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PUMP HEAT

Performance Untapped Modulation for Power and Heat via Energy Accumulation Technologies

PUMP-HEAT project

COMBINED CYCLE PERFORMANCE GAIN THROUGH INTAKE CONDITIONING

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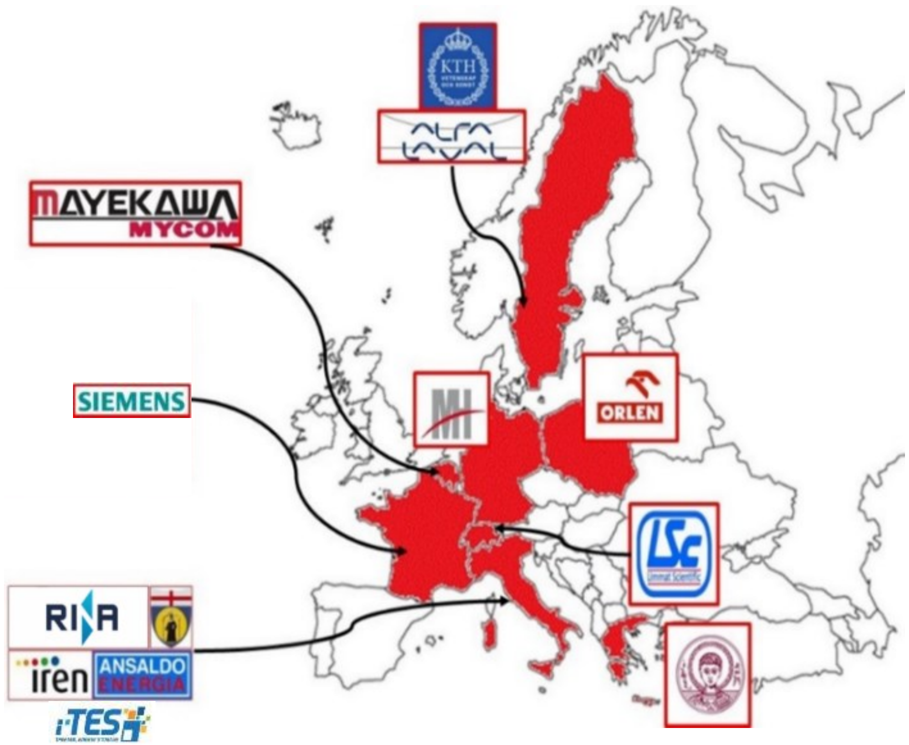
PUMP-HEAT Consortium



PUMP-HEAT

an Industry-driven Consortium

This guarantees:

- Industrial and Market interest to project outcomes
- Involvment of wide range of stakeholders
- Strong commitment to PHCC realization
- A common «project business» to be pursued made by «different actors' business»
- Ability to overcome contingencies

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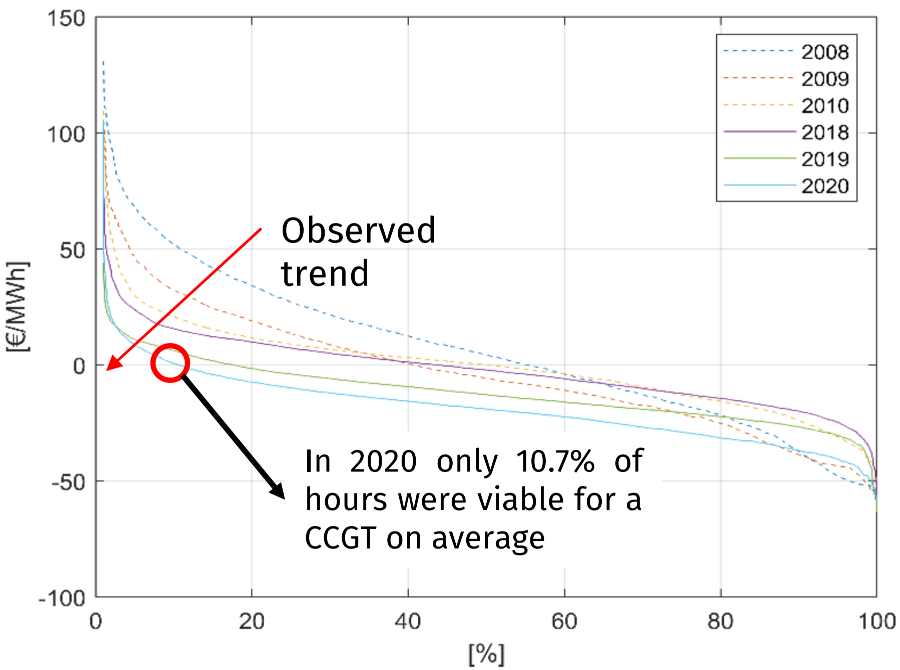
Power Oriented CCGT Market Viability Layout - Italy as a Case Study

