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Dynamic Modelling of a District Cooling Network with Modelica

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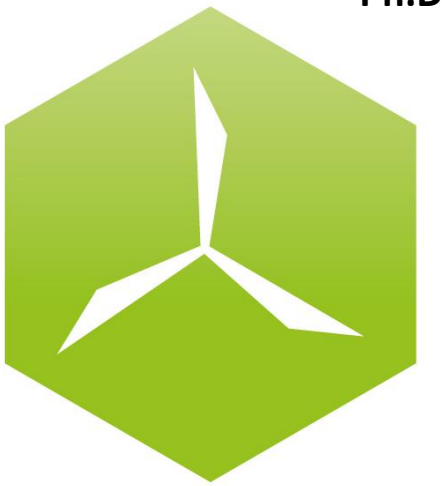

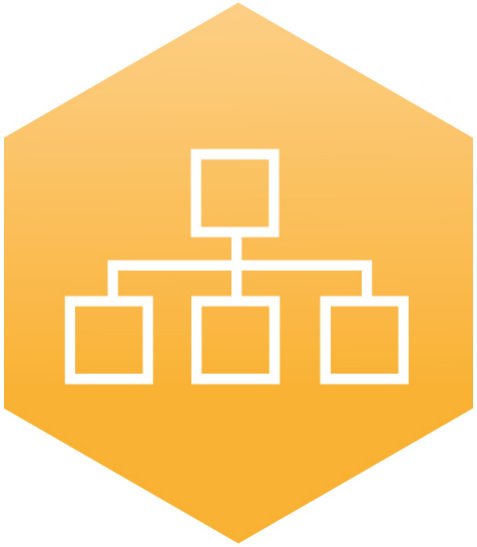

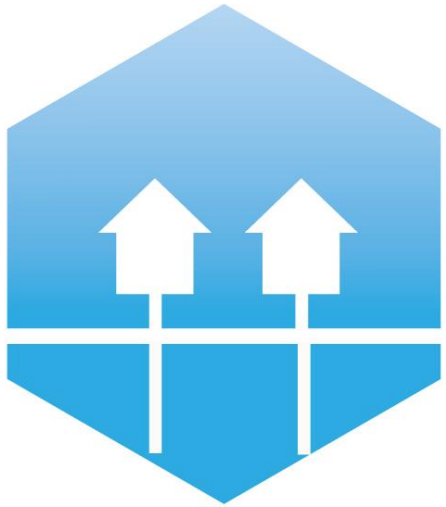

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Agenda

- **Objectives & Methodology**
- **Description of the District Cooling System**
- **Chilled-Water Production Flow Chart**
- **Centrifugal Chiller Model**
- **Simulation & Validation Results**
- **Conclusion & Research perspectives**

Objectives & Methodology

- **Long-term objective : Optimal control of Chilled-Water Production of a real District Cooling System**

→ **Detailed representation of main energy equipments**

- **1st step : Modelling and Calibration of the Chilled-Water Production Plant (CWPP) with Modelica**

→ **Modelling of all production modes**

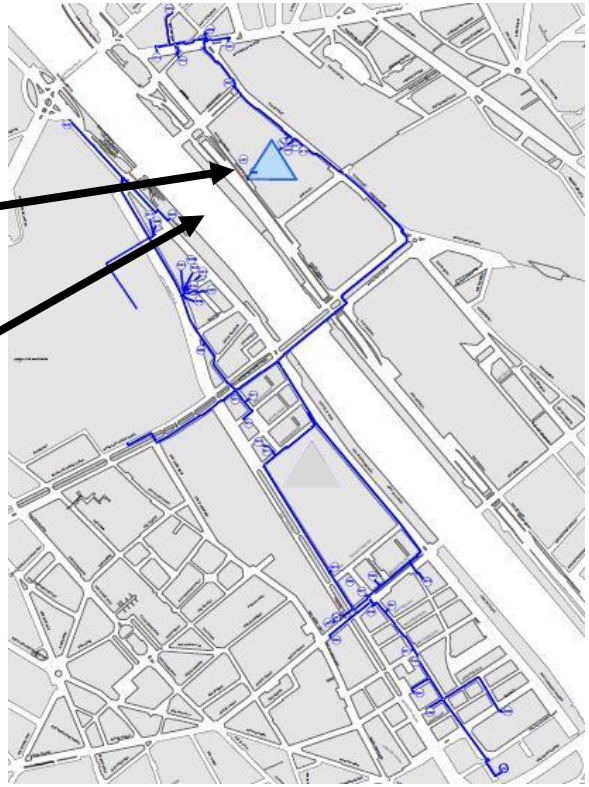
→ **Relevant boundaries (load, weather and controls as inputs)**

→ **Validation of model outputs against measured values**

AIM OF TODAY'S PRESENTATION

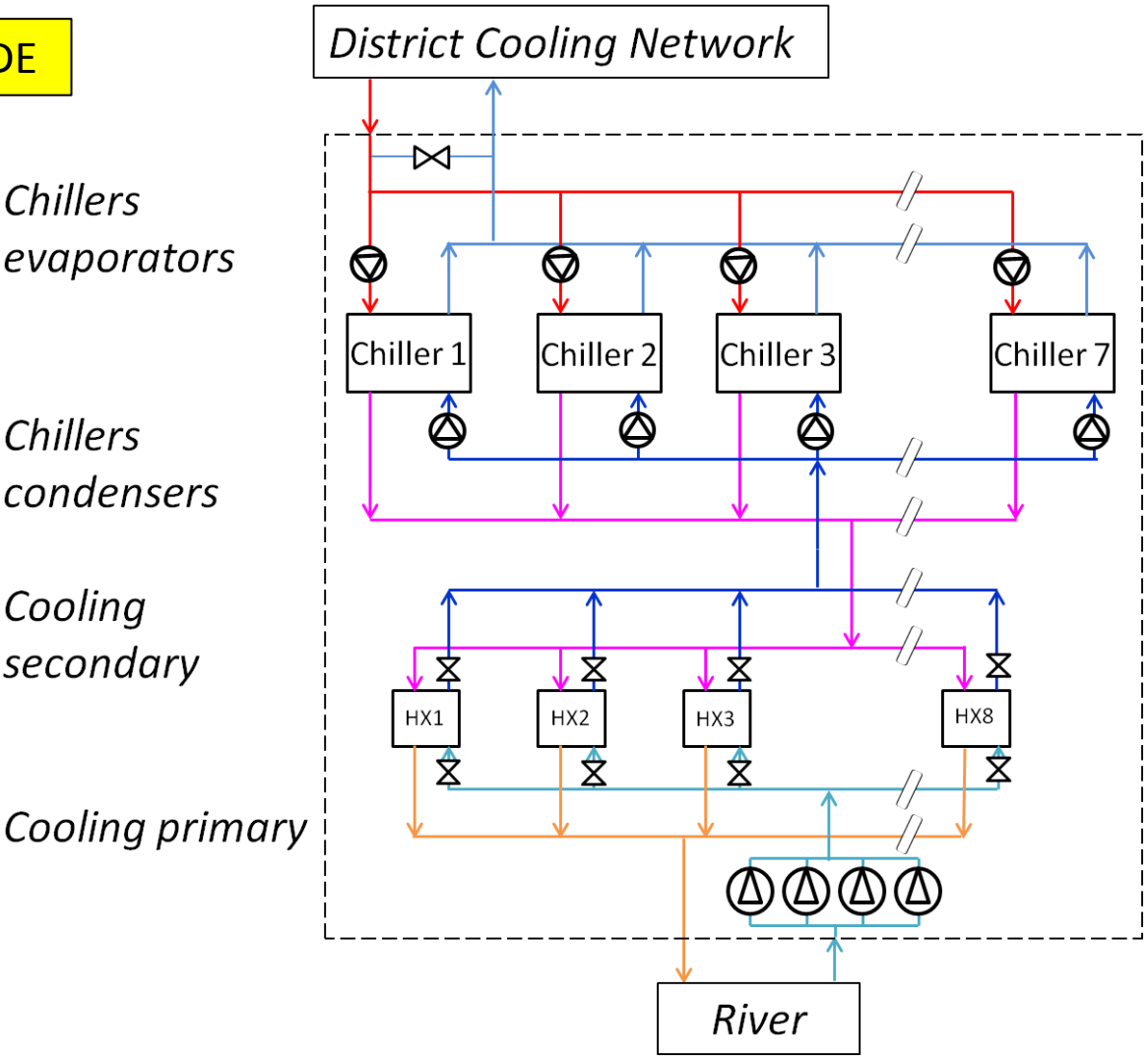
Description of the District Cooling System

