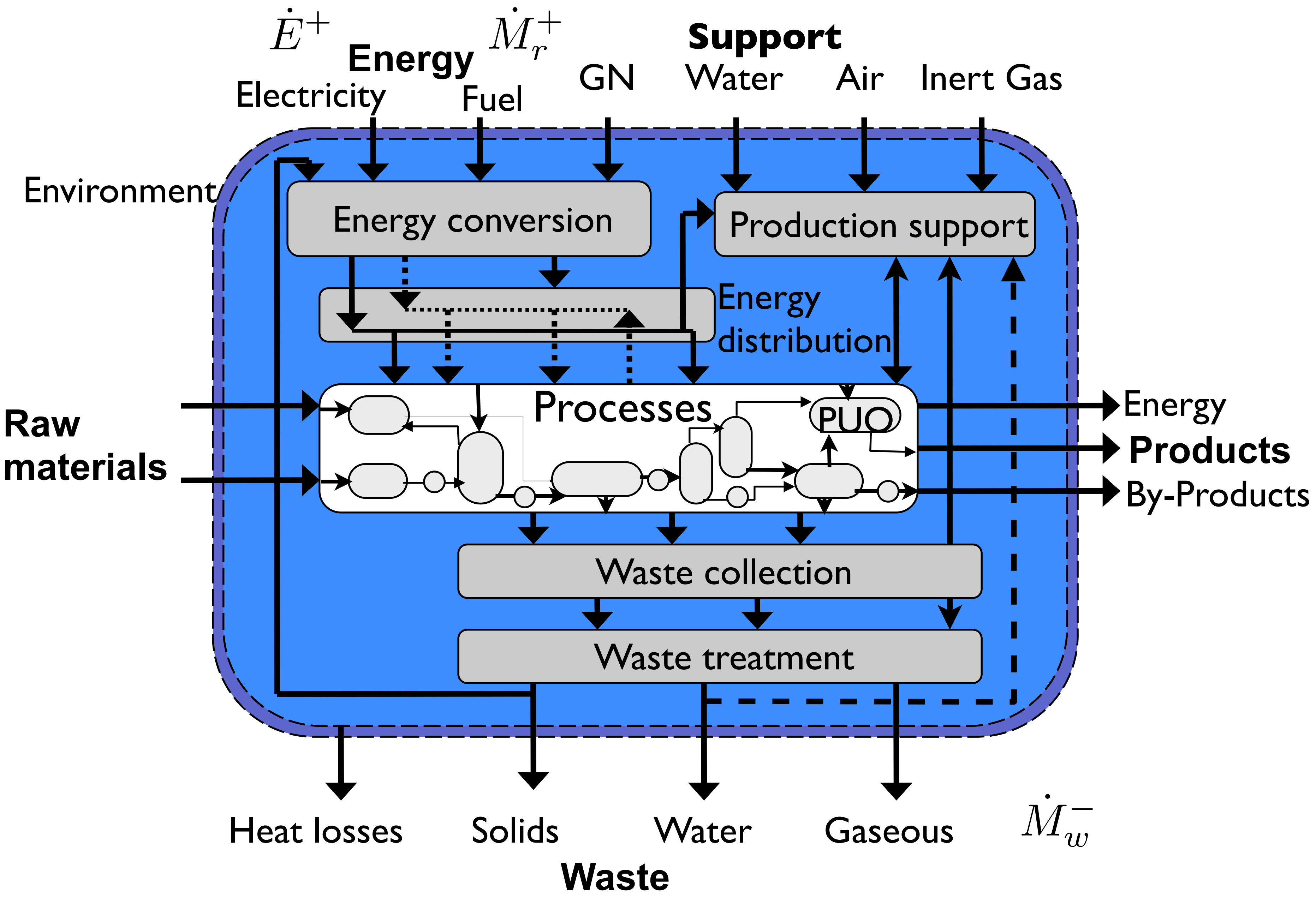
Hot and cold streams

IPESE
Industrial Process
and Energy Systems
Engineering

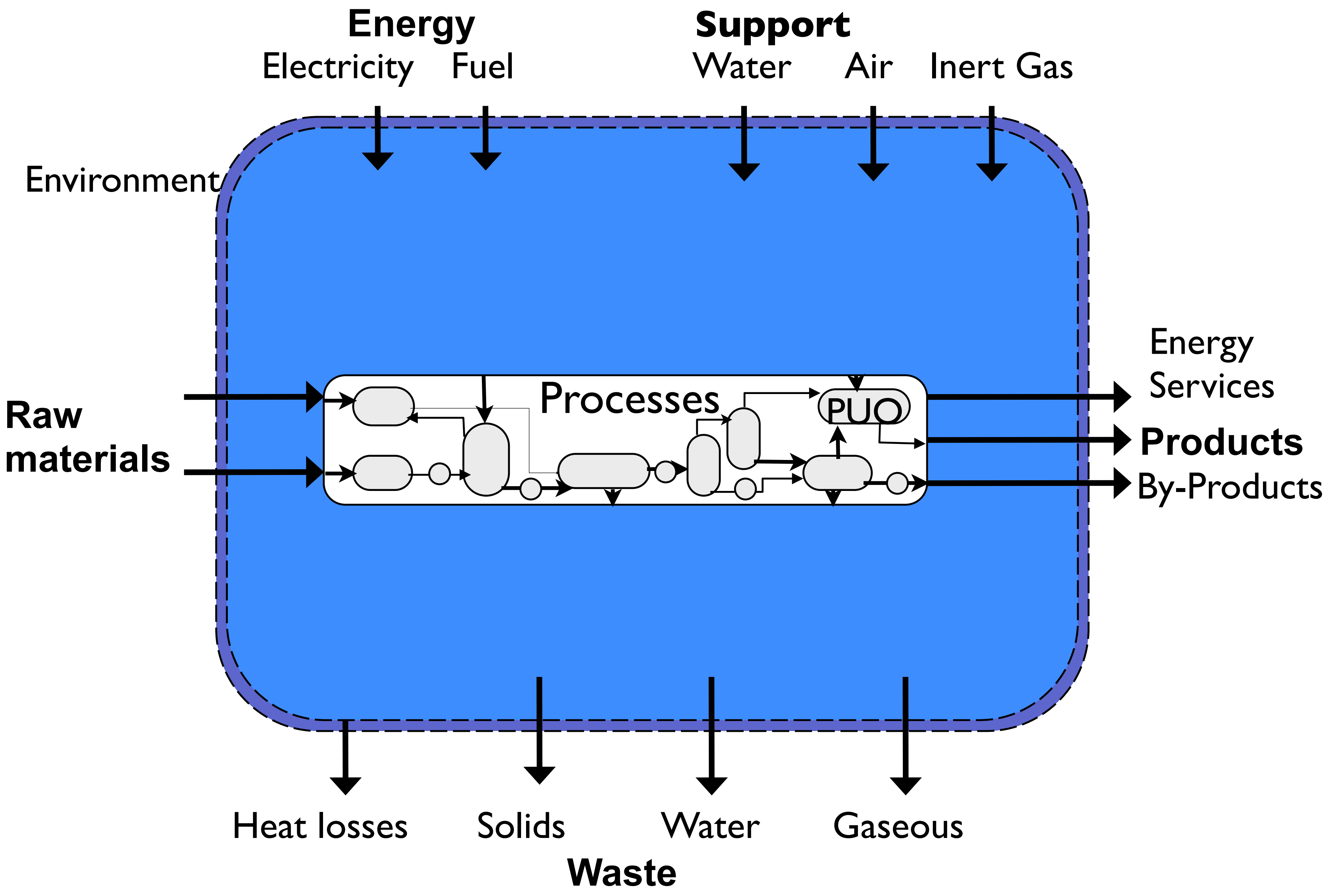
The process system



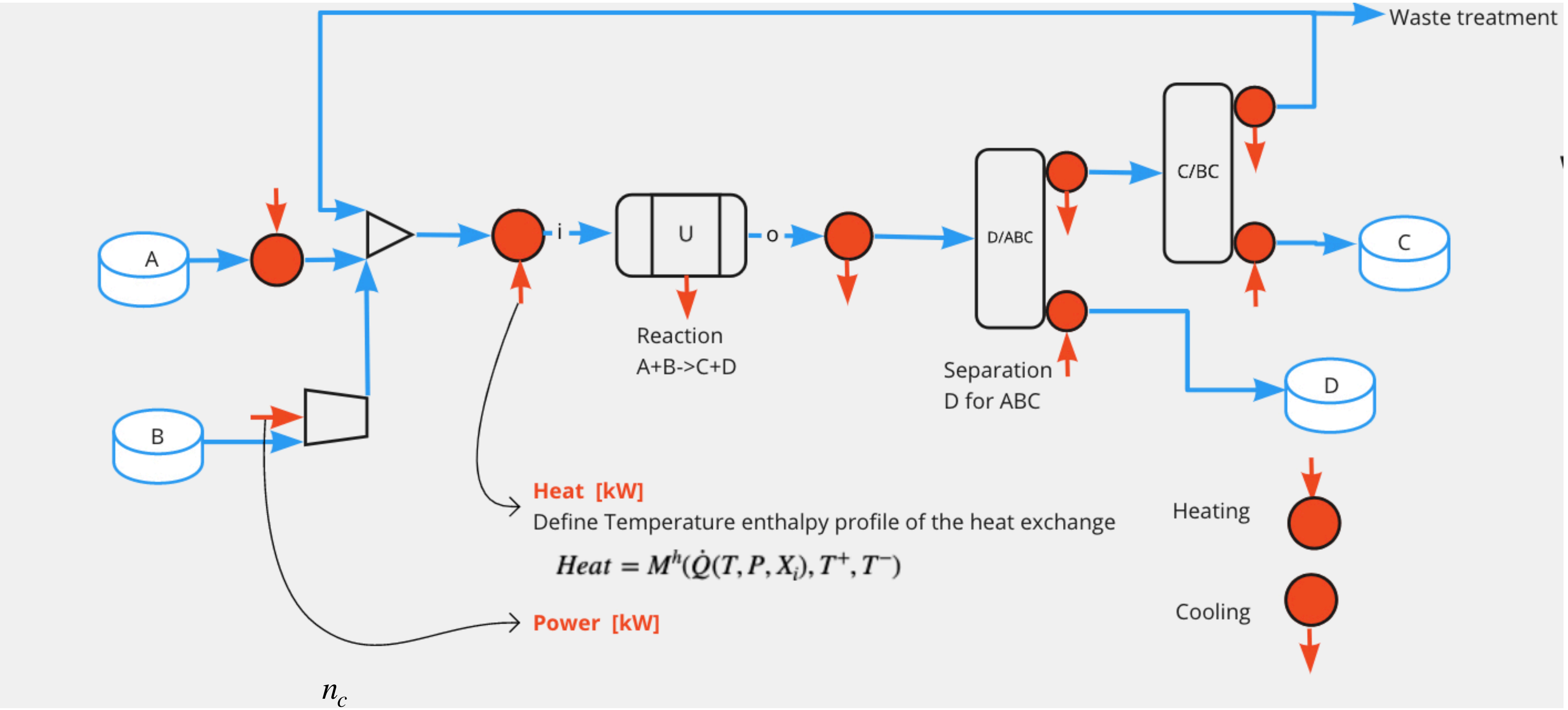
Definition of the process requirements

- Process streams
  - Flows are related to the process unit operations of the factory
    - Raw materials/products
    - Mechanical power/electricity
    - Support of production (water, gases, catalysts)
    - Waste
    - Packaging
    - Offices
- Utility streams : The way the process units receive the energy needed. “slave streams”
  - Flows calculated to supply the energy requirement
  - Flows that depend on the energy efficiency
  - Flows related to the energy cost
  - Distributed energy (steam, cooling water, glycol water)
  - Related mechanical power or electricity consumption

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 : $c_{ref}[CHF/kJ] \cdot \dot{Q}_{ref}[kJ/s] \cdot t_{op}[s/year]$

Hot and cold streams

- From raw materials tanks to process unit conditions
- From process unit to process unit
- Heat to realise process unit operation
- From process units to tanks
- From process units to environment

Identify the heat transfer interfaces

Heat load

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

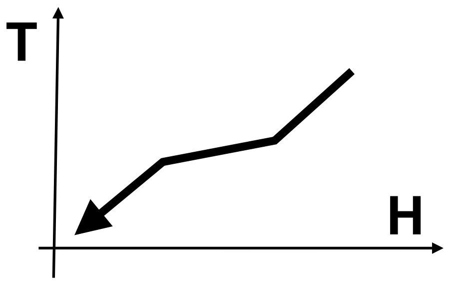
Target State
- Environment
- to process unit operation