Clean Spark Spread duration curve



$$CSS = pr_{el} - COE = pr_{el} - \left(\frac{pr_{gas} + e \cdot pr_{CO_2}}{\eta_{CCGT}} + O\&M_{var} \right)$$

Clean Spark Spread is key indicator to assess the market viability, it accounts:

- The cost of fuel
- The cost emission allowance
- The power plan efficiency
- The variable O&M costs

Exploiting other markets became more and more important

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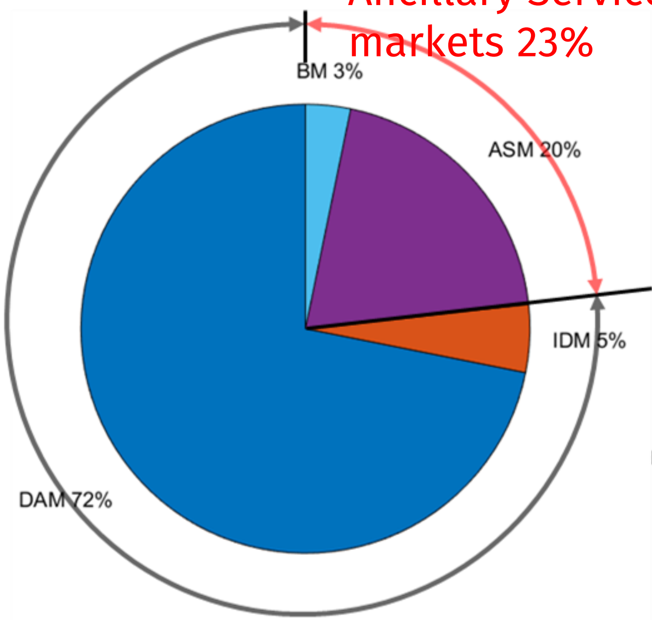
Power Oriented CCGT ecomic results - Italy as a Case Study

Revenues
(not including costs)

Energy-only markets 77%

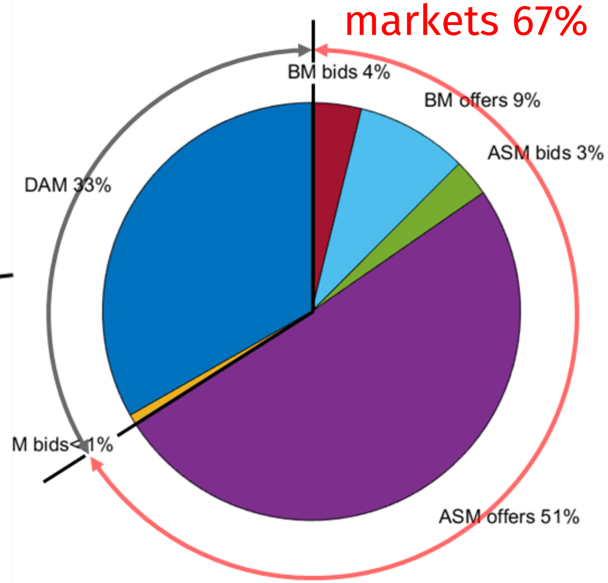
Ancillary Services markets 23%



Net Profits

Energy-only markets 33%

Ancillary Services markets 67%



Ancillary Services Market (ASM) Is e relevant source of profits for modern CCGTs

Vannoni, A, Garcia, JA, Mantilla, W, Guedez, R, & Sorce, A. "Ancillary Services Potential for Flexible Combined Cycles." *Proceedings of the ASME Turbo Expo 2021*. Virtual, Online. June 7–11, 2021. V004T06A015. ASME. https://doi.org/10.1115/GT2021-59587

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PUMP-HEAT in a nutshell

THE NEED: Gas Turbine (GT) OEMs and energy utilities look for power flexibility especially for CHP Combined Cycles (CC), constrained by thermal demand, hence providing limited grid services.

THE IDEA: PUMP-HEAT proposes an innovative concept based on the coupling of CCs with a fast-cycling highly efficient **Heat Pump** (HP) equipped with **Thermal Energy Storage** (TES).

