Integrated course „Energy Economics“
- Financial management -

Chair of Energy Systems | Department of Energy Systems
Technische Universität Berlin

Outline

- Fundamentals of finance
- Time value of money
- Capital structure and cost of capital
- Capital budgeting: NPV method
- NPV vs IRR
- Levelised cost of electricity (LCOE)

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Interest rates and inflation

A bank offers a one-year interest rate of 10%.

An individual who deposits €1.000 will receive €1.100 in a year.

Rate of inflation is 6% p.a.

A restaurant that charges €10 for a meal today will be charging €10.60 for the same meal in a year.

Today, the individual could buy *€1.000 / €10* = 100 meals.

In a year, they will be able to buy *€1.100 / €10,60* = 103,8 meals.

The resulting increase in consumption is **3,8%** (and not 10%).

↓ real interest rate

1+Nominal interest rate = (1+Real interest rate) x (1+Inflation rate)

$$\text{Real interest rate} = \frac{1 + \text{Nominal interest rate}}{1 + \text{Inflation rate}} - 1$$

Cash flow and inflation

Cash flow → real

Cash flow → nominal

Nominal cash flow: actual money in cash to be received / paid.

Real cash flow: the cash flow's purchasing power.

Nominal cash flows must be discounted at the nominal rate.

Real cash flows must be discounted at the real rate.

Capital budgeting: NPV (DCF) method

The value of a project is measured by its net present value (NPV): present value of the future cash flows minus the initial investment outlay.

1. Identify forecast all cash flows (revenues and costs) associated with a project (forecast).
2. Map the cashflows on a cash flow time chart.
3. Discount each cashflow using an applicable interest rate.
4. Sum up all the discounted cashflows (DCF) to obtain NPV
5. Invest only if NPV > 0 [NPV = 0 indifferent]

Capital budgeting: NPV (DCF) method

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+i)^t} = -I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t}$$

CF_t = Cash Flow in period t
I_0 = Investment in period 0
i = Interest rate / Discount rate
T = Time horizon / Economic lifetime
t = Period

Relevant cash flows

CF from financing activities:

- capital expenditures
- sale of assets

CF from operating activities:

- revenues
- operating expenses
- depreciation
- taxes
- change in working capital

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Relevant cash flows (continued)

e.g. unused storage facility (as alternatively, it can be used for another purpose)

Opportunity cost: potential benefit or income that is foregone as a result of selecting one alternative over another are considered.

Sunk cost: Cost incurred in the past that cannot be changed by any decision are ignored.

Salvation value: In case of abandonment (divestment), assets, typically, retain a residual value (future revenue).

Depreciation tax shield: Yearly depreciation amount is deducted from the income tax base.

The resulting tax saving [depreciation amount x tax rate] is added as a positive cash flow.

NPV method: Calculation example

Discount rate: 7%

Period t	Investment [1000 EURO]	Cash flow [1000 EURO]	Discount factor $(1+i)^{-t}$	PV [1000 EURO]
0	-3000	0	1,000	-3000,0
1	0	160	0,935	149,5
2	0	400	0,873	349,4
3	0	400	0,816	326,5
4	0	400	0,763	305,2
5	0	400	0,713	285,2
6	0	400	0,666	266,5
7	0	400	0,623	249,1
8	0	400	0,582	232,8
9	0	400	0,544	217,6
10	0	400	0,508	203,3
11	0	400	0,475	190,0
12	0	400	0,444	177,6
13	0	400	0,415	166,0
14	0	400	0,388	155,1
15	0	400	0,362	145,0
Total (NPV)				**418,9**

Internal rate of return

$$NPV = 0 = -I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1 + IRR)^t}$$

IRR is the value of interest rate i such that NPV = 0.

NPV rule: NPV > 0

IRR rule:* IRR > WACC (opportunity cost of capital)
for mutually exclusive projects: choose the highest IRR

NPV vs. IRR:

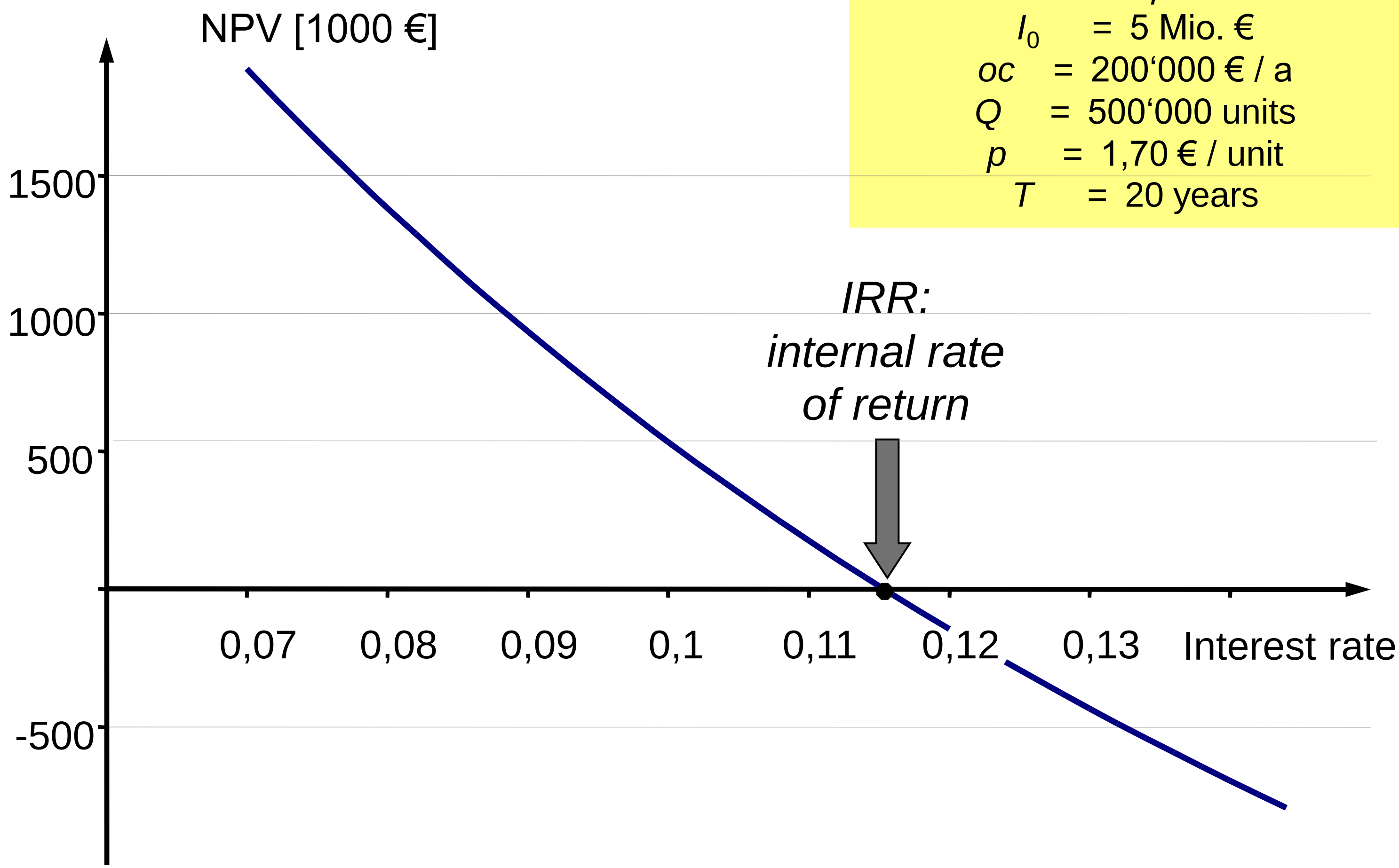
amount of surplus vs. percentage return / break-even point

absolute return vs. relative return

* for projects with an initial negative cash flow and subsequent positive cash flows

NPV and IRR

Example:
I_0 = 5 Mio. €
oc = 200‘000 € / a
Q = 500‘000 units
p = 1,70 € / unit
T = 20 years



Recap: Time value of money, NPV and IRR

Compounding:

$$K_T = K_0 \cdot (1+i)^T$$

Discounting:

$$K_0 = K_T \cdot \frac{1}{(1+i)^T}$$

K = Capital
i = Interest rate / Discount rate
T = Time horizon / Economic lifetime
K_0 = Present value
K_T = Value at the Time horizon

Net Present Value:

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+i)^t} = -I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t}$$

IRR:

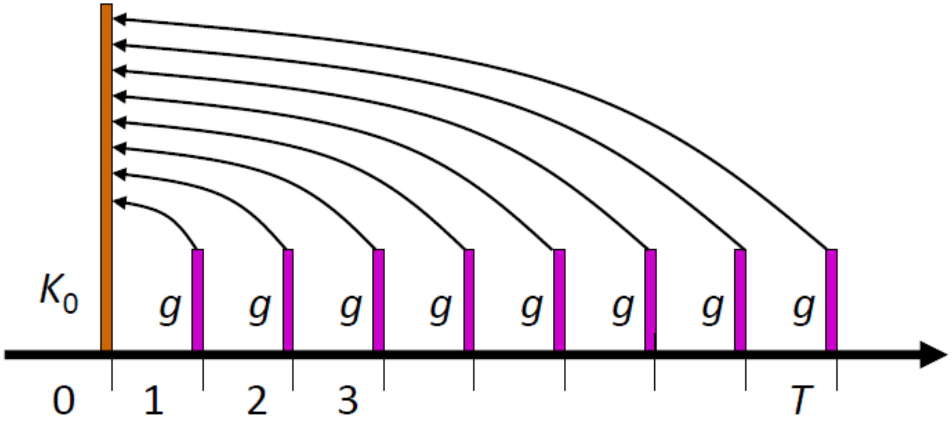
$$NPV = 0 = -I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+IRR)^t}$$

CF_t = Cash Flow in period t
I_0 = Investment in period 0
i = Interest rate / Discount rate
T = Time horizon / Economic lifetime
t = Period

Recap: Annuity

Annuity is a level stream of regular payments during a fixed number of periods.

K_0 = Present value
g = Periodical payment
i = Interest rate
q = $(1+i)$ Interest factor
T = Number of periods



Value at the end of period 0

$$K_0 = g\cdot\left(1+\frac{1}{q}+\frac{1}{q^2}+\ldots+\frac{1}{q^T}\right) = g\cdot\frac{q^T-1}{q-1}\cdot\frac{1}{q^T} = g\cdot\frac{1-q^{-T}}{q-1}$$

$$K_0 = g\cdot\frac{q^T-1}{q-1}\cdot\frac{1}{q^T} = g\cdot\frac{1-q^{-T}}{q-1}$$

$$K_0 = g\cdot Annuity\ factor_{i,T} \qquad with \quad Annuity\ factor_{i,T} = \frac{1}{i} - \frac{1}{i(1+i)^T}$$

Annuity factor

Years	Interest rate [%] 3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
1	0.971	0.966	0.962	0.957	0.952	0.943	0.935	0.926	0.917	0.909
2	1.913	1.900	1.886	1.873	1.859	1.833	1.808	1.783	1.759	1.736
3	2.829	2.802	2.775	2.749	2.723	2.673	2.624	2.577	2.531	2.487
4	3.717	3.673	3.630	3.588	3.546	3.465	3.387	3.312	3.240	3.170
5	4.580	4.515	4.452	4.390	4.329	4.212	4.100	3.993	3.890	3.791
6	5.417	5.329	5.242	5.158	5.076	4.917	4.767	4.623	4.486	4.355
7	6.230	6.115	6.002	5.893	5.786	5.582	5.389	5.206	5.033	4.868
8	7.020	6.874	6.733	6.596	6.463	6.210	5.971	5.747	5.535	5.335
9	7.786	7.608	7.435	7.269	7.108	6.802	6.515	6.247	5.995	5.759
10	8.530	8.317	8.111	7.913	7.722	7.360	7.024	6.710	6.418	6.145
11	9.253	9.002	8.760	8.529	8.306	7.887	7.499	7.139	6.805	6.495
12	9.954	9.663	9.385	9.119	8.863	8.384	7.943	7.536	7.161	6.814
13	10.635	10.303	9.986	9.683	9.394	8.853	8.358	7.904	7.487	7.103
14	11.296	10.921	10.563	10.223	9.899	9.295	8.745	8.244	7.786	7.367
15	11.938	11.517	11.118	10.740	10.380	9.712	9.108	8.559	8.061	7.606
20	14.877	14.212	13.590	13.008	12.462	11.470	10.594	9.818	9.129	8.514
25	17.413	16.482	15.622	14.828	14.094	12.783	11.654	10.675	9.823	9.077
30	19.600	18.392	17.292	16.289	15.372	13.765	12.409	11.258	10.274	9.427
35	21.487	20.001	18.665	17.461	16.374	14.498	12.948	11.655	10.567	9.644
40	23.115	21.355	19.793	18.402	17.159	15.046	13.332	11.925	10.757	9.779
45	24.519	22.495	20.720	19.156	17.774	15.456	13.606	12.108	10.881	9.863
50	25.730	23.456	21.482	19.762	18.256	15.762	13.801	12.233	10.962	9.915

