EPFL

Annualising the investment

Prof François Marechal

IPESE
Industrial Process
and Energy Systems
Engineering

Total cost of the energy system

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

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

$$CAPEX = \sum_{u=1}^{n_u} \frac{1}{\tau(n_{y,u}, i)} (I(S_u))$$

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

Annualising the investment

- Why ?
  - The Investment value (I [$]) to be compared with annual income and expenses (OPEX [$/year])
  - Money value of today (CAPEX) to be compared with future income or expenses (OPEX)

Annualizing an investment

Expected Cost in [CHF] of an investment (I) after n years under an interest rate of i

$$I^*(i, n_y) = I(1 + i)^{n_y} \quad [\$]$$

Where :

I : Investment in [$]

i : interest rate

n_y : expected lifetime [year]

$I^*(i, n_y)$:Value of I after $n_y$years with the interest rate of i

The interest rate is the one that is expected by the stakeholders of the company
Typically higher than the one proposed by a bank and higher then inflation rate

Value of a yearly income

Value in [CHF] of "n" annual paiements B [CHF/year] after n_y years with an interest rate of i

$$B^*(i, n_y) = \sum_{r=1}^{n_y} B(1+i)^{r-1} = B\frac{(1+i)^{n_y}-1}{i}$$

Each year : I'm investing my paiement at the interest rate i up to the end of the lifetime of the equipment

B [CHF/year] : is the annual profit = Sales - Expenses

B is made each year when the process is operational

We will assume that n is the same lifetime of the equipment

Having the same value after n years

- If the paiement B is the annual income of the project

$$B = \sum_{o} c_o \cdot \dot{m}_o^- - \sum_{i} c_i \cdot \dot{m}_i^+$$

- Present value V [in CHF today] of an annual income B after n years under an interest rate of i

$$V^*(i, n_y) = B^*(i, n_y) \rightarrow V[CHF] = B \frac{(1+i)^{n_y} - 1}{i(1+i)^{n_y}}$$

This is the equivalent investment in today's CHF of the expected annual income during n years with an interest rate of i

Having the same value after n years

- $B[CHF_{year_{project}}/year]$ can be compared with the equivalent investment $I \quad [CHF_{year_{project}}]$ made today :

$$I^*(i, n_y) = IC^*(i, n_y) \rightarrow IC[CHF/year] = I\frac{i(1+i)_y^n}{(1+i)^{n_y}-1}$$

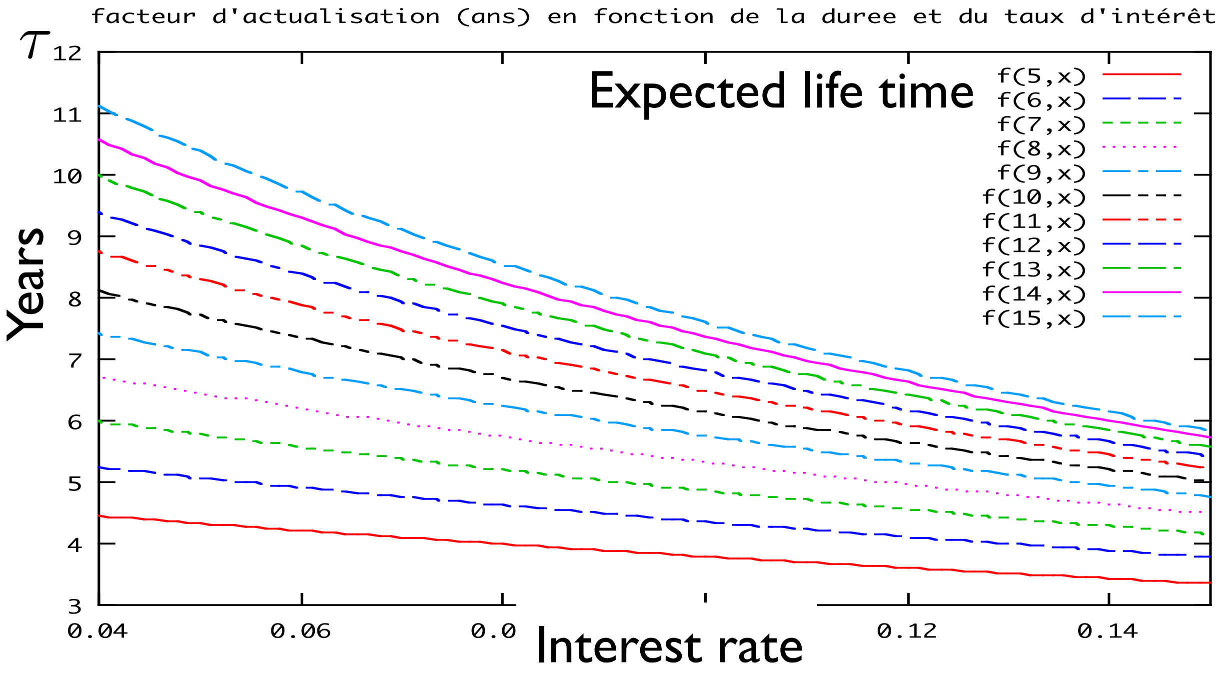
This is the equivalent income in today's CHF/year of the investment I during n years with an interest rate of i

