Long term performance analysis of a Dual-Source Heat Pump system by means of ALMABuild

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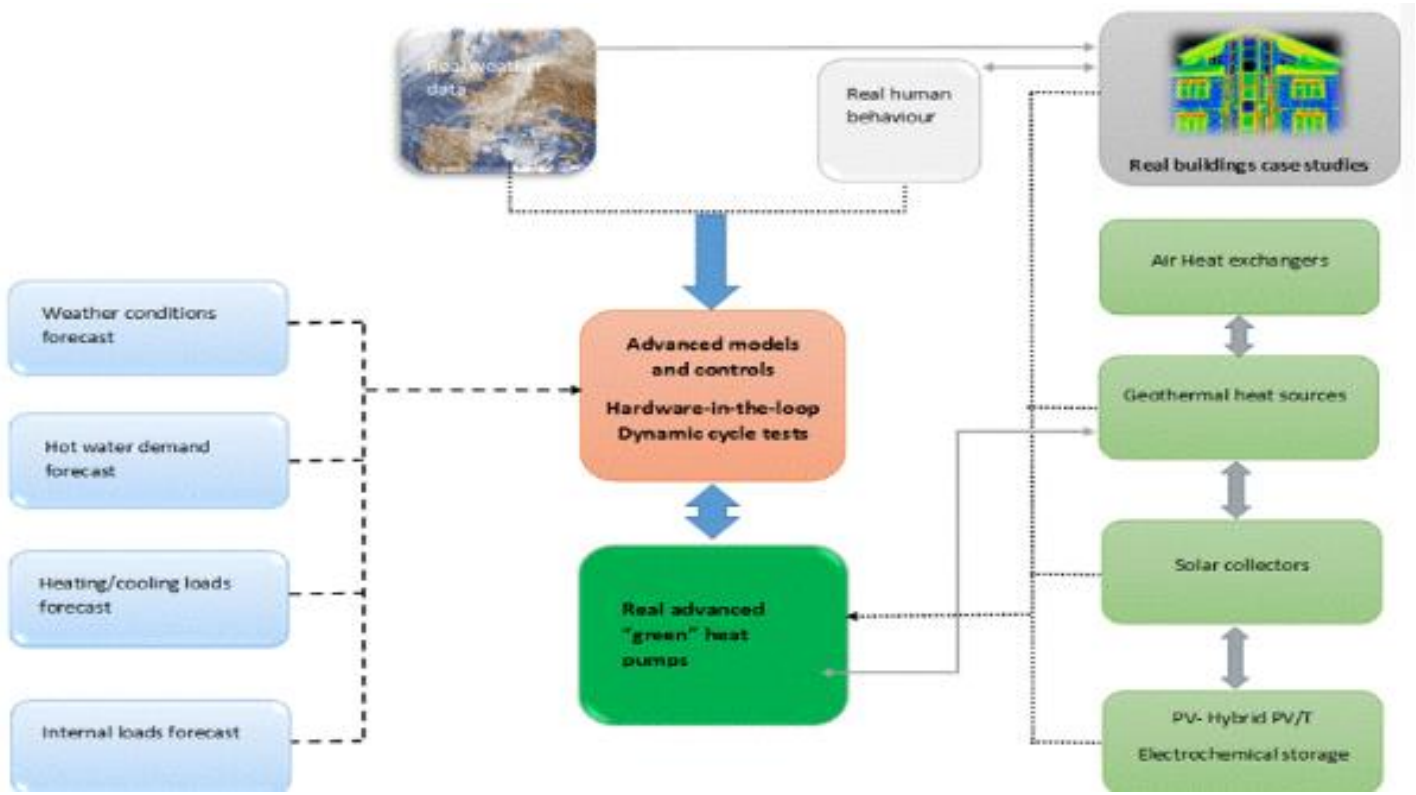
Project and Funding

FLEXHEAT: The energy **FLEX**ibility of enhanced **HEAT** pumps for the next generation of sustainable buildings (grant *2017KAAECT*)



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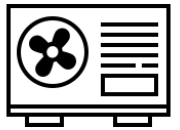
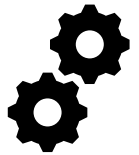
- **Traditional** and **Dual-Source** Heat Pumps (DSHPs)



- **ALMABuild**, an open-source Matlab-Simulink tool

- **Methodology**: **numerical model** and description of the **case study**



- **Results** of **numerical simulations**

- **Conclusions** and future developments

Traditional and Dual-Source Heat Pumps

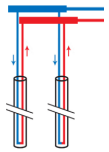
Traditional Heat Pumps

Air-Source Heat Pump (**ASHP**)

Brine deposition

✖ Performance influenced by the outdoor conditions

Ground-Coupled Heat Pump (**GCHP**)



