5. PLANNING OF SMALL AND MICRO POWER SYSTEMS

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- Small system
- Wind and diesel plant
- Micro system

Small system conditions

- Large city in a developing country
- Peak electricity load 200 MW
- Electricity consumption 1060 GWh/a
- Full power hours 5000 h/a

Power plant alternatives and capital costs

Plant type	EPC price (eur/kWe)	Owner's costs (eur/kWe)	Base costs (eur/kWe)	IDC (eur/kWe)	Investm. costs (eur/kWe)	Capital costs (eur/kWe)
Oil-fired plants						
- DECC-50 lbf	950,0	115,7	1065,7	43,2	1108,8	104,8
- DECC-50 hfo	920,0	122,9	1042,9	42,2	1085,2	102,5
- DE-50 hfo	850,0	113,6	963,6	39,0	1002,6	94,7
- DE-50 lfo	650,0	79,1	729,1	29,5	758,7	71,7
Gas-fired plants						
- DFCC-50 gas	920,0	177,3	1097,3	44,4	1141,7	107,9
- GE-50 gas	800,0	169,1	969,1	39,2	1008,3	95,3
- GT-40 gas	720,0	154,9	874,9	70,9	945,7	89,4
Other power plants						
- Coal-50	1500,0	165,9	1665,9	202,4	1868,3	176,5
- Biomass-50	950,0	550,0	1500,0	387,1	1887,1	178,3
- Wind- 25 x 2	1300,0	143,2	1443,2	116,9	1560,1	147,4

Generation costs

Plant type	Fixed costs (€/kWa)	Variable costs (€/MWh)	Generation costs (€/MWh)	(€/MWh)	(€/MWh)
Oil-fired plants			(500 h/a)	(1000 h/a)	(1500 h/a)
- DECC-50 lbf	137,4	77,7	352,6	215,1	**169,3**
- DECC-50 hfo	135,4	95,5	366,3	230,9	185,8
- DE-50 hfo	129,5	102,5	361,6	232,1	188,9
- DE-50 lfo	92,8	138,7	**324,4**	**200,6**	169,3
Gas-fired plants			(1500 h/a)	(3000 h/a)	(5000 h/a)
- DFCC-50 gas	163	94,0	**202,4**	**148,2**	**126,5**
- GE-50 gas	152	102,6	204,3	153,4	133,1
- GT-40 gas	165	146,6	256,8	201,7	179,6
- CHP-50 gas *	152	55,7	**156,9**	**106,3**	**86,1**
Other power plants			(3000 h/a)	(5000 h/a)	(7000 h/a)
- Coal-50	243,7	69,3	150,6	118,1	104,2
- Biomass-50	234,3	57,9	**136,0**	**104,7**	**91,4**
- Wind- 25 x 2	180,2	11,0			**71,1**
- CHP-50 gas *	152	56	**106,3**	**86,1**	77,4