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

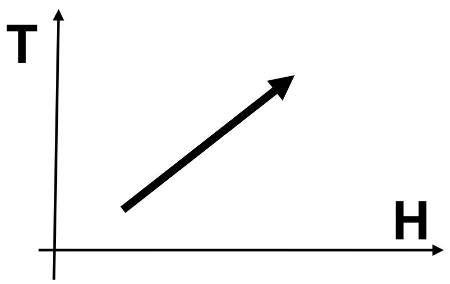


Heat/temperature profile

Cold Streams

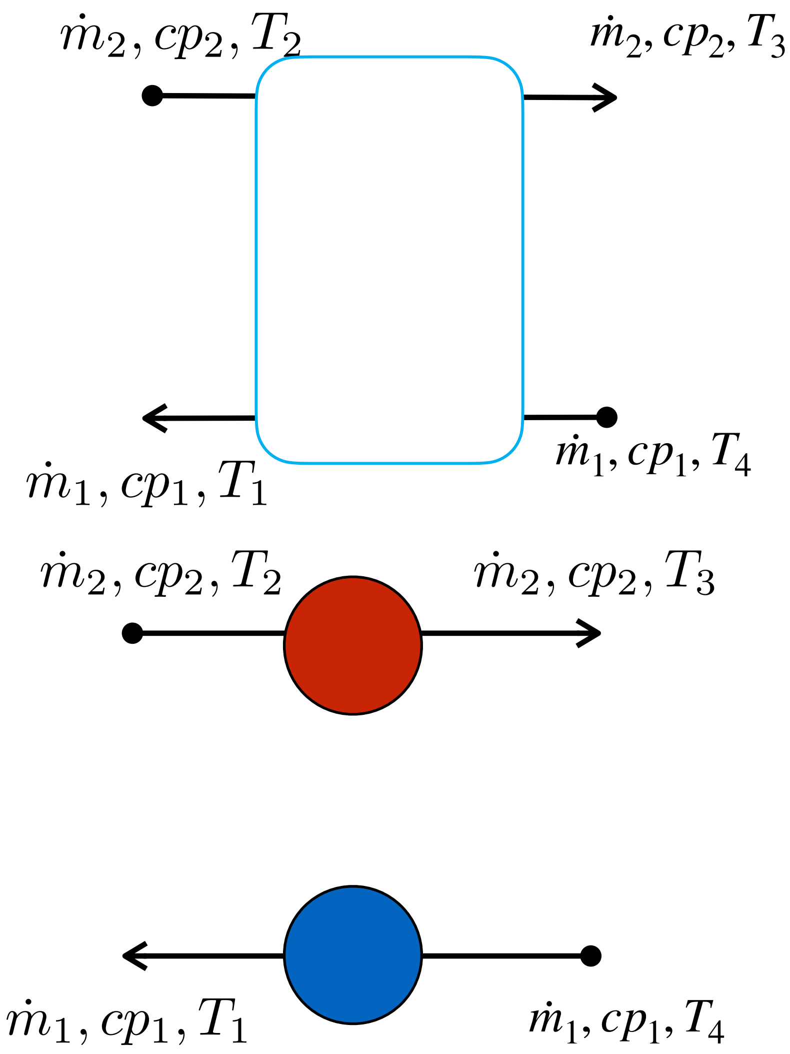
---> To be heated up

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

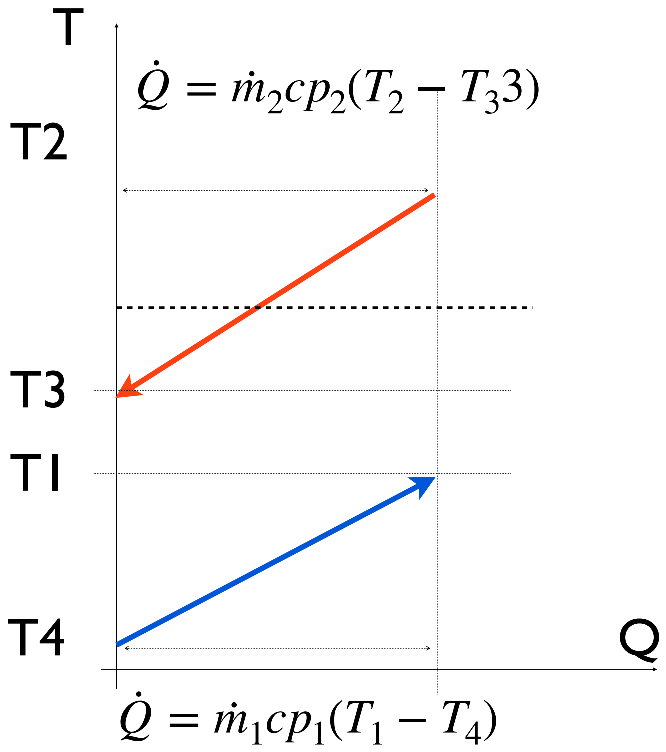


Heat/temperature profile

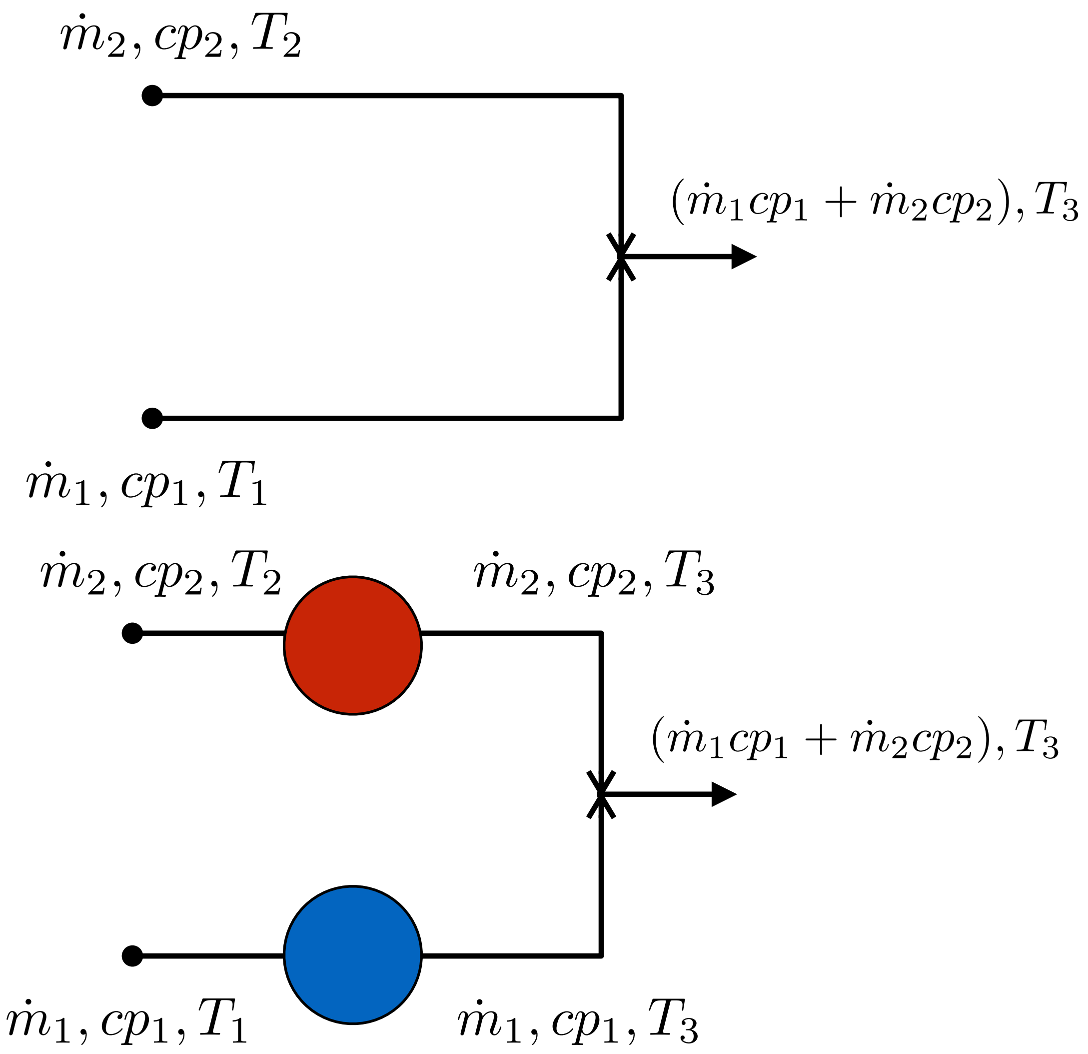
Existing heat exchangers

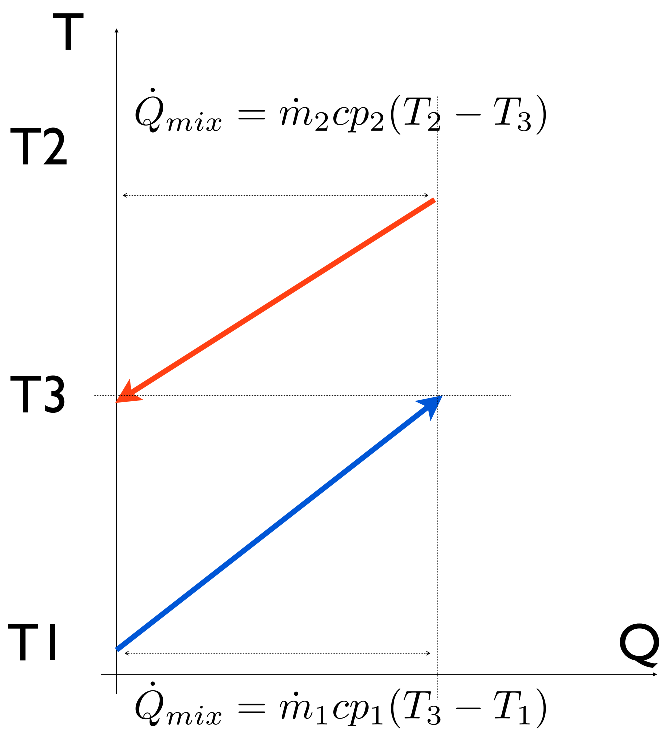


$$\dot{Q} = UA\Delta T_{lm} = UA\frac{(T_2 - T_1) - (T_3 - T_4)}{ln(T_2 - T_1) - ln(T_3 - T_4)}$$



