Università di Genova | TPG

180 kWh Cold Thermal Energy Storage: Experimental assessment

Low Emission Advanced Power – LEAP Workshop, 1-5th November 2021

Speaker:

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Agenda

- **PUMP-HEAT Project**
- **Cold Thermal Energy Storage**
- **Conclusions and discussion**

Introduction

Thermochemical Power Group

UNIVERSITÀ DEGLI STUDI DI GENOVA

<u>Tommaso Reboli</u>

Research fellow, Department of Mechanical, Energy, Management and Transport Engineering, University of Genoa, Italy

Ph.D. on the topic of Wave Energy Converters (2020)

Responsible for experimental activities of Pump Heat project

Involved in different other projects (LOLABAT, wave generator…)

4	2	3
Full Professor	Associate Professor	Assistant Professor
12	5	1
PhD Student	Associate Researcher	Technician

Agenda

- **PUMP-HEAT Project**
- **Cold Thermal Energy Storage**
- **Conclusions and discussion**

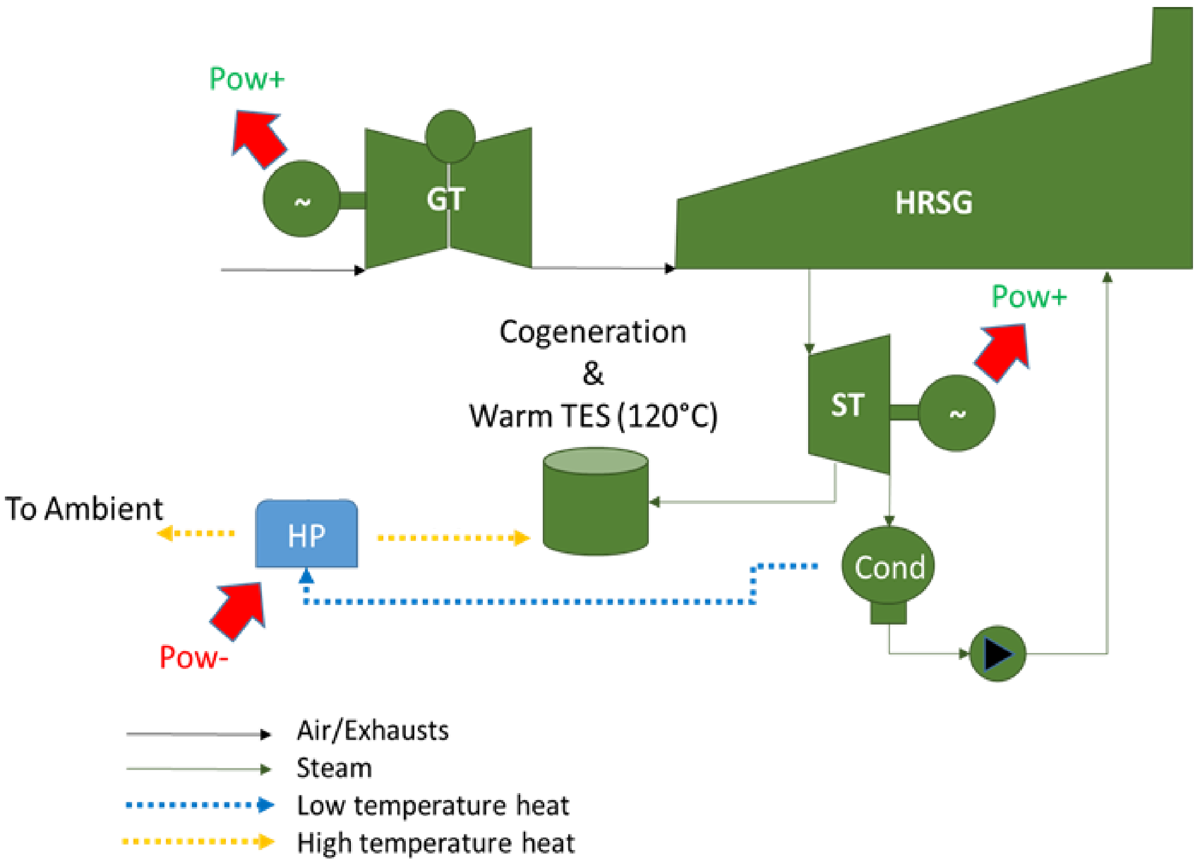
Pump Heat Project

Performance Untapped Modulation for Power and Heat via Energy Accumulation Technologies

<u>Aim of the project:</u> to increase the flexibility and operative range of Combined Cycles through integration with HP and TES

<u>Two different layouts</u>
- CHP configuration
- Power Oriented configuration

<u>CHP configuration</u>



Pump Heat Project

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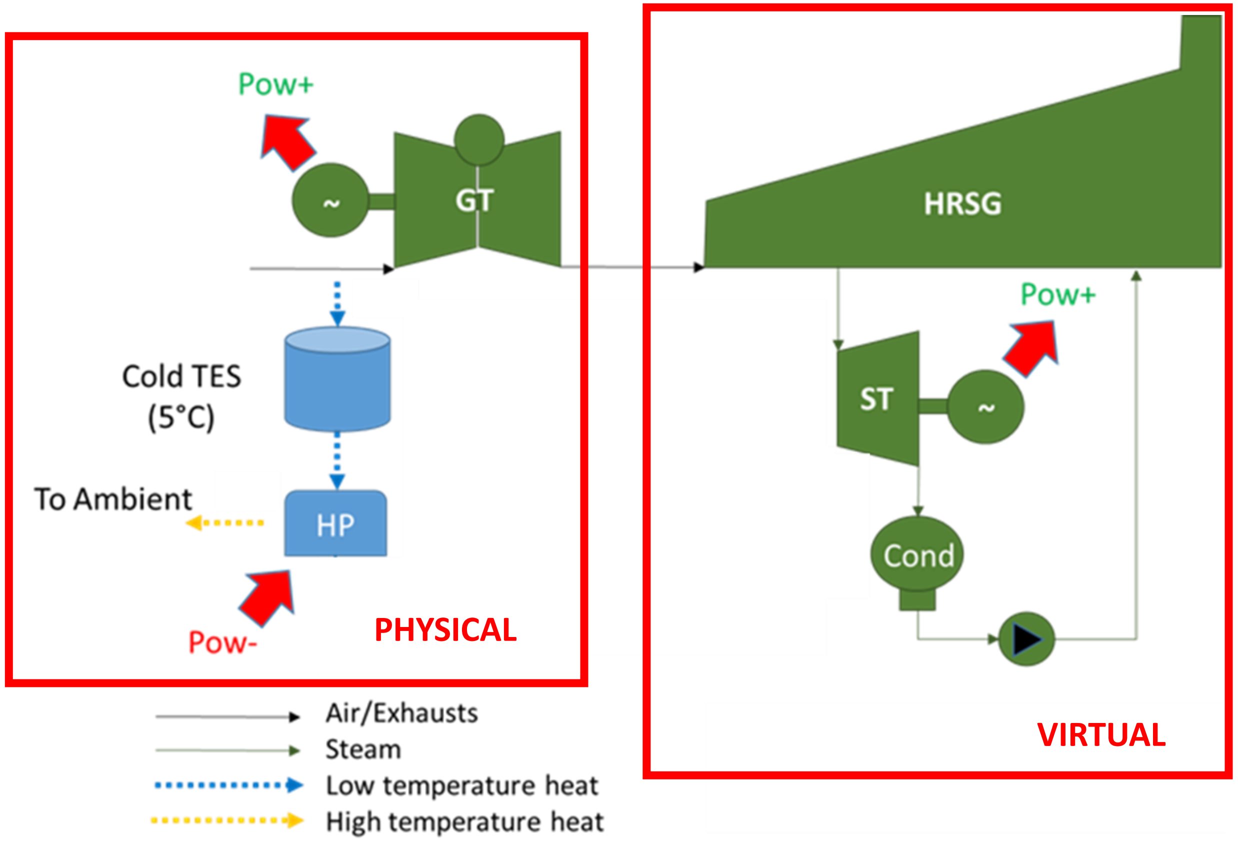
Power Oriented configuration



Pump Heat Project

PUMP HEAT

Performance Untapped Modulation for Power and Heat via Energy Accumulation Technologies

