Industrial Process Systems

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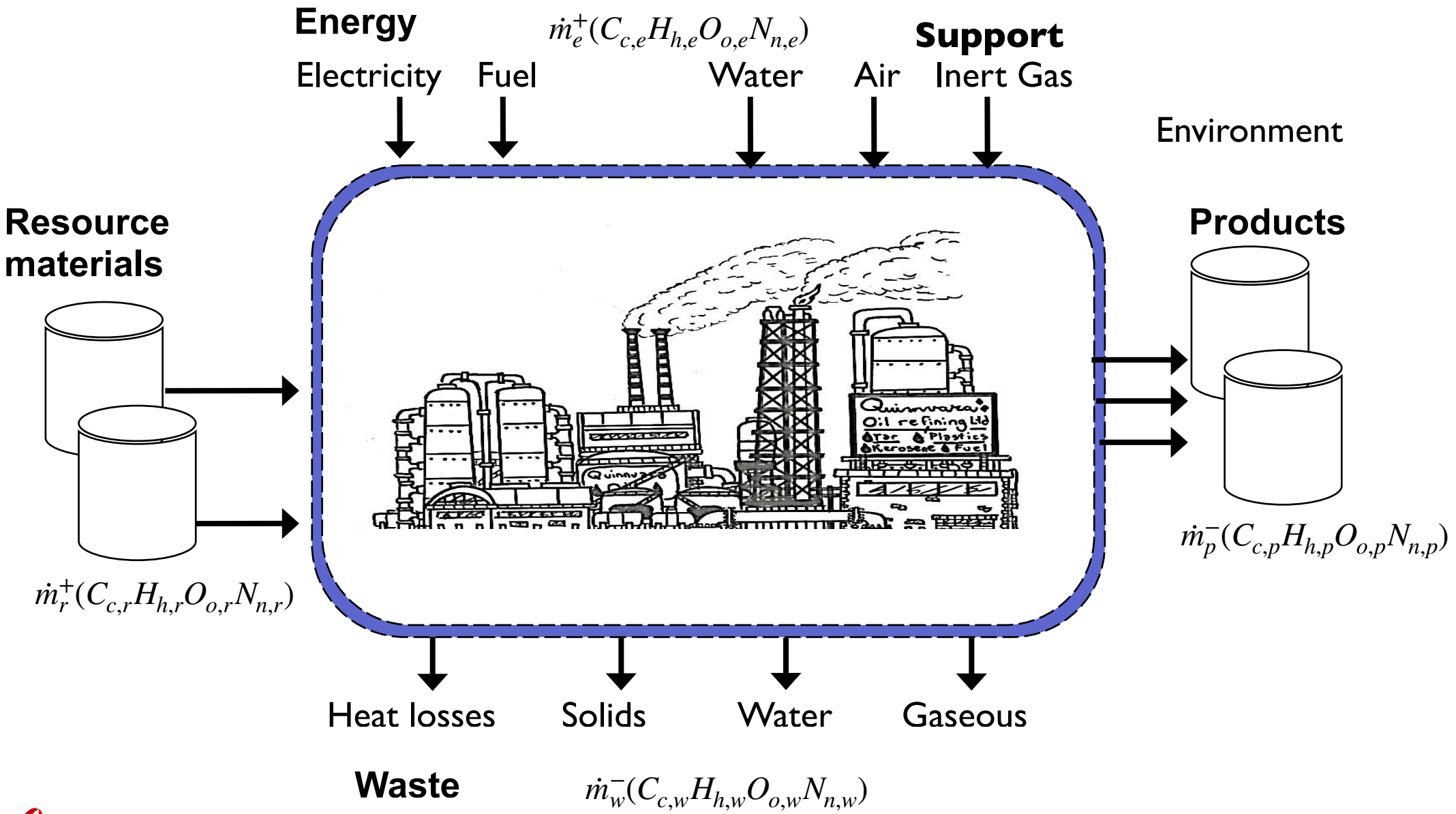
IPESE
Industrial Process
and Energy Systems
Engineering

An industrial process



Process development

- Decide :
  - The process units to buy
    - type, size and cost
    - support materials : e.g. catalysts
  - How they are interconnected
    - pipings
  - How they are operated
    - Operating conditions & profiles
  - How they are controlled
  - How do you mitigate risks related to the operation
- Inform about performances
  - Economic
  - Environmental impact
  - Social