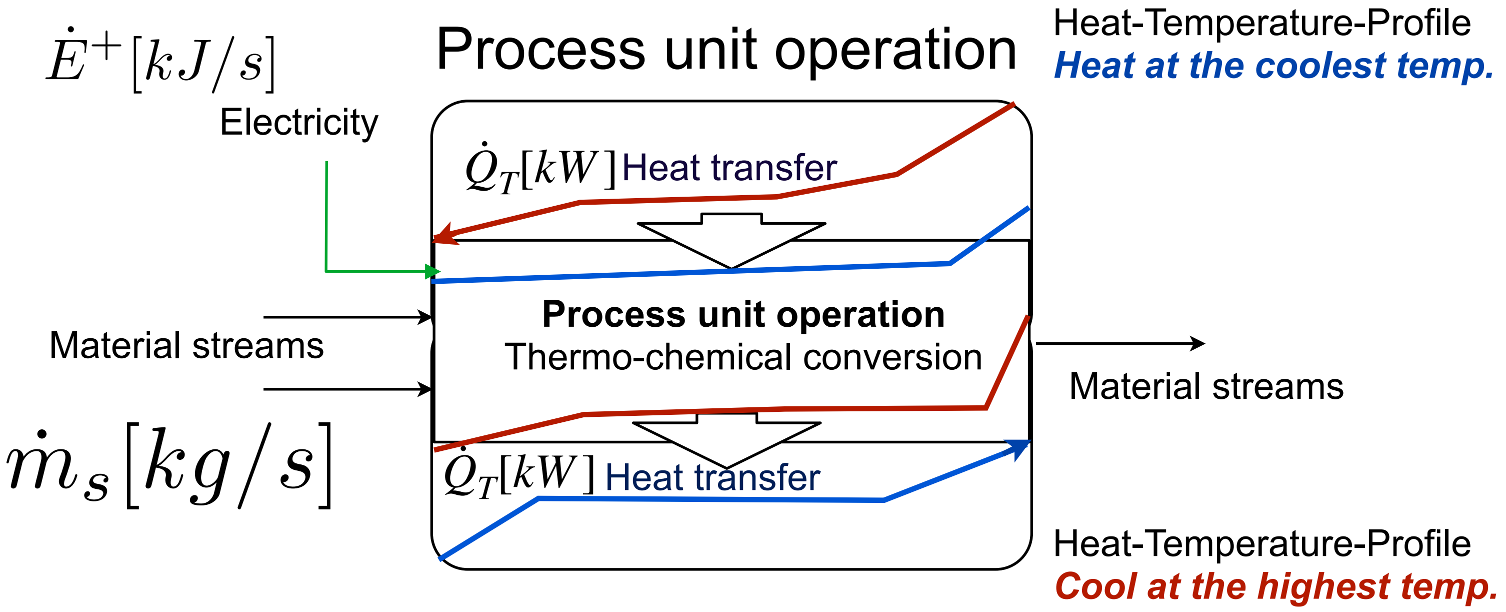
Mixing unit is a heat exchanger





Mixer are hidden heat exchangers, when well positioned (all temperatures above or below the pinch) they are cheap heat exchangers. When one of the 3 temperatures is on the other side of a pinch, the mixer is penalising. In the example above the heat of the hot stream above the pinch Tp is needed to heat a cold stream above the pinch. After the heat recovery it can be send to the mixer with the cold stream that should have been preheated by a hot stream below the pinch.