Capital recovery factor

Years	Interest rate [%] 3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
1	1.030	1.035	1.040	1.045	1.050	1.060	1.070	1.080	1.090	1.100
2	0.523	0.526	0.530	0.534	0.538	0.545	0.553	0.561	0.568	0.576
3	0.354	0.357	0.360	0.364	0.367	0.374	0.381	0.388	0.395	0.402
4	0.269	0.272	0.275	0.279	0.282	0.289	0.295	0.302	0.309	0.315
5	0.218	0.221	0.225	0.228	0.231	0.237	0.244	0.250	0.257	0.264
6	0.185	0.188	0.191	0.194	0.197	0.203	0.210	0.216	0.223	0.230
7	0.161	0.164	0.167	0.170	0.173	0.179	0.186	0.192	0.199	0.205
8	0.142	0.145	0.149	0.152	0.155	0.161	0.167	0.174	0.181	0.187
9	0.128	0.131	0.134	0.138	0.141	0.147	0.153	0.160	0.167	0.174
10	0.117	0.120	0.123	0.126	0.130	0.136	0.142	0.149	0.156	0.163
11	0.108	0.111	0.114	0.117	0.120	0.127	0.133	0.140	0.147	0.154
12	0.100	0.103	0.107	0.110	0.113	0.119	0.126	0.133	0.140	0.147
13	0.094	0.097	0.100	0.103	0.106	0.113	0.120	0.127	0.134	0.141
14	0.089	0.092	0.095	0.098	0.101	0.108	0.114	0.121	0.128	0.136
15	0.084	0.087	0.090	0.093	0.096	0.103	0.110	0.117	0.124	0.131
20	0.067	0.070	0.074	0.077	0.080	0.087	0.094	0.102	0.110	0.117
25	0.057	0.061	0.064	0.067	0.071	0.078	0.086	0.094	0.102	0.110
30	0.051	0.054	0.058	0.061	0.065	0.073	0.081	0.089	0.097	0.106
35	0.047	0.050	0.054	0.057	0.061	0.069	0.077	0.086	0.095	0.104
40	0.043	0.047	0.051	0.054	0.058	0.066	0.075	0.084	0.093	0.102
45	0.041	0.044	0.048	0.052	0.056	0.065	0.073	0.083	0.092	0.101
50	0.039	0.043	0.047	0.051	0.055	0.063	0.072	0.082	0.091	0.101

Task 1) NPV and IRR

A company in the waste disposal sector plans to buy a garbage truck to transport waste from a landfill to a waste incineration plant. The truck costs 500 000 €. Due to the operation of the truck, an annual constant cash flow of 120 000 € is estimated. The estimated lifetime of the truck is 6 years, after this period its residual value is 20 000 €.

a) Is the investment profitable? (Assuming an interest rate of 10%)?

To answer the question, find NPV.

T (years)	0	1	2	3	4	5	6
CF (T€)	−500	120	120	120	120	120	120
							20

(120 … 120: annuity)

$NPV = \sum$ → annuity (PV), $\sum_{}^{6}$ → residual value (PV)

$PV_{annuity} = g \cdot AF_{10\%, 6y} = 120\,000€ \cdot 4{,}355 = 522\,600€$

$PV_{residual\ value} = \frac{CF_t}{(1+i)^t} \rightarrow \frac{20\,000€}{(1{,}1)^6} = \frac{20\,000€}{1{,}77} = 11\,299€$

$NPV = -500.000€ + 522600€ + 11299€ =$

$= 33.899€ > 0$

⇒ profitable

Task 1) NPV and IRR

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A company in the waste disposal sector plans to buy a garbage truck to transport waste from a landfill to a waste incineration plant. The truck costs 500 000 €. Due to the operation of the truck, an annual constant cash flow of 120 000 € is estimated. The estimated lifetime of the truck is 6 years, after this period its residual value is 20 000 €.

b) What is the Internal Rate of Return (IRR)?

