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Power and Energy Systems
Engineering Economics

Applications Examples
Chapter 4 – Investment Appraisal Methods

Notes:
1. Cells with black characters include inputs
2. Cells with red characters include formulas
3. Some examples need for calculations the installation of Add_Ins developed by the author. See installation instruction in the file introduction.

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Panos Konstantin

Disclaimer

The Examples are solely and exlusively indented to provide support and assistance to the readers for practicing and better understanding of the theoretical part of this book.

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The author, Panos Konstantin, believes that all information and guidance provided and all calculations in these examples are correct. Nevertheless anyone using these examples should carry out their own due dilligence and appraisal of the contents.

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Proposals for improvements of the contents are welcome and will be considered in upcoming updates!

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Table _WACC_excl._tax

Item	Equity	Loan
Asset shares	30%	70%
Risk free rate of return / interest	5.0 %/a	5.0 %/a
Risk and venture premium	6.0 %/a	1.0 %/a
Cost of capital in nominal terms	11.0 %/a	6.0 %/a
$WACC_n$ in nominal terms	7.50 %/a	
./. Expected Inflation rate	2.00 %/a	
$WACC_r$ inflation adjusted	5.39 %/a	

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Table_WACC_incl._tax

Item	Equity	Loan
Asset shares	**30%**	**70%**
Expected returns after tax		
Risk free rate of return / interest	5.0 %/a	5.0 %/a
Venture risks premium	6.0 %/a	1.0 %/a
Country risk premium (depends on country)	0.0 %/a	0.0 %/a
Cost of capital in nominal terms, after tax	**11.0 %/a**	**6.0 %/a**
Corporate tax 25%	3.7 %/a	0.0 %/a
Cost of capital in nominal terms, before tax	**14.7 %/a**	**6.0 %/a**
WACC $_n$ **in nominal terms, before tax**	**8.60 %/a**	
./. Expected Inflation rate	2.00 %/a	
WACC $_r$ **inflation adjusted**	**6.47 %/a**	

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Table_ConversionEscalationRates

Item	Symbol	Real terms (esc_r)	Nominal terms ($_n$)
Inflation rate	*r*	*infl=0.00%/a*	*infl=2.00%/a*
OPEX fixed	*j*	escr= 1.00%/a	Escn= 3.02%/a
OPEX variable	*j*	escr= 1.50%/a	Escn= 3.53%/a
Conversion Formula		$esc_n=(1+esc_r)\times(1+inf)-1$	

Item	Symbol	Nominal terms ($_n$)	Real terms ($_r$)
Inflation rate	*r*	2.00%/a	0.00%/a
OPEX fixed	*j*	3.02%/a	escr= 1.00%/a
OPEX variable	*j*	3.53%/a	escr= 1.50%/a
Conversion Formula		*escr=(1+escn)/(1+inf)-1*	

Calculation in real terms *)			Year										
Item	Unit	Rates	0	1	2	3	4	5	6	7	8	9	10
CAPEX (Steam PP 700 MW, gross)	mln €		1,240	0	0	0	0	0	0	0	0	0	0
Electricity generation, net	GWh /a		4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860
OPEX													
OPEX, fixed, real terms *)	mln € / a	1.00% esc /a	27.3	27.6	27.8	28.1	28.4	28.7	29.0	29.3	29.6	29.9	30.2
OPEX, variable, real terms *)	mln € / a	1.50% esc /a	153.2	155.5	157.8	160.2	162.6	165.0	167.5	170.0	172.6	175.2	177.8
OPEX, fixed discounted **)	mln € / a	6.47%/a		25.9	24.6	23.3	22.1	21.0	19.9	18.9	17.9	17.0	16.1
OPEX, variable, discounted **)	mln € / a	6.47%/a		146.0	139.2	132.7	126.5	120.6	115.0	109.6	104.5	99.6	95.0
Present values													
Electricity generation, discounted	GWh	6.47%/a	34,986										
CAPEX	mln €		1,240										
OPEX, fixed, discounted	mln €		207										
OPEX, variable, discounted	mln €		1,189										
Total PV	mln €		**2,636**										
LEC, in real terms	**€ / MWh**		**75.33**										

$$LEC = \frac{CAPEX + \sum_{t=1}^{t=n} \frac{OPEX_t}{q^t}}{\sum_{t=1}^{t=n} \frac{W_{el\_t}}{q^t}}$$