Process unit heat transfer interface



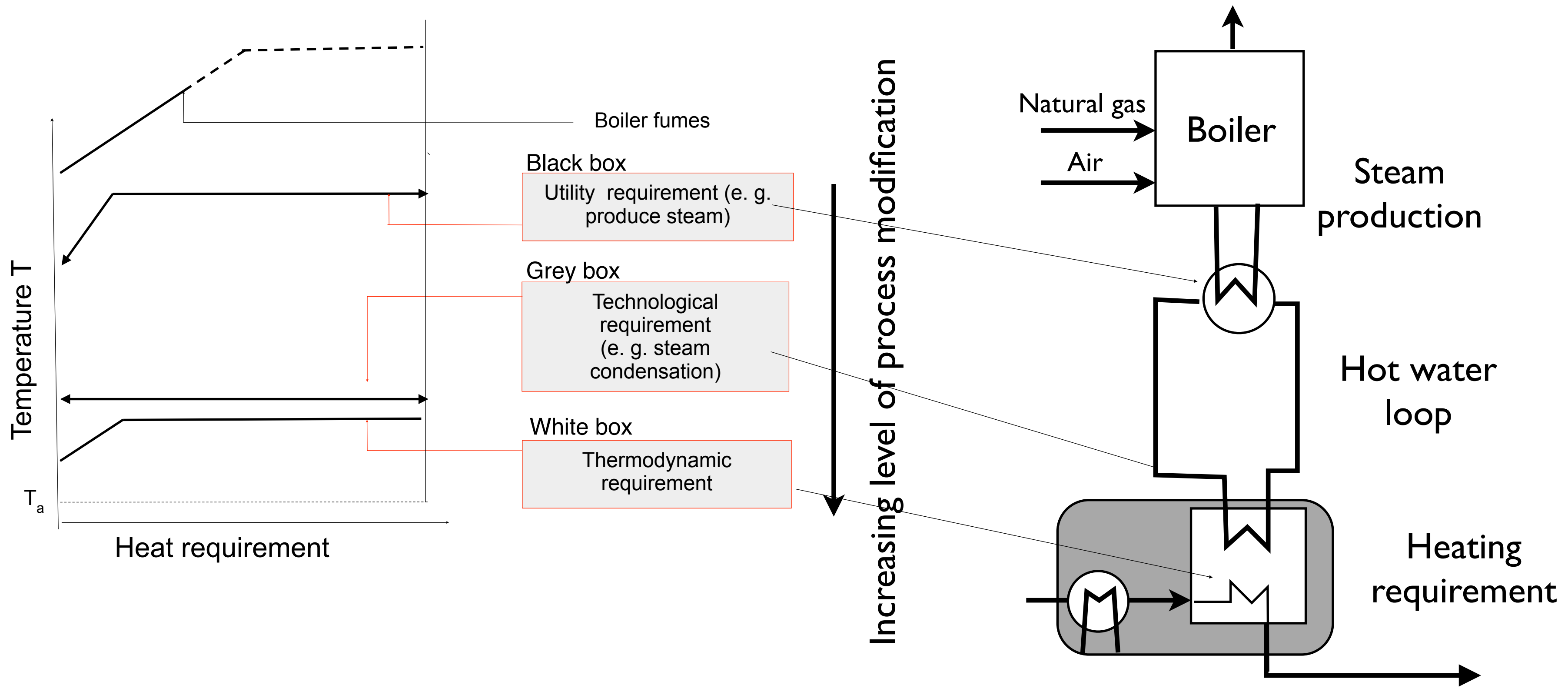
Define the heat transfer interface as a function of the specific interface

$$\dot{m}_s[kg/s] = m_s[kg/kgproduct] \cdot \dot{M}_p[kgproduct/s]$$

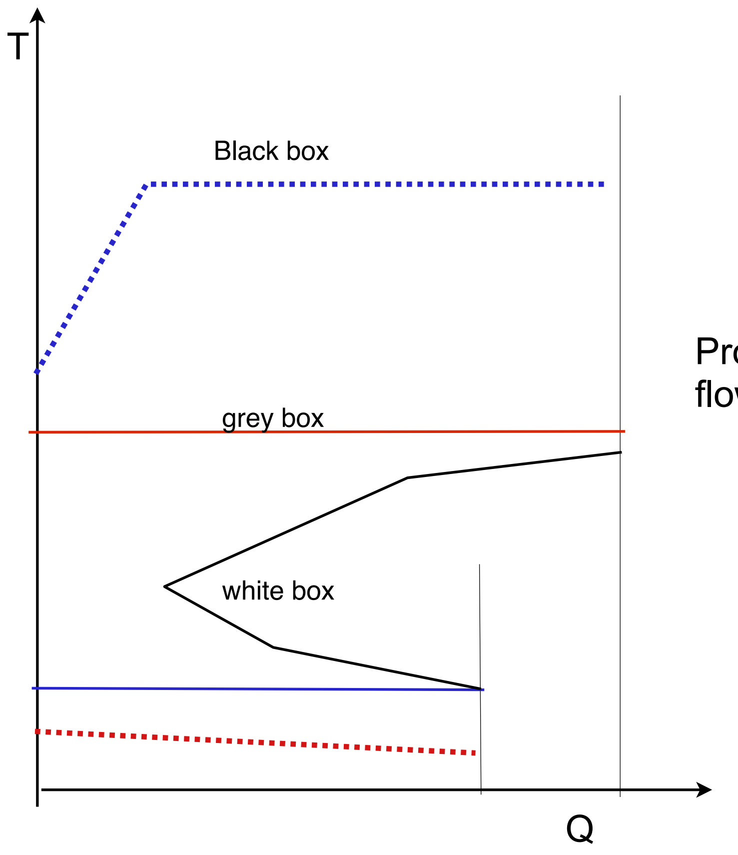
$$\dot{Q}_T[kW] = q_T[kJ/kg_{product}] \,.\, \dot{M}_p[kg_{product}/s]$$

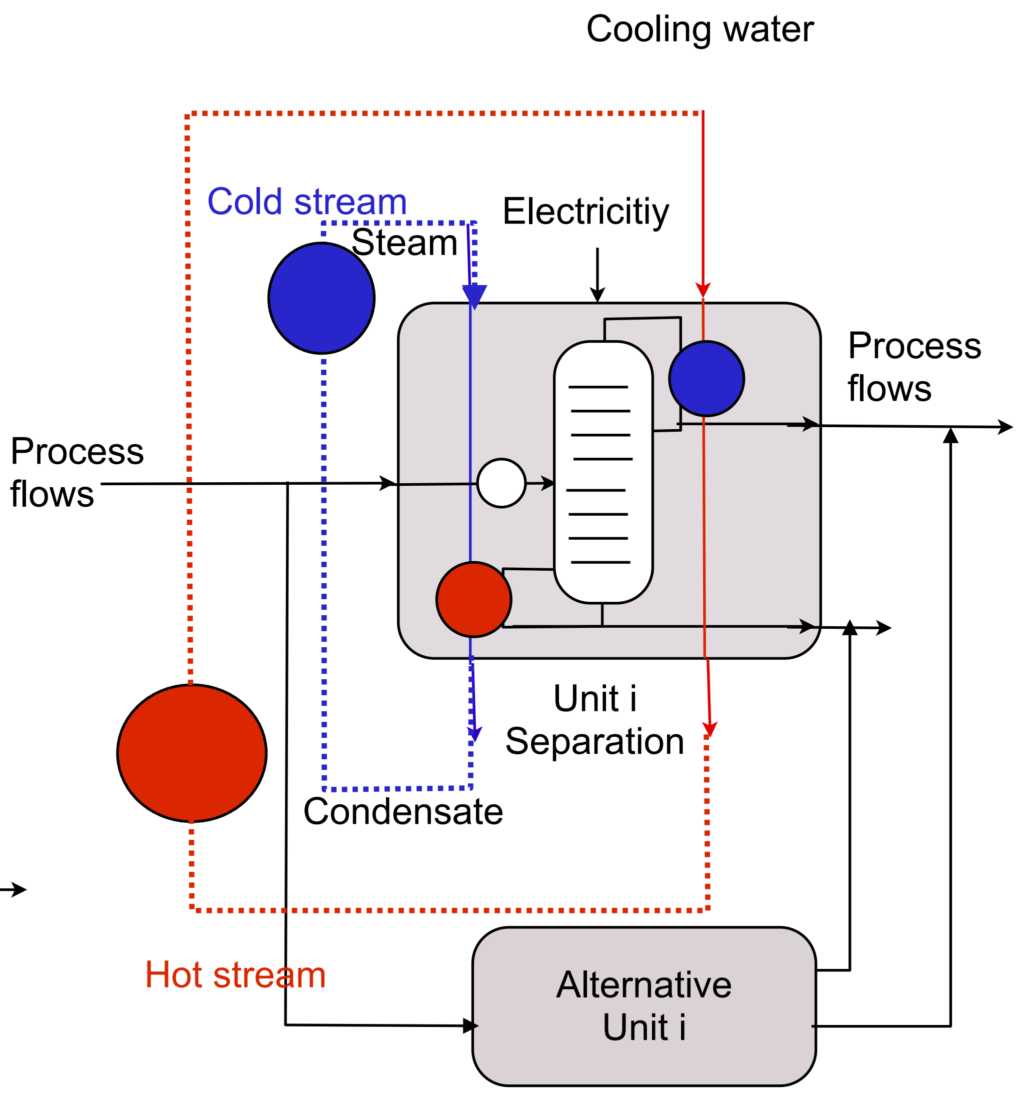
The goal will be to understand the role of energy in the process unit operations and its technological realisation
Define the heat transfer interface required to realise the unit operation

