11. PROFITABILITY EVALUATION OF NEW POWER PLANT ALTERNATIVES

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Profitability of new power plants

Contents

- Methodology
- Nuclear and wind power plants
- Coal power plants
- Gas peaking power plants
- Oil peaking power plants

Methodology
Cash flow model

Cash flow analysis using spread sheet forms*

1) Give annual power generation, fuel and electricity prices and investment costs
2) Program evaluates then cash flow of incomes, fuel, O&M and operating profit
3) Program calculates the net cash flow, discounted net cash flow and internal rate of return

* Cash flow models are available for internet orders.
See www.optimalpowersystems.com

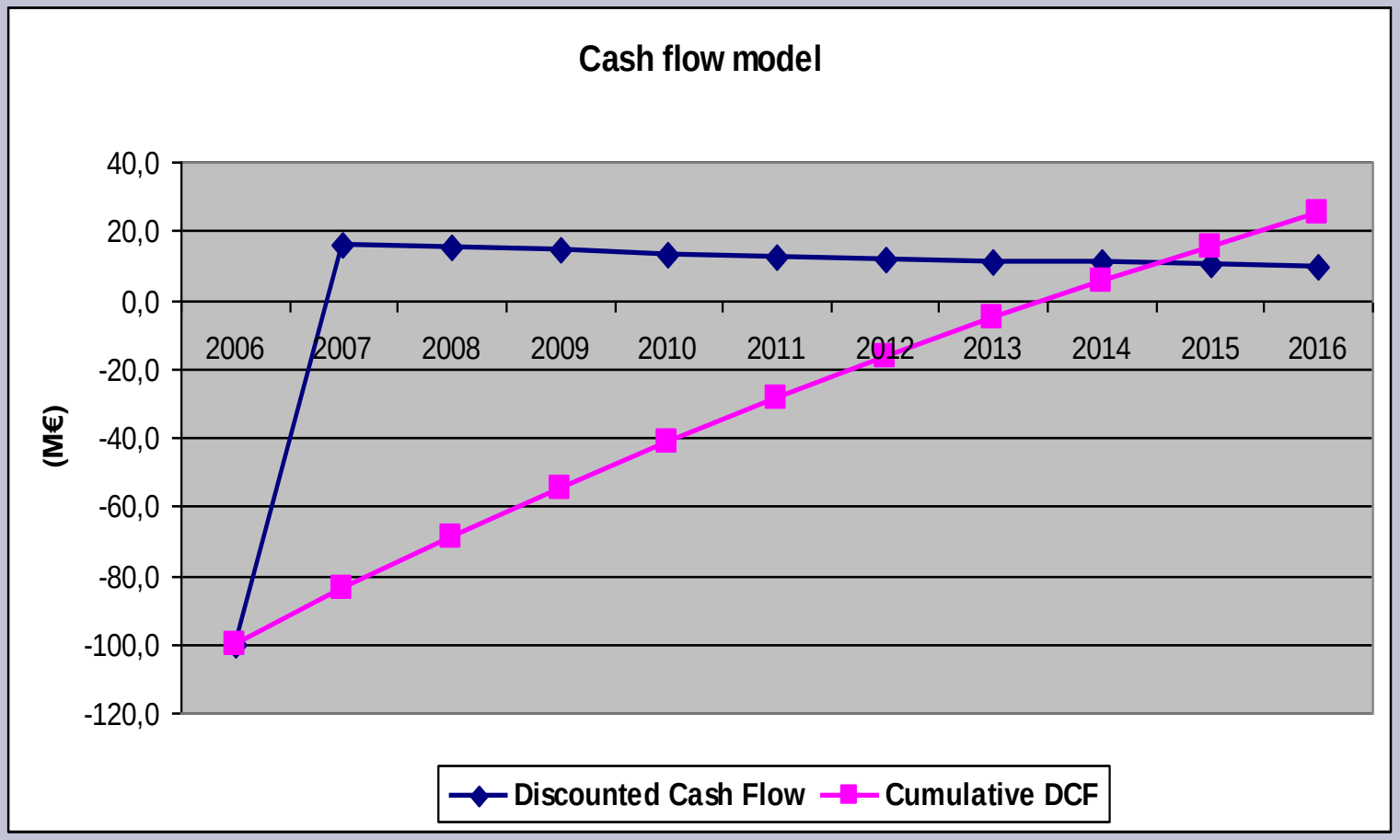
Methodology
Example of cash flow model

CASH FLOW MODEL of 120 MW POWER PLANT

Base year	2006	Electricty price	80	€/MWh	
Discount rate	8%	Fuel price	25	€/MWh	
Escalation	2%	O&M price	5	€/MWh	