Note: the spreadsheet is linked to the spreadsheets: WACC_incl._tax and Ex. 4.1_LEC_NPV_short
*) inflation adjusted 0.0 %/a **) Discount rate in real terms, from file WACC_incl_tax

Calculation in nominal terms *)			Year										
Item	Unit	Rates	0	1	2	3	4	5	6	7	8	9	10
CAPEX (Steam PP 700 MW, gross)	mln €		1,240	0	0	0	0	0	0	0	0	0	0
Electricity generation	GWh /a		4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860	4,860
OPEX													
OPEX, fixed, nominal **)	mln € / a	3.02% esc /a	27.3	28.1	29.0	29.8	30.8	31.7	32.6	33.6	34.6	35.7	36.8
OPEX, variable, nominal **)	mln € / a	3.53% esc /a	153.2	158.6	164.2	170.0	176.0	182.2	188.6	195.3	202.2	209.3	216.7
OPEX, fixed, discounted	mln € / a	8.60%/a		25.9	24.6	23.3	22.1	21.0	19.9	18.9	17.9	17.0	16.1
OPEX, variable, discounted	mln € / a	8.60%/a		146.0	139.2	132.7	126.5	120.6	115.0	109.6	104.5	99.6	95.0
Present values													
Electricity generation, discounted	GWh	8.60%/a	31,747										
CAPEX	mln €		1,240										
OPEX, fixed, discounted	mln €	8.60%/a	207										
OPEX, variable, discounted	mln €	0.00%/a	1,189										
Total PV	mln €		**2,636**										
LEC, nominal	**€ / MWh**		**83.02**										

$$LEC = \frac{CAPEX + \sum_{t=1}^{t=n} \frac{OPEX_t}{q^t}}{\sum_{t=1}^{t=n} \frac{W_{el\_t}}{q^t}}$$

Note: the spreadsheet is linked to the spreadsheets: WACC_incl._tax and Ex. 4.1_LEC_NPV_short
*) including Inflation 2.0 %/a
**) Discount rate in real terms, from file WACC_incl_tax
**) Teh escalation rates on nominal terms are calculated from the real escalation rates and the inflation rate

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Ex. 4.3_LECs_NPV_short

Item		Unit	In real terms	In nominal terms
Electricity generation, net	W_e	GWh /a	4,860	4,860
CAPEX (steam PP 700 MW gross)		mln €	1,240	1,240
Rates				
Inflation rate	j_{inf}	% /a	0.00%	2.00%
Discount rate (WACC)	i_r; i_n	% /a	6.47%	8.60%
OPEX				
OPEX, first year, fixed		mln € / a	27.3	27.3
Escalation rate **)	j_r; j_n	% /a	1.00%	3.02%
OPEX, first year, variable		mln € / a	153.2	153.2
*Escalation rate *)*	j_r; j_n	% /a	1.50%	3.53%
Present values				
Electricity generation *)	$PV(W_e)$	GWh	34,986	31,747
CAPEX (steam PP 700 MW gross)		mln €	1,240	1,240
OPEX, fixed, discounted ***)	*10 a*	mln €	207	207
OPEX, variable, discounted ***)	*10 a*	mln €	1,189	1,189
Net present cost NPC, total		**mln €**	**2,636**	**2,636**
LEC *(= NPC / PV (W_e))*		**€ / MWh**	**75.33**	**83.02**

Note: the spreadsheet is linked to the spreadsheet WACC_incl._tax

*) Calculated with Excel function *PV*

**) $j_n = (1+j_r) \times (1+j_{inf}) - 1$ *in percent format*

***) Calculated with Add-In: BWSesc

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Ex. 4.4_LECs_CBT_deflated LEC

