Supplementary Material

Modified Mixed-Integer Linear Programming Formulation Implemented in Microsoft Excel to Synthesize a Heat Exchanger Network with Multiple Utilities to Compare Process Flowsheets

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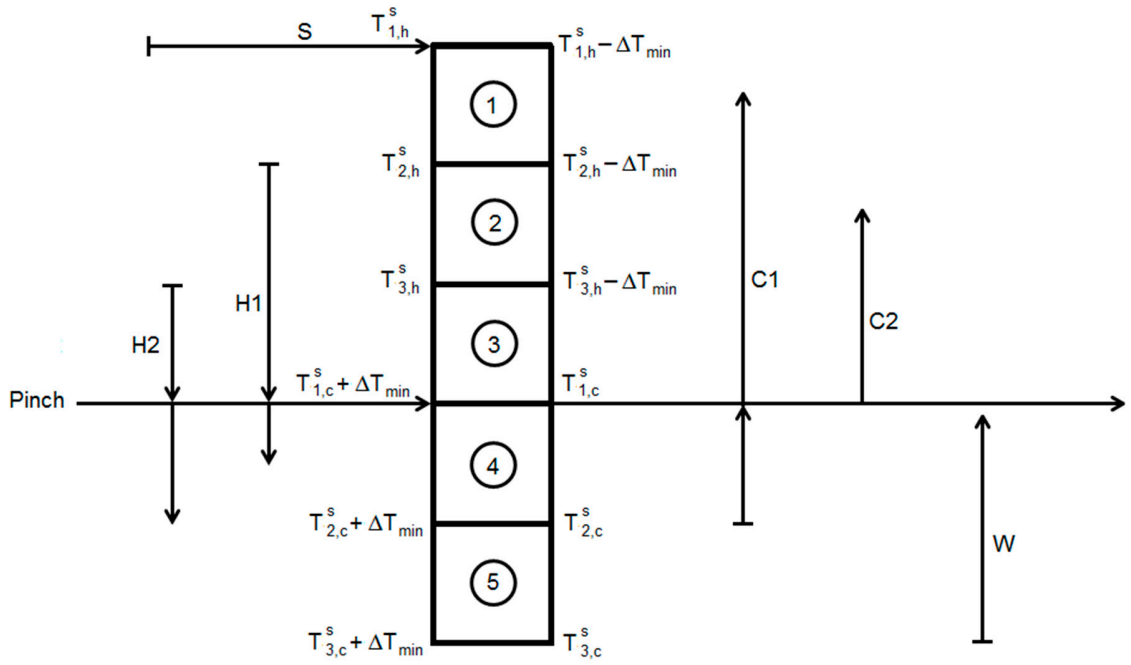


Figure S1. Temperature intervals derivation for m-MILP problem.

Nomenclature

$T^s_{1,h}$: the first source-temperature from hot streams ranked in temperature descending order

$T^s_{2,h}$: the second source-temperature from hot streams ranked in temperature descending order

$T^s_{3,h}$: the third source-temperature from hot streams ranked in temperature descending order

$T^s_{1,c}$: the first source-temperature from cold streams ranked in temperature descending order

$T^s_{2,c}$: the second source-temperature from cold streams ranked in temperature descending order

$T^s_{3,c}$: the third source-temperature from cold streams ranked in temperature descending order

ΔT_{min}: Minimum temperature difference

H1: hot stream 1

H2: hot stream 2

C1: cold stream 1

C2: cold stream 2

S: Steam

W: Water

Example 1 without multiple utilities

Table S1. Source and target temperatures, C value, and the multiple utilities for Example 1.

Stream	Source Temperature T^s (°C)	Target Temperature T^t (°C)	C (kW °C^{-1})	Reference
C1	60	180	3	(Seider, Seader, Lewin, & Widagdo, 2009)
C2	30	130	2.6	
H1	180	40	2	
H2	150	40	4	
MPS	280	280		(Chang, Chen, Wang, & Feng, 2017)
S	170	170		(Stijepovic & Linke, 2011)
BFW	110	110		(Seider et al., 2009)
W	15			(Chang et al., 2017)

Table S2. Adjusted temperatures using the Temperature Interval method for Example 1 with ΔT_{min}=10 °C.

