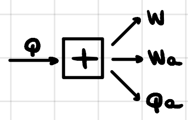
Lrev sist chiusi — Lrev sist ciclici

BIL EN: $\dot W = -\frac{d}{dt}(U^{ce}-U_a^{ce}) + \sum_J \{\dot m_{IN}(h_{IN}^c - h_a^c)\}_J - \sum_J \{\dot m_{OUT}(h_{OUT}^c - h_a^c)\}_J + \sum_J \dot\varphi_J \theta_J - T_a \dot S_{gen}$

$W_{rev} = \int_x^A (P-P_a)\,dV - \int_x^A (T-T_a)\,dS = \int_x^A (PdV - P_a dV - TdS + T_a dS) = \int_x^A (-dU - P_a dV + T_a dS) = U^{ce} - U_a^{ce} = EX^{u,PH}$

$ex^{PH} = h - h_a - T_a(s-s_a) + \frac{1}{2}(v^2 - v_a^2) + g(z - z_a) = W_{rev}$ $\qquad EX^{\varphi} = \varphi\left(1 - \frac{T_a}{T_{sorgente}}\right)$ $\qquad EX_{dis} = T_a \dot S_{gen}$

BIL EX $\dot W = -\frac{dEX^u}{dt} + \sum_J (\dot m_{IN} ex_{IN})_J - \sum_J (\dot m_{OUT} ex_{OUT}) + \sum_J \dot{EX}^{\varphi_J} + \sum_J \dot{EX}_{rad,J} - \dot{EX}_{dis}$



$\dot{ex}_{rad} = \dot{en}_{rad}\,\gamma = \frac{\sigma T^4}{i}\left(1 - \frac{4}{3}\frac{T_a}{T} + \frac{1}{3}\frac{T_a^4}{T^4}\right) \Rightarrow \dot{en}_{rad}\,\gamma = \dot{ex}_{rad}$ $\qquad ex = ex^{PH} + ex^{CH}$

$\overline{ex}^{CH} \overset{GI}{=} 0 - T_a\left(-R_u \ln \frac{P_a^{(IN)}}{P_{a,i}^{(OUT)}}\right) = T_a R_u \ln \frac{P_a}{P_{a,i}} = T_a R_u \ln \frac{1}{x_{a,i}}$ $\qquad \overline{ex}^{CH} = -\Delta \overline{g}_{@T_a,P_a} + \sum_{i,P} N_i \overline{ex}_i^{CH} - \sum_{i,R} N_i \overline{ex}_i^{CH}$

$\overline{ex}^{CH}_{misc} = \sum_i x_i \overline{ex}_i^{CH} + \underbrace{R_u T_a \sum_i x_i \ln x_i}_{\text{se moli reag} \neq 1}$ $\qquad ex^{CH}_{aria} = 0$

$ex^{PH} \overset{GP}{=} c_p(T-T_a) - T_a\left(c_p \ln\frac{T}{T_a} - R\ln\frac{P}{P_a}\right) = c_p T_a\left(\frac{T}{T_a} - 1 - \ln\frac{T}{T_a}\right) + T_a R \ln \frac{P}{P_a}$ $\qquad ex^{PH} \overset{LP}{=} c(T-T_a) + v(P-P_a) - T_a c \ln\frac{T}{T_a}$

$\overline{h}_{MIX,GI} = \sum_i x_i \overline{h}_i = \sum_i x_i [\overline{h}_{f_i}^0 + \Delta \overline{h}_i(T)]$ $\qquad \overline{s} = \overline{s}^0(T)_{@P_0} + \Delta\overline{s}(P) \overset{GI}{=} \overline{s}^0(T) - R_u \ln\frac{P}{P_0}$

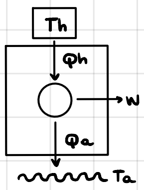
$\overline{s}_{MIX,GI} = \sum_i \left[\overline{s}_i^0(T) - R_u \ln \frac{P_i}{P_0}\right] = \sum_i x_i\left(\overline{s}_i^0(T) - R_u \ln\frac{x_i P}{P_0}\right) = \sum_i x_i \overline{s}_i^0(T) - R_u \sum_i x_i \ln x_i - R_u \ln\frac{P}{P_0}$

