Long term performance analysis of a Dual-Source Heat Pump system by means of the Matlab/Simulink tool ALMABuild

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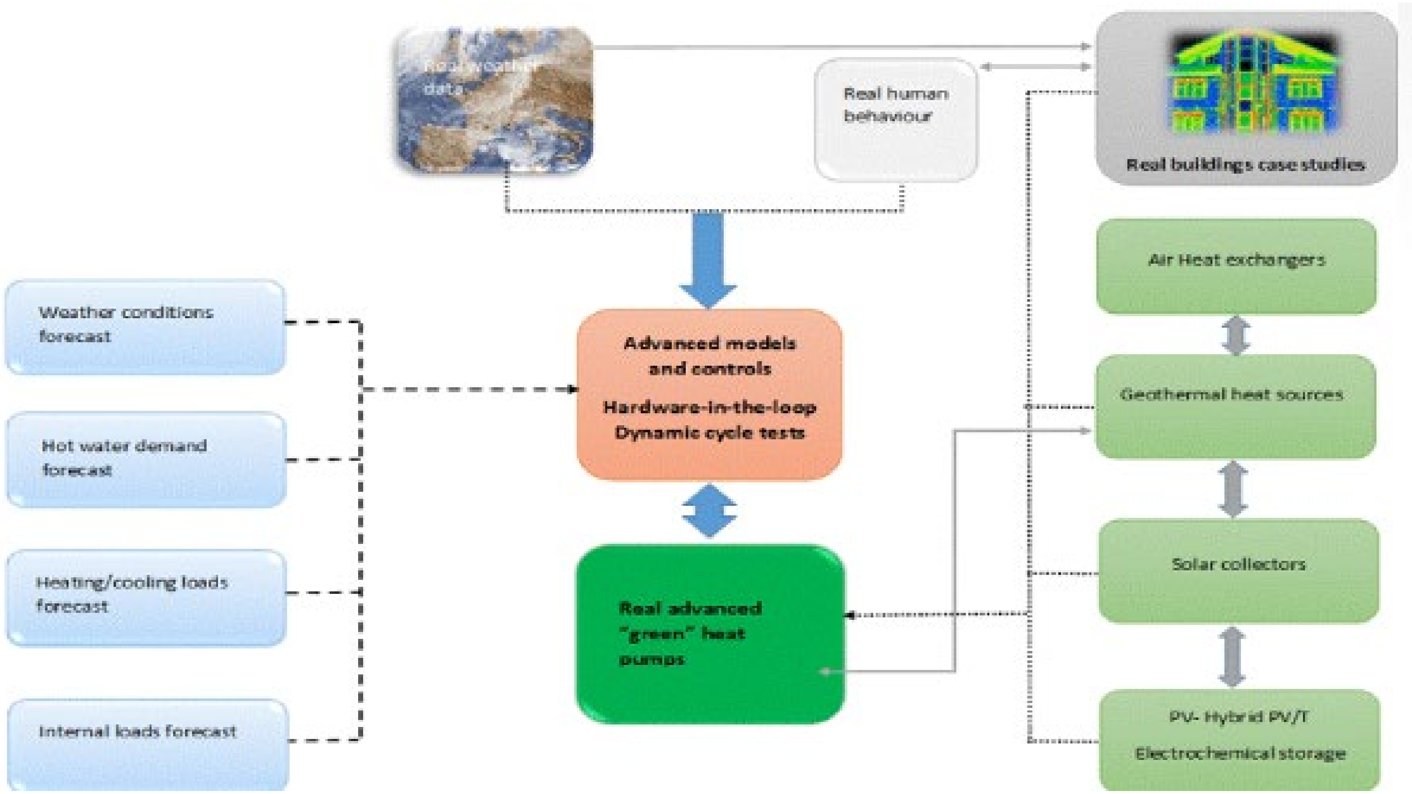
Project and Funding

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



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https://prin.mur.gov.it

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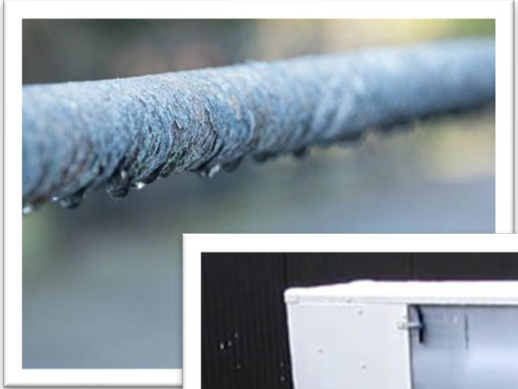
- **Traditional** and **Dual-Source** Heat Pumps (DSHPs)
- **ALMABuild**, an open-source Matlab-Simulink tool
- **Methodology**: **numerical model** of a DSHP and description of the **case study**
- **Results** of **numerical simulations**
- **Conclusions** and future developments

Traditional and Dual-Source Heat Pumps

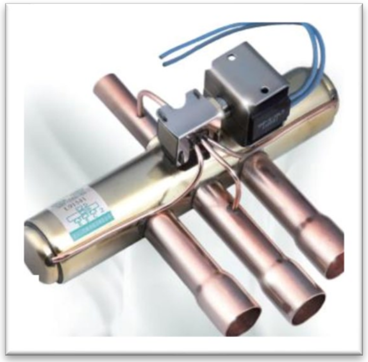
Air-Source Heat Pump (**ASHP**)

Brine deposition



Defrosting

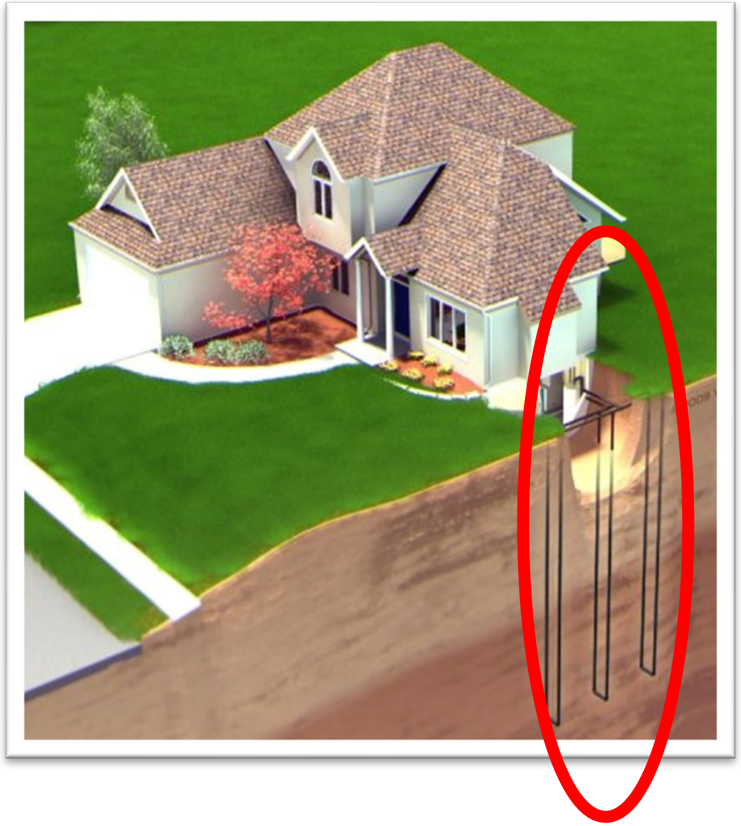
Reversing cycle



4-way valve

Traditional and Dual-Source Heat Pumps

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



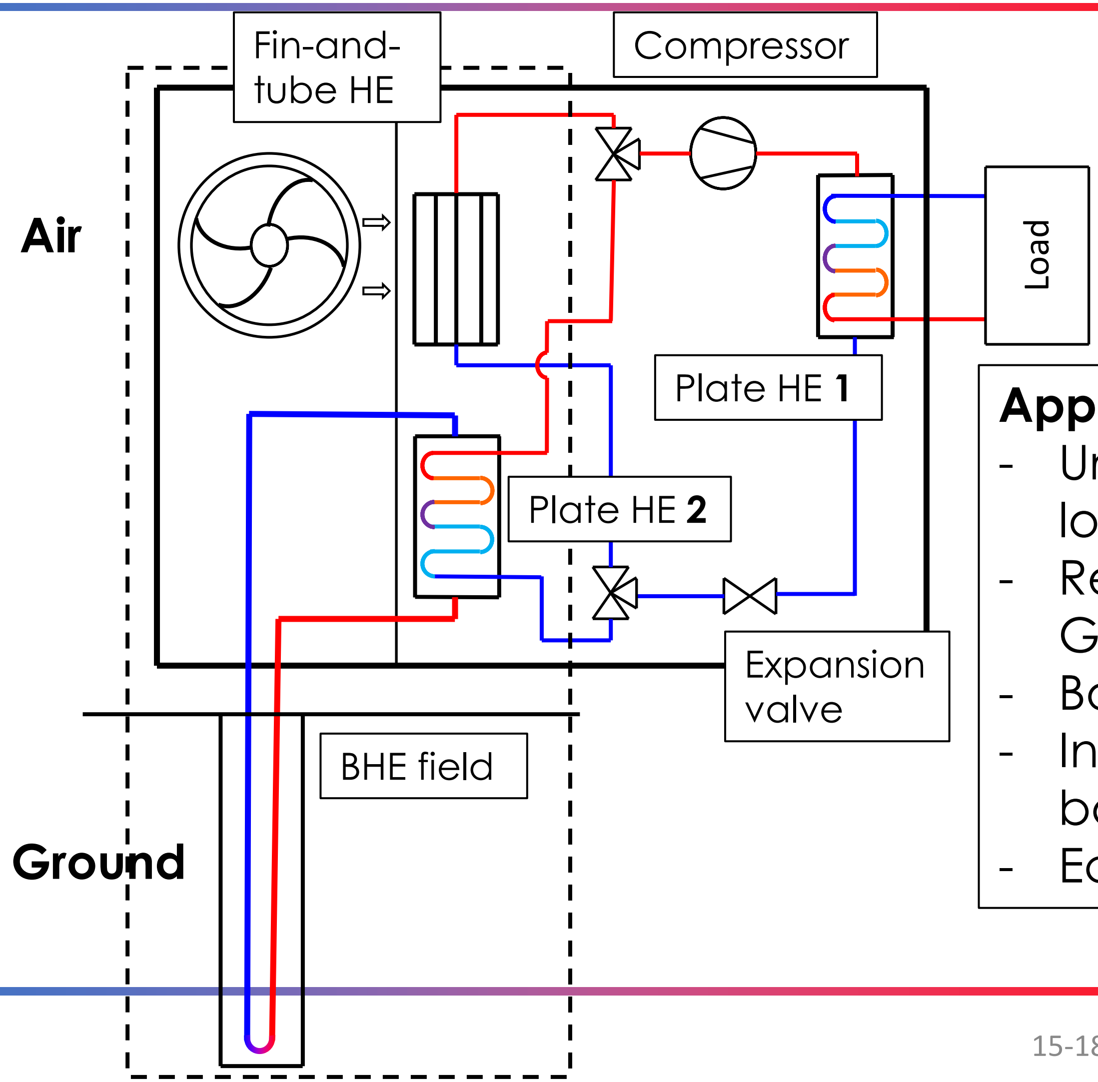
Vertical Borehole Heat Exchangers (BHEs)