Process requirements can be defined with different interfaces

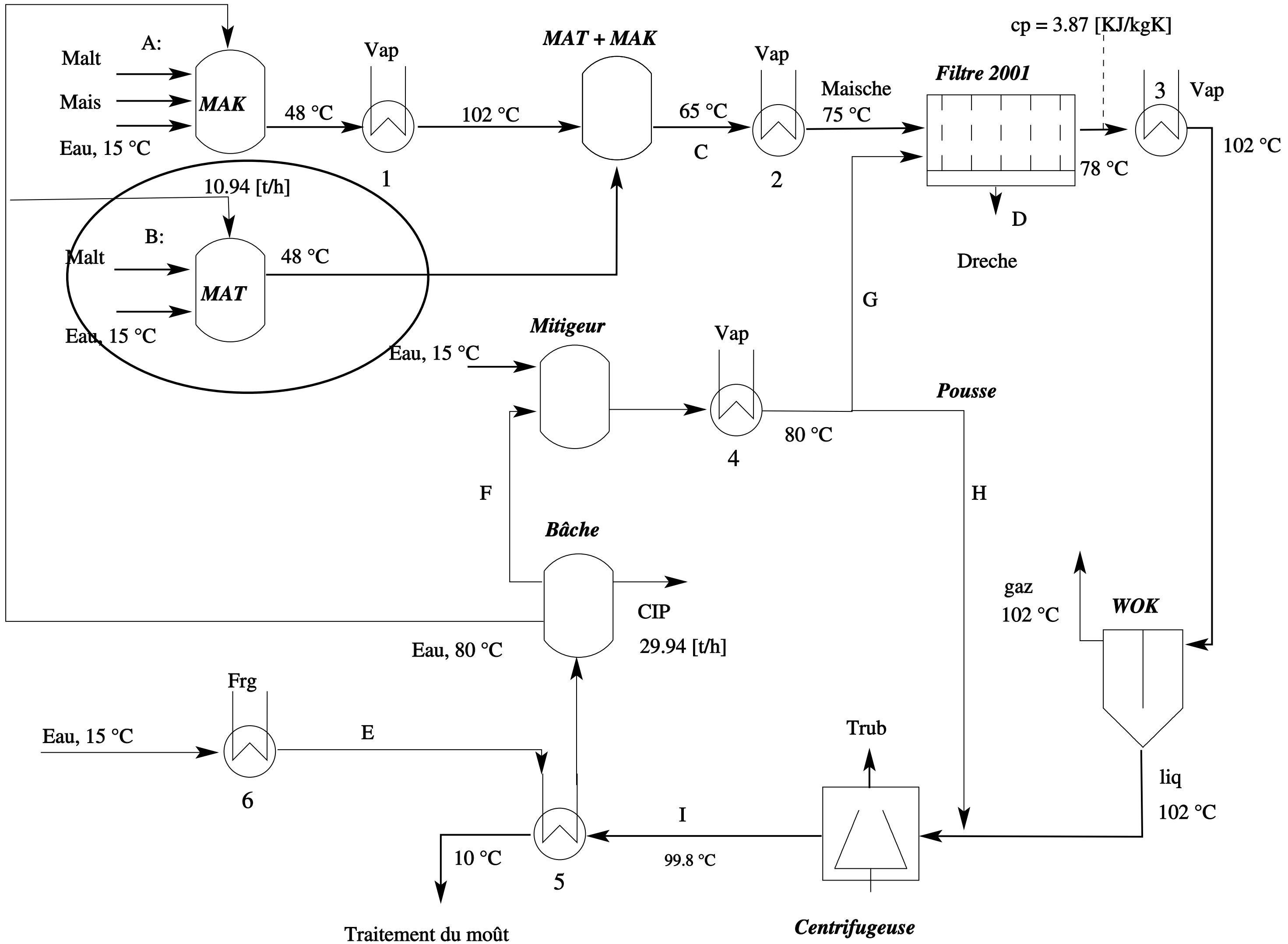


Defining Unit Operation heat exchange Interfaces



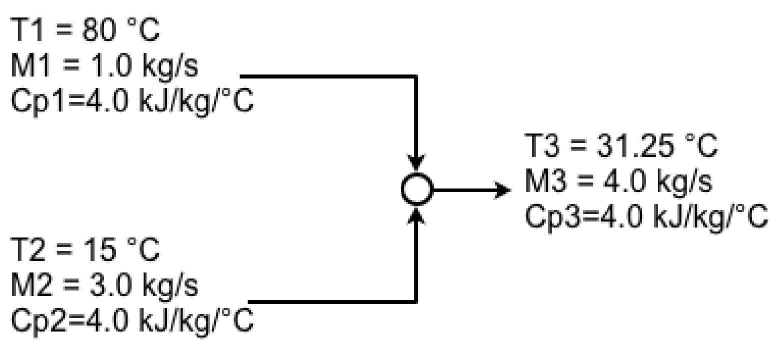


Hot Section of a Brewery : definition of heat exchange interfaces

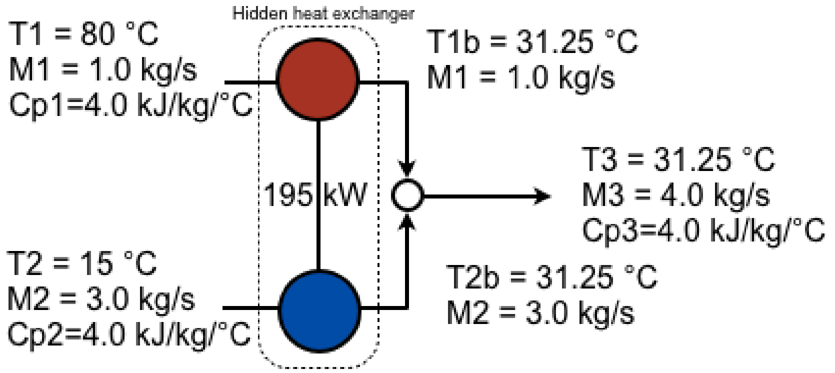


Mixer representation

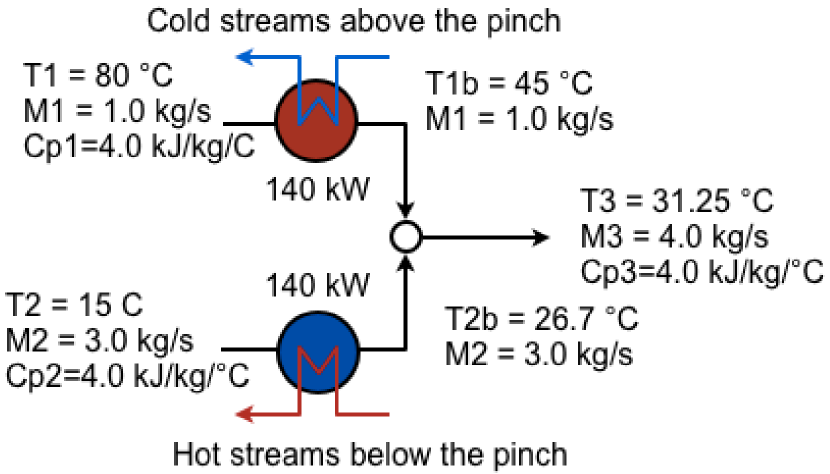