The integrated system features an **advanced control** concept for smart scheduling:

- the HP modulates power to cope with the CC reserve market constraints;
  - the *high temperature heat* can be exploited in the district heating network (DHN);
  - the *low temperature cooling* can be used for gas turbine inlet cooling.

The CC integration with a HP and a cold/hot TES brings to a reduction of the Minimum Environmental Load (MEL) and to an increase in power ramp rates, while enabling power augmentation at full load and increasing electrical grid resilience and flexibility.

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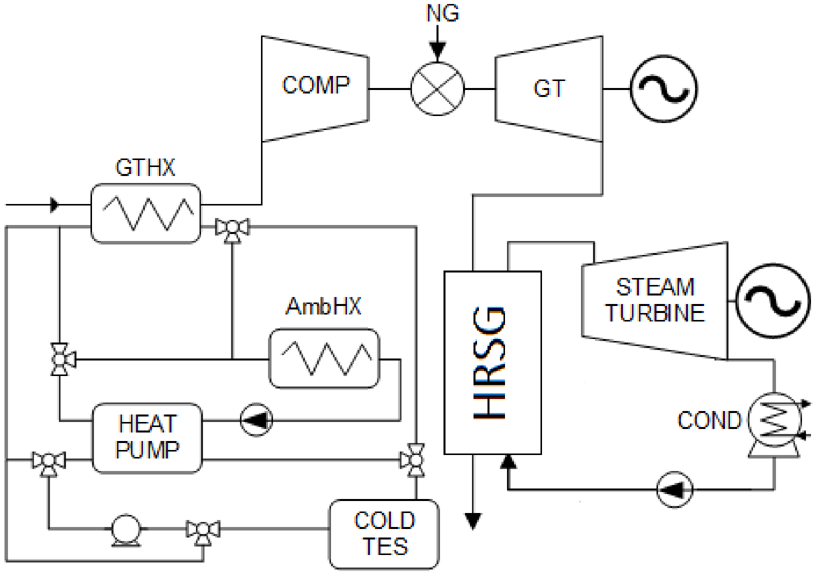
Power Oriented CC Layout



- ✓ The proposed solution is an Integrated Inlet Conditioning system, IIC, featuring an Heat Pump and a Cold Thermal Energy Storage;
- ✓ The aim is to exploit the Power consumption of the HP as a Smart Load during low (or negative) electrical price periods, charging the Cold TES.
- ✓ TES is discharged in electricity peak price period to increase power output
- ✓ This is an OEM independent solution which apply to both, new and refitted power assets.

The Integrated Inlet Conditioning system aim to modulate the GT intake temperature to:

1. Peak production increase, decreasing the intake temperature;
2. Minimum Environmental Load Decrease, by increasing the intake temperature;
3. Off-Design Efficiency Enhancement, by increasing intake temperature

Turning intake temperature from a constraint to a control parameter!

