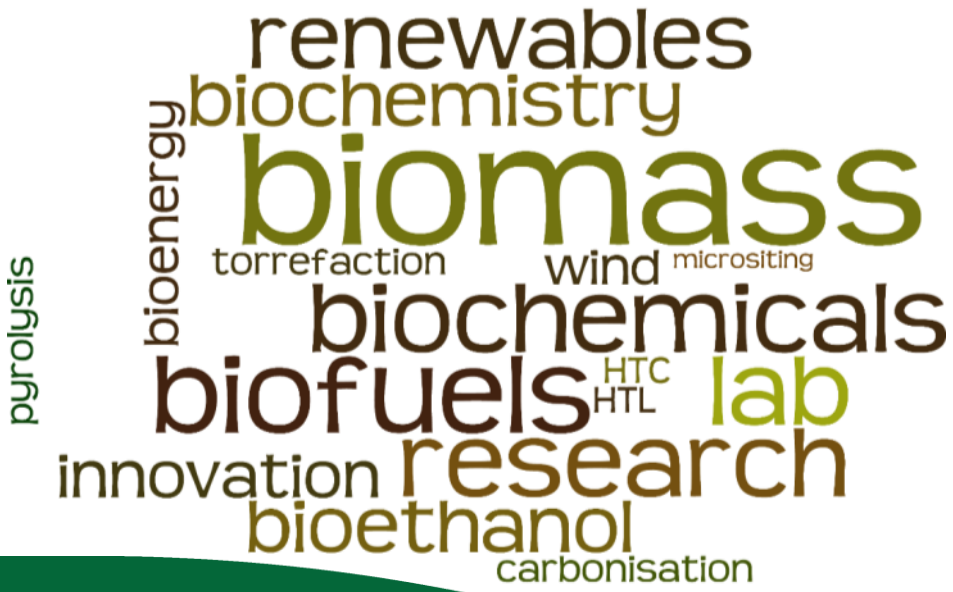
Tar Separation and Conversion using Microwaves (TSC-MW) to improve Conversion Efficiency into Electric Energy from Pyro-gasification



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Outline

- **Introduction**
  - Context, Aim and Objective
- **Experimental set-up**
  - Gasification system and feedstock
  - Tar separation and conversion module (DEVELTAR)
- **Results**
- **Conclusion**

Context: gasification and energy efficiency

- Tar content in producer gas hinders the possibility of power generation from biomass
- Wet system for gas cleaning generates remarkable amount of effluents and does not recover heat from the producer gas (efficiency loss)
- MW makes possible to concentrate most of the energy on the target molecules avoiding a general increase of temperature
- The DEVELTAR module is not intended for a specific pyrolysis or gasification technology, but as wide-ranging add-on module to be coupled to the gas cleaning line

Context: DEVELTAR research project

DEVELTAR is an Italian research project developed by *Sea Marconi Technologies SaS* and *Spike Renewables SrL* with the financial support of *CCSE*

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Florence (Italy)

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A. M. Rizzo

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The aim of the project consist in the design and test of a system (module) for the **removal of tars from pyrolysis and gasification gaseous effluents,** in order to **improve** both the **quality** as fuels and the conversion **energy efficiency**.

Spike Renewables SrL

Spike Renewables SrL is an Engineering company composed by scientists from the University of Florence, Department of Energy CREAR (Research Center for Renewable Energy) and engineers with previous experience in General Electric Co. (Gas Turbine Division for Power Generation Applications).

Focus on renewable energies:

- Engineering of Electrical and Technological Systems in commercial, residential, industrial and healthy buildings – HVAC – Building Technology
- CHP and Hydro Power EP
- Concentrated solar power CSP-CPV
- Biomass and bioenergy/biofuels processes and plants EP
- Microalgae for biofuel pilot plant EP
- Biomass thermochemical conversion - HTL – Flash Pyrolysis Patented Processes

Sea Marconi Technologies SaS

Sea Marconi Technology is an Italian SME operating in the field of energy and the environment. Founded in 1968 and headquartered in Torino, Sea Marconi provides diagnostics and decontamination products and services. Sea Marconi performs life cycle management of electrical equipment filled with insulating fluid such as transformers. Mission of the company is the protection of environmental resources and customer assets.

