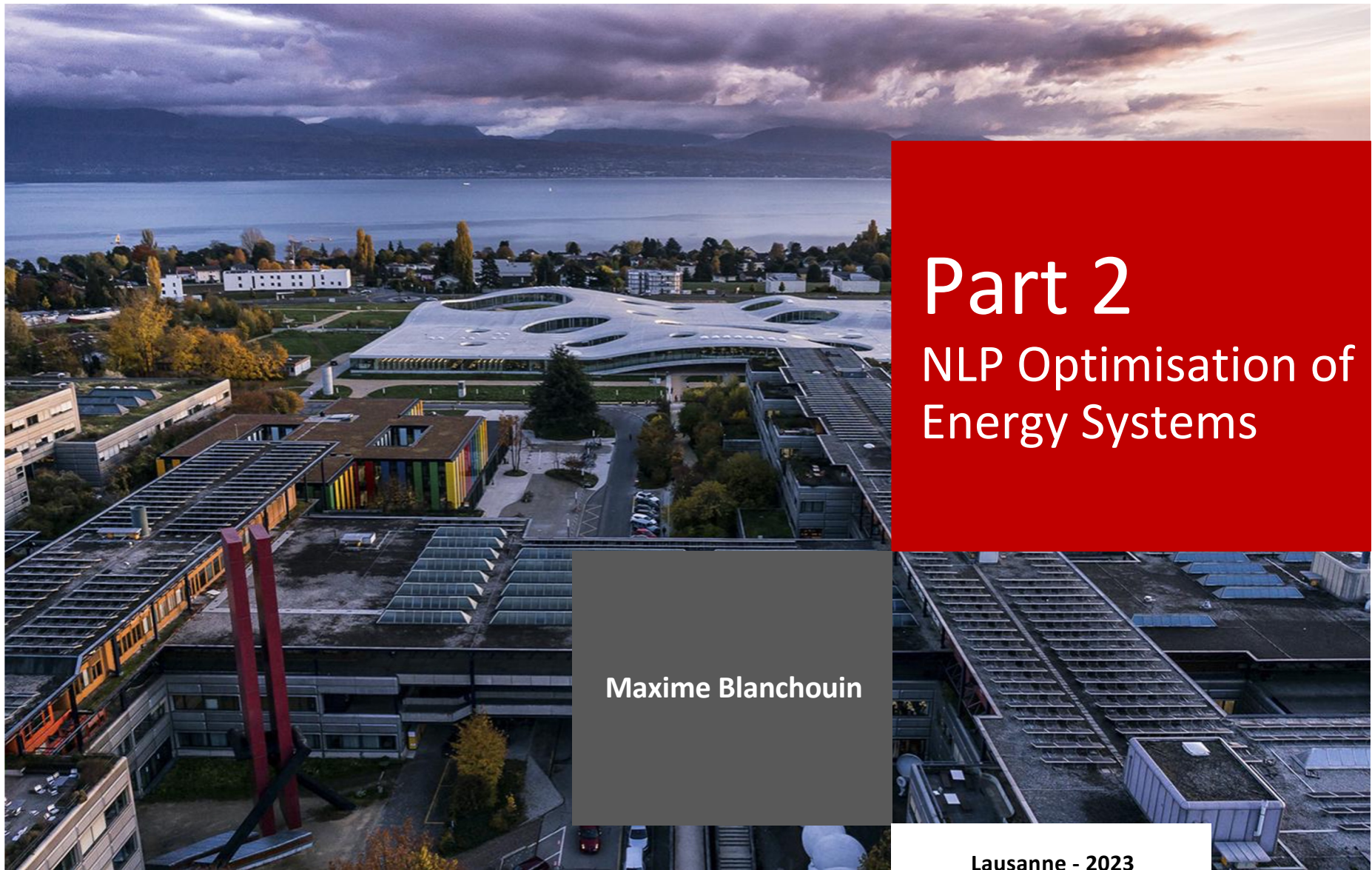




Part 2

NLP Optimisation of Energy Systems

Maxime Blanchouin

Lausanne - 2023

General overview of part 2



Source : <https://www.epfl.ch/about/sustainability/energy/central-heating-unit/>



- Challenge : Give **recommendation** to EPFL on how to **improve the heat recovery**
 - Characterize the given options
 - Determine the preferable option / trade-off among the suggested alternatives