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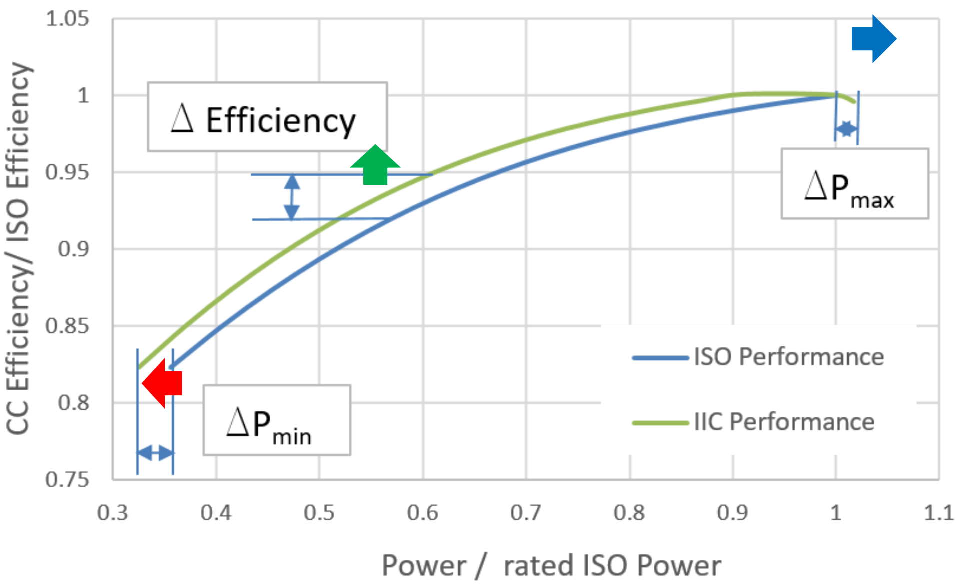
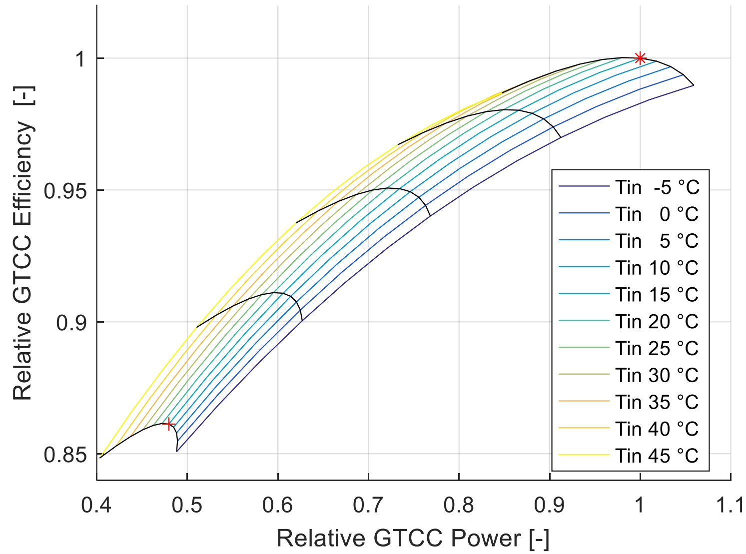
Flexibility and efficiency with Power Oriented CCGT Pump Heat Layout

1. Peak production increase (ΔPmax), decreasing the intake temperature;
2. Minimum Environmental Load Decrease, by increasing the intake temperature;
3. Off-Design Efficiency Enhancement, by increasing intake temperature





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Preliminary Thermo-economic results for Power Oriented (PO) layout

- ✓ **PO PHCC** was modeled in details to assess flex enhancement:
- ✓ Peak production increase an Increase of the Pmax of +14% was assessed using the **cold TES** , up to +12% adopting direct cooling with **HP** with a sligth negative effect over the efficiency (-1.2 pt%)
- ✓ Reduction of the **Minimum Environmental Load** (Pmin -17%), with a reduction of just 1.5 pt% of efficiency. Reduction of fuel consumption help increase up to 15% the Turn Down operating hours. Reducing Start-up and Shut-Down number.
- ✓ **Enhancement of annual average efficiency** by inlet heating of ca 2%

Mantilla, W, García, J, Guédez, R, & Sorce, A. "Short-Term Optimization of a Combined Cycle Power Plant Integrated With an Inlet Air Conditioning Unit." *Proceedings of the ASME Turbo Expo 2020*. Virtual, Online. September 21–25, 2020. https://doi.org/10.1115/GT2020-15162
Sorce, A, Giugno, A, Marino, D, Piola, S, & Guedez, R. "Analysis of a Combined Cycle Exploiting Inlet Conditioning Technologies for Power Modulation." *Proceedings of the ASME Turbo Expo 2019*. Phoenix, Arizona, USA. June 17–21, 2019. V003T06A022. ASME. https://doi.org/10.1115/GT2019-91541