$\overline{ex}^{PH}(T,P) \overset{GI}{=} \overline{ex}^{PH}(T) + T_a R_u \ln\frac{P}{P_a}$

$\overline{ex}^{PH}_{MIX}(T,P) = \sum_i x_i \overline{ex}^{PH}(T) + T_a R_u \ln\frac{P}{P_a}$ $\qquad$ isobara con LI/GI: $ex_1 - ex_2 = h_1 - h_2 - T_a(s_1 - s_2) = c(T_1 - T_2) - T_a c \ln\frac{T_1}{T_2}$

TRANSIZ FASE: $ex_1 - ex_2 = \Delta h_{tr} - T_a \frac{\Delta h_{tr}}{T}$ $\qquad q_{tr} = c_{sol}(T_{SAT} - T_{IN}) + \Delta h_{tr} + c_{liq}(T_{OUT} - T_{SAT})$

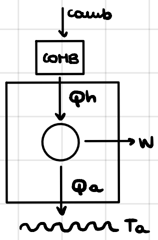
SISTEMA CICLICO MOTORE



$\dot{EX}^{\varphi h} = \dot W + \dot{EX}_{DIS}$

$\eta_{ex} = \frac{\dot W}{\dot{EX}^{\varphi h}} = \frac{\dot W}{\dot\varphi h\,\theta}$, $\theta \to 1 - \frac{T_a}{T}$

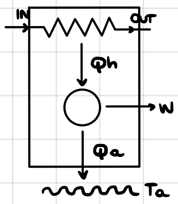
$\eta = \frac{\dot W}{\dot\varphi h}$



$\dot m_{comb} ex^{CH}_{comb} = \dot W + \dot{EX}_{dis}$

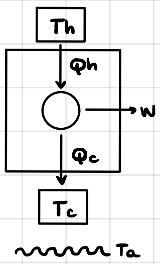
$\eta_{ex} = \frac{\dot W}{\dot m_{comb} ex^{CH}_{comb}}$

$\eta = \frac{\dot W}{\dot m_{comb} PCI}$



$\dot m(ex_{IN} - ex_{OUT}) = \dot W + \dot{EX}_{dis}$

$\eta_{ex} = \frac{\dot W}{\dot m(ex_{IN} - ex_{OUT})}$



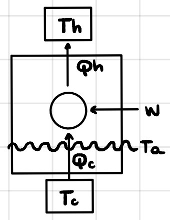
$\dot W = \dot{EX}^{\varphi h} - \dot{EX}^{\varphi c} - \dot{EX}_{DIS}$

$\dot{EX}^{\varphi h} = \dot W + \dot{EX}^{\varphi c} + \dot{EX}_{DIS}$

$\eta_{ex} = \frac{\dot W + \dot{EX}^{\varphi c}}{\dot{EX}^{\varphi h}}$

$\eta = \frac{\dot W + \dot\varphi_c}{\dot m PCI}$ $\qquad \eta_{ex} = \frac{\dot W + \dot{EX}^{\varphi c}}{\dot m ex^{CH}_{comb}}$

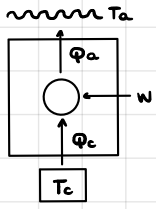
SISTEMA TOTAL ENERGY



$\dot W = \dot{EX}^{\varphi h} + |\underbrace{\dot{EX}^{\varphi c}}_{\dot\varphi_c\left(\frac{T_a}{T_c} - 1\right)}| + \dot{EX}_{DIS}$

$\eta_{ex} = \frac{\dot{EX}^{\varphi h} + |\dot{EX}^{\varphi c}|}{\dot W}$

FRIGORIFERO COMPRESSIONE

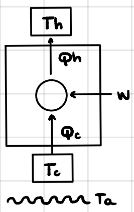


$\dot W = |\dot{EX}^{\varphi c}| + \dot{EX}_{dis}$

$\eta_{ex} = \frac{|\dot{EX}^{\varphi c}|}{\dot W}$

$\varepsilon_f = \frac{\dot\varphi_c}{\dot W}$

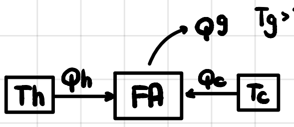
POMPA DI CALORE SOLLEVATA



$\dot W + \dot{EX}^{\varphi c} = \dot{EX}^{\varphi h} + \dot{EX}_{DIS}$

$\eta_{ex} = \frac{\dot{EX}^{\varphi h}}{\dot W + \underbrace{\dot{EX}^{\varphi c}}_{\text{piccola}}}$