Vertical Boreholes

Drilling machine

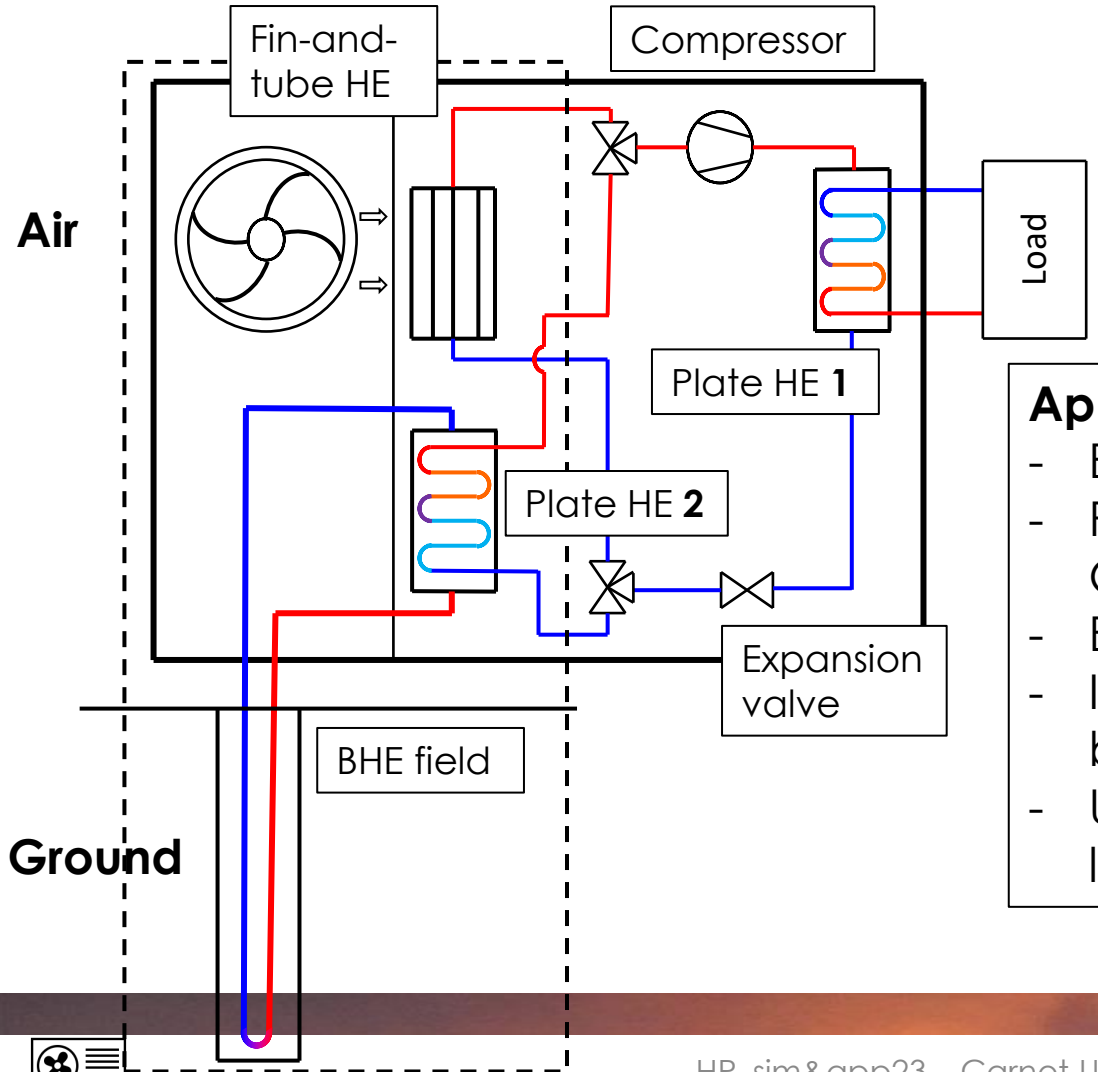
✖ Elevated investment cost

- Problem to be solved -

How to **reduce** the **high investment cost** related to the Borehole Heat Exchanger (BHE) field and **maintain** **high performance**?

Traditional and Dual-Source Heat Pumps

Dual-Source Heat Pump (**DSHP**) **prototype**



HEGOS

Nuove pompe di calore per l'harvesting energetico in smart buildings

www.hegos.cnainnovazione.net/

Progetto cofinanziato dal Fondo europeo di sviluppo regionale

POR FESR EMILIA-ROMAGNA 2014/2020

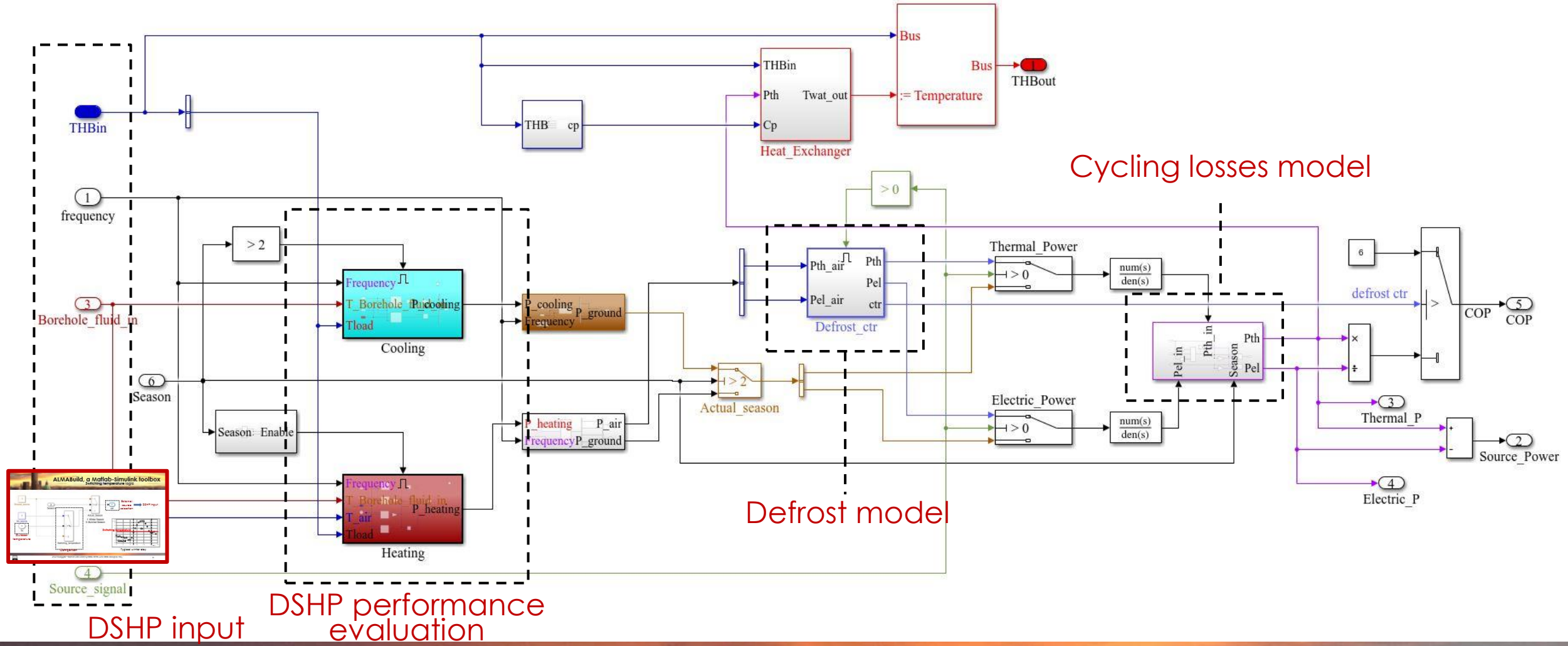
RegioneEmilia-Romagna

Applications

- Economic saving
- Refurbishment of GCHPs
- Borefield undersized
- Incorrect design of the borefield
- Unbalanced building loads