Stream	T^s(°C)	T^t(°C)	C (kW °C^{-1})	Adjusted temperatures	
				T^s(°C)	T^t(°C)
C1	60	180	3	60	180
C2	30	130	2.6	30	130
H1	180	40	2	170	30
H2	150	40	4	140	30

Table S3. MER targets and the pinch value using the Temperature interval method for Example 1.

Temperature intervals (°C)		$\sum C_H$-$\sum C_C$ (kW °C^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the Medium-pressure steam (kW)
					[a]60
180	170	-3	-30	-30	30
170	[b]140	-1	-30	-60	0
140	130	3	30	-30	30
130	60	0.4	28	-2	58
60	30	3.4	102	100	[c]160

[a]Medium-pressure steam value
[b]Pinch temperature for cold streams
[c]Water value

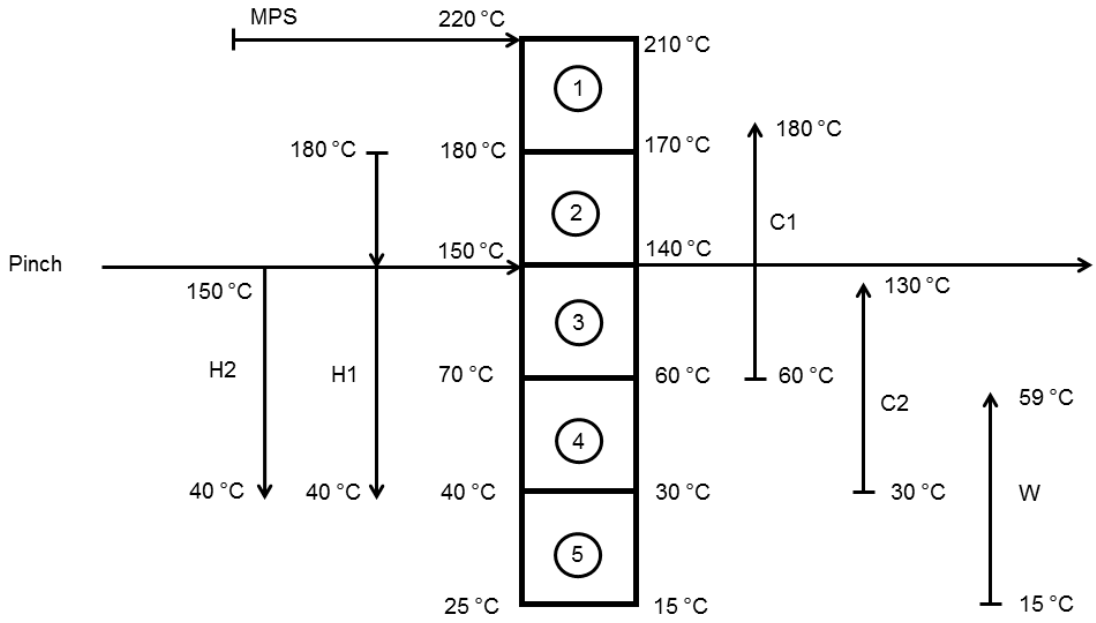


Figure S2. Temperature intervals for Example 1.

Table S4. Energy balances for Example 1.

No.	Stream	Energy balances
1	MPS	$R_{MPS,1} + Q_{MPS,C1,1} = Q^{H}_{MPS,1}$
2		$Q_{MPS,C1,2} - R_{MPS,1} = Q^{H}_{MPS,2}$
3	H1	$R_{H1,2} + Q_{H1,C1,2} = Q^{H}_{H1,2}$
4		$R_{H1,3} + Q_{H1,C1,3} + Q_{H1,C2,3} = Q^{H}_{H1,3}$
5		$R_{H1,4} + Q_{H1,C2,4} + Q_{H1,W,4} - R_{H1,3} = Q^{H}_{H1,4}$
6		$Q_{H1,W,5} - R_{H1,4} = Q^{H}_{H1,5}$
7	H2	$R_{H2,3} + Q_{H2,C1,3} + Q_{H2,C2,3} = Q^{H}_{H2,3}$
8		$R_{H2,4} + Q_{H2,C2,4} + Q_{H2,W,4} - R_{H2,3} = Q^{H}_{H2,4}$
9		$Q_{H2,W,5} - R_{H2,4} = Q^{H}_{H2,5}$
10	C1	$Q_{MPS,C1,1} = Q^{C}_{C1,1}$
11		$Q_{MPS,C1,2} + Q_{H1,C1,2} = Q^{C}_{C1,2}$
12		$Q_{H1,C1,3} + Q_{H2,C1,3} = Q^{C}_{C1,3}$
13	C2	$Q_{H1,C2,3} + Q_{H2,C2,3} = Q^{C}_{C2,3}$
14		$Q_{H1,C2,4} + Q_{H2,C2,4} = Q^{C}_{C2,4}$

