Clean and efficient microCHCP by micro turbine based hybrid systems.

Dr Michel Delanaye, MITIS SA
Aachen, 25/09/24

Fit4Micro

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This is already happening …

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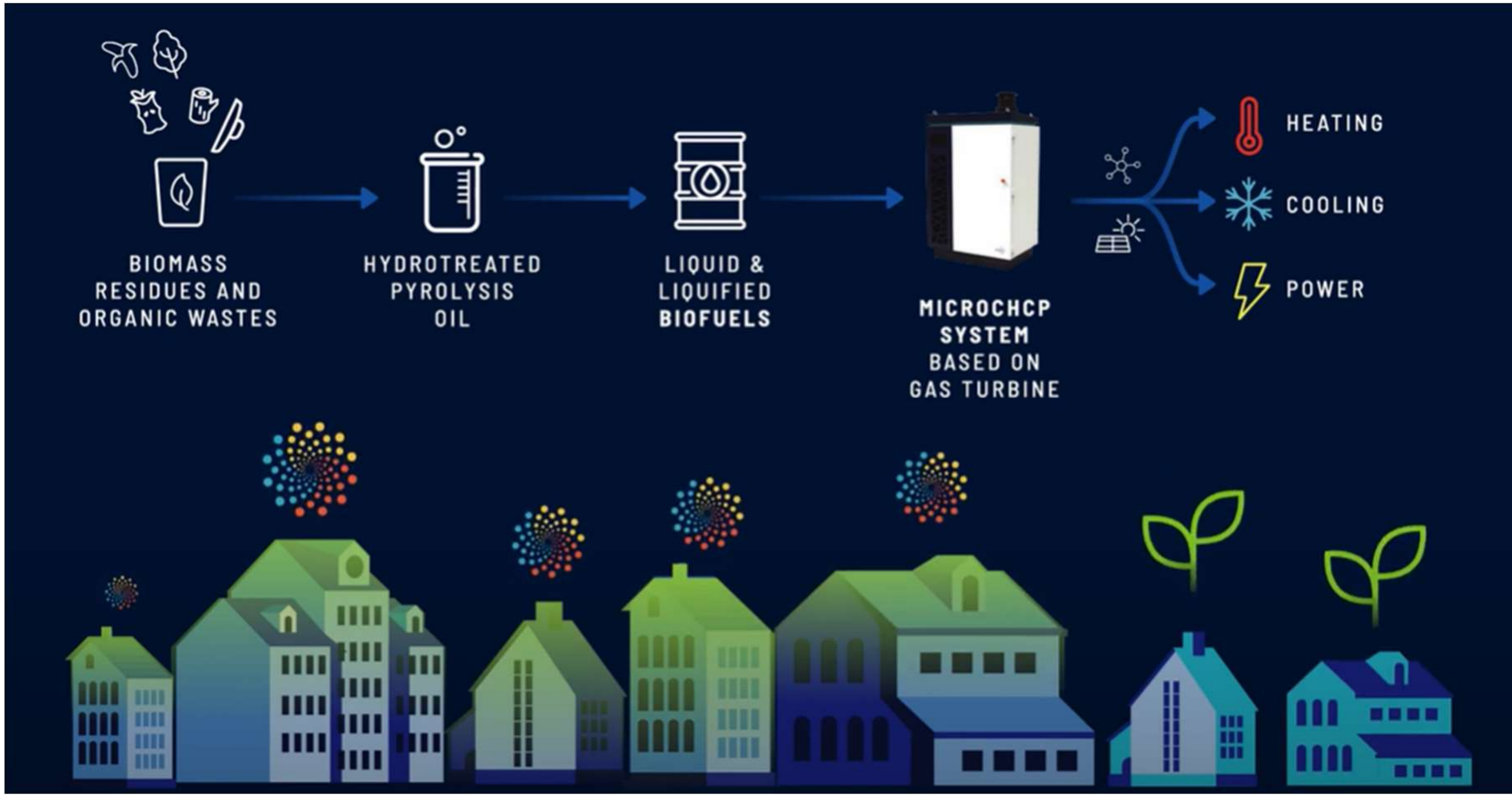
European building sector :

- 40% final energy
- 36% GHG
- 79% Heating, Cooling, DHW
- **75% fossil fuel dependent**
- Renovation rate is low: 12%
- 70-80% existing buildings in Net-Zero 2050

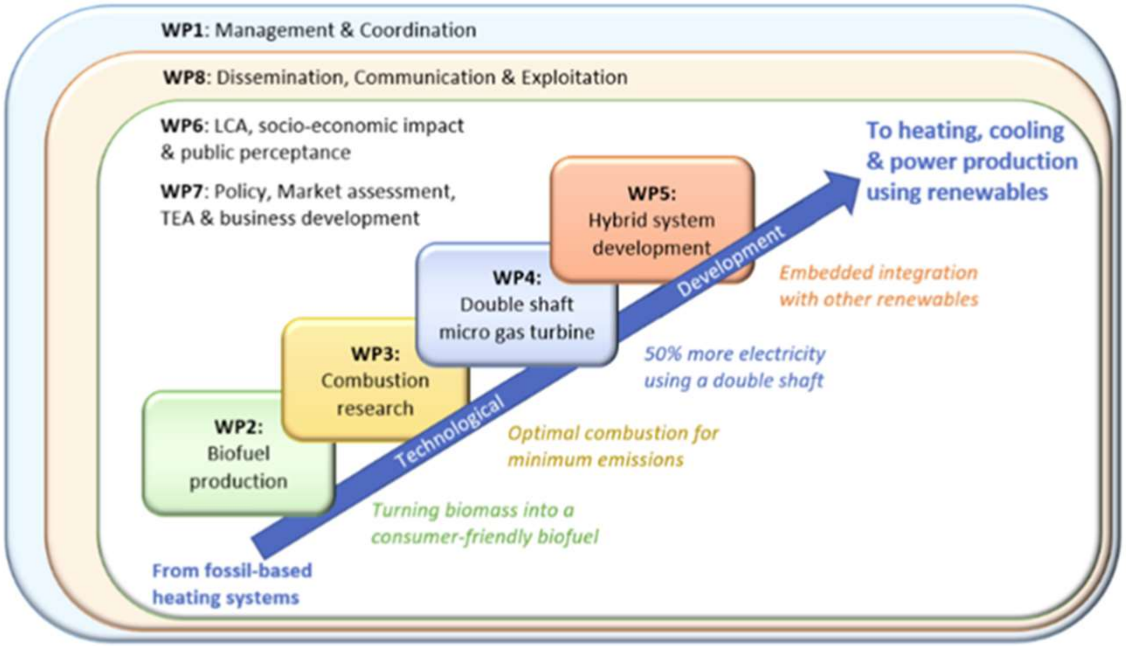
Urgent need to switch off fossil fuels

Switching fossil fuel off means ….
Multiple combined solutions

- Reduce energy consumption :
  - Lower heat demand
  - More efficient heating supply
  - Better distribution networks
- Use new bio fuels:
  - mix of green electricity
  - low-carbon gases
  - biofuels from biomass/biogas
- Increase use of electric or hybrid heat pumps



- RIA 9 partners
- Budget: 5 MEUR
- Duration: 48 Mths
- 1/10/2022



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etaflorence renewableenergies
COGEN EUROPE

Impact

- Increased technical performance, robustness, feasibility and penetration of renewables at “residential/commercial” level
    - Replacing conventional oil-fired boilers by modern high efficiency hybrid microCCHP systems using liquid biofuels
- Increase technology leadership and competitiveness of our European industry
    - MITIS (micro-CHP), BTG (HPBO fuels), Fahrenheit.cool (adsorption chillers)
- Increased production share of renewables at consumer level
    - Decrease HPO price, widening residual waste cost & green H2
- Increased socioeconomic and environmental sustainability of renewables-based energy systems at household level
    - Replacing DHO by HPO
    - Using low emissions flameless combustion
    - Use forest residues and bark for HPBO & green hydrogen to reach 15gCO2eq/MJ biofuel (ok for 80% GHG cut wrt oil based)

