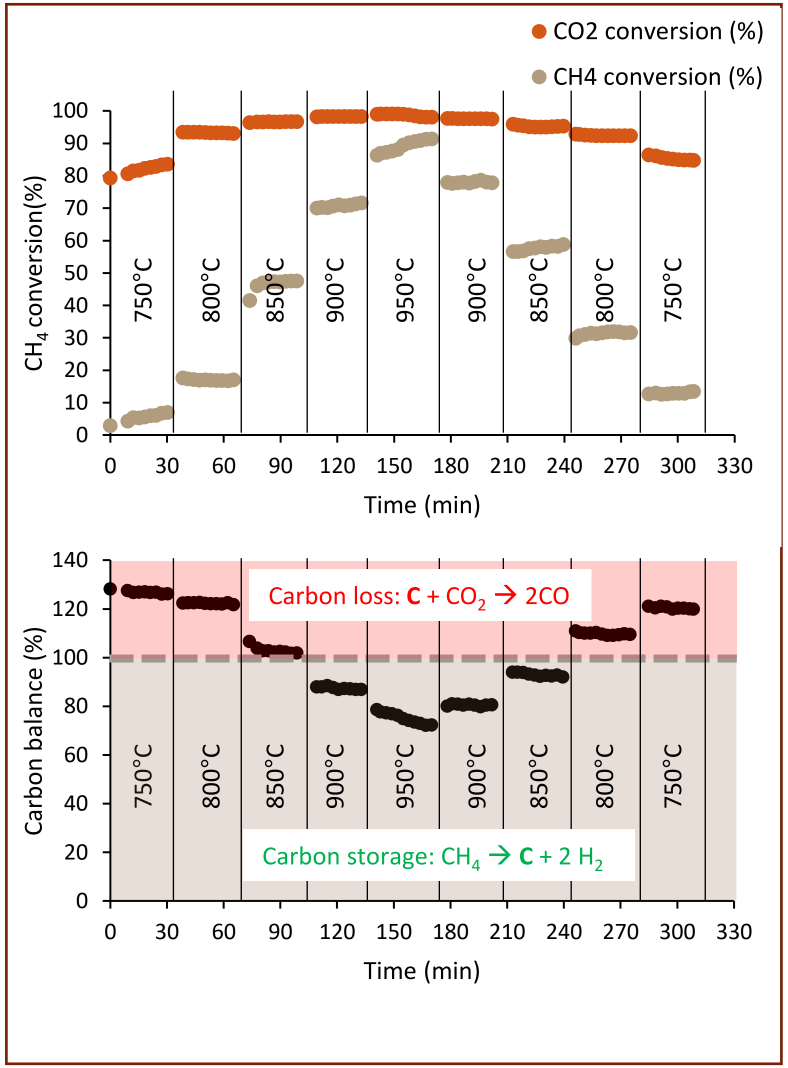
Catalytic Fluidized bed at lab scale

- Biogas conversion (CH_4:CO_2 = 2:1)
  - Conventional heating (elec. Furnace)
- Titan catalyst : Iron-based
  - (Very) cheap and available
  - Good fluidization,
  - No deactivation after 2 hrs TOS)
- Temperature Effect
  - Carbon formation occurs at T>850°C
    - Methane cracking dominates
  - Carbon gazeification at T<850°C
    - Boudouard reaction dominates



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Catalytic Fluidized bed at lab scale

