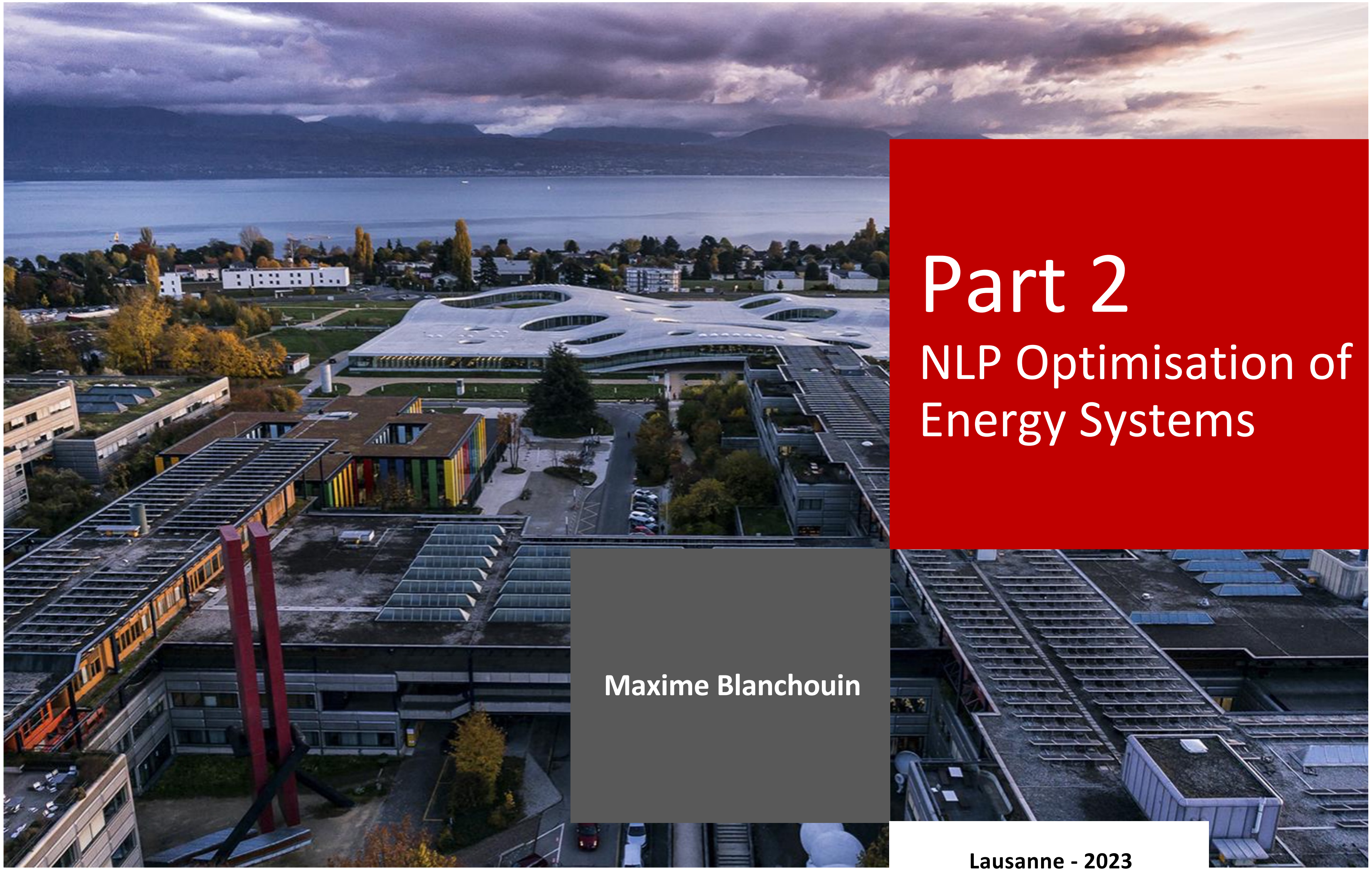

Part 2

NLP Optimisation of Energy Systems

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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:

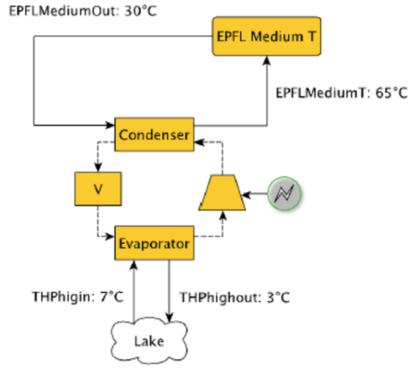
- Calculate the current energy bill of EPFL heating system
- Evaluate 3 alternative configurations and compute their KPIs :
    - CAPEX
    - OPEX
    - Payback time
    - Minimum Temp difference ΔT_{min}
    - HEX areas

What you will learn:

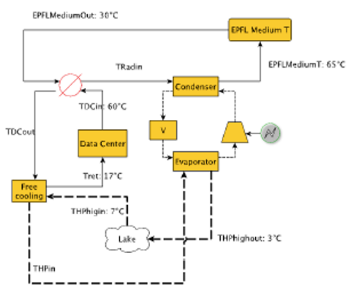
- Formulate NLP optimizations for energy recovery
- Understand AMPL and its integration on VSC
- Understand how the parameters variations influence the optimization process.

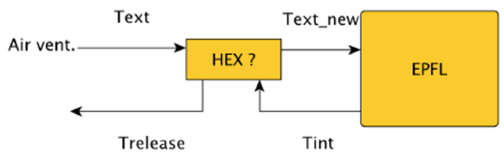
1 Reference case + 3 different scenarios

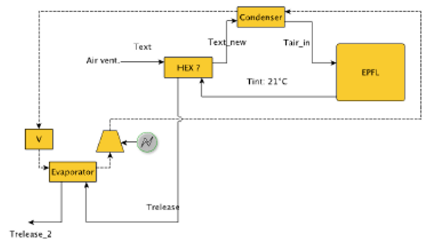
2.1 Reference case



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

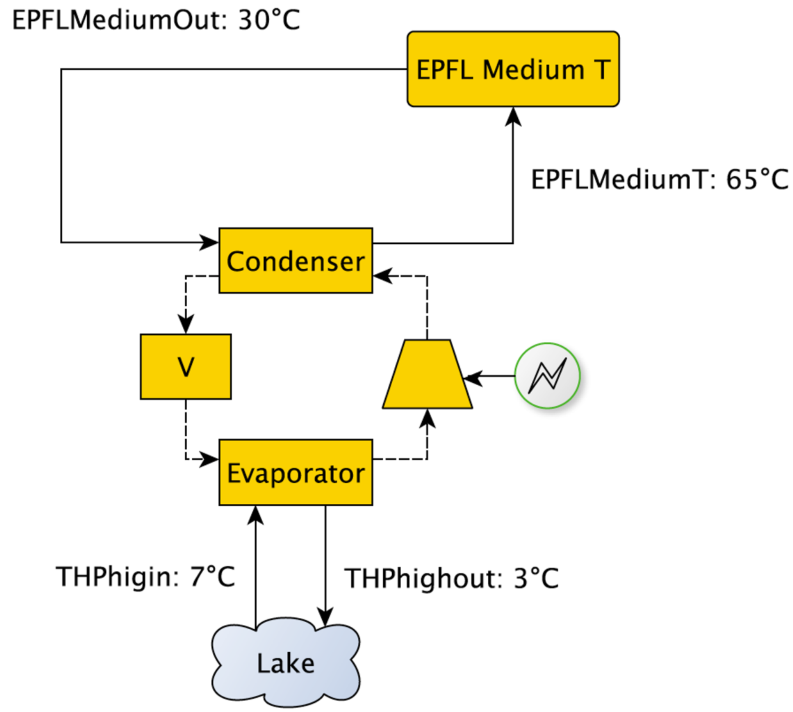






Reference case

- **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:

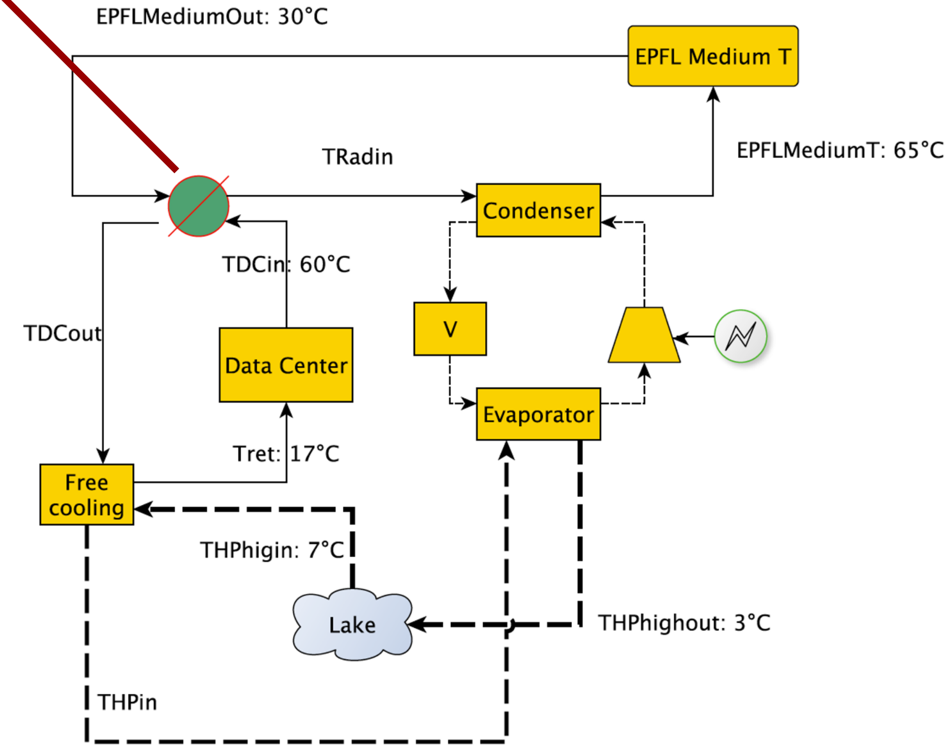
- Calculate the energy bill (electric consumption of the compressor)
- Describe the flowsheet from a thermodynamic point of view