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014
Generation	GWh		1000	1000	1000	1000	1000	1000	1000	1000
Efficiency	%		43%	43%	43%	43%	43%	43%	43%	43%
Fuel consumption	GWh		2326	2326	2326	2326	2326	2326	2326	2326
Electricity price	€/MWh		81,6	83,2	84,9	86,6	88,3	90,1	91,9	93,7
Fuel price	€/MWh		25,5	26,0	26,5	27,1	27,6	28,2	28,7	29,3
O&M Costs	€/MWh		5,1	5,2	5,3	5,4	5,5	5,6	5,7	5,9
Cash flows										
Investment	M€	-100								
Income	M€		81,6	83,2	84,9	86,6	88,3	90,1	91,9	93,7
Fuel	M€		-59,3	-60,5	-61,7	-62,9	-64,2	-65,5	-66,8	-68,1
O&M	M€		-5,1	-5,2	-5,3	-5,4	-5,5	-5,6	-5,7	-5,9
Operating profit	M€		17,2	17,5	17,9	18,3	18,6	19,0	19,4	19,8
Cash flow	M€	-100,0	17,2	17,5	17,9	18,3	18,6	19,0	19,4	19,8
Cumulative	M€	-100,0	-82,8	-65,3	-47,4	-29,1	-10,5	8,5	27,9	47,6
Profitability indicators										
Discounted Cash Flow		-100,0	15,9	15,0	14,2	13,4	12,7	12,0	11,3	10,7
Cumulative DCF		-100,0	-84,1	-69,0	-54,8	-41,4	-28,7	-16,8	-5,5	5,2
Internal rate of return	%	11,5%								

Methodology
Discouted cash flow in example



Methodology
Results of example

- In example of a 120 MW gas plant we assume
  - Generation = 1000 GWh
  - Electricity price = 80 eur/MWh
  - Fuel price = 25 eur/MWh
  - O&M price = 5 eur/MWh
  - Investment costs = 100 Meur
- We will get following results
  - Internal rate of return = 11.5 %
  - Cumulative Discounted Cash Flow = 5.2 Meur
  - From the diagram: Pay-back time will be 7 a

Methodology Assumptions

- In the analysis we will study additionally
  - Energy generation in peak, intermediate and base load separately
  - Sales of ancillary services (regulation, spinning and non-spinning reserves)
- After the evaluation the mode, which gives the highest internal rate of return will be selected for each power plant

Methodology
Prices

If we assume* that electricity prices are:

1) Peak load is generated 819 hours at price of 126,7 eur/MWh (= variable costs of LFO plant)
2) Intermediate load is generated 1208 hours at price 73,8 eur/MWh (= variable costs of gas plant)
3) Base load is the remaining hours at price of 47,9 eur/MWh (variable costs of coal plant)

* The capacity mix is assumed to be optimal. See presentation planning of national power systems

Profitability of base load power plants

Base load power plants
Performance

		Nuclear	Wind
Output	MW	1500	150
Net efficiency	%	35	-
Investment	eur/kW	2666	1332

Base load power plants

Nuclear power plant without A/S

OPTIMAL POWER SYSTEMS		NUCLEAR PLANT						8.9.08	Asko Vuorinen			
Parameters		**Plant output**		**1500**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency		35,0%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment		2665	€/kW		Intermediate		73,8	€/MWh	1208	100 %
Escalation	2,5%	Fuel price		2,8	€/MWh		Base load		47,9	€/MWh	5973	100 %
		CO2-content		0	kg/MWh		Total		58,8	€/MWh	8000	100 %
		CO2-price		25,0	€/t		Regulation		25,0	€/MWh	0	0 %
		FOM		28,1	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM		6,8	€/MWh		Non-spinning		5,0	€/MWh	0	0 %
Year		2008	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
- Income	M€			718	736	755	774	793	813	833	854	875
- Fuel costs	M€			-96	-98	-101	-103	-106	-109	-111	-114	-117
- CO2 costs	M€			0	0	0	0	0	0	0	0	0
- VOM costs	M€			-82	-84	-86	-88	-90	-92	-95	-97	-99
- FOM costs	M€			-42	-43	-44	-45	-47	-48	-49	-50	-51
Operating profit	M€			499	511	524	537	550	564	578	593	607
Investment	M€	-800	-800									
Cash flow	M€	-800	-800	499	511	524	537	550	564	578	593	607
Disc. cash flow	M€	-1175	-863	499	473	449	426	404	384	364	346	328
Cumulative	M€	-1175	-5 066	-4 567	-4 094	-3 645	-3 219	-2 814	-2 430	-2 066	-1 720	-1 392
Internal rate of return		11,2%										

Base load power plants

Nuclear power plant

- Nuclear plant gives high IRR = 13 %
- But nuclear plants need a lot of ancillary services, if the plant is the largest unit

  1) Primary reserves increase by dP1

  2) Secondary reserves increase by dP2

Approximate values:

dP2 = (Pnuclear unit – P second largest unit)/n

n = number of large nuclear units in the system

dP1 = 0,8 x dP2, where 0,2 is generated by selfregulation

Base load power plants

Nuclear power plant with A/S and transm.