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Two different layouts

- CHP configuration
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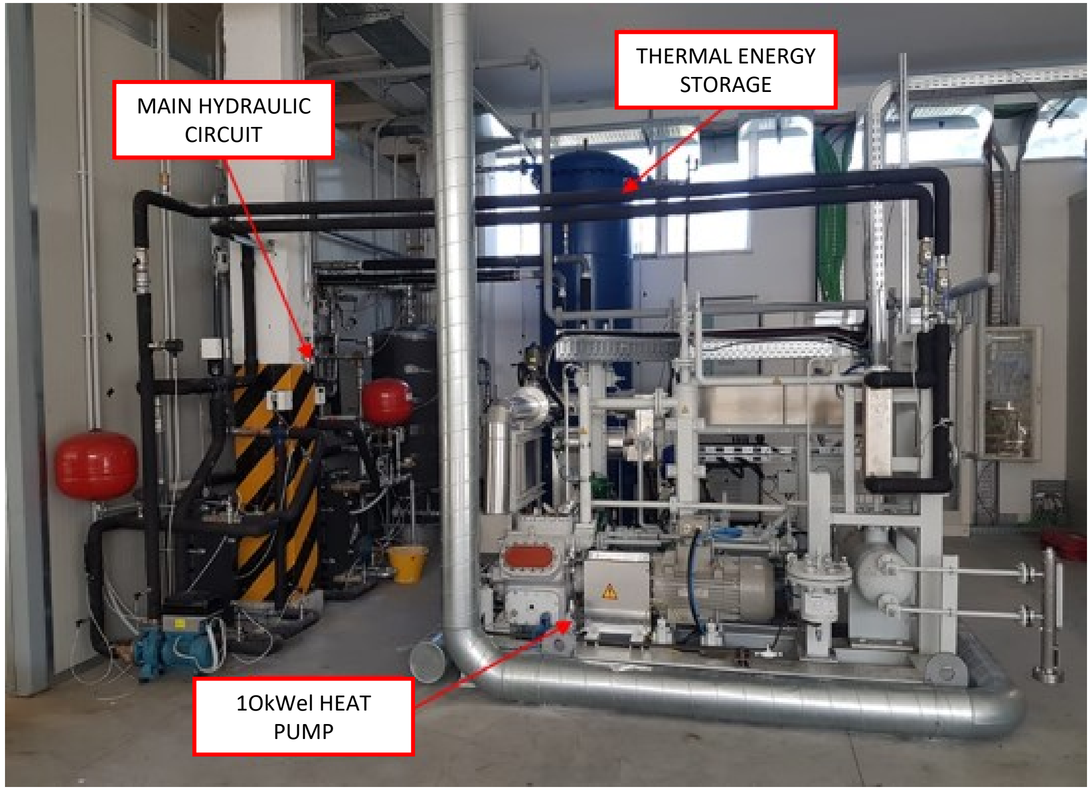
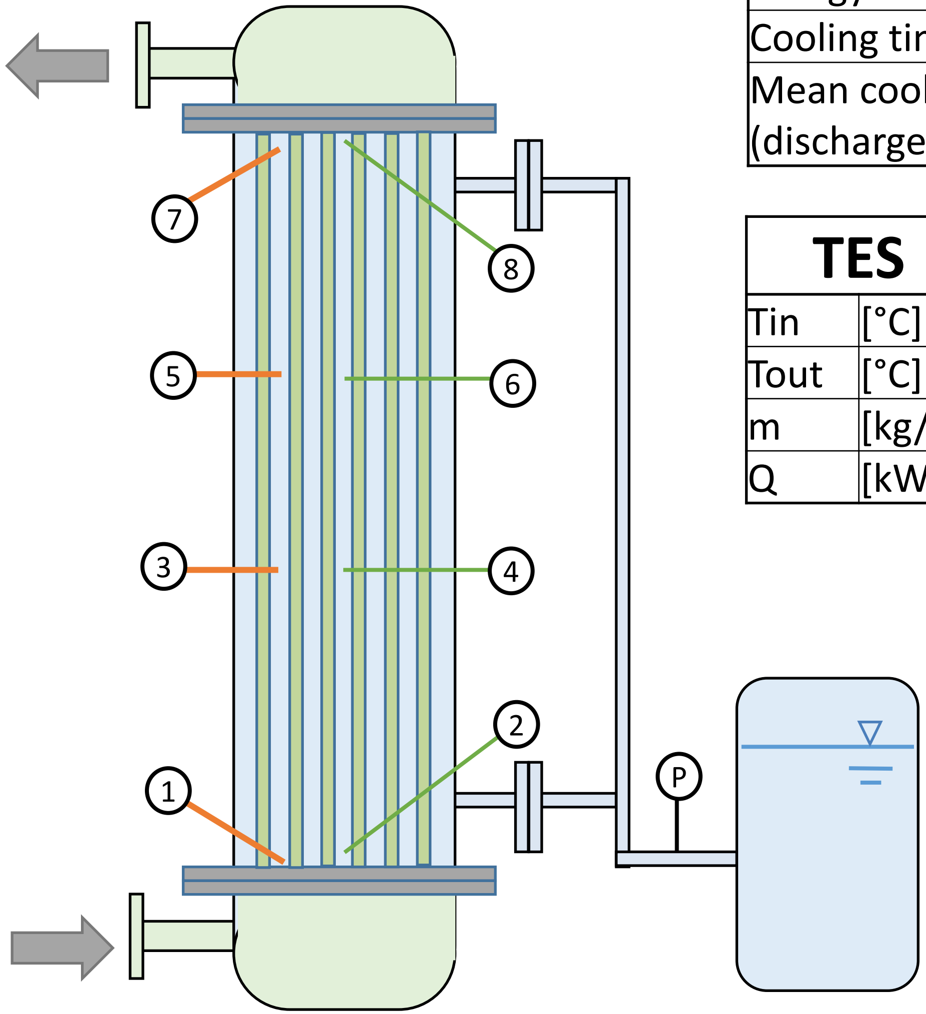
Power Oriented configuration
Validation site



Agenda

- PUMP-HEAT Project
- **Cold Thermal Energy Storage**
- Hot Thermal Energy Storage

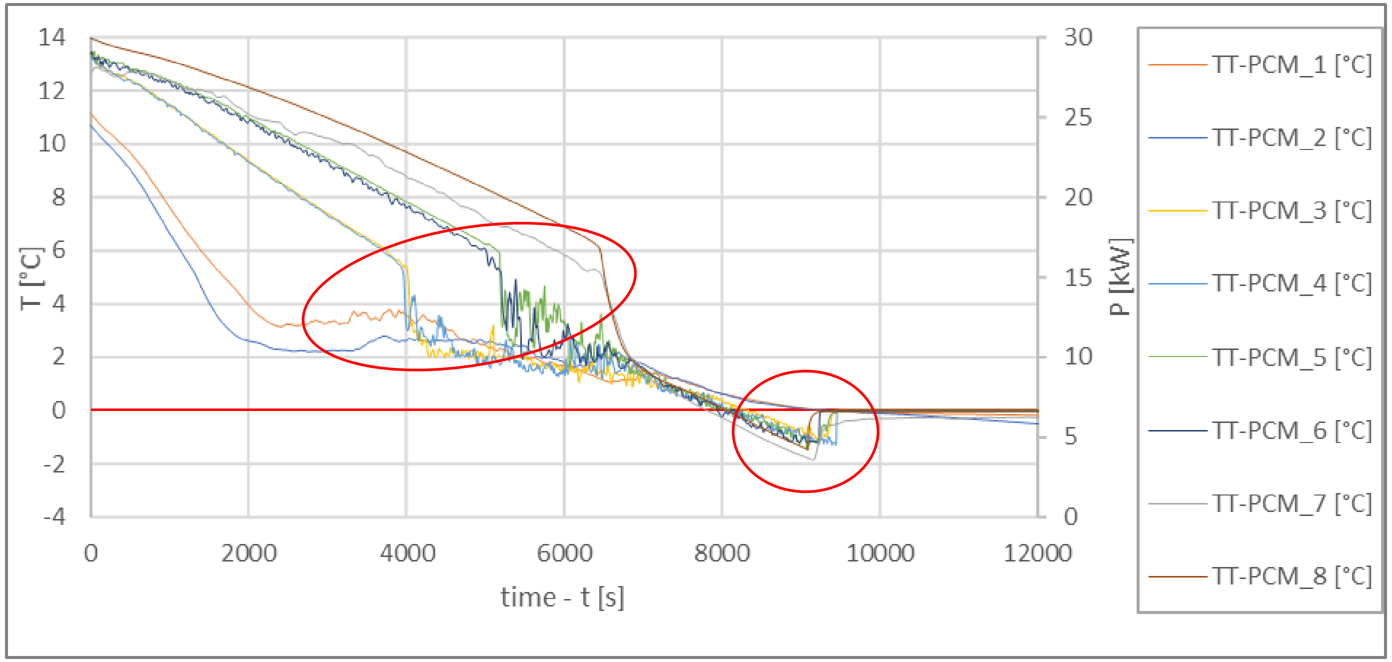
Cold Thermal Energy Storage – Equipment description



TES ENERGETIC PARAMETERS		
Energy stored	100	[kWh]
Cooling time	4	[hr]
Mean cooling power (discharge)	25	[kW]

