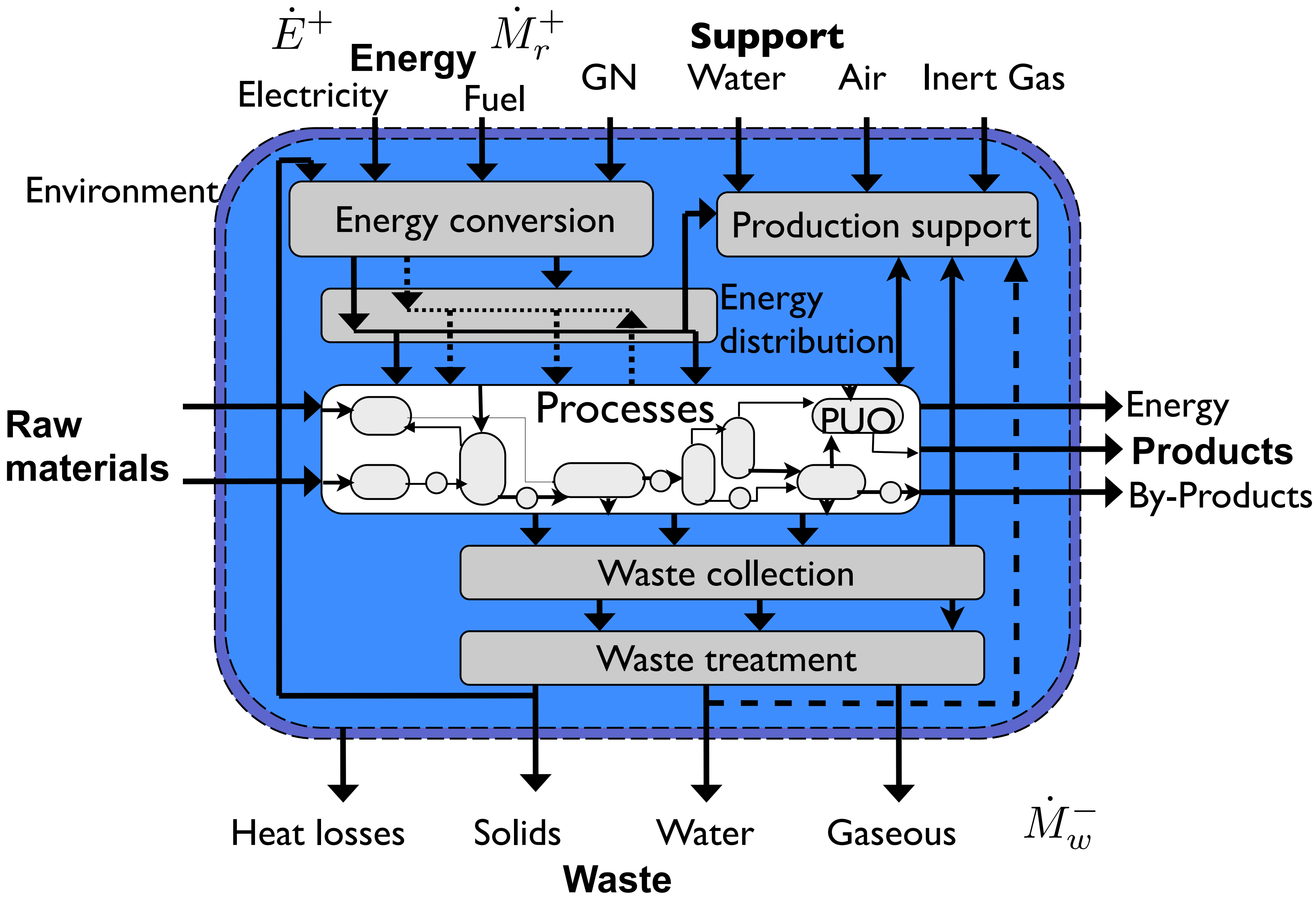
Hot and cold streams

IPESE
Industrial Process
and Energy Systems