Recent activities on renewables

- Development of a new patented 3-stage thermochemical conversion technology (LORVER project)
- Microalgae conversion in biofuels (mainly ethanol)
- Several ongoing initiatives on pyrolysis and gasification

RE-CORD

- **RE-CORD** was established as a public/private **not for profit Research Centre** (according to EU and National Legislation).
- **Members**: **University of Florence** (***CREAR*** and the ***Montepaldi*** *farm*), ***Spike Renewables Srl*** and ***Pianvallico SpA***
- RE-CORD Consortium combines skills and resources (personnel, laboratories and equipments) of its members, creating a critical mass able to develop research and activities of primary-level science and technology.

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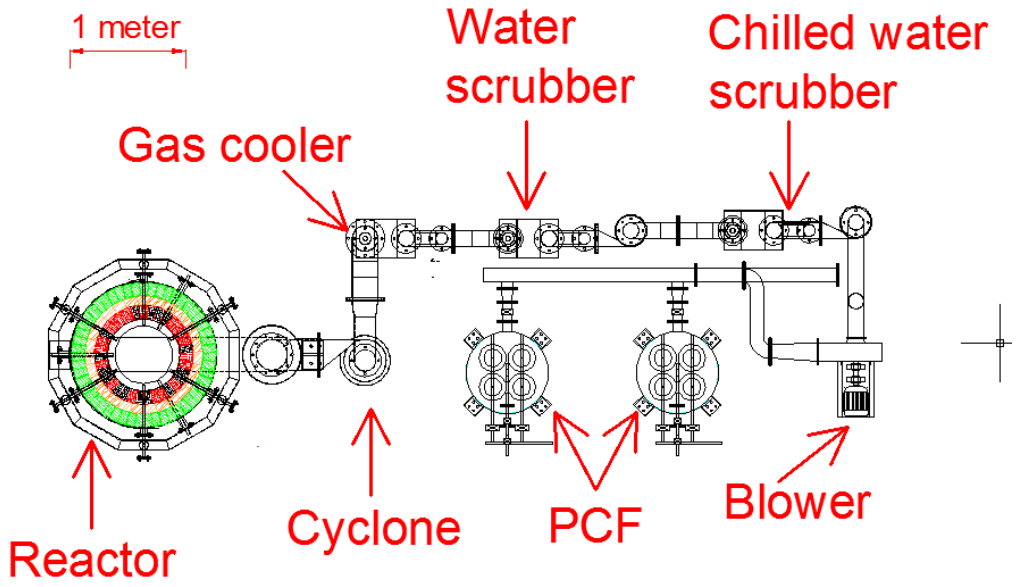
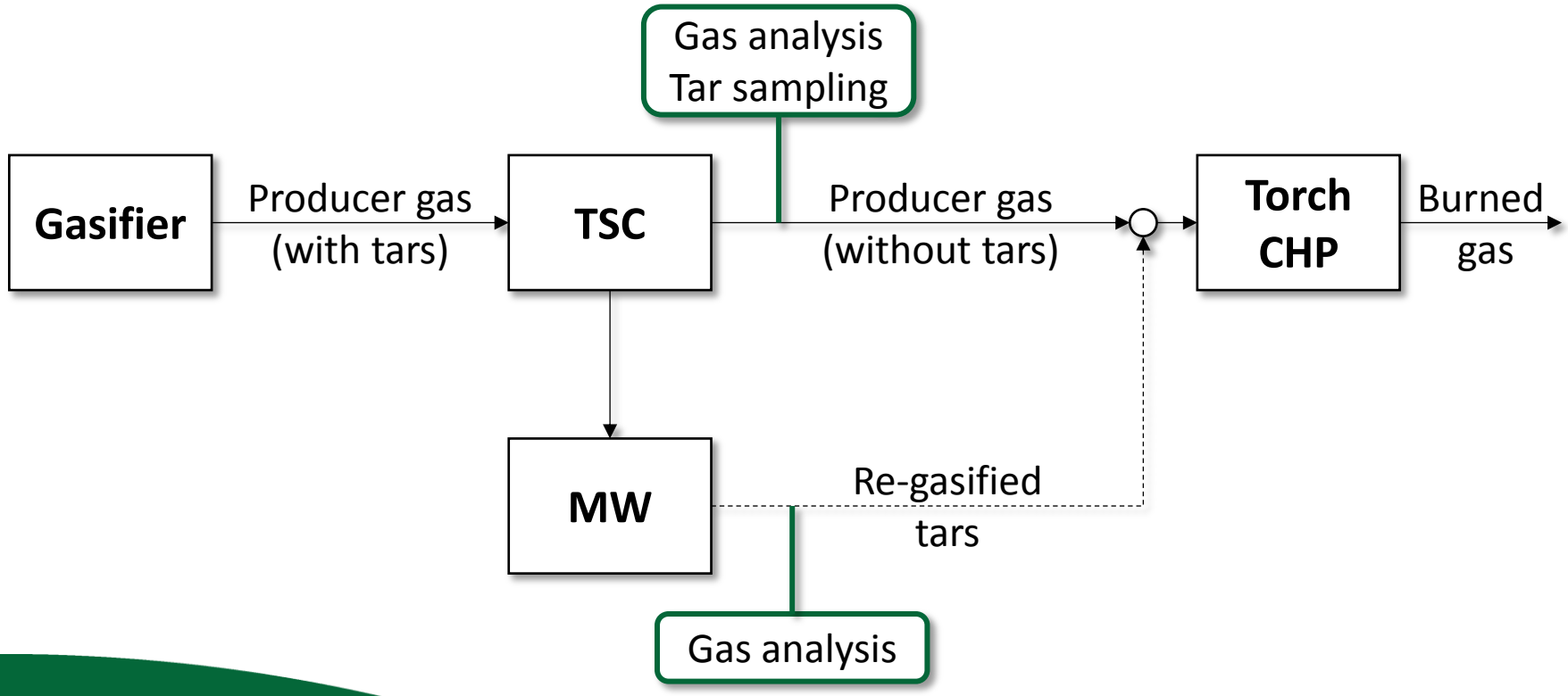
RE-CORD Gasifier