TES		charge	discharge 1	discharge 2
Tin	[°C]	-2	12	20
Tout	[°C]	1.2	9.4	16.8
m	[kg/s]	2	1	2
Q	[kW]	25	10	25

Cold Thermal Energy Storage – Experimental car



- Tdi = density inversion temperature
- Tn = nucleation temperature

Visualization of dendritic ice growth in supercooled water inside cylindrical capsules
Sergio Leal Braga, Juan José Milón

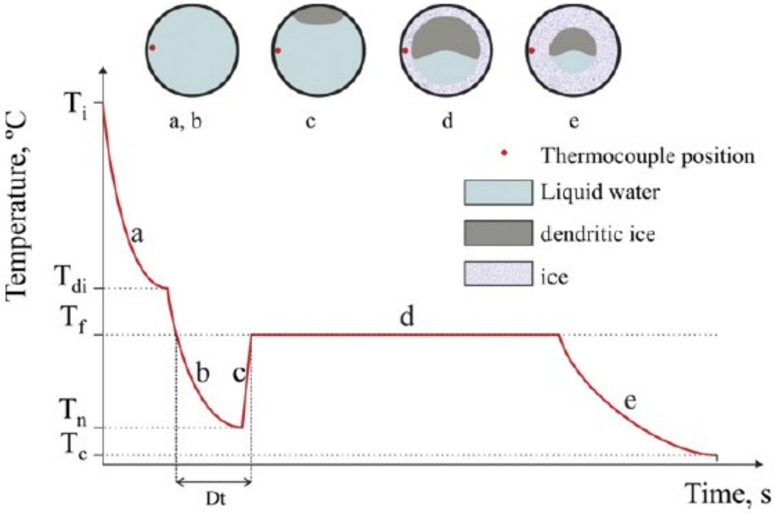
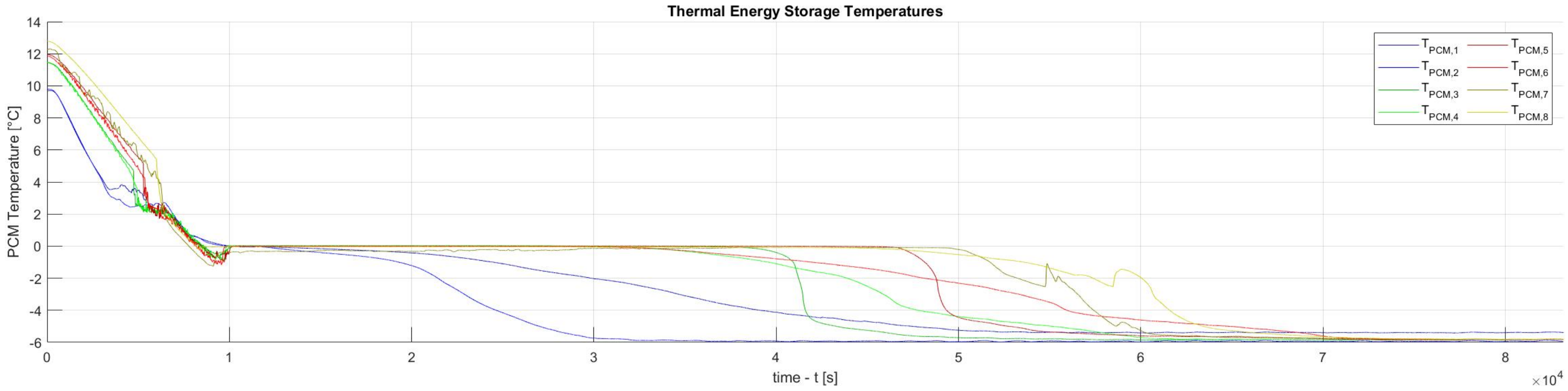
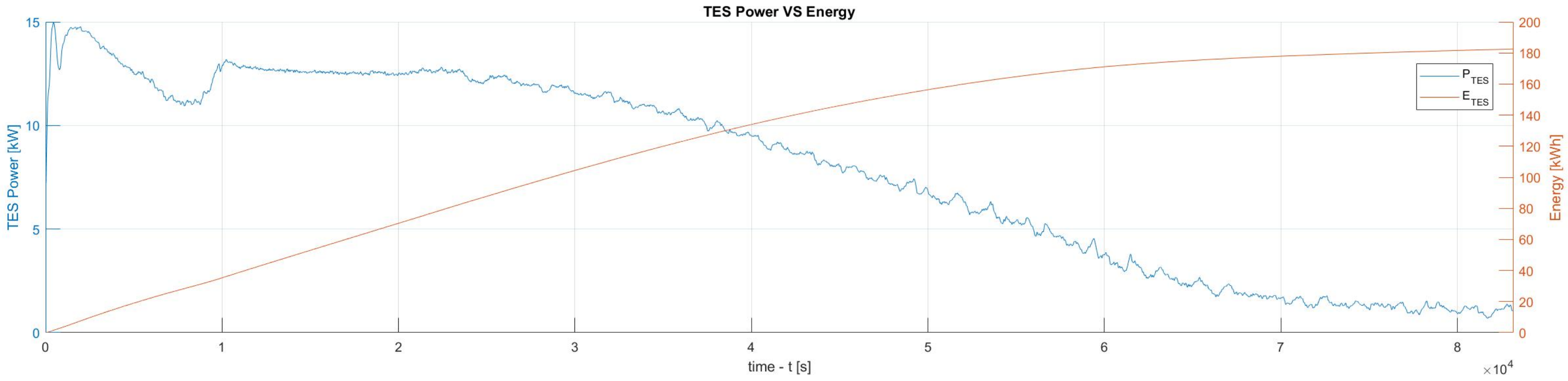


Fig. 1. Water freezing process.