- **Eastern Part of Paris District Cooling Network**
- **44 MW Chilled-Water Production Plant (CWPP)**
- **Cooling by Seine river**
- **≈ 50 substations**



Chilled-Water Production Flow Chart

CHILLER MODE



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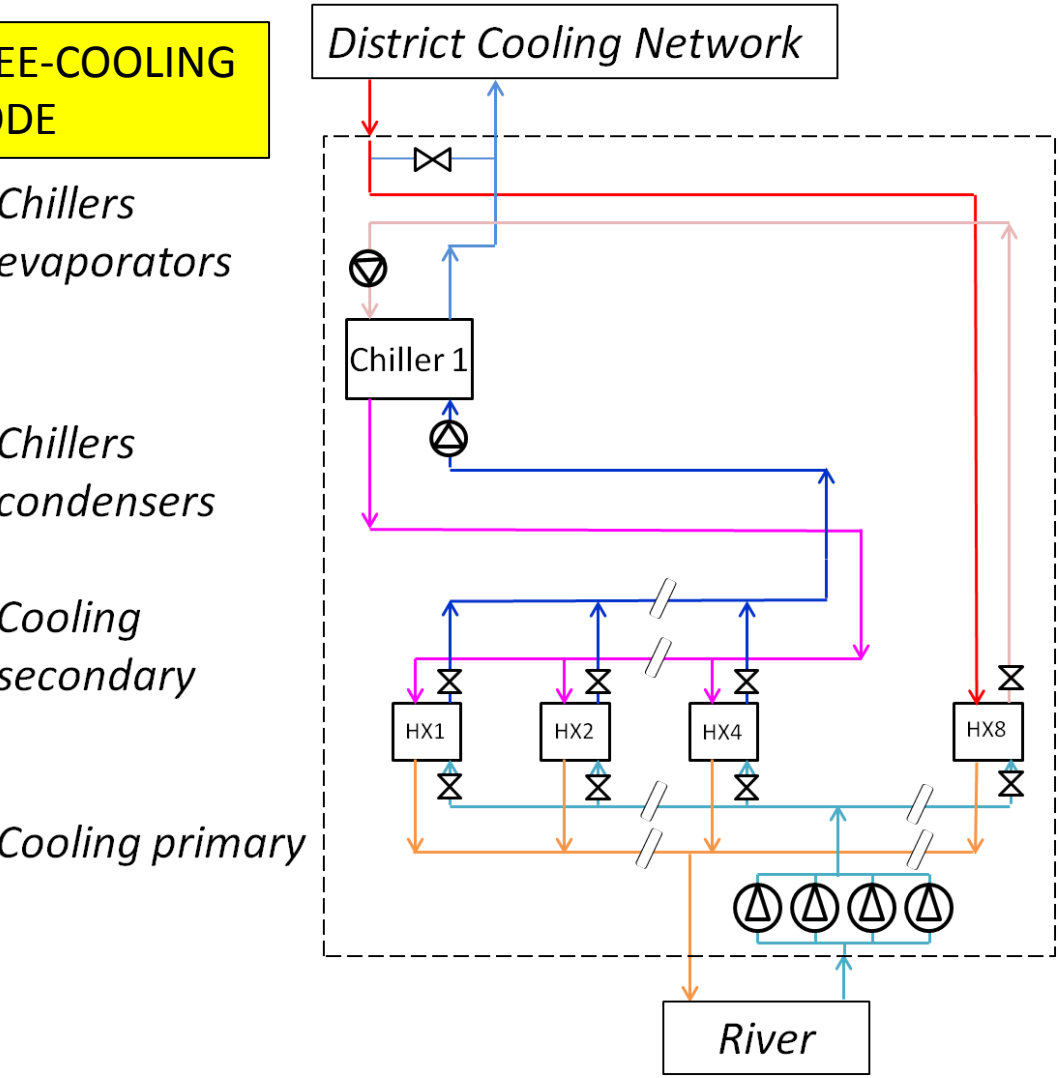
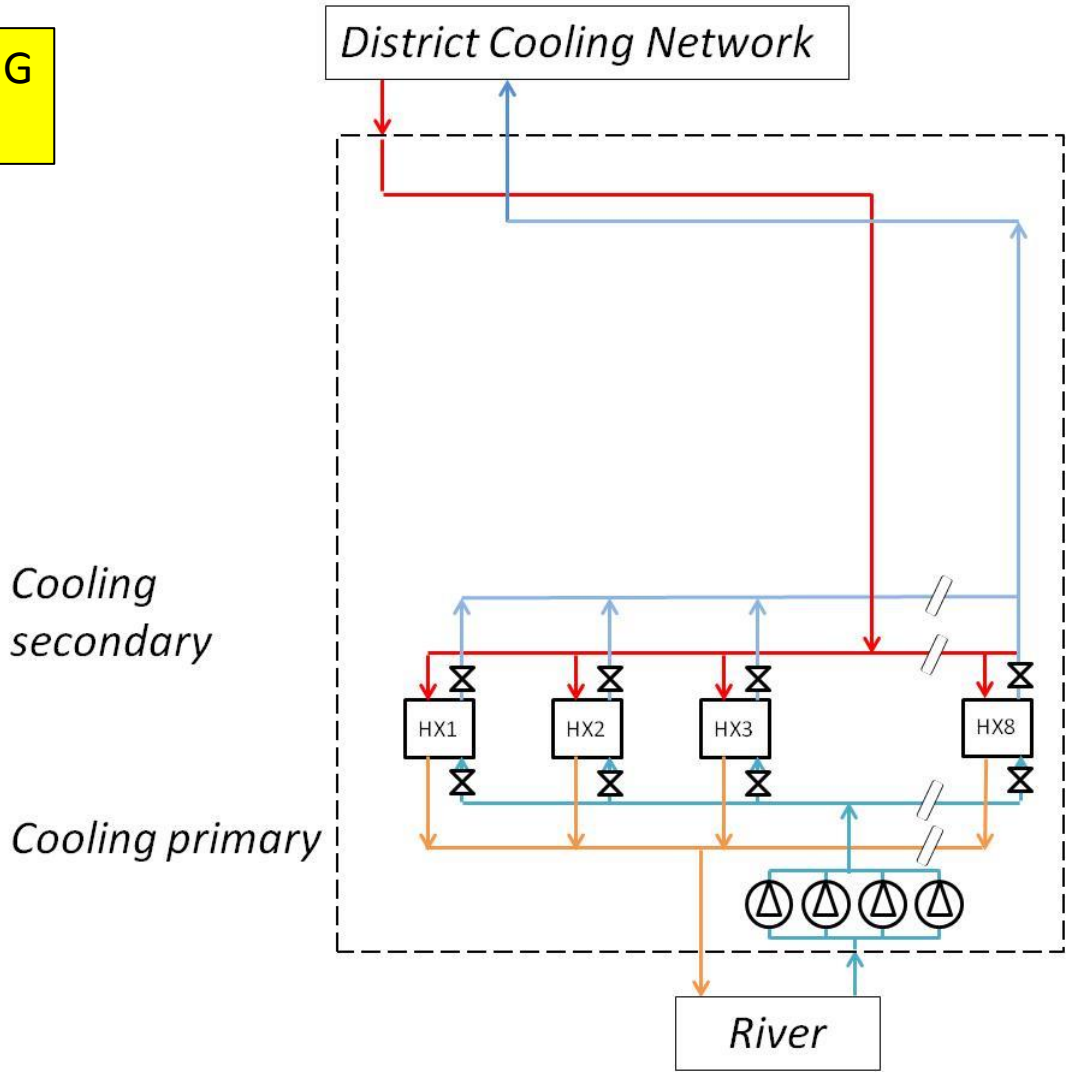
Chilled-Water Production Flow Chart