Drilling machine

Borehole head

Traditional and Dual-Source Heat Pumps

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



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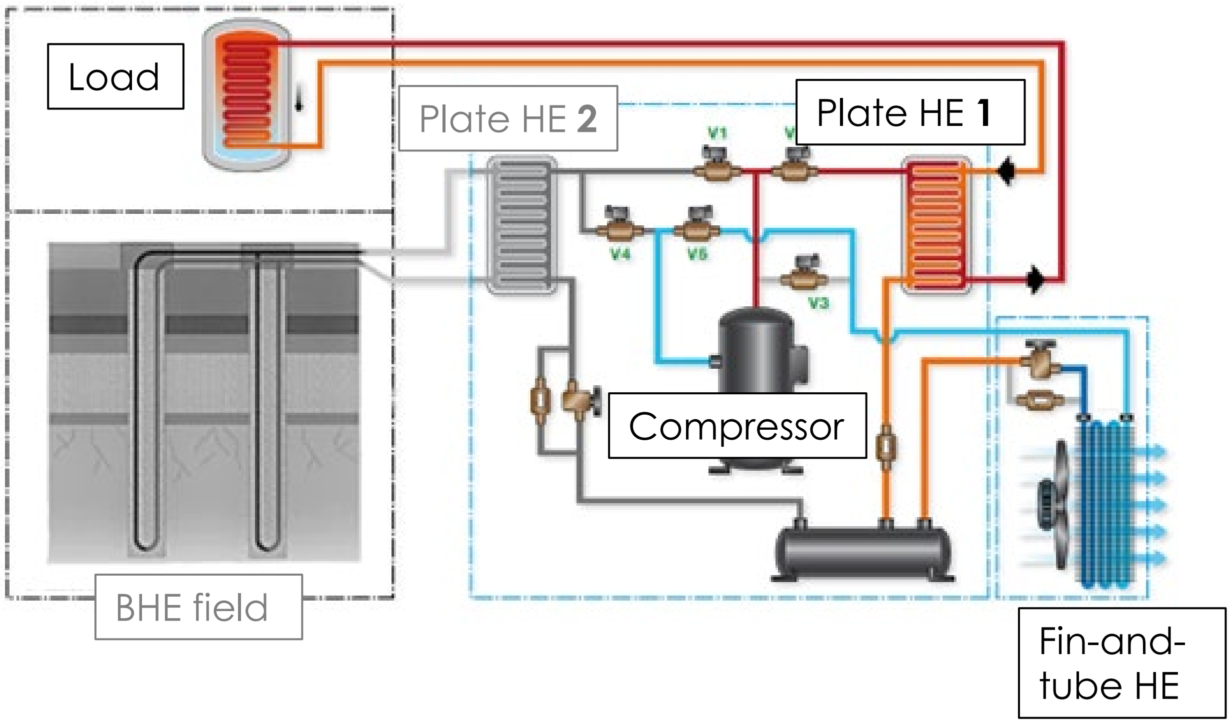
POR FESR EMILIA-ROMAGNA 2014/2020
RegioneEmilia-Romagna