Item		Unit	In real terms	In nominal terms
Power plant				
Electrical output, gross	P_{gross}	MW	700	700
Electrical output, net	P_{net}	MW	648	648
Full load hours	t	h / a	7,500	7,500
Electricity generation, net	W_e	GWh /a	4,860	4,860
Life time		a	10	10
CAPEX		mln €	1,240	1,240
Rates				
Inflation rate	j_{inf}	% /a	0.00%	2.00%
Discount rate (WACC)	i_r; i_n	% /a	6.47%	8.60%
OPEX				
OPEX, first year, fixed		mln € / a	27.3	27.3
Escalation rate **)	j_r; j_n	% /a	1.00%	3.02%
OPEX, first year, variable		mln € / a	153.2	153.2
*Escalation rate *)*	j_r; j_n	% /a	1.50%	3.53%
Present values				
Power ***)	$PV(P_{net})$	MW	4,904	4,904
Electricity production ***)	$PV(W_e)$	GWh	34,986	34,986
CAPEX		mln €	1,240	1,240
OPEX, fixed, discounted ***)		mln €	207	207
OPEX, variable, discounted ***)		mln €	1,189	1,189
Tariff, for the 1st year of the period				
Capacity tariff		€ /kWa	295.0	295.0
Volume tariff		€ / MWh	33.98	33.98
Composite tariff		€ / MWh	73.31	73.31

Note: the spreadsheet is linked to the spreadsheet WACC_incl._tax

*) Calculated with Excel function *PV*

**) $j_n = (1+j_r) \times (1+j_{inf}) - 1$ *in percent format*

***) calculated with Add-In: BWSesc

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Ex. 4.5 to 4.7 IRR

Goal seek, required revenues to obtain	IRROE=11.0 %/a	after tax	=294,886
		Input expenses	-50,000

IRR on investment

Year		0	1	2	3	4	5
CAPEX		**-1,000,000**					
Payment series							
Revenues	esc 2.5 %/a		294,886	302,258	309,815	317,560	325,499
Expenses	esc 3.5 %/a		-50,000	-51,750	-53,561	-55,436	-57,376
Total in- & outflows *)	**IRROI=8.7 %/a**	**-1,000,000**	**244,886**	**250,508**	**256,253**	**262,124**	**268,123**

*) Excel function: ***IRR*** (mark series of values, guess 10%)

IRR on equity before tax (Corporate tax is not a payments series !)

Year		0	1	2	3	4	5
CAPEX		**-1,000,000**					
Loan	70%	**700,000**					
Outstanding principal (for calculation of interest)			560,000	420,000	280,000	140,000	0
Payment series							
Revenues	esc 2.5 %/a		294,886	302,258	309,815	317,560	325,499
Expenses	esc 3.5 %/a		-50,000	-51,750	-53,561	-55,436	-57,376
Interest on loan	6.0 %/a		-42,000	-33,600	-25,200	-16,800	-8,400
Loan repayment	5 a		-140,000	-140,000	-140,000	-140,000	-140,000
Total in- & outflows *)	**IRROE=14.0 %/a**	**-300,000**	**62,886**	**76,908**	**91,053**	**105,324**	**119,723**

*) Excel function: ***IRR*** (mark series of values, guess 10%)

IRR on equity after tax (Corporate tax is a payment series !)

Year		0	1	2	3	4	5
CAPEX		**-1,000,000**					
Depreciation (for calculation of corporate tax only)			-200,000	-200,000	-200,000	-200,000	-200,000
Loan	70%	**700,000**					
Outstanding principal (for calculation of interest only)			560,000	420,000	280,000	140,000	0
Payment series							
Revenues	esc 2.5 %/a		294,886	302,258	309,815	317,560	325,499
Expenses	esc 3.5 %/a		-50,000	-51,750	-53,561	-55,436	-57,376
Interest on loan	6.0 %/a		-42,000	-33,600	-25,200	-16,800	-8,400
Corporate tax	25.0 %		-722	-4,227	-7,763	-11,331	-14,931
Loan repayment	5 a		-140,000	-140,000	-140,000	-140,000	-140,000
Total in- & outflows *)	**IRROE=11.0 %/a**	**-300,000**	**62,165**	**72,681**	**83,290**	**93,993**	**104,792**

*) Excel function: ***IRR*** (mark series of values, guess 10%)

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Ex. 4.8_Anuity vs livetime

Options 1: Single Investment in 1st year only, life time 4 years discount rate *i* = 6.0%

Item	Unit	0	1	2	3	4	5	6	7	8	9	10	11	12
ΣP_i	CU	100.00	100.00	0	0	0								
ΣPV_0	CU	100.00												
Annuity	CU / a	**27.23**	Excel Function *PMT(Interest rate; life time ;PV CAPEX; 0;1)*											