* CHP plant has 85 % efficiency

** wind has been evaluated by using 3000 full power hour generation

Break even

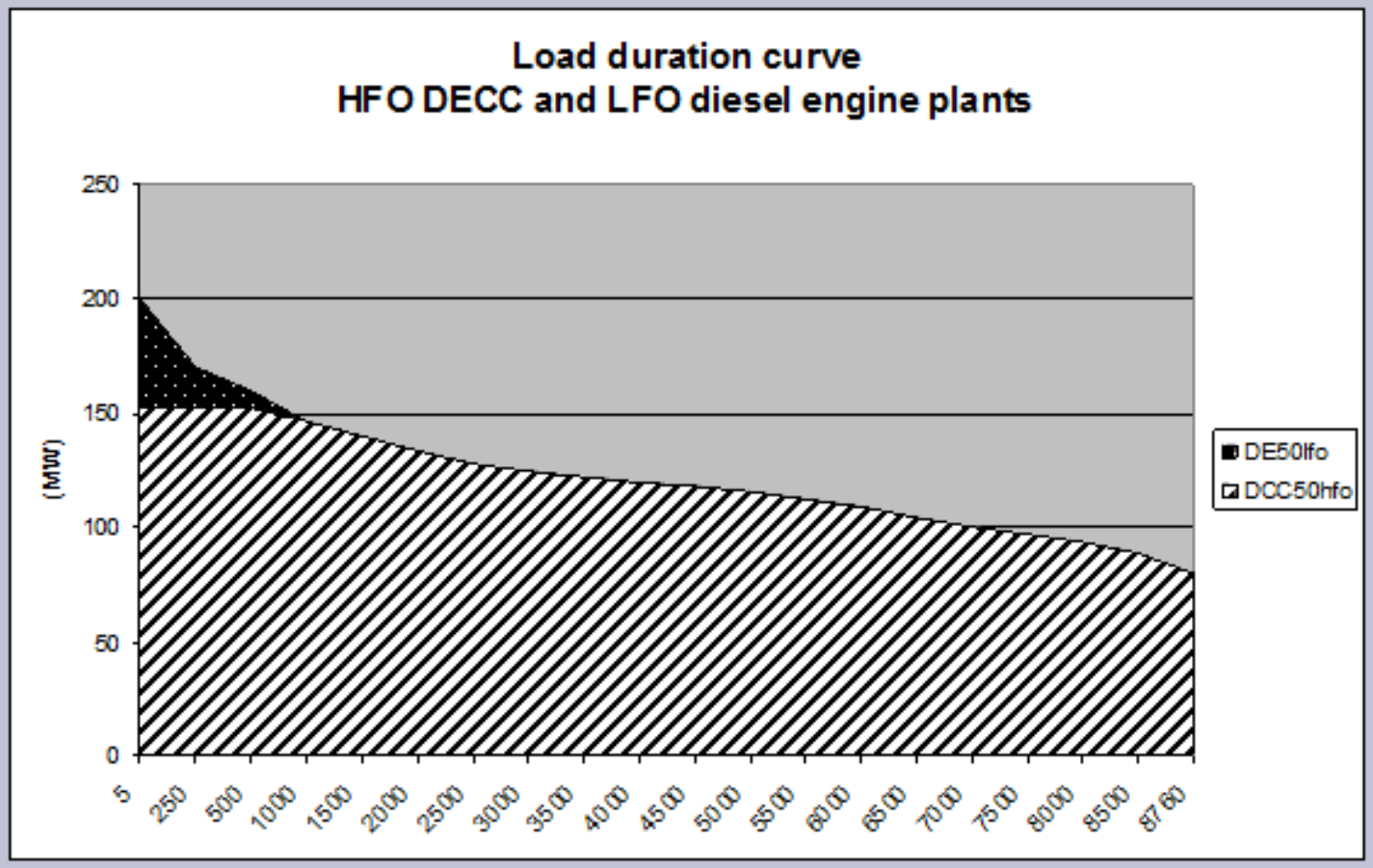
- The break even costs of the LFO Diesel plant and the HFO DECC plant would be at

- t = (135 400 – 92 800)/(138.7 – 95.5) = 991 h/a

Step wise evaluation

Step	*DECC plant MW*	*LFO plant MW*	*Generation costs eur/MWh*
0	*0.0*	*238*	*159.6*
1	*17.8*	*221*	*154.3*
2	*35.6*	*204*	*149.1*
3	*53.5*	*187*	*143.8*
4	*71.3*	*153*	*137.0*
5	*89.1*	*136*	*131.8*
6	*106.9*	*119*	*127.2*
7	*124.7*	*102*	*124.0*
8	*142.8*	*85*	*122.8*
9	*160.4*	*68*	*122.6*
10	***178.2***	***34***	***121.5***
11	*196.0*	*17*	*122.2*
12	*213.8*	*0*	*122.9*