Project Part II:

What you will do:

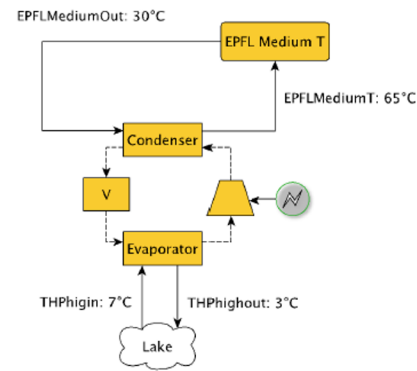
- Calculate the current energy bill of EPFL heating system
- Evaluate 3 alternative configurations and compute their KPIs :
 - CAPEX
 - OPEX
 - Payback time
 - Minimum Temp difference ΔT_{min}
 - HEX areas

What you will learn:

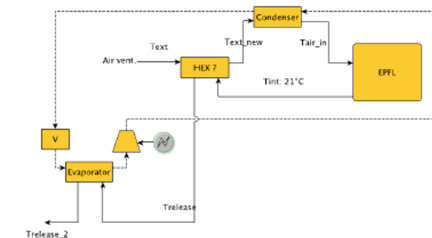
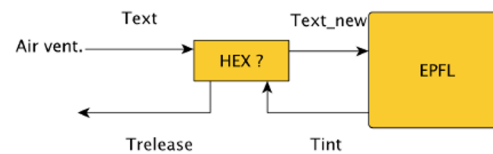
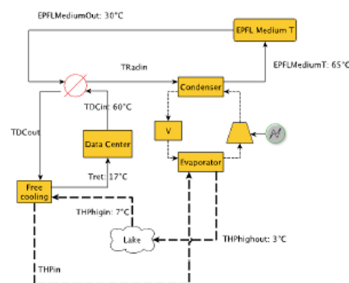
- Formulate NLP optimizations for energy recovery
- Understand AMPL and its integration on VSC
- Understand how the parameters variations influence the optimization process.

1 Reference case + 3 different scenarios

2.1 Reference case



- 2.2 Data Center heat recovery
- 2.3 Ventilation heat recovery
- 2.4 Ventilation + HP heat recovery

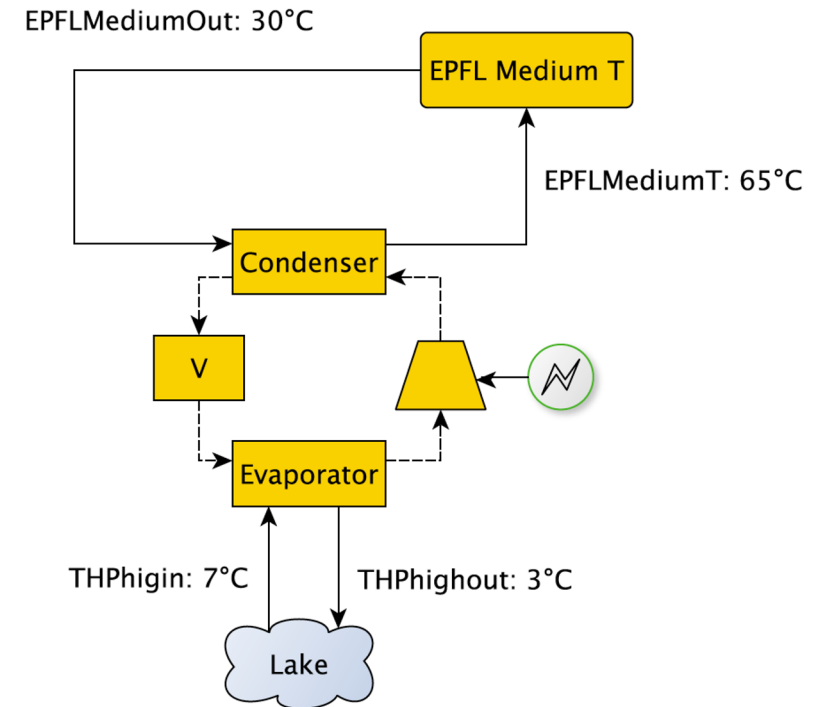


Reference case

- **Medium temperature** heat is supplied partially by a heat pump (HP) that uses lake water
- Carnot efficiency: 55%
- Lake temperature constant throughout the year