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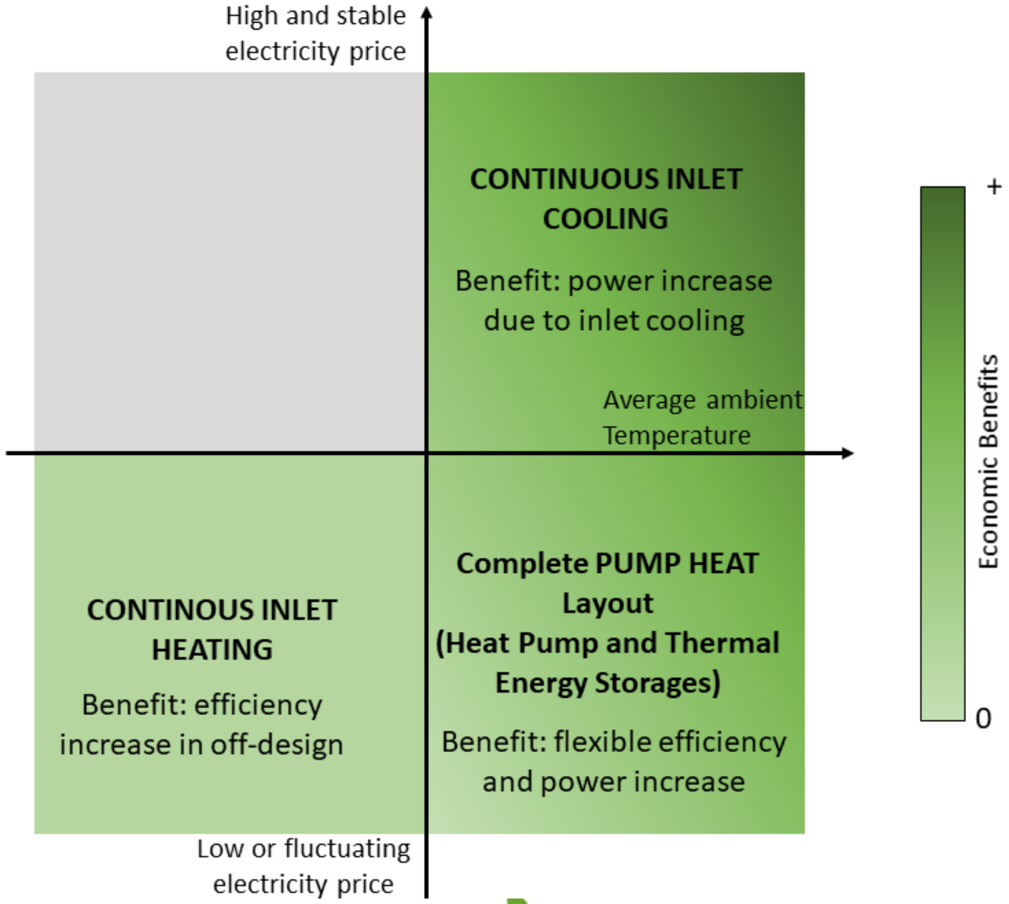
Impact of the boundary condition Oriented (PO) layout



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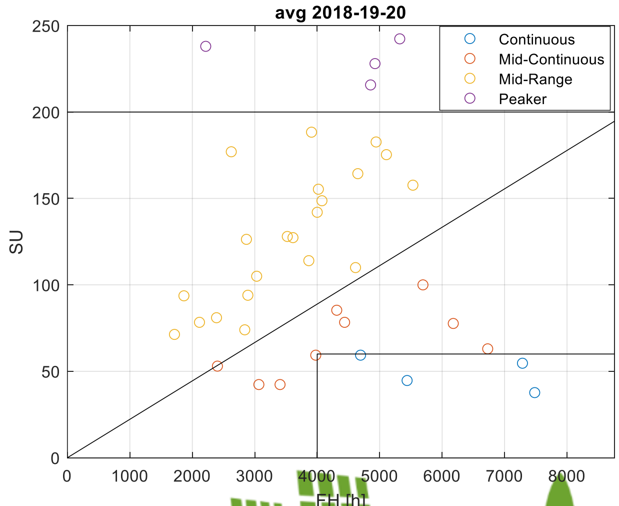
Data Set

	n. sites	n. CCGT units	n. GT	Overall zonal capacity
NORD	13	22	30	10,394 MW
CNORD	2	2	2	756MW
CSUD	7	10	13	4,077MW
SUD	4	4	6	2,713MW
ROSN	4	6	8	3,275MW
SICI	1	1	2	780MW
SARD	0	0	0	0MW
Total	**31**	**45**	**61**	**122 GW**

- **45 power-oriented** (no-CHP) CCGT have been considered
- Considered plants are distributed **among 6 market zones**
- **The analysis cover the 97.5%** of Italian CCGTs
- 2018, 2019 and 2020 were considered



Operating Profile	Load Factor [%]	FH [h]	Annual SU	ODFH [%]
Continuous	54.3	6226	49	52.0
Mid-Continuous	34.3	4467	67	66.5
Mid-Range	28.5	3524	128	63.8
Peaker	29.7	4329	231	60.7