Load duration curve



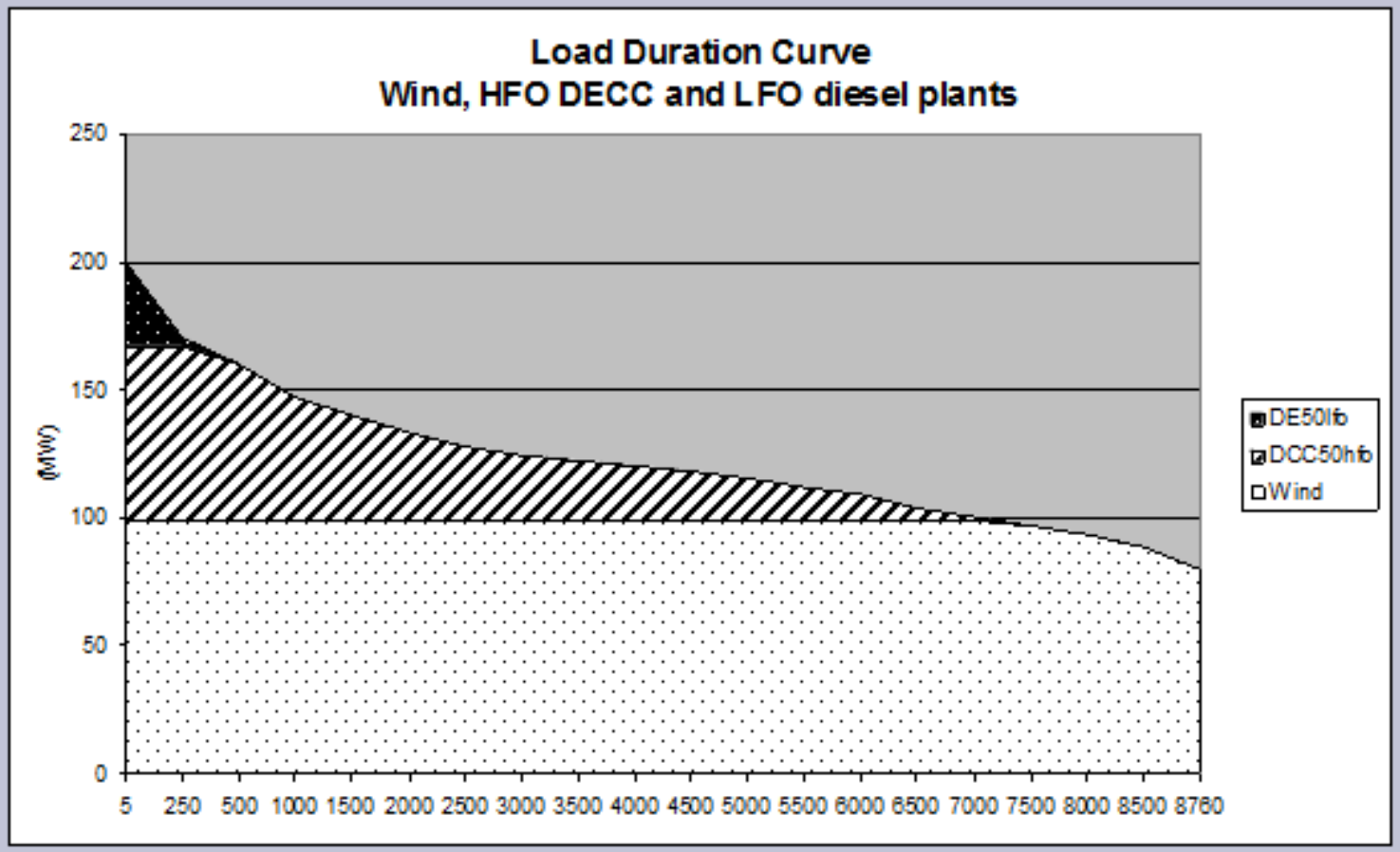
Optimal system with diesel engine plants

Power plant	Capacity of system	Electricity generation	Annual costs	Generatio costs	CO2-Emissions
	(MW)	(GWh)	(M€)	(€/MWh)	(1000t)
HFO DECC plant	178,2	1052,3	124,6	118,4	649
LFO Diesel plants	34,0	4,0	3,7	924,7	3
Total	**212,2**	**1056,3**	**128,3**	**121,5**	652