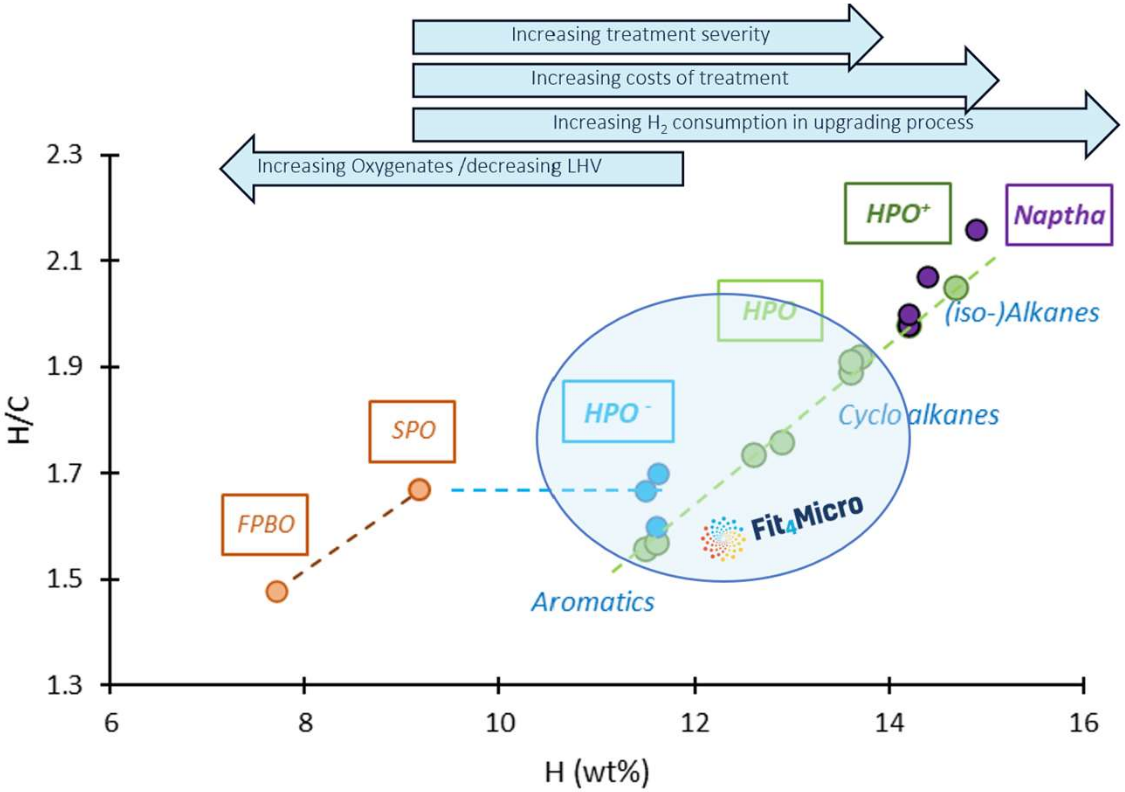
WP2: Biofuel production

SO-4: Production of truly sustainable 2nd generation liquid biofuels suitable to fuel the microCHCP system

- ✓ *Ex: KPI-4a: Production of **HPO with LVH > 40 MJ/kg** from residual biomass materials.*

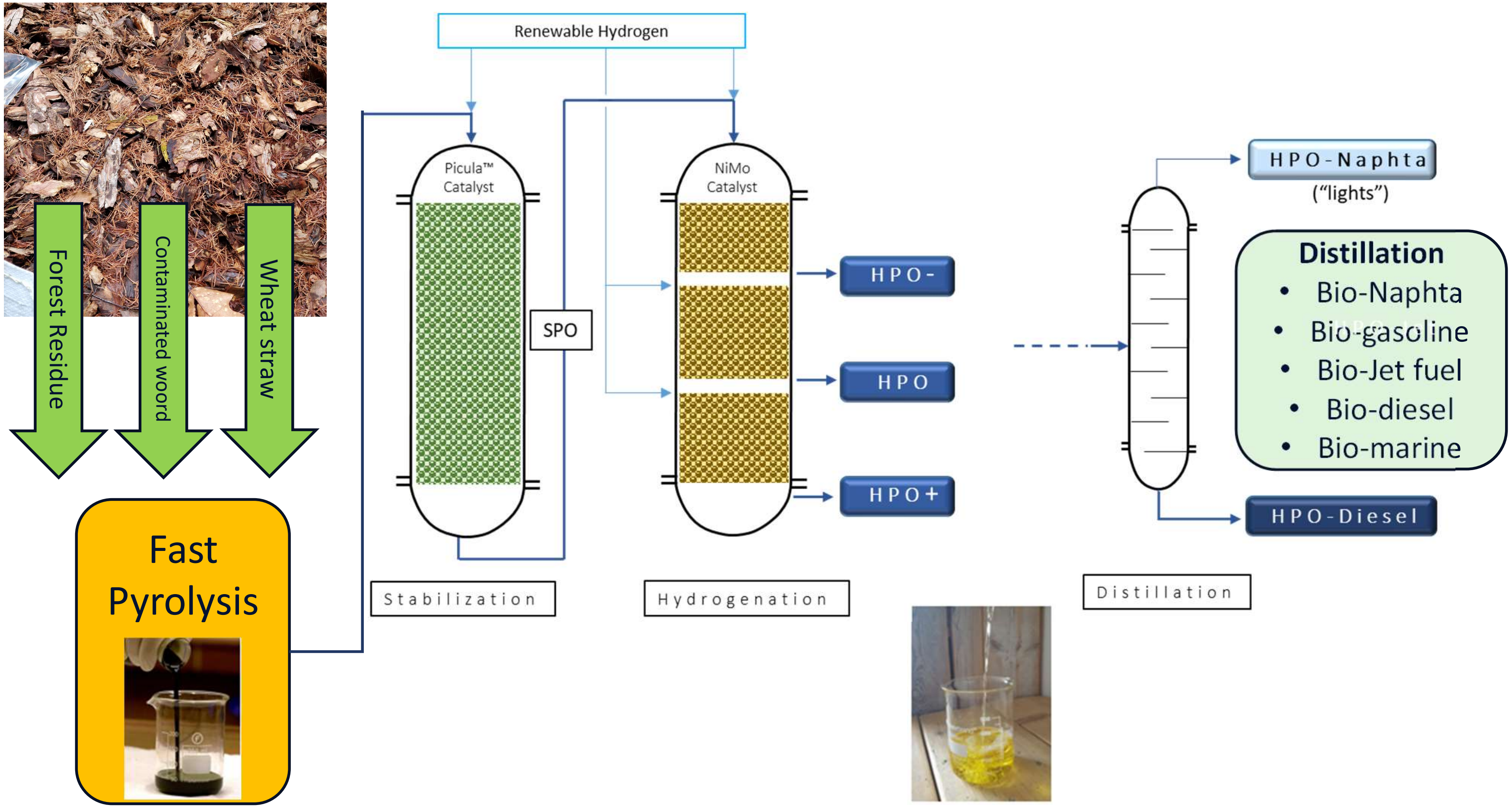
SO-5: Achieving economically competitive operation for the microCHCP system.

- ✓ *KPI-5b: Producing biofuels with cost price < 22 €/GJ **(~0.08 €/KW_h)***



Product qualities as function of hydrogen content

Production HPO (Hydrotreated Pyrolysis Oil)



Production HPO (Hydrotreated Pyrolysis Oil)

- Production of hydrotreated pyrolysis oil (HPO)
  - Reference quality (task 2.1) *current SOTA*
  - Low severity (task 2.2) *lowering fuel costs*
  - From residues (task 2.3) *lowering fuel costs*
  - Nitrogen removal (task 2.4) *limiting emissions*
- Supporting activities
  - Standardization & fuel logistics (task 2.5) - **OWI**
  - Input for value chains (task 2.6)

Removal of inorganic contaminants from the residue-derived FPBO (new microfiltration, adsorption)

	Parameter	Unit	FPBO	HPO'	HPO	HPO'	HPO''	HPO (ref)	HPO-
	BTG-Reference No.			3201	3237	3241	3245	3711	3689
	Water content*	wt.%	25.6	0	0.0055	0.01	0.01		0.5
	Density (T=20 °C)	kg/l	1.18	0.82	0.843	0.83	0.84	0.85	0.88
	Viscosity (20°C)	cSt	14.5 (40)	2.2	2.4	2.9	2.9	2.8	10
	Acid number	mg KOH/g	64	-	0.08	<0.01	<0.01	<0.01	0.66
	Carbonyl content	mmol/g	4.3	0	0	0	0	0	0
	MCRT	wt.%	18	0	0	0	0.1	0	0.5
	Flash point	°C	-	14.3	-6	11	19	5	18
	DCN/ICN	-	-	41.3	35	43.5	48.5		
	Ox. Stability (PetroOxy)	min	-					274	
	Carbon content	wt.%	43.7	85.9	86.1	86.7	86.6	87.8	83.8
	Hydrogen content	wt.%	7.8	14.7	12.8	13.5	13.6	12.5	12.5
KPI < 100 ppm	Nitrogen content	ppm	0.2	0	<5	<5	<5	16	1,120
	Sulfur	ppm		7.6	4.7	1.1	1.2	<5	<5
	Chlorine	ppm		<10				<10	<10
	Oxygen (by difference)	wt.%	48.2	0	1.1	0	0	0	4.4
	Higher Heating Value (calc)	MJ/kg	18.6	48.4	46.2	47.3	47.4	46.3	43.2
	Lower Heating Value (calc)	MJ/kg	16.8	45.2	43.4	44.4	44.5	43.6	40.7
KPI > 40 MJ/kg	Net Heat of combustion (meas.)	MJ/kg	-	43.2	42.1	42.5	42.9	42.2	39.6
	IBP Simdis (D86)	°C	-		105.7	85	114.5		
	FBP	°C	-		398.3	413.2	398.6		