Engineering

The process system



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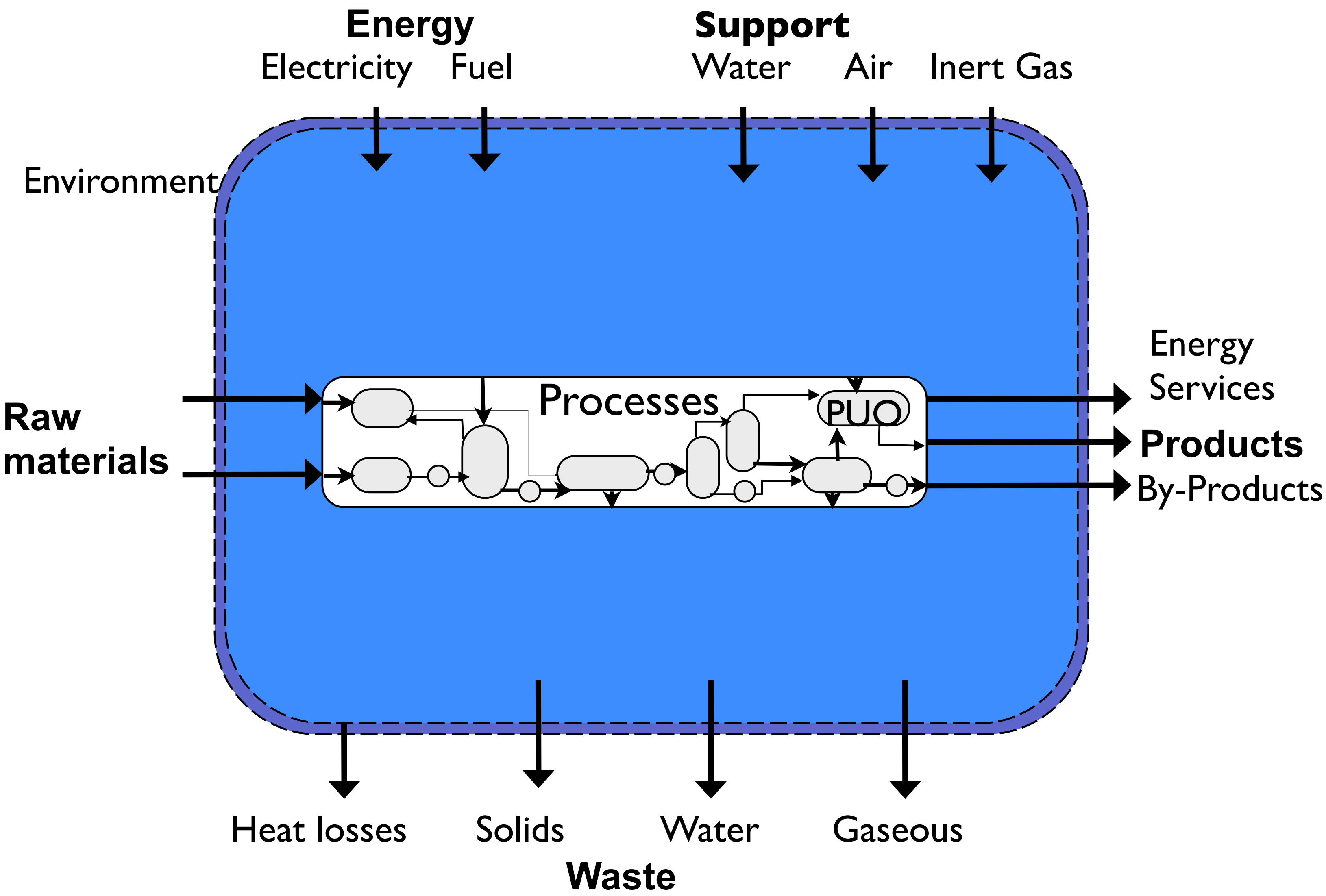
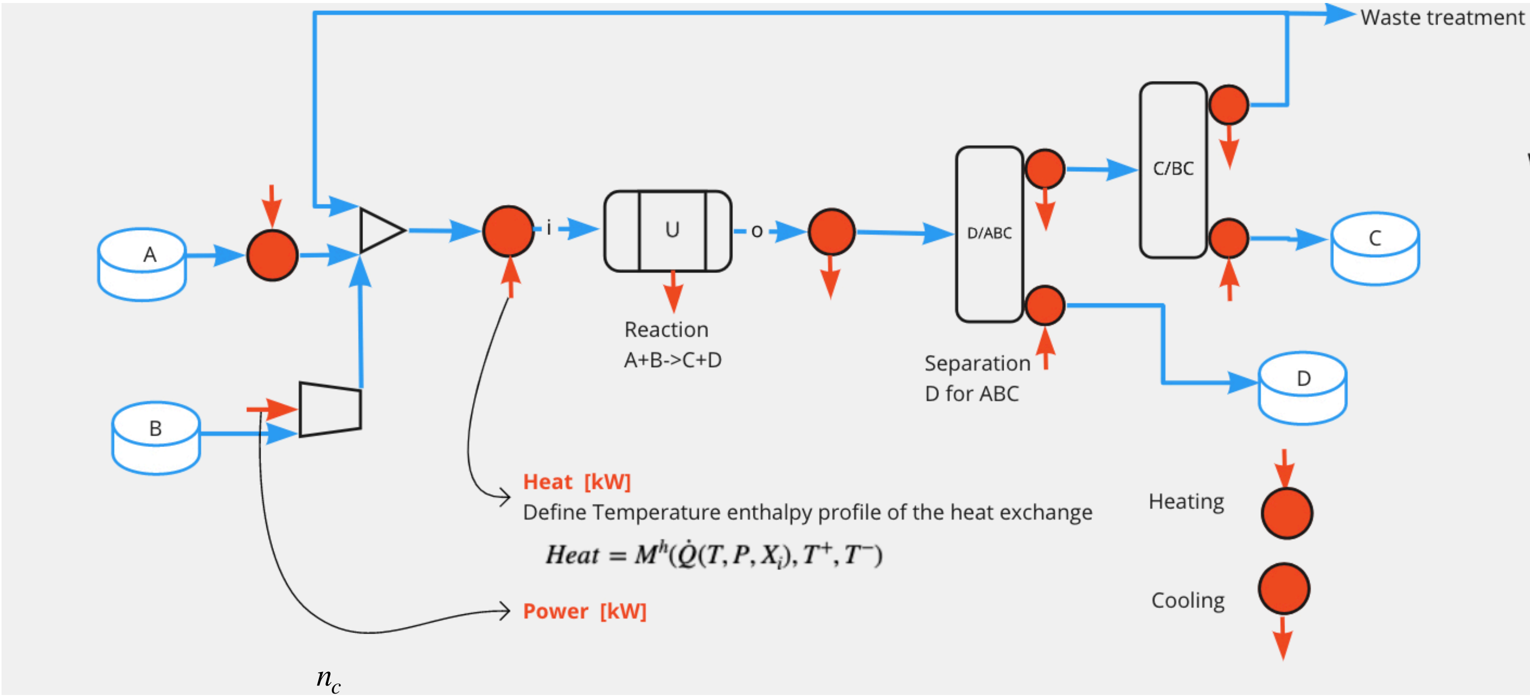
The process units