OPTIMAL POWER SYSTEMS			NUCLEAR PLANT					8.9.08		Asko Vuorinen	
			Including 840 €/kW system costs								
Parameters		**Plant output**	**1500**	**MW**		**Operation**	**Electr. price**		**Hours**	**Load**	
First year	2013	Efficiency	35,0%			Peak load	126,7	€/MWh	819	100 %	
Discount rate	8,0%	Investment	3505	€/kW		Intermediate	73,8	€/MWh	1208	100 %	
Escalation	2,5%	Fuel price	2,8	€/MWh		Base load	47,9	€/MWh	5973	100 %	
		CO2-content	0	kg/MWh		Total	58,8	€/MWh	8000	100 %	
		CO2-price	25,0	€/t		Regulation	25,0	€/MWh	0	0 %	
		FOM	28,1	€/kWa		Spinning	15,0	€/MWh	0	0 %	
		VOM	6,8	€/MWh		Non-spinning	5,0	€/MWh	0	0 %	

Year		2008	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement												
- Income	M€			718	736	755	774	793	813	833	854	875
- Fuel costs	M€			-96	-98	-101	-103	-106	-109	-111	-114	-117
- CO2 costs	M€			0	0	0	0	0	0	0	0	0
- VOM costs	M€			-82	-84	-86	-88	-90	-92	-95	-97	-99
- FOM costs	M€			-42	-43	-44	-45	-47	-48	-49	-50	-51
Operating profit	M€			499	511	524	537	550	564	578	593	607
Investment	M€	-1052	-1052									
Cash flow	M€	-1052	-1052	499	511	524	537	550	564	578	593	607
Disc. cash flow	M€	-1545	-1136	499	473	449	426	404	384	364	346	328
Cumulative	M€	-1545	-6 662	-6 164	-5 691	-5 241	-4 815	-4 411	-4 027	-3 663	-3 317	-2 989
Internal rate of return		8,6%										

Wind power plants

Base load power plants

Wind power plant without A/S

OPTIMAL POWER SYSTEMS					ONSHORE WIND POWER PLANT				8.9.08	Asko Vuorinen			
Parameters		**Plant output**			**150**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency						Peak load		126,7	€/MWh	819	30 %
Discount rate	8,0%	Investment			1332	€/kW		Intermediate		73,8	€/MWh	1208	30 %
Escalation	2,5%	Green certificate price			0,0	€/MWh		Base load		47,9	€/MWh	5973	30 %
		CO2-content				kg/MWh		Total		58,8	€/MWh	8000	30 %
		CO2-price				€/t		Regulation		25,0	€/MWh	0	0 %
		FOM			15,3	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			11,0	€/MWh		Non-spinning		5,0	€/MWh	0	0 %
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity Income	M€				21,5	22,1	22,6	23,2	23,8	24,4	25,0	25,6	26,3
- Certificate income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- VOM costs	M€				-4,0	-4,1	-4,2	-4,3	-4,4	-4,5	-4,6	-4,7	-4,8
- FOM costs	M€				-0,7	-0,7	-0,7	-0,7	-0,8	-0,8	-0,8	-0,8	-0,8
Operating profit	M€				16,9	17,3	17,8	18,2	18,7	19,1	19,6	20,1	20,6
Investment	M€	0	-100	-100									
Cash flow	M€	0	-100	-100	16,9	17,3	17,8	18,2	18,7	19,1	19,6	20,1	20,6
Disc. cash flow	M€	0	-117	-108	16,9	16,0	15,2	14,4	13,7	13,0	12,4	11,7	11,1
Cumulative	M€	0	-117	-224	-208	-191	-176	-162	-148	-135	-123	-111	-100
Internal rate of return		8,8%											

Base load power plants

Wind power plant with A/S

OPTIMAL POWER SYSTEMS				ONSHORE WIND POWER PLANT				8.9.08		Asko Vuorinen		
				with 45 MW fast reserves								
Parameters		**Plant output**		**150**	**MW**		**Operation**	**Electr. price**		**Hours**	**Load**	
First year	2013	Efficiency					Peak load	126,7	€/MWh	819	30 %	
Discount rate	8,0%	Investment		1500	€/kW		Intermediate	73,8	€/MWh	1208	30 %	
Escalation	2,5%	Green certificate price		0,0	€/MWh		Base load	47,9	€/MWh	5973	30 %	
		CO2-content			kg/MWh		Total	58,8	€/MWh	8000	30 %	
		CO2-price			€/t		Regulation	25,0	€/MWh	0	0 %	
		FOM		15,3	€/kWa		Spinning	15,0	€/MWh	0	0 %	
		VOM		11,0	€/MWh		Non-spinning	5,0	€/MWh	0	0 %	
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity I	M€				21,5	22,1	22,6	23,2	23,8	24,4	25,0	25,6	26,3
- Certificate	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- VOM costs	M€				-4,0	-4,1	-4,2	-4,3	-4,4	-4,5	-4,6	-4,7	-4,8
- FOM costs	M€				-0,7	-0,7	-0,7	-0,7	-0,8	-0,8	-0,8	-0,8	-0,8
Operating pr	M€				16,9	17,3	17,8	18,2	18,7	19,1	19,6	20,1	20,6
Investment	M€	0	-113	-113									
Cash flow	M€	0	-113	-113	16,9	17,3	17,8	18,2	18,7	19,1	19,6	20,1	20,6
Disc. cash fl	M€	0	-131	-122	16,9	16,0	15,2	14,4	13,7	13,0	12,4	11,7	11,1
Cumulative	M€	0	-131	-253	-236	-220	-205	-190	-176	-163	-151	-139	-128
Internal rate of return		7,6%											