WP3: Biofuel combustion research

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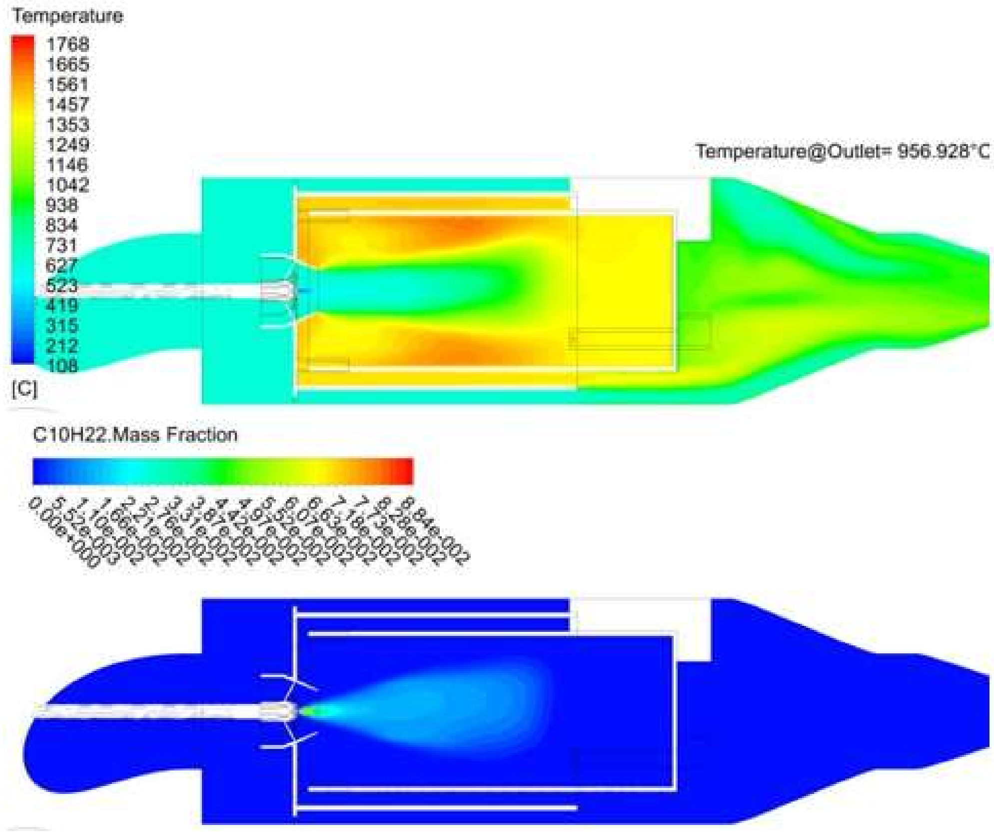
SO-3: Flameless combustion of liquid biofuels with same or higher efficiency than natural gas in the gas turbine cycle.

- ✓ *Ex: KPI-3b: Pollutant emissions to be 50% of the actual norms or lower, with* ***NO_x < 60 mg/kW_h fuel***



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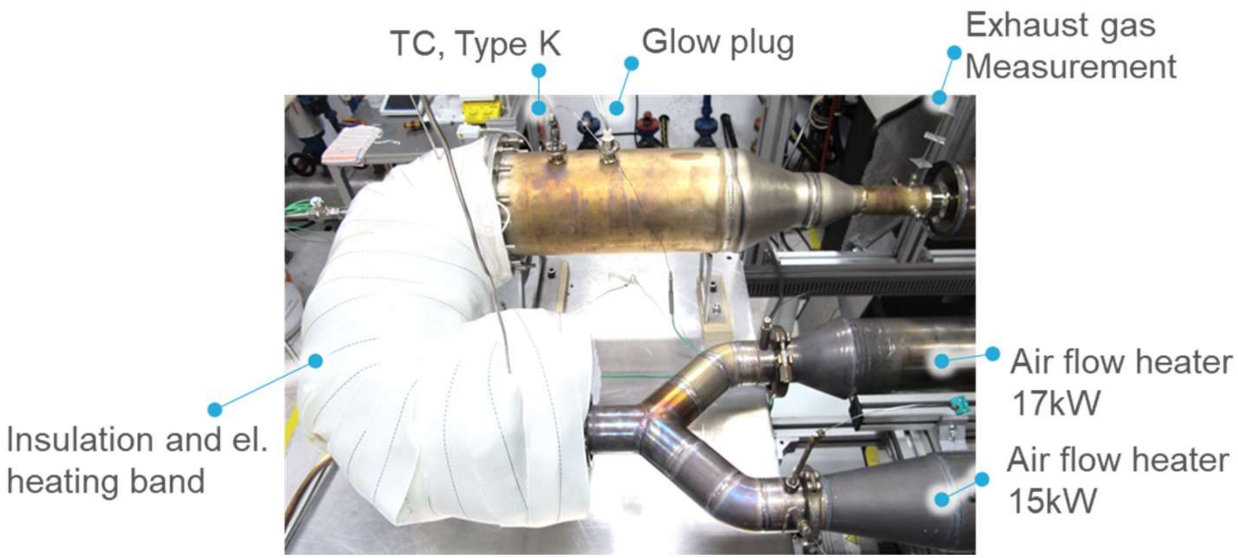
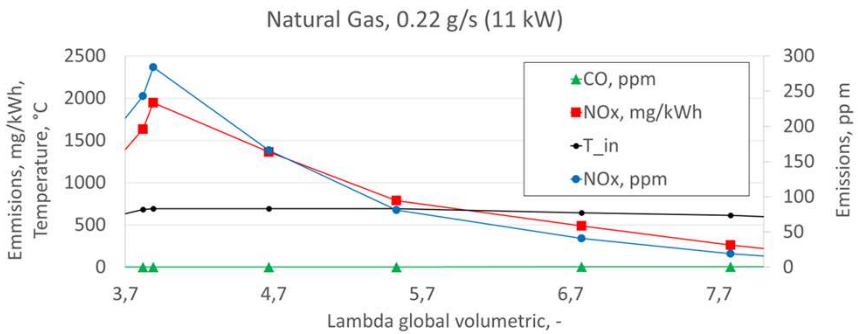
Flameless combustion for liquid fuels

- Upgrading an existing liquid fuel atomizer and developing new flameless burners to use the liquid biofuels for the low- and high-pressure stages of the IRRGT microturbine
- Conducting a detailed experimental test campaign to evaluate the performance of the new combustors
- Optimization of flameless burner technology in terms of stability, operating range and flue gas emissions

Top view of CC and air-heaters (pre-insulation)