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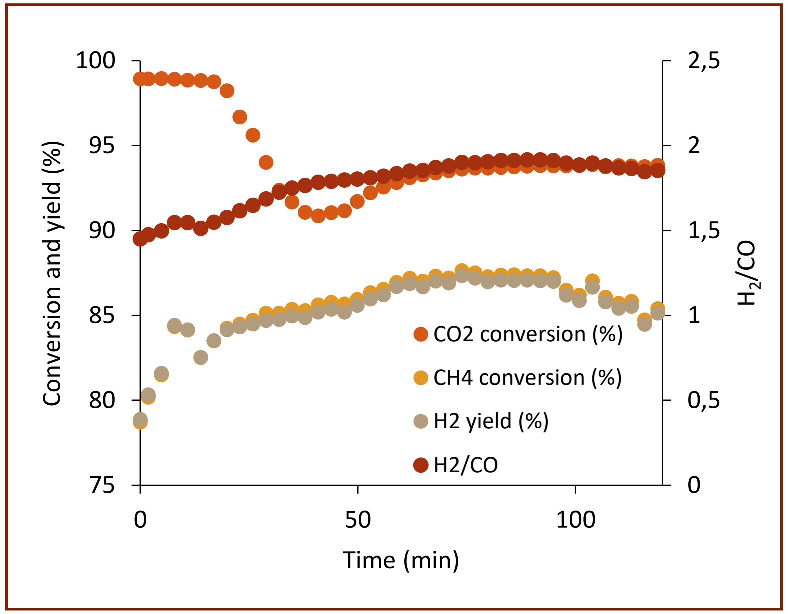
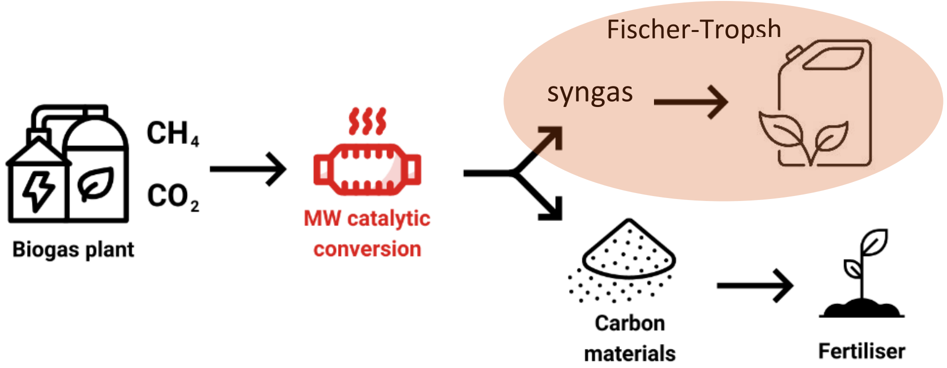
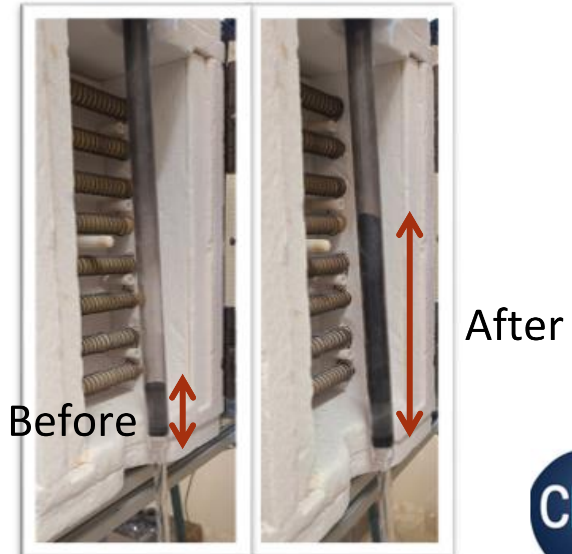
- Biogas conversion (CH_4:CO_2 = 2:1)
  – Conventional heating (elec. furnace)
- At 950°C – Thermodynamic equilibrium achieved
  – X_{CH4} > 85%, X_{CO2} =95%, X_{Carbon} = **- 31%**
- Biogas to Liquid Fuels via decarbonized syngas
  – Outlet : H_2 (62%), CO (33%), CH_4 (4%), CO_2 (1%)
  – Carbon storage : 0,3kg / $kg_{catalyst}$ / hr
  – Selectivity H_2 : CO = 2 : 1 ratio allowing FT Synthesis
  – No need for gas separation (H_2/CH_4, CO_2/CH_4)







Carbon production

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Titan preliminary results: Carbon type