Base load power plants

Wind power plant with A/S and certificates

OPTIMAL POWER SYSTEMS				ONSHORE WIND POWER PLANT				8.9.08		Asko Vuorinen		
				with Certificates								
Parameters		**Plant output**		**150,0**	**MW**		**Operation**	**Electr. price**		**Hours**	**Load**	
First year	2013	Efficiency					Peak load	126,7	€/MWh	819,1	30 %	
Discount rate	8,0%	Investment		1332,0	€/kW		Intermediate	73,8	€/MWh	1208,1	30 %	
Escalation	2,5%	Green certificate price		20,0	€/MWh		Base load	47,9	€/MWh	5972,8	30 %	
		CO2-content			kg/MWh		Total	58,8	€/MWh	8000,0	30 %	
		CO2-price			€/t		Regulation	25,0	€/MWh	0,0	0,0	
		FOM		15,3	€/kWa		Spinning	15,0	€/MWh	0,0	0,0	
		VOM		11,0	€/MWh		Non-spinning	5,0	€/MWh	0,0	0,0	
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity Income	M€				21,5	22,1	22,6	23,2	23,8	24,4	25,0	25,6	26,3
- Certificate income	M€				7,2	7,4	7,6	7,8	7,9	8,1	8,3	8,6	8,8
- VOM costs	M€				-4,0	-4,1	-4,2	-4,3	-4,4	-4,5	-4,6	-4,7	-4,8
- FOM costs	M€				-0,7	-0,7	-0,7	-0,7	-0,8	-0,8	-0,8	-0,8	-0,8
Operating profit	M€				24,1	24,7	25,3	26,0	26,6	27,3	27,9	28,6	29,4
Investment	M€	0	-100	-100									
Cash flow	M€	0	-100	-100	24,1	24,7	25,3	26,0	26,6	27,3	27,9	28,6	29,4
Disc. cash flow	M€	0	-117	-108	24,1	22,9	21,7	20,6	19,6	18,6	17,6	16,7	15,9
Cumulative	M€	0	-117	-224	-200	-177	-156	-135	-116	-97	-79	-63	-47
Internal rate of return		12,8%											

Nuclear and wind power plants
Summary

Nuclear wind power plants may give high IRR, but consume A/S-reserves

Nuclear plant needs 100 % backup within 15 secons

Wind power plants need 28 % backup within 60 minutes

Coal power plants

Base load power plants

Coal power plant

OPTIMAL POWER SYSTEMS				COAL 500 SC PLANT					8.9.08		Asko Vuorinen		
Parameters		**Plant output**		**500**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**	
First year	2013	Efficiency		40,0%			Peak load		126,7	€/MWh	819	100 %	
Discount rate	8,0%	Investment		1264	€/kW		Intermediate		73,8	€/MWh	1208	100 %	
Escalation	2,5%	Fuel price		7,9	€/MWh		Base load		47,9	€/MWh	5973	100 %	
		CO2-content		0,341	kg/MWh		Total		58,8	€/MWh	8000	100 %	
		CO2-price		25,0	€/t		Regulation		25,0	€/MWh	0	0 %	
		FOM		19,3	€/kWa		Spinning		15,0	€/MWh	0	0 %	
		VOM		6,6	€/MWh		Non-spinning		5,0	€/MWh	0	0 %	
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Income	M€				239	245	252	258	264	271	278	285	292
- Fuel costs	M€				-79	-81	-83	-85	-87	-89	-92	-94	-96
- CO2 costs	M€				-85	-87	-89	-92	-94	-96	-99	-101	-104
- VOM costs	M€				-26	-27	-28	-28	-29	-30	-31	-31	-32
- FOM costs	M€				-10	-10	-10	-10	-11	-11	-11	-11	-12
Operating profit	M€				39	40	41	42	43	44	45	47	48
Investment	M€	-211	-211	-211									
Cash flow	M€	-211	-211	-211	39	40	41	42	43	44	45	47	48
Disc. cash flow	M€	-265	-246	-228	39	37	35	34	32	30	29	27	26
Cumulative	M€	-265	-511	-739	-699	-662	-627	-593	-561	-531	-503	-475	-450
Internal rate of return		5,6%											

Coal power plant

- Coal fired plant has IRR = 5.6 %
- If the coal plant is the largest unit in the system, it will need A/S reserves
- If the coal plant is flexible, it can generate A/S reserves and increase IRR