CHILLER + FREE-COOLING MODE



Chilled-Water Production Flow Chart

FREE-COOLING MODE



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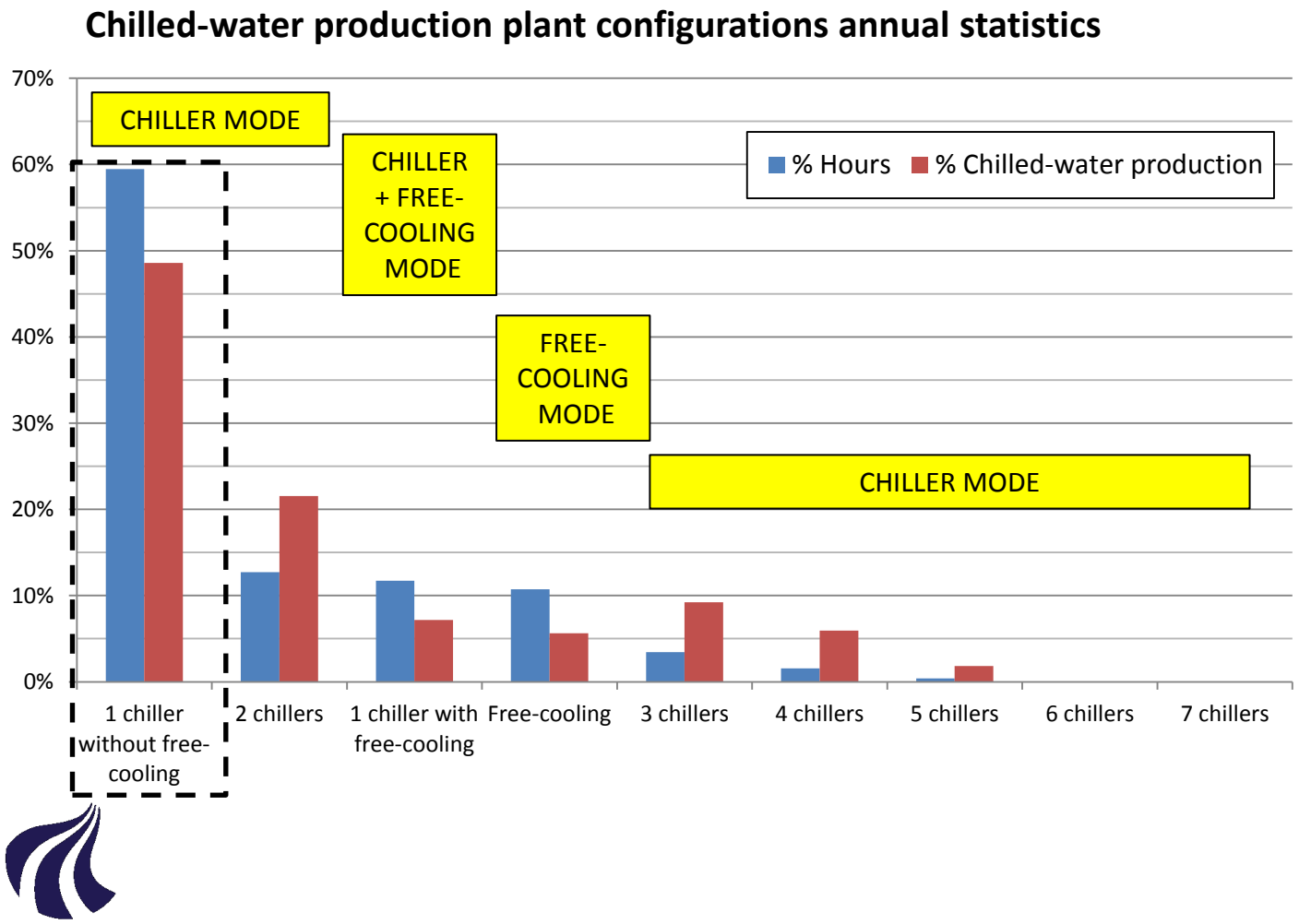
Chilled-water production statistics



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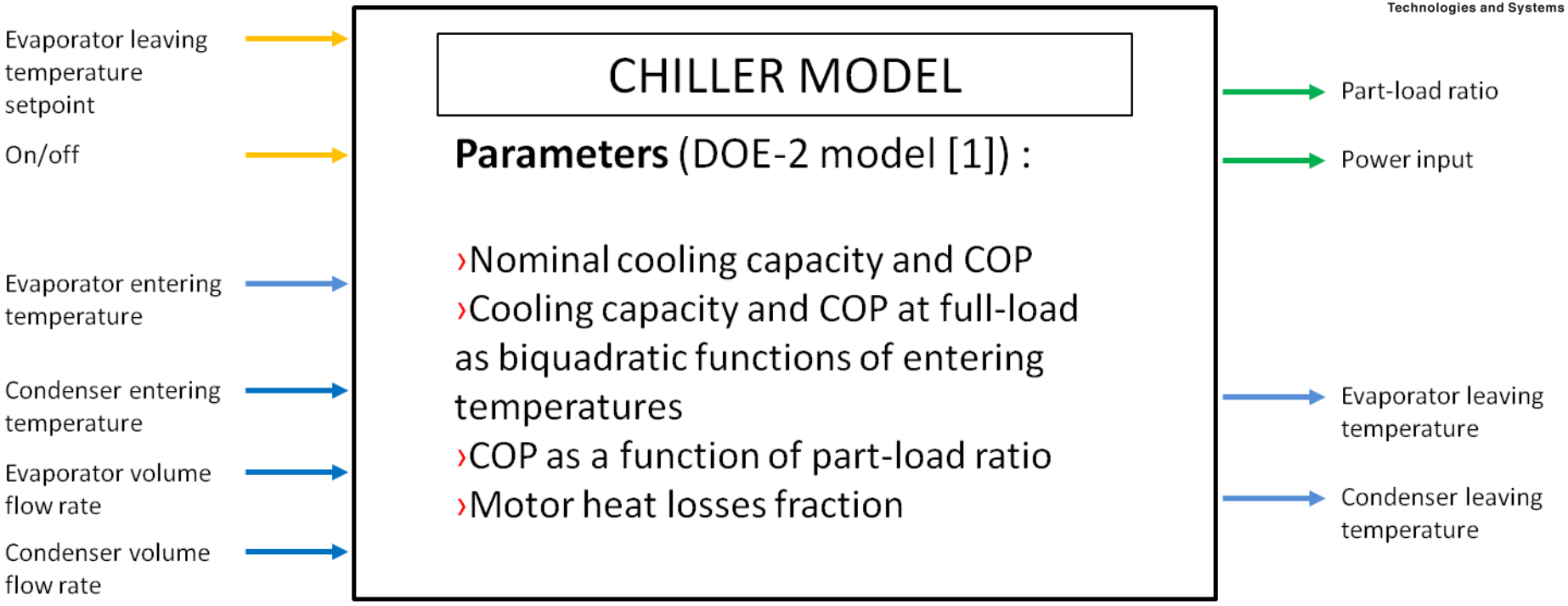
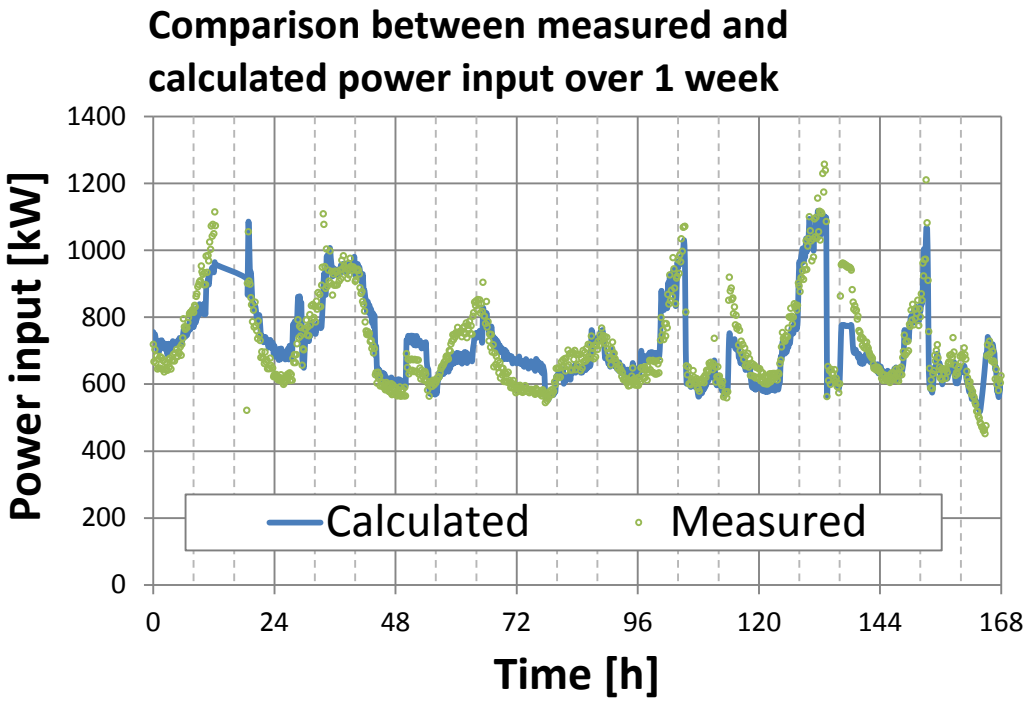
Centrifugal chiller model