FRIGO ASSORBIMENTO

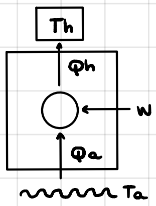


$T_g > T_a$ $\qquad COP = \frac{\varphi_c}{\varphi_h}$

$\eta_{ex} = \frac{\dot{EX}^{\varphi h} + |\dot{EX}^{\varphi c}|}{\dot{EX}^{\varphi g}}$

$\dot{EX}^{\varphi g} = \dot{EX}^{\varphi h} + |\dot{EX}^{\varphi c}| + \dot{EX}_{DIS}$

POMPA DI CALORE



$\dot W = \dot{EX}^{\varphi h} + \dot{EX}_{DIS}$

$\eta_{ex} = \frac{\dot{EX}^{\varphi h}}{\dot W} = \frac{\dot\varphi h\,\theta}{\dot W} = COP\,\theta$

CALDAIA $\quad \eta_I = \frac{\dot E_t}{\dot m PCI}$ $\quad \eta_{ex} = \frac{\dot E_t \theta}{\dot m ex^{CH}_{comb}} \simeq \eta_I \theta$ $\quad \eta_I = \frac{E_t}{\dot m PCS}$ (a condens)

FOTOVOLTAICO $\quad \eta_{PV} = \frac{\dot E_e}{\dot{EN}_{rad}}$ $\quad \eta_{ex,PV} = \frac{\dot E_e}{\dot{EX}_{rad}} = \frac{\dot E_e}{\dot{EN}_{rad}\gamma} = \frac{\eta_{PV}}{\gamma}$

SOLARE TERMICO $\quad \eta_{SOL} = \frac{\dot E_t}{\dot{EN}_{rad}}$ $\quad \eta_{ex,SOL} = \frac{\dot E_t \theta}{\dot{EN}_{rad}\gamma} = \eta_{SOL}\frac{\theta}{\gamma}$

CH_4:
PCI = 802,3 kJ/kmol
ex^{CH} = 830,2 kJ/kmol
PCS = 890,4 kJ/kmol = φ_{comb}
h_f = -74,81 kJ/kmol

C_2H_6:
PCI = 1427,9 kJ/kmol
ex^{CH} = 1493,9 kJ/kmol

POMPA DI CALORE $\quad COP = \frac{\dot\varphi h}{\dot E_e}$ $\quad \eta_{ex,PdC} = \frac{\dot{Ex}^{\varphi h}}{\dot E_e}$

$\eta_{ex,PdC_{TOT}} = \frac{\dot E_t \theta}{\dot m ex^{CH}_{comb}} = \frac{\dot E_t \theta}{\dot E_e}\eta_{ex,es} = COP\,\theta\,\eta_{ex,es}$

COGENERATORE

$\eta_{I,cog} = \frac{\dot E_e + \dot E_t}{\dot E_c} = \eta_e + \eta_t$

$\eta_{ex} = \frac{\dot E_e + \dot E_t \theta}{\dot{EX}_{comb}} \simeq \eta_e + \eta_t \theta$