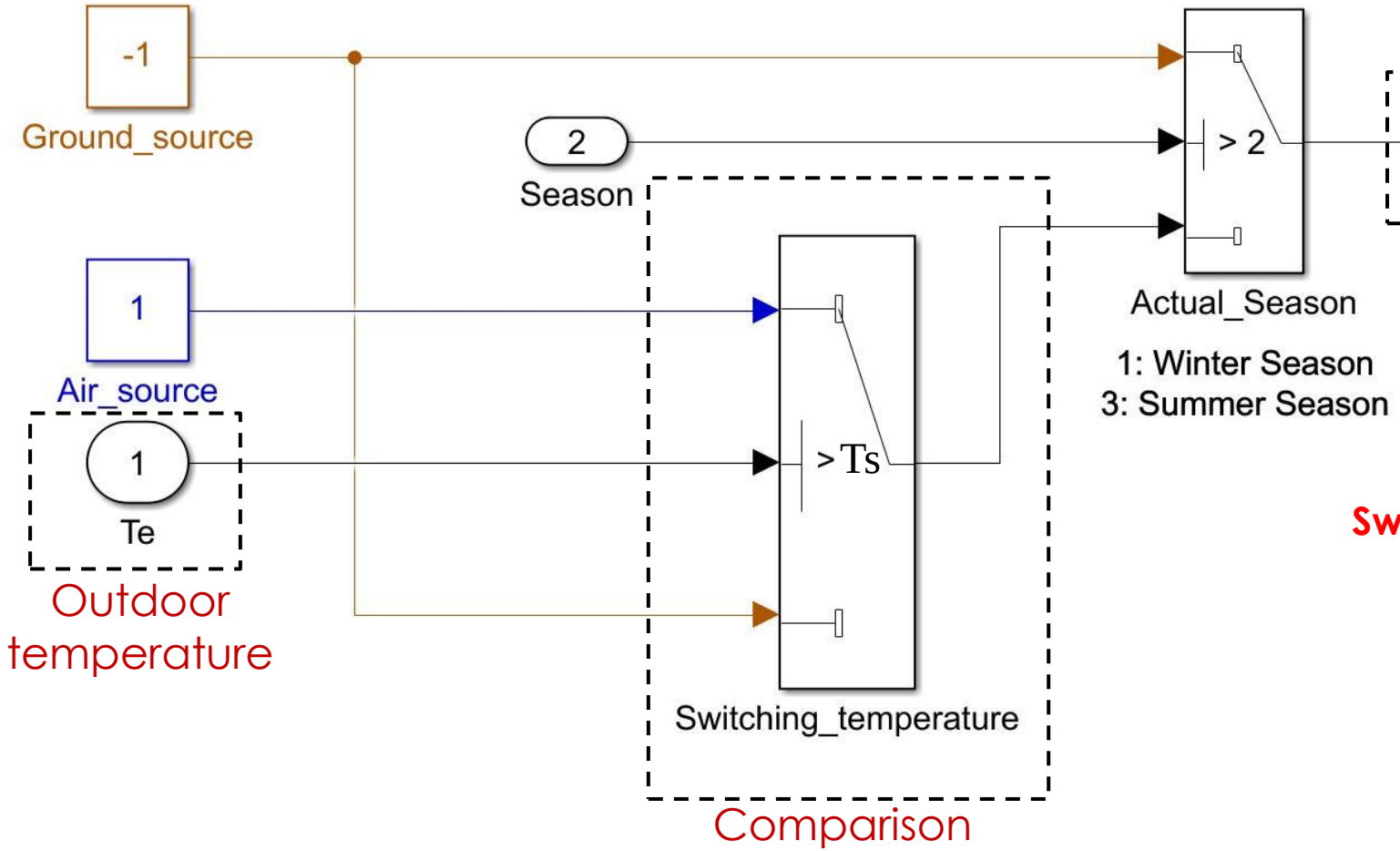
ALMABuild, a Matlab-Simulink toolbox

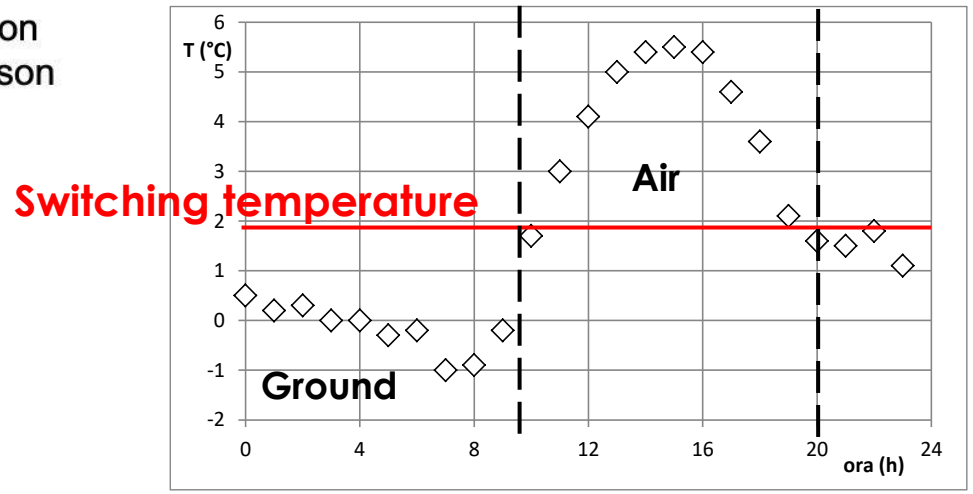
DSHP modeling



ALMABuild, a Matlab-Simulink toolbox

Switching temperature logic

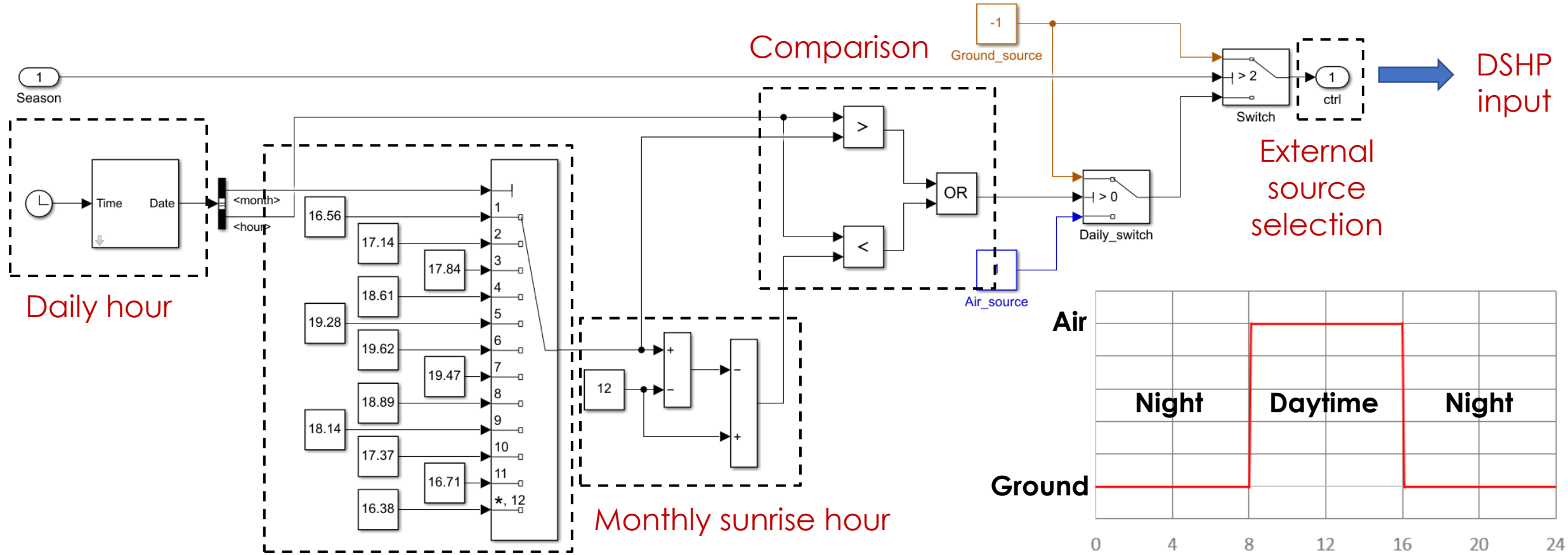




Typical winter day

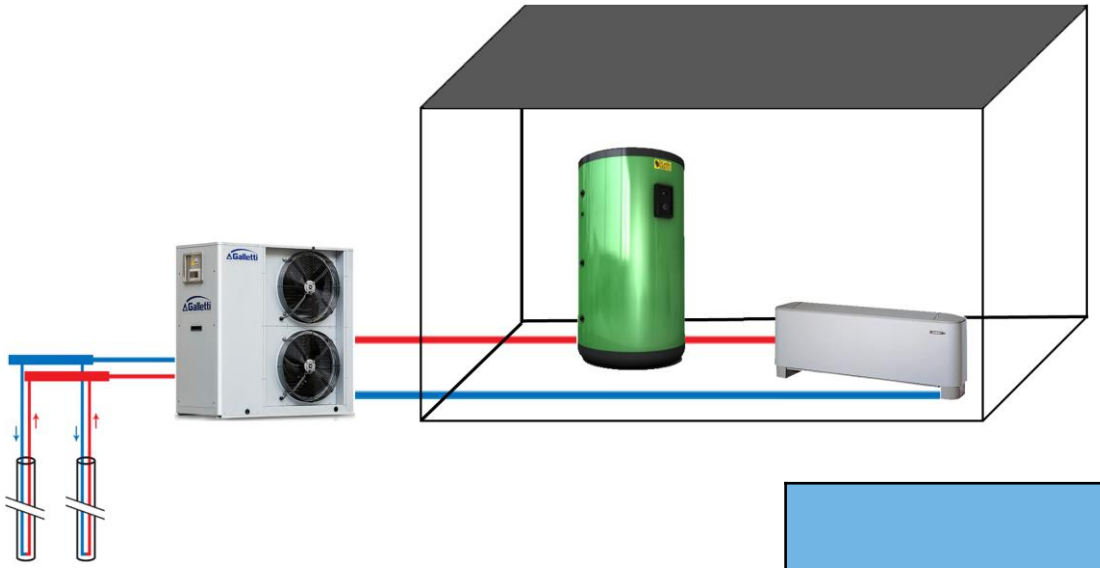
ALMABuild, a Matlab-Simulink toolbox

Scheduled times logic