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

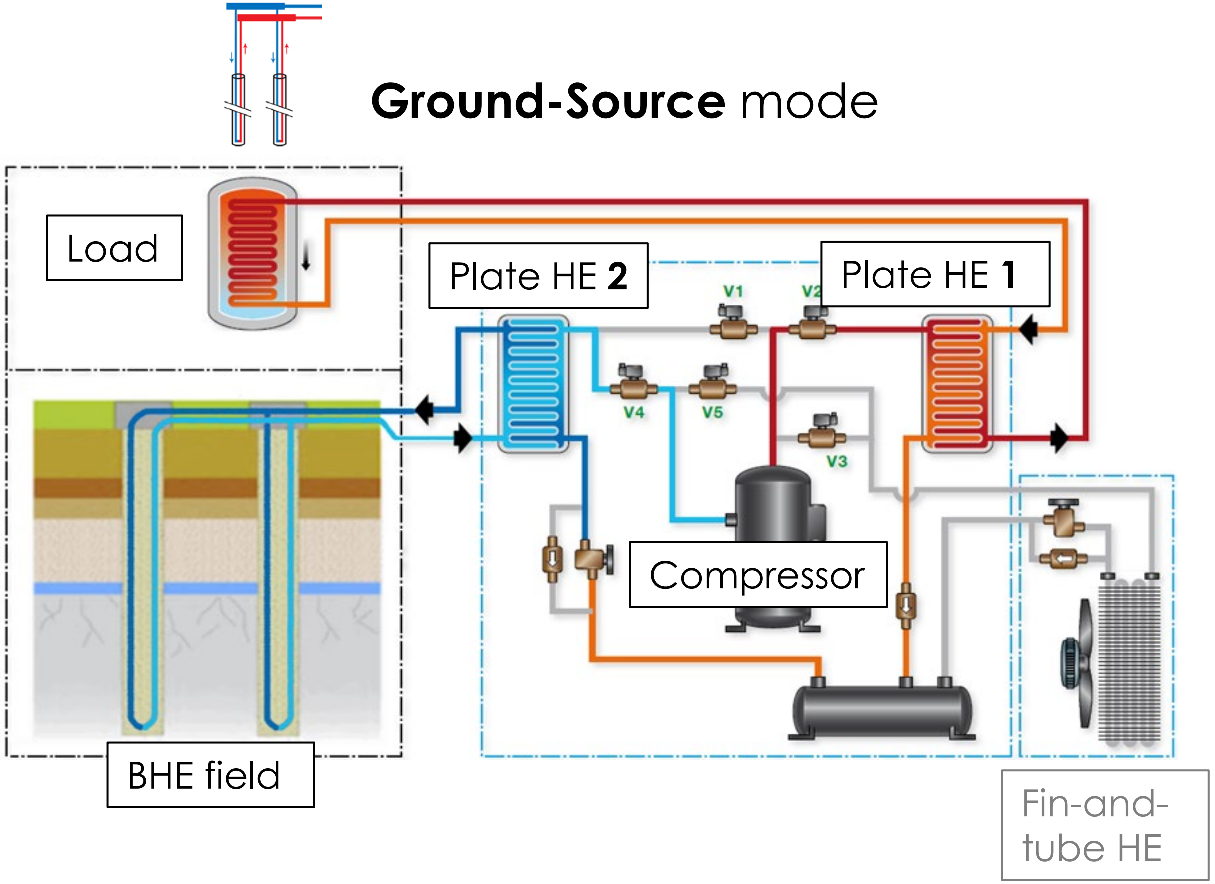
Traditional and Dual-Source Heat Pumps

Dual-Source Heat Pump **DSHP**, **Heating**

Air-Source mode

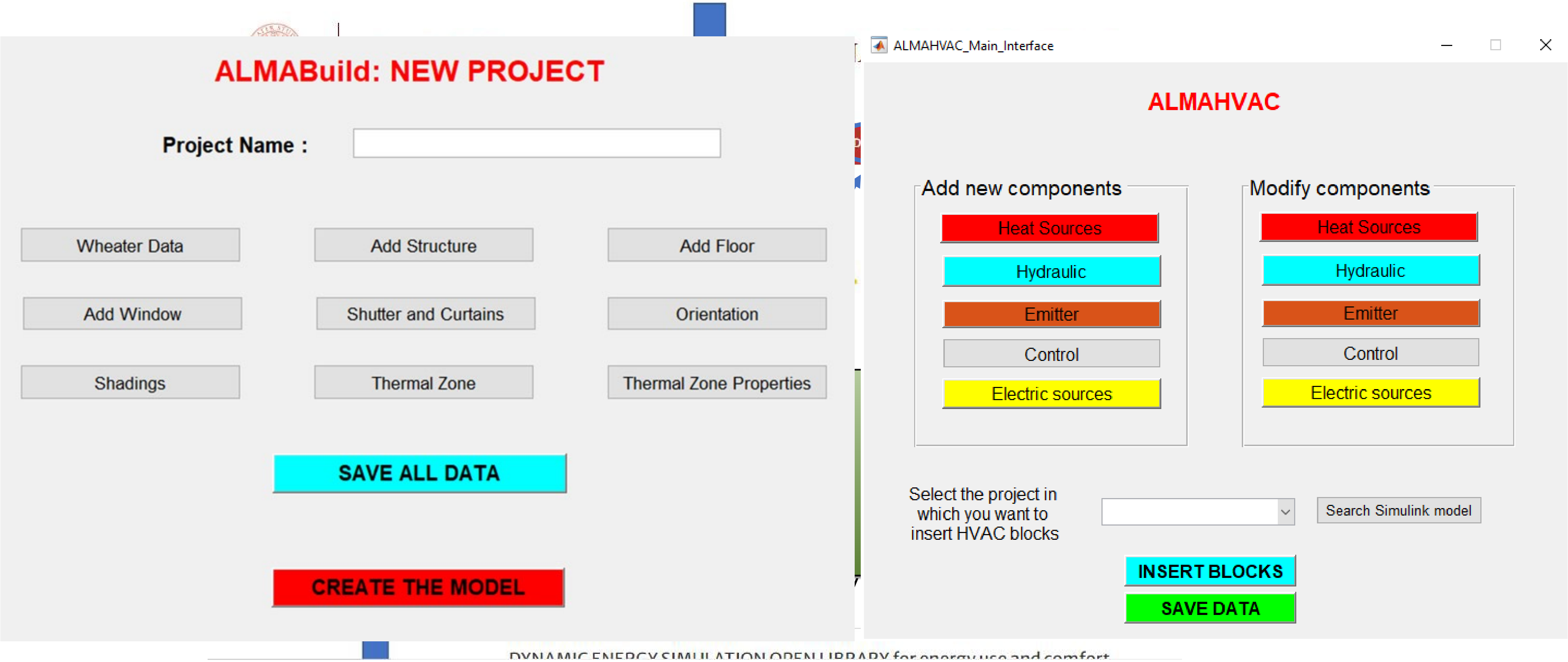


Ground-Source mode



ALMABuild, a Matlab-Simulink toolbox

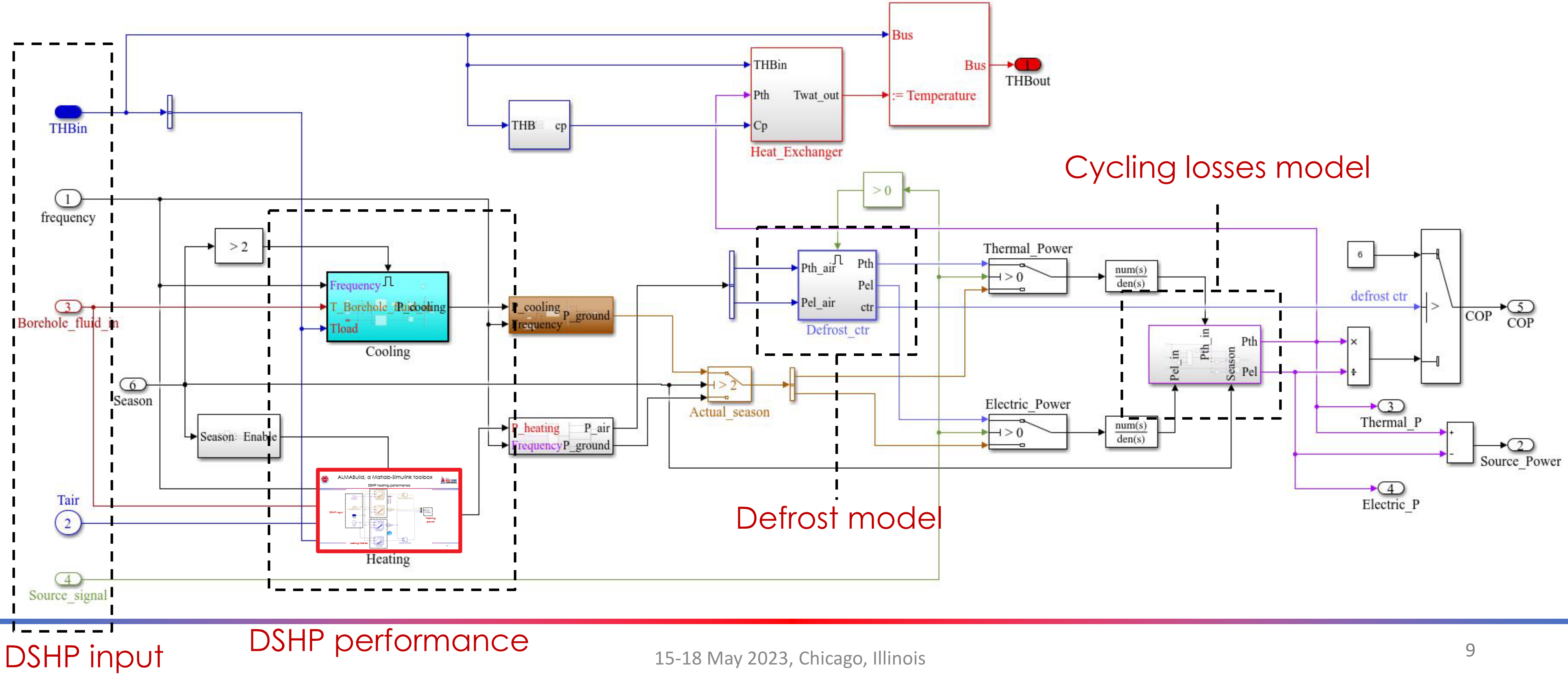
Open-source tool operating in the Simulink environment for the simulation of coupled **building-HVAC** systems under dynamic thermal conditions