$= \eta_e \frac{PCI}{ex^{CH}} + \eta_t \frac{PCI}{ex^{CH}}\theta$

COMPRESSORE

RAZ: $\dot W + \dot m ex_{IN} = \dot m ex_{OUT} + \dot{EX}_{DIS}$

$\eta_{ex,RAZ} = \frac{\dot m ex_{OUT}}{\dot W + \dot m ex_{IN}}$

FUNZ: $\dot W = \dot m(ex_{OUT} - ex_{IN}) + \dot{EX}_{DIS}$

$\eta_{ex,FUNZ} = \frac{\dot m(ex_{OUT} - ex_{IN})}{\dot W}$

TURBINA

RAZ: $\dot m ex_{IN} = \dot W + \dot m ex_{OUT} + \dot{EX}_{DIS}$

$\eta_{ex,RAZ} = \frac{\dot W + \dot m ex_{OUT}}{\dot m ex_{IN}}$

FUNZ: $\dot m(ex_{IN} - ex_{OUT}) = \dot W + \dot{EX}_{DIS}$

$\eta_{ex,FUNZ} = \frac{\dot W}{\dot m(ex_{IN} - ex_{OUT})}$

$\dot{EX}_{DIS} = \dot m T_a (S_{OUT} - S_{IN})$

COMB $\quad EX_{comb} = EN_{comb}\frac{ex^{CH}}{PCI}$

VALVOLA $\quad \dot m(ex_{IN} - ex_{OUT}) = \dot{EX}_{DIS}$

$\dot m[-T_a(s_{IN} - s_{OUT})] = \dot{EX}_{DIS}$

SCAMBIATORI DI CALORE RAZ: $\dot m_c ex_{IN,c} + \dot m_f ex_{IN,f} = \dot m_c ex_{OUT,c} + \dot m_f ex_{OUT,f} + \dot{EX}_{DIS}$ $\qquad \eta_{ex,RAZ} = \frac{\dot m_c ex_{OUT,c} + \dot m_f ex_{OUT,f}}{\dot m_c ex_{IN,c} + \dot m_f ex_{IN,f}}$

- SOPRA T_a

$\dot m_c(ex_{IN} - ex_{OUT})_c = \dot m_f(ex_{OUT} - ex_{IN})_f + \dot{EX}_{DIS}$

$\eta_{ex,FUNZ} = \frac{\dot m_f(ex_{OUT} - ex_{IN})_f}{\dot m_c(ex_{IN} - ex_{OUT})_c}$

- SOTTO T_a

$\dot m_f(ex_{IN} - ex_{OUT})_f = \dot m_c(ex_{OUT} - ex_{IN})_c + \dot{EX}_{DIS}$

$\eta_{ex,FUNZ} = \frac{\dot m_c(ex_{OUT} - ex_{IN})_c}{\dot m_f(ex_{IN} - ex_{OUT})_f}$ molto variabile

REAZ END

Bil en $\bar{h}_R + \bar{q} = \bar{h}_P$ $\quad \bar{h} = \bar{h}_{f@T_0,p_0} + \Delta\bar{h}(T,P)$ $\quad \bar{ex}_R + \bar{ex}^q = \bar{ex}_P + \bar{ex}_{DIS}$ $\quad$ FUNZ $\eta_{ex,f} = \dfrac{\bar{ex}_P - \bar{ex}_R}{\bar{ex}^q}$ $\quad$ RAZ $\eta_{ex,r} = \dfrac{\bar{ex}_P}{\bar{ex}_R + \bar{ex}^q}$

COMB $C_\alpha H_\beta$

$$C_\alpha H_\beta + \left(\alpha + \frac{\beta}{4}\right)\lambda\,(O_2 + 3{,}76 N_2) \xrightarrow{\text{se completa}} \alpha CO_2 + \frac{\beta}{2} H_2O_{(g)} + \left(\alpha + \frac{\beta}{4}\right)(\lambda - 1) O_2 + \left(\alpha + \frac{\beta}{4}\right)\lambda\, 3{,}76 N_2$$

$$(\bar{h}_f + \Delta\bar{h})_{comb} + N_{aria}(\bar{h}_f + \Delta\bar{h})_{aria} = \sum_i N_i(\bar{h}_{f,i} + \Delta\bar{h}_i) + \bar{q}_{perso}$$

$N_P[\sum_i x_i(\bar{h}_{f,i} + \Delta\bar{h}_i)]$

$$\overline{PCI} = \sum_{i,R} N_i \bar{h}_{f,i} - \sum_{i,P} N_i \bar{h}_{f,i} \qquad PCI \simeq \sum_i N_i \Delta\bar{h}_{i@T_{af}}$$

$$\overline{PCI} + \Delta\bar{h}_{comb} + N_{aria}\Delta\bar{h}_{aria} = \sum_i N_i \Delta\bar{h}_{i@T_{af}} + \bar{q}_{perso}$$