Cold Thermal Energy Storage – Experimental campaign

mass flow = 1,2 kg/s	Tin = -6°C	Fluid direction = bottom to top





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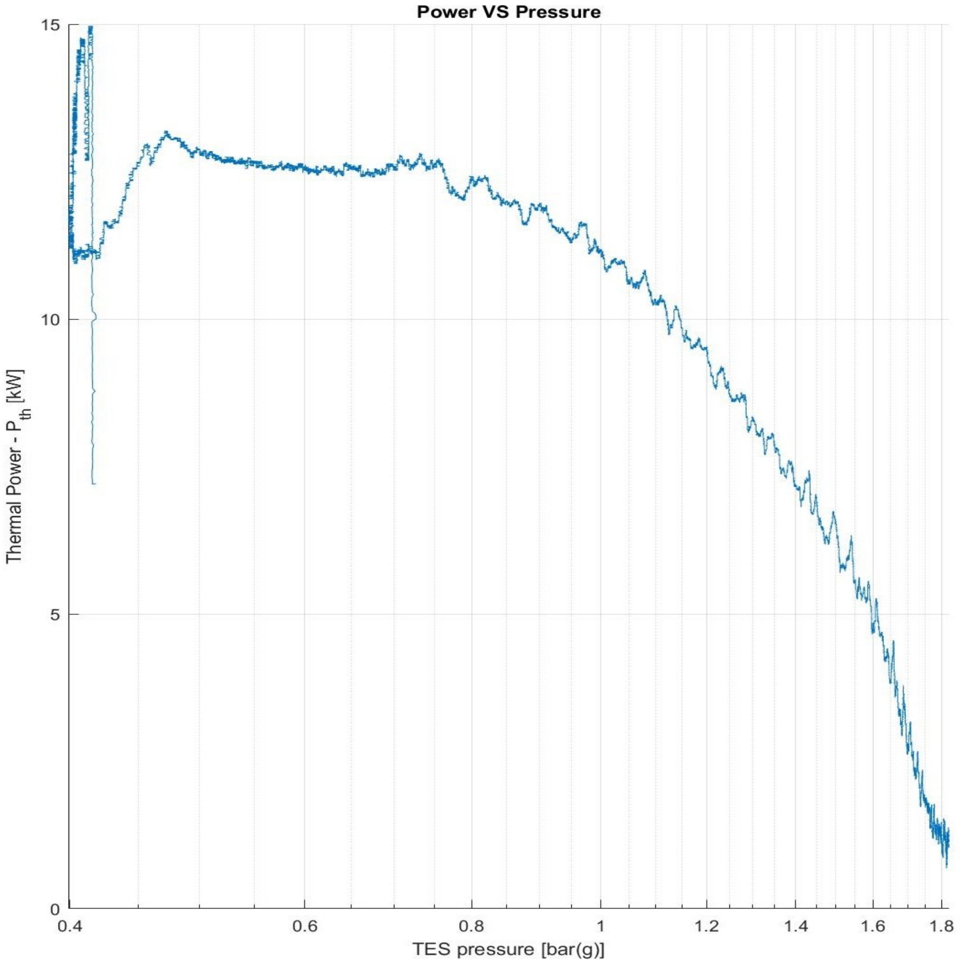
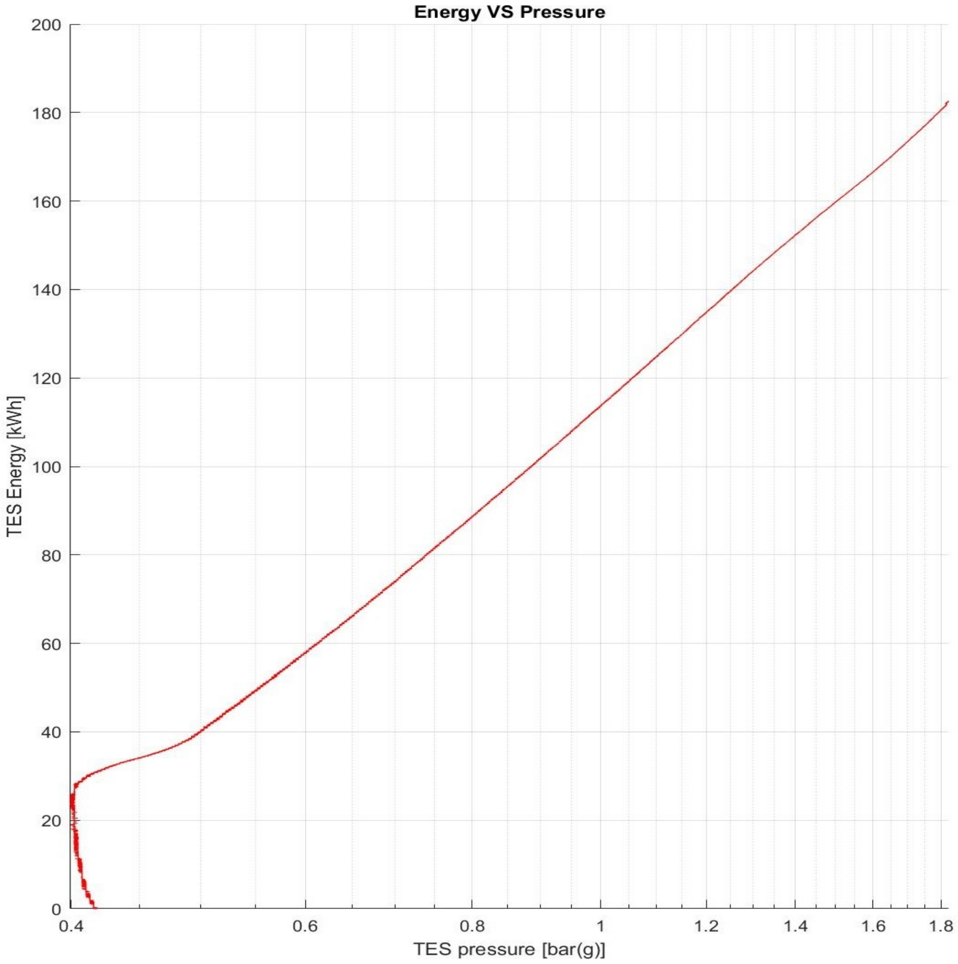
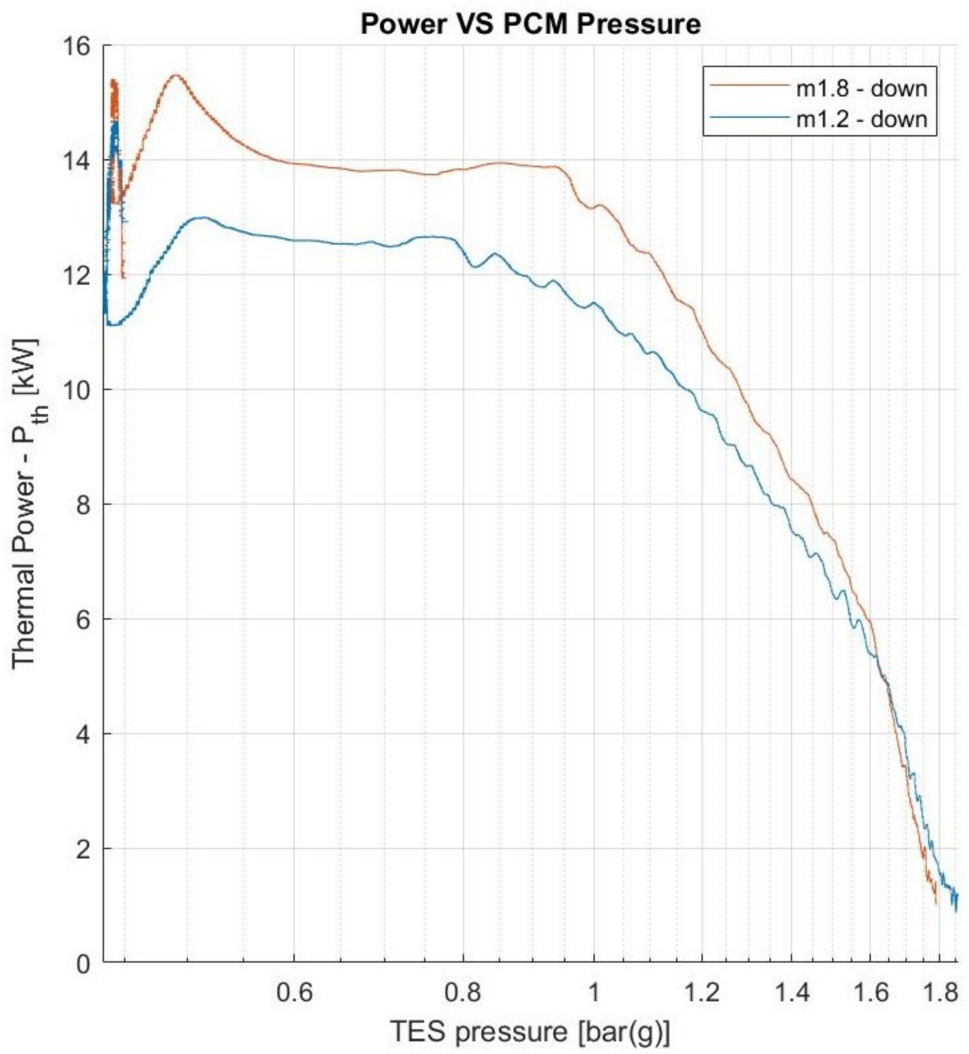
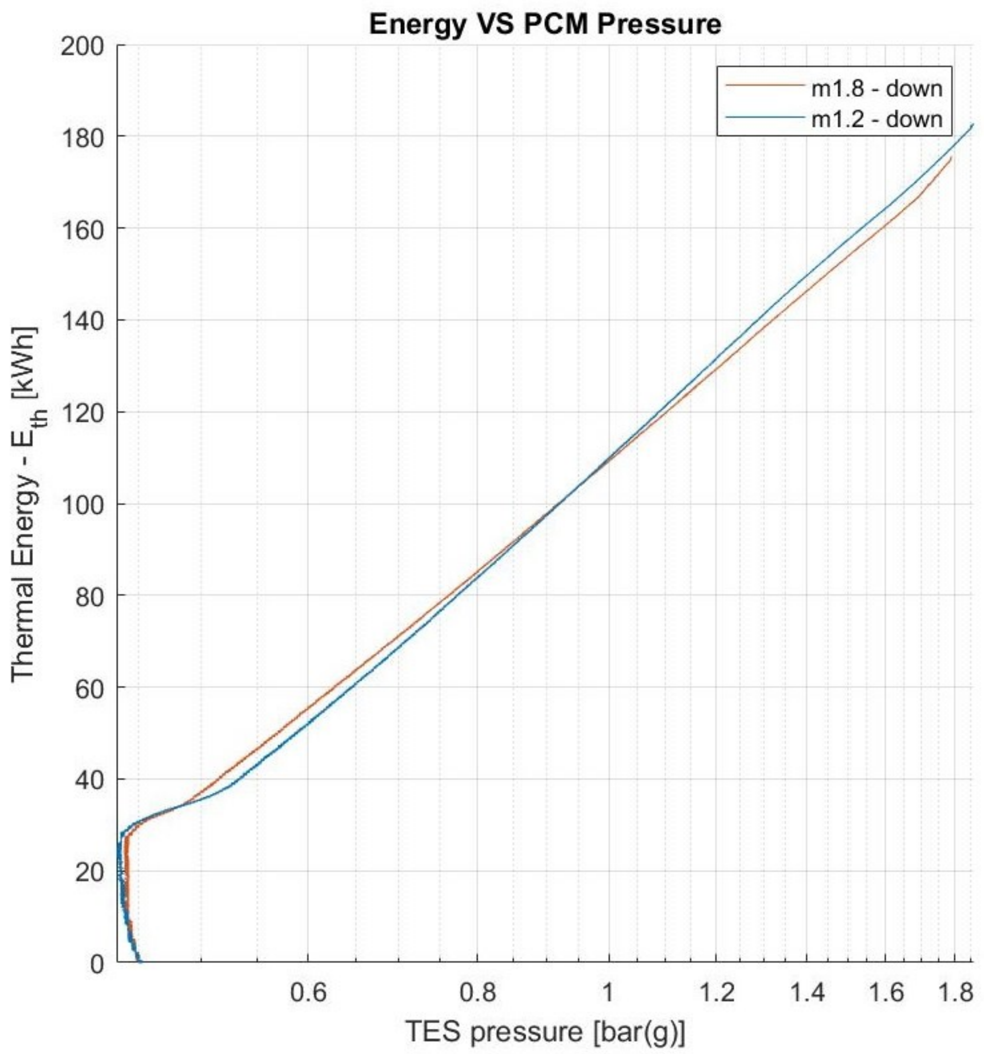