Nuclear and coal power plants

Flexible coal power plant with regulation

OPTIMAL POWER SYSTEMS				COAL FIRED PLANT					8.9.08		Asko Vuorinen		
Parameters		**Plant output**			**500**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			40,0%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment			1600	€/kW		Intermediate		73,8	€/MWh	1208	100 %
Escalation	2,5%	Fuel price			7,9	€/MWh		Base load		47,9	€/MWh	5973	80 %
		CO2-content			0,341	kg/MWh		Total		58,8	€/MWh	8000	85 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	5973	20 %
		FOM			19,3	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			6,6	€/MWh		Non-spinning		5,0	€/MWh	0	0 %
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Income	M€				218	223	229	235	240	246	253	259	265
- Fuel costs	M€				-59	-60	-61	-63	-65	-66	-68	-70	-71
- CO2 costs	M€				-63	-65	-66	-68	-70	-71	-73	-75	-77
- VOM costs	M€				-19	-20	-20	-21	-21	-22	-22	-23	-24
- FOM costs	M€				-10	-10	-10	-10	-11	-11	-11	-11	-12
Operating pr	M€				67	69	71	72	74	76	78	80	82
Investment	M€	-267	-267	-267									
Cash flow	M€	-267	-267	-267	67	69	71	72	74	76	78	80	82
Disc. cash fl	M€	-336	-311	-288	67	64	61	58	55	52	49	47	44
Cumulative	M€	-336	-647	-935	-868	-804	-743	-686	-631	-579	-530	-484	-439
Internal rate of return		8,3%											

Flexible coal power plant with regulation

- Selling of regulation reserves will increase IRR from 5.6 % to 8.3 %
- The plant will operate at 80 % load for 5866 hours annually and offer regulation by +/- 20 %
- It will operate at the 100 % load for intermediate and peak hours*

* Regulation reserves are generated by gas or diesel engine plants for intermediate and peak hours (2134 h/a)

Gas fired peaking power plants

Gas fired peaking power plants
Performance

Plant type		*Dual-fuel*	*Gas Engine*	*Gas Turbine*
Output		*160 MW*	*160 MW*	*160 MW*
Number of engines		*10*	*20*	*4*
Engine output	*MWe*	*16*	*8*	*40*
Plant output	*MWe*	*160*	*160*	*158*
Fuel input	*MWt*	*367*	*372*	*426*
Net efficiency	*%*	*43.5*	*42.8*	*37.1*

Gas fired peaking power plants

Gas Engine plant in energy service

OPTIMAL POWER SYSTEMS		Gas engine peaking GE160								8.9.08 Asko Vuorinen			
Parameters		**Plant output**			**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			42,8%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment			880	€/kW		Intermediate		73,8	€/MWh	1208	0 %
Escalation	2,5%	Fuel price			25,0	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content			0,202	kg/MWh		Total		58,8	€/MWh	8000	10 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	0	0 %
		FOM			12,2	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			6,0	€/MWh		Non-spinning		5,0	€/MWh	0	0 %
		Heat output			0,0	MW		Heat price		0,0	€/MWh		
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				16,6	17,0	17,4	17,9	18,3	18,8	19,3	19,7	20,2
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-7,7	-7,8	-8,0	-8,2	-8,4	-8,7	-8,9	-9,1	-9,3
- CO2 costs	M€				-1,5	-1,6	-1,6	-1,7	-1,7	-1,7	-1,8	-1,8	-1,9
- VOM costs	M€				-0,8	-0,8	-0,8	-0,8	-0,9	-0,9	-0,9	-0,9	-1,0
- FOM costs	M€				-2,0	-2,0	-2,1	-2,1	-2,2	-2,2	-2,3	-2,3	-2,4
Operating profit	M€				4,7	4,8	4,9	5,0	5,1	5,3	5,4	5,5	5,7
Investment	M€	0	-28	-113									
Cash flow	M€	0	-28	-113	4,7	4,8	4,9	5,0	5,1	5,3	5,4	5,5	5,7
Disc. cash flow	M€	0	-33	-122	4,7	4,4	4,2	4,0	3,8	3,6	3,4	3,2	3,1
Cumulative	M€	0	-33	-154	-149,8	-145,4	-141,2	-137,2	-133,4	-129,9	-126,4	-123,2	-120,1
Internal rate of return		0,9%											

Gas fired peaking power plants

Gas Engine plant in energy service only

- Plant will be operated
  - 2027 hours at full load and generates only energy
- IRR = 1.0 %

