EPFL

Key performance indicators

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IPESE
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KPI : Key Performance Indicators of a system

General formula of the KPI in KPI unit/lifetime

$$KPI = \int_{t=0}^{LifeTime} \left(\sum_{r=1}^{n_r} \dot{m}_r^+(t) v_r^{+,KPI}(t) + \dot{E}^+(t) v_e^{+,KPI}(t) - \dot{E}^-(t) v_e^{-,KPI}(t) + \sum_{u=1}^{n_u} f_u(t) v_{m,u}^{KPI} \right) dt + \sum_{u=1}^{n_u} v_u^{KPI}(I_u(S_u))$$

KPI [KPI unit/lifetime] for n_p conditions of operation over the lifetime of the system

$$KPI = \sum_{p=1}^{n_p} \left(\sum_{r=1}^{n_r} \dot{m}_{r,p}^+ v_{r,p}^{+,KPI} + \dot{E}_p^+ v_{e,p}^{+,KPI} - \dot{E}_p^- v_{e,p}^{-,KPI} + \sum_{u=1}^{n_u} f_{u,p} v_{m,u}^{KPI} \right) d_p + \sum_{u=1}^{n_u} v_u^{KPI}(I_u(S_u))$$

$\dot{m}_{r,p}^+, \dot{E}_p^+, \dot{E}_p^-$ [kg/s, kW] : flows calculated in the system configuration during conditions p

d_p [s/lifetime] : probability of appearance of conditions p during the life time of the system

$v_{r,p}^{+,KPI}$ [KPI/kg]: value given to flows or investment to characterize the system configuration during conditions p

$v_{e,p}^{+,KPI}$ [KPI/kJ]: value given to Electricity to characterize the system configuration during conditions p

$v_{m,u}^{KPI}$ [KPI/use of u]: value of the maintenance cost of unit during the conditions p

v_u^{KPI} [KPI/$ invested] : value given to the investment of unit u in the system (typically in $\frac{\$^{2020}}{year}\frac{1}{\$_{invested}}$)

$I_u(S_u)$ [$ invested/Size of u] : investment in the equipment of the system

Example of key performance indicators

$$TotalCost[CHF/year] = OPEX + CAPEX + Tax$$

$$OPEX = \sum_{p=1}^{n_p} (\sum_{r=1}^{n_r} \dot{m}^+_{r,p} c^+_{r,p} + \dot{E}^+_p c^+_{e,p} - \dot{E}^-_p c^-_{e,p} + \sum_{u=1}^{n_u} f_{u,p} cm_u) d_p$$

$$CAPEX = \sum_{u=1}^{n_u} \frac{1}{\tau(n_{y,u}, i)} (I1_u y_u + I2_u f_u^{max})$$

$$Tax = CO_2^+ \gamma^{CO_2^+}$$

$$CO_2^+ = \sum_{p=1}^{n_p} (\sum_{r=1}^{n_r} \dot{m}^+_{r,p} \epsilon_r^{CO_2} + \dot{E}^+_p \epsilon_{e,p}^{CO_2^+} - \dot{E}^-_p \epsilon_{e,p}^{CO_2^-}) d_p$$

$$Impact = \zeta^{CO_2^+} (CO_2^+ + \sum_{u=1}^{n_u} \frac{1}{n_{y,u}} (\xi_{c_u}^{CO_2} + \xi_{d_u}^{CO_2}) f_u^{max})$$

$$RES = \sum_{p=1}^{n_p} (\sum_{r_{res}=1}^{n_{r_{res}}} \dot{m}^+_{r_{res},p} + \sum_{u=1}^{n_u} f_{u,p} e_{u,p}^{res^+}) d_p$$

$$\dot{E}^+_p + \dot{E}^-_p + \sum_{u=1}^{n_u} f_{u,p} (e_{u,p}^{res^+} - e^-_{u,p}) = 0 \qquad \forall p = 1..n_p$$