https://site.unibo.it/almabuild/it

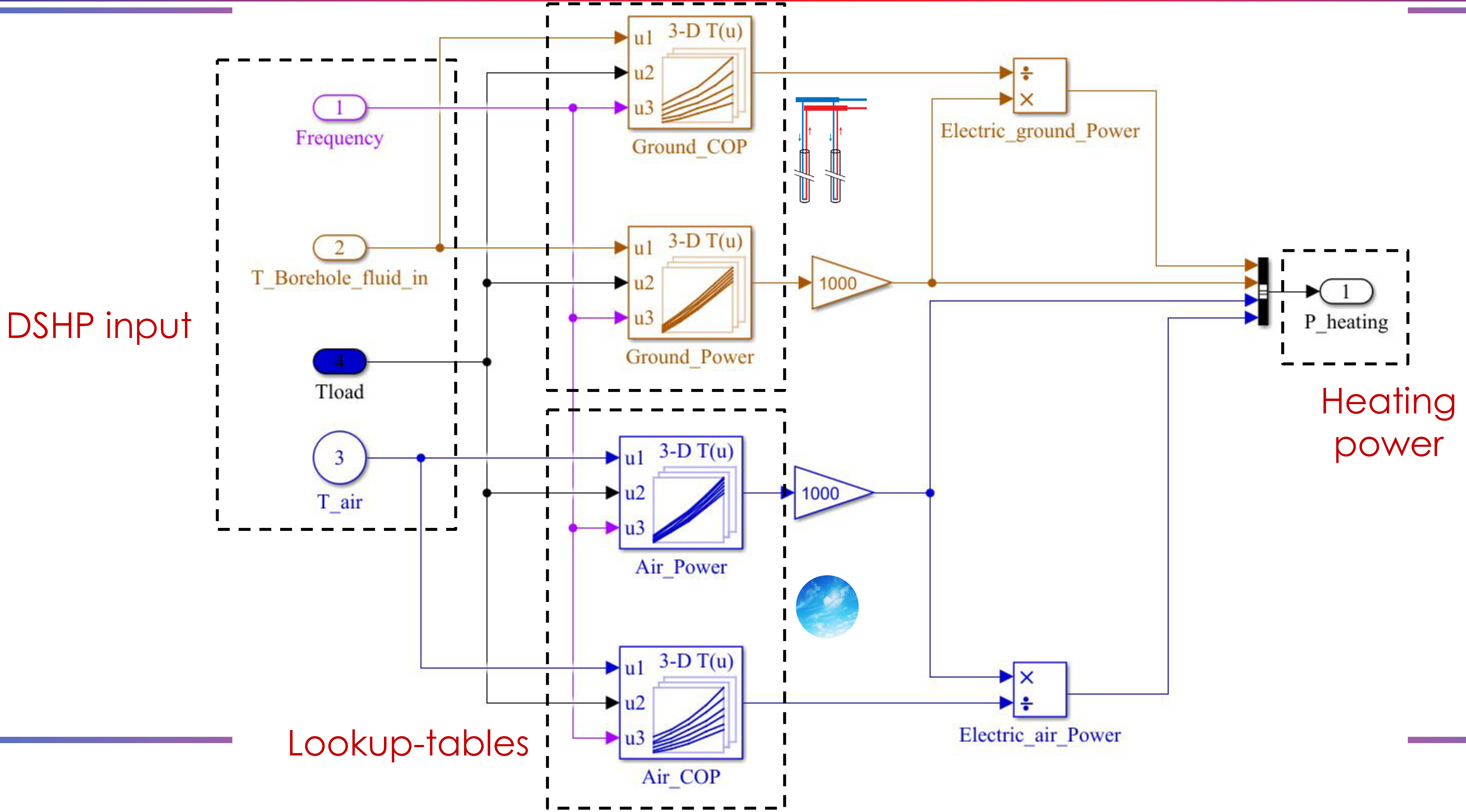
ALMABuild, a Matlab-Simulink toolbox

DSHP modeling



ALMABuild, a Matlab-Simulink toolbox

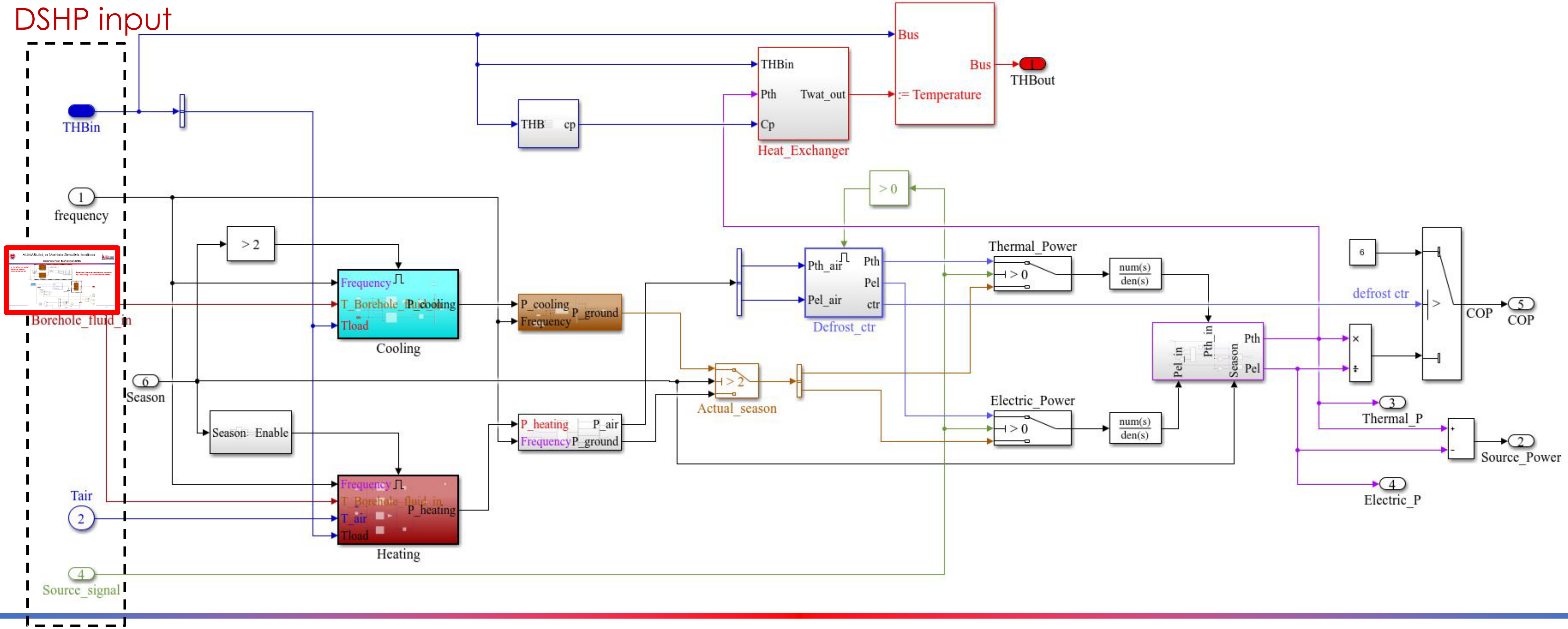
DSHP heating performance



ALMABuild, a Matlab-Simulink toolbox

DSHP modeling

DSHP input

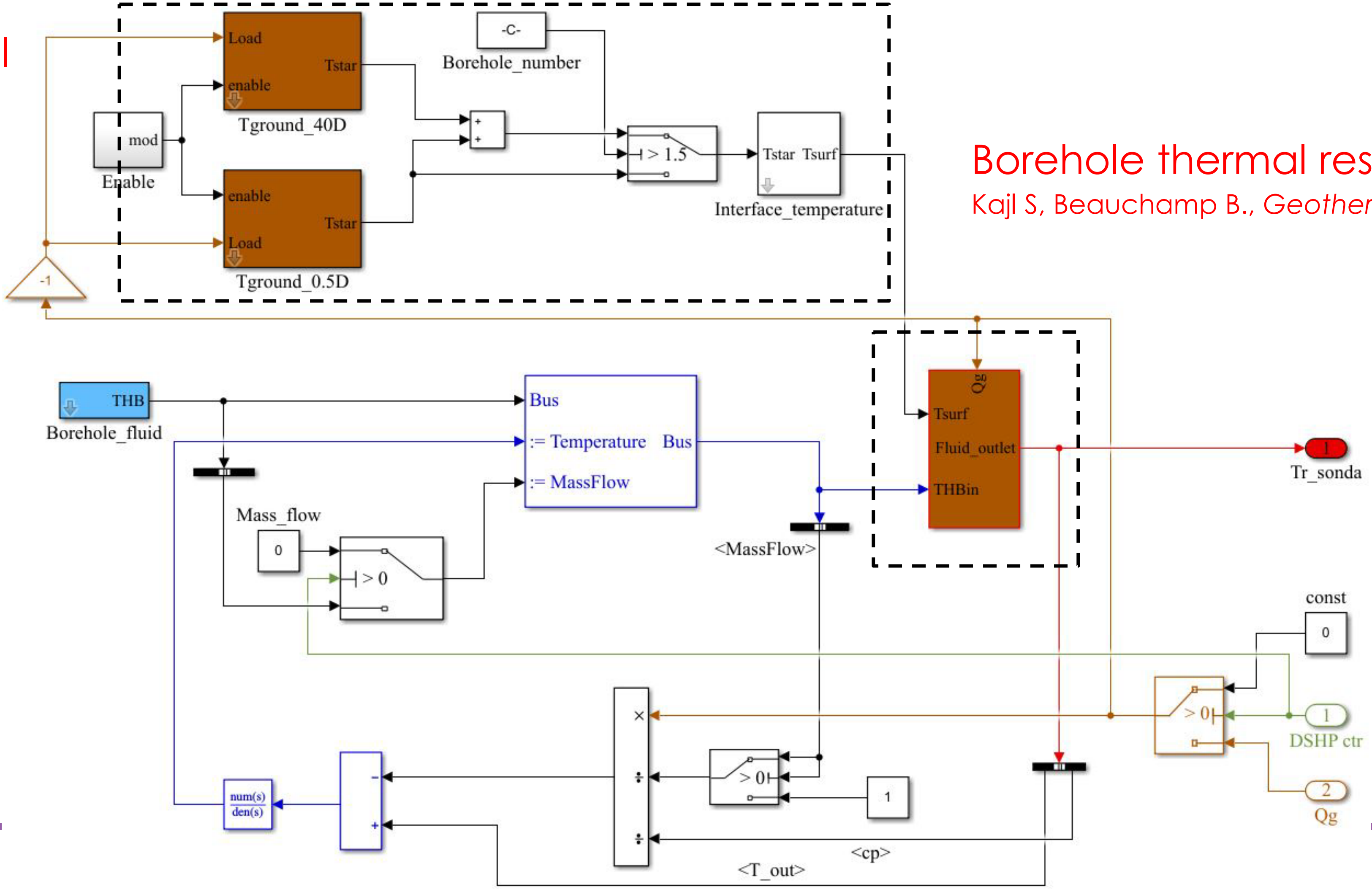


ALMABuild, a Matlab-Simulink toolbox

Borehole Heat Exchangers **BHEs**

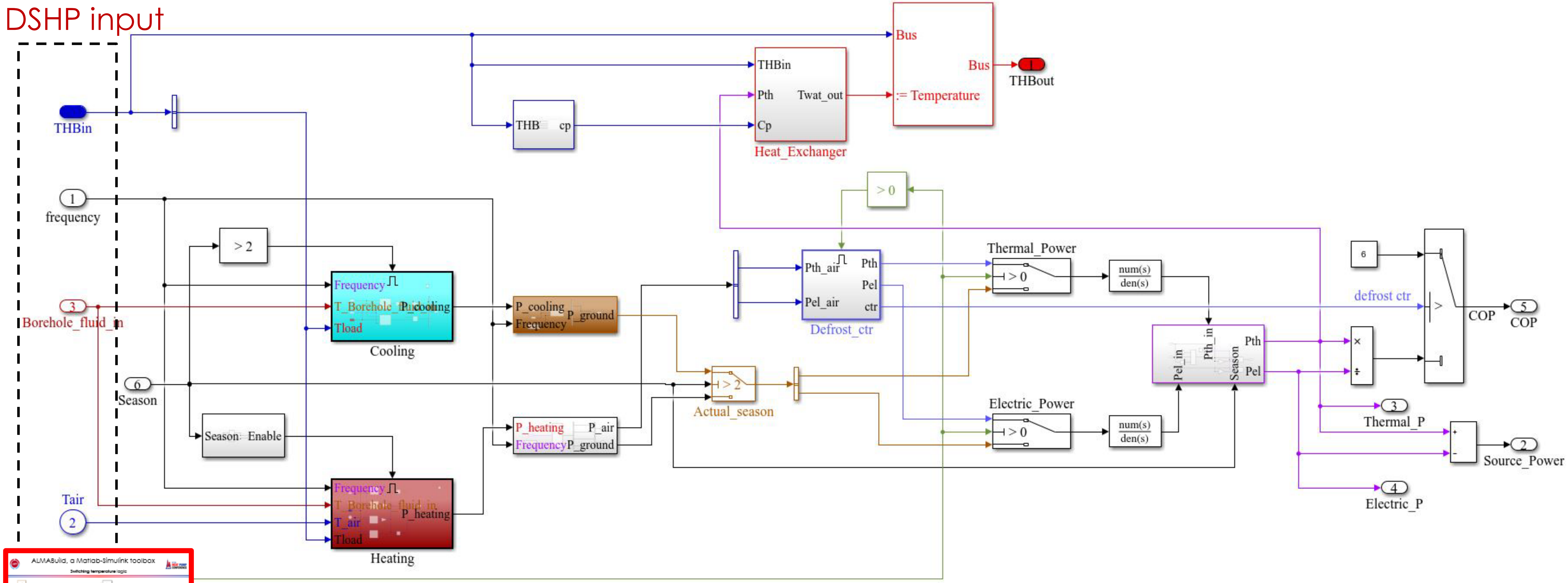
g-functions model
(Zanchini E, Lazzari S., *Energy* 2013;**59**:570–80)

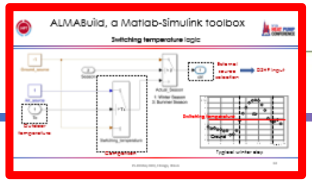
Borehole thermal resistance (Lamarche L, Kajl S, Beauchamp B., *Geothermics* 2010;**39**:187–200)