Wind power integration

Small system

Integrated wind and diesel power system

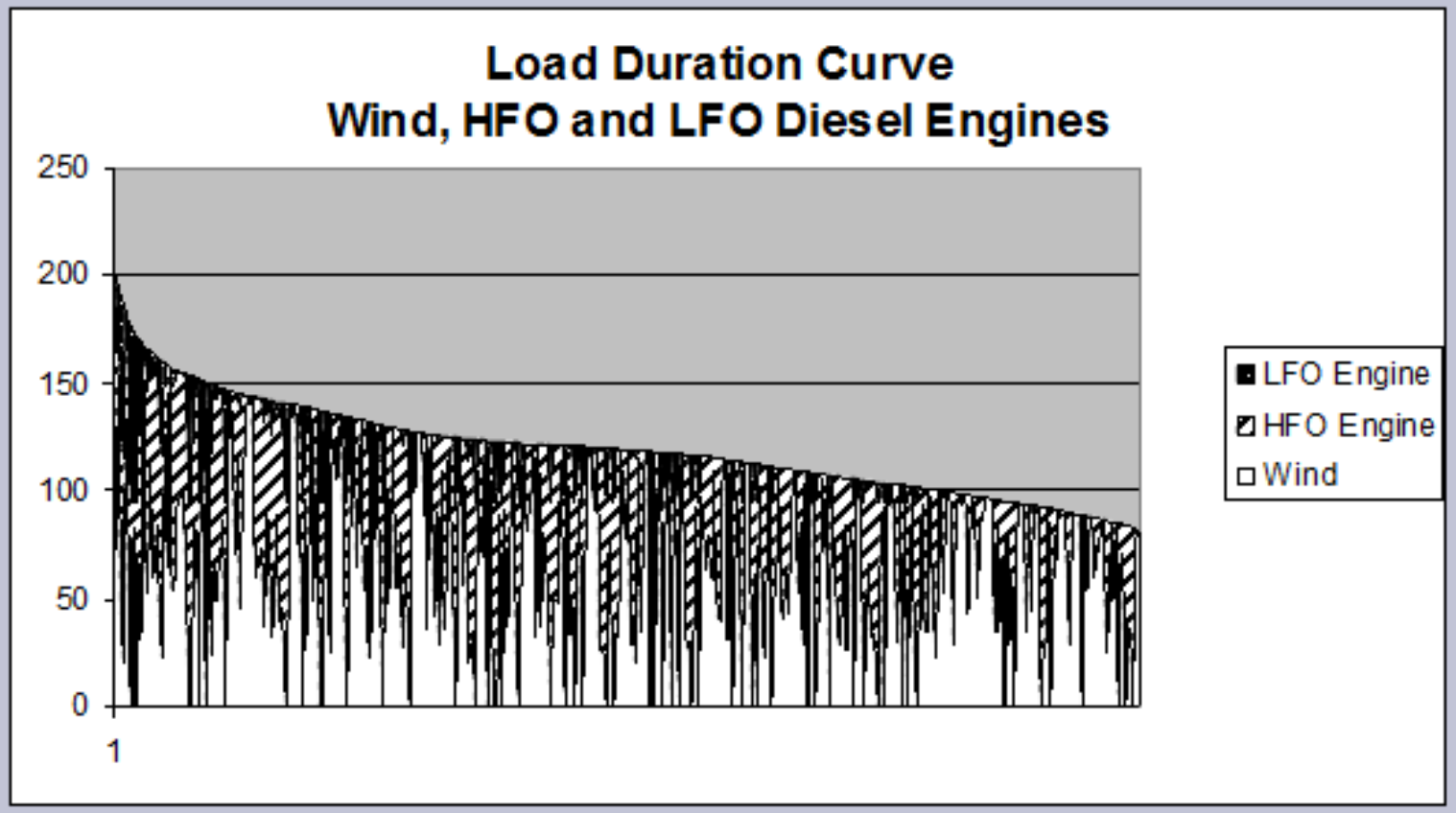


Generation costs integrated wind diesel system

	Capacity of system (MW)	*Electricity generation (GWh)*	*Annual costs (M€)*	*Generation costs (€/MWh)*
- Wind energy plants	*330*	*855*	*68.9*	*80.5*
- HFO DECC plants	*71*	*196*	*28.4*	*144.7*
- LFO Diesel plants	*153*	*5*	*14.9*	*2990*
Total	*554*	*1056*	*112.2*	*106.2*