OPEX : Operating Expenditure

$$OPEX[CHF/year] = \sum_{p=1}^{n_p}(\sum_{r=1}^{n_r} \dot{m}^+_{r,p} c^+_{r,p} + \dot{E}^+_p c^+_{e,p} - \dot{E}^-_p c^-_{e,p} + \sum_{u=1}^{n_u} f_{u,p} cm_u) d_p$$

with

$\dot{m}^+_{r,p}[kg/h]$ flow of resource r in period p

$c^+_{r,p}[CHF/kg]$ specific price of resource r in period p

$\dot{E}^+_p[kW]$ Electricity import in period p

$c^+_{e,p}[CHF/kWh]$ Electricity price at import in period p

$\dot{E}^-_p[kW]$ Electricity export in period p

$c^-_{e,p}[CHF/kWh]$ Electricity price at export in period p

$n_u[-]$ number of units

$f_{u,p}[-]$ level of use of unit u in period p

$cm_u[CHF/h]$ specific maintenance cost of unit u

$d_p[h/year]$ duration of period p

We assume that the specific prices are valid for the whole life time : 25 years !!!!

CAPEX : Capital Expenditure

Capital Expenditure is the amount of money needed to buy the equipment, it is expressed on an annual basis

$$CAPEX[CHF/year] = \sum_{u=1}^{n_u} \frac{1}{\tau(n_{y,u}, i)} (I1_u y_u + I2_u f_u^{max})$$

$\frac{1}{\tau(n_{y,u}, i)}$	$[\frac{1}{year}]$	annualisation factor of unit u
$n_{y,u}$	$[year]$	expected life time of unit u
$I1_u$	$[CHF]$	fixed investment of unit u
y_u	$[-]$	existence unit u
$I2_u$	$[CHF]$	proportional investment cost of unit u
f_u^{max}	$[-]$	size of unit u

CO2 emissions

- Measures the amount of CO2 emissions associated to the operation of the system during the n_p operating conditions p.

$$CO_2^+[kgCO_2/year] = \sum_{p=1}^{n_p}(\sum_{r=1}^{n_r} \dot{m}_{r,p}^+ \epsilon_r^{CO_2} + \dot{E}_p^+ \epsilon_{e,p}^{CO_2^+} - \dot{E}_p^- \epsilon_{e,p}^{CO_2^-})d_p$$

$\epsilon_r^{CO_2}[kgCO_2/kg_r]$	kg CO2 emitted per unit of resource r burnt (local emissions)	-> SCOPE 1
$\epsilon_{e,p}^{CO_2^+}[kgCO_2/kWh_e]$	kg CO2 emitted per kWh of electricity consumed	-> SCOPE 2
$\epsilon_{e,p}^{CO_2^-}[kgCO_2/kWh_e]$	kg CO2 avoided per kWh of electricity exported (substituted in the grid)	

$$Tax[CHF/year] = CO_2^+ \gamma^{CO_2^+}$$

$\gamma^{CO_2^+}[CHF/kgCO_2]$ CO2 tax per kg CO2 emitted

SCOPE 1 emissions : directly emitted on site

SCOPE 2 emissions : indirectly emitted (i.e. emitted at the time of the production of the electricity or for the supply of the resource

Environmental impact

$$Impact[ImpactUnit/year] = \zeta^{CO_2^+}(CO_2^+ + \sum_{u=1}^{n_u} \frac{1}{n_{y,u}}(\xi_{c_u}^{CO_2} + \xi_{d_u}^{CO_2})f_u^{max})$$

$\zeta^{CO_2^+}[ImpactUnit/kg_{CO_2}]$	Impact of CO2 emissions per kg of CO2 emitted
$\xi_{c_u}^{CO_2}[kg_{CO_2}]$	life cycle CO2 emissions during the construction of unit u
$\xi_{d_u}^{CO_2}[kg_{CO_2}]$	life cycle CO2 emissions during the dismantling of unit u

An impact value is given to an emission. It concerns SCOPE1, SCOPE 2 or SCOPE 3 (considering the life cycle)
The impact is typically measured by life cycle impact assessment indicators.