Description of the case study

Building and **HVAC system**



Design conditions:
T external air: **-7 °C**
Tin load: 35 °C

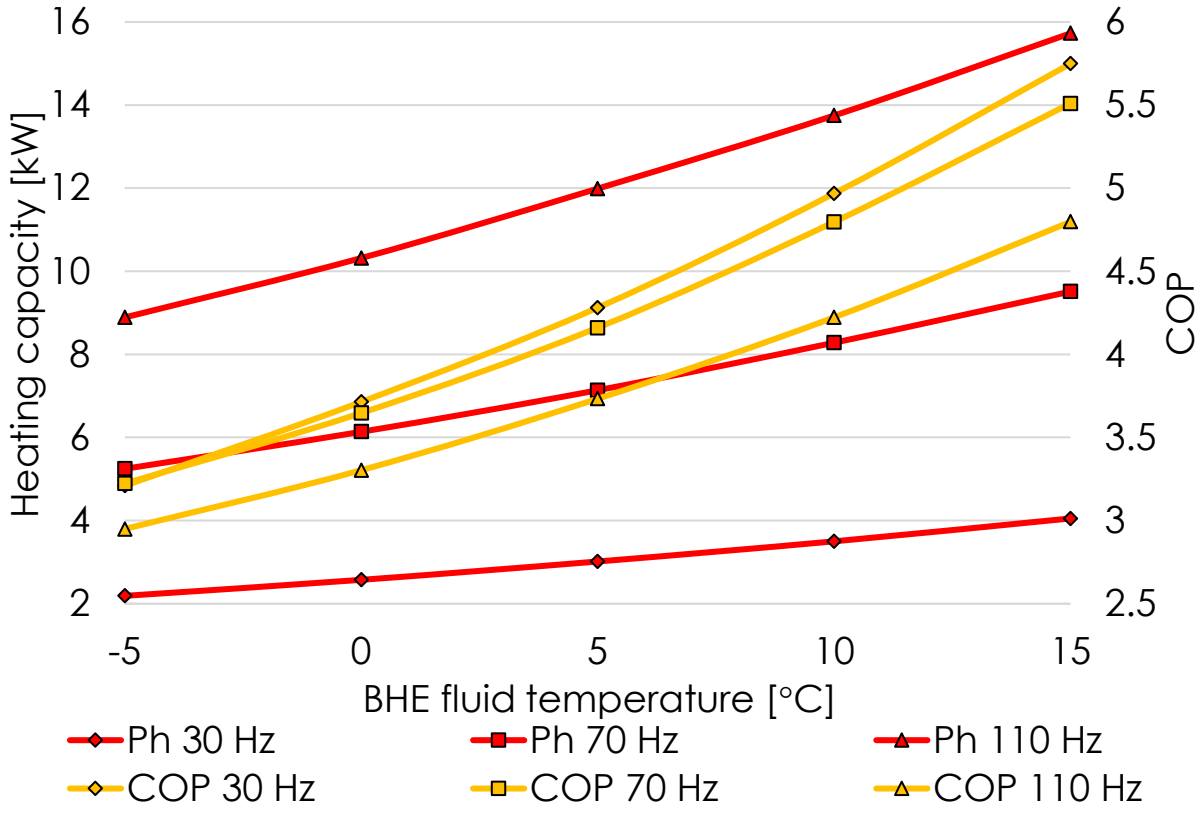
Design conditions:
T out borehole: **-5 °C**
Tin load: 35 °C

Unbalanced loads

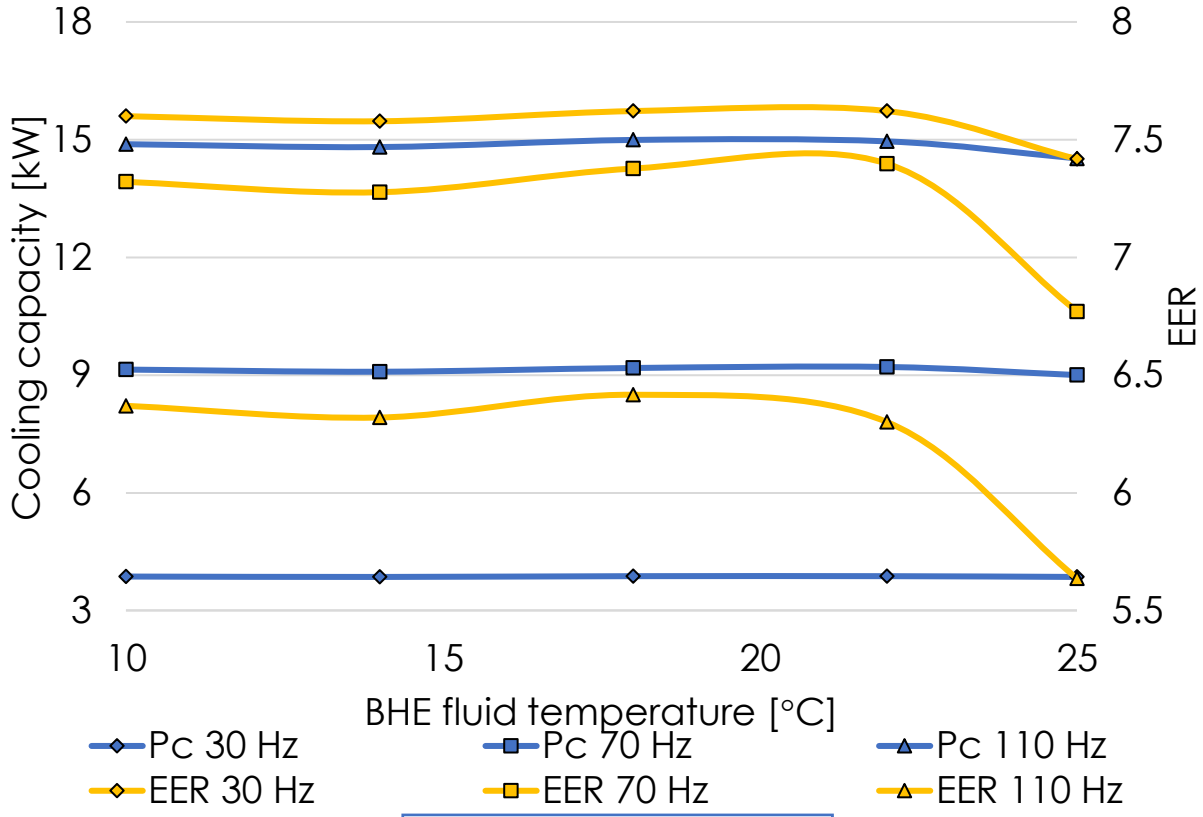
	Heating [kW]	Cooling [kW]
Thermal load	6.15	1.66
ASHP capacity	8.51	3.55
GCHP capacity	8.89	3.86