Project evaluation

- Net present value : $NPV[CHF_{year_{project}}] = B\frac{(1+i)^n - 1}{i(1+i)^n} - I \geq 0$

- Annualised Cost :

$$Profit[CHF_{year_{project}}/year] = B - \frac{i(1+i)^n}{(1+i)^n - 1} \cdot I = B - \frac{1}{\tau} \cdot I \geq 0$$



Over how many years the investment has to be "amortised"

Retrofit project : benefit vs incremental investment

Sales

$$\Delta Sales[CHF/year]$$

Products — Electricity

$$\int_{t_0}^{t_f}\left(\sum_{P=1}^{n_P}\Delta\dot{M}_P^-(t)c_P^-(t)+\Delta E^-(t)c_e^-\right)dt$$

Operating costs

$$\Delta Cost[CHF/year]$$

Raw material — Fuel — Electricity — Waste

$$\int_{t_0}^{t_f}\left(\sum_{R=1}^{n_R}\Delta\dot{M}_R^+(t)c_R^+(t)+\sum_{F=1}^{n_F}\Delta\dot{M}_F^+(t)c_F^+(t)+\Delta E^+(t)c_e^+ +\sum_{W=1}^{n_W}\Delta\dot{M}_W^-(t)c_W^-(t)\right)dt$$

Profit [CHF/year]

$$\Delta B[CHF/year]=\Delta Sales[CHF/year]-\Delta Cost[CHF/year]$$

Investments : CAPEX [CHF/year]

$$\Delta IC[CHF/year]=\Delta I\frac{i(1+i)^n}{(1+i)^n-1}$$

Energy savings investment

$$Profit[\$/year] = \Delta OPEX + \Delta Tax - \Delta CAPEX$$

$$\Delta OPEX + \Delta Tax \quad [\$/year] = (OPEX_{ref} - OPEX_{new}) + (Tax_{ref} - Tax_{new}) \geq 0$$

$$\Delta CAPEX \quad [\$/year] = CAPEX_{ref} - CAPEX_{new} \leq 0$$

Project profitability

$$\text{Rate of Return} \quad [\text{years}] \quad = \frac{\Delta I}{\Delta B}$$

How many years are needed to recover the investment
Risk !

$$\text{Net Present Value} \quad [\$] \quad = \Delta B \frac{(1+i)^{n_y}-1}{i(1+i)^{n_y}} - \Delta I \geq 0$$

After nyears

$$\text{Annualised Profit} \quad [\frac{\$}{year}] \quad = \Delta B - \Delta I \frac{i(1+i)^{n_y}}{(1+i)^{n_y}-1} = \Delta B - \frac{I}{\tau} \geq 0$$

$$\text{Internal interest rate} \quad [\%] \quad i^* | \Delta B \frac{(1+i^*)^{n_y}-1}{i^*(1+i^*)^{n_y}} - \Delta I = 0$$

ΔI	$[\$]$	Additional investment
ΔB	$[\frac{\$}{year}]$	Annual expected profit from the investment
n_y	$[\text{year}]$	Expected life time of the equipment

$$\Delta I \quad [\$] = -\Delta CAPEX \quad [\$/year] \cdot \tau(i, n_y) \quad [year]$$

!!! Annual expected benefit is assumed with the energy price of today !!!