15	W	$Q_{H1,W,4} + Q_{H2,W,4} = Q^{C}_{W,4}$
16		$Q_{H1,W,5} + Q_{H2,W,5} = Q^{C}_{W,5}$
17		$Q^{H}_{MPS,1} + Q^{H}_{MPS,2} = 60\ kW$

Table S5. Variables to solve the energy balances for Example 1.

No.	Variable
1	$RMPS,1^{a}$
2	$QMPS,C1,1^{a}$
3	$QMPS,1\text{^}H^{a}$
4	$QMPS,C1,2^{a}$
5	$QMPS,2\text{^}H^{a}$
6	$QH1,C1,2^{b}$
7	$RH1,2^{b}$
8	$QH1,C1,3^{b}$
9	$QH1,C2,3^{b}$
10	$RH1,3^{b}$
11	$QH1,C2,4^{b}$
12	$QH1,W,4^{b}$
13	$RH1,4^{b}$

14	QH1,W,5[b]
15	QH1,5^H[b]
16	QH2,C1,3[c]
17	QH2,C2,3[c]
18	RH2,3[c]
19	QH2,C2,4[c]
20	QH2,W,4[c]
21	RH2,4[c]
22	QH2,W,5[c]
23	QH2,5^H[c]
24	yS-C1[d]
25	y(H1-C1)_above_pinch[d]
26	y(H1-C1)_below_pinch[d]
27	yH1-C2[d]

28	yH1-W[d]
29	yH2-C1[d]
30	yH2-C2[d]
31	yH2-W[d]

Continuous variables related to [a]MPS utility stream, [b]H1, and [c]H2 hot streams. [d]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S6. Constant parameters to solve energy balances for Example 1.

No.	Parameter	Value (kW)
1	QH1,2^H	60
2	QH1,3^H	160
3	QH1,4^H	60
4	QH2,3^H	320
5	QH2,4^H	120
6	QC1,1^C	30
7	QC1,2^C	90
8	QC1,3^C	240
9	QC2,3^C	182
10	QC2,4^C	78
11	QW,4^C	105.46
12	QW,5^C	54.55

Table S7. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 1.

No.	Parameter	Value (kW)
1	U(MPS-C1) = min(60;120)	60
2	U(H1-C1)_above_pinch = min(60;90)	60
3	U(H1-C1)_below_pinch = min(160;240)	160
4	U(H1-C2) = min(220;260)	220
5	U(H1-W) = min(220;160)	160
6	U(H2-C1) = min(320;240)	240
7	U(H2-C2) = min(440;260)	260
8	U(H2-W) = min(440;160)	160

Table S8. Restrictions describing heat exchangers between utilities and streams from Example 1.

No.	Heat exchanger	Restrictions
1	MPS-C1	$Q_{MPS,C1,1} + Q_{MPS,C1,2} - y_{MPS-C1}U_{MPS-C1} \leq 0$
2	(H1-C1)_above_pinch	$Q_{H1,C1,1} + Q_{H1,C1,2}$ $- (y_{H1-C1})_{above_pinch}(U_{H1-C1})_{above_pinch} \leq 0$
3	(H1-C1)_below_pinch	$Q_{H1,C1,3}$ $- (y_{H1-C1})_{below_pinch}(U_{H1-C1})_{below_pinch} \leq 0$
4	H1-C2	$Q_{H1,C2,3} + Q_{H1,C2,4} - y_{H1-C2}U_{H1-C2} \leq 0$
5	H1-W	$Q_{H1,W,4} + Q_{H1,W,5} - y_{H1-W}U_{H1-W} \leq 0$
6	H2-C1	$Q_{H2,C1,3} - y_{H2-C1}U_{H2-C1} \leq 0$
7	H2-C2	$Q_{H2,C2,3} + Q_{H2,C2,4} - y_{H2-C2}U_{H2-C2} \leq 0$
8	H2-W	$Q_{H2,W,4} + Q_{H2,W,5} - y_{H2-W}U_{H2-W} \leq 0$