Inlet (resources) and outlet (products,services, emissions) flows characterisation

- Chemical : $C_c H_h O_o \alpha_a$ => Thermodynamic $(T_c, P_c, T_{eb}, \omega)$
- Toxicity/risks
- State on market :

Mass flow : $\dot{M}_i^+ \quad [kg/s]$

Molar flow : $\dot{N}_i^+ [kmol/s]$

Composition : $\dot{x}_{i,j} [\,\%\,]$

- Cost or market value : $c_i \quad [CHF/kg]$
- Energy (inc. heat of formation) :

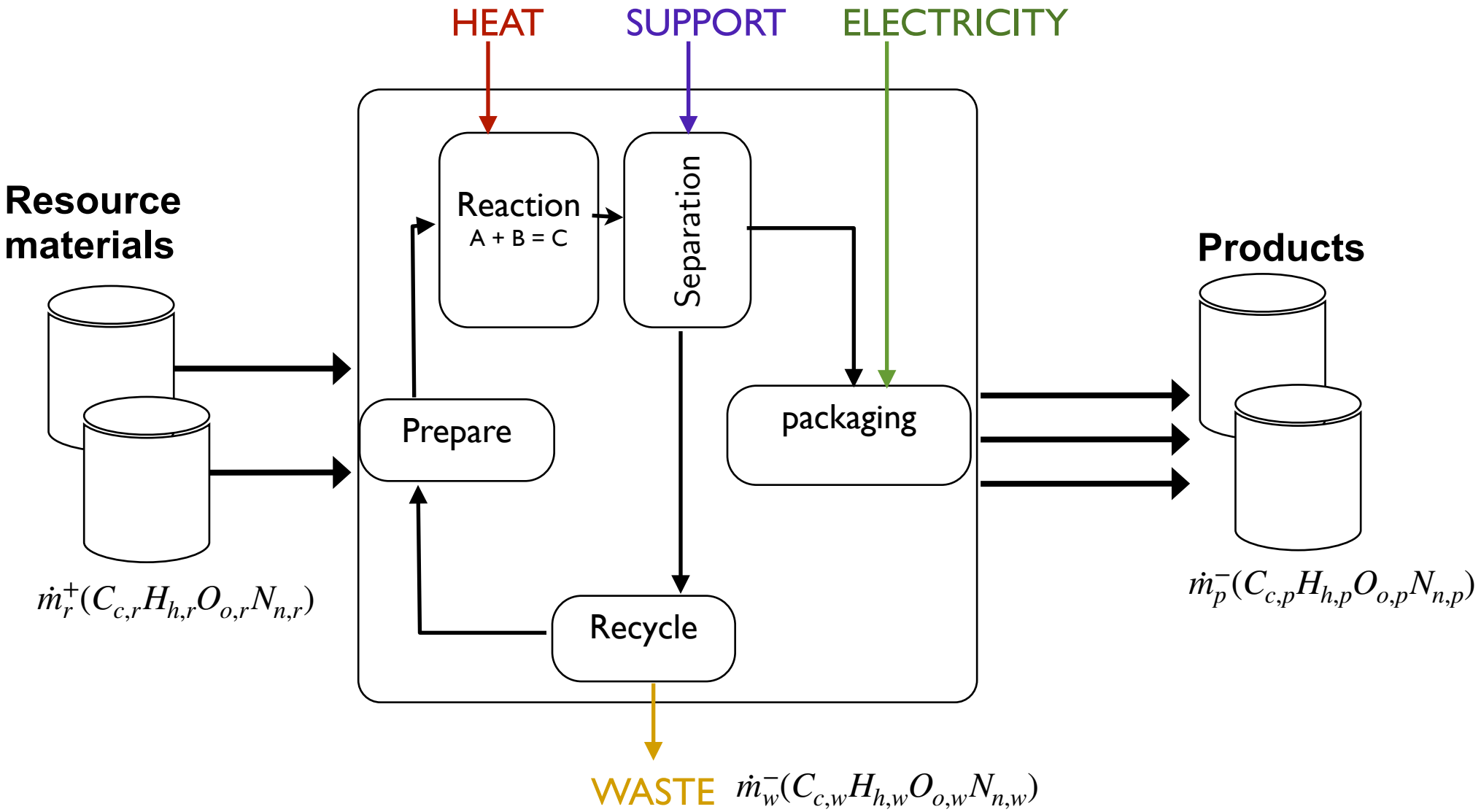
$$H_i[kJ/year] = \int_{year} \dot{M}_i^+(t) \cdot h_i(t) dt$$