Flowsheet representation



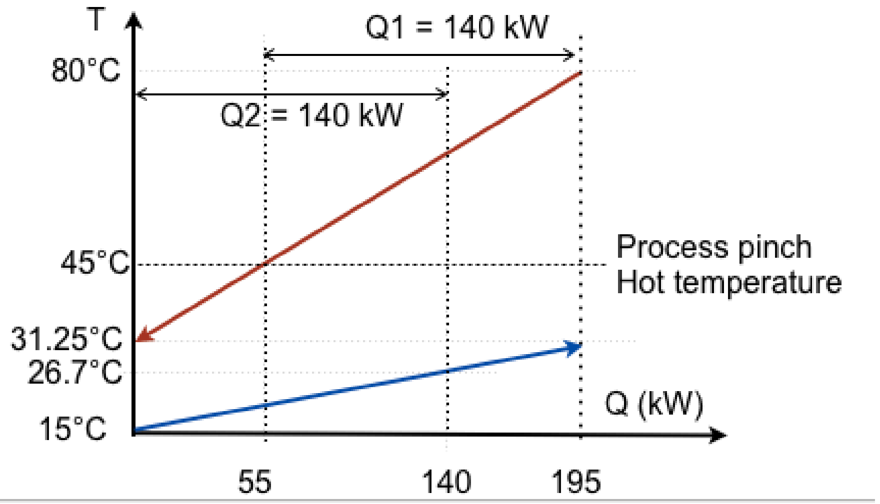
Heat transfer requirement



Heat exchange after pinch identification

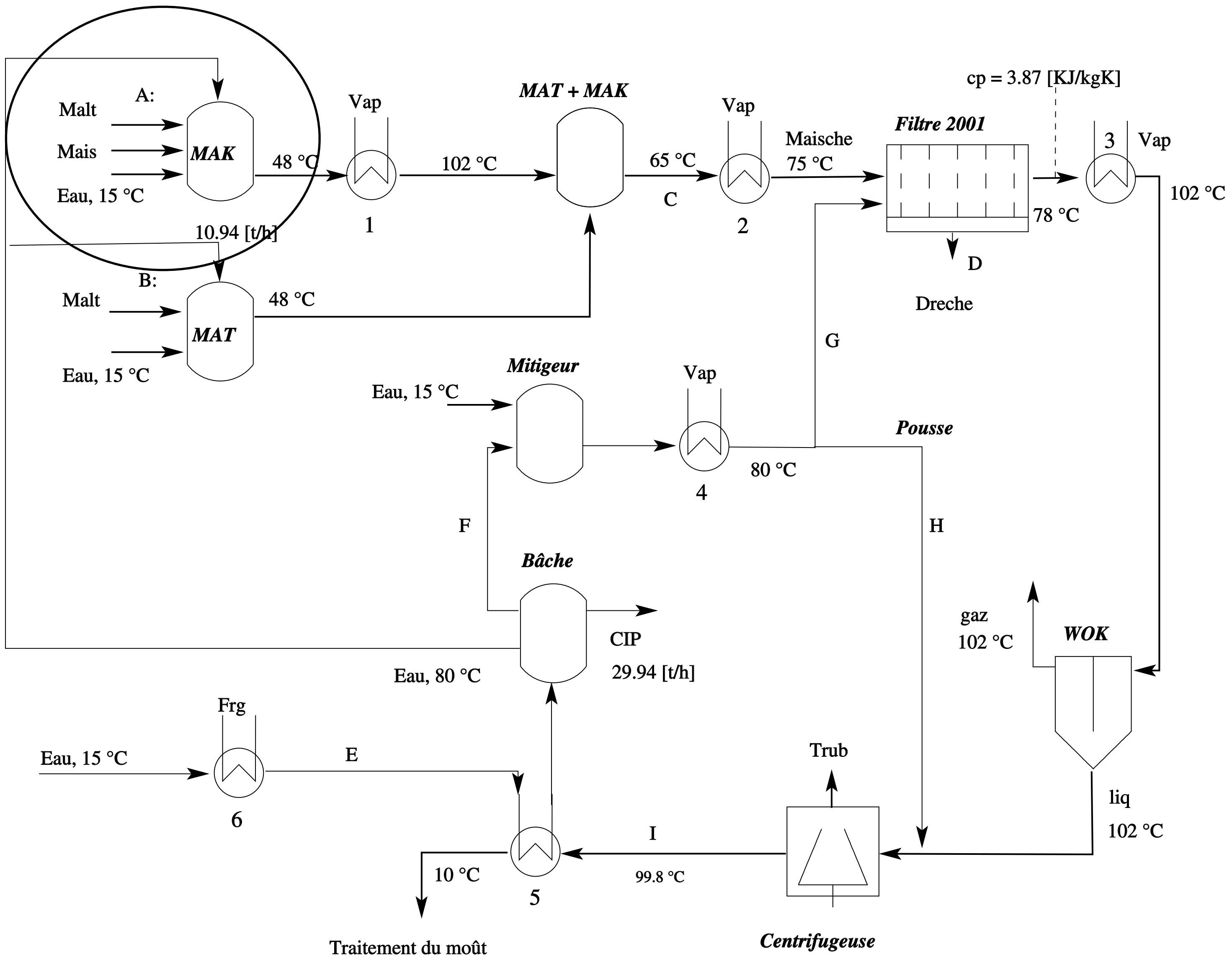


Hot and cold streams of the mixer

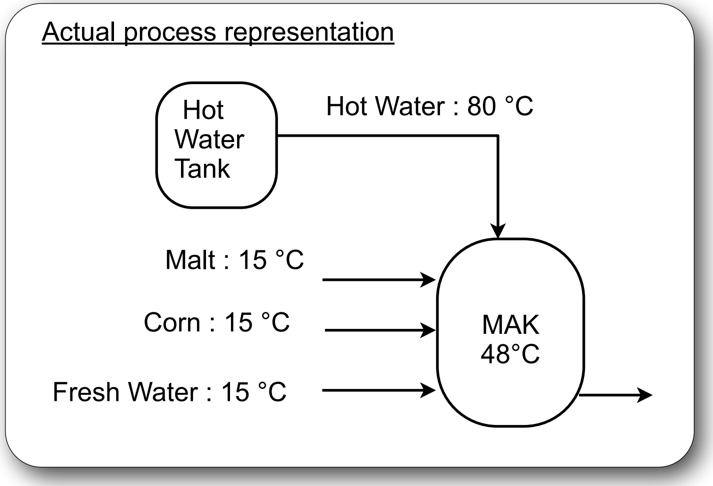


Hot Section of Brewery : hot water injection

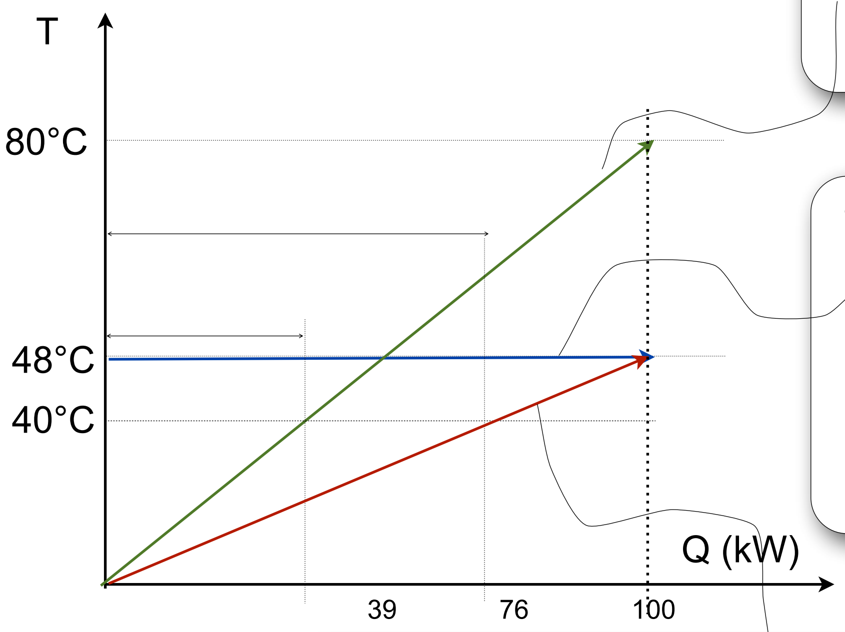
Other examples are given in the lecture notes