Table S9. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 1.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	MPS-C1	QMPS,C1,1	30
		QMPS,C1,2	30
1	(H1-C1)_ above_pinch_process	QH1,C1,2	60
2	H1-C2	QH1,C2,3	160
		QH1,C2,4	60
3	H2-C1	QH2,C1,3	240
4	H2-C2	QH2,C2,3	22
		QH2,C2,4	18
Cooler	H2-W	QH2,W,4	105.46
		QH2,W,5	54.55

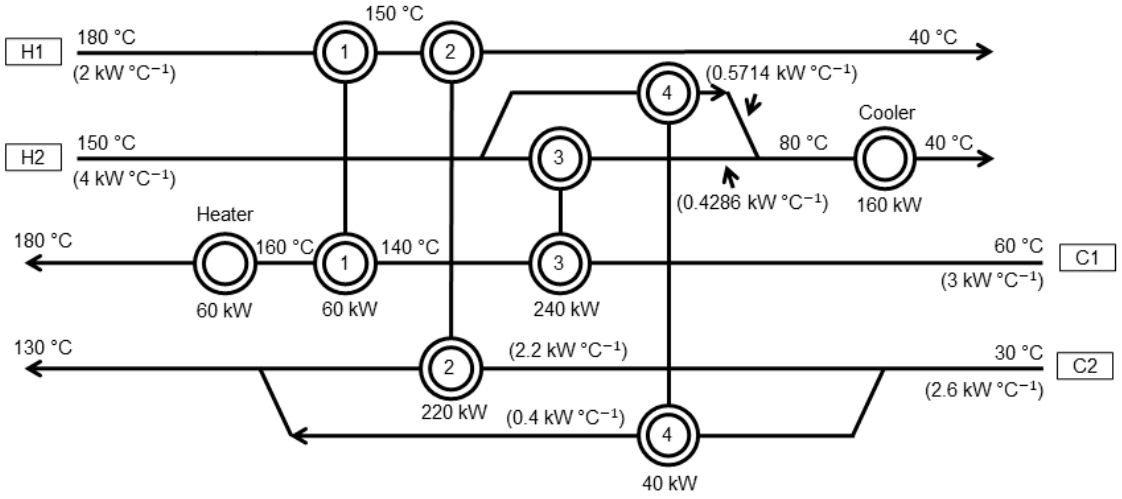


Figure S3. HEN with MPS and W for Example 1.

Table S10. Costs for HEN without multiple utilities for Example 1.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P (\$)
1	14.42	9.37	17830.03
2	14.42	34.36	13427.71
3	14.42	37.48	13176.9
4	32.71	2.75	17830.03
Cooler	22.94	15.71	17013.88
Heater	109.7	1.23	17830.03
		Total	97108.57