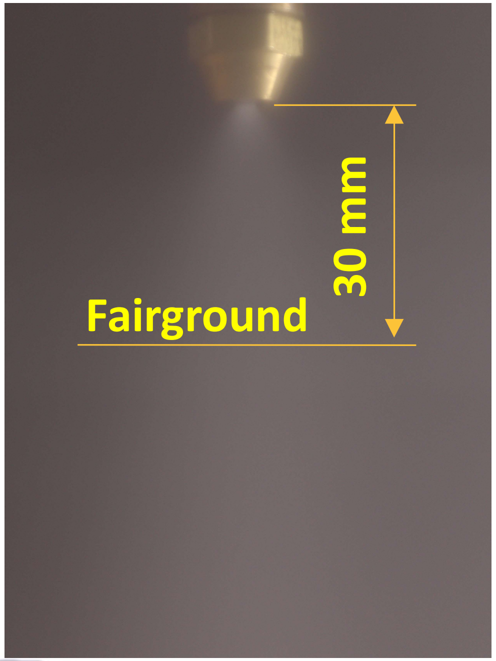


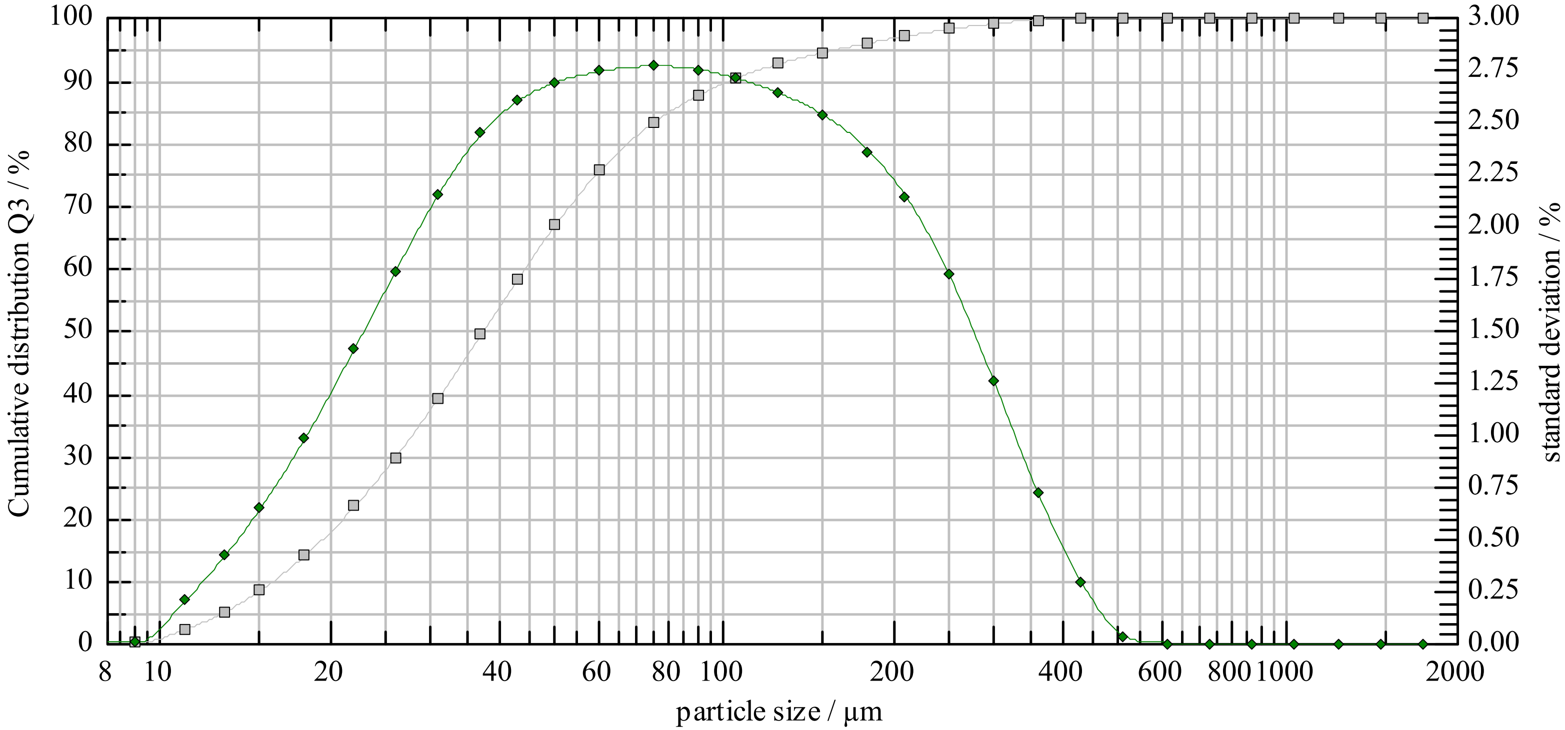


Atomization, spray quality, ULB measurements

Determination of droplet size, DHO

Nozzle: Delavan SNA, 5 kg/h, atom. air: 20 slm, saturated at 15 slm

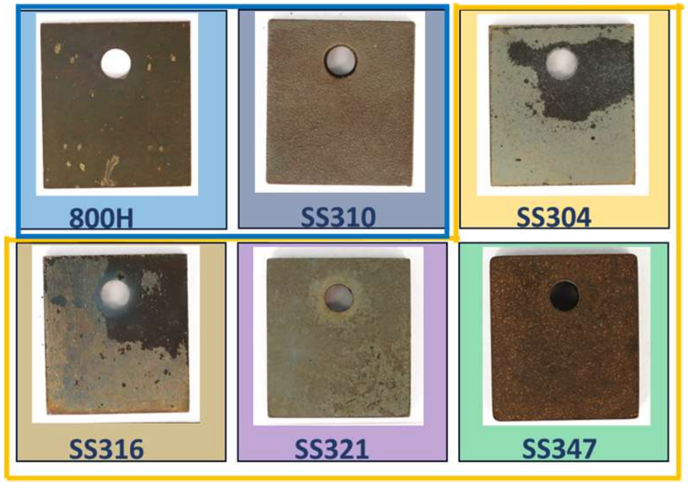




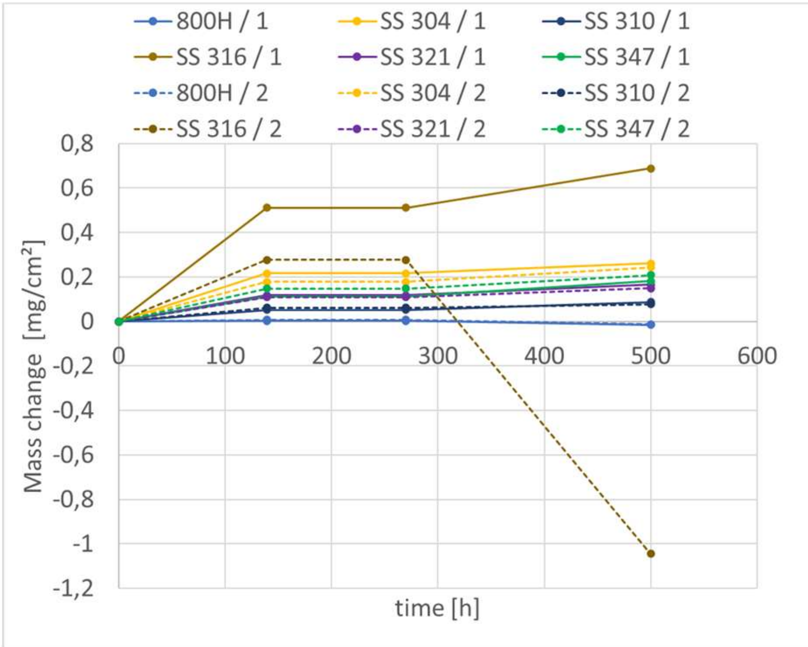
x_{10} = 15.84 µm x_{50} = 37.48 µm x_{90} = 107.95 µm SMD = 31.22 µm

High-temperature materials‘ assessment

- Determination of long-term stable, high-temperature, oxidation-resistant materials for the combustion chamber and turbine wheels that meet the requirements



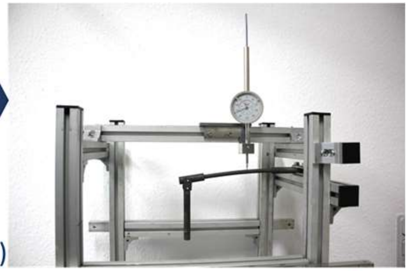
Photographs of 18x20 mm^2 alloy samples after 270 h



Furnace

100h

Bending measurement at RT (discontinuous)



WP4: Humidifed Intercooled Regenerative Reheat Gas Turbine Cycle

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SO-1: Validation of the hybrid microCHCP (relevant environment)

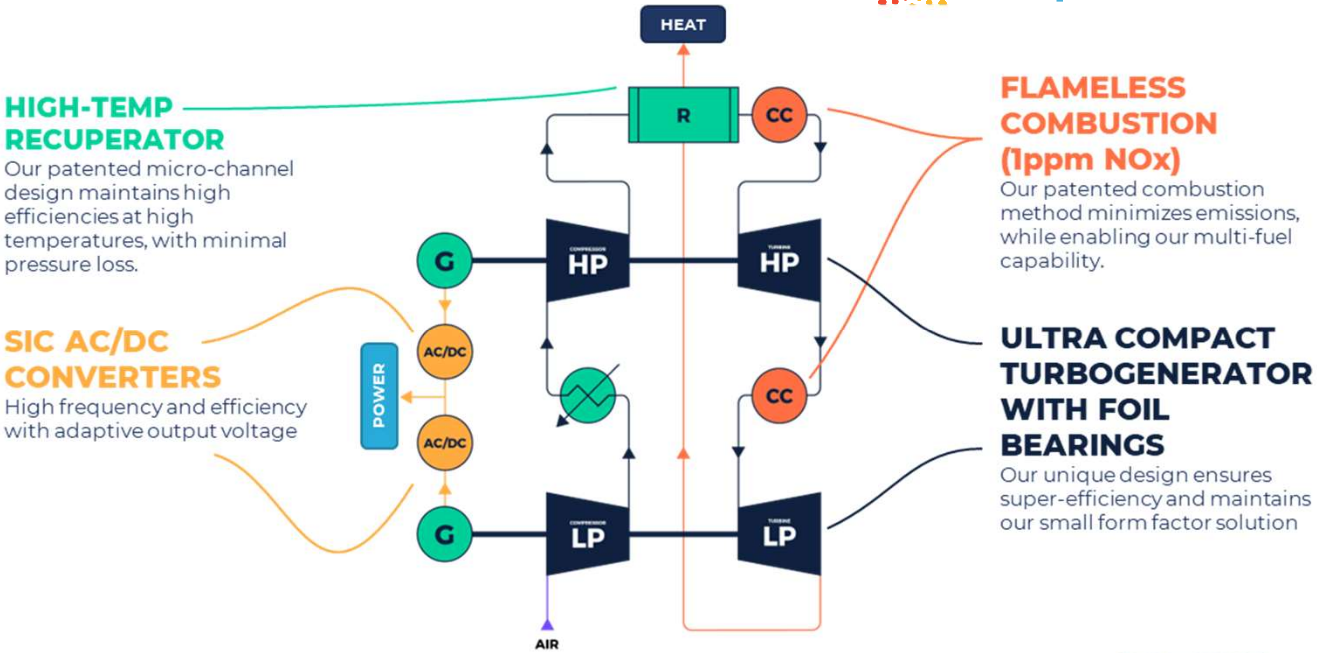
- ✓ *Ex: KPI-2a: Achieving at least **40%** electrical efficiency.*