Find i at which NPV = 0

$$-500.000€ + 120.000€ \cdot \underbrace{\left(\frac{1}{iRR} - \frac{1}{iRR(1+iRR)^6}\right)}_{AF_{iRR,6y}} + \underbrace{\frac{20000€}{(1+iRR)^6}}_{\text{discount factor } iRR,6y} = 0$$

Solve by trial and error method: iterate with different estimated iRR values until NPV ≈ 0.

Task 1) NPV and IRR

A company in the waste disposal sector plans to buy a garbage truck to transport waste from a landfill to a waste incineration plant. The truck costs 500 000 €. Due to the operation of the truck, an annual constant cash flow of 120 000 € is estimated. The estimated lifetime of the truck is 6 years, after this period its residual value is 20 000 €.

b) What is the Internal Rate of Return (IRR)?

As at 10% NPV > 0, IRR must be > 10%. Thus, try 15%. As at 15% NPV < 0, continue searching for 10% < IRR < 15% etc.

i	NPV (€)
10%	33.920
15%	-37.215
12%	1000
12,25%	-160 ≈ 0

IRR = 12,25%

See Excel file on calculating in Excel.

Task 2) Break even and Production threshold

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The investment costs for a production plant are 1 Mio. €. The capacity of the production plant is 100 units per year, with variable costs per unit being 80 €. The estimated lifetime of the production plant is 7 years. Assume an interest rate of 8%.

a) How much are the annual capital costs?

$I_0 = 1000.000 €$

$i = 8\%$

$T = 7y$

$g = I_0 \cdot CRF_{8\%, 7y}$ or: $g = \frac{I_0}{AF_{8\%, 7y}}$

annual capital cost $= 1000.000 € \cdot 0{,}192 = 192.000 €/a$

Task 2) Break even and Production threshold

The investment costs for a production plant are 1 Mio. €. The capacity of the production plant is 100 units per year, with variable costs per unit being 80 €. The estimated lifetime of the production plant is 7 years. Assume an interest rate of 8%.

b) At which price is the production profitable?

$$P_{breakeven} = \frac{C_{fix}}{Q} + C_{var}$$

$$P_{breakeven} = \frac{192\,000\ €}{100\ units} + 80\ €/unit =$$

$$= 2000\ €/unit$$

Task 2) Profit threshold and Production threshold

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The investment costs for a production plant are 1 Mio. €. The capacity of the production plant is 100 units per year, with variable costs per unit being 80 €. The estimated lifetime of the production plant is 7 years. Assume an interest rate of 8%.

c) At which price is the production threshold reached?

$P_{shutdown} = C_{var}$

80€/unit

Levelised cost of electricity (LCOE)

Generic formula:

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+i)^t} = -I_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t}$$

For electricity generation: CF are derived from operating cost and revenues from selling electricity

$$NPV = -I_0 + \sum_{t=1}^{T} \frac{(p_{E,t} - oc_t) \cdot Q_t}{(1+i)^t} = -I_0 + (p_E - oc) \cdot Q \cdot \sum_{t=1}^{T} \frac{1}{(1+i)^t}$$

oc operating cost per unit of energy Q

p_E revenue per unit of energy Q

Q total amount of electricity output over lifetime

$$p_E - oc = \frac{I_0}{Q \cdot \sum_{t=1}^{T} \frac{1}{(1+i)^t}}$$

$\sum_{t=1}^{T} \frac{1}{(1+i)^t} = AF_{i,T}$

Solving for p_E results in levelised cost of electricity (LCOE):

$$p_E = \frac{I_0}{Q \cdot AF_{i,T}} + oc$$

Levelised cost of electricity (LCOE)

$$p_E = \frac{I_0}{Q \cdot AF_{i,T}} + oc$$

lifetime costs divided by lifetime electricity output

Lifetime costs: PV of total cost of building and operating

LCOE allows comparison of technologies regardless of lifetime, installed capacity, cost of capital, risk and return.

- initial capital cost*

  * *specific investment costs*: investment costs divided by capacity

- annual operating expenses
- capacity factor
- discount rate
- operational life

Levelised cost of electricity (LCOE)

How to calculate the generation costs per unit of electricity?

$$LCOE = \frac{I_0 \cdot CRF_{i,\,t}}{Q_t} + oc$$

Q_t = Cap * FLH

Q_t	annual electricity output
Cap	installed capacity (rated power)
FLH	full load hours: annual output divided by Cap

$$\text{Capacity factor} = \frac{Q_t\ [\text{kWh}]}{\text{Cap}\ [\text{kW}] * 8.760\text{h}}$$