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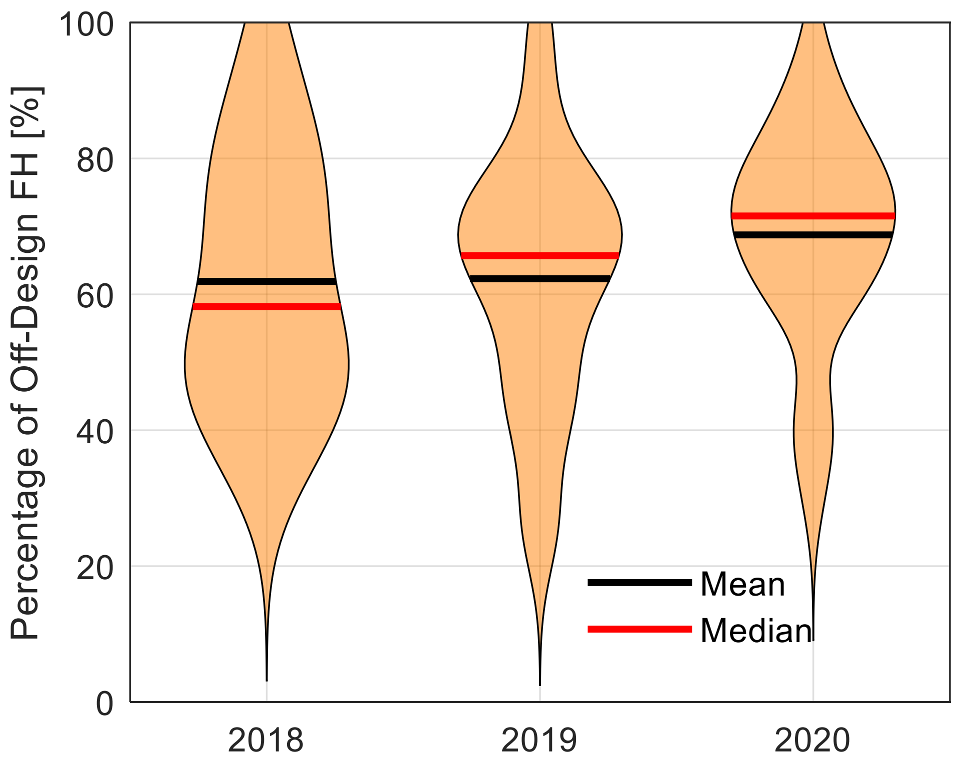
Percentage of Off Design Fired Hours

$$ODFH = \frac{\sum FH(0.38 \leq CCGT\% \leq 0.9)}{\sum FH}$$

Data shows clearly how the production evolved between 2018 and 2020 years with the CCGTs that spend nowadays more percentage of their time at partial load (about the 70% of the time against the 60% of two 2018).



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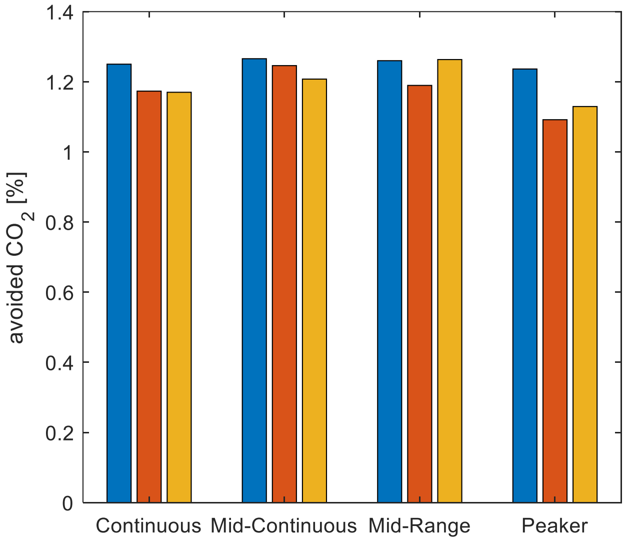
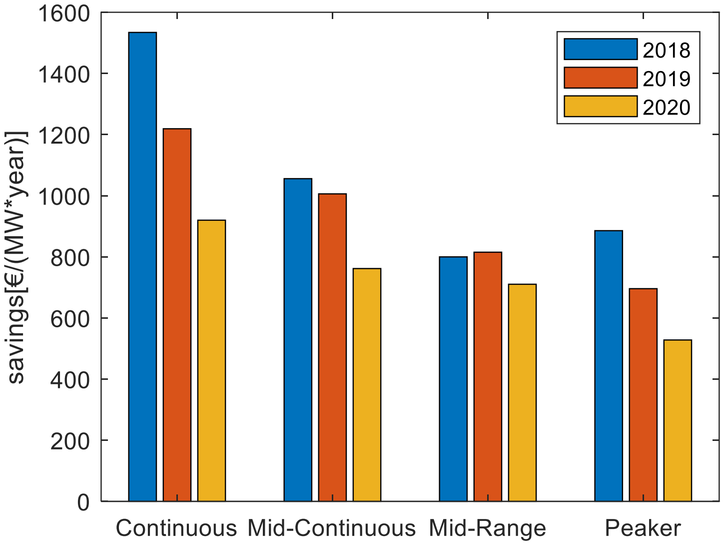
Results: Environmental and Economic Benefit