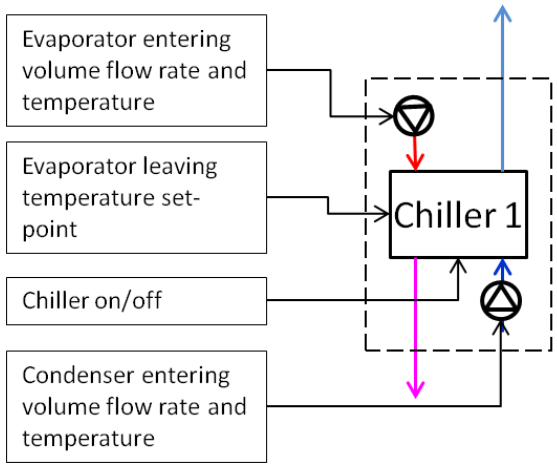


[1] Department of Energy (DoE). DOE2 reference manual, Part 1, version 2.1. Berkeley (California): Lawrence Berkeley National Laboratory; 1980.

Centrifugal chiller model

Calibration of parameters [2]



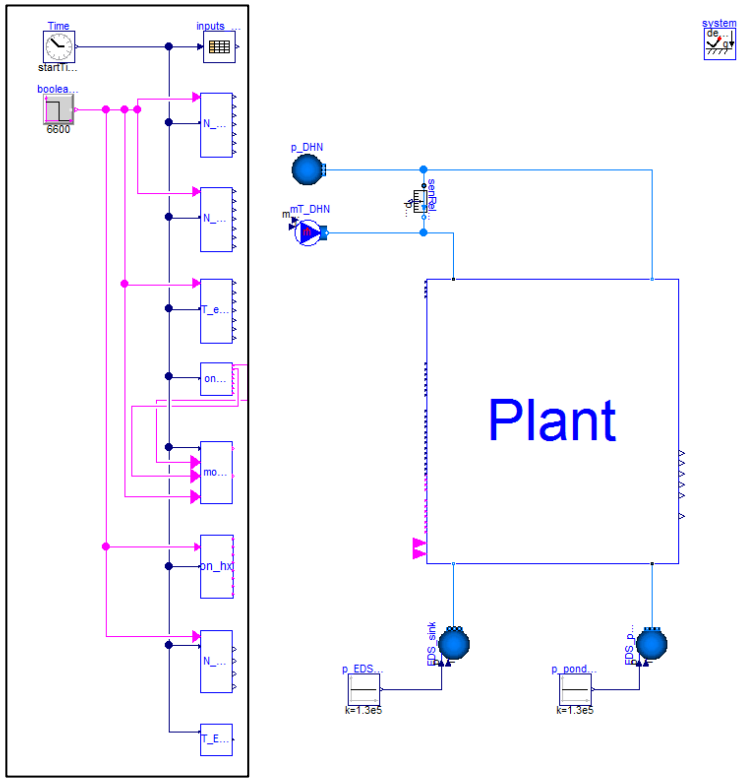


Power input [kW]	
MAPE	6.5%
CV	8.9%
RMSE	65.0

[2] Lee, Tzong-Shing, Ke-Yang Liao, and Wan-Chen Lu. 2012. "Evaluation of the Suitability of Empirically-Based Models for Predicting Energy Performance of Centrifugal Water Chillers with Variable Chilled Water Flow." *Applied Energy* 93 (May): 583–95.

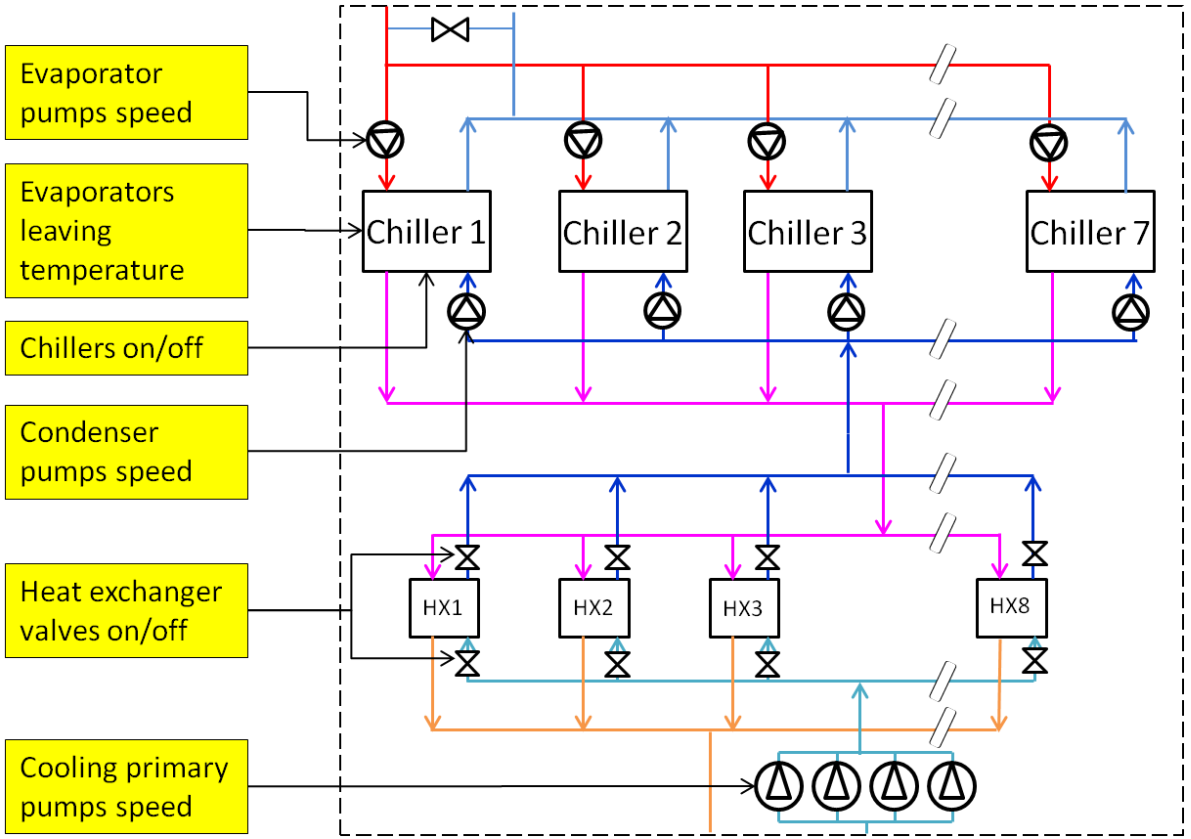
Simulation in chiller mode

- **Period : 1 week**
- **Measured controls, inputs and outputs**
- **Data time step : 10 minutes**
- **Simulation environment : Dymola**