Your objective:

- Calculate the energy bill (electric consumption of the compressor)
- Describe the flowsheet from a thermodynamic point of view

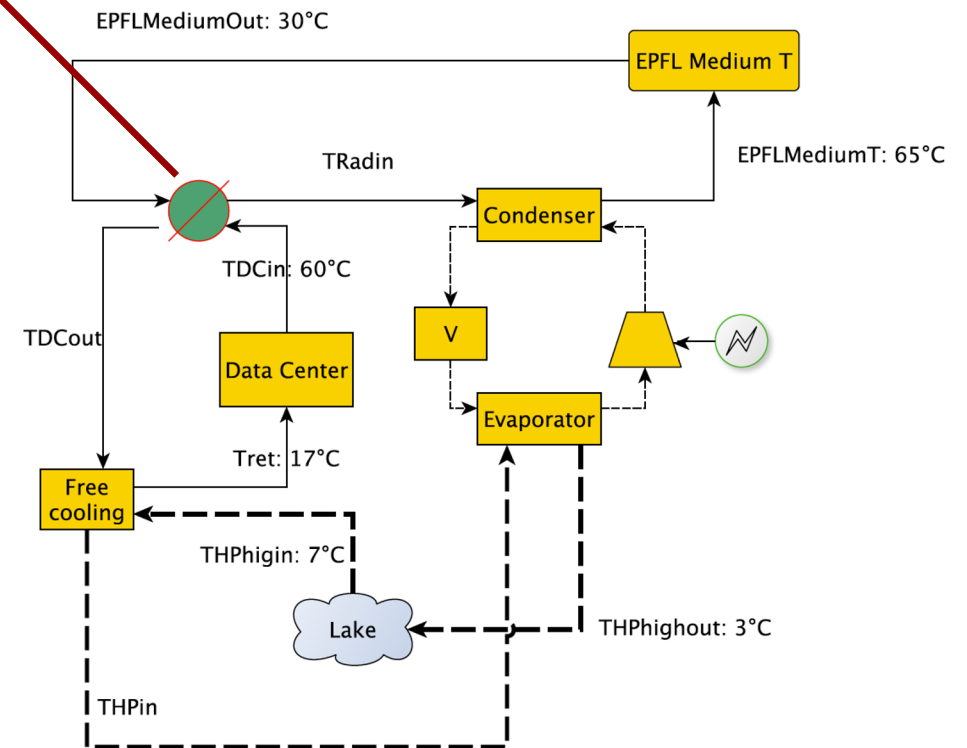


Data center

Data center HEX

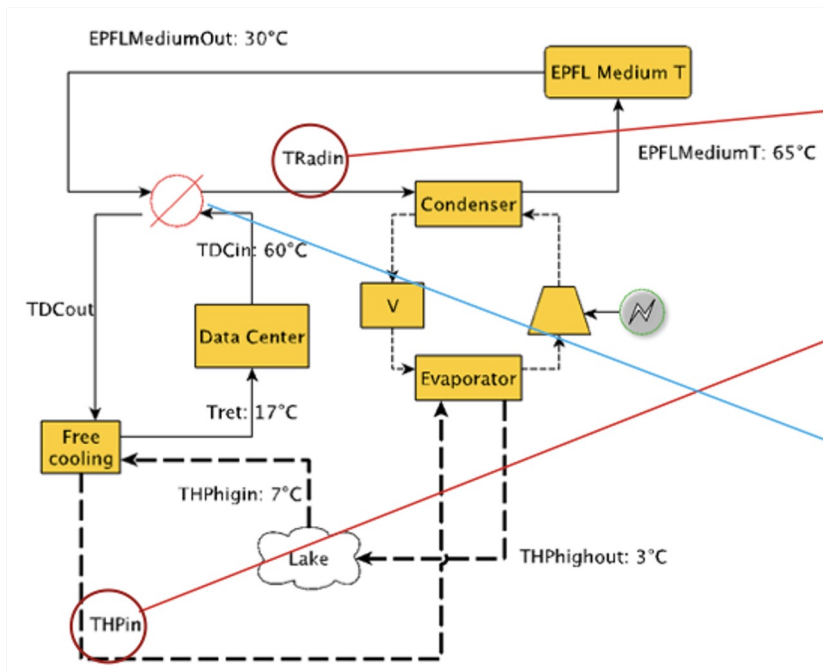
Tasks:

- Data Center from EPFL need to be cooled down. What if we could reuse that heat, in a win-win situation?
- Find the optimal heat exchanger area with ΔT_{min} optimization
- Calculate new energy bill (if worth it)
- Evaluate economic indicators



Pre-heating

Trade-off



$$COP = \eta \frac{T_{cond}}{T_{cond} - T_{evap}}$$

$$COP = \frac{Q_{cond}}{E}$$

$$Opex = f(E)$$

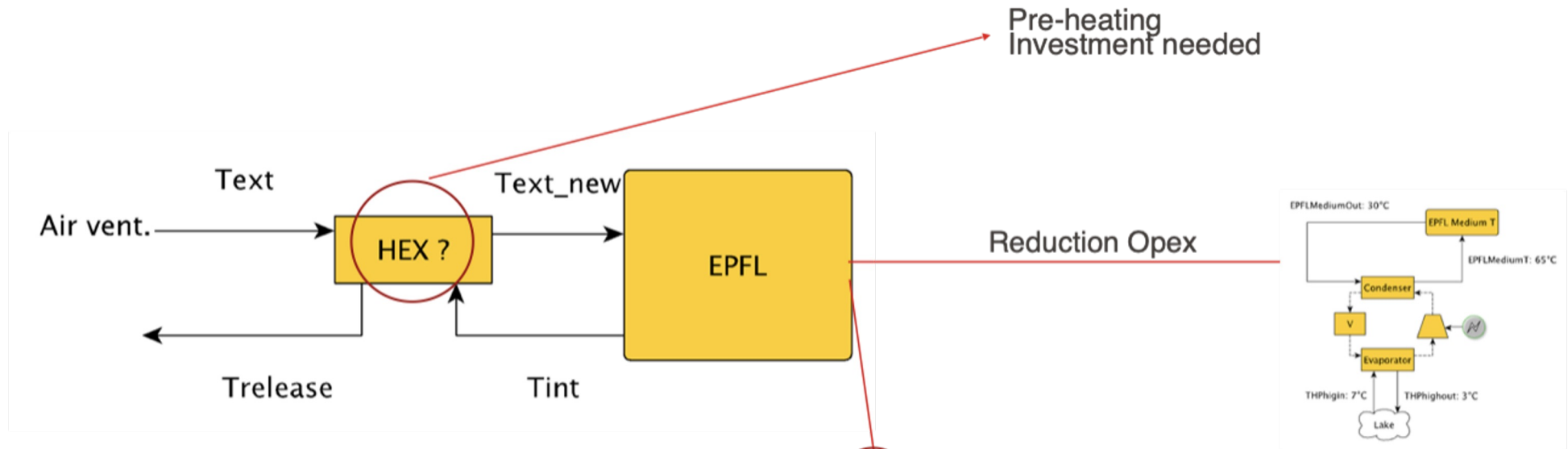
$$Area = \frac{Q_{HEX}}{U * \Delta T_{ln}}$$