Example 1 with multiple utilities

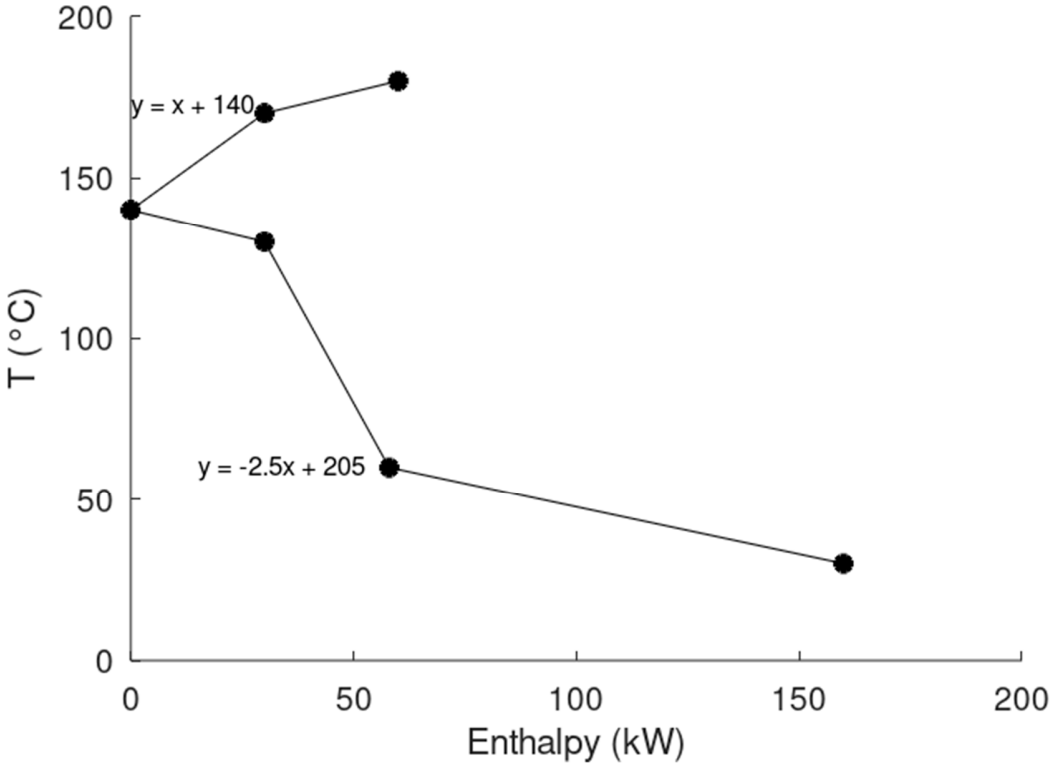


Figure S4. Grand Composite Curve for Example 1. Equations “y=x+140” and “y=-2.5x+205” correspond to the line between 170 °C and 150 °C and 130 °C and 60 °C, respectively.

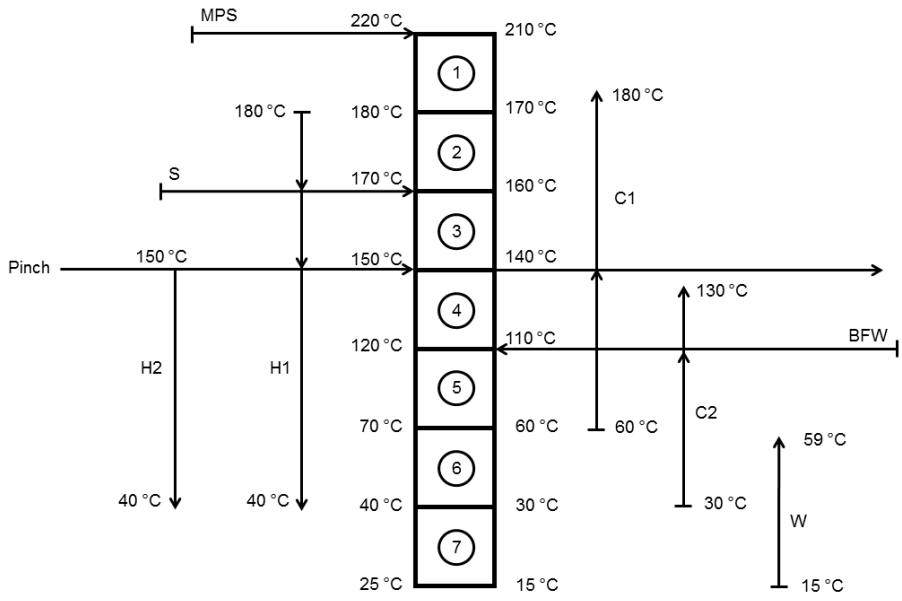


Figure S5. Temperature intervals for Example 1 with multiple utilities.

Table S11. Energy balances for Example 1 with multiple utilities.