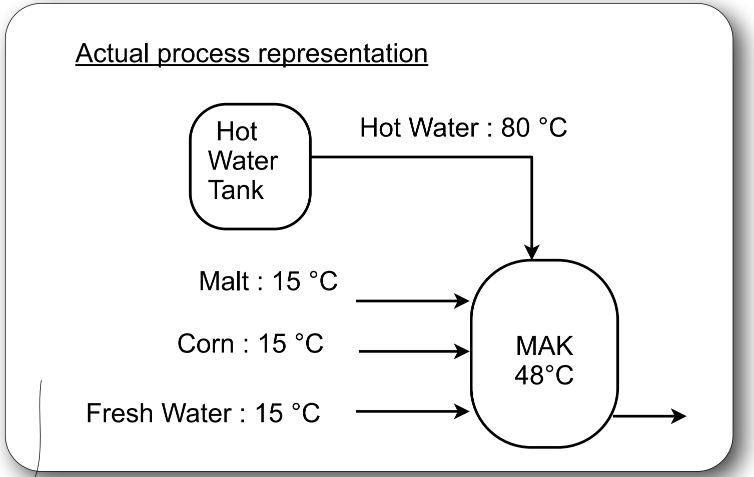


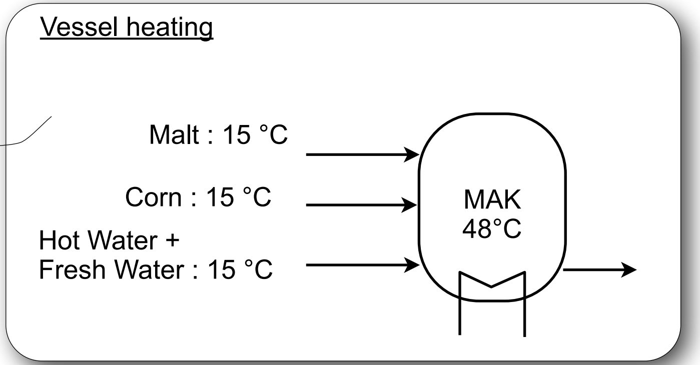
Unit operation MAK

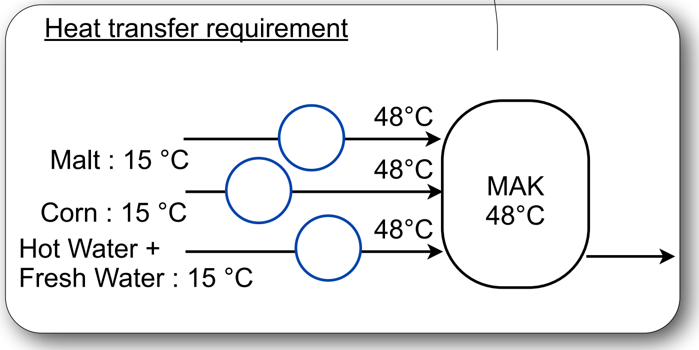


Unit operation MAK

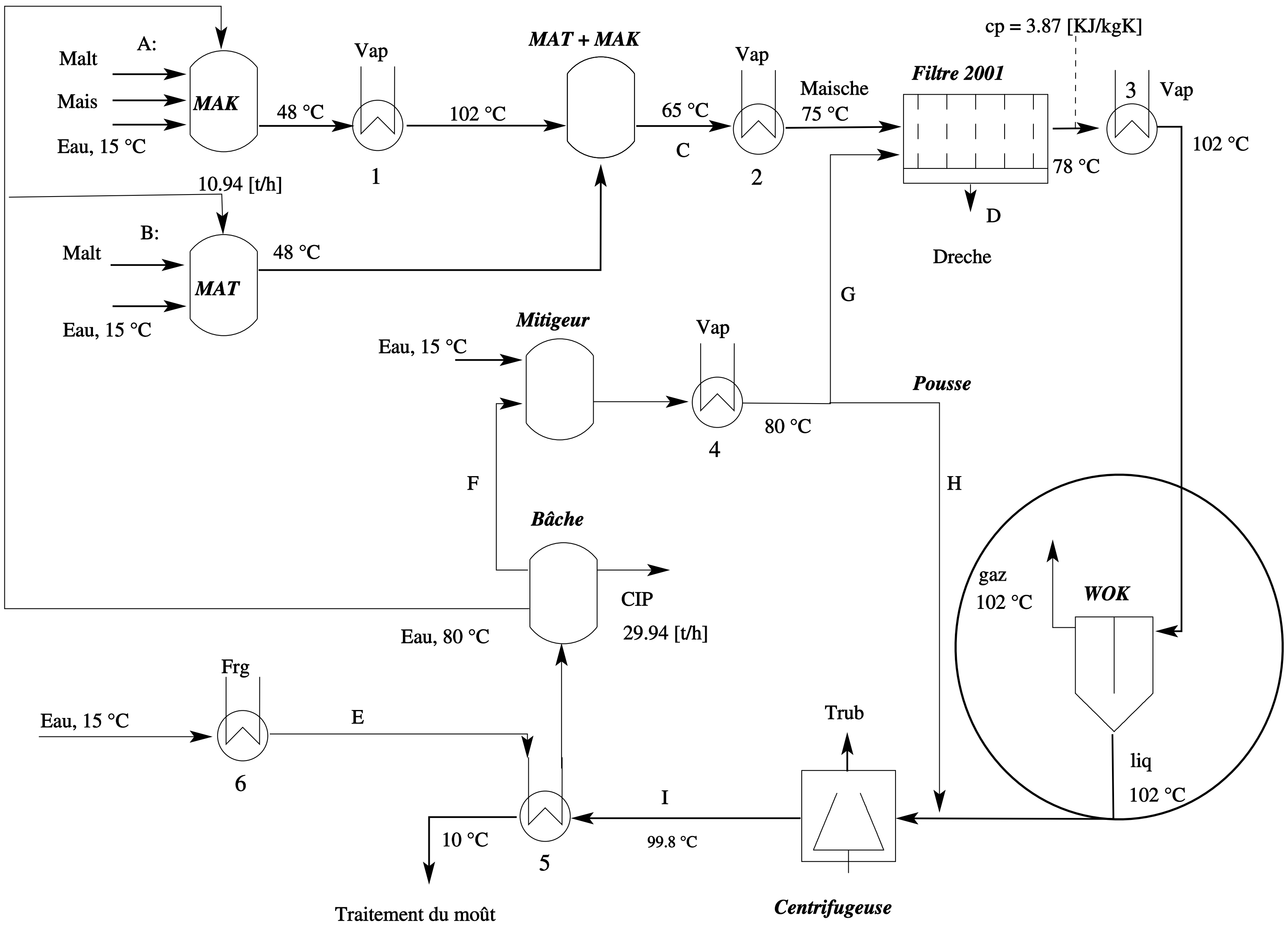




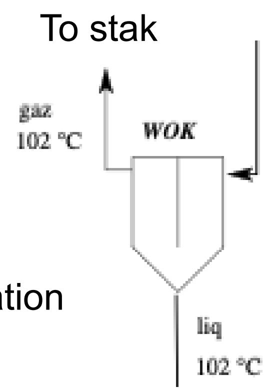




Hot Section of Brewery : definition of streams

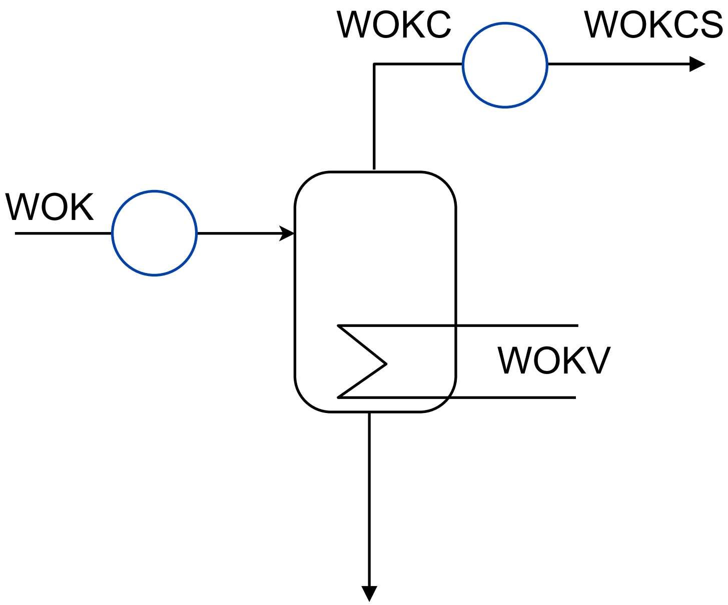


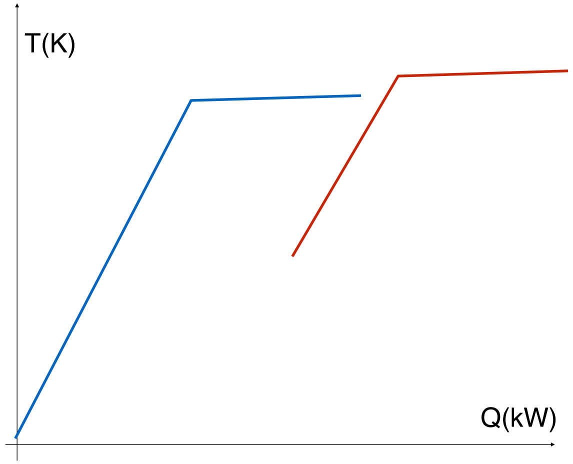
Recover waste heat lost in the environment