Cold Thermal Energy Storage – Experimental campaign

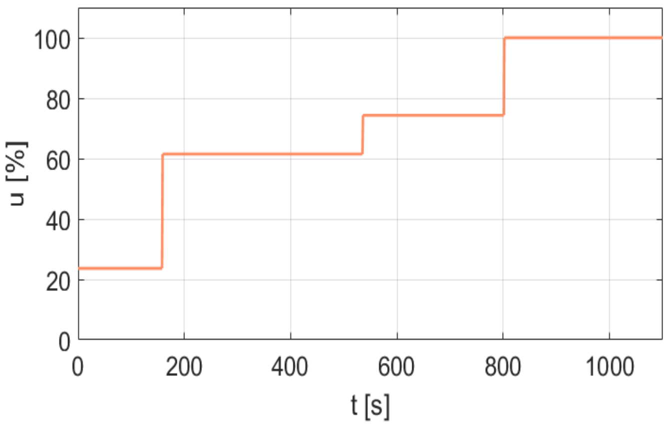
- Same T_{in}, same directions, different mass flow

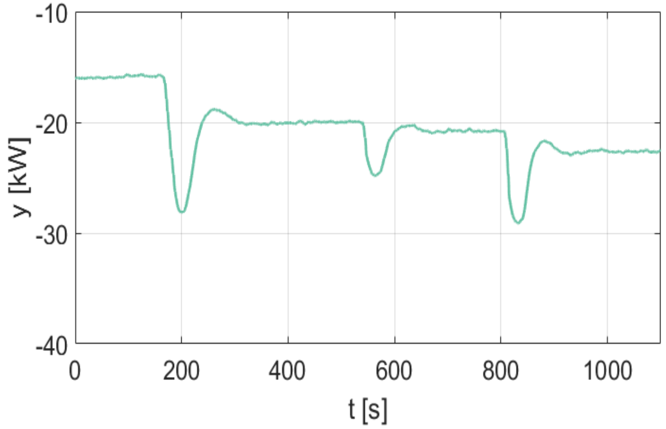




Cold Thermal Energy Storage – Experimental campaign

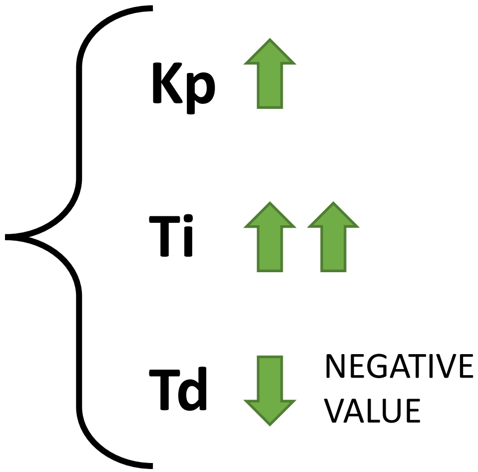
- Dynamic response – TES DISCHARGE

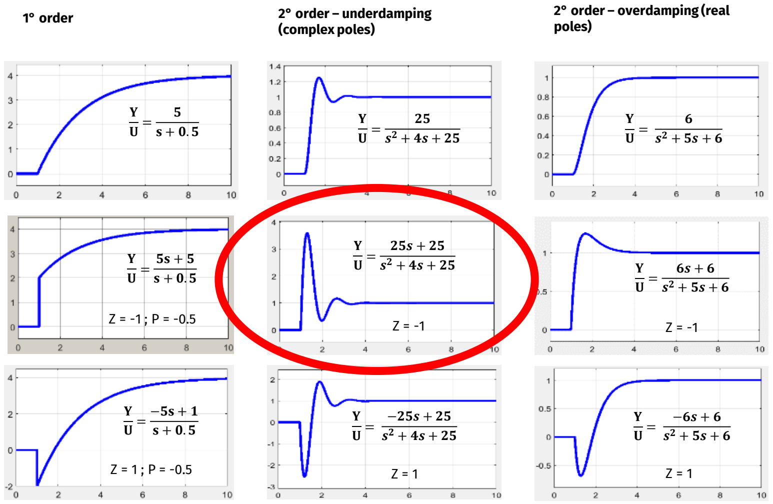




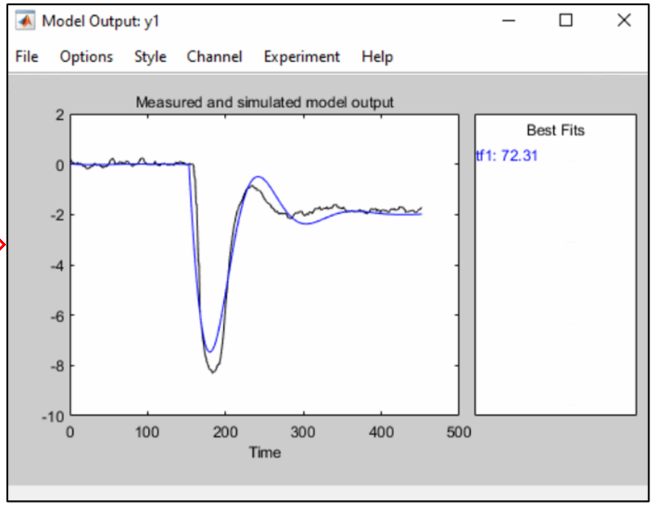
Step Response
u(t) = mass flow controller
Y(t) = thermal power output

PID Tuning





Transfer Function
2 poles, 1 zero



Agenda

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Conclusions and discussion

Cold Thermal Energy Storage:
static equipment useful to be integrated in industrial / energy processes
- ✓ TES Charge with different process variables performance evaluation
- ✓ Characterization of the equipment (TES CHARGE) - ONGOING
- ✓ Dynamic response and PID tuning - ONGOING

Discussion:
- TES DISCHARGE characterization: what should be the best way to approach it – e.g. specific industrial application requirements?
- Control strategies for dynamic control of the power? There should be a «universal approach» that let to handle with this case considering also TES SOC / load characteristics?