Simulation in chiller mode

Measured Controls



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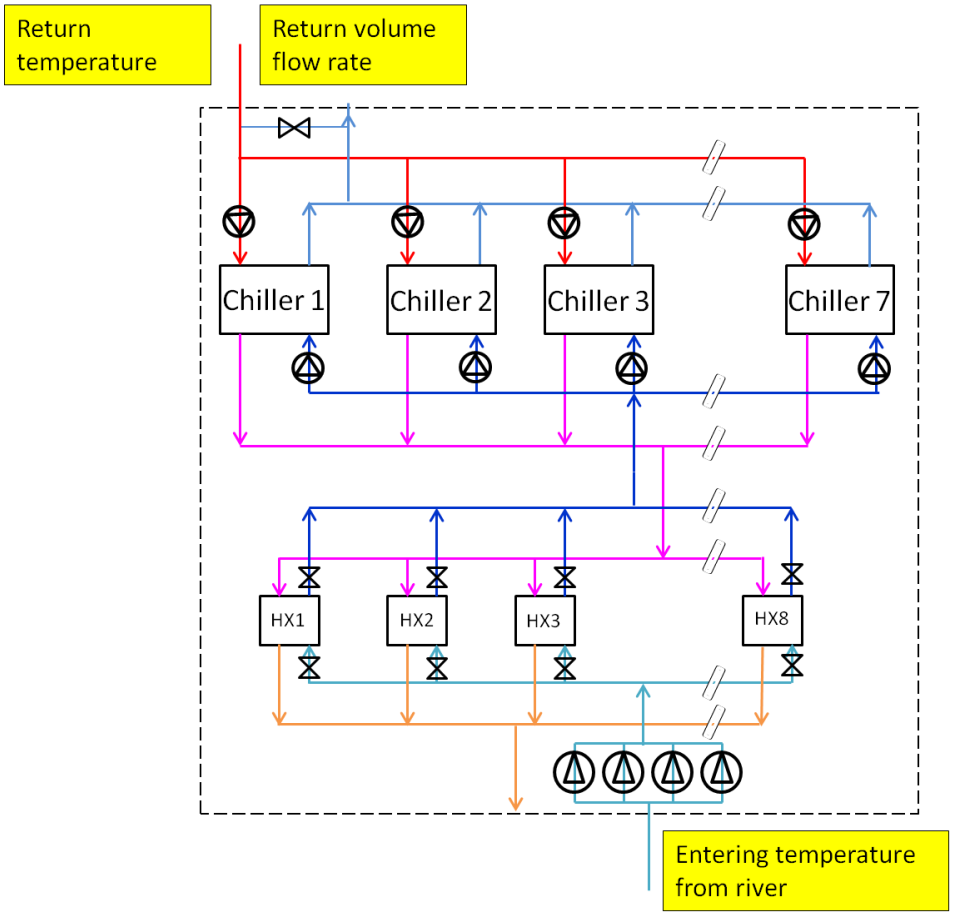
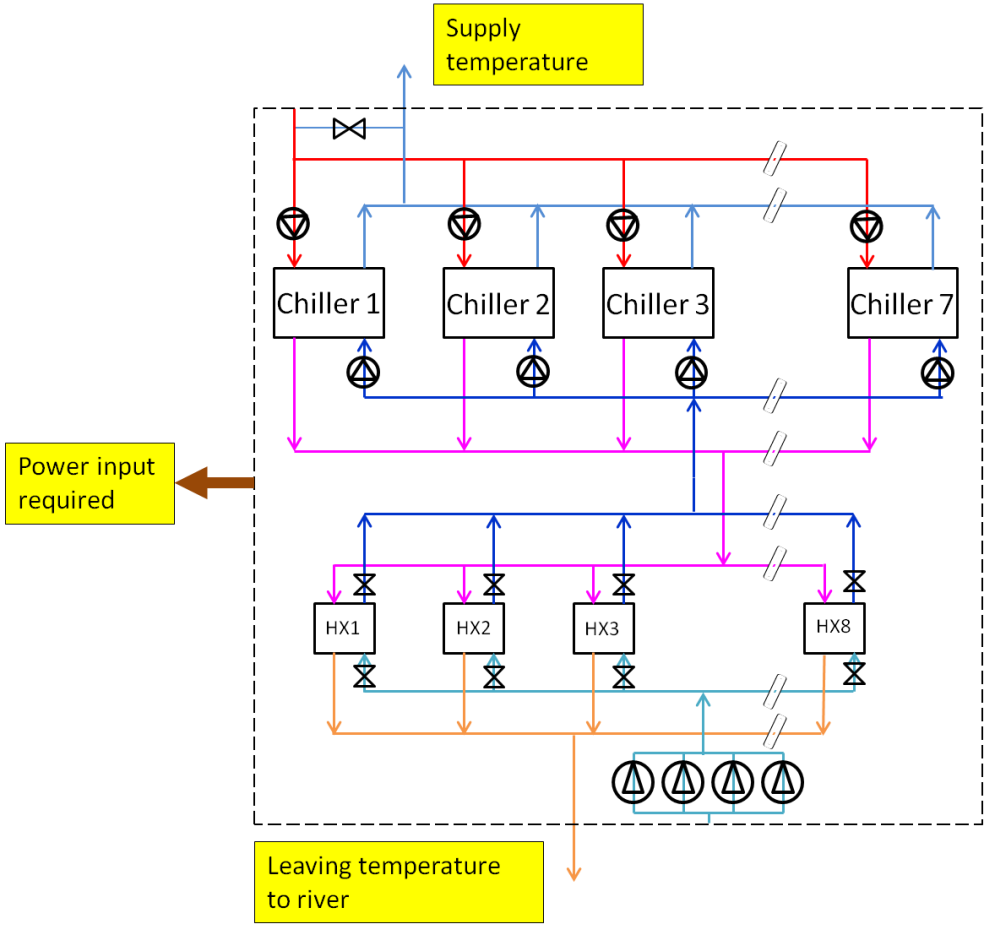
Simulation in chiller mode