- Exergy :

$$E_i[kJ/year] = \int_{year} \dot{M}_i^+(t) \cdot k_i(t) dt = \int_{year} \dot{M}_i^+(t) \cdot (h_i(t) - T_0(t) \cdot s_i(t))\, dt$$

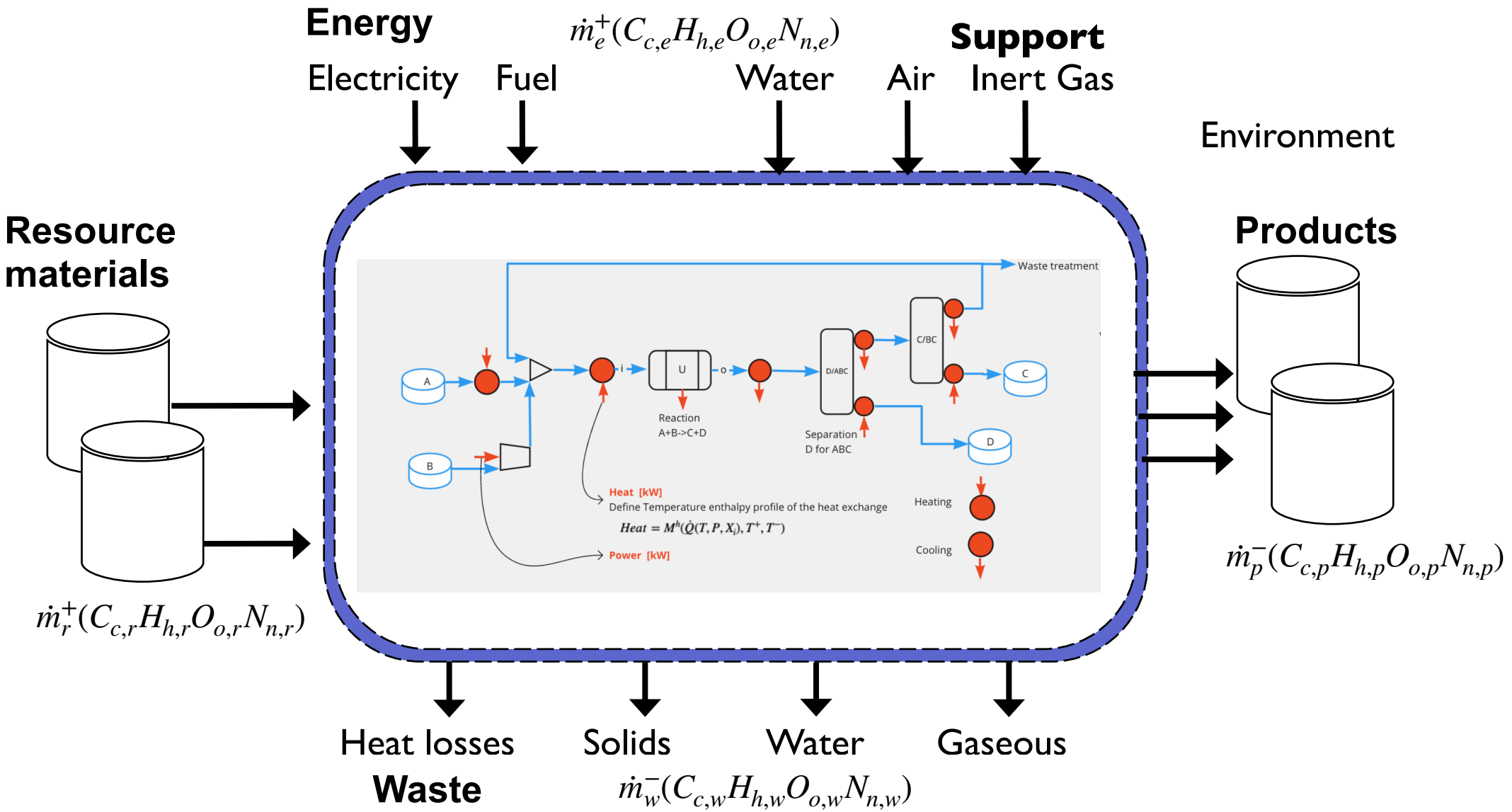
- Gibbs free energy

Process block flow diagram



Process recipe : Process steps defined by their function in the production

Process flowsheet



Process unit operation replaced by the equipment to realise the operation

The state of each stream is defined

Process flowsheet : unit sizes

Energy $\dot{m}_e^+(C_{c,e}H_{h,e}O_{o,e}N_{n,e})$

Electricity | Fuel