Gas fired peaking power plants

GE plant with regulation and non-spinning

OPTIMAL POWER SYSTEMS		Gas engine peaking GE 160								8.9.08 Asko Vuorinen			
		Energy, regulation and non-spin											
Parameters		**Plant output**			**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			42,8%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment			880	€/kW		Intermediate		73,8	€/MWh	1208	70 %
Escalation	2,5%	Fuel price			25,0	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content			0,202	kg/MWh		Total		58,8	€/MWh	8000	21 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	1208	30 %
		FOM			12,2	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			6,0	€/MWh		Non-spinning		5,0	€/MWh	5973	100 %
		Heat output			0,0	MW		Heat price		0,0	€/MWh		
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				34,3	35,1	36,0	36,9	37,8	38,8	39,7	40,7	41,7
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-15,8	-16,2	-16,6	-17,0	-17,4	-17,9	-18,3	-18,8	-19,2
- CO2 costs	M€				-3,2	-3,3	-3,4	-3,4	-3,5	-3,6	-3,7	-3,8	-3,9
- VOM costs	M€				-1,6	-1,6	-1,7	-1,7	-1,8	-1,8	-1,9	-1,9	-1,9
- FOM costs	M€				-2,0	-2,0	-2,1	-2,1	-2,2	-2,2	-2,3	-2,3	-2,4
Operating profit	M€				11,7	12,0	12,3	12,6	12,9	13,3	13,6	13,9	14,3
Investment	M€	0	-28	-113									
Cash flow	M€	0	-28	-113	11,7	12,0	12,3	12,6	12,9	13,3	13,6	13,9	14,3
Disc. cash flow	M€	0	-33	-122	11,7	11,1	10,6	10,0	9,5	9,0	8,6	8,1	7,7
Cumulative	M€	0	-33	-154	-142,8	-131,6	-121,1	-111,1	-101,6	-92,5	-84,0	-75,8	-68,1
Internal rate of return		8,9%											

Gas fired peaking power plants

GE plant with regulation and non-spinning

Plant will be operated

1) 819 hours at full load and generates only energy
2) 1208 hours at 70 % load and generates energy and regulation (+/- 30 %)
3) 5973 hours at hot standby and generates non-spinning reserves

Profitability

IRR improves to 8.9 %

Gas fired peaking power plants

Aeroderivative Gas Turbine plant with regulation and non-spinning

OPTIMAL POWER SYSTEMS		Gas turbine peaking ADGT 160								8.9.08 Asko Vuorinen			
		Peak energy, regulation and non-spin											
Parameters		**Plant output**			**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			38,0%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment			977	€/kW		Intermediate		73,8	€/MWh	1208	70 %
Escalation	2,5%	Fuel price			25,0	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content			0,202	kg/MWh		Total		58,8	€/MWh	8000	21 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	1208	30 %
		FOM			12,7	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			8,6	€/MWh		Non-spinning		5,0	€/MWh	5973	100 %
		Heat output			0,0	MW		Heat price		0,0	€/MWh		
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				34,3	35,1	36,0	36,9	37,8	38,8	39,7	40,7	41,7
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-17,8	-18,2	-18,7	-19,2	-19,6	-20,1	-20,6	-21,1	-21,7
- CO2 costs	M€				-3,6	-3,7	-3,8	-3,9	-4,0	-4,1	-4,2	-4,3	-4,4
- VOM costs	M€				-2,3	-2,3	-2,4	-2,5	-2,5	-2,6	-2,7	-2,7	-2,8
- FOM costs	M€				-2,0	-2,1	-2,1	-2,2	-2,2	-2,3	-2,4	-2,4	-2,5
Operating profit	M€				8,6	8,8	9,0	9,2	9,4	9,7	9,9	10,2	10,4
Investment	M€	0	-31	-125									
Cash flow	M€	0	-31	-125	8,6	8,8	9,0	9,2	9,4	9,7	9,9	10,2	10,4
Disc. cash flow	M€	0	-36	-135	8,6	8,1	7,7	7,3	6,9	6,6	6,2	5,9	5,6
Cumulative	M€	0	-36	-172	-163,0	-154,9	-147,2	-139,8	-132,9	-126,3	-120,1	-114,1	-108,5
Internal rate of return		4,8%											

Gas fired peaking power plants

Aeroderivative Gas Turbine plant with regulation and non-spinning

Plant will be operated

1) 819 hours at full load and generates only energy
2) 1208 hours at 70 % load and generates energy and regulation (+/- 30 %)
3) 5973 hours at hot standby and generates non-spinning reserves

Profitability

IRR = 4.8 %

LFO fired peaking plant

LFO fired peaking plant
Performance

Plant type		*Diesel engine*	*Diesel engine*	*Gas turbine*
Output		*160 MW*	*160 MW*	*160 MW*
Number of engines		*10*	*20*	*4*
Engine output	*MWe*	*16*	*8*	*40*
Plant output	*MWe*	*160*	*160*	*158*
Fuel input	*MWt*	*367*	*373*	*426*
Net efficiency	*%*	*43.5*	*42.8*	*37.1*