ALMABuild, a Matlab-Simulink toolbox

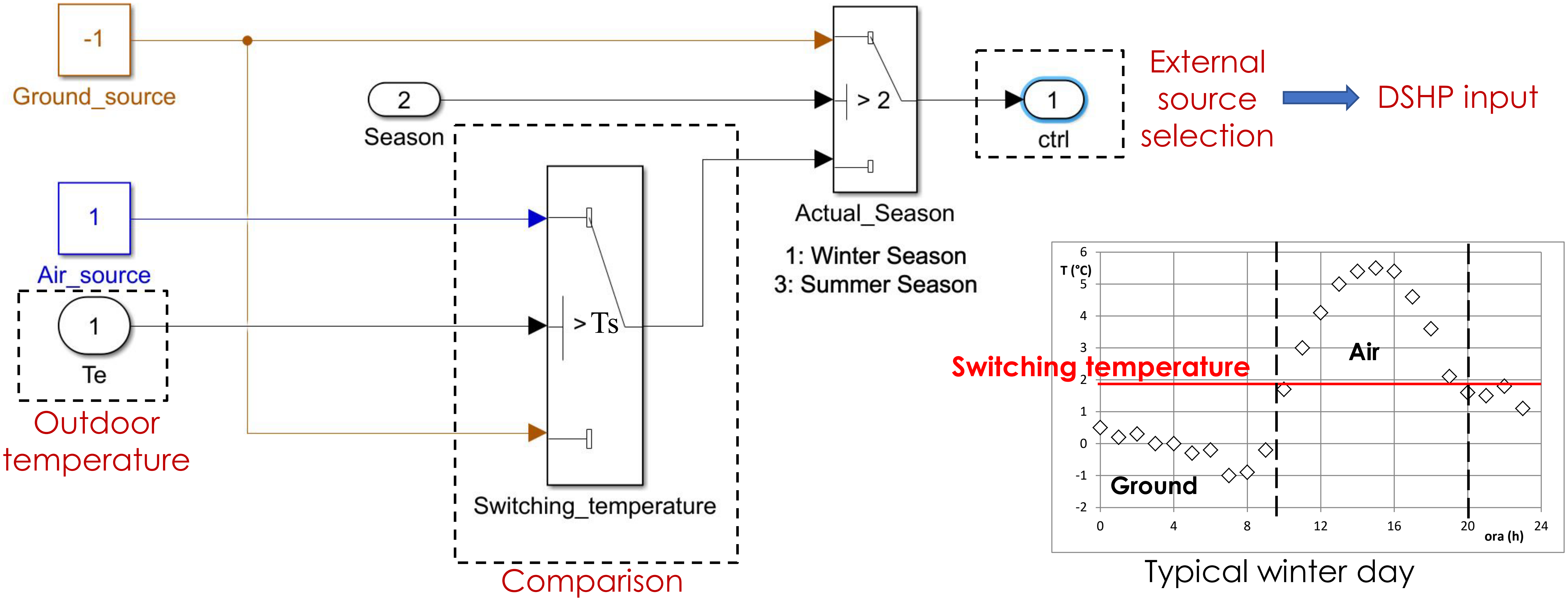
DSHP modeling





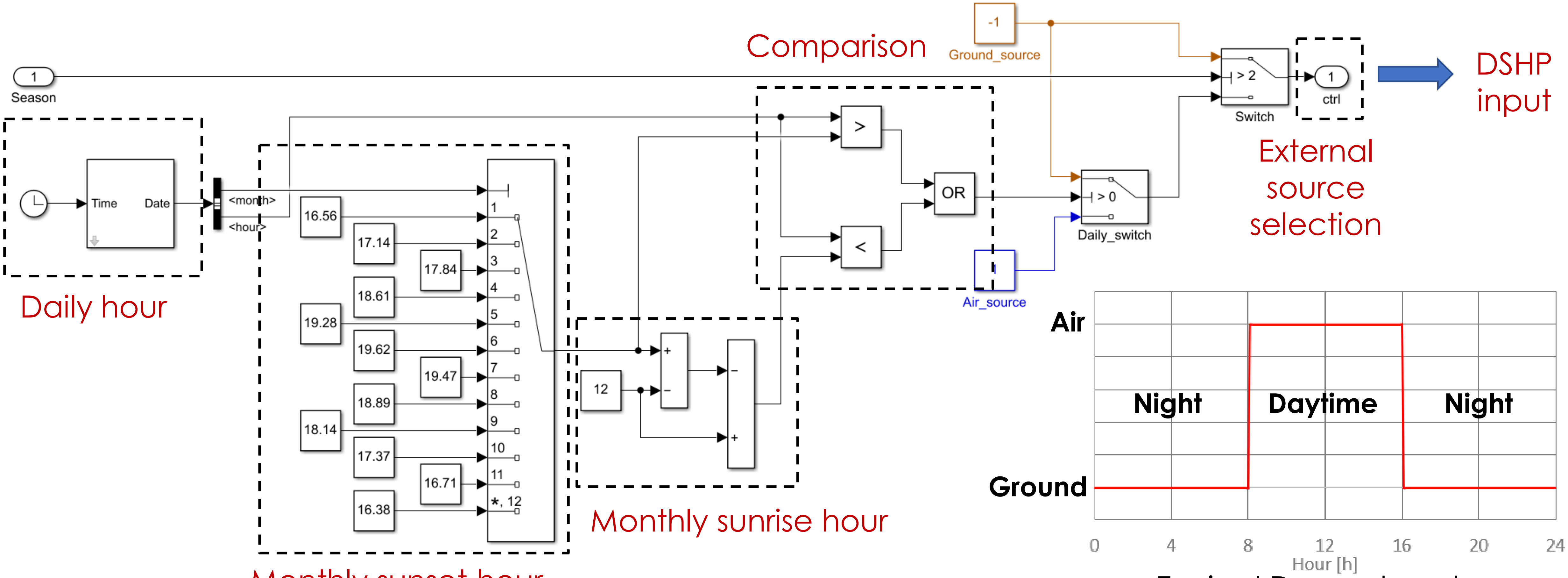
ALMABuild, a Matlab-Simulink toolbox

Switching temperature logic



ALMABuild, a Matlab-Simulink toolbox

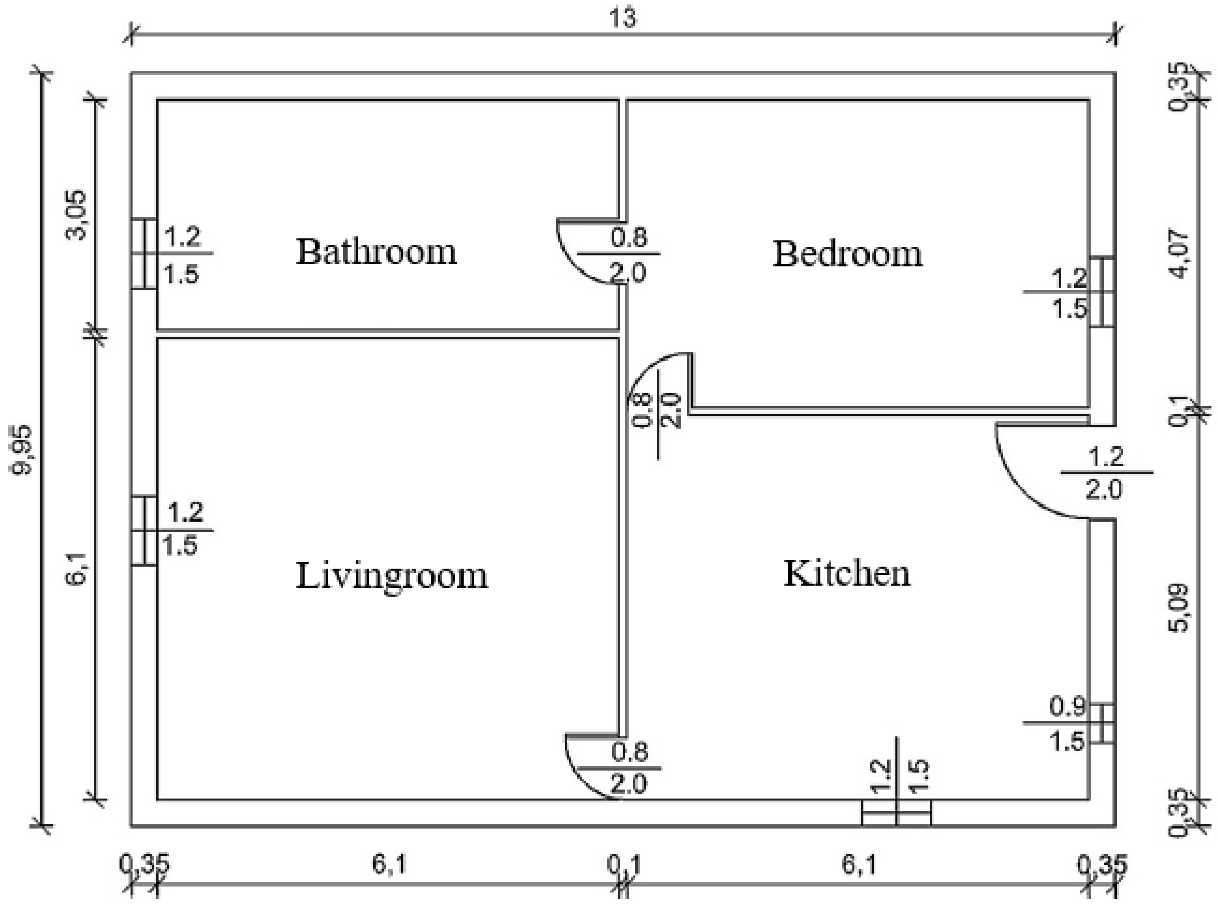
Scheduled times logic



Typical December day

Description of the case study

Building and **HVAC system**