Process Energy use



Heating requirement : $\dot{Q}_{heat} = \sum_{c=1}^{n_c} \dot{Q}_{cold}$, Cost of heat requirement : $c_{heat}[CHF/kJ] \cdot \dot{Q}_{heat}[kJ/s] \cdot t_{op}[s/year]$

Cooling requirement : $\dot{Q}_{cooling} = \sum_{h=1}^{n_h} \dot{Q}_{hot}$, Cost of cooling requirement : $c_{cool}[CHF/kJ] \cdot \dot{Q}_{cool}[kJ/s] \cdot t_{op}[s/year]$

Refrigeration requirement : $\dot{Q}_{ref} = \sum_{h=1}^{n_h} \dot{Q}_{hot,T_{hot}<T_{amb}}$, Cost of cooling requirement : $c_{ref}[CHF/kJ] \cdot \dot{Q}_{ref}[kJ/s] \cdot t_{op}[s/year]$

Identify the heat transfer requirements

Heat load

$$\dot{Q} = -\dot{m}_c \int_{T_{in,c}}^{T_{out,c}} cp_c dT \simeq \dot{m}_c cp_c (T_{in,c} - T_{out,c})$$

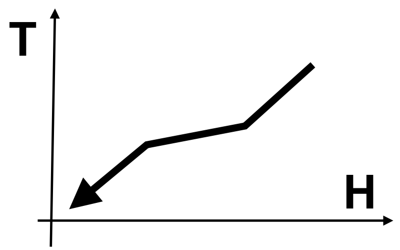
Target State
- Environment
- to process unit operation

Inlet State
- Environment
- from process unit operation

Hot Streams

---> To be cooled down

Examples
- Distillation condenser
- Exothermic reactor
- Fumes
- Steam condenser
- Hot stream of a refrigeration cycle

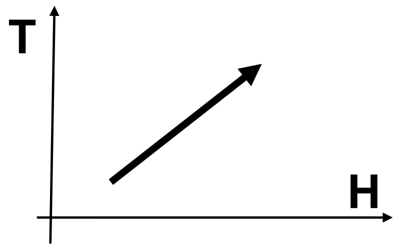


Heat/temperature profile

Cold Streams

---> To be heated up

Examples
- Distillation boilers
- Reactants Preheating
- Cooling water
- Steam production
- Cold stream of a refrigeration cycle

