

Table S1. Extracted process stream data in the plants of example 1

Plants	Index	Type	$T_s / ^\circ\text{C}$	$T_i / ^\circ\text{C}$	Q / MW
CDP	1	c	30	125	21.4
	2	c	123	205	20.2
	3	c	200	360	41.2
	4	c	350	380	10.6
	5	h	120	60	6.6
	6	h	140	67	6.3
	7	h	327	60	5.3
	8	h	242	142	1.3
	9	h	202	60	1.7
	10	h	326	213	3.8
	11	h	295	60	9.9
	12	h	165	42	3.2
	13	h	165	80	1.3
	14	h	235	115	9.2
	15	h	235	80	4.4
	16	h	310	180	7.0
	17	h	310	80	3.2
	18	h	360	95	27.4
RHP	19	c	95	385	30
	20	c	85	385	35.5
	21	c	360	385	2.8
	22	c	52	320	1.3
	23	h	400	361	7.2
	24	h	360	50	19.1
	25	h	360	50	2.7
	26	h	130	40	2.1
	27	h	226	155	2.2
	28	h	235	50	1.6
	29	h	381	95	26.6
FCCP	30	c	95	215	11.1
	31	c	241	245	16.4
	32	c	30	241	8.3
	33	h	119	45	15.5
	34	h	165	58	8.4
	35	h	220	60	3.5
	36	h	285	182	9.7
	37	h	360	285	15.7
	38	h	285	100	1.1
	39	c	40	105	11.3
SWSP	40	c	130	133	16.2
	41	h	130	40	13.6

Table S2. Parameters of the utility system for example 1

Boundaries	Boiler	Turbines		
		r1	r2	r3
Upper boundary / $\text{t}\cdot\text{h}^{-1}$	65	30	22	20
Lower boundary / $\text{t}\cdot\text{h}^{-1}$	24	12	8	8
Maximum power generation / MW	NA	>1.2	>1.2	>1.5

Table S3. Parameters of steam

Steam levels	MPS	LPS	VLPS
Pressure / MPa	3.5	1.0	0.3
$SSPP_i / ^\circ\text{C}$	438	290	175
$SP_i / ^\circ\text{C}$	243	180	134
$EEP_i / ^\circ\text{C}$	242	179	133
$EP_i / ^\circ\text{C}$	60	60	60
$LS_i / \text{MJ}\cdot\text{t}^{-1}\cdot^\circ\text{C}^{-1}$	2.60	2.20	2.10
$LH_i / \text{MJ}\cdot\text{t}^{-1}$	1752.97	2014.44	2163.44
$LW_i / \text{MJ}\cdot\text{t}^{-1}\cdot^\circ\text{C}^{-1}$	4.18	4.18	4.18

Table S4. Solution results of example 1

	Levels	CDP	RHP	FCCP	SWSP	Boiler	Turbines		
							r1	r2	r3
Level 1	Gas requirement / t·h ⁻¹	2.2	1.5	0.0	NA	5.1	NA	NA	NA
	MPS / t·h ⁻¹	NA	NA	NA	NA	52.0	-30.0	0.0	NA
	LPS / t·h ⁻¹	NA	NA	NA	NA	NA	30.0	0.0	0.0
	Hot utility / MW	22.0	14.7	0.0	NA	NA	NA	NA	NA
	Cold utility / MW	19.2	6.6	18.1	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	2.3	0.0	0.0
	Isentropic efficiency	NA	NA	NA	NA	NA	0.80	NA	NA
Level 2	Gas requirement / t·h ⁻¹	2.2	1.5	0.1	NA	5.2	NA	NA	NA
	MPS / t·h ⁻¹	0.7	5.0	4.4	NA	53.3	-30.0	-11.4	NA
	LPS / t·h ⁻¹	6.8	-4.6	-4.1	NA	NA	30.0	11.4	-9.5
	Hot utility / MW	22.6	15.4	0.6	NA	NA	NA	NA	NA
	Cold utility / MW	14.0	6.6	18.1	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	2.3	0.7	1.1
	Isentropic efficiency	NA	NA	NA	NA	NA	0.80	0.64	0.60
Level 3	Gas requirement / t·h ⁻¹	2.7	2.3	0.5	NA	3.6	NA	NA	NA
	MPS / t·h ⁻¹	9.3	16.1	10.8	NA	32.4	-30.0	-16.6	NA
	LPS / t·h ⁻¹	5.8	-6.0	-5.6	NA	NA	30.0	16.6	-10.8
	Hot utility / MW	27.9	23.3	4.7	NA	NA	NA	NA	NA
	Cold utility / MW	12.9	6.3	17.9	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	2.3	1.2	1.4
	Isentropic efficiency	NA	NA	NA	NA	NA	0.80	0.75	0.68
Retrofit	Gas requirement / t·h ⁻¹	1.7	2.3	0.5	NA	4.5	NA	NA	NA
	Oil requirement / t·h ⁻¹	0.9	0.0	0.0	NA	0.0	NA	NA	NA
	MPS / t·h ⁻¹	9.3	13.8	5.9	0.0	45.0	-30.0	-22.0	NA
	LPS / t·h ⁻¹	5.8	-3.4	0.0	-24.4	NA	30.0	22.0	0.0
	Hot utility / MW	27.9	23.3	4.7	16.2	NA	NA	NA	NA
	Cold utility / MW	12.9	6.2	17.8	4.7	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	2.3	1.7	0.0
	Isentropic efficiency	NA	NA	NA	NA	NA	0.80	0.81	NA