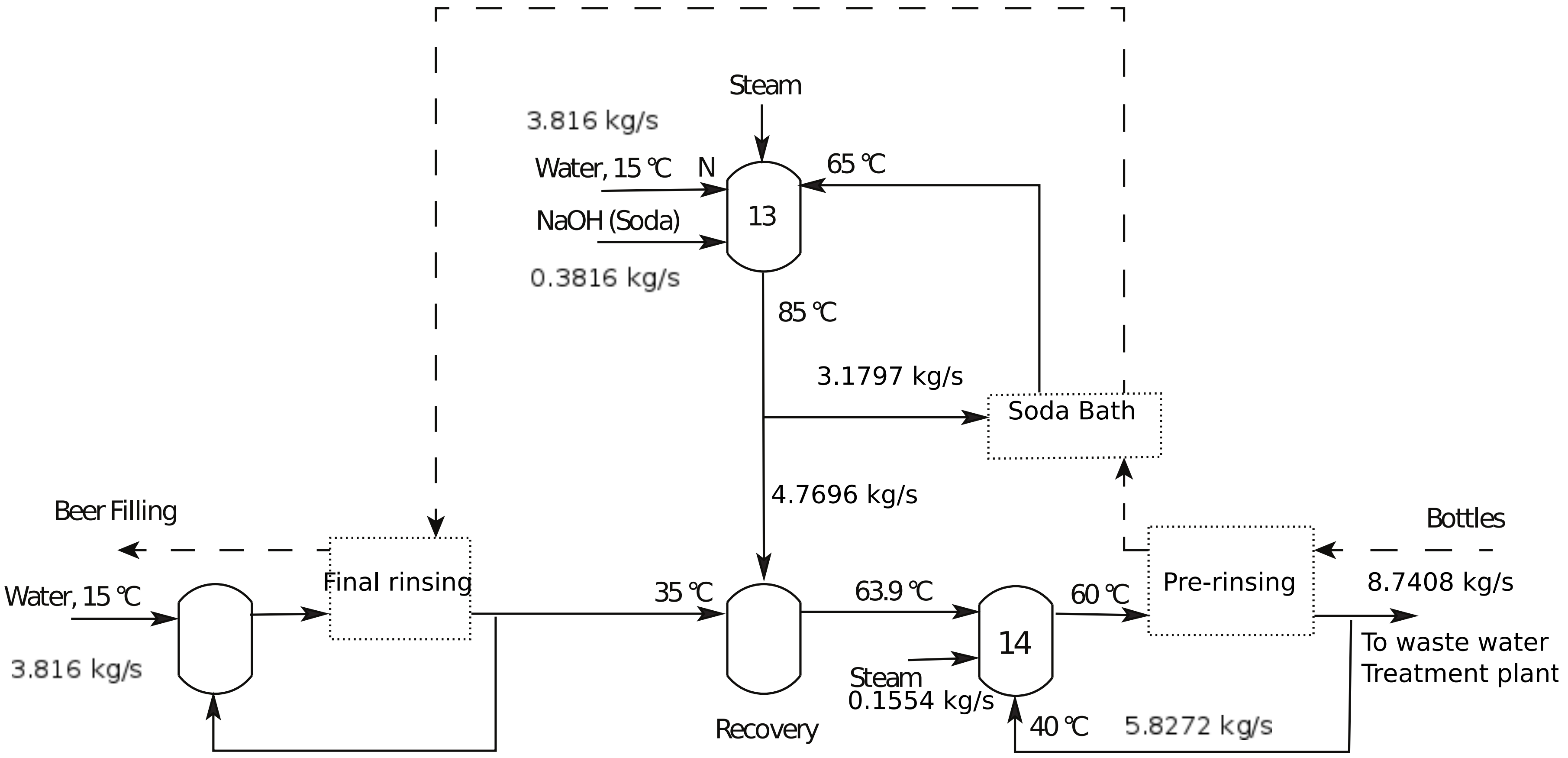
WOK : evaporation

Nom	Tin [°C]	Tout [°C]	$\dot{M}$ [kg/s]	$\dot{Q}$ [kW]
WOK	78	102	16.2	1504
WOKV	102	102	-	4513
WOKC	95	95	2.3	4513
WOKCS	95	25	2.3	674

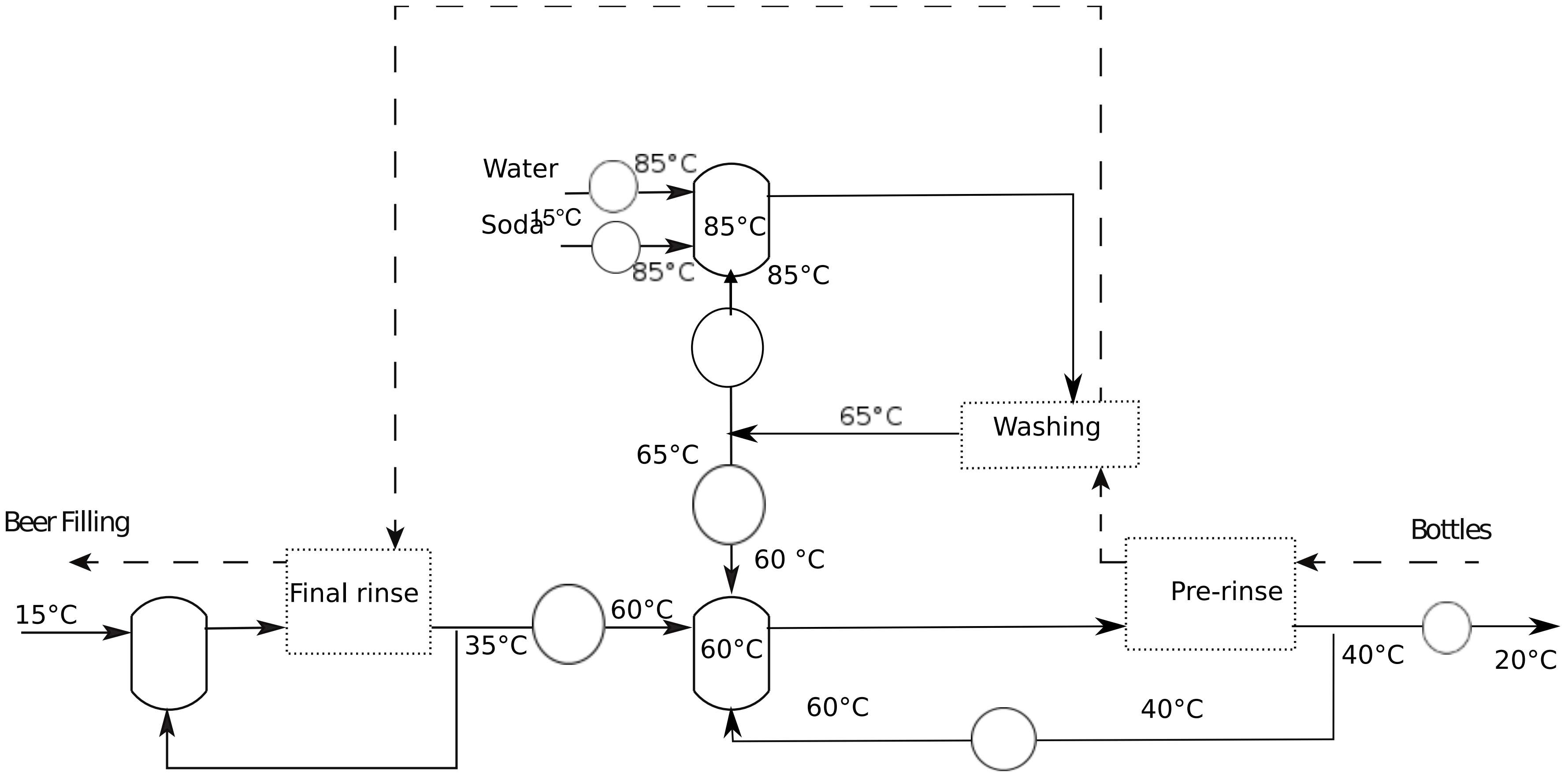




Example : Cleaning in place system



cleaning in place requirements



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