IISc (Bangalore, IN, Prof. Dasappa)

- Downdraft, Open top, Twin fire
- Approx. 70 kg/h dry biomass, 190 kg/h producer gas flow, 70 kWe (gross)
- Water scrubber for gas cleaning



DEVELTAR module's test campaign layout



DEVELTAR module

Feedstock	Gasifier	DEVELTAR	Engine
• wood chips • W max 15% • ash max 5% • low dust	• Downdraft • open top • twin fire	• Heat recovery and tar removal	• Heat and power generation

Tar removal and conversion (DEVELTAR module)

- Collecting tar from producer gas
- Air-blown allothermal tar re-gasification through microwave-assisted heating
- Improving producer gas characteristics
- Dry system

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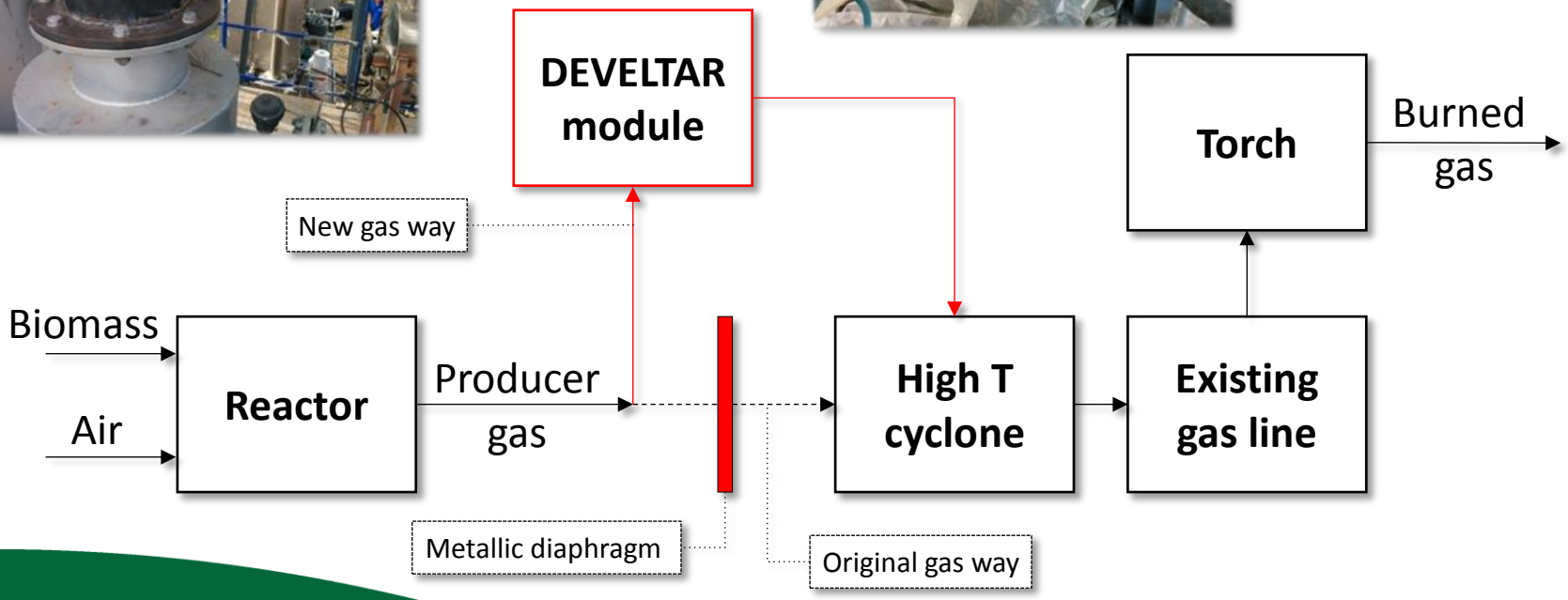
DEVELTAR module's connection layout

In line insertion



DEVELTAR measurement campaign

Tar sampling line

- Measurement of:
  - biomass flow
  - producer gas composition
  - residual tar content after DEVELTAR module
  - gas composition after MW reactor

Tar sampling

- **Tars sampling and collection with impingers**
- **Procedure derived from CEN/TS 15439:2008**
  (main difference = cold gas sampling 40° C)
  - Constant flow sampling (2-6 L/min)
  - Three type of impingers:
    - Empty
    - Isopropanol filled, with frit
    - Isopropanol filled, without frit
  - Two thermostatic baths:
    - + 40° C
    - - 20° C

Producer gas analysis

- NDIR gas analyser

- Instrument protection from tars through impinger traps:
    - Water bubbler impinger (dust removing)
    - Active carbon impinger (heavy organics removing)
    - Calcium chloride impinger (water vapor removing)

Gasifier feedstock

Property			Mixed Wood chips	Reference norms
Ultimate analysis				
C	*ad*[b]	*%wt*	48.1	UNI EN 15104
H	*ad*	*%wt*	5.8	UNI EN 15104
N	*ad*	*%wt*	0.1	UNI EN 15104
O[a]	*ad*	*%wt*	39.3	Calculated
Proximate analysis				
Volatile matter	*ad*	*%wt*	75.2	UNI EN 15148
Umidity	*ad*	*%wt*	6.1	UNI EN 14774-3
Fixed carbon	*ad*	*%wt*	18.0	Calculated
Ash	*ad*	*%wt*	0.8	UNI EN 14775
HHV	*ad*	$MJ \cdot kg^{-1}$	18.4	UNI EN 14918
LHV	*dry*	$MJ \cdot kg^{-1}$	18.2	Calculated

[a]: by difference.

[b]: as determined.

Wood chips

mix of Hardwood and Softwood

Summary of the test campaign

- 24 h total tests
- 4 day test campaign
- 1711 kg of biomass (70kg/h = full load)

