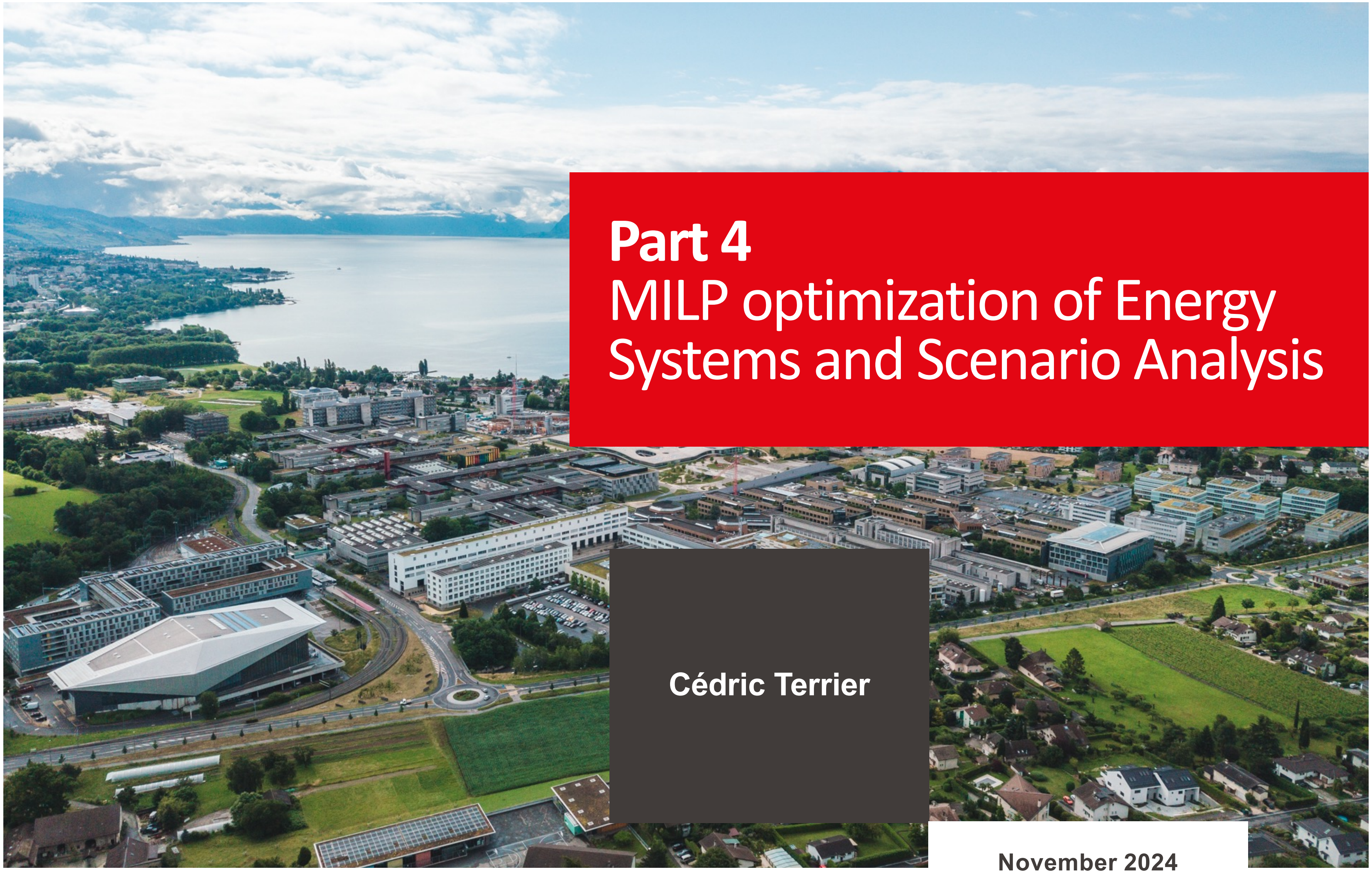
EPFL



Part 4
MILP optimization of Energy Systems and Scenario Analysis

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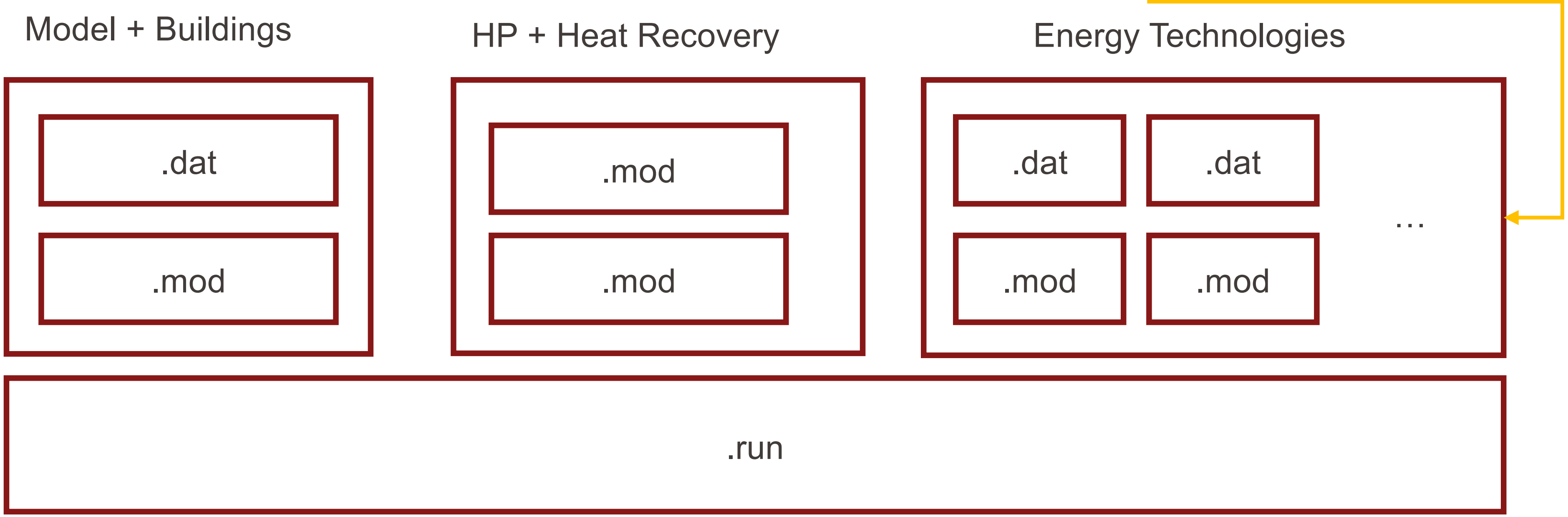
Project Structure

Boiler	Geothermal cogeneration system
Two 1-stage heat pumps	Cogeneration engine
2-stage heat pump	Solid oxide fuel cell (SOFC)
Photovoltaic panels	Your ideas



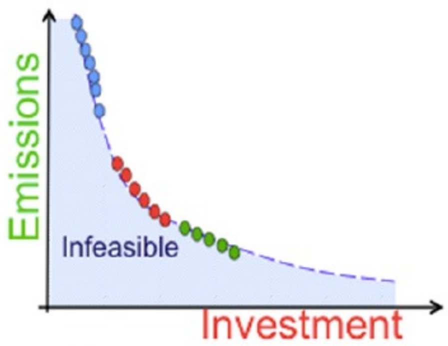
Overview

- Adapt your current model of EPFL energy systems with the results obtained from the previous parts

(Part 1: heating clusters and buildings characteristics, Part 2: Heat recovery scenarios, Part 3: Heat pump model)