Description of the case study

DSHP performance map, **Ground-Source** mode



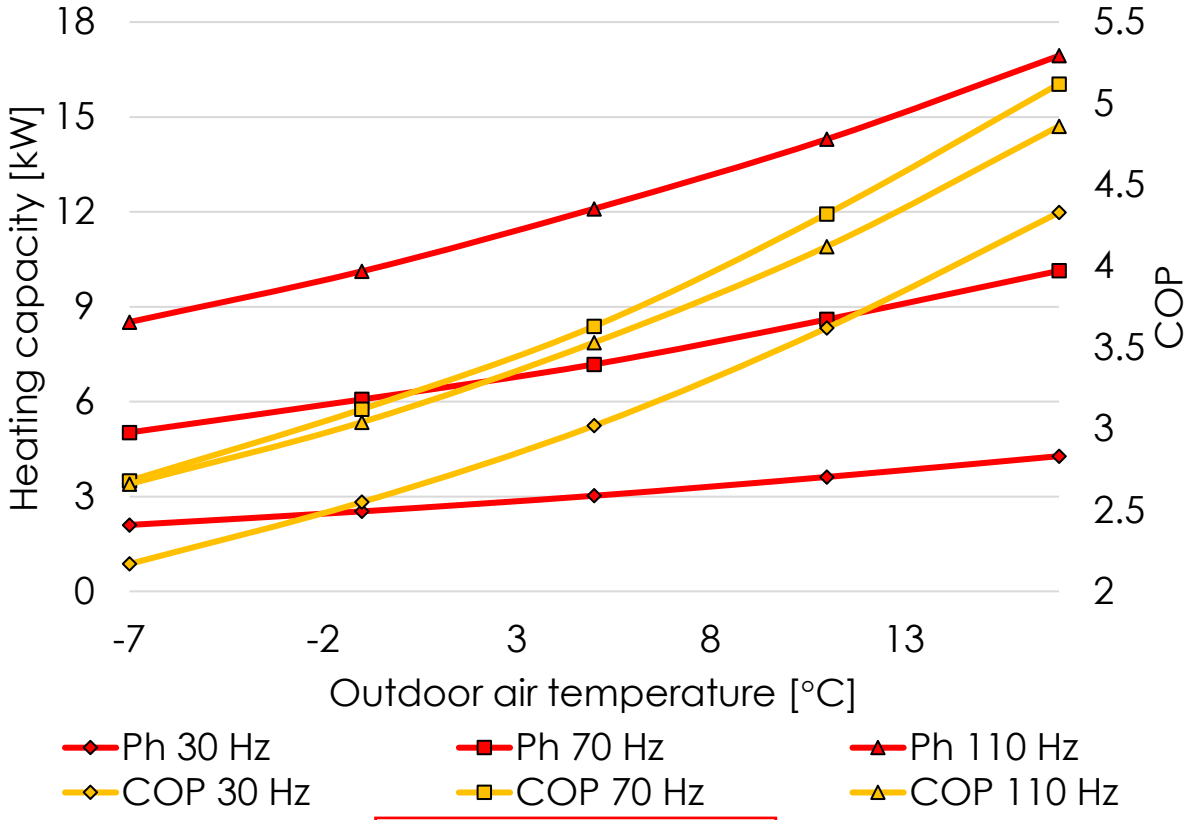
Tin load 35 °C
Tout load 40 °C



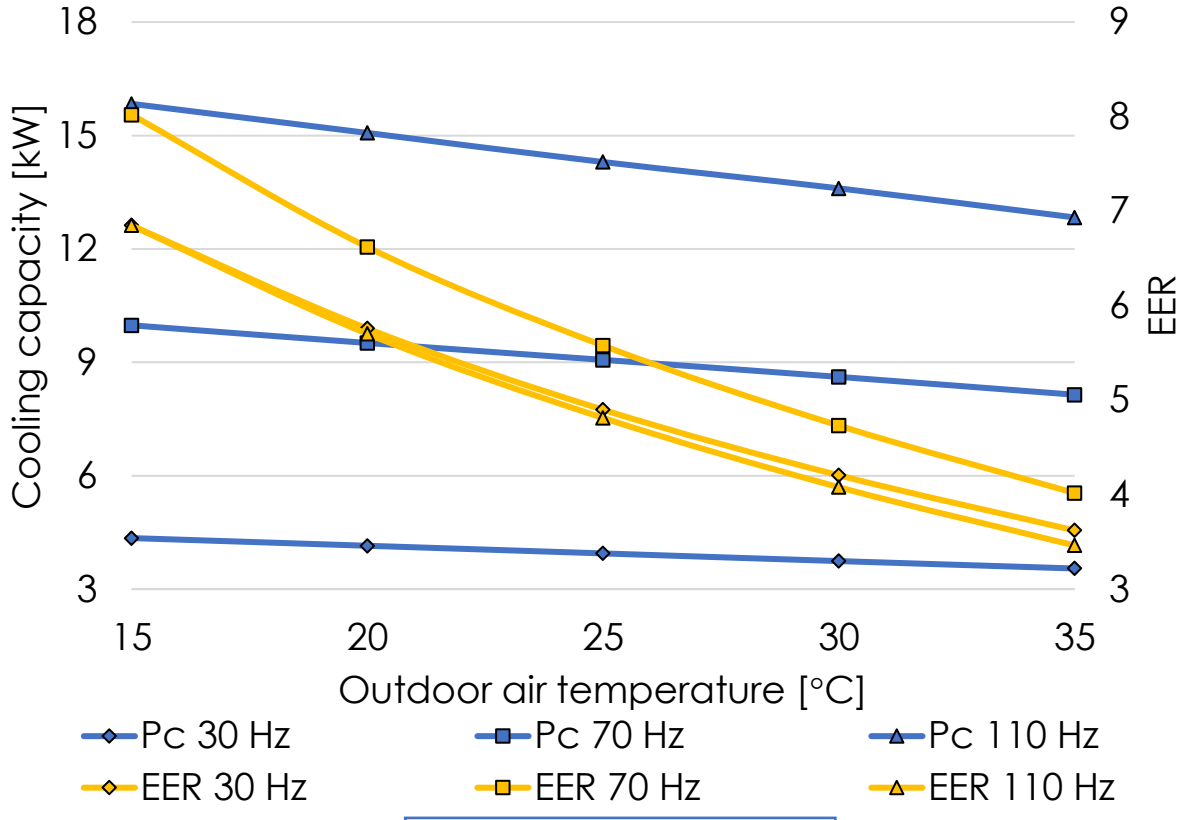
Tin load 15°C
Tout load 10 °C

Description of the case study

DSHP performance map, **Air-Source** mode



Tin load 35 °C
Tout load 40 °C



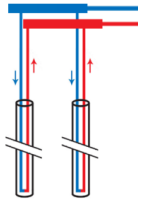
Tin load 15°C
Tout load 10 °C

Description of the case study

Configurations of HVAC system

Case **A**: HVAC system based on an inverter-driven **GCHP**

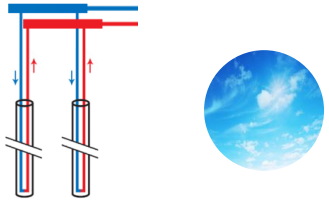
2 boreholes 60 m each (120m tot)



Case **B**: HVAC system based on an inverter-driven **ASHP**

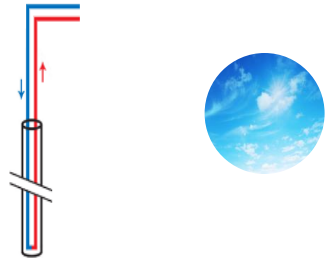
Cases **C** and **D**: HVAC system based on an inverter-driven **DSHP**

