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Power and Energy Systems
Engineering Economics

Applications Examples
Chapter 7 – Project Analysis under Uncertainties

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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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!

Last Update June 2015

Item		Unit	Value
Power balance,engine CHP			
Electrical output, net		kW_e	1,500
Thermal output,	σ=70%	kW_t	2,143
Fuel Input	η=85%	kW_t	4,286
Energy balance, cogeneration			
Electricity generation	7,000 h/a	MWh_e / a	10,500
Heat generation	7,000 h/a	MWh_t / a	15,000
Fuel consumption	7,000 h/a	MWh_t / a	30,000
Financial constraints			
Gas price for LHV		€ / MWh_t	25.00
Electricity purchase price *)		€ / MWh_e	60.00
Annual costs			
Fixed costs **)		th.€ / a	176.0
Fuel costs		th.€ / a	750.0
Subtotal		**th.€ / a**	**926.0**
minus electricity credit ***)		th.€ / a	630.0
Residual costs of heat		**th.€ / a**	**296.0**
Specific cost of heat		**€ / MWh_t**	**19.73**

*) For purchase from grid + including use of system charges
**) Calculated in separate file (annuity CAPEX + fixed O&M costs)
***) Avoided costs for purchase electricity from the grid

Heat-Only Boiler

Heat generation		MWh_t / a	15,000
Fuel consumption	η=88%	MWh_t / a	17,045
Gas price in LHV		€ / MWh_t	25.00
Specific cost of heat		**€ / MWh_t**	**28.41**

Sensitivity Analysis Ex. 7-1

Full load hours		Gas price		Electricity Credit	
h /a	€ / MWh_t	€ / MWh_t	€ / MWh_t	€ / MWh_e	€ / MWh_t
base case	19.73	base case	19.73	base case	19.73
4000	28.53	20	9.73	50	26.73
5000	24.43	25	19.73	55	23.23
6000	21.69	30	29.73	60	19.73
7000	19.73	35	39.73	63	17.63
8000	18.27	40	49.73	70	12.73