2-pipe fan coils as emitters

Thermal storage 500 lt

Description of the case study

Building **thermal loads**

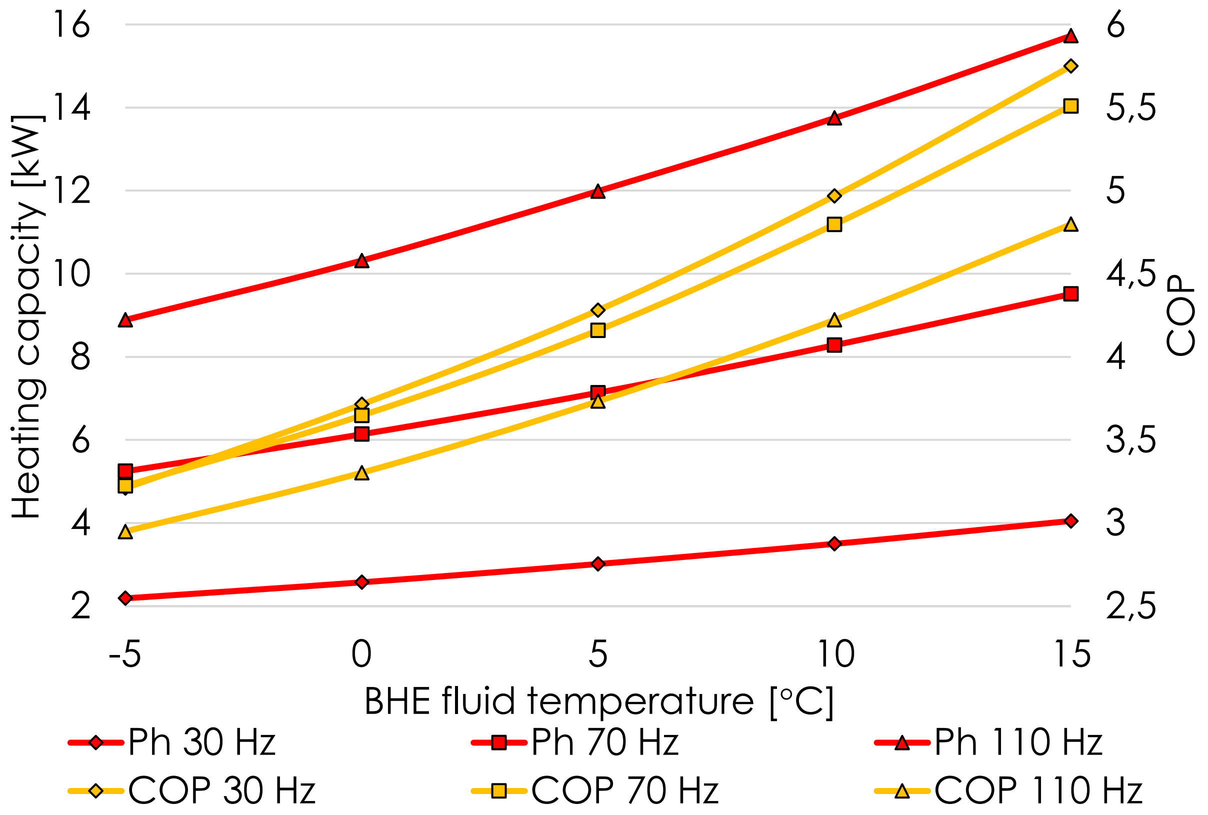
	Heating [kW]	Cooling [kW]
Thermal load	6.15	1.66
ASHP capacity	8.51	3.55
GCHP capacity	8.89	3.86

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

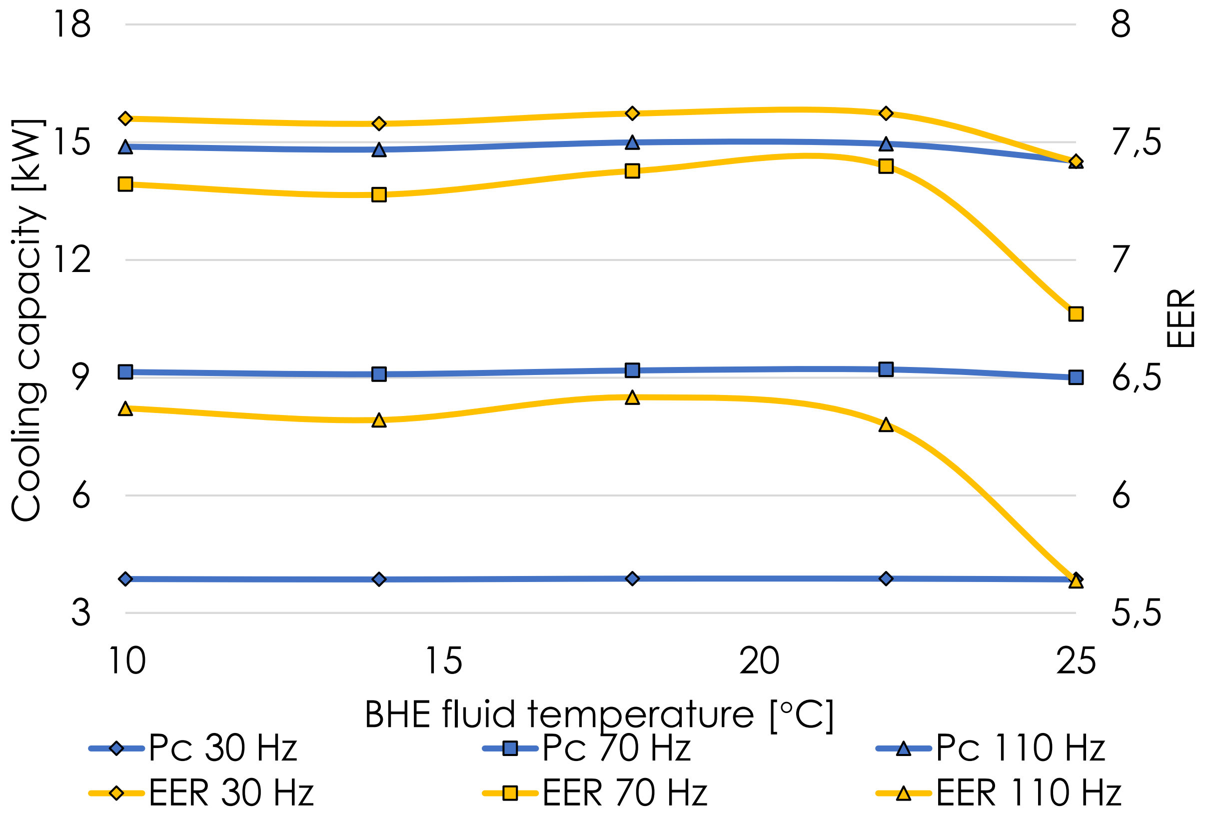
Design conditions:
T out borehole: -5 °C
Tin load: 35 °C