2 boreholes 60 m each (120 m tot) (**100%** length)



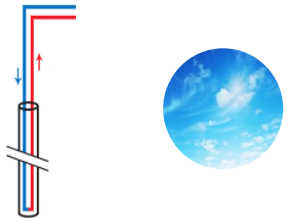
C1

1 borehole 90 m long (**75%** length)



C2

1 borehole 70 m long (**60%** length)



C3

1 borehole 60 m long (**50%** length)

C4

Switching temperature logic

Case **D**

Scheduled times logic

Results

Key Performance Indicators (**KPIs**)

$$SCOP = \frac{\sum_{i=0}^{t_h} E_{h,i}}{\sum_{i=o}^{t_h} E_{el,i}}$$

Seasonal Coefficient of Performance

$$SEER = \frac{\sum_{i=0}^{t_c} E_{c,i}}{\sum_{i=o}^{t_c} E_{el,i}}$$

Seasonal Energy Efficiency Ratio

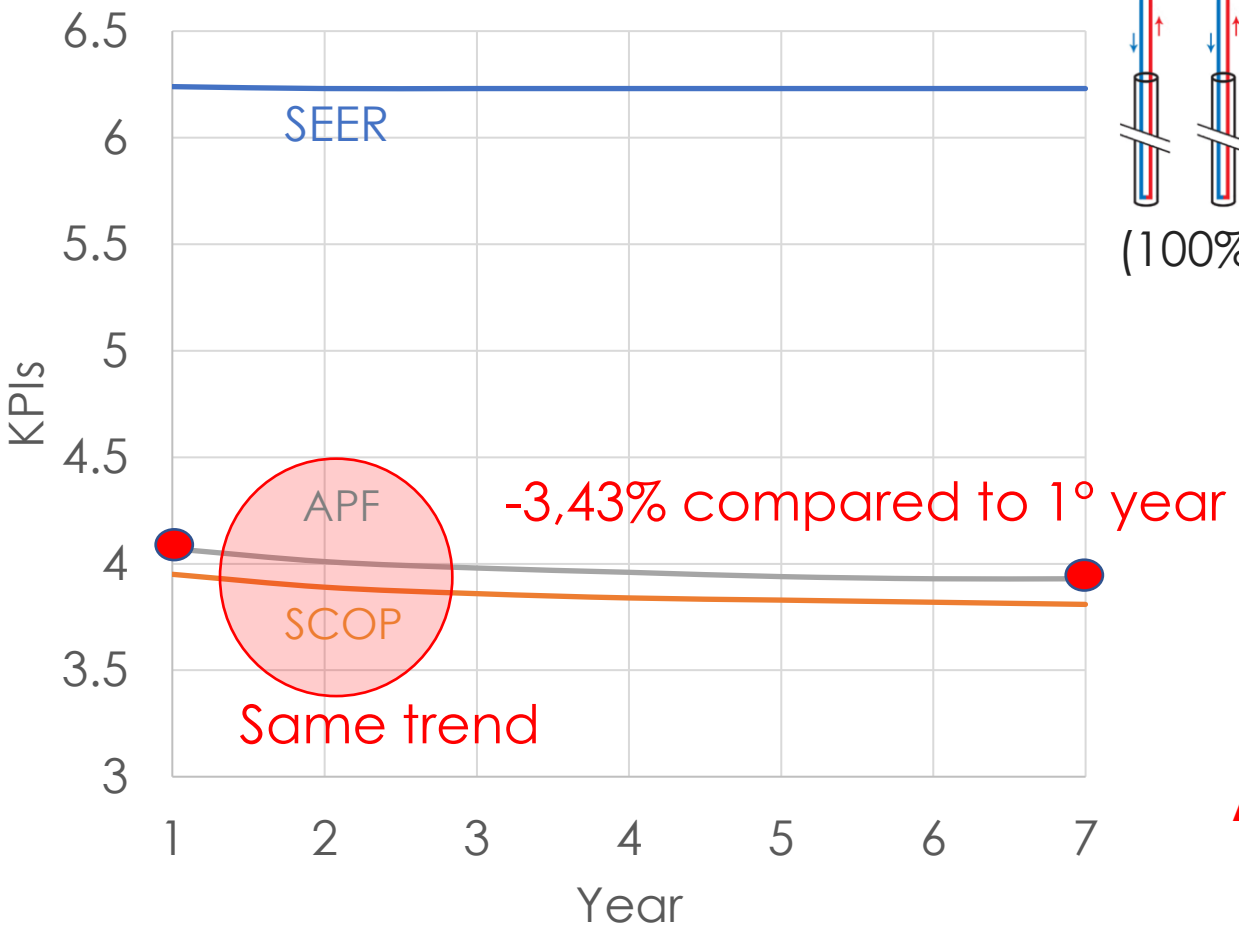
$$APF = \frac{\sum_{i=0}^{t_h+t_c} E_{h,i} + E_{c,i}}{\sum_{i=o}^{t_h+t_c} E_{el,i}}$$

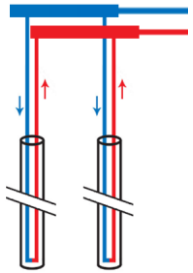
Annual Performance Factor

Results

Case **A** and case **B**

GCHP Case **A**





(100%)