Cost saving (122-106)/122 = 13 %

Independent wind and diesel system

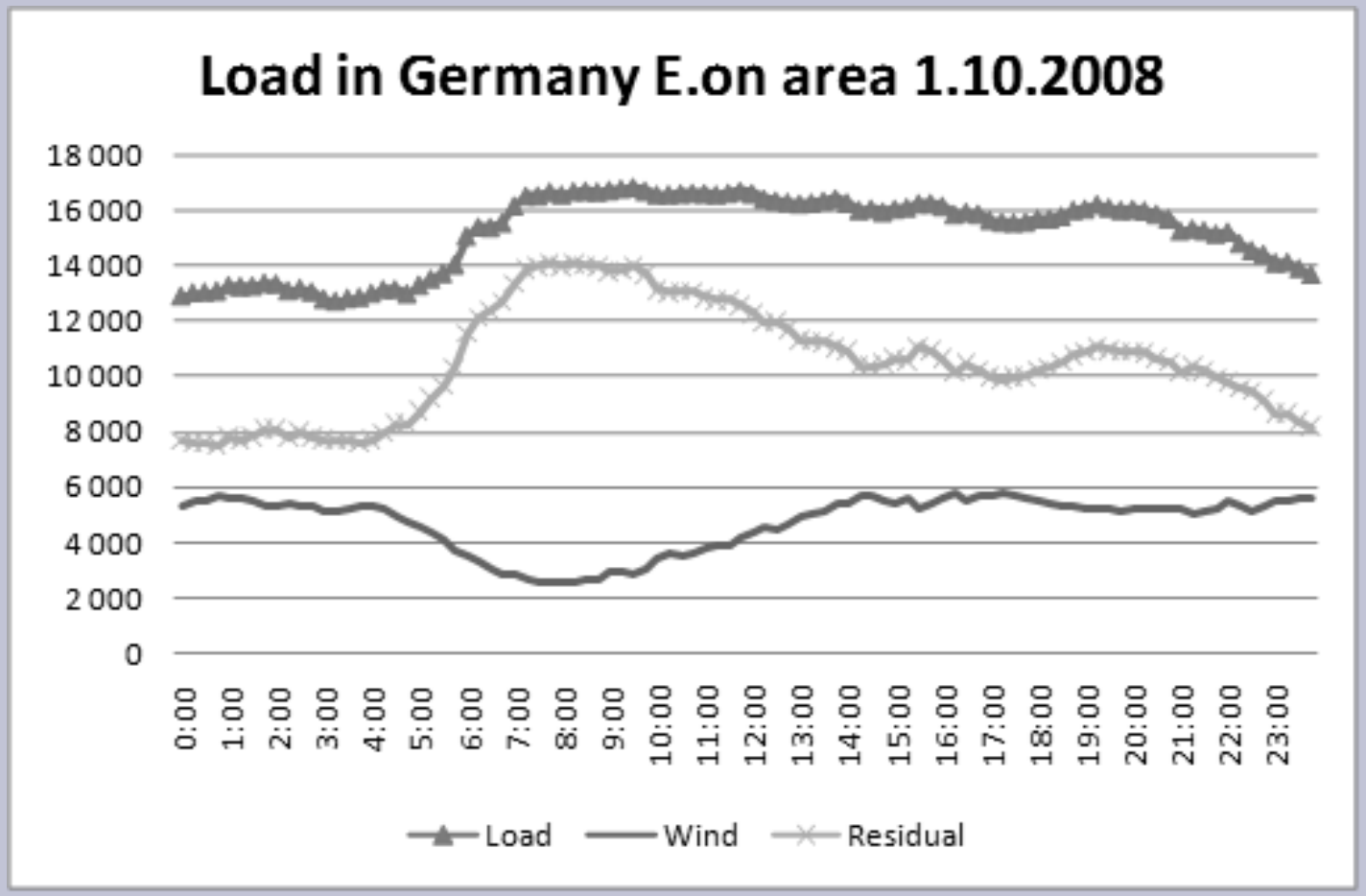


Generation costs of independent wind and diesel system

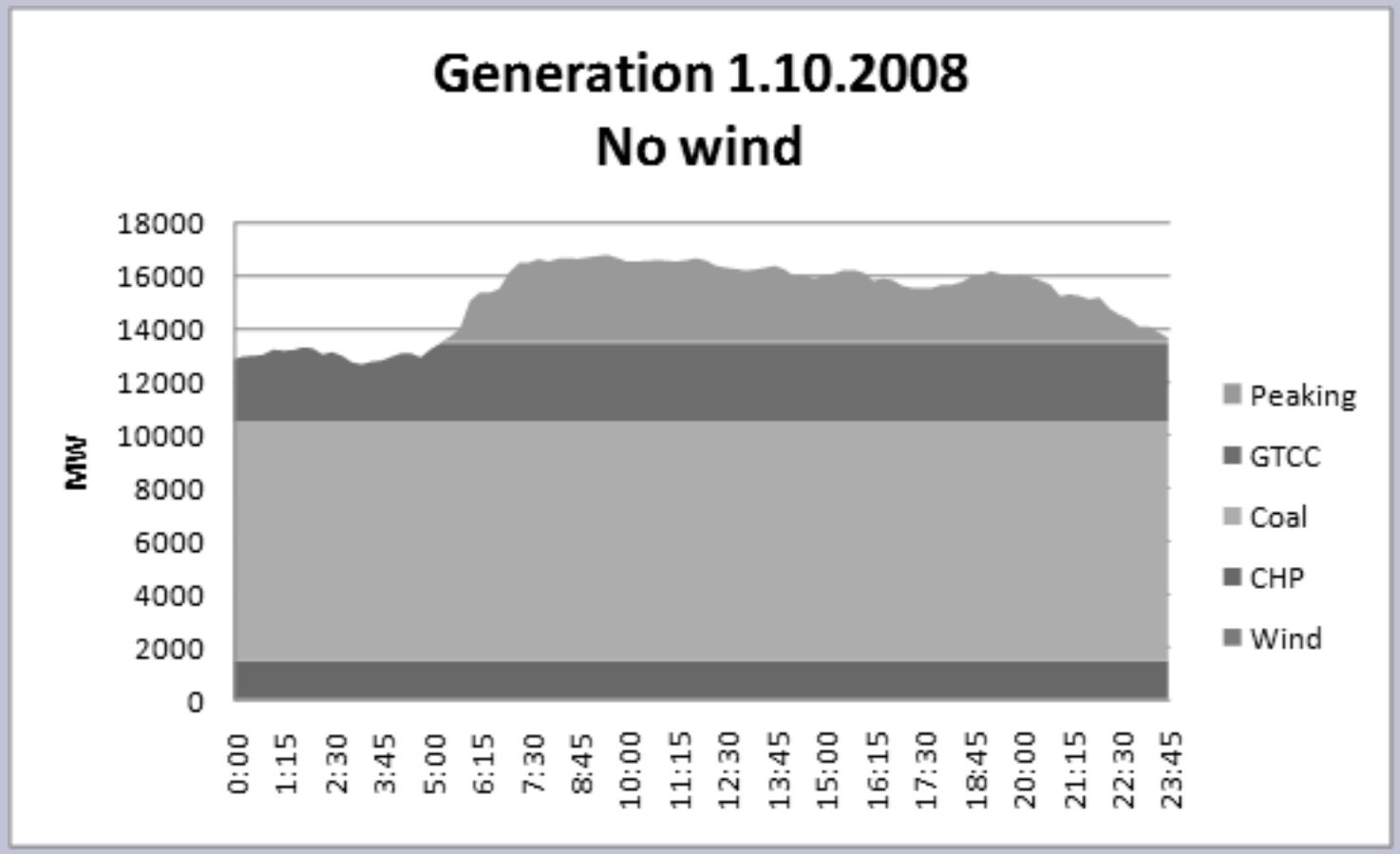
	Capacity of system (MW)	*Electricity generation (GWh)*	*Annual costs (M€)*	*Generation costs (€/MWh)*
- Wind energy plants	*230*	*634*	*48.4*	*76.4*
- HFO Diesel plants	*99*	*384*	*52.2*	*135.9*
- LFO Diesel plants	*132*	*40*	*17.9*	*441.5*
Total	*461*	*1058*	*118.5*	*112.0*