Data center

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

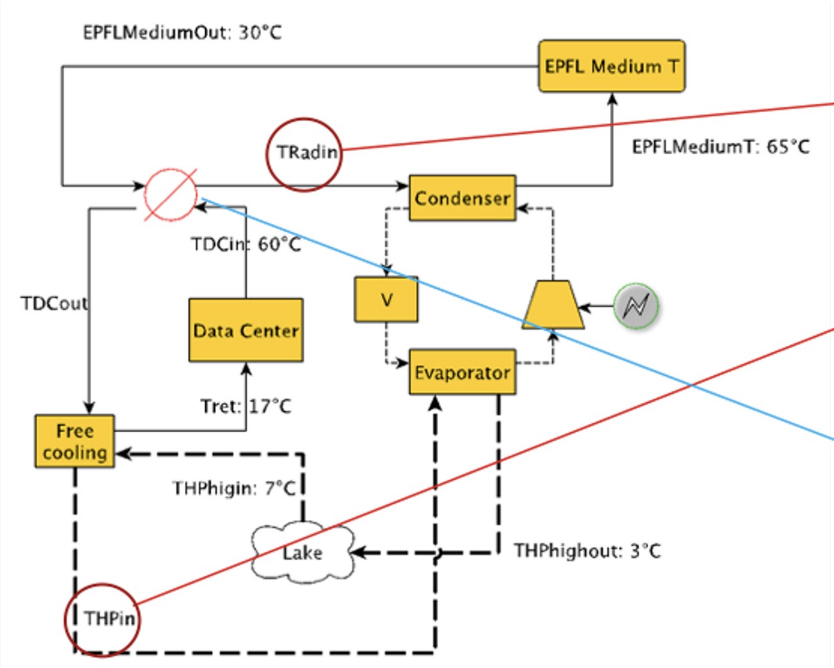
Data center HEX



Pre-heating

Trade-off

x



$$COP = \eta \frac{Tcond}{Tcond \; - Tevap}$$

$$COP = \frac{Qcond}{E}$$

$$Opex = f(E)$$

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

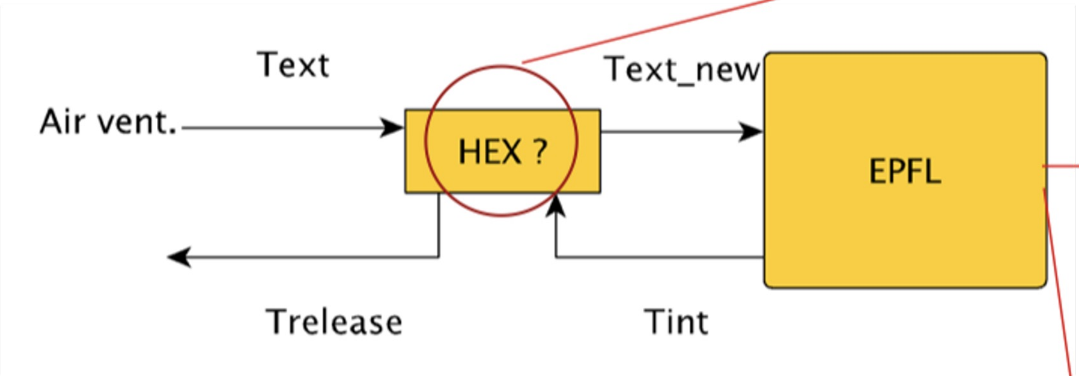
$$\Delta T_{ln} = f(TRadin)$$

$$Capex = f(Area)$$

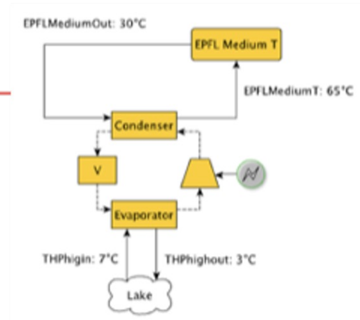
Non-linear

▪ Integration of Ventilation -> Ventilation

Pre-heating
Investment needed



Reduction Opex

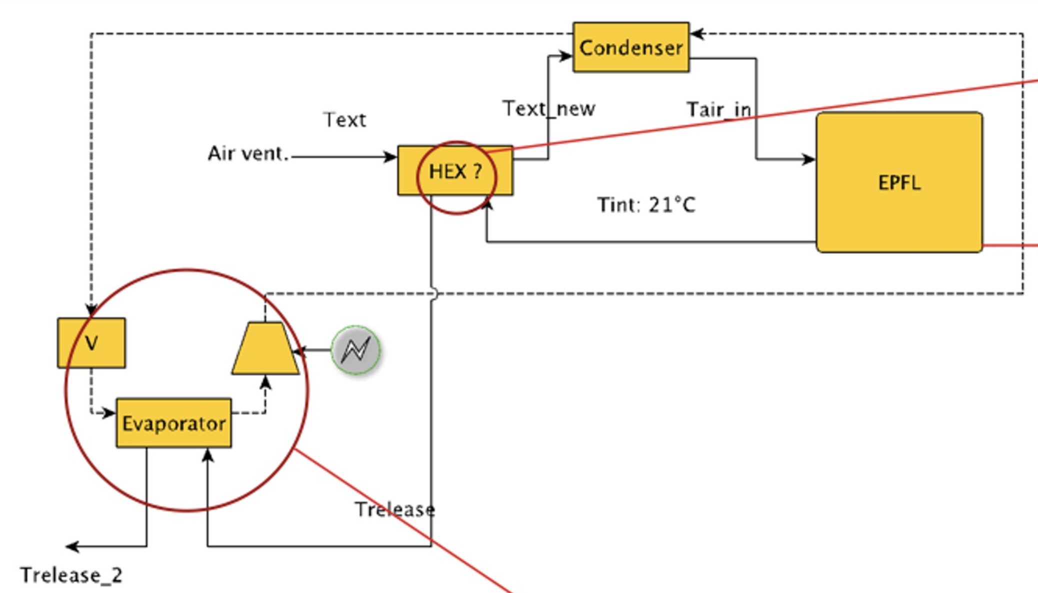