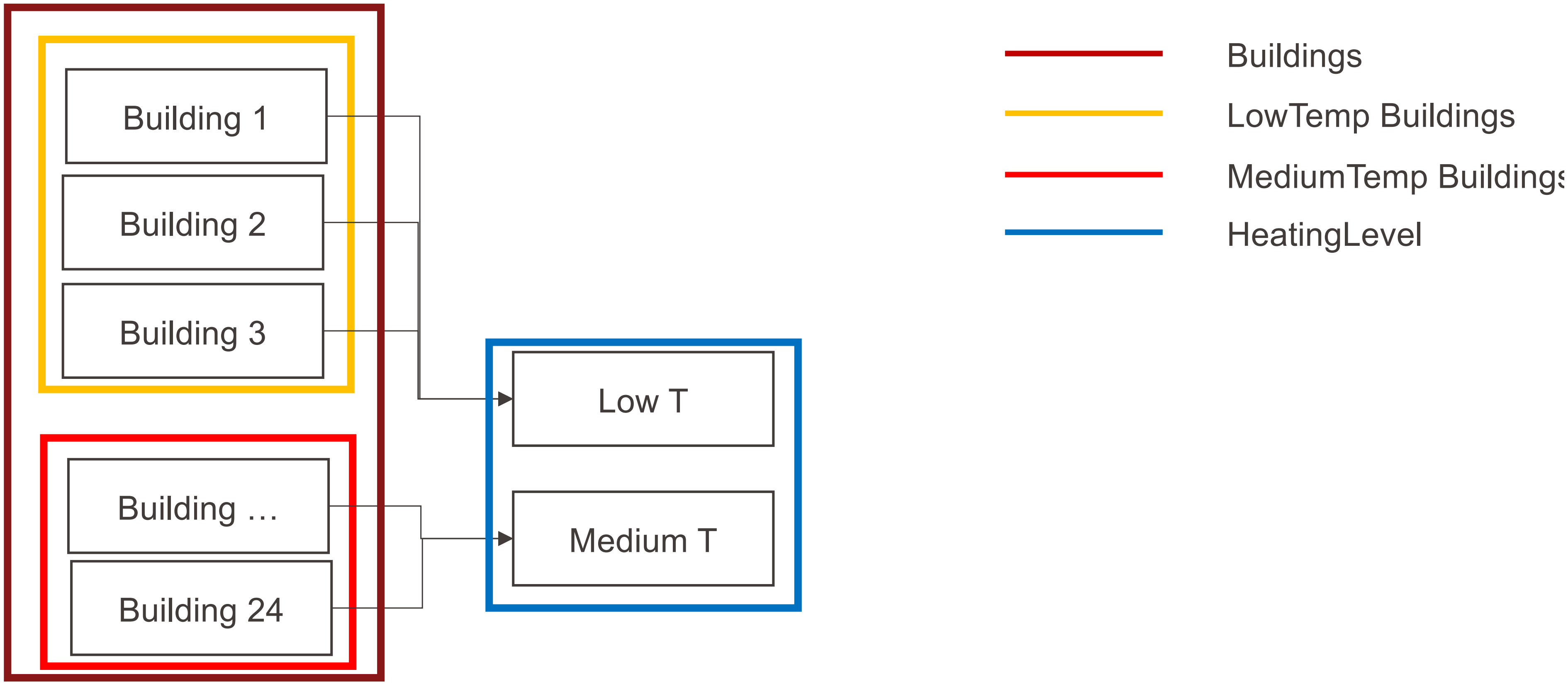
- Suggest at least three different new energy systems (different scenarios → different objective function)
  - *EPFL has very little money to invest at present and wants to minimize the costs of installing new technologies.*
  - *Due to the financial crisis, EPFL expects to have much less money in the coming years and wants to minimize the operating costs.*
  - *EPFL wants to become a greener university and wants to minimize the total equivalent carbon emissions.*

- Conduct a multi-objective (Pareto) optimization: analyzing the trade-off between different objectives
- Assess the sensitivity of your solutions to variations: natural gas and electricity prices, carbon tax..