Cost saving (122-112)/122= 9%

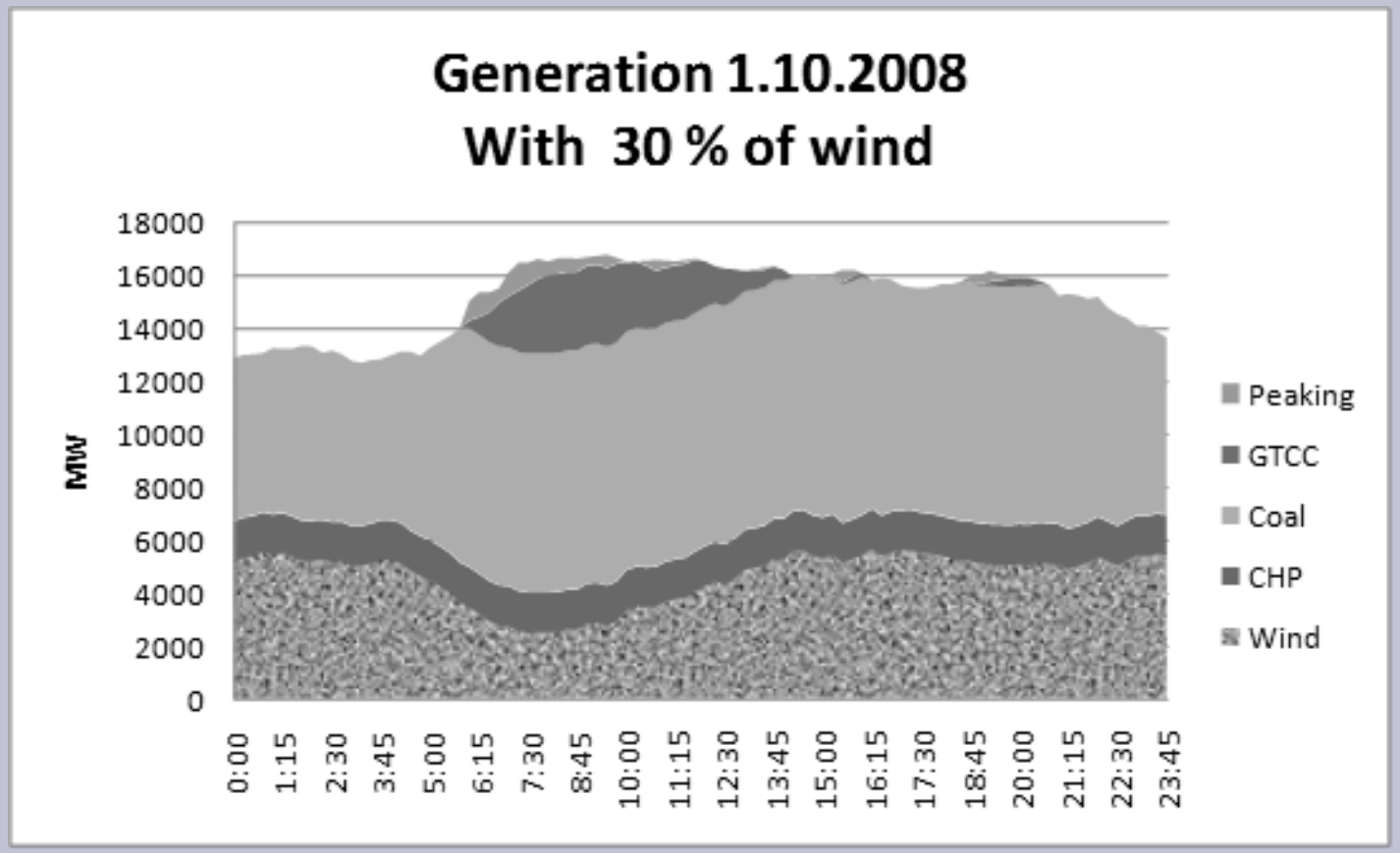
Large interconnected power system (E.ON Germany)



Generation without the wind



Generation with 30 % wind



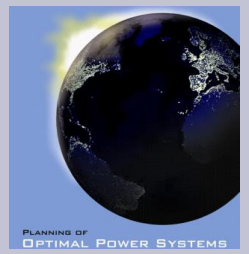
Influence of wind generation

		Wind	CHP	Coal	GTCC	Peaking	Total
Generation							
- No wind	GWh	-	36	216	70	43	365
- With wind	GWh	112	36	197	17	3	365
- Change	GWh	112	-	- 19	- 53	- 40	-
CO2-emissions							
- No wind	tCO2	-	9 000	194 400	27 848	30 199	261 447
- With wind	tCO2	-	9 000	177 288	6 627	2 293	195 208
- Change	tCO2	-	-	- 17 112	- 21 221	- 27 906	- 66 239
							-25 %
Costs							
- No wind	keur	-	1 764	11 102	5 472	5 984	24 322
- With wind	keur	1 231	1 764	10 125	1 302	454	14 877
- Change	keur	1 231	-	- 977	- 4 170	- 5 529	- 9 445
							-39 %
Income							
- No wind	keur						46 273
- With wind	keur						32 631
- Change	keur						- 13 642
							-29 %
Profit							
- No wind	keur						21 951
- With wind	keur						17 754
- Change	keur						- 4 197

