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Power and Energy Systems
Technologies & Economics

Case Study
Integrated Model
Cost Allocation _Electrical Equivalent
Extraction-Condensing CHP

Notes:

1. Cells with black characters include inputs
2. Cells with red characters include formulas

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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 March 2016

Performance Calculations

Item		Formulas	Unit	Values
Extraction-condensing cycle, rated output				
Rated electrical output, gross		P_{gross}	MW_e	110.0
Rated electrical output, net	9 kW	P_{net}		101.0
Heat extraction at 12 bar	100 t / h	Q_{12bar}	MW_t	70.7
Heat extraction at 6 bar	50 t / h	Q_{6bar}	MW_t	33.7
Firing power rate		Q_f	MW_t	359.7
Performance parameters				
Tota efficiency, cogeneration		η_{tot}	-	82.5%
Electricity-to-heat ratio, 12 bar steam		σ_{12bar}	kWh_e / kWh_t	0.335
Electrical equivalent, 12 bar steam		$\beta_{12\ bar}$	kWh_e / kWh_t	0.289
Electricity-to-heat ratio, 6 bar steam		σ_{6bar}	kWh_e / kWh_t	0.403
Electrical equivalent, 6 bar steam		$\beta_{6\ bar}$	kWh_e / kWh_t	0.255
Annual Energy Balance				
Electricity generation, gross, total	7,500 h/a	W_{gross}	MWh_e / a	825,157
of which cogenerated		$W_{cogen} = \Sigma\sigma_i x Q_i$	MWh_e / a	215,011
Electricity generation, net, total	7,500 h/a	W_{net}	MWh_e / a	757,657
Heat generation 12 bar	6,500 h/a	$Q_{t,\ 12\ bar}$	MWh_t / a	459,720
Heat generation 6 bar	4,500 h/a	$Q_{t,6\ bar}$	MWh_t / a	151,530
Fuel consumption		Q_f	MWh_t / a	2,579,642
Equivalent cond. cycle performance				
Cond. Equivalent power, gross		P_{cond_equ}	MW_e	139.1
Cond. equivalent elect. Efficiency		η_{cond_equ}	-	*38.66%*
Cond. equivalent annual electricity production		W_{cond_equ}	**MWh / a**	***996,686***
Annual electricity production, gross	7,500 h/a	$W_{e\_net} = P_{net} \times t_{FLH}$	MWh / a	825,157
Equivalent elec. production, 12 bar steam	459,720	$\beta_{12\ bar} x\ Q_{t\_12\ bar}$	MWh / a	132,908
Equivalent elec. production, 6 bar steam	151,530	$\beta_{6\ bar} x\ Q_{t\_6\ bar}$	MWh / a	*38,621*
Fuel consumption		Q_f	MWh_t / a	**2,578,078**
			Deviation	0.06%

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Electricity generation cost

Item			Unit	Value
Power and energy balance, cond. Equivalent				
Power output, gross			MW_e	139.1
Power output, net	9.0	*Pnet*	MW_e	130.1
Electricity generation, gross	7,500 h/a		GWh_e/a	1,042.9
Electricity generation, net	7,500 h/a	*Wnet*	GWh_e/a	975.4
Fuel consumption			GWh_t/a	2,578.1
Financial parameters				
Discount rate, in real terms			-	6.5%
Lifetime			a	30.0
Fuel price	85 €/tce	8.14 €/tce	€ / MWh_t	10.4
CAPEX	2001 €/kW		**mln €**	**278.2**
Annual generation costs, in real terms		***CT***	**mln € /a**	**59.5**
Annualized CAPEX		CC	mln € /a	21.3
OPEX fixed	3.5% x CAPEX	COF	mln € /a	9.7
Fuel cost		CF	mln € /a	26.9
Non-fuel variable costs	1.50 €/MWhe	CV	mln € /a	1.6
Specific electricity generation cost, in real terms				
Composite generation cost	$ce=CT/P_{e\_net}$		**€ / MWhe**	**61.03**
Capacity cost	$cc_e=(CC+COF)/W_{e\_net}$		€ /kW a	238.68
Energy cost	$cv_e=(CF+CV)/W_{e\_net}$		€ / MWh_e	29.20

input CAPEX

Cost Allacation

Item		Formulas	Unit	Value
Electricity generation cost				
Composite cost	*tFCH=7,500 h/a*	$ce=1000*cc_e/t_{FCH}+cv_e$	€ / MWh	61.03
Capacity cost		cc_e	€ / (kWa)	238.68
Energy cost		cv_e	€ / MWh	29.20
Heat generation cost, 12 bar steam				
Composite cost	*tFCH=6,500 h/a*	$c_{H12}=1000*cc_{12}/t_{FCH}+c_{v12}$	€ / MWh	19.06
Capacity cost	*β=0.289*	$cc_{12}=\beta_{12bar}\ x\ cc_e$	€ / (kWa)	69.00
Energy cost		$cv12=\beta_{12bar}\ x\ cv_e$	€ / MWh	8.44
Heat generation cost, 6 bar steam				
Composite cost	*tFCH=4,500 h/a*	$c_{H6}=1000*cc_6/t_{FCH}+cv_6$	€ / MWh	20.96
Capacity cost	*β=0.255*	$cc_6=\beta_{6bar}\ x\ cc_e$	€ / (kWa)	60.83
Energy cost		$cv6=\beta_{6bar}\ x\ cv_e$	€ / MWh	7.44