Note: Heat cost in heat only boiler without cogeneration 28.41

Sensitivity Cogen – Boiler heat

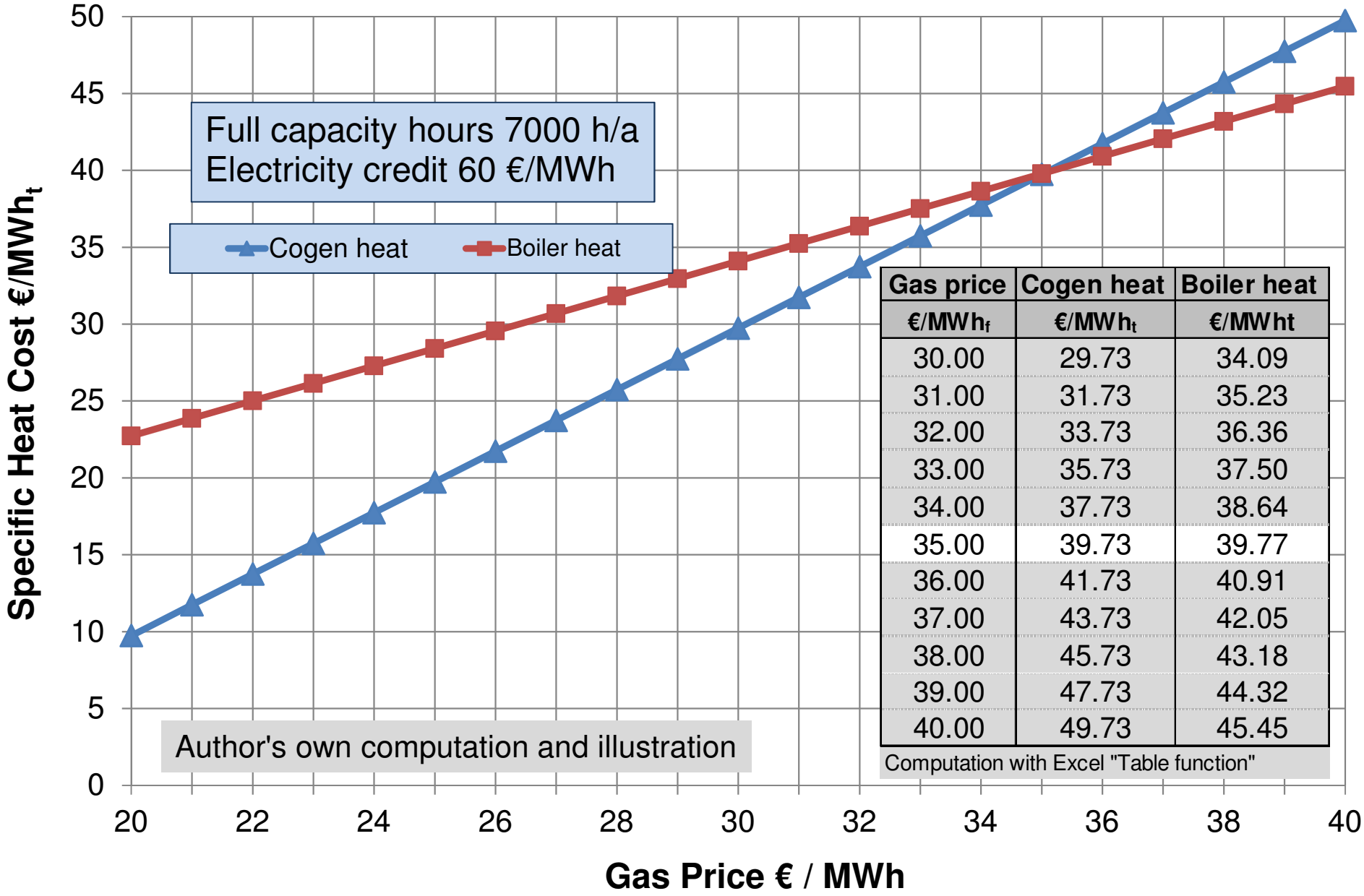
Gas price	Cogen heat	Boiler heat
€/MWh	19.73	28.41
20	9.73	22.73
21	11.73	23.86
22	13.73	25.00
23	15.73	26.14
24	17.73	27.27
25	19.73	28.41
26	21.73	29.55
27	23.73	30.68
28	25.73	31.82
29	27.73	32.95
30	29.73	34.09
31	31.73	35.23
32	33.73	36.36
33	35.73	37.50
34	37.73	38.64
35	39.73	39.77
36	41.73	40.91
37	43.73	42.05
38	45.73	43.18
39	47.73	44.32
40	49.73	45.45

Example 7-2

Cogen heat vs. Boiler heat

Gas price	Cogen heat	Boiler heat
€/MWh_t	€/MWh_t	€/MWht
30.00	29.73	34.09
31.00	31.73	35.23
32.00	33.73	36.36
33.00	35.73	37.50
34.00	37.73	38.64
35.00	39.73	39.77
36.00	41.73	40.91
37.00	43.73	42.05
38.00	45.73	43.18
39.00	47.73	44.32
40.00	49.73	45.45

Computation with Excel "Table function"



Gas price	Cogen heat	Boiler heat
€/MWh$_f$	€/MWh$_t$	€/MWht
30.00	29.73	34.09
31.00	31.73	35.23
32.00	33.73	36.36
33.00	35.73	37.50
34.00	37.73	38.64
35.00	39.73	39.77
36.00	41.73	40.91
37.00	43.73	42.05
38.00	45.73	43.18
39.00	47.73	44.32
40.00	49.73	45.45

Computation with Excel "Table function"

EE-Ch-7_Uncertainties-Analysis_Examples.xls
Ex. 7-3 scenarios

Item	Unit	Worst Case	Most Likely	Best Case
Energy balance, cogeneration				
Full load hours	h/a	6,000	7,000	8,000
Electricity generation	MWh_e / a	9,000	10,500	12,000
Heat generation	MWh_t / a	12,857	15,000	17,143
Fuel consumption	MWh_t / a	25,714	30,000	34,286
Financial constraints				
Gas price in LHV	€ / MWh_t	30.00	25.00	20.00
Electricity purchase price *)	€ / MWh_e	57.00	60.00	63.00
Annual costs				
Fixed costs **)	th.€ / a	176.0	176.0	176.0
Fuel costs	th.€ / a	771.4	750.0	685.7
Subtotal	**th.€ / a**	**947.4**	**926.0**	**861.7**
minus electricity credit ***)	th.€ / a	513.0	630.0	756.0
Residual costs of heat	**th.€ / a**	**434.4**	**296.0**	**105.7**
Specific cost of heat	**€ / MWh_t**	**33.79**	**19.73**	**6.17**
Heat-Only Boiler				
Heat generation	MWh_t / a	12,857	15,000	17,143
Fuel consumption η =88%	MWh_t / a	14,610	17,045	19,481
Gas price in LHV	€ / MWh_t	30.00	25.00	20.00
Specific cost of heat	**€ / MWh_t**	**34.09**	**28.41**	**22.73**