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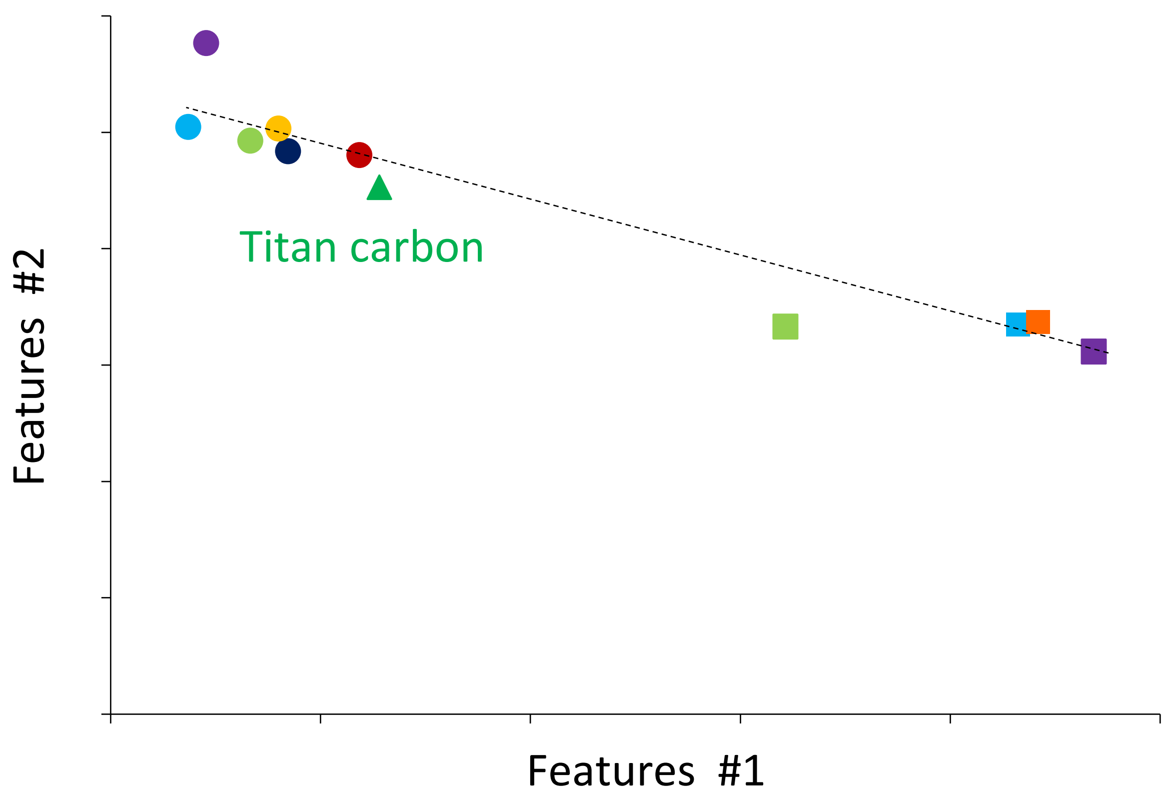
- Establishment of structural correlation between very diverse class of carbons
- Comparison of « Fingerprints » of Titan carbons with reference materials
- **TITAN: Turbostratic carbon**
- « Contamination » by Iron