LFO fired peaking plant

Diesel Engine plant without A/S

OPTIMAL POWER SYSTEMS			Diesel engine peaking DE 160							8.9.08	Asko Vuorinen		
			Energy service										
Parameters		**Plant output**			**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			41,0%			Peak load		126,7	€/MWh	819	100 %
Discount rate	8,0%	Investment			727	€/kW		Intermediate		73,8	€/MWh	1208	0 %
Escalation	2,5%	Fuel price			36,7	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content			0,267	kg/MWh		Total		58,8	€/MWh	8000	10 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	0	0 %
		FOM			7,8	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			8,1	€/MWh		Non-spinning		5,0	€/MWh	0	0 %
		Heat output			0,0	MW		Heat price		0,0	€/MWh		

Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				16,6	17,0	17,4	17,9	18,3	18,8	19,3	19,7	20,2
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-11,7	-12,0	-12,3	-12,6	-12,9	-13,3	-13,6	-13,9	-14,3
- CO2 costs	M€				-2,1	-2,2	-2,2	-2,3	-2,4	-2,4	-2,5	-2,5	-2,6
- VOM costs	M€				-1,1	-1,1	-1,1	-1,1	-1,2	-1,2	-1,2	-1,3	-1,3
- FOM costs	M€				-1,2	-1,3	-1,3	-1,3	-1,4	-1,4	-1,4	-1,5	-1,5
Operating profit	M€				0,4	0,4	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Investment	M€	0	-23	-93									
Cash flow	M€	0	-23	-93	0,4	0,4	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Disc. cash flow	M€	0	-27	-101	0,4	0,4	0,4	0,4	0,3	0,3	0,3	0,3	0,3
Cumulative	M€	0	-27	-128	-127,2	-126,8	-126,4	-126,0	-125,7	-125,4	-125,0	-124,7	-124,5
Internal rate of return		-11,3%											

LFO fired peaking plant

Diesel Engine plant without A/S

- Plant operates
  - 819 hours at 100 % load and generates only energy
- Without ancillary services a diesel engine plant has negative IRR

LFO fired peaking plant

Diesel Engine plant with regulation and non-spinning

OPTIMAL POWER SYSTEMS				Diesel engine peaking plant, DE160					8.9.08 Asko Vuorinen			
				Energy, regulation and nonspinning service								
Parameters		**Plant output**		**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency		41,0%			Peak load		126,7	€/MWh	819	70 %
Discount rate	8,0%	Investment		707	€/kW		Intermediate		73,8	€/MWh	1208	0 %
Escalation	2,5%	Fuel price		36,7	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content		0,267	kg/MWh		Total		58,8	€/MWh	8000	7 %
		CO2-price		25,0	€/t		Regulation		25,0	€/MWh	819	30 %
		FOM		7,8	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM		8,1	€/MWh		Non-spinning		5,0	€/MWh	7181	100 %
		Heat output		0,0	MW		Heat price		0,0	€/MWh		

Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				19,3	19,8	20,3	20,8	21,3	21,9	22,4	23,0	23,6
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-8,5	-8,7	-8,9	-9,1	-9,3	-9,6	-9,8	-10,1	-10,3
- CO2 costs	M€				-1,5	-1,6	-1,6	-1,7	-1,7	-1,7	-1,8	-1,8	-1,9
- VOM costs	M€				-0,7	-0,8	-0,8	-0,8	-0,8	-0,8	-0,9	-0,9	-0,9
- FOM costs	M€				-0,9	-0,9	-0,9	-0,9	-1,0	-1,0	-1,0	-1,0	-1,1
Operating profit	M€				7,7	7,9	8,1	8,3	8,5	8,7	9,0	9,2	9,4
Investment	M€	0	-23	-90									
Cash flow	M€	0	-23	-90	7,7	7,9	8,1	8,3	8,5	8,7	9,0	9,2	9,4
Disc. cash flow	M€	0	-26	-98	7,7	7,3	7,0	6,6	6,3	5,9	5,6	5,4	5,1
Cumulative	M€	0	-26	-124	-116,4	-109,1	-102,1	-95,5	-89,3	-83,3	-77,7	-72,3	-67,2
Internal rate of return		6,9%											

LFO fired peaking plant

Diesel Engine plant with regulation and non-spinning

The diesel engine plant produces

1) energy at 70 % load for 819 hours
2) regulation +/- 30 % for 819 hours
3) non-spinning service for 7181 hours

The profitability

IRR = 6.9 %

LFO fired peaking plant

Gas turbine plant in energy service

- The gas turbines which cannot generate A/S services have negative cash flows*
- Only those GT plants which can generate non-spinning services can be profitable**