ASHP Case **B**

SEER	SCOP	APF
4.06	2.80	2.87
-35%	-40%	-27%

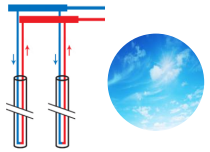
Compared to **GCHP**

ASHP performs a large number of on-off cycles

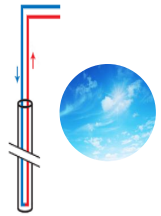
Results

Cases **C**, **DSHP**, **switching temperature** logic

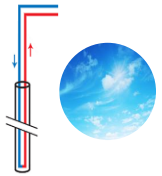
C1 (100%)



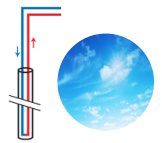
C2 (75%)

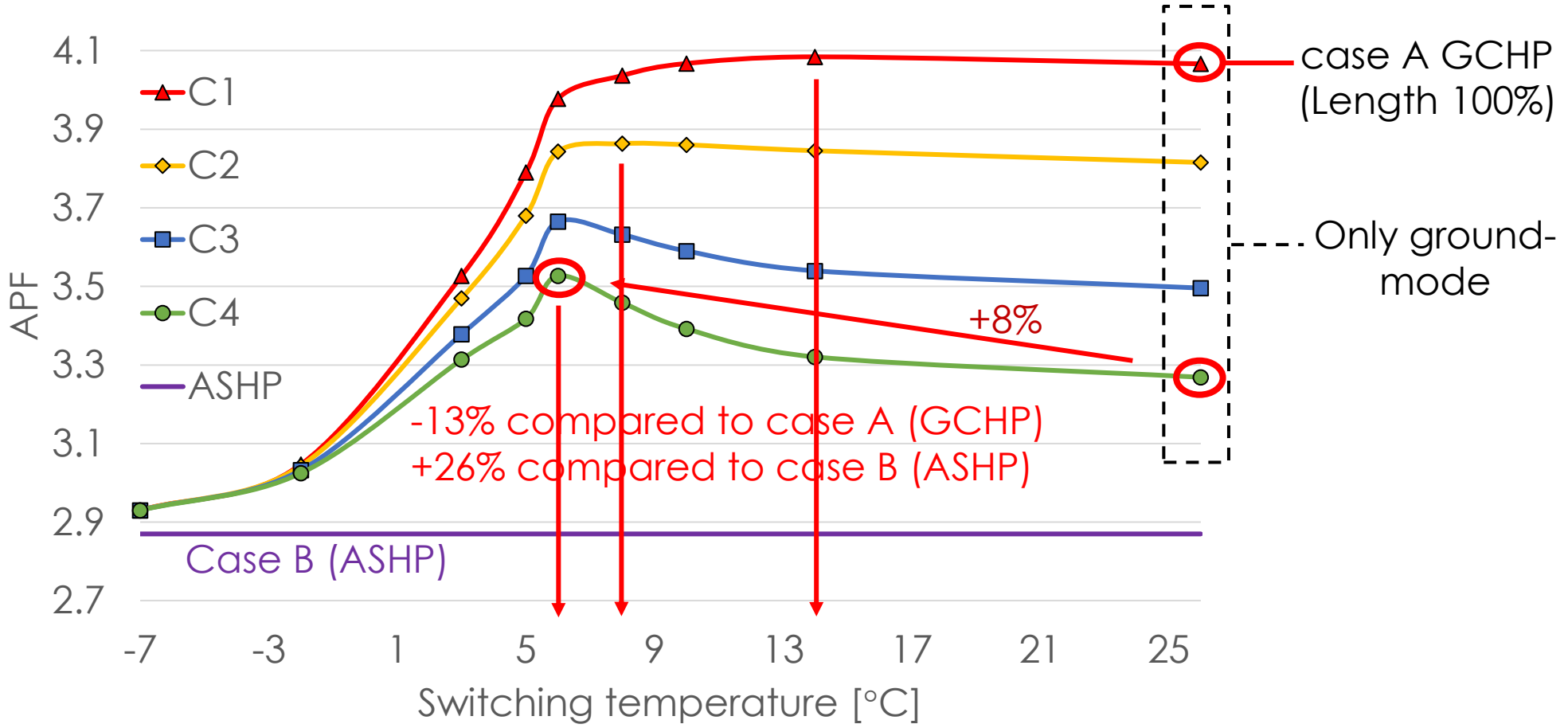


C3 (60%)



C4 (50%)