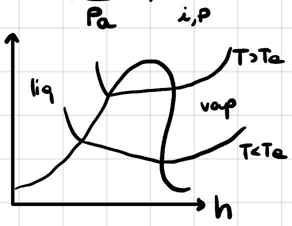
$\bar{ex}^{PH}_{fumi}$ $\quad$ $\bar{ex}^{CH}_{fumi}$ → solo se uso fumi dopo la combustione

$$N_R(\bar{ex}^{PH} + \bar{ex}^{CH})_{comb} + N_{aria}(\bar{ex}^{PH} + \bar{ex}^{CH})_{aria} = \underbrace{\sum_{i,P} N_i \bar{ex}^{PH}_{i@T_{af}} + N_P \bar{R}_u T_0 \ln\frac{P}{P_0}}_{} + \underbrace{\sum_{i,P} N_i \bar{ex}^{CH}_i + \bar{R}_u T_0 \underbrace{\sum_{i,P} N_i \ln x_i}_{\text{moli reag} \neq 1}}_{} + \bar{ex}_{DIS}$$

($N_R \to N_{PCI}$)

comb completa o stechi → $\bar{ex}^{CH}_{fumi}$ trascurabile

leva $h = (1-x)h_l + x h_v$ $\quad x = \dfrac{h - h_l}{h_v - h_l}$ $\quad \varphi = \sum_i N_i(\Delta h_{max} - \Delta h_{min})$



ALLOCAZIONE COSTI

$$\sum_{i,IN} \dot{C}_i + \dot{Z} = \sum_{i,OUT} \dot{C}_i \qquad \dot{C} = c\,\dot{EX} \;[€/h] \quad (c \to €/kWh)$$

$c = 0$ → scarti o aria

$$\dot{C} = c_{ex}\dot{EX} = c_{en}\dot{EN} \Rightarrow c_{ex} = \frac{c_{en}\dot{EN}}{\dot{EX}} \;[€/kWh] \qquad c_{en} = \frac{c_{ex}\dot{EX}}{\dot{EN}}$$

$$\begin{cases} \dot{C}_{IN} + \dot{Z} = \dot{C}_{OUT} \\ \dot{EX}_{IN} = \dot{EX}_{OUT} + \dot{EX}_{DIS} \\ \dot{C} = c\,\dot{EX} \end{cases}$$

$$c_{IN}\dot{EX}_{IN} + \dot{Z} = c_{OUT}\dot{EX}_{OUT}$$

$$c_{IN}(\dot{EX}_{OUT} + \dot{EX}_{DIS}) + \dot{Z} = c_{OUT}\dot{EX}_{OUT}$$

$$c_{OUT} = c_{IN} + \frac{c_{IN}\dot{EX}_{DIS}}{\dot{EX}_{OUT}} + \frac{\dot{Z}}{\dot{EX}_{OUT}}$$

$r = \dfrac{c_{OUT} - c_{IN}}{c_{IN}}$ ↗ alto → attenzione a $c\dot{EX}_{DIS}$ e $\dot{Z}$; ↘ basso → $c_{IN}\uparrow$

$f = \dfrac{\dot{Z}}{\dot{Z} + c_{IN}\dot{EX}_{DIS}}$ ↗ <0,5 devo $\dot{Z}\uparrow$, $\dot{EX}_{DIS}$ determinante; ↘ >0,5 $\dot{Z}$ determinante

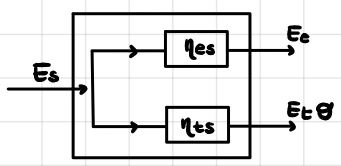
$$\dot{Z} = \dot{Z}^{TCI} + \dot{Z}^{O\&M} \;[€/h]$$

$$\dot{Z}^{TCI} = \frac{TCI}{ore}\,crf \qquad crf = \frac{i(1+i)^n}{(1+i)^n - 1}$$