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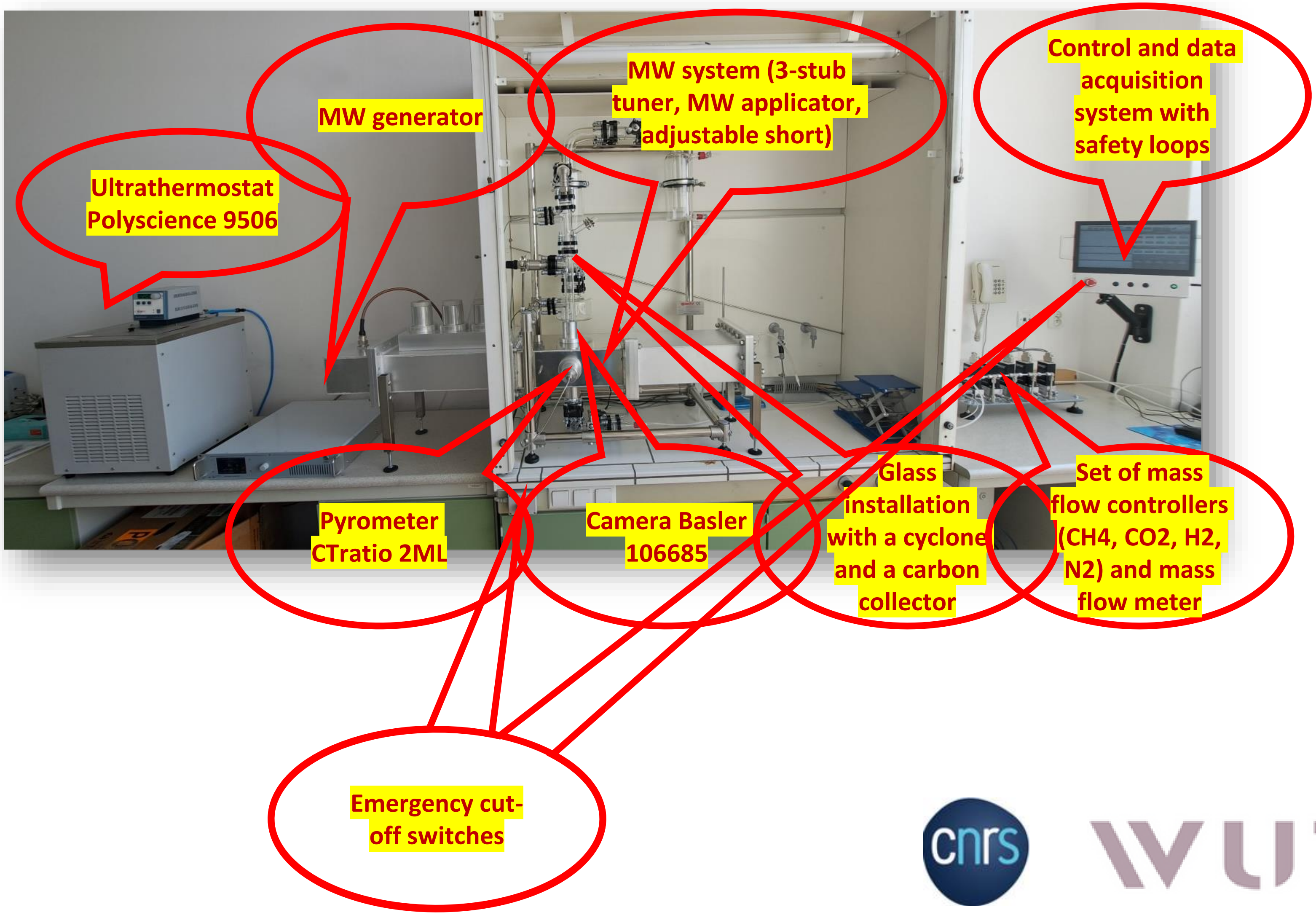
TITAN MW reactor technology at Lab scale

- Two installations
  - WUT, Warsaw
  - CNRS, Lyon
- MW equipments
  - 1.3 kW, 915 MHz Solid State generator (Leanfa, Italy)
  - Waveguide and cavity (Muegge, DE)
- 915 MHz MW technologies
  - Commercially available
  - Allows large reactor size (D=30cm)
  - Scalable in modular approach



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Why 915 MHz for TITAN?
Grid electric efficiency (GEE)

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Frequency, MHz	GEE of magnetron-based generators, %			GEE of solid-state generators[c], %
	HV power supply Linear or switch-mode	Magnetron	Overall GEE[a], HV power supply x Magnetron	
915	90-95	~90	80-85[b]	< 60
2450	90-95	~70	60-65[b]	40-50

[a] GEE of magnetron x GEE of HV power supply

[b] Overall mains electrical power consumed to operate magnetron-based generators is calculated as follows: 100 kW, 915 MHz - 100 kW/0.85 ~ 118 kW for 85% efficiency and ~125 kW for 80% efficiency. Similarly, a 6 kW, 2.45 GHz consumes ~ 9-10 kW

[c] GEE of LDMOS transistors is lower than the equivalent power GaN

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Upscaling TITAN MW reactor technology

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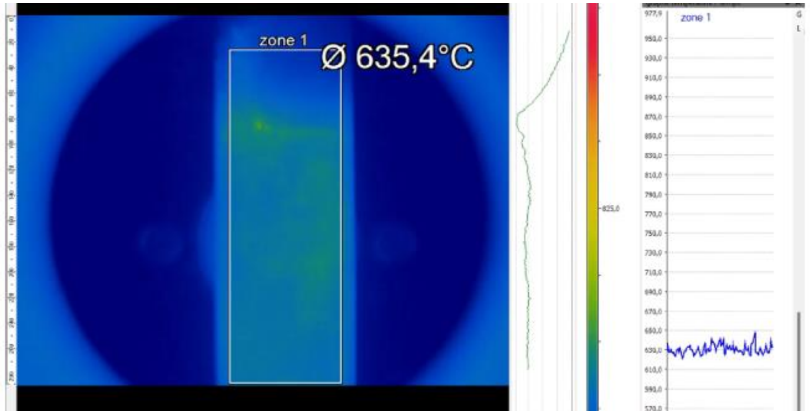
- Fluidization under MW heating – a challenge
  - Fluidization depends on volume flow
  - which depends on gas phase temperature
  - which depends on catalyst heating
  - which depends on the bed and the temperature
  - Which depends on fluidization