Description of the case study

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



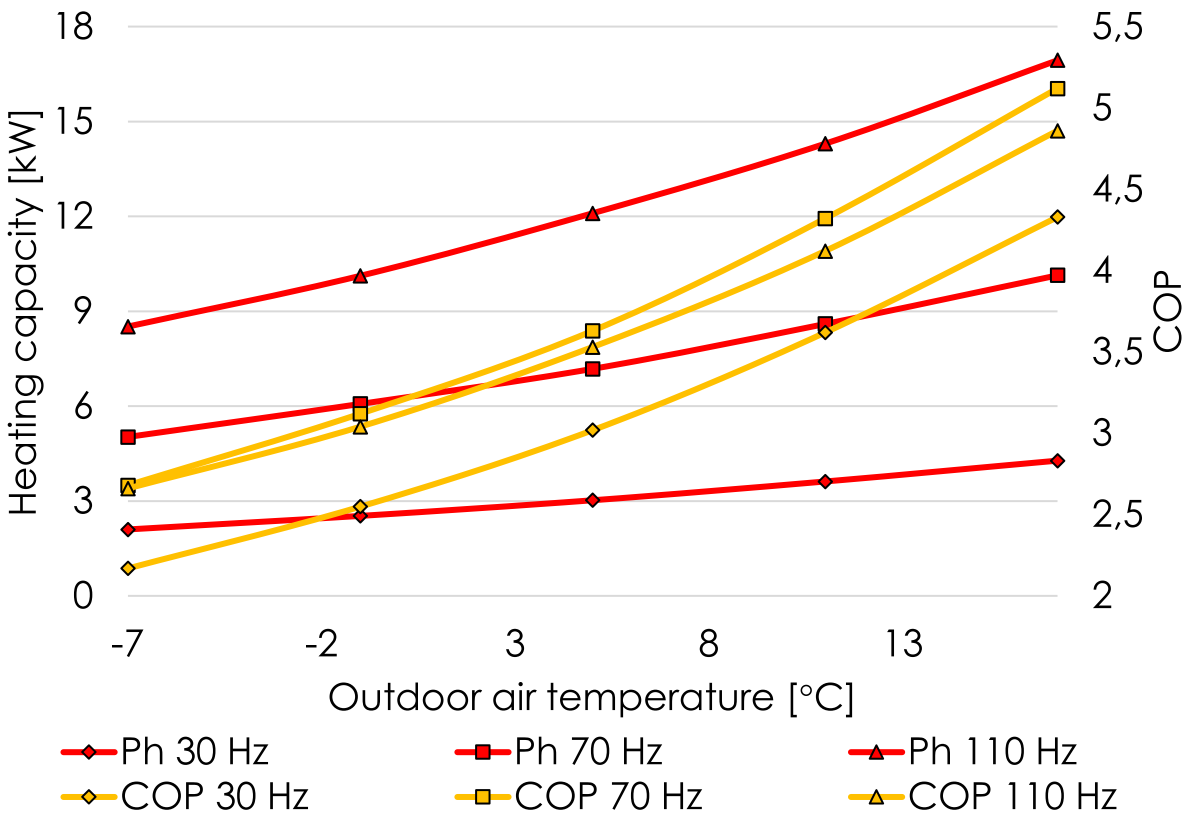
Tin load 35 °C
Tout load 40 °C



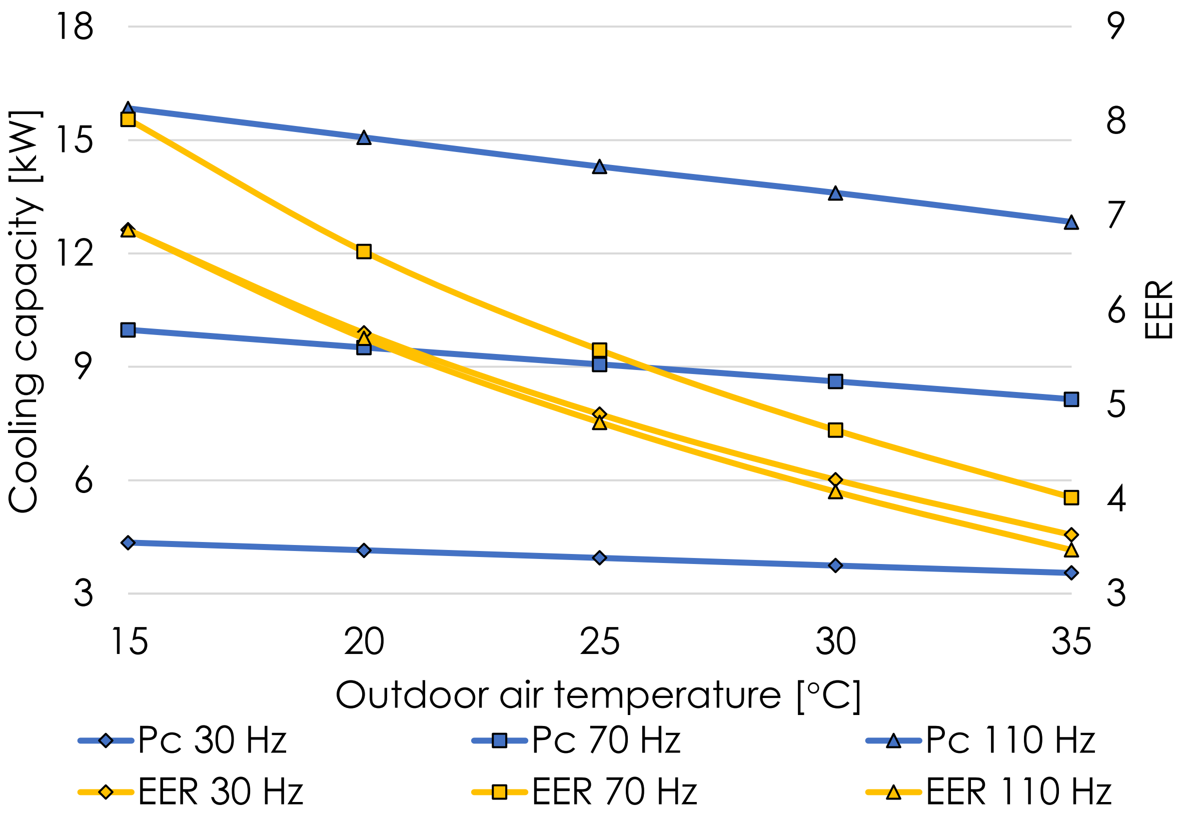
Tin load 15°C
Tout load 10 °C

Description of the case study

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



Tin load 35 °C
Tout load 40 °C



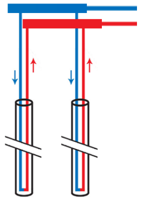
Tin load 15°C
Tout load 10 °C

Description of the case study

Configurations of HVAC system

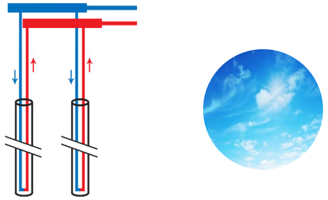
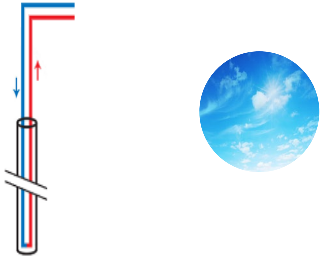
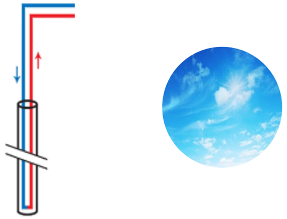
Case **A**: HVAC system based on an inverter-driven **GCHP**

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**

C1	C2	C3	C4	Case D
2 boreholes 60 m each (120 m tot) (**100%** length) 	**1** borehole 90 m long (**75%** length) 	**1** borehole 70 m long (**60%** length) 	**1** borehole 60 m long (**50%** length) 	**Scheduled times** logic

C1 **C2** **C3** **C4**

Switching temperature logic

Results

Key Performance Indicators

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

Seasonal Coefficient of Performance

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

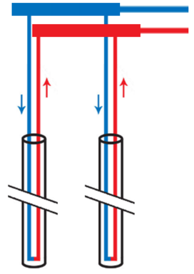
Seasonal Energy Efficiency Ratio

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

Annual Performance Factor

Results

Case **A**, **GCHP**



(100%)

Seasonal and annual performance factors, GCHP

Year	1	2	3	4	5	6	7
SEER	6.24	6.23	6.23	6.23	6.23	6.23	6.23
SCOP	3.95	3.89	3.86	3.84	3.83	3.82	3.81
APF	4.07	4.01	3.98	3.96	3.94	3.93	3.93
Δ_{APF} [%]	0	-1.45	-2.17	-2.64	-2.98	-3.24	-3.43

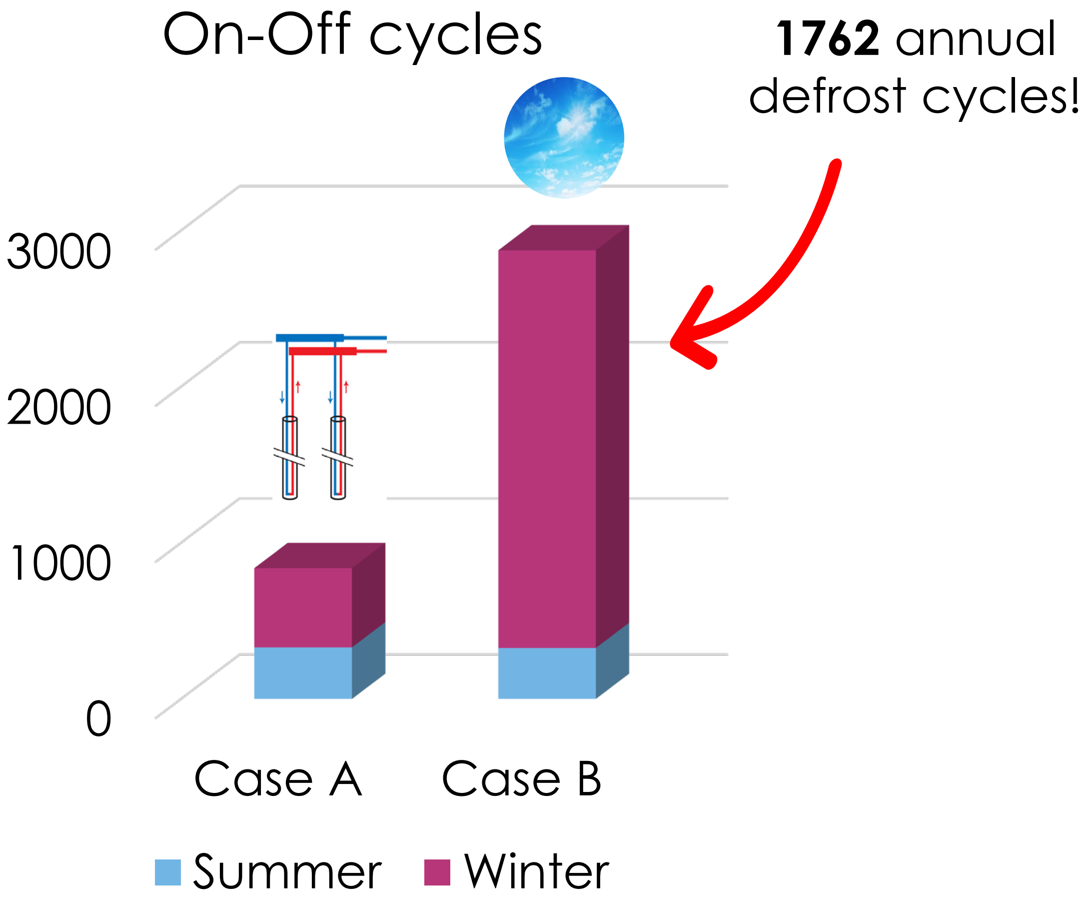
Results

Case **B**, **ASHP**

Seasonal and annual performance factors, ASHP

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

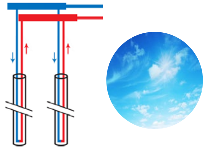
Compared to **GCHP**



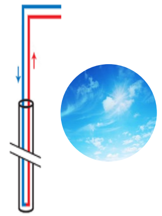
Results

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

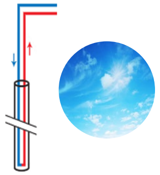
C1
(100%)



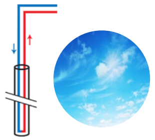
C2
(75%)