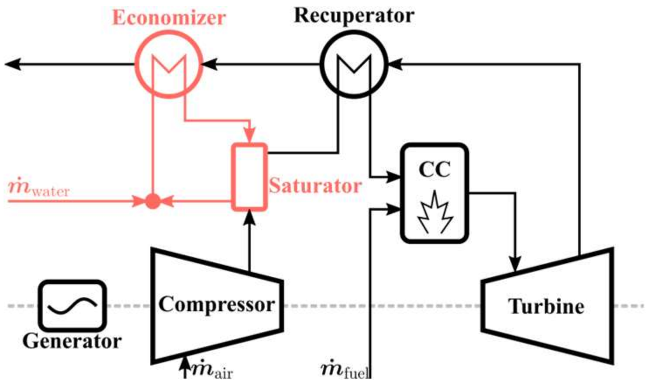
SO-3: Flameless combustion of liquid biofuels with same or higher efficiency than natural gas in the gas turbine cycle.

- ✓ *Ex: KPI-3b: Pollutant emissions to be 50% of the actual norms or lower, with **NO_x < 60 mg/kW_h fuel***

SO-5: Achieving economically competitive operation for the microCHCP system.

- ✓ *KPI-5a: Investment costs for the microCHCP < 2500/**500 €/KW_e** for a 20 KW_e system, achieving pay-back times < 10 years. (*)*





	Steam injection	Water injection	saturator
	$\Delta\eta/\eta_{ref}$	$\Delta\eta/\eta_{ref}$	$\Delta\eta/\eta_{ref}$
µ10	+10.9%	+9.4%	+12.9%
µ20	+13.2%	+15.0%	+22.9%

mHat cycle

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LP stage – micro-10

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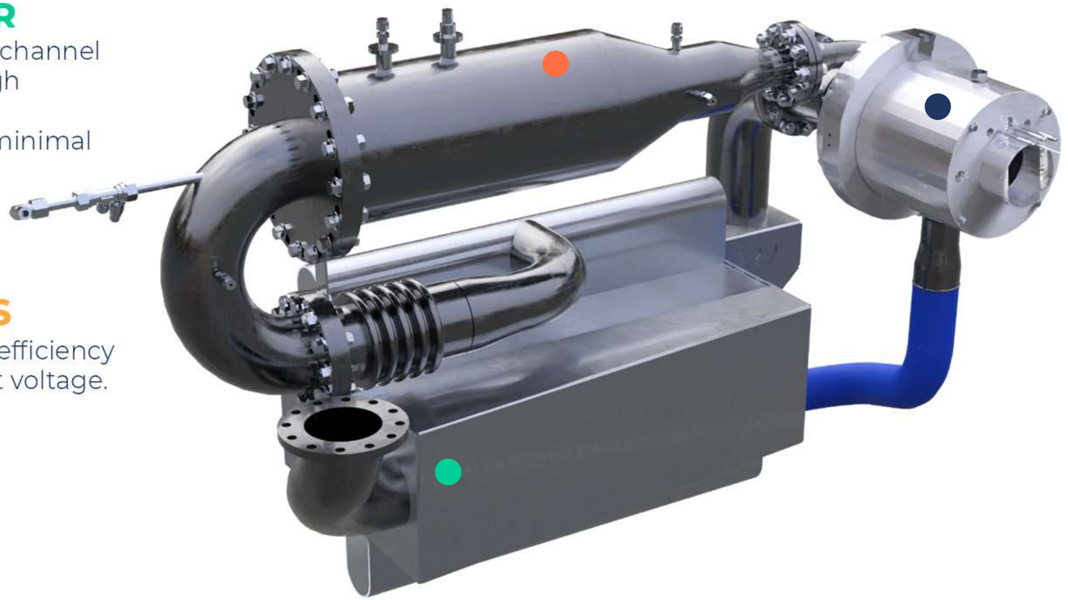
SOLARIMPULSE EFFICIENT SOLUTION AUGUST 2020

HIGH-TEMP RECUPERATOR

Our patented micro-channel design maintains high efficiencies at high temperatures, with minimal pressure loss.

SiC AC/DC CONVERTERS

High frequency and efficiency with adaptive output voltage.



FLAMELESS COMBUSTION (1ppm NOx)

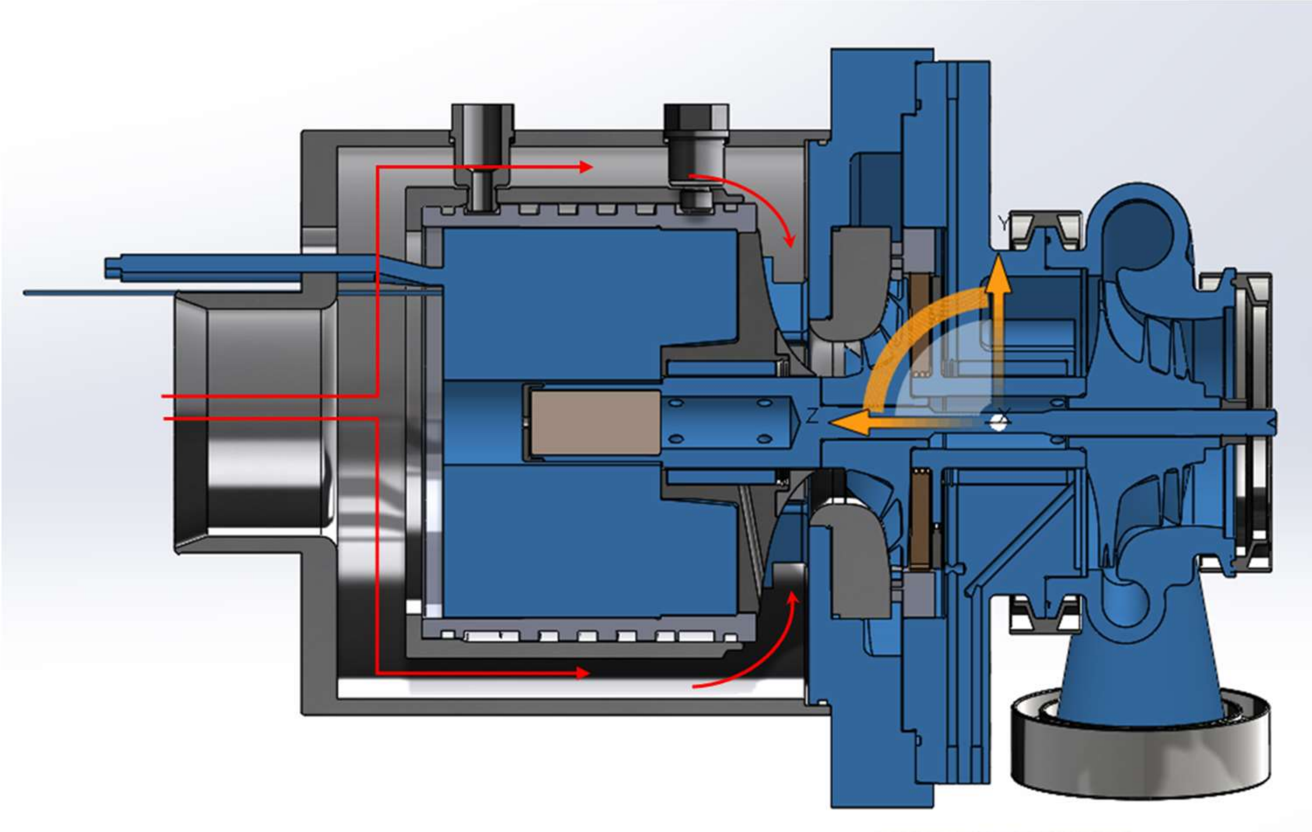
Our patented combustion method minimizes emissions, while enabling our multi-fuel capability.