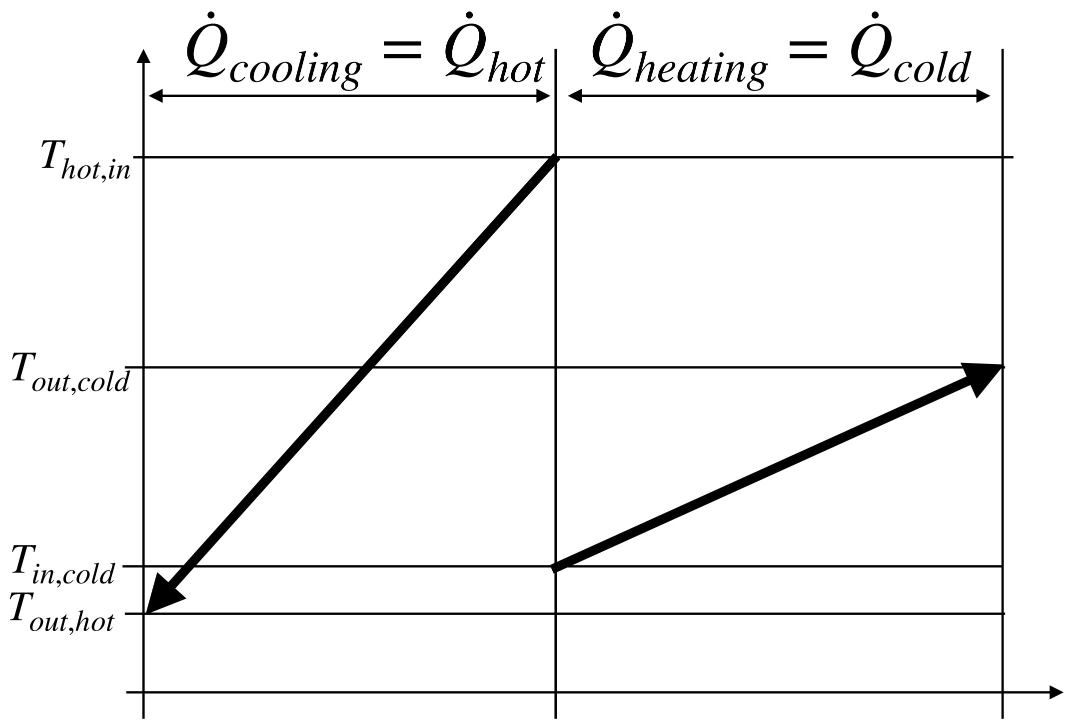


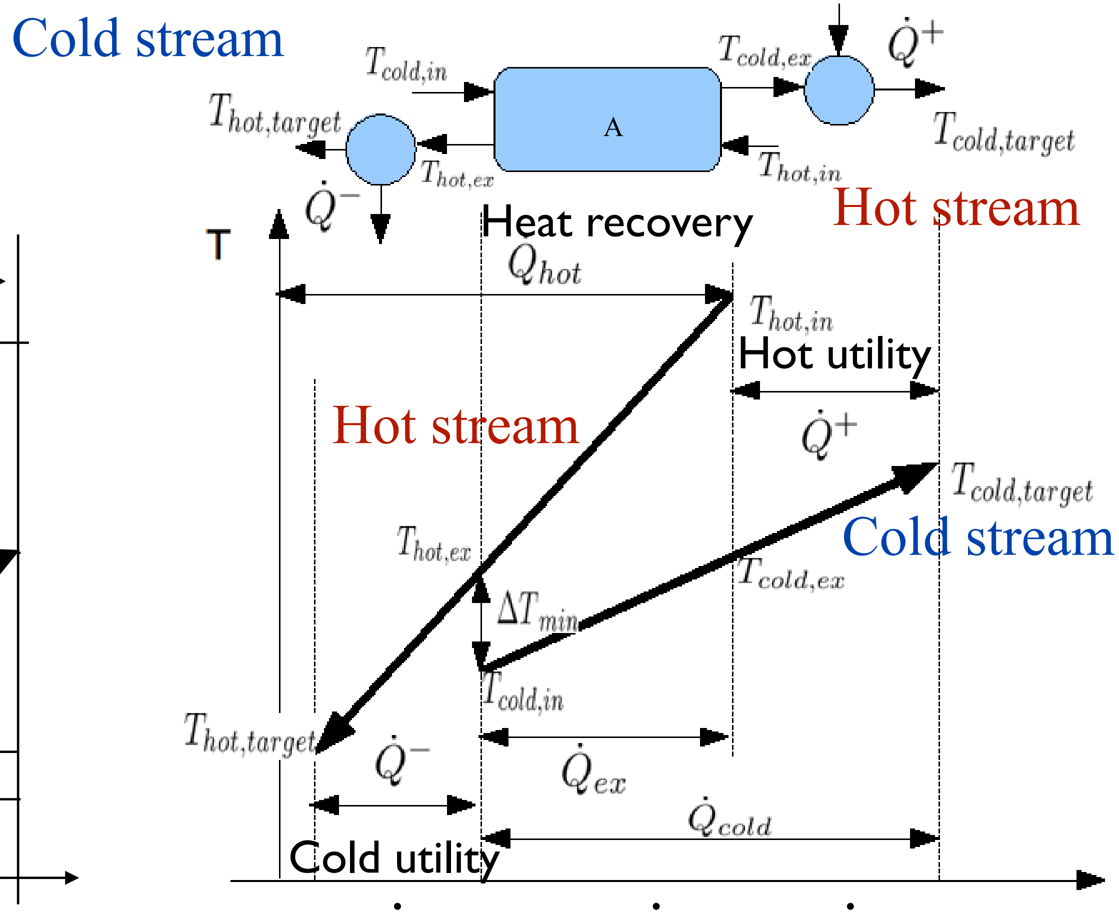
Heat/temperature profile

Do not forget the system limits

- Streams leaving the system (in the condition of market)
  - Minimum target temperatures (equilibrium with ambience !)
  - Minimum pressure required (expansion ?)
- Waste streams (do not waste heat or cold in the environment)
  - Heat recovery possible
  - Waste heat conversion
  - Recycle (material streams have also an energy value)
  - Emission control
- Raw material preparation
  - Alternative raw materials : Waste streams ?
  - Preprocess locally to avoid expensive supply chains
- Industrial symbiosis opportunities
  - Exchange with other systems

Heat recovery : Heat exchanger





$$\dot{Q}_{heating} = \dot{Q}_{cold} - \dot{Q}_{ex}$$
$$\dot{Q}_{cooling} = \dot{Q}_{hot} - \dot{Q}_{ex}$$

ΔTmin value : optimization problem

$$min_{\Delta T_{min}} TotalCost = OC_{ex}(\Delta T_{min}) + IC_{ex}(\Delta T_{min})$$