Table S5. Parameters of the utility system for example 2

Boundaries	Boilers				Turbines				
	b1	b2	r1	r2	r3	r4	r5	r6	r7
Upper boundary / $\text{t}\cdot\text{h}^{-1}$	120	60	120	120	50	120	80	120	80
Lower boundary / $\text{t}\cdot\text{h}^{-1}$	65	30	50	50	20	60	40	45	35
Maximum power generation / MW	NA	NA	>1.2	>1.2	>1.2	>1.2	>1.2	>1.5	>1.5

Table S6. Solution results of example 2

	Items	CDP	RHP	HCP	FCCP	DHP	GHP	Boilers		Turbines						
								b1	b2	r1	r2	r3	r4	r5	r6	r7
Level 1	Fuel requirement / t·h ⁻¹	5.6	0.3	4.0	0.0	1.5	0.9	11.2	5.6	NA	NA	NA	NA	NA	NA	NA
	MPS / t·h ⁻¹	NA	NA	NA	NA	NA	NA	120.0	60.0	-115.0	0.0	-20.0	NA	NA	NA	NA
	LPS / t·h ⁻¹	NA	NA	NA	NA	NA	NA	NA	NA	115.0	0.0	20.0	-105.0	0.0	NA	NA
	VLPS / t·h ⁻¹	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	105.0	0.0	-105.0	0.0
	Hot utility / MW	56.9	2.8	40.3	0.0	15.2	8.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cold utility / MW	63.5	26.3	59.5	21.1	3.3	7.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	NA	NA	NA	8.9	0.0	0.9	6.2	0.0	10.3	0.0
	Isentropic efficiency	NA	NA	NA	NA	NA	NA	NA	NA	0.81	NA	0.47	0.80	NA	0.80	NA
Level 2	Fuel requirement / t·h ⁻¹	5.9	0.6	4.0	0.8	1.6	0.9	11.2	5.0	NA	NA	NA	NA	NA	NA	NA
	MPS / t·h ⁻¹	2.8	14.6	0.0	55.5	8.0	2.7	120.0	52.5	-120.0	-91.1	0.0	NA	NA	NA	NA
	LPS / t·h ⁻¹	23.4	16.5	0.1	-49.6	-7.3	-2.5	NA	NA	120.0	91.1	0.0	-120.0	-41.7	NA	NA
	VLPS / t·h ⁻¹	18.0	0.0	3.5	0.0	0.0	0.9	NA	NA	NA	NA	NA	120.0	41.7	-120.0	-64.1
	Hot utility / MW	59.3	6.0	40.4	7.8	16.3	9.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cold utility / MW	32.8	4.6	57.0	20.3	3.3	7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	NA	NA	NA	9.3	6.6	0.0	7.3	2.1	12.1	6.2
	Isentropic efficiency	NA	NA	NA	NA	NA	NA	NA	NA	0.81	0.76	NA	0.83	0.68	0.83	0.79
Level 3	Fuel requirement / t·h ⁻¹	7.3	0.9	5.4	0.9	2.7	1.8	11.0	0.0	NA	NA	NA	NA	NA	NA	NA
	MPS / t·h ⁻¹	26.3	19.9	22.2	57.6	24.4	15.9	116.8	0.0	-120.0	-118.1	0.0	NA	NA	NA	NA
	LPS / t·h ⁻¹	21.5	15.8	0.1	-49.8	-8.6	-2.9	NA	NA	120.0	118.1	0.0	-120.0	-64.3	NA	NA
	VLPS / t·h ⁻¹	15.0	-0.7	1.2	0.0	-0.2	0.4	NA	NA	NA	NA	NA	120.0	64.3	-120.0	-80.0
	Hot utility / MW	74.5	9.3	55.9	9.3	27.9	18.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cold utility / MW	31.9	4.4	55.5	20.2	2.3	6.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Electricity / MW	NA	NA	NA	NA	NA	NA	NA	NA	9.3	9.2	0.0	7.3	3.7	12.1	8.0
	Isentropic efficiency	NA	NA	NA	NA	NA	NA	NA	NA	0.81	0.81	NA	0.83	0.78	0.83	0.82