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764706, PUMP-HEAT

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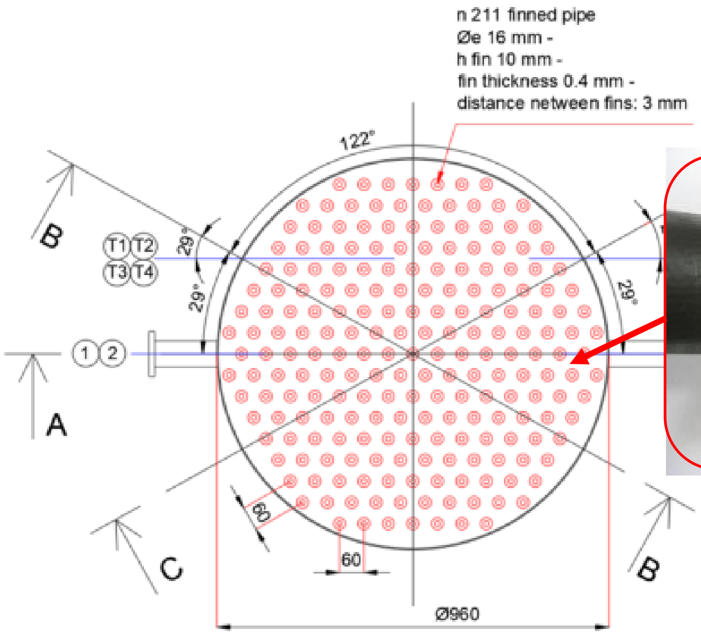
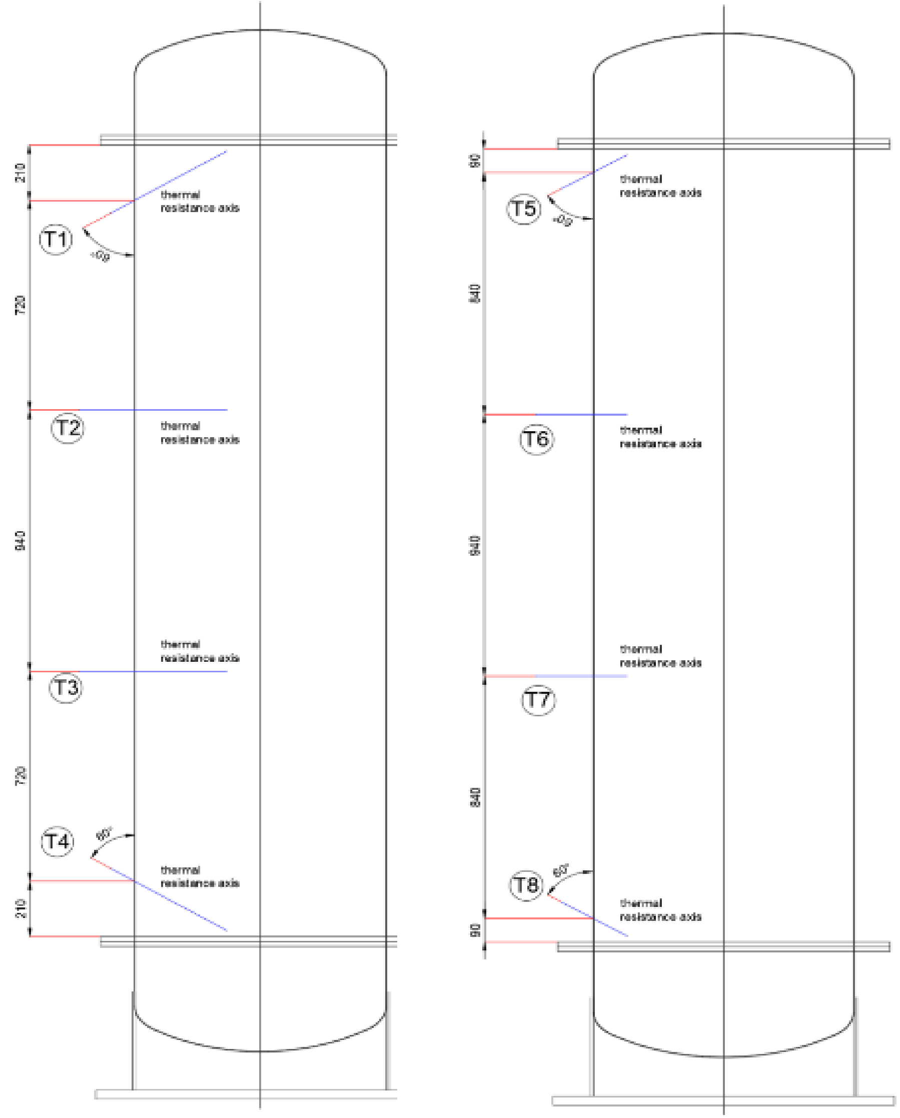
Cold Thermal Energy Storage – Equipment description

pipe length	2,8	m
pipe external diameter	0,016	m
fin external diameter	0,036	mm
fin thickness	0,0004	m
number of fins for each meter	333	1/m
minimum distance between pipes	60	mm
number of pipes	211	[-]
vessel internal diameter	0,96	m
PCM volume	1,86	m3





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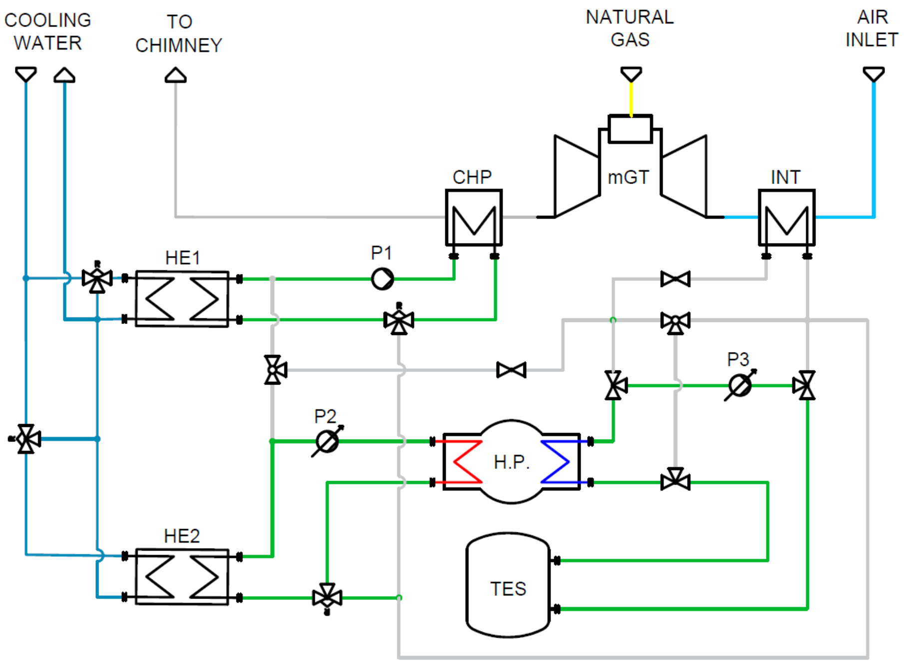
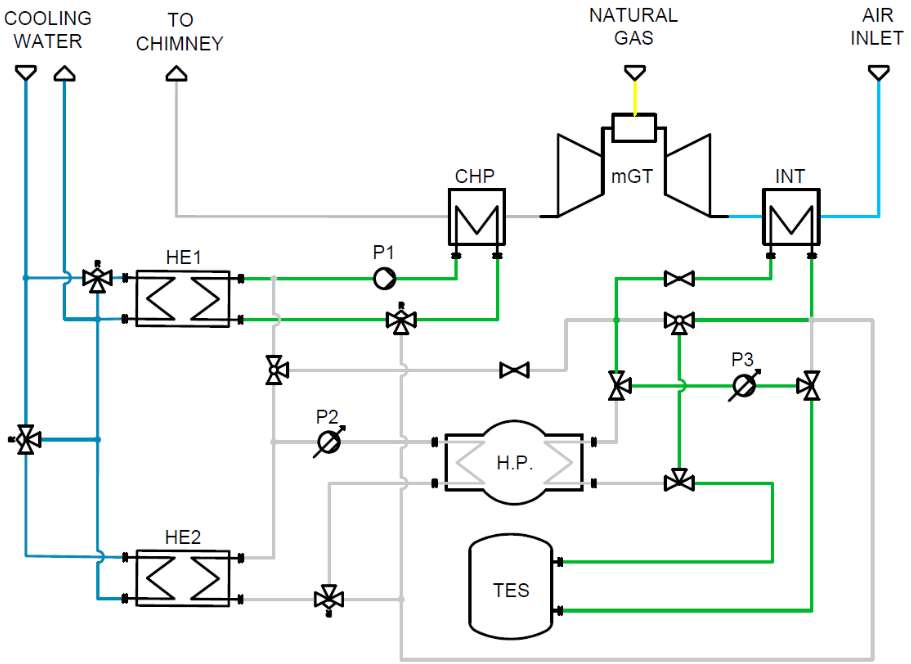


TES CHARGE



TES DISCHARGE

Operation Mode	Ambient temperature	Electricity price
Charging	-	Lowest price hours
Discharging	> Set Point Temp	Highest price hours
Continuous cooling	> Set Point Temp	< Mean price

Cold Thermal Energy Storage – Experimental campaign

Performance comparison

- Same Tin, same directions different mass flow
- Same mass flow, same directions, different Tin
- Same mass flow, same Tin, different directions

	Tin [°C]	mass flow [kg/s]	direction
A	-6	1,2	Bottom to top
B	-6	0,9	Bottom to top
C	-6	1,8	Bottom to top
D	-4	1,2	Bottom to top
E	-6	1,2	Top to bottom