Support

Water | Air | Inert Gas

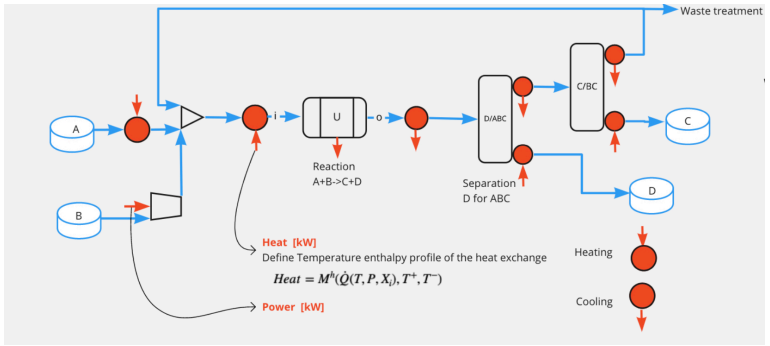
Environment

Resource materials

$\dot{m}_r^+(C_{c,r}H_{h,r}O_{o,r}N_{n,r})$

Chemical conversion recipe

Process unit operation $\Rightarrow S_u = f_u(\dot{m}_u^{+/-}, \pi_u)$



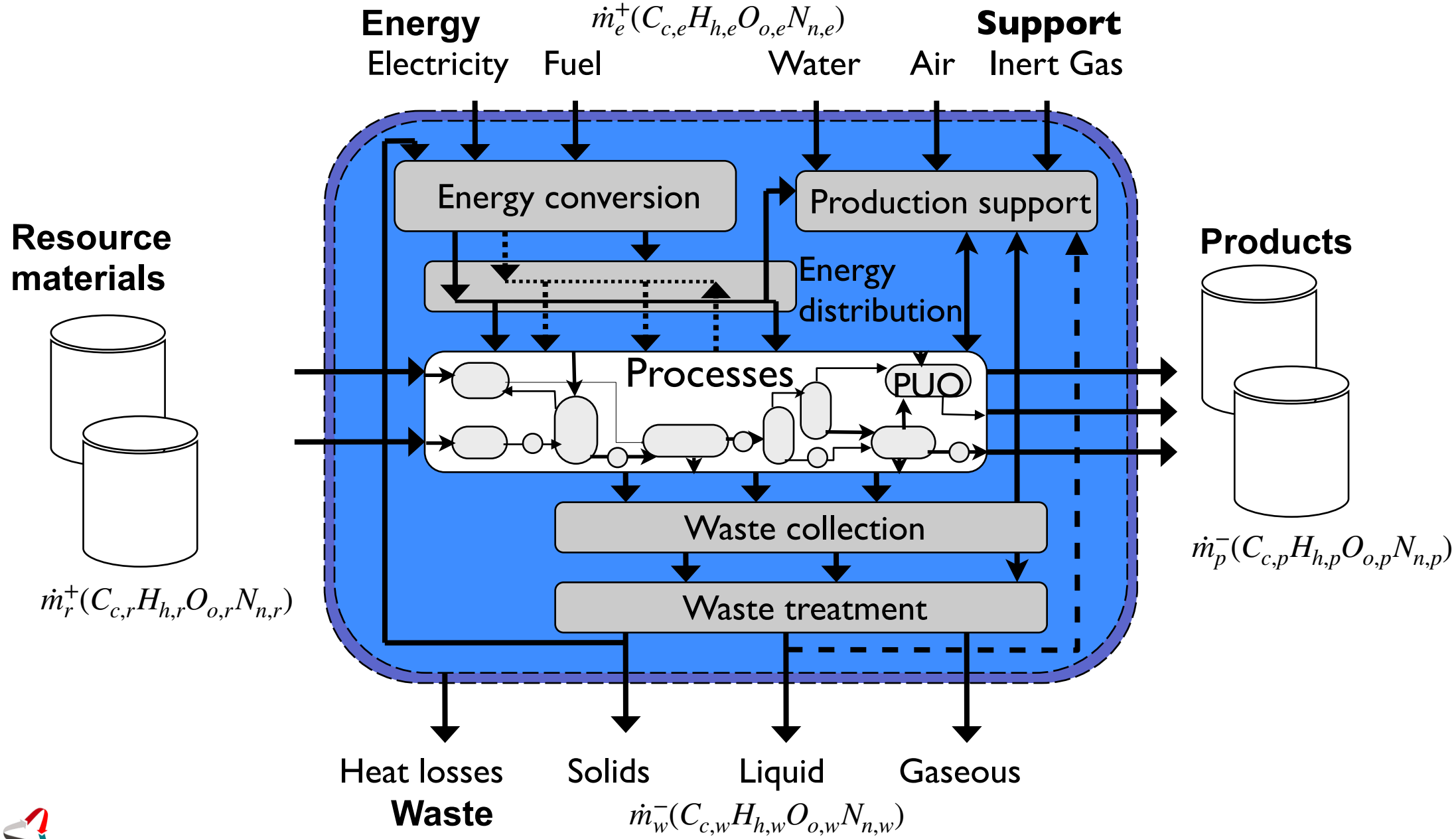
Products

$\dot{m}_p^-(C_{c,p}H_{h,p}O_{o,p}N_{n,p})$

Heat losses | Solids | Water | Gaseous

Waste $\dot{m}_w^-(C_{c,w}H_{h,w}O_{o,w}N_{n,w})$

Closing the mass and energy balances



Process performance assessment

Energy