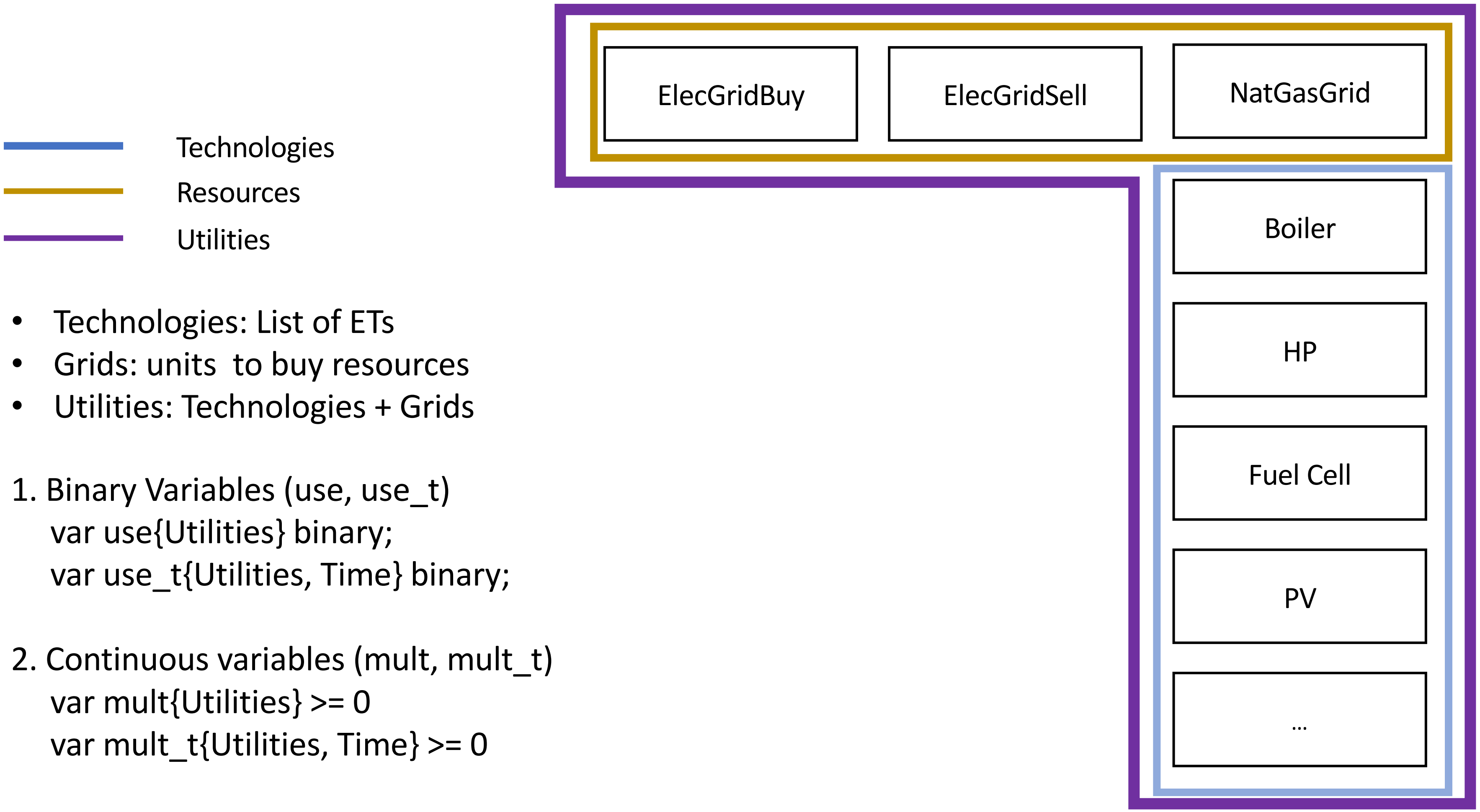


Thermo-economic pareto

Structure of the sets



Utilities Set