Cold Thermal Energy Storage – Experimental campaign

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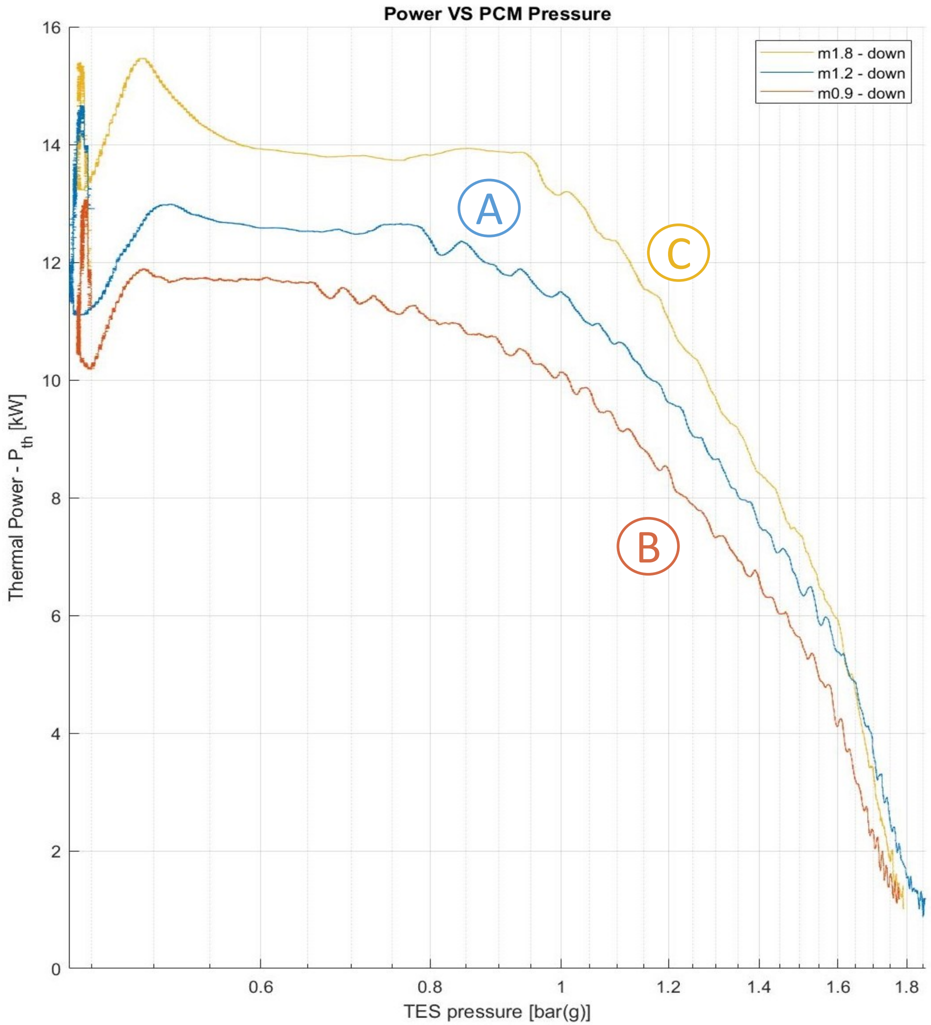

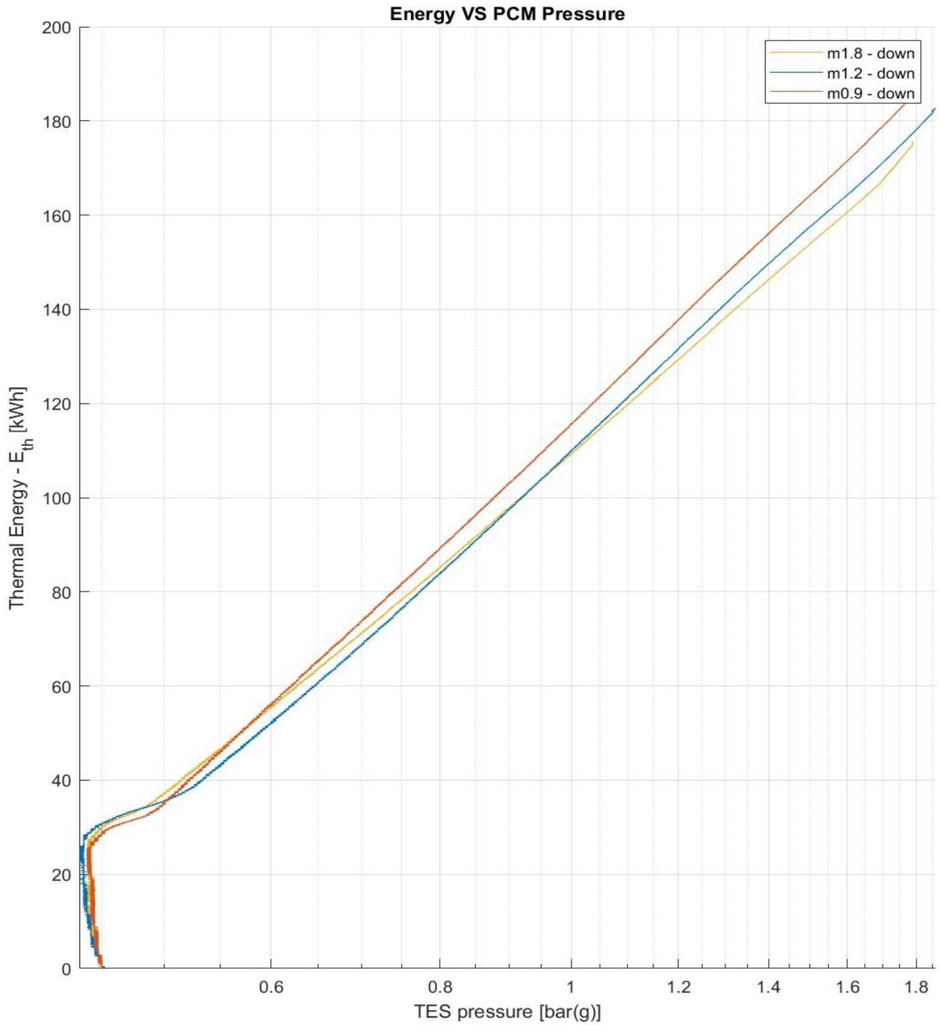

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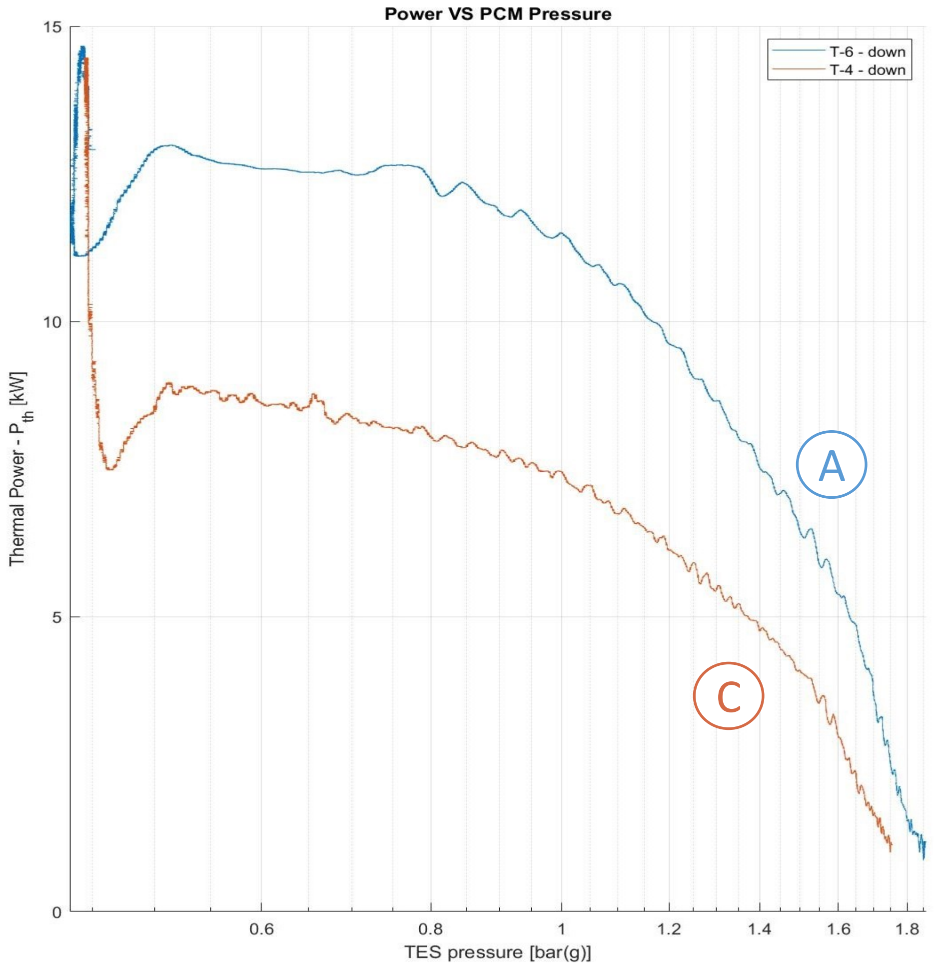