$$Q(t) = A_{th} \cdot \{U \cdot (T_{int} - T_{ext}(t)) + m_{air} \cdot c_{p,air} \cdot (T_{int} - T_{ext_new}(t)) - k_{sun} \cdot Irr(t) - Q_{people}(t)\} - Q_{el}(t) \quad (3.1)$$

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

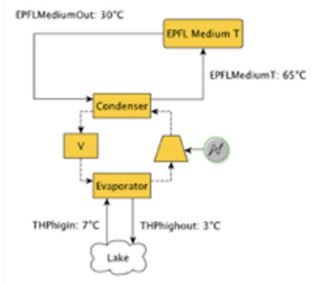
New equation for heat loads

Integration of Ventilation with HP -> Ventilation_HP



Pre-heating
Investment needed

Reduction Opex



Pre-heating
Investment needed

Ventilation heat exploited
2 times

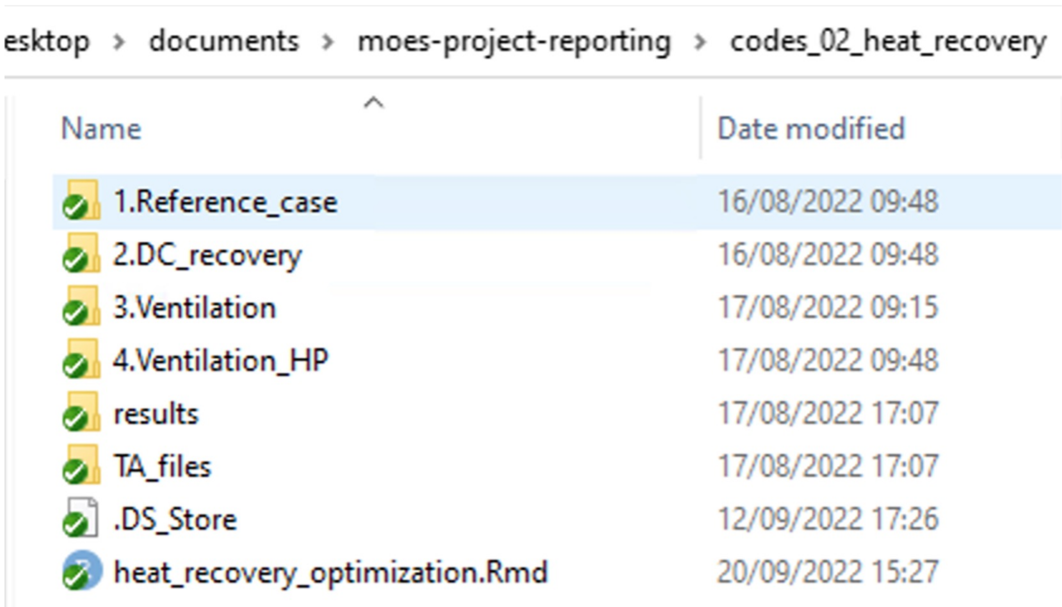
Remember :

- Full characterization of each of the **four** scenarios
  - All **thermodynamical** properties
    - Mass flows, temperatures, c_p ...
  - Equipment **sizes**
  - Heat **loads**