ANSYS FLUENT

- MW Fluidized Bed reactor Modelling
  - Process models : Hydrodynamic, heat Transfer and electromagnetic field
  - Catalytic kinetic model : Langmuir-Hinshelwood and power law expressions

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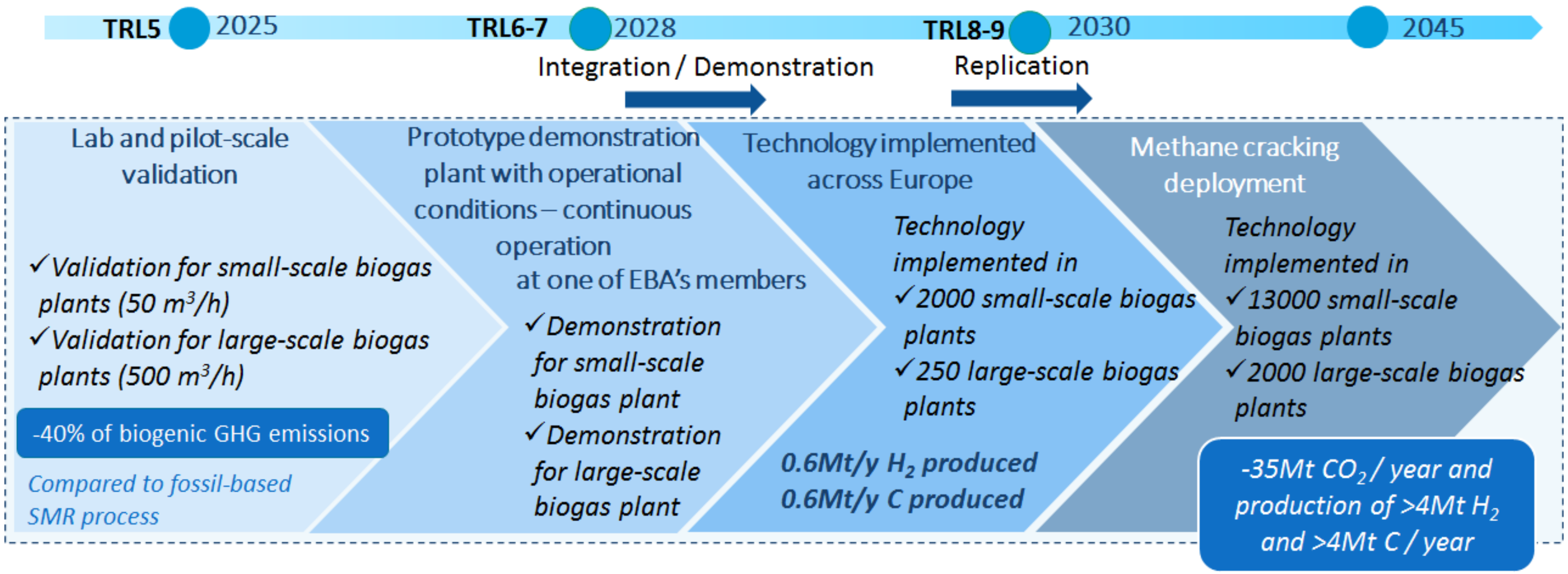

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2024 - Key Int. Conferences

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Oct 31st
Deadline

March 15th
Deadline

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- **CNRS – IRCELYON**
  Ingenierie team
- **Warsaw University of Technology**
  Faculty of chemical and process engineering
- **Microwave Technologies Consulting (MTC)**
- **European Biogas Association (EBA)**
- **University of Hohenheim**
  Soil biology / Biogeophysics teams
- **Process Design Center BV (PDC)**
- **ESD-SIC BV**

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Thank you for your attention !

https://titan.cnrs.fr/

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