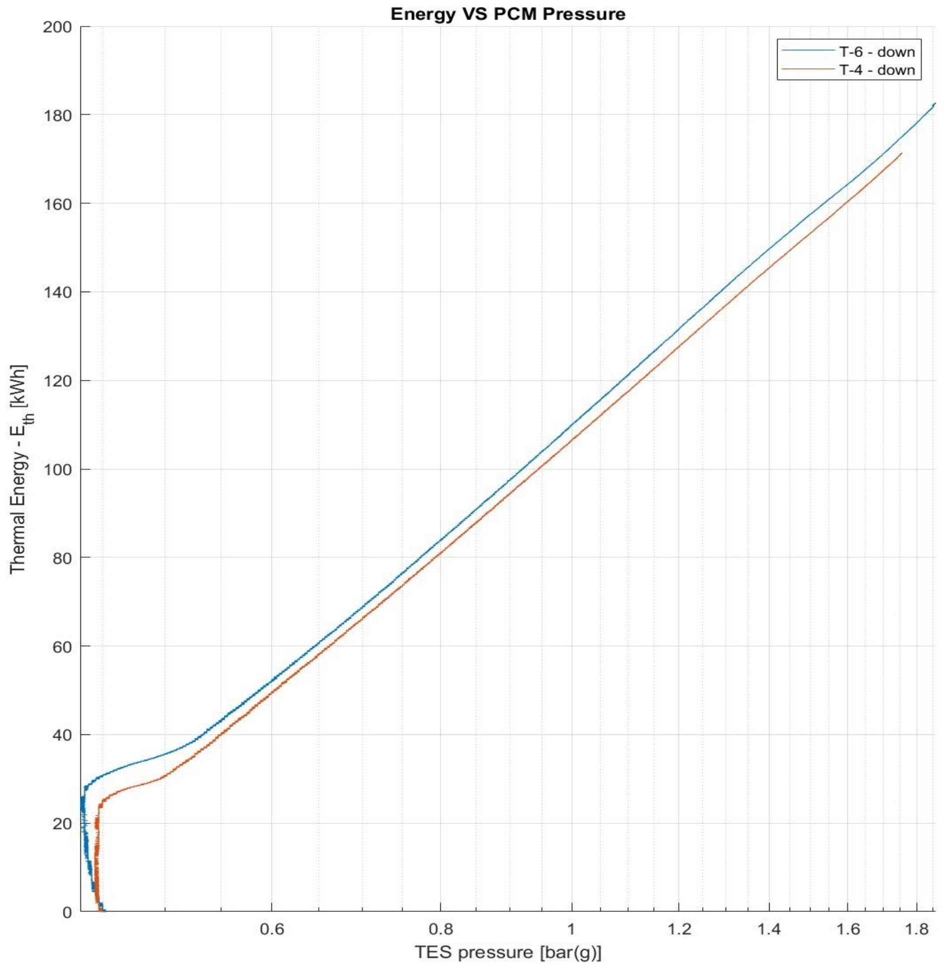

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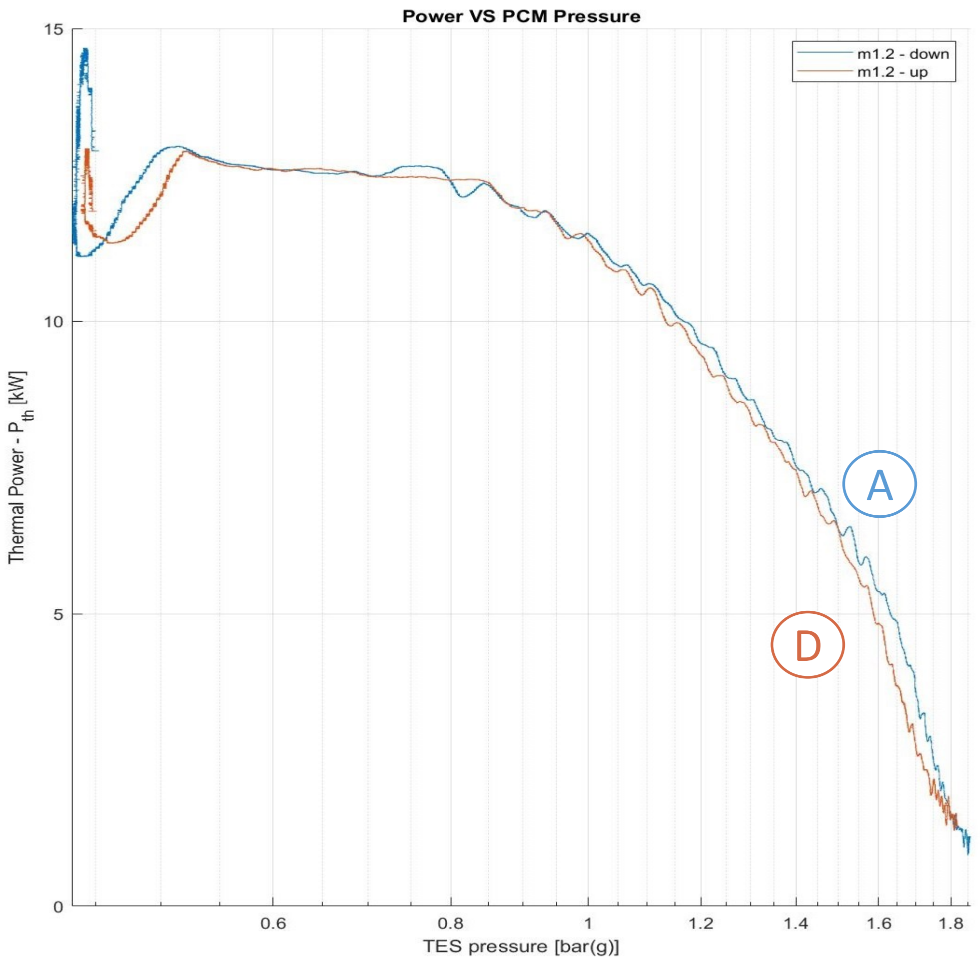

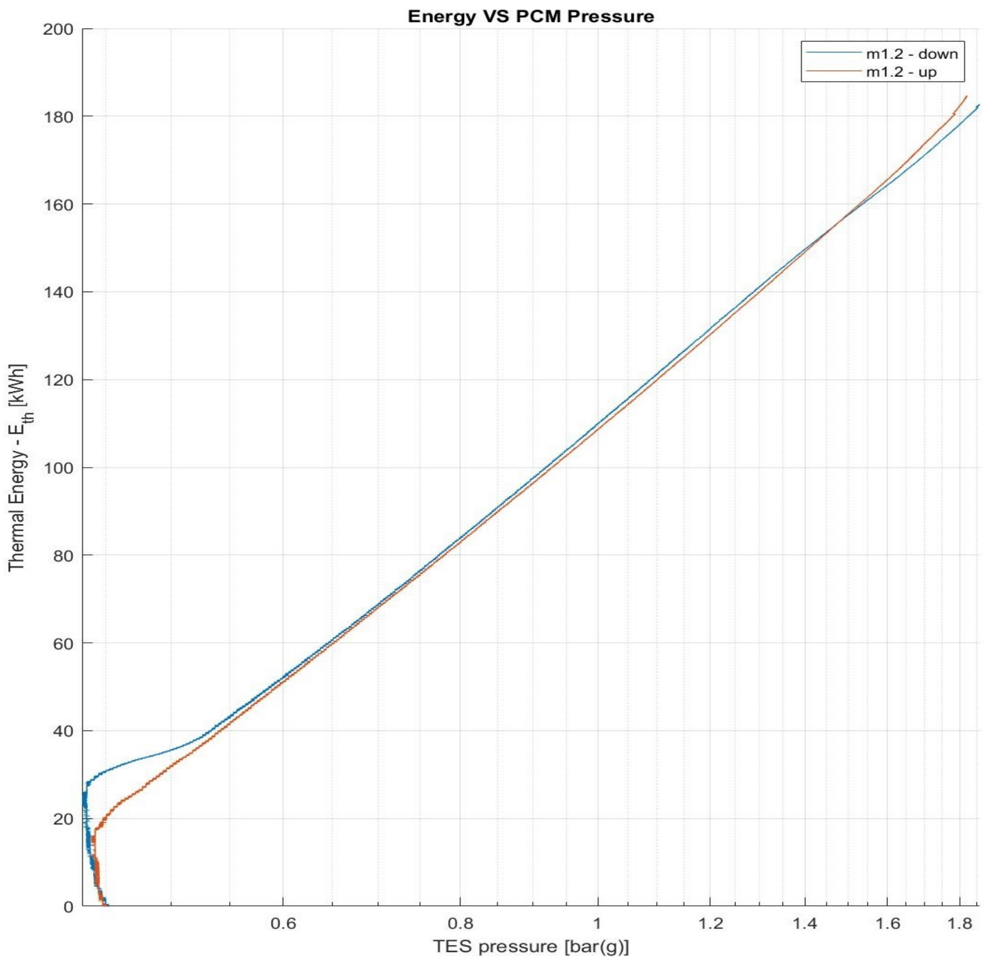

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