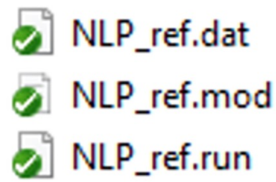
- In addition to the **costs** !!
  - OPEX, CAPEX and TOTEX

Project Files

4 heat recovery scenarios



3 ampl files per scenario:
.dat = data
.mod = model
.run = run optimization



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:

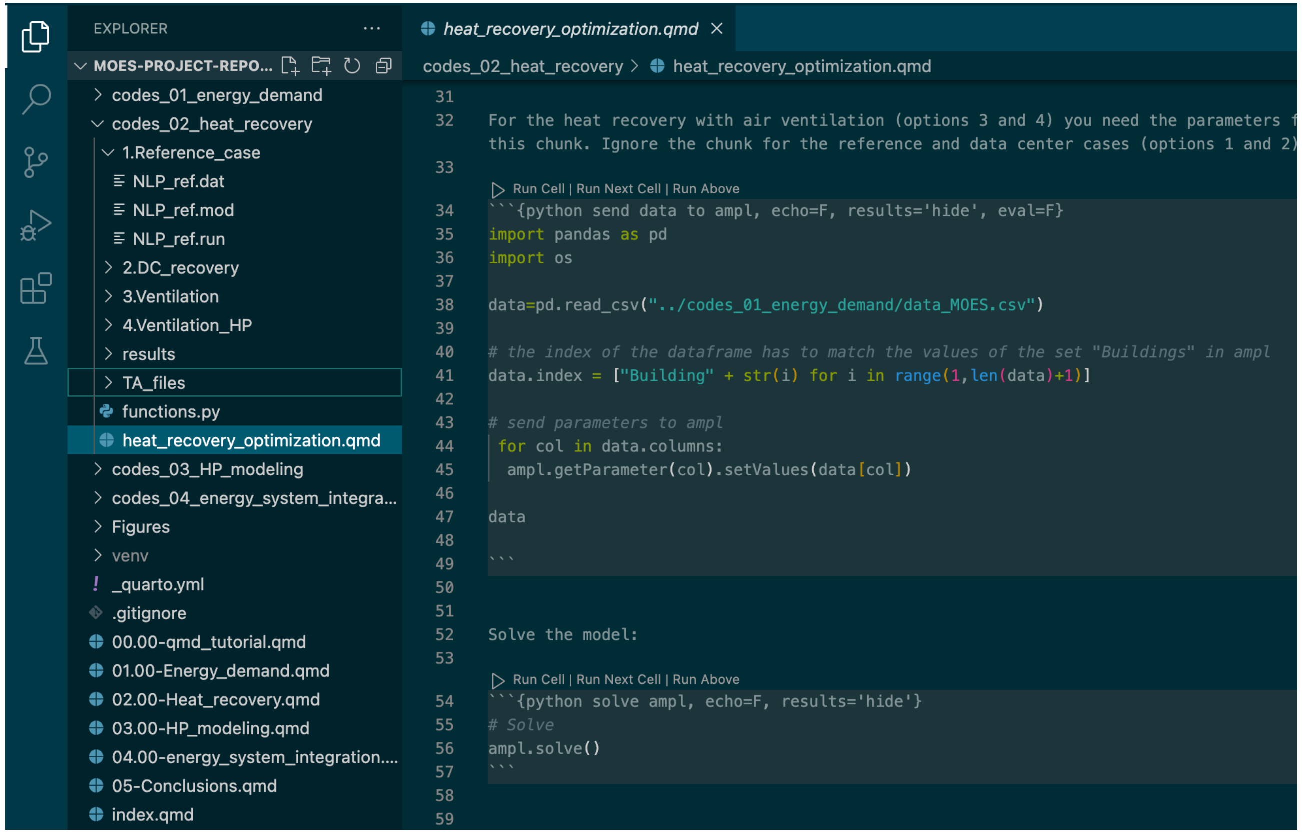
- Parameters should have default values
- Variables should have default constraints
- Don't forget to put **;** at the end of each entity

```
# 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



EPFL

Merci