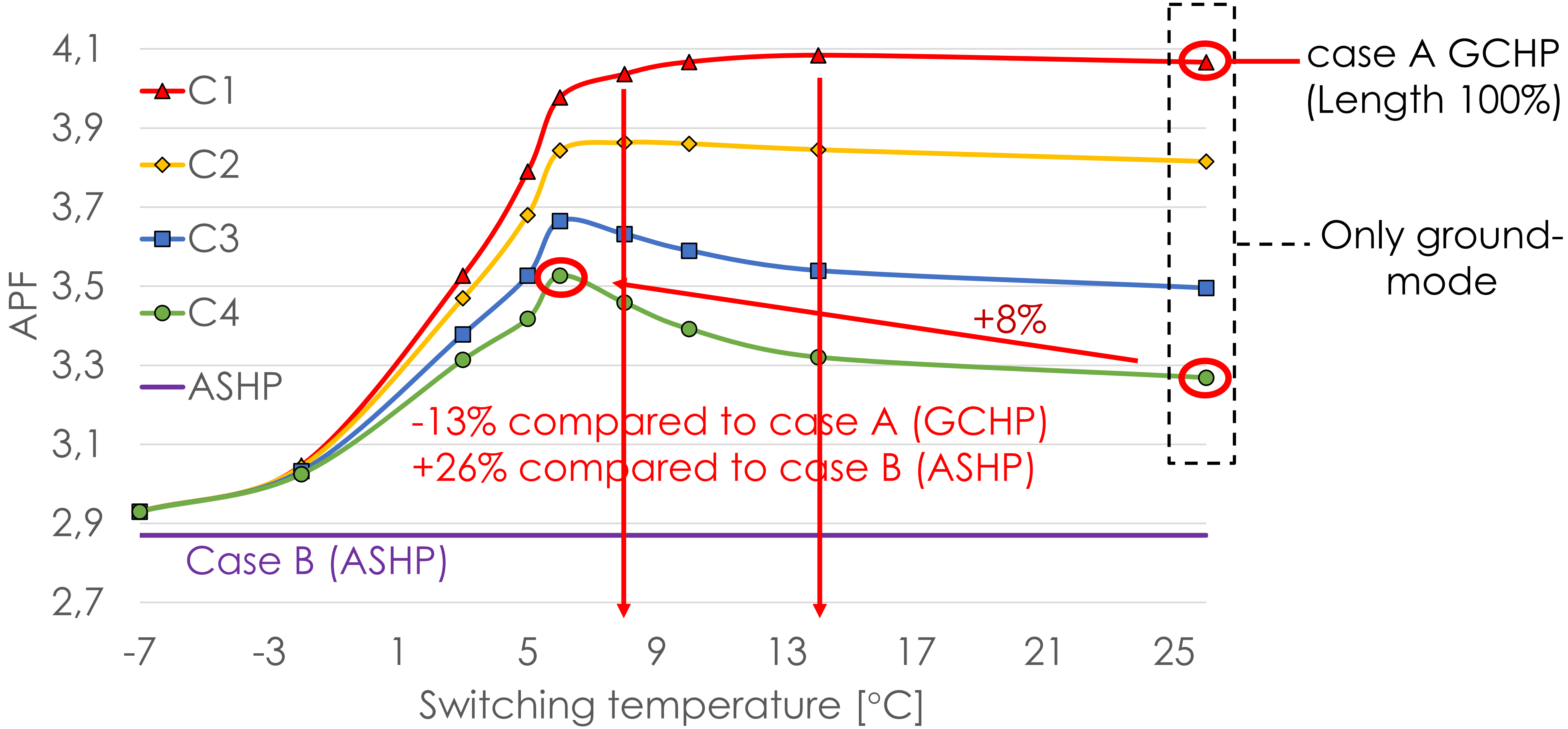


C3
(60%)



C4
(50%)

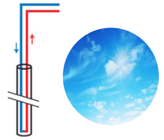




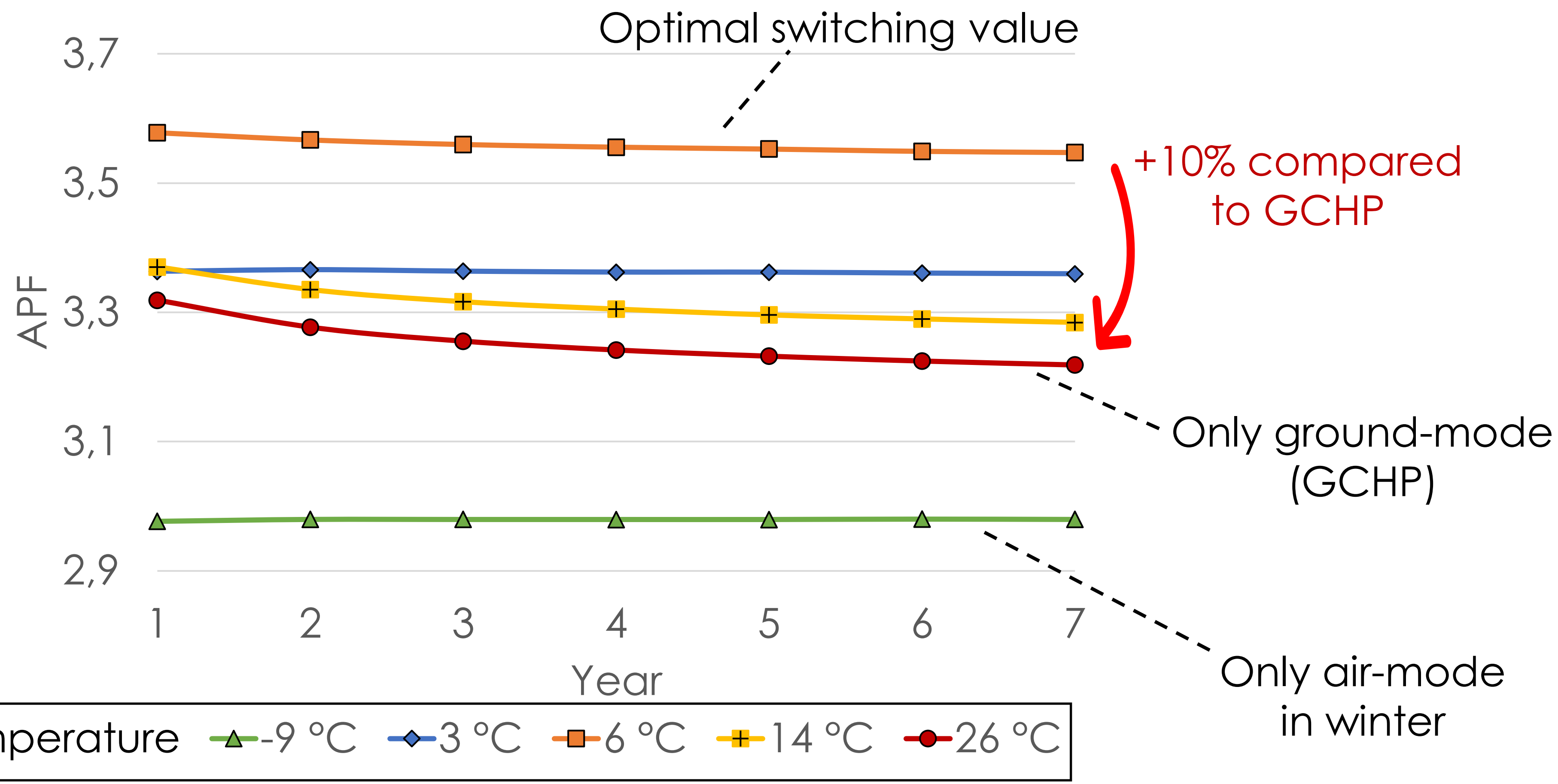
Results

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

C4
(50%)



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



Results

Case **D**, **DSHP**, **scheduled times** logic

D
(50%)

Year	1	2	3	4	5	6	7
SEER	6.24	6.23	6.23	6.23	6.23	6.23	6.23

Case A

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

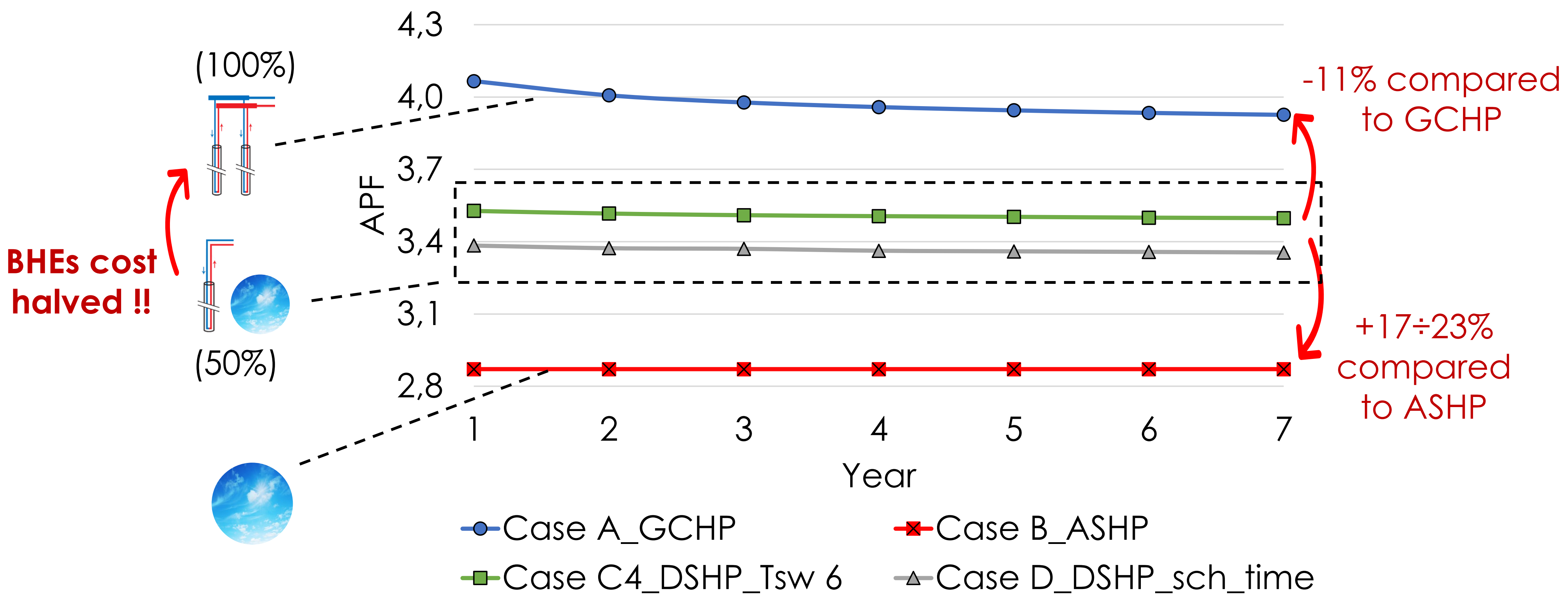
Same performance of case **A**!!

(100%)

-1% only

Results

Comparison



Conclusion and future developments

- **Dynamic model** of a **DSHP** developed with **ALMABuild**
- Heating/cooling performance, defrost and cycling energy losses considered
- **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 your attention!

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https://site.unibo.it/almabuild/it