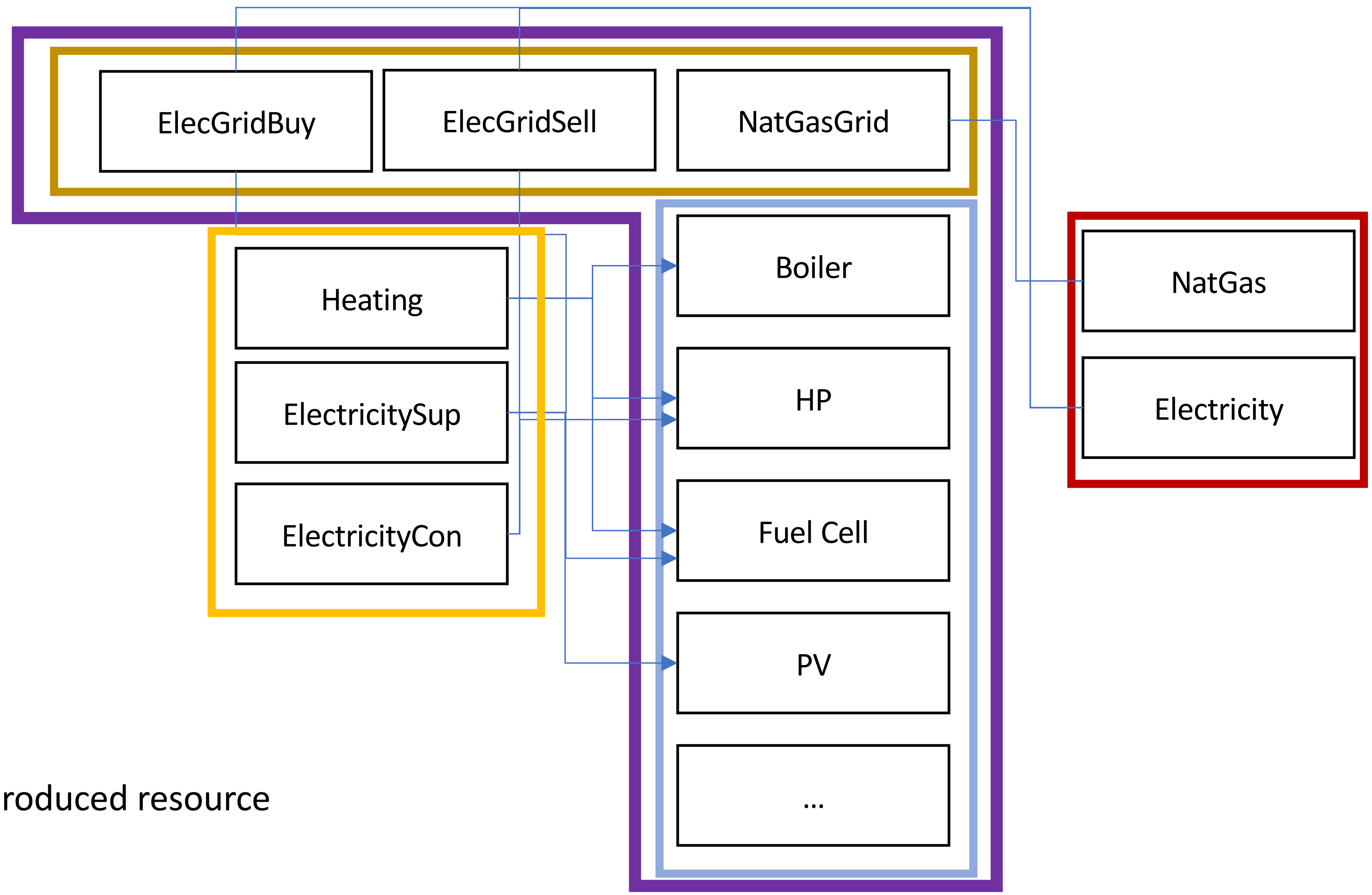


- Technologies: List of ETs
- Grids: units to buy resources
- Utilities: Technologies + Grids