Load and weather inputs

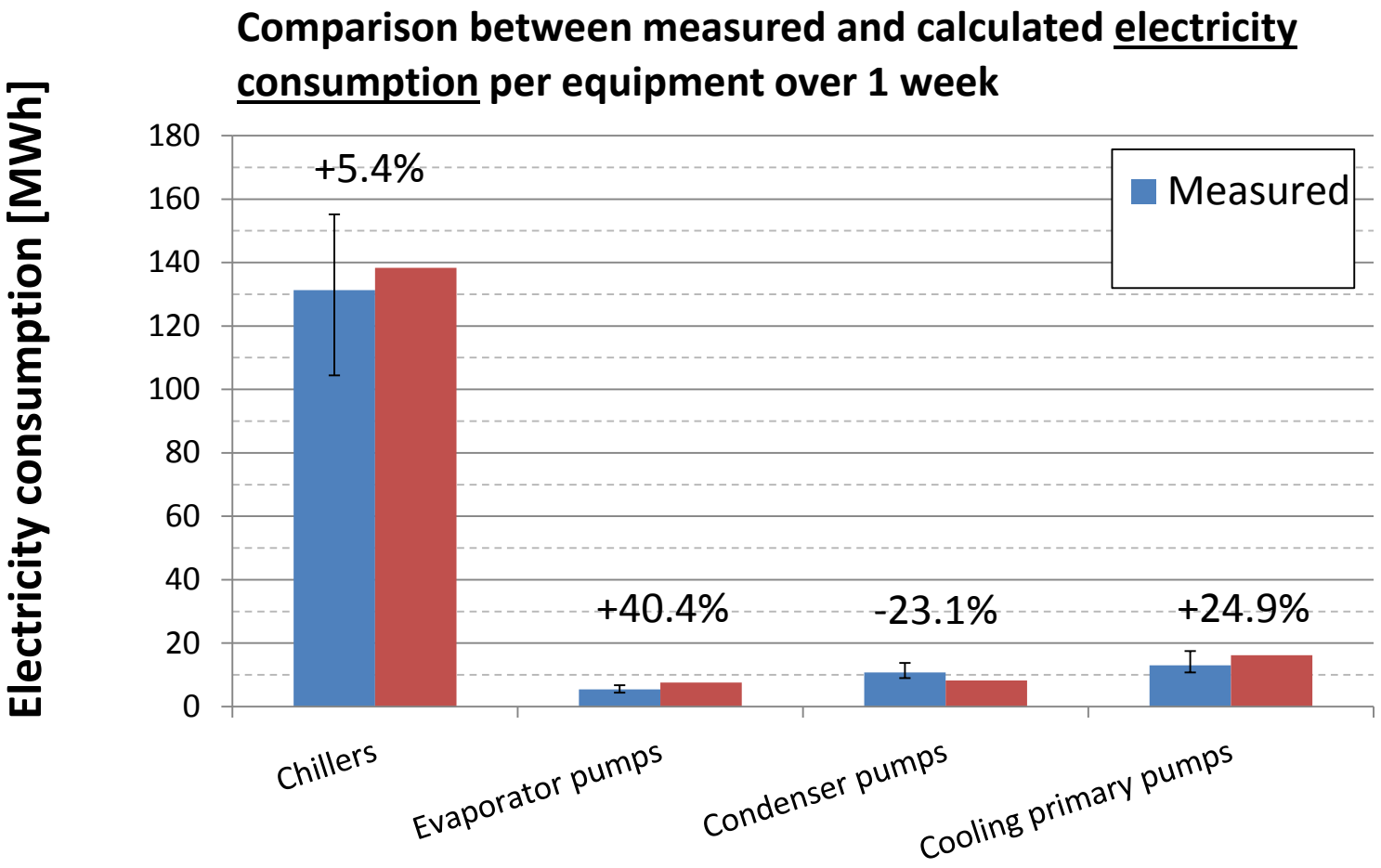


Simulation in chiller mode

Outputs to be compared



Validation results



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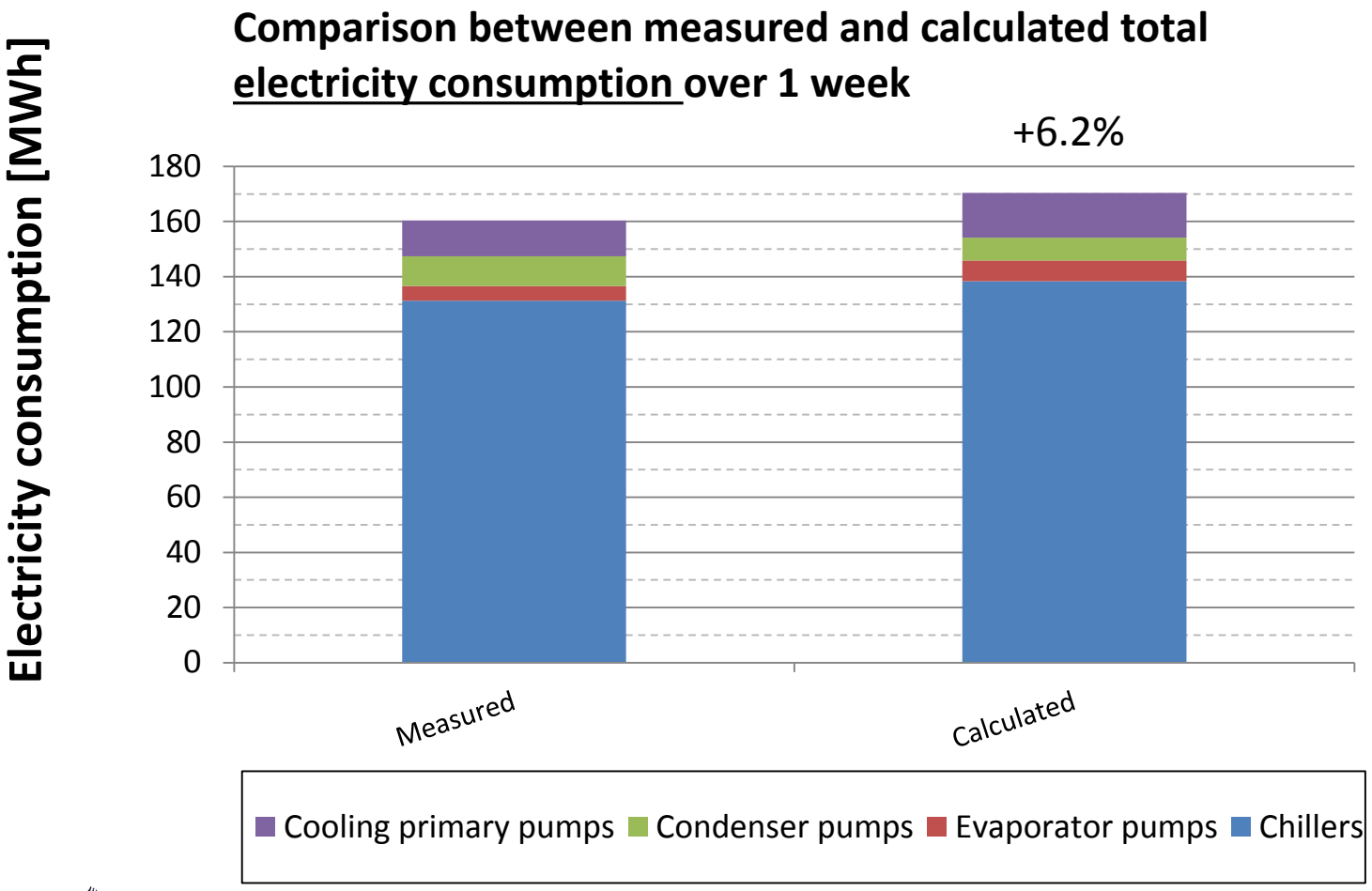
Validation results