Option 1 as above: Investments 1st, 5th and 9th year, total life time 12 years discount rate *i* = 6.0%

ΣP_i	CU	300.00	100.00	0	0	0	100	0	0	0	100	0	0	0
ΣPV_0	CU	241.95	100.00				79.21				62.74			
Annuity	CU / a	**27.23**	Excel Function *PMT(Interest rate; life time ;PV CAPEX; 0;1)*											

Option 2: Single Investment, life time 12 years discount rate *i* = 6.0%

ΣP_i	CU	241.95	241.95											
ΣPV_0	CU	241.95	241.95	0	0	0	0	0	0	0	0	0	0	0
Annuity	CU / a	**27.23**	Excel Function *PMT(Interest rate; life time ;PV CAPEX; 0;1)*											

Note: All investments at the beginning of the respective year

ΣP_i: *V*alues at current cost level (CU year 0), (1st, 5th, 9th year)

ΣPV_0 : Present values of investments P_i referred to the time "0" *PVo =PVi /(1+i)^(t-1)*

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Ex 4.9_Annu

Item	Unit	in real terms	in nominal terms
Techno / economic constraints			
Rated power output, net (700 MW gross)	MW	648	648
Electricity generation, net 7500 h/a	GWh / a	4,860	4,860
Life time	a	10	10
Discount rate	% / a	6.47%	8.60%
Inflation	% / a	0.00%	2.00%
Escalation rate OPEX, fixed	% / a	1.00%	3.02%
Escalation rate OPEX, variable	% / a	1.50%	3.53%
CAPEX	**mln €**	**1,240**	**1,240**
OPEX at operation start (beginning of 1st year)			
OPEX, fixed (personnel, maintenance, etc)	mln € / a	27.3	27.3
OPEX, variable (fuel, consumables)	mln € / a	153.2	153.2
Annual costs			
Annualized CAPEX	mln € / a	172.3	189.8
OPEX, fixed *) (Add-In ANesc)	mln € / a	28.7	31.6
OPEX, variable (incl. fuel) *) (Add-In ANesc)	mln € / a	165.2	182.0
Total	**mln € / a**	**366.1**	**403.5**
Specific costs			
capacity cost (fixed costs)	€ / (kW a)	310.11	341.75
Energy cost	€ / MWh	33.98	37.45
Composite cost LEC	**€ / MWh**	**75.33**	**83.02**

*) levelized including escalation

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Ex. 4.10_Payback

Item	Unit	Standard motor	High efficiency motor
Technical parameters			
Rated capacity	kW	1,500	1,500
Full load operating hours	h/a	7,000	7,000
Efficiency	-	92.1%	95.3%
Electricity consumption	MWh /a	11,404	11,018
CAPEX	US$	750,000	835,000
Electricity price	US$ / MWh	55.00	55.00
Discount rate *r*	-	15.0%	
Annual costs	US$ / a	627,229	605,981
Incremental CAPEX: $-\Delta I_o$	US$	85,000	
Cost saving: ΔE_t	US$ / a	21,248	
Simple Payback	a	4.00	
Discounted payback t_{pb} *)	a	6.6	

$$-\Delta I_0 + \sum_{t=1}^{t=t_{pb}} \frac{\Delta E_t}{q^{t_{pb}}} = 0$$

*) Discounted payback calculated with the "PV and goal seek function of MS Excel

Note: Apply formula as follows: **-ΔIo-PV(discount rate (r),nper(t_{pb}), ΔE_t , 0 ,0)**
then goal seek "set cell to value 0 by changing t_{pb}"

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Ex. 4.11_ROI

Item	Unit	Standard motor	High efficiency motor
Technical parameters			
Rated capacity	kW	1,500	1,500
Full load operating hours	h/a	7,000	7,000
Efficiency	-	92.1%	95.3%
Electricity consumption	MWh /a	11,404	11,018
CAPEX	US$	750,000	835,000
Electricity price	US$ / MWh	55.00	55.00
Annual costs	US$ / a	627,229	605,981
Incremental CAPEX: $-\Delta I_o$	US$	85,000	
Cost saving: ΔE_t	US$ / a	21,248	
ROI	-	**25%**	