$$\Delta T_{ln} = f(TRadin)$$

$$Capex = f(Area)$$

Non-linear

■ Integration of Ventilation -> Ventilation

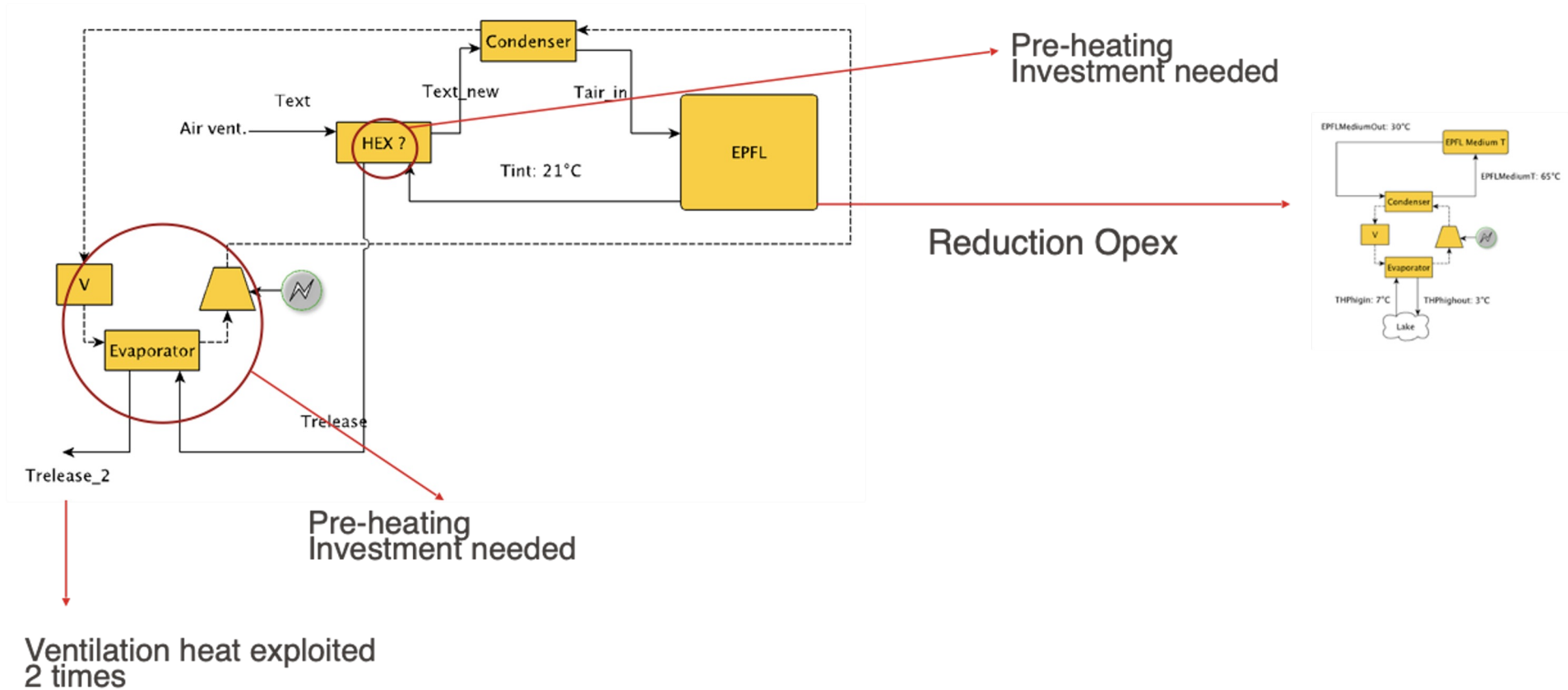


$$Q(t) = A_{th} \cdot \{U \cdot (T_{int} - T_{ext}(t)) + m_{air} \cdot c_{p,air} \cdot (T_{int} - T_{ext_{new}}(t)) - k_{sun} \cdot Irr(t) - Q_{people}(t)\} - Q_{el}(t) \quad (3.1)$$

$$Q_{th}(t) = \Delta t \{A_{th} \cdot (k_{th} \cdot (T_{int} - T_{ext}(t)) - k_{sun} \cdot \dot{i}(t) - \dot{q}_{people}(t)) - f_{el} \cdot \dot{Q}_{el}(t)\}$$