i = tasso interesse, n = numero anni

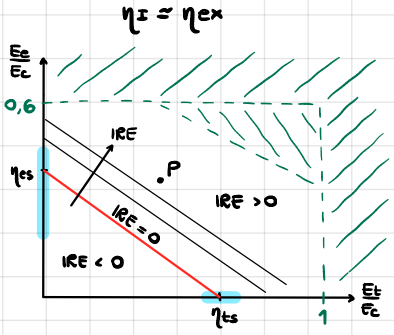
$$TCI = TCI_i \cdot \sum PEC_i$$

SOLUZIONE TRADIZIONALE

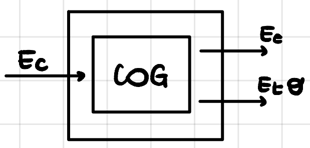


$$\eta_{ex,A} = \frac{E_e + E_t\theta}{\underbrace{\frac{E_e}{\eta_{es}} + \frac{E_t\theta}{\eta_{ts}\theta}}_{E_s}}$$

$\eta_I = \eta_{ex}$



SOLUZIONE COGENERATIVA



$$\eta_{ex,B} = \frac{E_e + E_t\theta}{E_c}$$

$k = \dfrac{E_e}{E_t}$ $\quad \eta = \eta_e + \eta_t$

ITA $\quad IRE = 1 - \dfrac{E_c}{\dfrac{E_e}{\eta_{es}\cdot p} + \dfrac{E_{t,civ}}{\eta_{ts,civ}} + \dfrac{E_{t,ind}}{\eta_{t,ind}}} \geq 0{,}10 \quad + \quad LT = \dfrac{E_t}{E_e + E_t} \geq 0{,}15$

$P[\eta_t; \eta_e]$ $\quad IRE = PES = \dfrac{E_s - E_c}{E_s} = 1 - \dfrac{E_c}{\dfrac{E_e}{\eta_{es}} + \dfrac{E_t\theta}{\eta_{ts}\theta}} = 1 - \dfrac{1}{\dfrac{\eta_e}{\eta_{es}} + \dfrac{\eta_t\theta}{\eta_{ts}\theta}}$

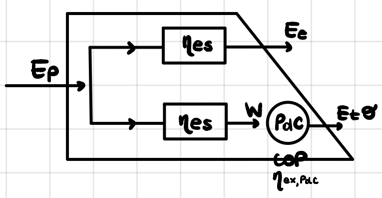
Ⓐ → Ⓑ $\;$ B se $\eta_{ex,B} > \eta_{ex,A} \Rightarrow E_c < \dfrac{E_e}{\eta_{es}} + \dfrac{E_t\theta}{\eta_{ts}\theta}$

Ⓐ → Ⓒ $\;$ C se $\eta_{ex,C} > \eta_{ex,A} \Rightarrow \dfrac{E_e}{\eta_{es}} + \dfrac{E_t}{COP\,\eta_{es}} < \dfrac{E_e}{\eta_{es}} + \dfrac{E_t}{\eta_{ts}}$

$$RPS = \frac{E_s - E_P}{E_s} = 1 - \frac{E_P}{E_s}$$

Ⓑ → Ⓒ $\;$ C se $\eta_{ex,C} > \eta_{ex,B}$ $\quad RPC = \dfrac{E_c - E_P}{E_c} = 1 - \dfrac{E_P}{E_c} = 1 - \dfrac{\dfrac{E_P}{\eta_{es}} + \dfrac{E_t\theta}{COP\,\eta_{es}\theta}}{E_c}$

ALTRA SOLUZIONE



$$\eta_{ex,C} = \frac{E_e + E_t\theta}{\frac{E_e}{\eta_{es}} + \frac{W}{\eta_{es}}} = \frac{E_e + E_t\theta}{\frac{E_e}{\eta_{es}} + \frac{E_t}{COP\,\eta_{es}}} = \frac{E_e + E_t\theta}{\frac{E_e}{\eta_{es}} + \frac{E_t\theta}{\eta_{ex,pdc}\,\eta_{es}}}$$

$$\eta_{ex} = \eta_e + \eta_t\theta$$

$\eta_{ts} < COP\,\eta_{es}$ $\quad COP \simeq 2$ $\quad \theta < \dfrac{\eta_{ex,PdC}\,\eta_{es}}{\eta_{es}} \simeq 0{,}25$