OIL-FREE ULTRA COMPACT TURBOGENERATOR WITH AIR FOIL BEARINGS

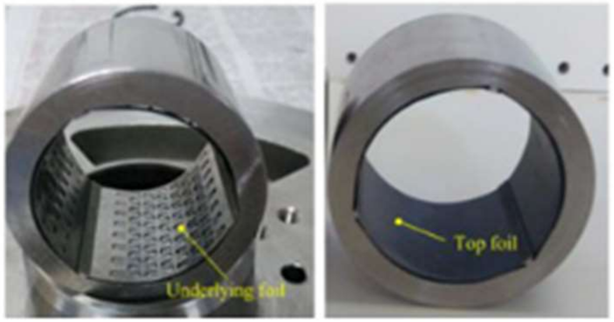
Our unique design ensures super-efficiency and maintains our small form fac

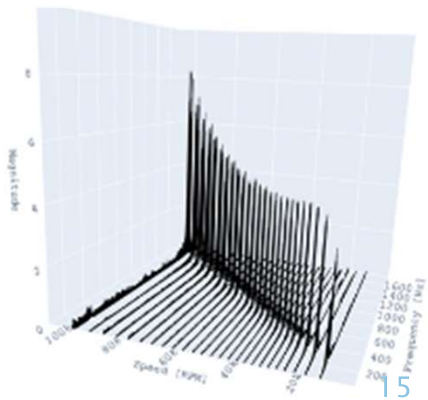
Protected through 12 patents and patent applications in EU, US, CN.

Turbo LP V50 : patented compact design



Air Foil Bearing Development





Saturation tower design for micro-20 mHAT (28 kW)

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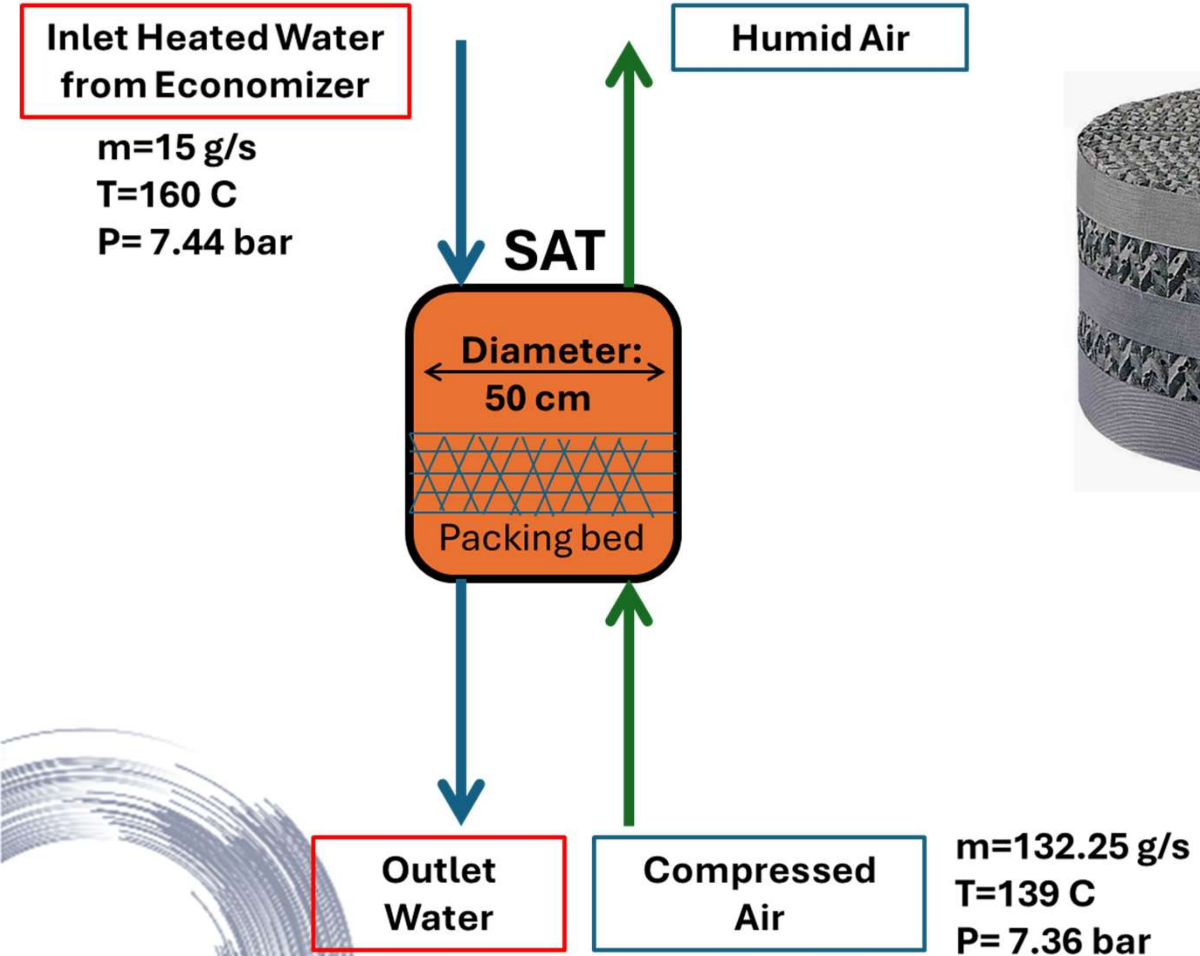

Packing type: CY
Material: Standard
Dimension: Standard

Height: 10 cm-100 cm
Diameter: 50 cm

WP5: Integrated hybrid trigeneration system development & evaluation

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- SO-6: Demonstrate and validate the sustainability of the HPO-fuelled microCHCP system by detailed LCA assessment.

✓ *KPI-6a: Primary energy savings > **100%** through improved fuel utilization efficiency.*

✓ *KPI-6b: GHG emission savings > **80%** compared to using domestic heating oil fuelled CHP system with similar H:P ratio (55% heat, 35% electric).*

✓ *KPI-6c: Reduction of GHG emissions for cooling by **100%** compared to compression cooling by using water as refrigerant.*

- Design at least 2 hybrid systems and variants for different use cases
- Develop robust and efficient control strategies
- Test a system demonstrator for two most promising use cases in a laboratory environment
- Optimize and evaluate systems based on system simulations

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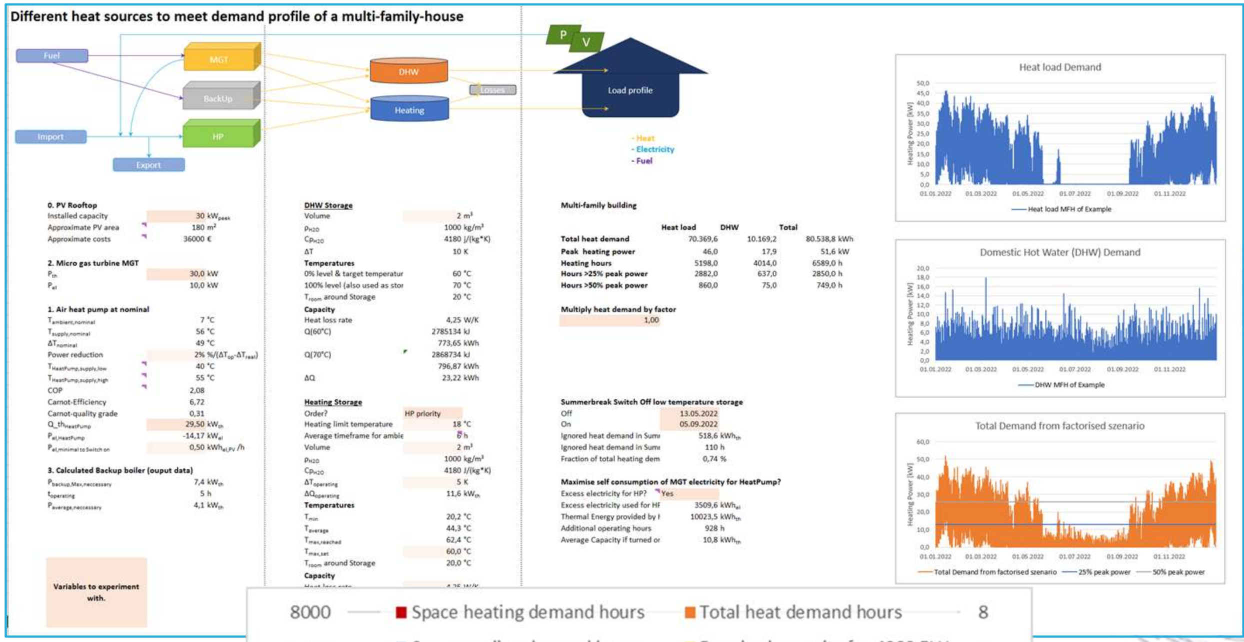
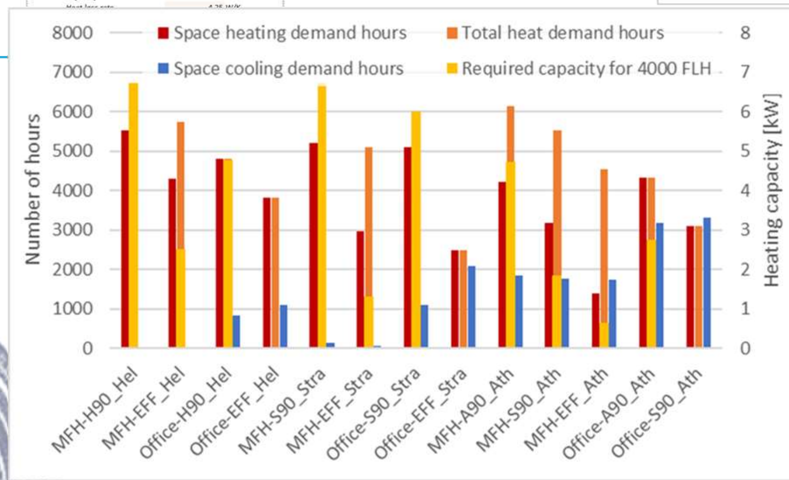
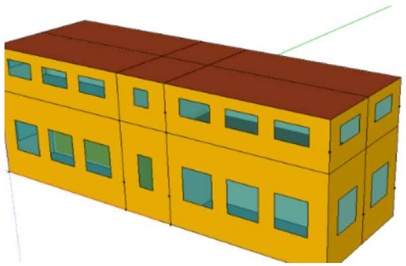
Definition of use cases and system design