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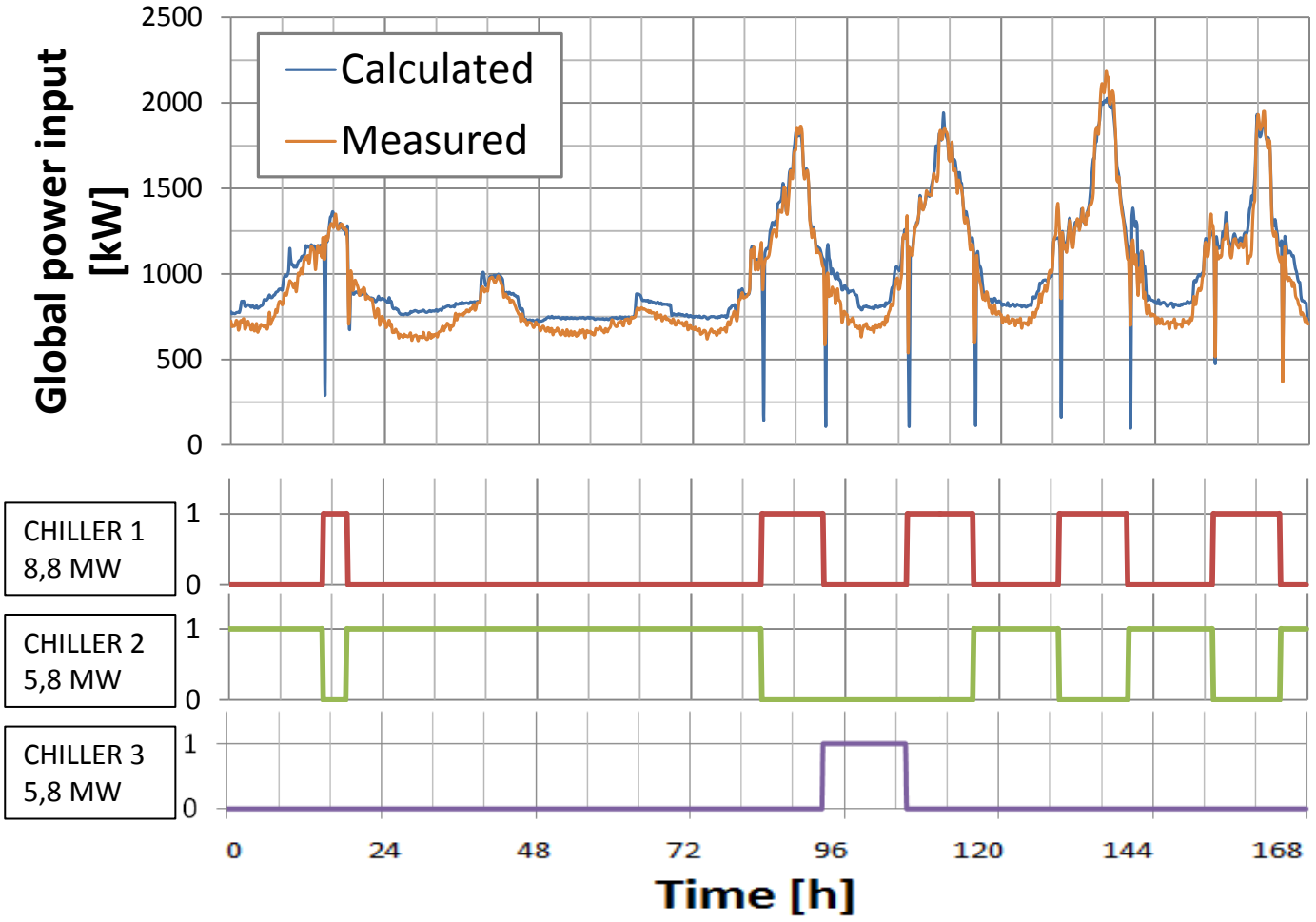
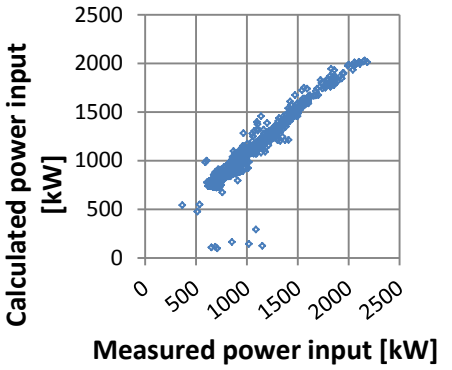
Validation results

Comparison between measured and calculated power input over 1 week





Power input [kW]	
MAPE	10.9%
CV	11.8%
RMSE	113.0

- Over-estimation with very low demand
- Under-estimation with high peak demand

Conclusion & Research perspectives

- **Satisfactory total power input modelling for the chiller production mode**
- **Modelling improvements : pumps**
- **Validation in progress : other production modes**
- **Towards operational optimization : add a control model, to be optimized**

Questions

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Thank you for your attention

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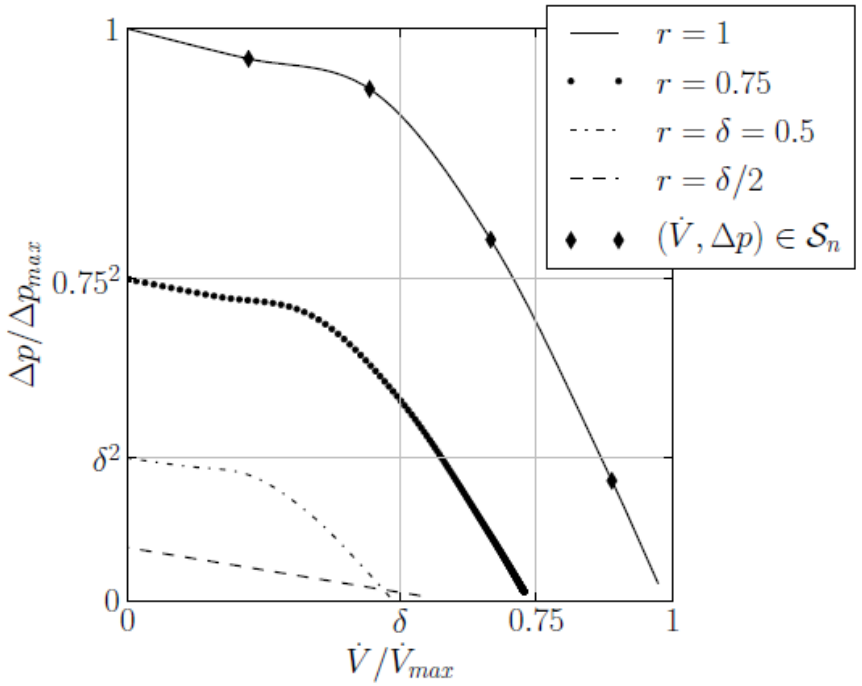
Pump model

Representation

Hydraulic model [3]

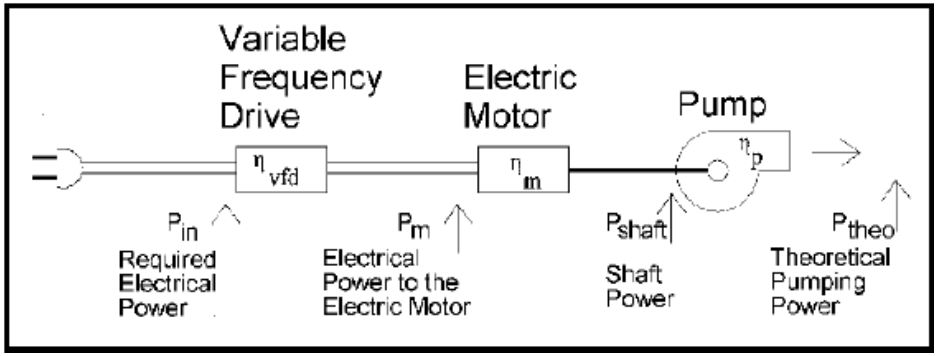


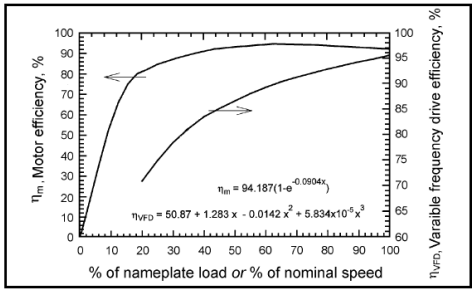
[3] Wetter, Michael. 2015. "FAN AND PUMP MODEL THAT HAS A UNIQUE SOLUTION FOR ANY PRESSURE BOUNDARY CONDITION AND CONTROL SIGNAL."