IRE 0, RPC 0 } tutte 3 sol uguali

CAR

$$IRE = PES = \frac{E_s - E_c}{E_s} = 1 - \frac{E_c}{\frac{E_e}{\eta_{es}} + \frac{E_t}{\eta_{ts}}} = 1 - \frac{1}{\frac{\eta_e}{\eta_{es}} + \frac{\eta_t}{\eta_{ts}}} \geq 10\%$$

ITA $\quad IRE = 1 - \dfrac{E_c}{\dfrac{E_e}{\eta_{es}\cdot p} + \dfrac{E_{t,civ}}{\eta_{ts,civ}} + \dfrac{E_{t,ind}}{\eta_{t,ind}}} \geq 0{,}10 \quad + \quad LT = \dfrac{E_t}{E_e + E_t} \geq 0{,}15$

$$\eta_{ed} = \frac{E_e}{E_c - \frac{E_t}{\eta_{ts}}} \geq \eta_{es}$$

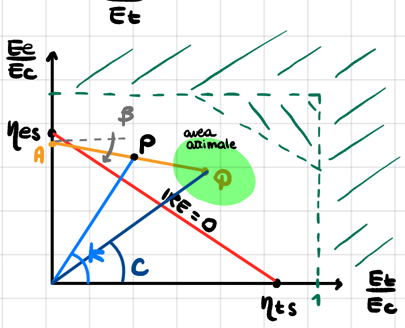
EU: $\eta = \dfrac{E_e + E_t}{E_c} \geq \eta_{CHP}$

- se $\eta \geq \eta_{CHP}$: prendo P e $PES_{@P} \geq 0{,}10 \Rightarrow$ P è CAR
- se $\eta < \eta_{CHP}$: spacco P
  - A: solo en elettrica
  - φ: cogenerazione ⇒ $PES_{@\varphi} \geq 0{,}10$ parz CAR

$P[\eta_t; \eta_e]$ $\quad$ eq retta : $\dfrac{E_e}{E_c} = -\beta\dfrac{E_t}{E_c} + \eta_{c\sigma}$

$A[0, \eta_{c\sigma}]$ → se non recuperasse calore

$k = \dfrac{E_e}{E_t}$



indice max recupero termico

$$k_{@\varphi} = C = \left.\frac{E_e}{E_t}\right|_{MAX}$$

$E_t = H_{CHP}$ [heat]

$E_{e@\varphi} = E_{e,cog} = E_{CHP} = C H_{CHP}$

$E_{nonCHP} = E_e - E_{CHP}$

$\eta_{c\sigma} = \eta_{e@P} + \beta\,\eta_{T@P} = \dfrac{E_{nonCHP}}{F_{nonCHP}}$ [Fuel]

$F_{nonCHP} = \dfrac{E_{nonCHP}}{\eta_{c\sigma}}$

$F_{CHP} = E_c - F_{nonCHP}$

⇒ identificati A e φ :

Ⓐ E_{nonCHP}, F_{nonCHP}, $\eta_{c\sigma}$ $\quad A[0; \eta_{c\sigma}]$

Ⓟ E_{CHP}, H_{CHP}, F_{CHP}, C $\quad \varphi[\eta_t^\varphi; \eta_e^\varphi]$

con $\eta_t^\varphi = \dfrac{H_{CHP}}{F_{CHP}}$ $\quad \eta_e^\varphi = \dfrac{E_{CHP}}{F_{CHP}}$

$$\eta_t^\varphi = \frac{\eta_{CHP} - \eta_{c\sigma}}{1 - \beta} \qquad \eta_e^\varphi = \eta_{CHP} - \eta_t^\varphi \qquad C = \frac{\eta_e^\varphi}{\eta_t^\varphi} = \frac{\eta_{c\sigma} - \beta\eta_{CHP}}{\eta_{CHP} - \eta_{c\sigma}}$$

$$PES_{@\varphi} = 1 - \frac{F_{CHP}}{\frac{E_{CHP}}{\eta_{es}} + \frac{H_{CHP}}{\eta_{ts}}} = 1 - \frac{1}{\frac{\eta_e^\varphi}{\eta_{es}} + \frac{\eta_t^\varphi}{\eta_{ts}}} \geq 0{,}10 \Rightarrow$$

P è CAR per la parte in φ