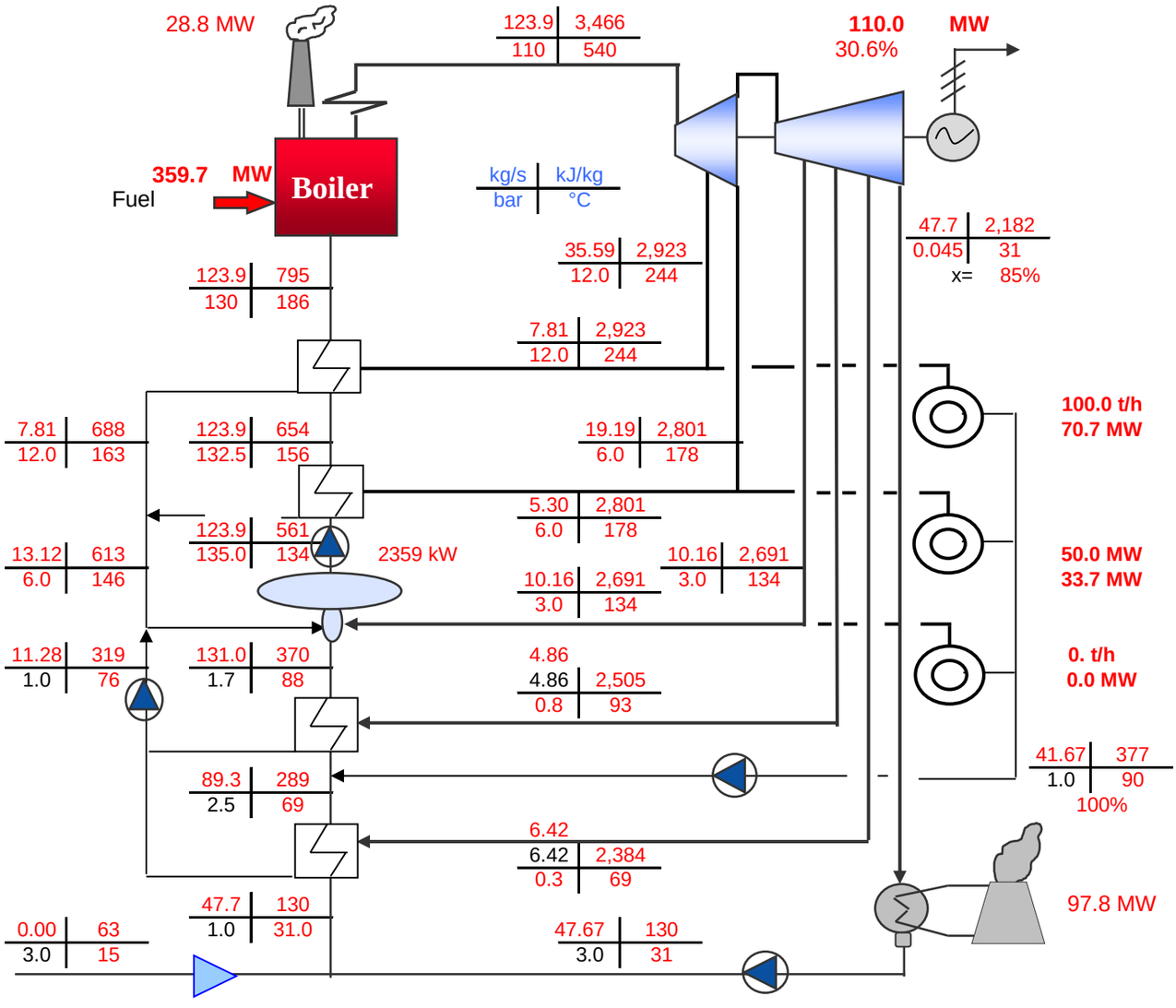
TE-CaseStudy-9_Cost-Allocation_Elect-Equivalent-Extraction-cond-CHP.xls
Control Results

Control Calculation

Item	Output	Spec. Cost	Unit	Value
Electricity			**th. € /a**	***55,316***
Capacity	139.1	238.68	th. € /a	33,189
Energy	757,657	29.20	th. € /a	22,127
12 bar steam			**th. € /a**	***8,762***
Capacity	70.7	69.00	th. € /a	4,880
Energy	459,720	8.44	th. € /a	3,881
6 bar steam			**th. € /a**	***3,176***
Capacity	33.7	60.83	th. € /a	2,048
Energy	151,530	7.44	th. € /a	1,128
Total	**-**	-	th. € /a	**67,254**

Electricity	757,657	61.03	**th. € /a**	***46,239***
12 bar steam	459,720	19.06	th. € /a	8,762
6 bar steam	151,530	20.96	th. € /a	3,176
Total	**-**	-		**58,177**

TE-CaseStudy-9_Cost-Allocation_Elect-Equivalent-Extraction-cond-CHP.xls
CHP-no reahet



Generator power, gross	MW	110.0
Firing power rate:	MW	359.7
Live steam	MW	359.7
Reheat	MW	0
Electrical efficiency, gross	%	30.59%
Total efficiency	%	59.61%