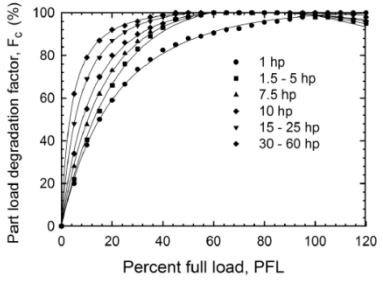
Pump model

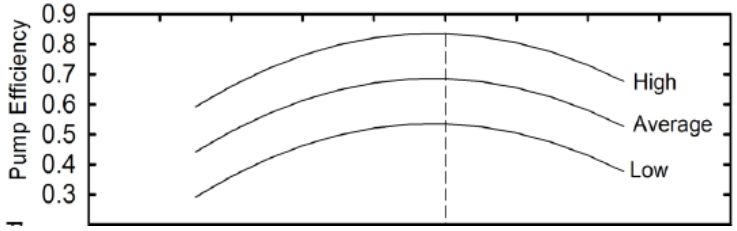
Representation

Power input model [4] [5]







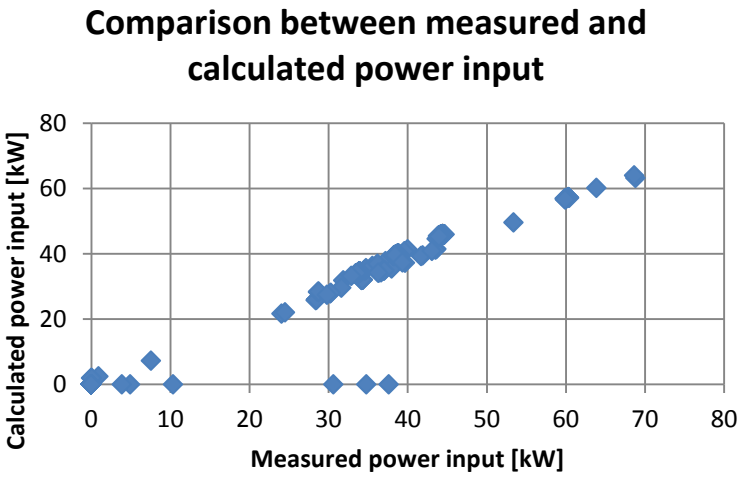


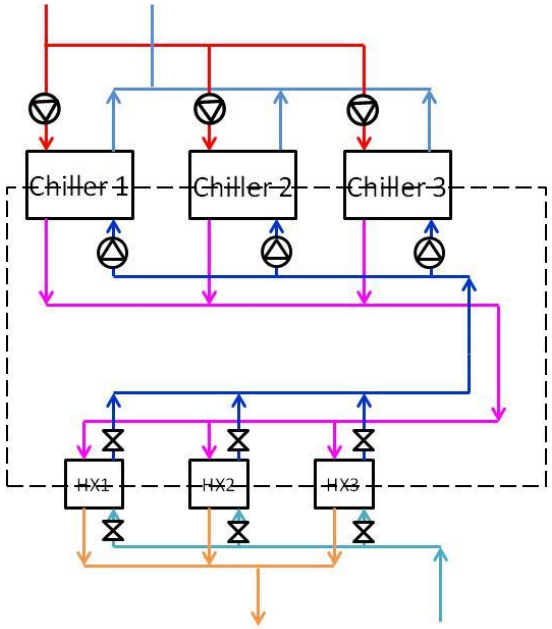
[4] Bernier, and Bourret. 1999. "Pumping Energy And Variable Frequency Drives."

[5] Sfeir, and Bernier. 2005. "A Methodology to Evaluate Pumping Energy Consumption in GCHP Systems."

Pump model

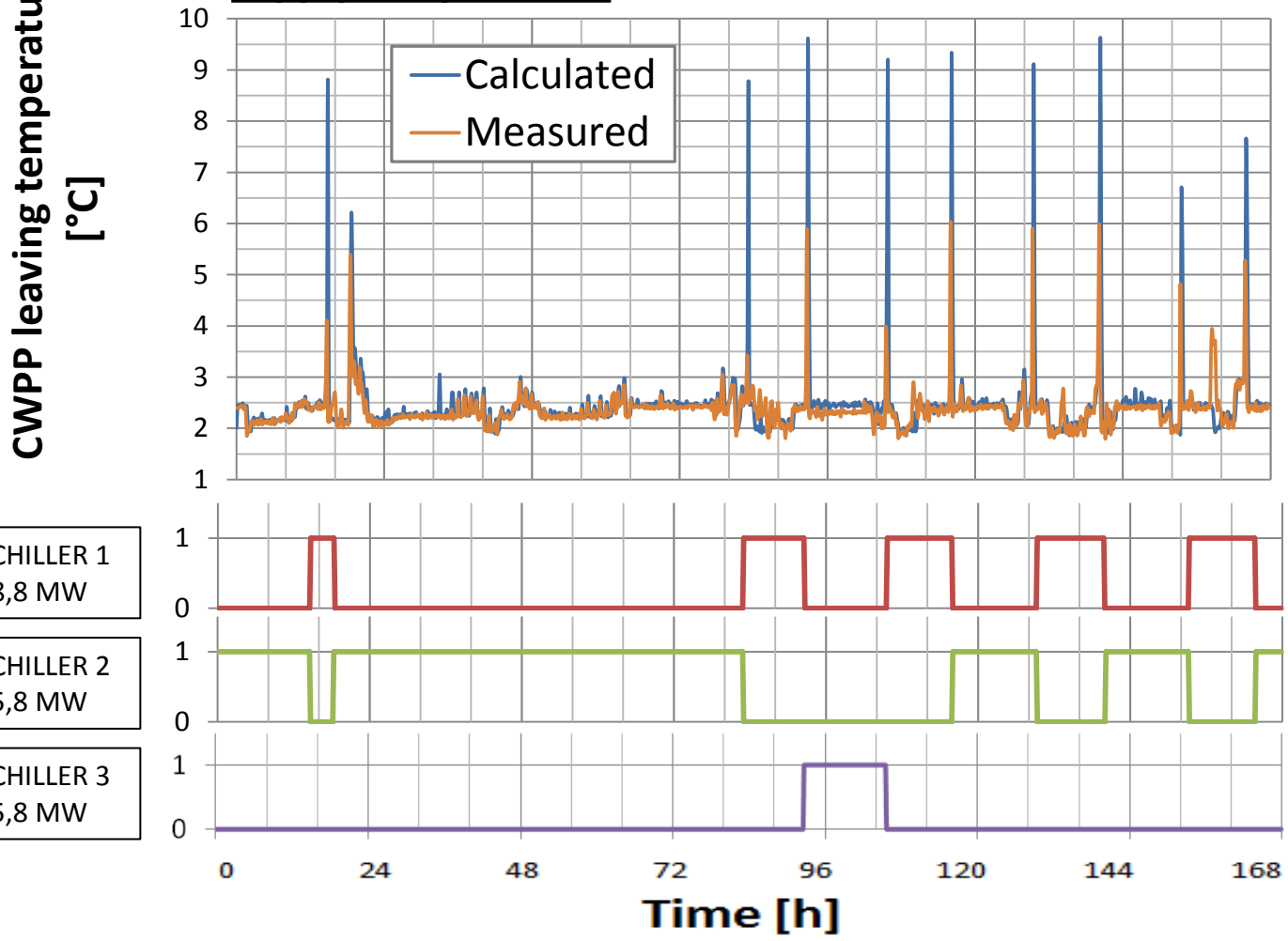
Calibration

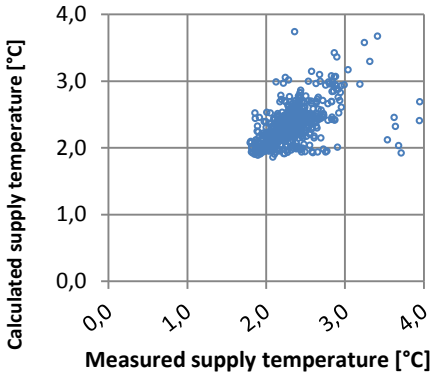




Validation results

Comparison between measured and calculated CWPP supply temperature over 1 week





Supply chilled water temperature [K]	
RMSE	0.7

- Significant over-estimation at chiller start-up phases