Influence of wind generation for utility in the 1.10. case

Change in CO2-emissions	-25%
Change in fuel costs	-39%
Change in income	-29%
-drops electricity price	
Change in net profit	-20%

Micro power systems



Micro power generators

Type	*Electrical Output (kW)*	*Electrical Efficiency (%)*	*Total Efficiency (%)*	*CO2 Emissions (g/kWh)*
Microturbines	*30 - 200*	*20-25 %*	*80 %*	*250 - 800*
IC Engines	*1 - 100*	*30-35 %*	*75 %*	*270 - 670*
IC Engines	*100 - 1000*	*35-40 %*	*80 %*	*250 - 570*
PEM fuel cells	*1 – 100*	*35-40 %*	*80 %*	*250 - 570*
SOFC fuel cells	*1 – 100*	*40-45 %*	*85 %*	*235 - 500*
SOFC fuel cells	*100-1000*	*40-45 %*	*85 %*	*235 - 500*
Stirling Engines	*1 – 100*	*35-45 %*	*85 %*	*250 - 500*

Applications

- Offices 100-1000 kW
  - IC-engines and microturbines
  - SOFC fuel cells in the future
- Homes1-5 kW
  - IC engines and solar cells to day
  - PEM-fuel cells in the future
- Caravans and boats 0,1-1 kW
  - IC-engines today
  - Methanol fuel cells in the future

Summary

- Small independent system can be built using diesel plants
- Wind power drops system costs, CO2-emissions and electricity prices
- Micro power systems are coming in the near future

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

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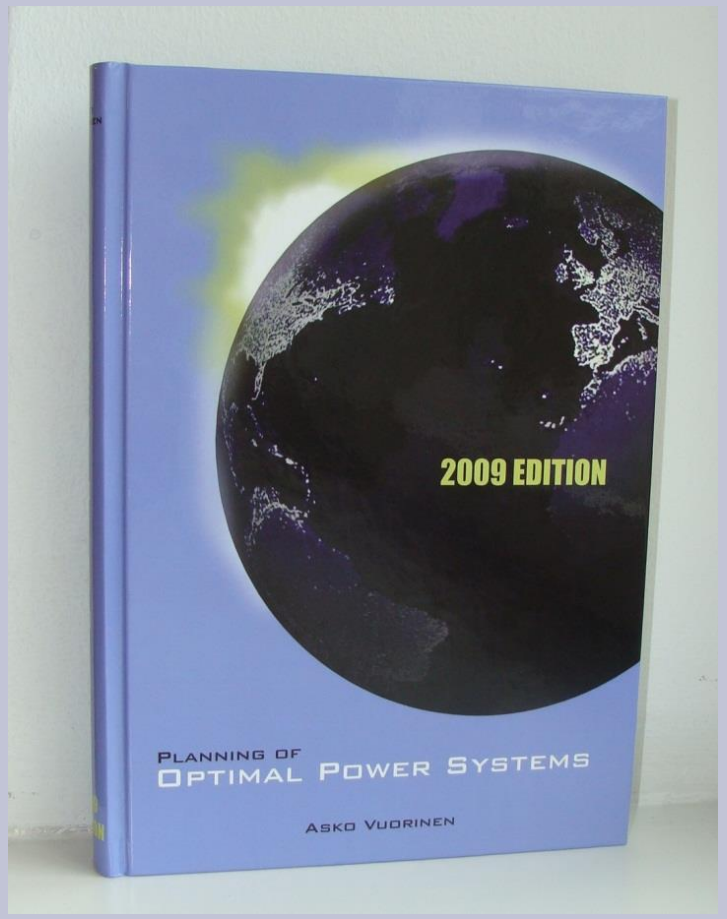

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