$$\int_t \sum_e (v_e \cdot \dot{m}_e^{+}(C_{c,e}H_{h,e}O_{o,e}N_{n,e}))dt$$

Electricity

Fuel

Support

Water

Air

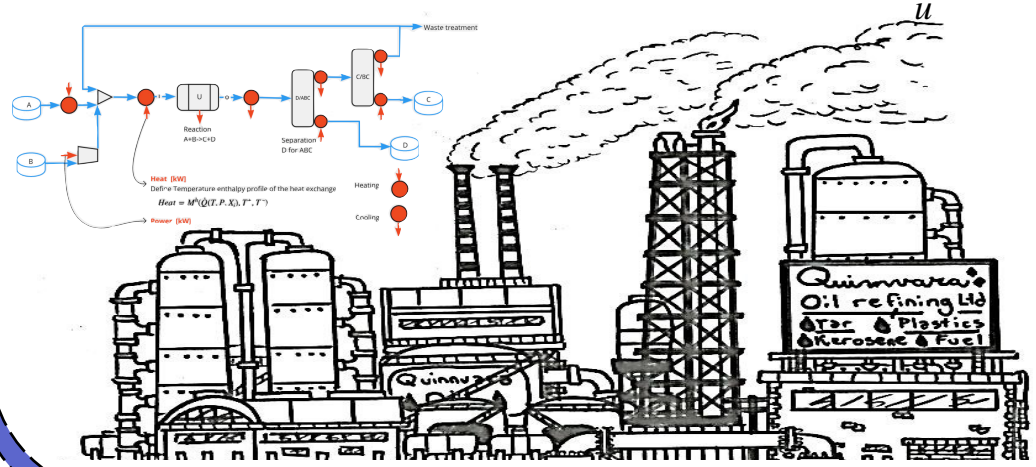
Inert Gas

Environment

Resource materials

$$\int_t \sum_r (v_r \cdot \dot{m}_r^{+}(C_{c,r}H_{h,r}O_{o,r}N_{n,r}))dt$$

Process units $=> S_u = f_u(\dot{m}_u^{+/-}, \pi_u) => \frac{1}{\tau}\sum_u I_u(S_u)$



Products

$$\int_t \sum_p (v_p \cdot \dot{m}_p^{-}(C_{c,p}H_{h,p}O_{o,p}N_{n,p}))dt$$

Heat losses

Solids

Water

Gaseous

Waste

$$\int_t \sum_w (v_w \cdot \dot{m}_w^{-}(C_{c,w}H_{h,w}O_{o,w}N_{n,w}))dt$$