- average increase of efficiency larger than the 1.1% with a proportional impact on the CO2 emissions and fuel cost savings
- continuous CCGTs benefit: 2018 1534 eur/(MW*year) = 613,600 eur/year for a 400 MWe
  2020 920 eur/(MW*year) = 368,000 eur/year
- 2021 benefit foreseen between 1 and 0.5 million euro/year

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Thermo-economic results for Inlet Intake Heating

- A statistical analysis of the Italian CCGTs Power Oriented fleet, composed by 45 Units for a total of 122 GW of installed capacity, confirmed that the CCGTs are spending more time at partial load (70% in 2020)
- The efficiency gain and environmental benefit is higher than 1.1%
- The absolute conomic gain is dependent by the CO2 ETS price and by the Natural Gas Cost
- For the continuous CCGTs the benefit 1534 eur/(MW*year) equal to 613,600 eur/year for a 400 MWe CCGT in 2018 vs 920 eur/(MW*year) equal to 368,000 eur/year in 2020
- 2021 benefit foreseen between 1 and 0.5 million euro/year
- installations in the northern regions, can take advantage of the presence of already installed anti-icing devices to exploit this untapped potential at reduced cost

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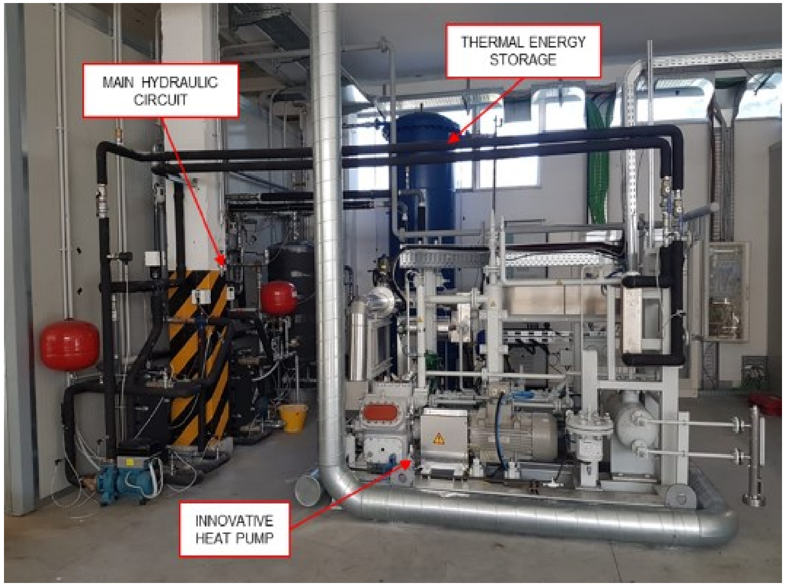
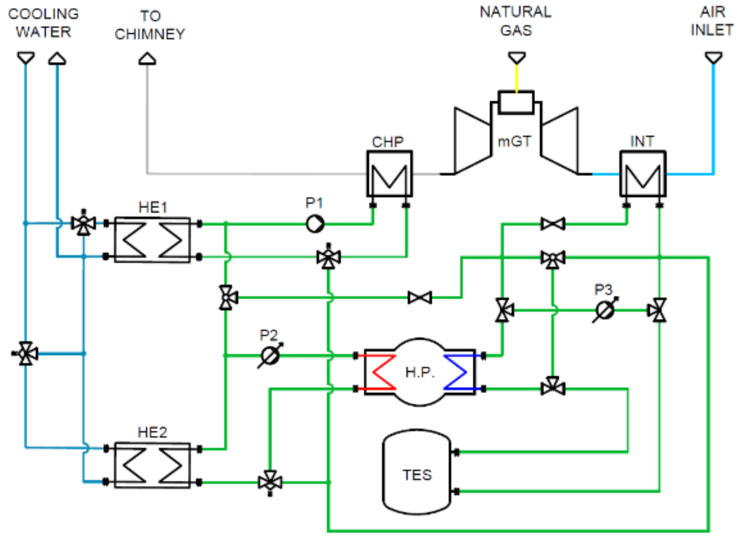
PUMP HEAT Validation site (UNIGE)