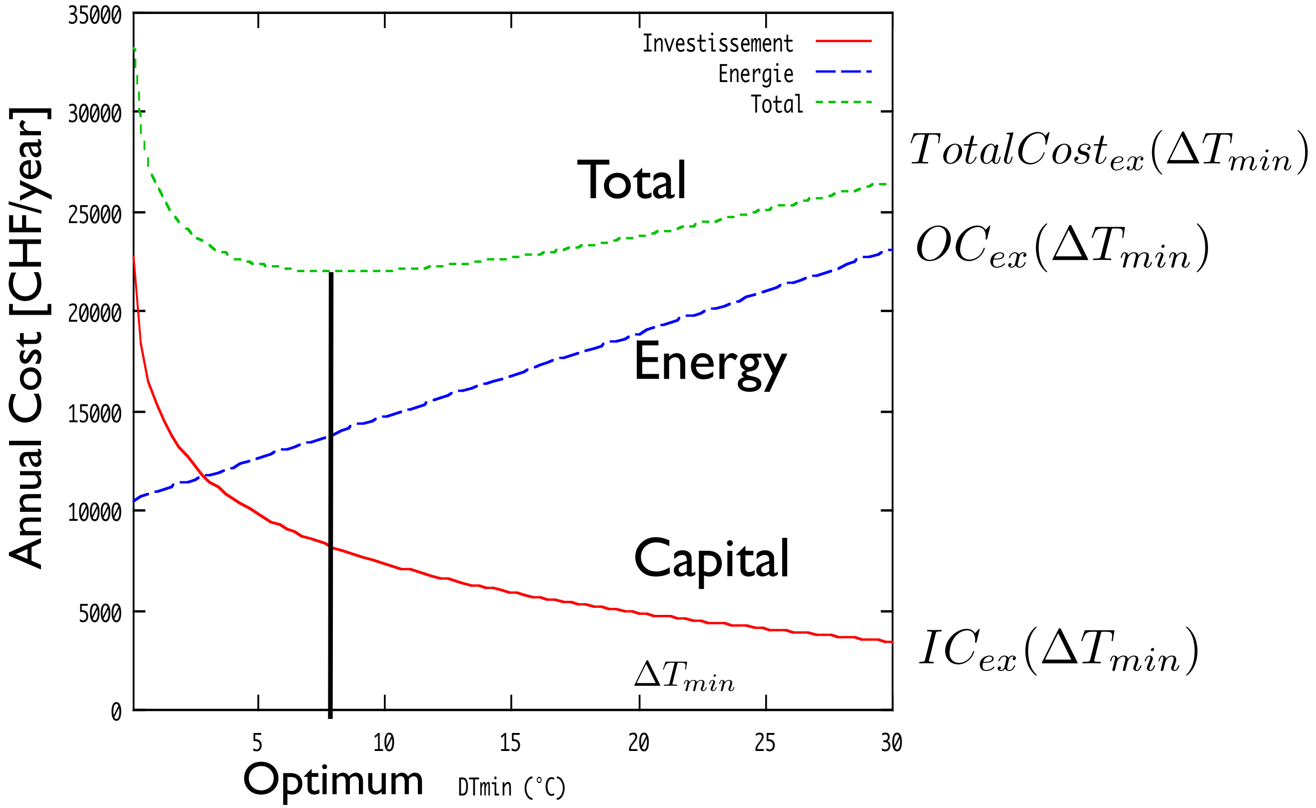
$$OC_{ex}(\Delta T_{min}) = (c_{cold} \cdot (\dot{Q}_{hot} - \dot{Q}_{ex}(\Delta T_{min})) + c_{hot} \cdot (\dot{Q}_{cold} - \dot{Q}_{ex}(\Delta T_{min}))) \cdot time_{year}$$

$$IC_{ex}(\Delta T_{min}) = (\frac{i(1+i)^{ny_{ex}}}{(1+i)^{ny_{ex}} - 1}) \cdot a_{ex} \cdot (\frac{\dot{Q}_{ex}(\Delta T_{min})}{U_{ex}\Delta T_{lm}(\Delta T_{min})})^{b_{ex}}$$

- DTmin value depends on
  - Operating time
  - Heat transfer coefficient
  - Heat load
  - Energy cost
  - Type of heat exchanger
  - Cost of the heat exchanger
  - Investment strategy
    - interest rate
    - expected life time

ΔTmin value : optimization problem

Annual cost as a function of ΔTmin



$$\Delta OC_{ex}(\Delta T_{min}) = \Delta IC_{ex}(\Delta T_{min})$$

Generalisation heat exchanges requirements