EE-Ch-7_Uncertainties-Analysis_Examples.xls
Ex. 7-4_probability calculation

As in book

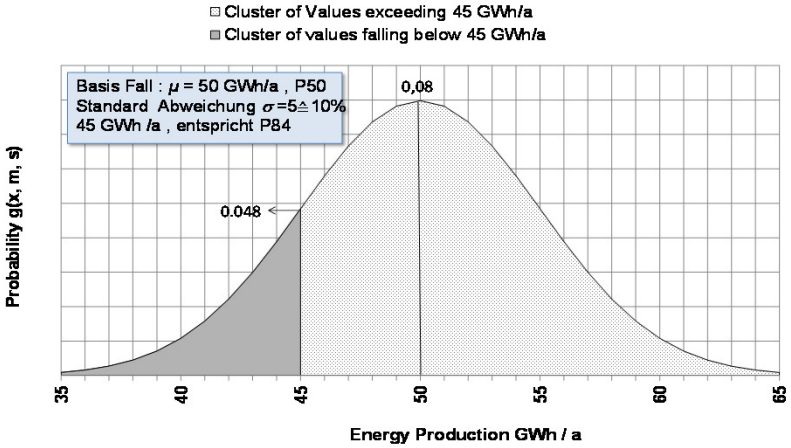
he base case yield of a wind farm for reference conditions is $\mu = 50$ GWh/a, the andard deviation is $\sigma = 5$. Find the g-value, the cluster of values below =45 GWh/a (cumulative probability *CUP*).

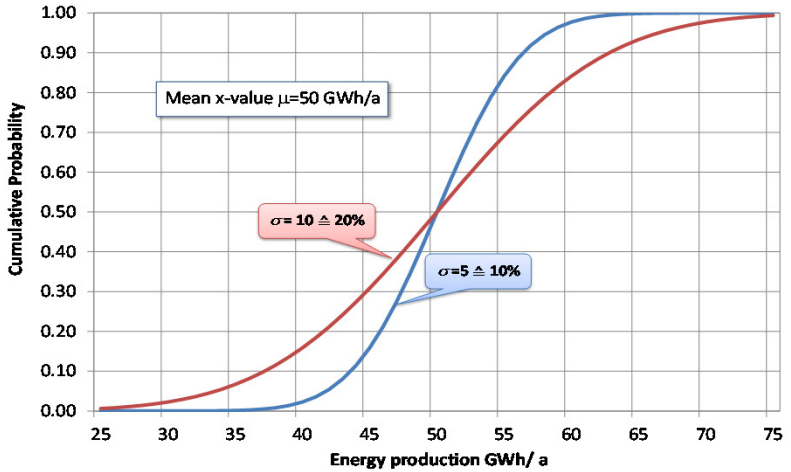
$$g(x) = NORM.Dist(45,50,5,FALSE) = 0.048$$

$$CUP = NORM.Dist(45,50,5,TRUE) = 0.16$$

cumulative probability CUP=0.16 (16%) means that the probability that a yield of 5 GWh may not be reached is 16%; the probability that it may be reached or ceeded is 84%. In other words the exceedance probability is P84

Item	Symbol	Unit	Probability	Cummulative
Value on the x-axis	x	GWh/a	45	45
Base case yield , mean	μ	GWh/a	50	50
Standard deviation	σ	-	5	5
Logical funktion	–	-	FALSCH	WAHR
Value y-axis	–	-	0.048	0.159