- Project Validation site, placed within Tirreno Power power plant, Savona (Italy)
- 100 kW_e micro gas turbine
- Fast response HP, 10 kW_e
- Cold thermal storage, 100 kWh, T range -5°C to +5°C

Università di Genova

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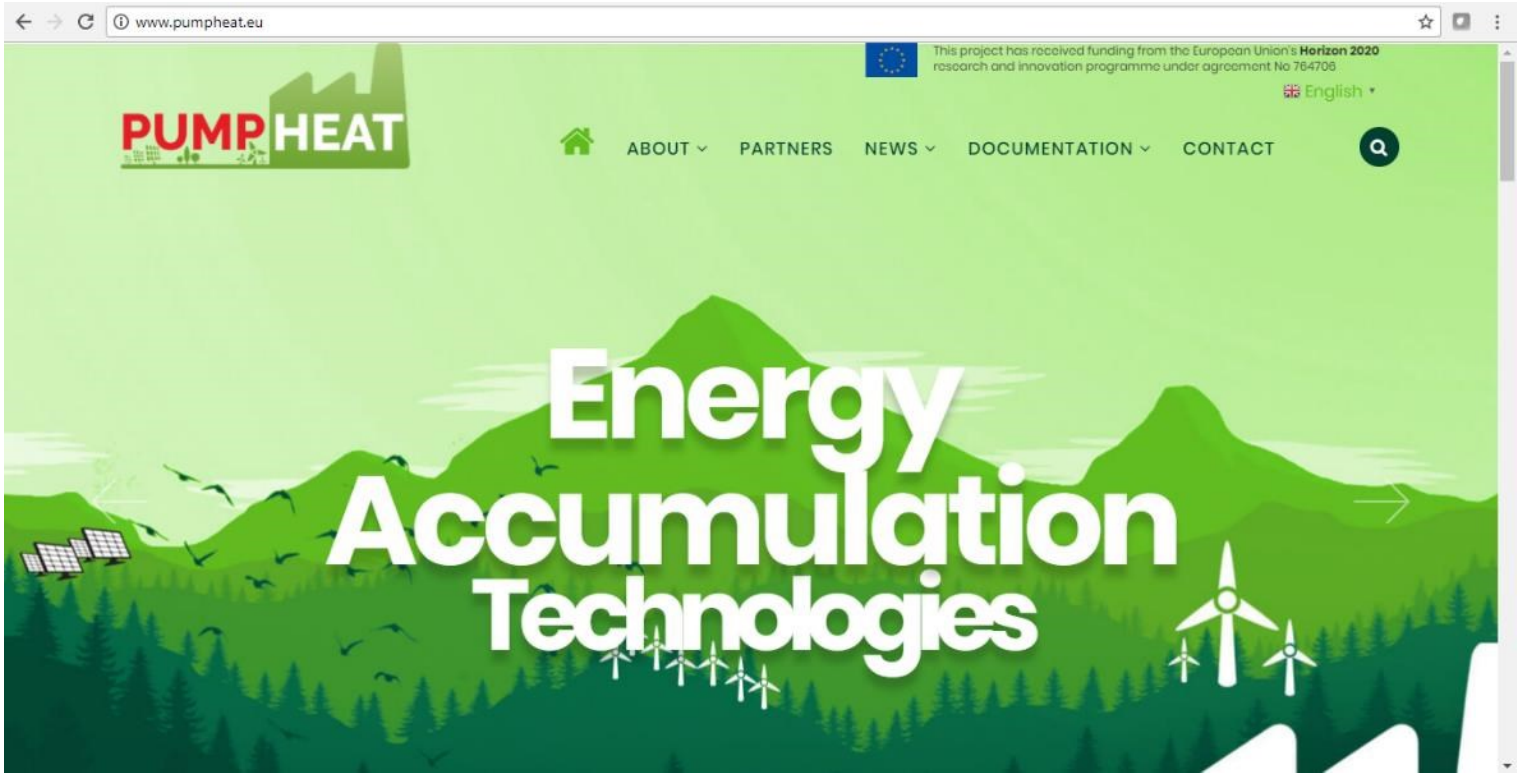
Would you like to support PUMP-HEAT?



www.pumpheat.eu

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ANCILLARY SERVICES POTENTIAL

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LATENT HEAT RECOVERY

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THANKS FOR YOUR TIME