1. Binary Variables (use, use_t)
   var use{Utilities} binary;
   var use_t{Utilities, Time} binary;

2. Continuous variables (mult, mult_t)
   var mult{Utilities} >= 0
   var mult_t{Utilities, Time} >= 0

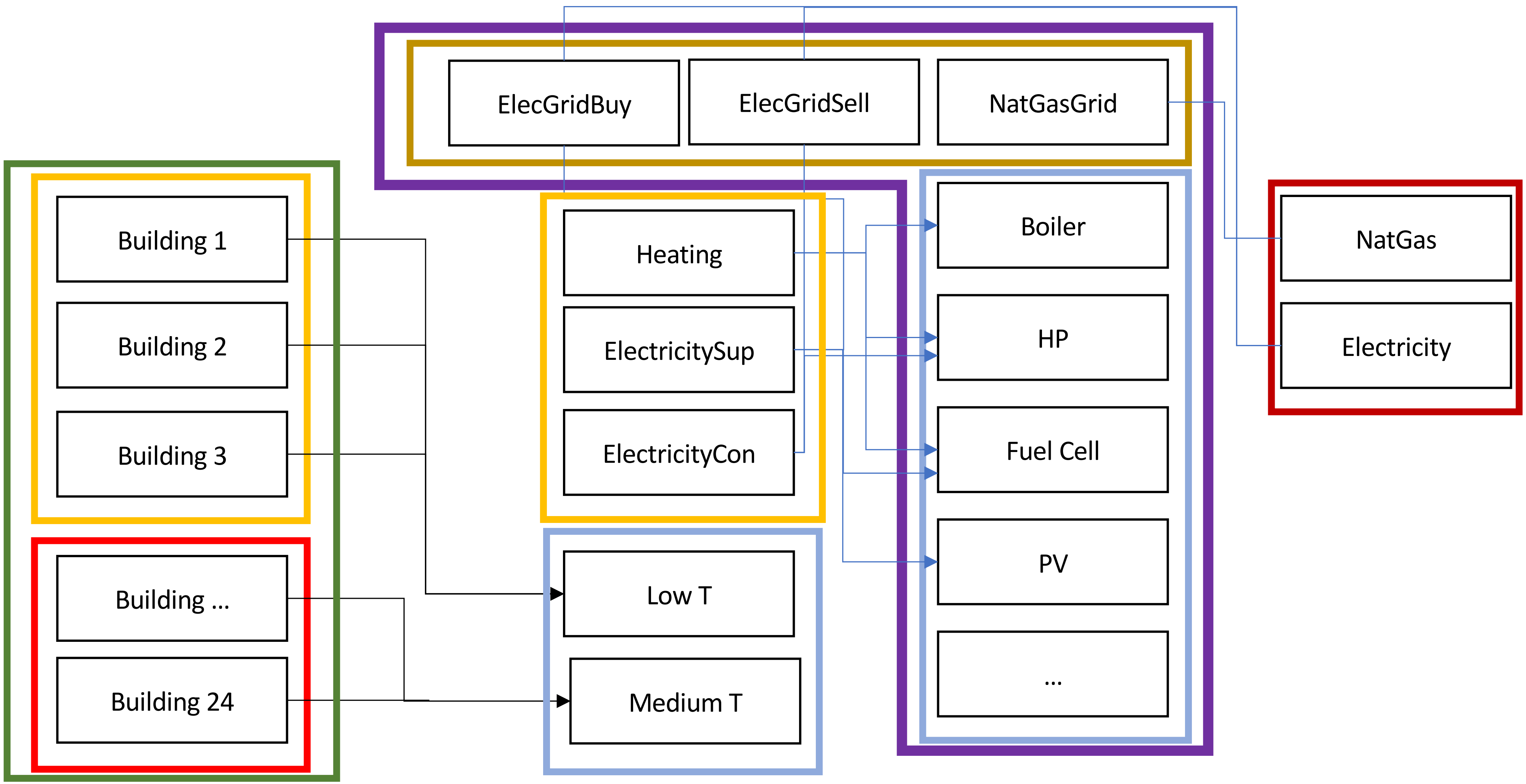
Layers and other sets



UtilitiesType
Layer

- UtilitiesType:
  - Type of technology
  - List of ET sub-sets
- Layer:
  - Type of consumed/produced resource
  - List of ET sub-sets

Overall structure of the sets



Constraints: heating balances

In the model

Decision variable for operation

```
Qheatingdemand['LowT',t] = Σ_u Qheatingsupply[u] * mult_heating_t[u,t,'LowT']
Qheatingdemand['MediumT',t] = Σ_u Qheatingsupply[u] * mult_heating_t[u,t,'MediumT']
```

Your task

```
cinv1['HP2stage']
cinv2['HP2stage']
```

HP

```
Qheatingsupply ['HP2stage']

Flowin['Electricity','HP2stage'] =
Qheatingsupply ['HP2stage'] / COP
```

Constraints: resource balance

Resource balance:

$$\sum_u \texttt{FlowInUnit[l,u,t]} = \sum_u \texttt{FlowOutUnit[l,u,t]}$$

```
FlowInUnit[l,u,t] = mult_t[u,t] * Flowin[l,u]

FlowOutUnit[l,u,t] = mult_t[u,t] * Flowout[l,u]
```

Your task

```
cinv1['HP2stage']
cinv2['HP2stage']
```

HP

```
Qheatingsupply ['HP2stage']

Flowin['Electricity','HP2stage'] =
Qheatingsupply ['HP2stage'] / COP
```

reference size

Constraints: electricity balance

$$\text{Edemand}[t] + \sum_u \text{FlowInUnit}[l,u,t] = \sum_u \text{FlowOutUnit}[l,u,t]$$

Observe that:

Sum over UtilitiesOfType['ElectricityCons'] and UtilitiesOfType['ElectricityProd']

These are subset of utilities consuming and producing electricity

Objective function: TOTEX

$$\text{OPEX} = \sum_{u,t} (\texttt{cop1[u]} * \texttt{use\_t[u,t]} + \texttt{cop2[u]} * \texttt{mult\_t[u,t]}) * \texttt{top[t]}$$

$$\text{CAPEX} = \sum_{tech} (\texttt{cinv1[tc]} * \texttt{use[tc]} + \texttt{cinv2[tc]} * \texttt{mult[tc]})$$

cop1[u]: fixed operating cost of the utility u [CHF/h]

cinv1[tc]: fixed investment cost of the technology tc [CHF/h]

cop2[u]: variable operating cost of the utility u [CHF/h] = energy tariff

cinv2[tc]: variable investment cost of the technology tc [CHF/y]

You can easily change the energy tariffs in moes.dat: c_spec

Your TODOs

Read part 4 of **Project description.pdf**

Check that your ampl files is running with PVs and boilers

Add your typical days

Include your best heat recovery option as a new unit (the model should be linear)

Add heatpumps using the COP from Part 3

Add other types of units you would like to integrate and new layers if needed (biogas, biomass, H2, …)

Run scenarios, sensitivity analysis on energy tariffs, pareto fronts