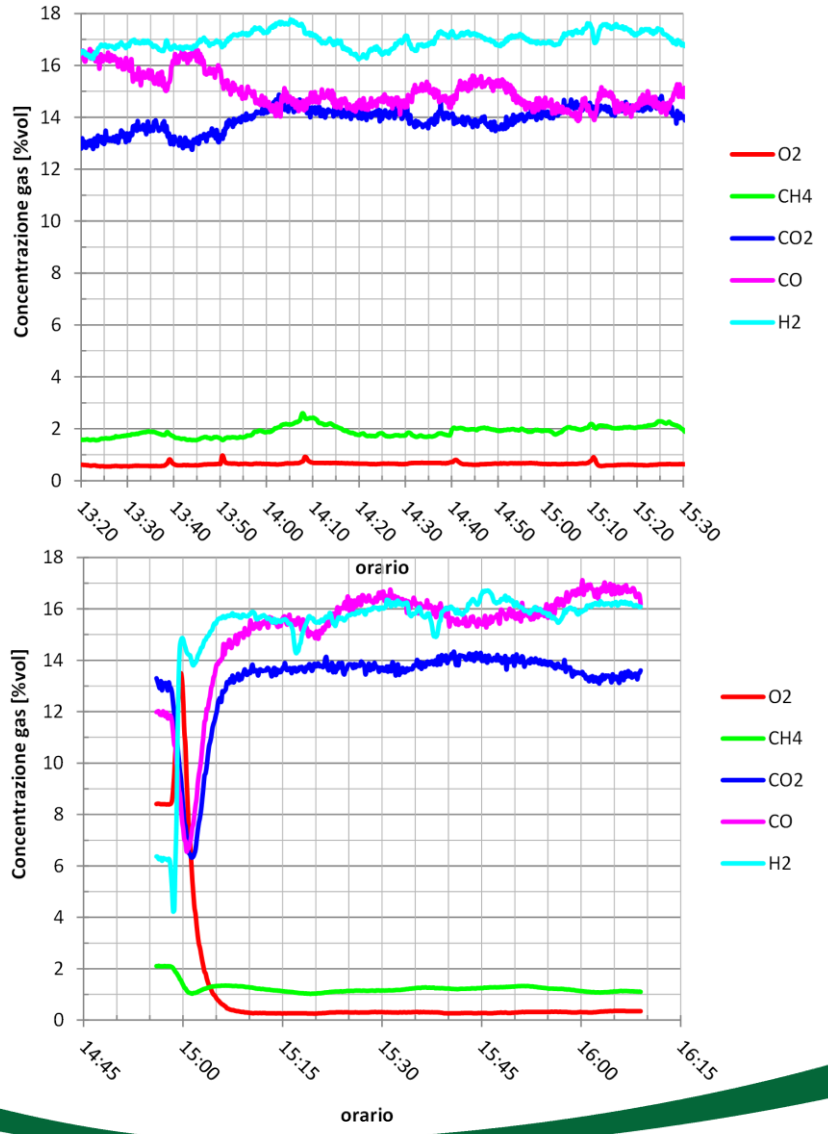
Gas analysis after DEVELTAR module

Species	Average composition and stability [%vol]		
H2	17.00	±	0.32
CO	15.00	±	0.65
CO2	13.93	±	0.45
O2	0.64	±	0.06
CH4+	1.90	±	0.21
N2 (calc.)	51.53		-

3rd day Gas analysis results

Species	Average composition and stability [%vol]		
H2	15.88	±	0.38
CO	15.94	±	0.54
CO2	13.74	±	0.26
O2	0.30	±	0.03
CH4+	1.19	±	0.08
N2 (calc.)	52.96		-

4th day Gas analysis results



Conclusions

- **DEVELTAR module successfully tested over a 24h period without major faults**

- **Tar concentration in cold gas after DEVELTAR module measured**
  - 500 - 534 mg/m^3 of GC-detectable compounds (95% benzene)
  - 482 – 484 mg/m^3 of gravimetric tar (minimal overlap with GC)
  - compared to original tar content in producer gas of 1100 mg/m^3 the DEVELTAR module efficiency is above 55%
  - Comparable with existing small-scale gasification plants

- **Heat recovery from DEVELTAR module as high-temperature air (avg. ≈150° C)**
  - Overall gasification efficiency improved by around 7-8%
  - Through minor system enhancements, efficiency can be further improved up to 10% or more, depending on the actual output temperature of producer gas

Further developments

- Long-term testing of DEVELTAR module will be performed in conjunction with a proprietary pyro-gasification plant owned by Sea Marconi (Lorraine Region – France)
- DEVELTAR module was also designed to operate with this unit
- Process optimizations and minor improvements are expected from this test campaign

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Thanks for your attention!

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