New equation for heat loads

■ Integration of Ventilation with HP -> Ventilation_HP



Remember :

- Full characterization of each of the **four** scenarios
 - All **thermodynamical** properties
 - Mass flows, temperatures, c_p ...
 - Equipment **sizes**
 - Heat **loads**
- In addition to the **costs** !!
 - OPEX, CAPEX and TOTEX

Project Files

4 heat recovery scenarios

esktop > documents > moes-project-reporting > codes_02_heat_recovery

Name	Date modified
 1.Reference_case	16/08/2022 09:48
 2.DC_recovery	16/08/2022 09:48
 3.Ventilation	17/08/2022 09:15
 4.Ventilation_HP	17/08/2022 09:48
 results	17/08/2022 17:07
 TA_files	17/08/2022 17:07
 .DS_Store	12/09/2022 17:26
 heat_recovery_optimization.Rmd	20/09/2022 15:27

3 ampl files per scenario:

.dat = data

.mod = model

.run = run optimization

 NLP_ref.dat
 NLP_ref.mod
 NLP_ref.run

Next steps:

- Follow the instructions on the qmd tutorial to run the AMPL files on VSC
- Start from the Reference Case
- Parameters and variables are already defined in the models
- You have to implement the equations that define the model constraints.
- Apply the same methodology on the next 3 cases, with further constraints since you are adding an additional HEX!

AMPL

5 main entities:

- Parameters: **param**
- Variables: **var**
- Sets: **set**
- Constraints: **subject to**
- Objective function: **minimize obj**

Important remarks:

- Parameters should have default values
- Variables should have default constraints
- Don't forget to put ; at the end of each entity

```
# Sets & Parameters

set Time default {}; #your time set from the
param Qheating{Time}; #your heat demand from
param top{Time}; #your operating time from th

param EPFLMediumT := 65; #[degC] - desired
param EPFLMediumOut := 30; # temperature of r

param CarnotEff := 0.55; #assumption: car
param Cel := 0.20; #[CHF/kWh] opera

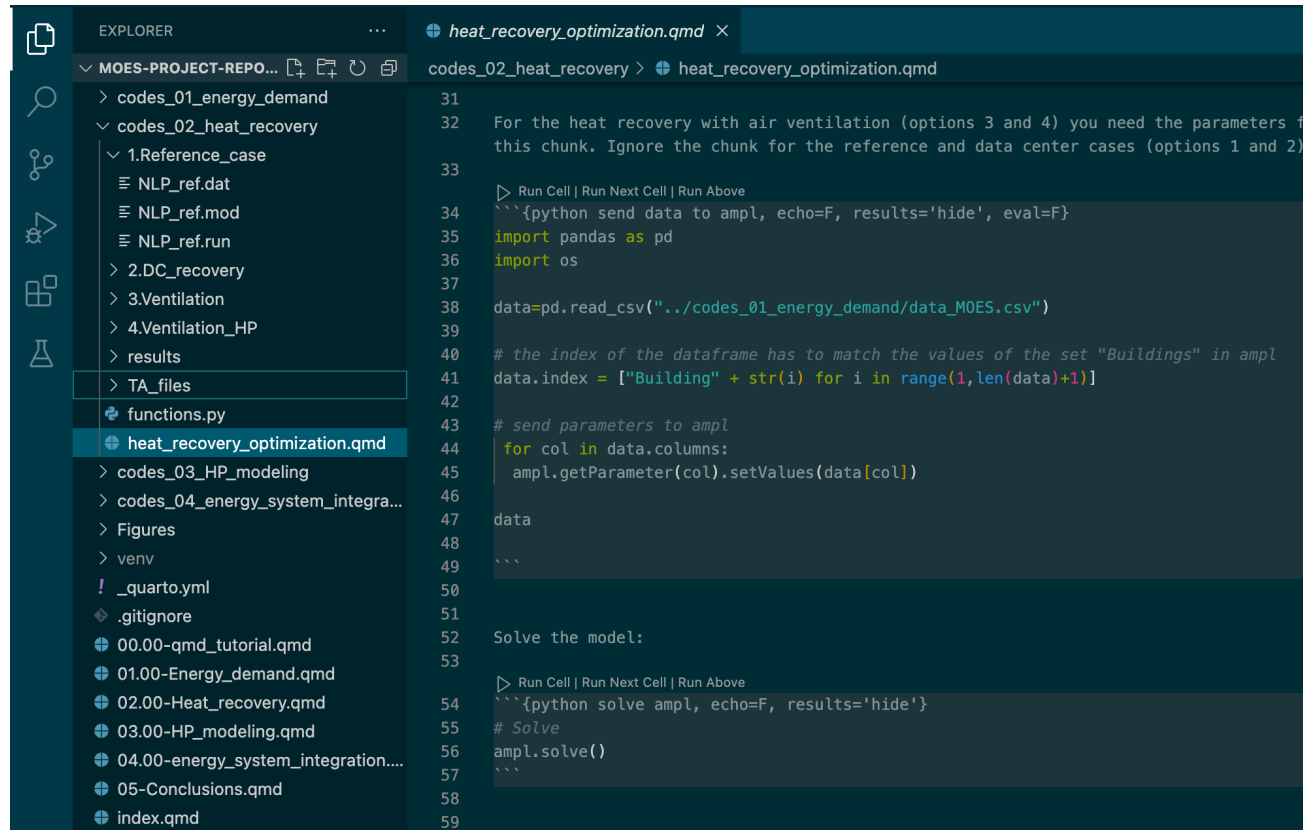
param THPhighin := 7; #[deg C] temperatur
param THPhighout := 3; #[deg C] temperatur

#####
# Variables

var E{Time} >= 0.001; # [kW] electric
var TLMCond{Time} >= 0.001; #[K] logarithmi
var Qevap{Time} >= 0.001; #[kW] heat extr
var Qcond{Time} >= 0.001; #[kW] heat deli
var COP{Time} >= 0.001; #coefficient of
```