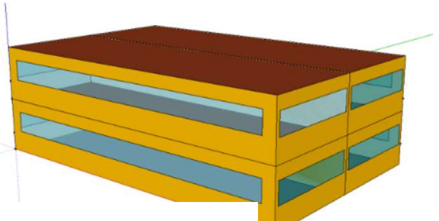
- Multi-family + Office buildings (simulated in Trnsys)
  - 3 locations: Athens, Strasbourg, Helsinki
  - 2 building standards typical 90s building standard of respective location and highly efficient building standard
- Health and lodging buildings (simulated in synPro)
  - 1 location: Potsdam (Germany)
  - 3 average buildings: before 1979, between 1980 and 2009, after 2009







Multi-family home (MFH)



Office Building

Heating and cooling case testing

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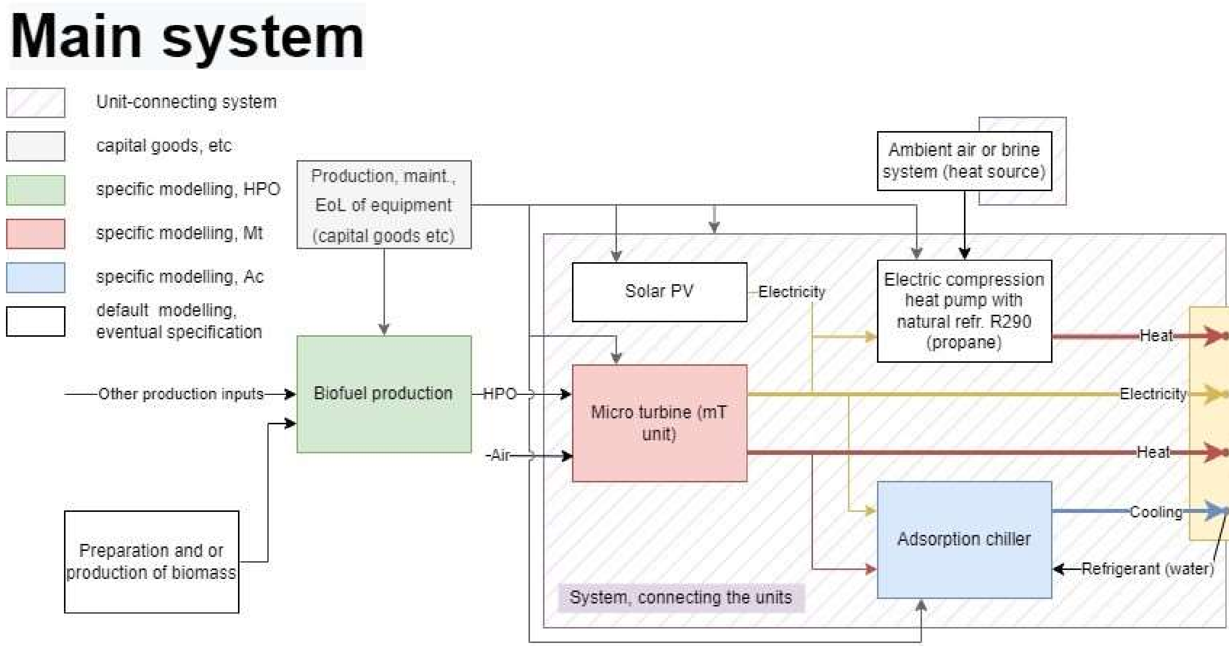
Heat pumps to be integrated with the micro gas turbine are tested..

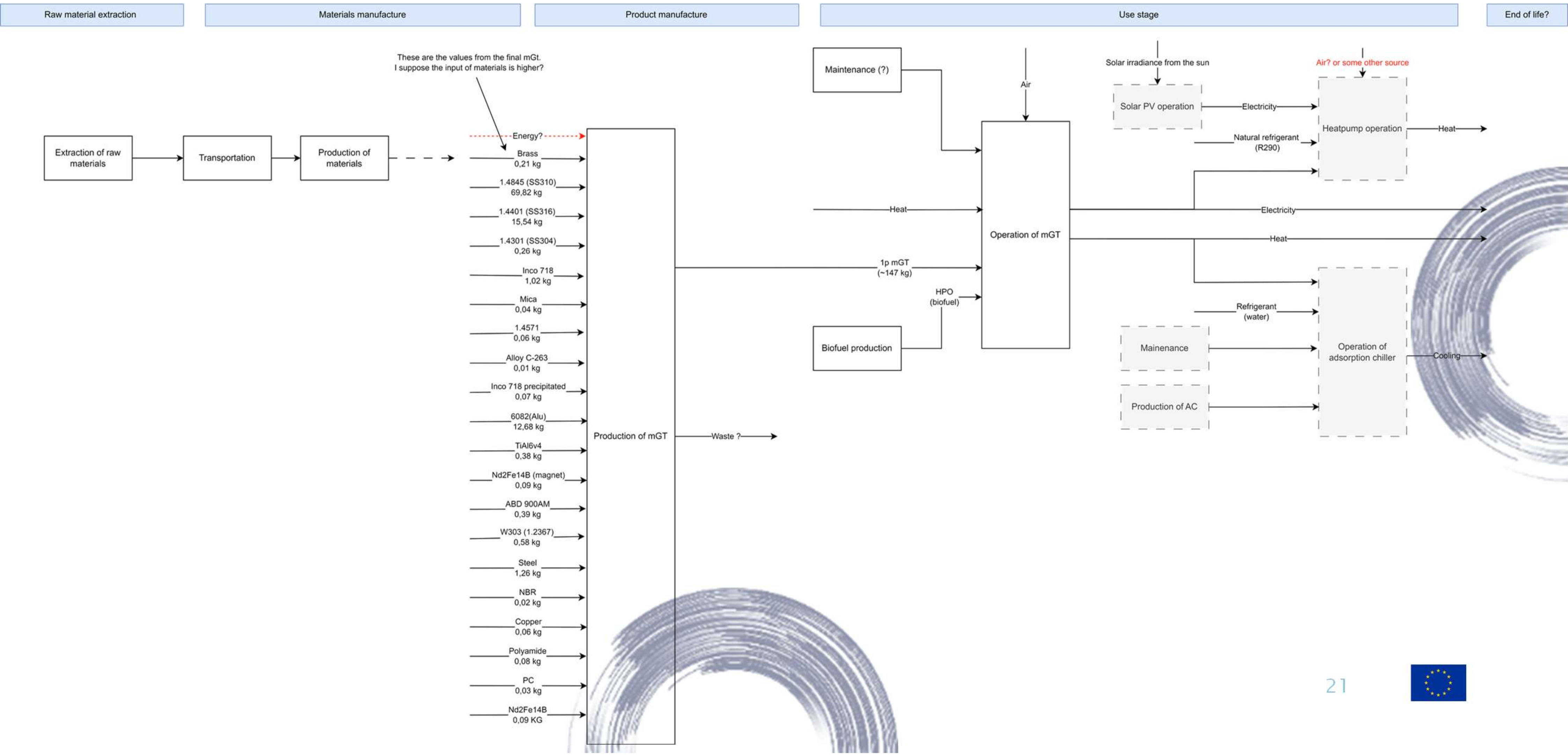
- Silicagel adsorption module from Fahrenheit
- R290 Heat Pump from MITIS