*Industrial gas turbines cannot be started up in 10 minutes

** aero-derivetives can start up in 10 minutes)

LFO fired peaking plant

GT plant with regulation and non-spinning

OPTIMAL POWER SYSTEMS		Gas turbine peaking plant, ADGT 160								8.9.08 Asko Vuorinen			
		Energy, regulation and nonspinning service											
Parameters		**Plant output**			**160**	**MW**		**Operation**		**Electr. price**		**Hours**	**Load**
First year	2013	Efficiency			36,0%			Peak load		126,7	€/MWh	819	70 %
Discount rate	8,0%	Investment			808	€/kW		Intermediate		73,8	€/MWh	1208	0 %
Escalation	2,5%	Fuel price			36,7	€/MWh		Base load		47,9	€/MWh	5973	0 %
		CO2-content			0,267	kg/MWh		Total		58,8	€/MWh	8000	7 %
		CO2-price			25,0	€/t		Regulation		25,0	€/MWh	819	30 %
		FOM			8,4	€/kWa		Spinning		15,0	€/MWh	0	0 %
		VOM			12,2	€/MWh		Non-spinning		5,0	€/MWh	7181	100 %
		Heat output			0,0	MW		Heat price		0,0	€/MWh		
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Income statement													
- Electricity	M€				19,3	19,8	20,3	20,8	21,3	21,9	22,4	23,0	23,6
- Heat income	M€				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
- Fuel costs	M€				-9,6	-9,9	-10,1	-10,4	-10,6	-10,9	-11,2	-11,5	-11,7
- CO2 costs	M€				-1,7	-1,8	-1,8	-1,9	-1,9	-2,0	-2,0	-2,1	-2,1
- VOM costs	M€				-1,1	-1,1	-1,2	-1,2	-1,2	-1,3	-1,3	-1,3	-1,4
- FOM costs	M€				-0,9	-1,0	-1,0	-1,0	-1,0	-1,1	-1,1	-1,1	-1,1
Operating profit	M€				5,9	6,0	6,2	6,3	6,5	6,7	6,8	7,0	7,2
Investment	M€	0	-26	-103									
Cash flow	M€	0	-26	-103	5,9	6,0	6,2	6,3	6,5	6,7	6,8	7,0	7,2
Disc. cash flow	M€	0	-30	-112	5,9	5,6	5,3	5,0	4,8	4,5	4,3	4,1	3,9
Cumulative	M€	0	-30	-142	-136,0	-130,4	-125,1	-120,0	-115,3	-110,7	-106,4	-102,3	-98,5
Internal rate of return		3,3%											

LFO fired peaking plant

GT plant with regulation and non-spinning

The GT plant produces

1) energy at 70 % load for 819 hours
2) regulation +/- 30 % for 819 hours
3) non-spinning service for 7181 hours

The profitability

IRR = 3,3 %

LFO fired peaking plant
Summary

- The best operation mode for LFO plant is peaking, regulating and non-spinning service

- With A/S revenues the IRR of diesel engine plant becomes 7 %

Summary and conclusions

- The profitability of any type of power plant can be evaluated using cash flow models used in the presentation
- The best cash flow models can evaluate the infuence of ancillary services
- The flexible power plants, which can generate ancillary services can improve the profitability considerably

For details see reference text book ”**Planning of Optimal Power Systems**”

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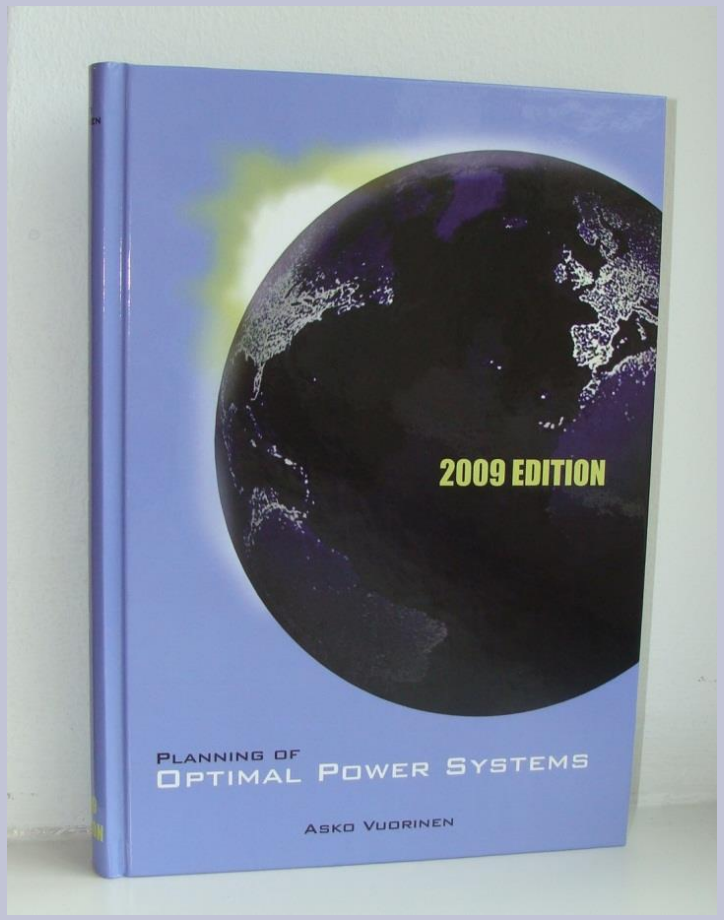

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