Link between parts

- Run the project for the first time from the .run file to make sure everything is working well
- Then use this .qmd file to run the scenarios with your parameters from part.1 (k_{th} , k_{sun} , clustering data...) directly in python



```
EXPLORER
MOES-PROJECT-REPO...
  codes_01_energy_demand
  codes_02_heat_recovery
    1.Reference_case
      NLP_ref.dat
      NLP_ref.mod
      NLP_ref.run
    2.DC_recovery
    3.Ventilation
    4.Ventilation_HP
    results
    TA_files
    functions.py
    heat_recovery_optimization.qmd
  codes_03_HP_modeling
  codes_04_energy_system_integra...
  Figures
  venv
  _quarto.yml
  .gitignore
  00.00-qmd_tutorial.qmd
  01.00-Energy_demand.qmd
  02.00-Heat_recovery.qmd
  03.00-HP_modeling.qmd
  04.00-energy_system_integration....
  05-Conclusions.qmd
  index.qmd

heat_recovery_optimization.qmd
codes_02_heat_recovery > heat_recovery_optimization.qmd
31
32 For the heat recovery with air ventilation (options 3 and 4) you need the parameters f
this chunk. Ignore the chunk for the reference and data center cases (options 1 and 2)
33
34 Run Cell | Run Next Cell | Run Above
35 {python send data to ampl, echo=F, results='hide', eval=F}
36 import pandas as pd
37 import os
38
39 data=pd.read_csv("../codes_01_energy_demand/data_MOES.csv")
40
41 # the index of the dataframe has to match the values of the set "Buildings" in ampl
42 data.index = ["Building" + str(i) for i in range(1,len(data)+1)]
43
44 # send parameters to ampl
45 for col in data.columns:
46     ampl.getParameter(col).setValues(data[col])
47
48 data
49
50
51
52 Solve the model:
53
54 Run Cell | Run Next Cell | Run Above
55 {python solve ampl, echo=F, results='hide'}
56 # Solve
57 ampl.solve()
58
59
```


EPFL



Merci