WP6: LCA, socio-economic impact, public acceptance

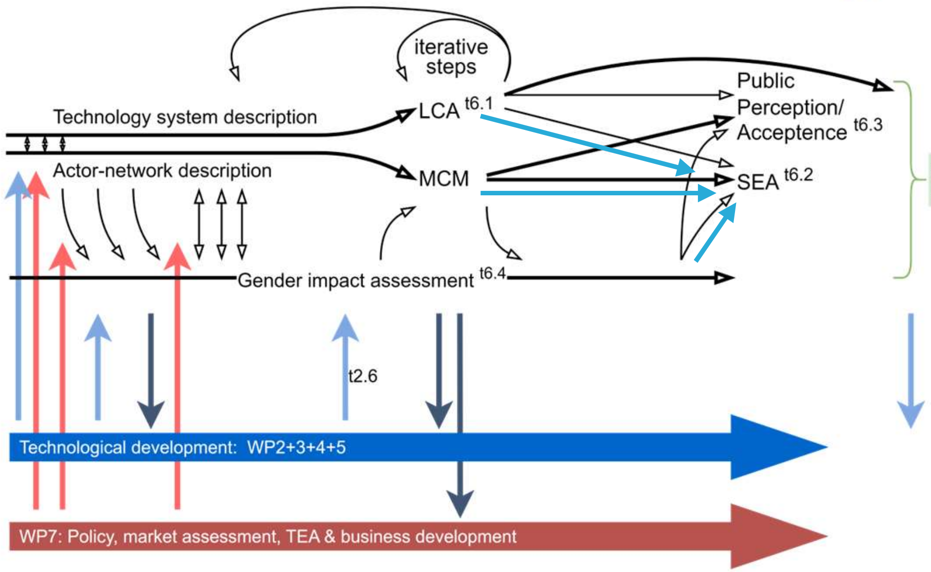
1. To determine the environmental sustainability performance of the microCHCP system fueled with HPO
2. To investigate the socio-economic impact of the Fit4Micro technology on the society.
3. To determine the public acceptance of the mGT based microCHCP system.
4. To perform a gender impact assessment for the microCHCP system.



Inventory: Microturbine system

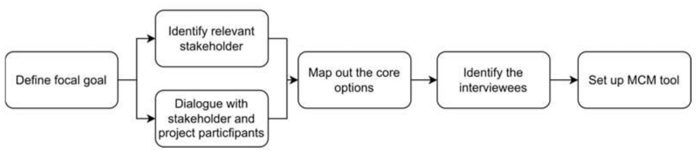


Socio-economic analysis

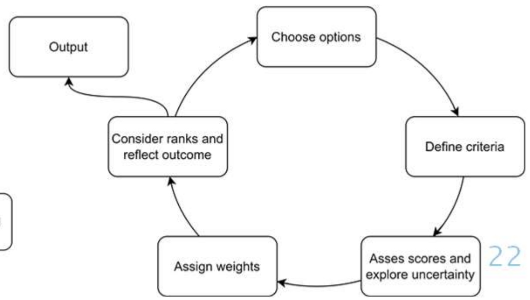


- MCM (multi criteria mapping) analysis is initiated
- LCA based externality cost analysis to be made
- Gender based analysis finished

Preparing for MCM



MCM interview



WP7: Policy, market assessment

1. Monitored and assessed key policy files that have the potential to impact the uptake of micro-CHP and hybrid heating solutions.
2. Market assessment
3. Technico-economical analysis
4. Business development

Opportunities

- Increased focus on energy efficiency, especially for renewable gases
- Need to accelerate the decarbonisation of buildings
- Moving away from the combustion of fossil fuels in buildings (incl. natural gas)
- RES gases/bioenergy of strategic importance to displace Russian gas
- Electrification requires scaling up the deployment of flexible generation
- Micro-CHP & hybrids recognised as green investments

Threats

- Prioritising electrification and district heating for buildings
- Prioritising gas, even renewable gases, for hard-to-decarbonise industrial customers (vs. space heating/electricity)
- Promoting "non-fossil“/non-gas flexibility options, namely demand-side response and storage

High-level findings

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- Overall, the micro-CHP sector is stagnant, given competition and support coming from heat pumps
- Renewable CHP is expected to grow. Yet uncertainty remains around the availability, affordability and support for renewable fuels
- Low awareness across EU markets about off-grid applications/bioliquids
- Countries with potential for growth (Off-grid/bioliquids): Czech Republic, France, Germany, Netherlands, Poland, Turkey

Segment	Current trend*	Outlook*	Key markets
RES	50%	70%	AT, CZ, DK, DE, NL, PL, ES, TR
Off grid micro-CHP, Domestic, Small commercial	78%	80%	CZ, FR, TR
Bioliquids	45%	55%	DE, PL, NL, TR

WP8: Where to find us ?

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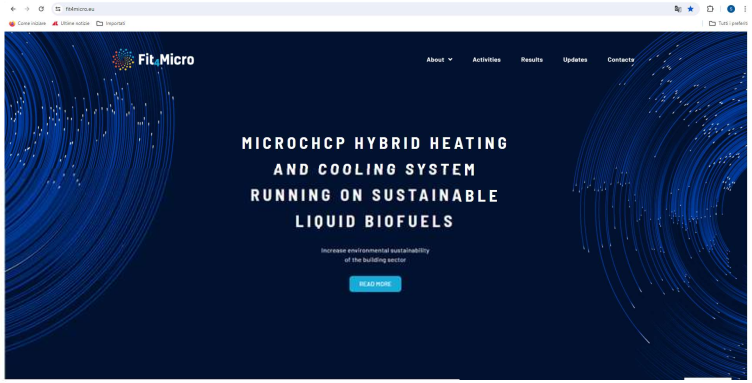

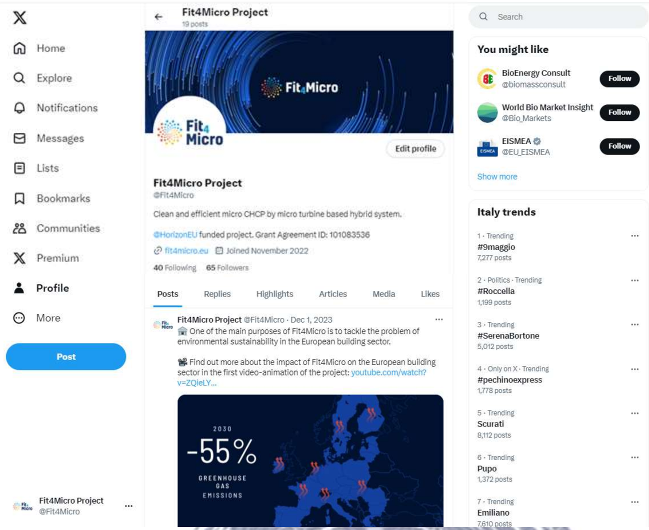

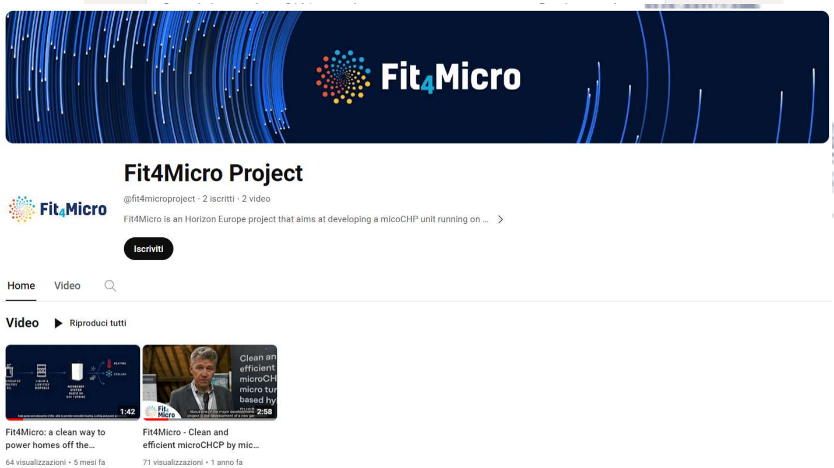

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