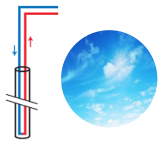




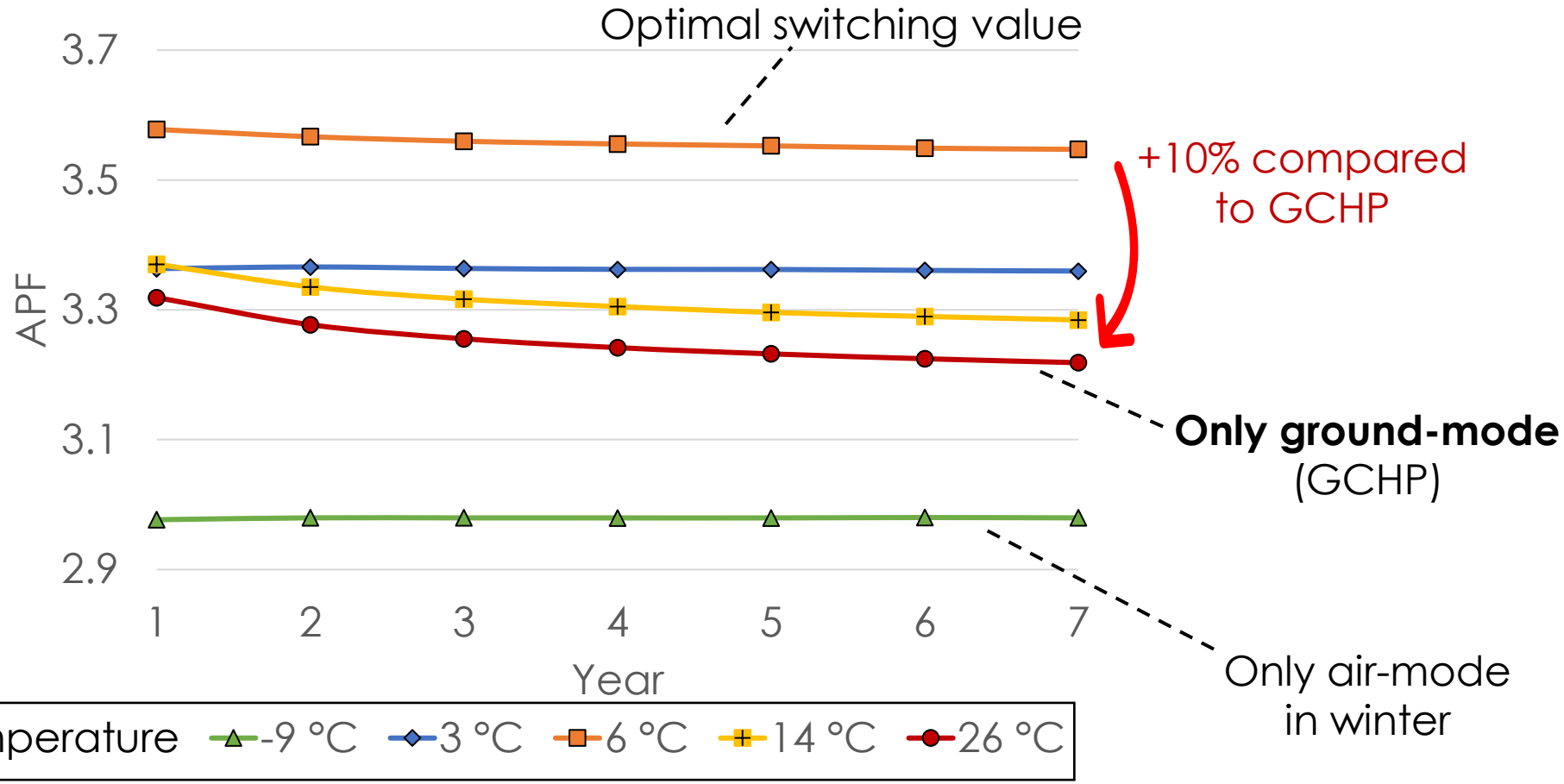
Results

Cases **C4**, **DSHP**, **switching temperature** logic

C4
(50%)

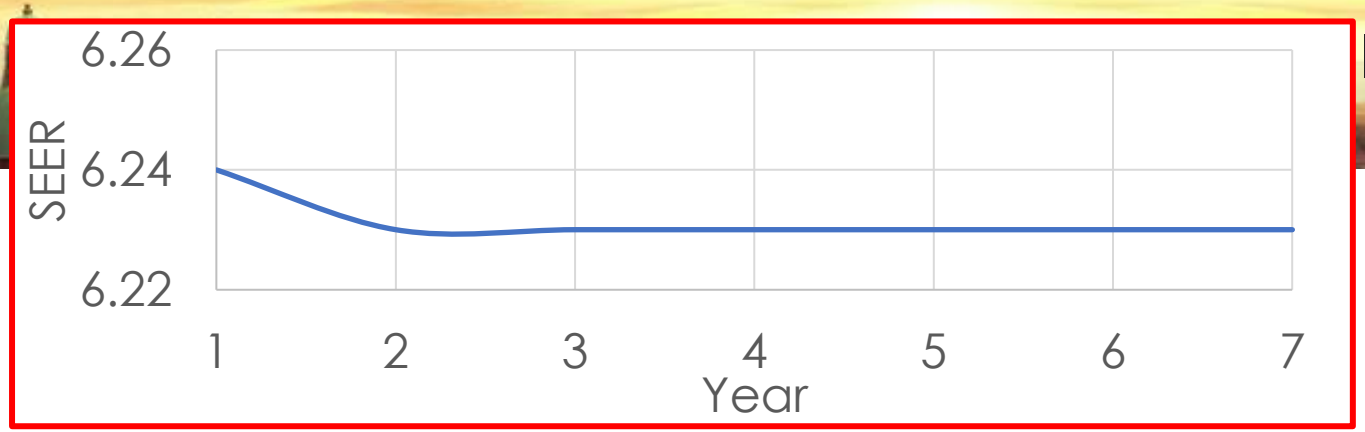


Different **switching temperatures** and **7-years** analysis



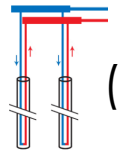
Results

logic



D
(50%)

Case A



(100%)

7-years analysis

Year	1	2	3	4	5	6	7
SEER	6.23	6.23	6.23	6.23	6.24	6.24	6.24
SCOP	3.26	3.25	3.25	3.24	3.24	3.23	3.23
APF	3.38	3.37	3.37	3.36	3.36	3.36	3.35

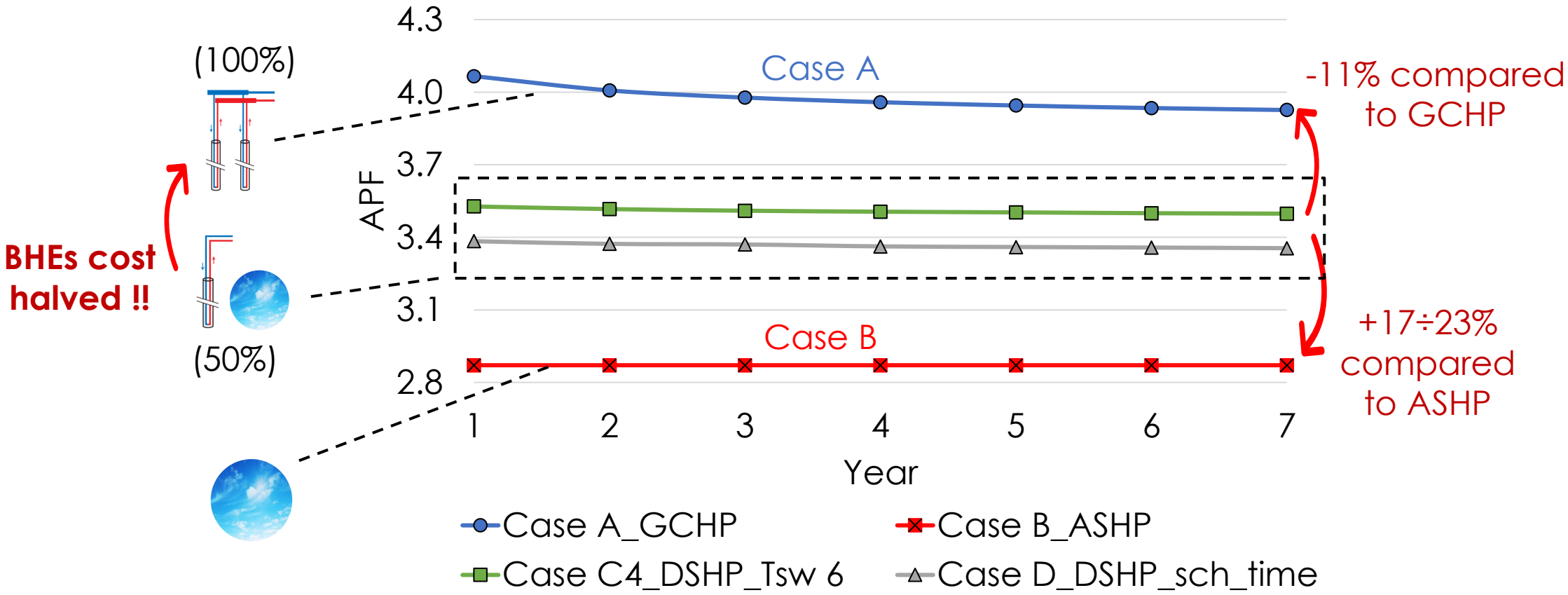
-1% only

Same performance of case **A** but with **halved** BHE !!

Balancing of the building loads

Results

Comparison



Conclusion and future developments

- ✓ **Dynamic model** of a **DSHP** developed with **ALMABuild**
- ✓ **Switching temperature** logic with better efficiency compared to **scheduled times** logic
- ✓ **Long-term performance DSHP**: **-11%** compared to **GCHP**, **+23%** compared to **ASHP** (**BHE length** reduced by **50%**), **limited** ground **temperature drift**
- ➢ Future developments: **experimental validation** with dynamic tests, **new control strategies**

Thanks for you attention

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