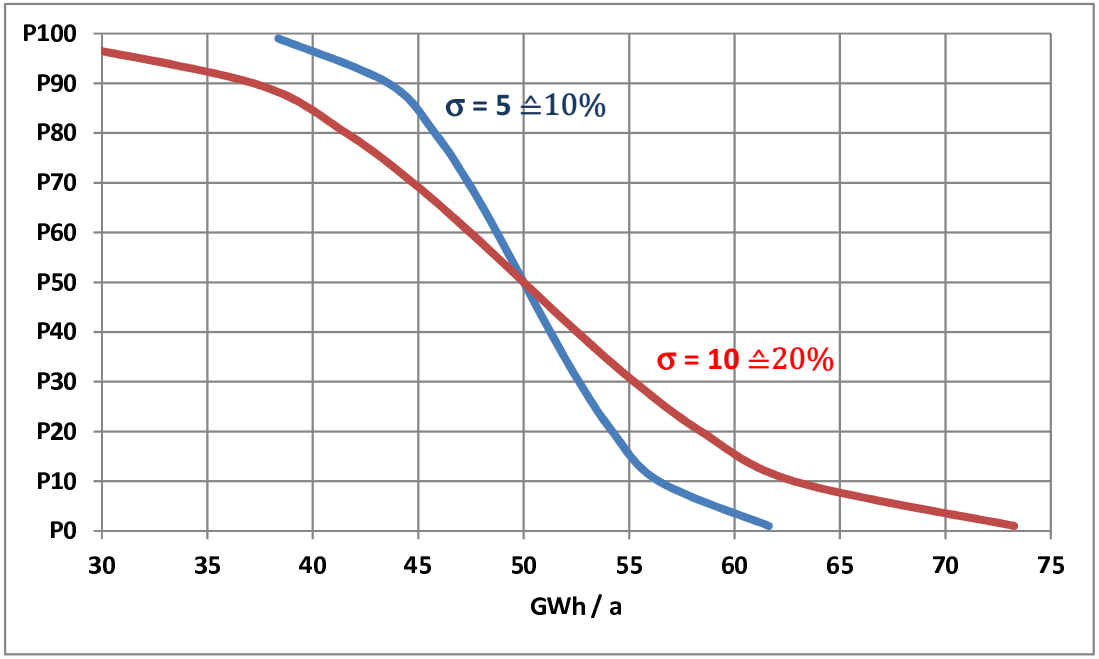
EE-Ch-7_Uncertainties-Analysis_Examples.xls
Ex. 7-5_Excedance probability

As in book

The base case yield of a wind farm for reference conditions is $\mu = 50$ GWh/a, the standard deviation is $\sigma = 5$. Find the yield with an exceedance probability of P90.

$$X_P = 100 - NORM.INV(90/100, 50, 5) = 43.6 \quad [\text{GWh/a}]$$

Item	Symbol	Value	Value
Mean μ	**μ**	**50**	**50**
Standard deviation	**σ**	**5**	**10**
Exceedance Probability	P0		
Exceedance Probability	P1	61.6	73.3
Exceedance Probability	P10	56.4	62.8
Exceedance Probability	P20	54.2	58.4
Exceedance Probability	P30	52.6	55.2
Exceedance Probability	P40	51.3	52.5
Exceedance Probability	P50	50.0	50.0
Exceedance Probability	P60	48.7	47.5
Exceedance Probability	P70	47.4	44.8
Exceedance Probability	P80	45.8	41.6
Exceedance Probability	P90	43.6	37.2
Exceedance Probability	P99	38.4	26.7
Exceedance Probability	P100		



EE-Ch-7_Uncertainties-Analysis_Examples.xls
Ex. 7-6_country premium

As in book

Given:

Currency US$

Interest rate for Aaa rating 6%

Country's rating class: Baa1, Bps 150

Premium:

Premium in nominal terms: CRP_n = 1.5x150/100 = 2.25 %

Interest rate, nominal: i_n = 6%+2.25% = 8,25%

Premium in real terms: CRP_r = ((1+0.0825)/(1+0.06)-1)x100 = 2.12 %

EE-Ch-7_Uncertainties-Analysis_Examples.xls
Ex. 7-7 WACC country premium

Item		Equity	Loan
Asset shares		30%	70%
After tax rates			
Risk free rates		5.0 %/a	5.0 %/a
Venture/credit default premium		6.0 %/a	1.0 %/a
Project type risk premium		0.0 %/a	0.0 %/a
Country risk premium	Rating Baa1	1.5 %/a	1.5 %/a
Subtotal rate after tax		12.5 %/a	7.5 %/a
Corporate tax *)	25%	4.2 %/a	0.0 %/a
Cost of capital in nominal terms, before tax		16.7 %/a	7.5 %/a
$WACC_n$ in nominal terms, before tax		10.25 %/a	
./. Expected Inflation rate		2.00 %/a	
$WACC_r$ inflation adjusted		8.09 %/a	

WACC: Weighted Average Cost of Capital

*) depends on country legislation