No.	Stream	Energy balance
1	MPS	$R_{MPS,1} + Q_{MPS,C1,1} = Q^H_{MPS,1}$
2		$Q_{MPS,C1,2} - R_{MPS,1} = Q^H_{MPS,2}$
3	H1	$R_{H1,2} + Q_{H1,C1,2} = Q^H_{H1,2}$
4		$R_{H1,3} + Q_{H1,C1,3} = Q^H_{H1,3}$
5		$R_{H1,4} + Q_{H1,C1,4} + Q_{H1,C2,4} = Q^H_{H1,4}$
6		$Q_{H1,C2,5} + Q_{H1,BFW,5} - R_{H1,4} = Q^H_{H1,5}$
7		$R_{H1,6} + Q_{H1,C2,6} + Q_{H1,W,6} = Q^H_{H1,6}$
8		$Q_{H1,W,7} - R_{H1,6} = Q^H_{H1,7}$
9	S	$R_{S,3} + Q_{S,C1,3} = Q^H_{S,3}$
10	H2	$R_{H2,4} + Q_{H2,C1,4} + Q_{H2,C2,4} = Q^H_{H2,4}$
11		$Q_{H2,C2,5} + Q_{H2,BFW,5} - R_{H2,4} = Q^H_{H2,5}$
12		$R_{H2,6} + Q_{H2,C2,6} + Q_{H2,W,6} = Q^H_{H2,6}$
13		$Q_{H2,W,7} - R_{H2,6} = Q^H_{H2,7}$
14	C1	$Q_{MPS,C1,1} = Q^C_{C1,1}$

15		$Q_{MPS,C1,2} + Q_{H1,C1,2} = Q^{C}_{C1,2}$
16		$Q_{S,C1,3} + Q_{H1,C1,3} = Q^{C}_{C1,3}$
17		$Q_{H1,C1,4} + Q_{H2,C1,4} = Q^{C}_{C1,4}$
18	C2	$Q_{H1,C2,4} + Q_{H2,C2,4} = Q^{C}_{C2,4}$
19		$Q_{H1,C2,5} + Q_{H2,C2,5} = Q^{C}_{C2,5}$
20		$Q_{H1,C2,6} + Q_{H2,C2,6} = Q^{C}_{C2,6}$
21	BFW	$Q_{H1,BFW,5} + Q_{H2,BFW,5} = Q^{C}_{BFW,5}$
22	W	$Q_{H1,W,6} + Q_{H2,W,6} = Q^{C}_{W,6}$
23		$Q_{H1,W,7} + Q_{H2,W,7} = Q^{C}_{W,7}$
24		$Q^{H}_{MPS,1} + Q^{H}_{MPS,2} = 40\ kW$

Table S12. Variables to solve the energy balances for Example 1 with multiple utilities.

No.	Parameter
1	RMPS,1[a]
2	QMPS,C1,1[a]
3	QMPS,1^H[a]
4	QMPS,C1,2[a]
5	QMPS,2^H[a]
6	RH1,2[b]
7	QH1,C1,2[b]
8	RH1,3[b]
9	QH1,C1,3[b]
10	RH1,4[b]
11	QH1,C1,4[b]
12	QH1,C2,4[b]
13	QH1,C2,5[b]
14	QH1,BFW,5[b]

15	RH1,6[b]
16	QH1,C2,6[b]
17	QH1,W,6[b]
18	QH1,W,7[b]
19	QH1,7^H[b]
20	RS,3[c]
21	QS,C1,3[c]
22	RH2,4[d]
23	QH2,C1,4[d]
24	QH2,C2,4[d]
25	QH2,C2,5[d]
26	QH2,BFW,5[d]

27	RH2,6[d]
28	QH2,C2,6[d]
29	QH2,W,6[d]
30	QH2,W,7[d]
31	QH2,7^H[d]
32	y(MPS-C1)[e]
33	y(H1-C1)_above_S_pinch[e]
34	y(H1-C1)_above_process_pinch[e]
35	y(H1-C1)_above_BFW_pinch[e]
36	y(H1-BFW)[e]
37	y(H1-C2)_above_BFW_pinch[e]

38	y(H1-C2)_below_BFW_Pinch[e]
39	y(H1-W)[e]
40	y(H2-C1)_above_BFW_pinch[e]
41	y(H2-C2)_above_BFW_pinch[e]
42	y(H2-C2)_below_BFW_Pinch[e]
43	y(H2-BFW)[e]
44	y(H2-W)[e]
45	y(S-C1)_above_process_pinch[e]

Continuous variables related to [a]MPS and [c]S utility streams, [b]H1, and [d]H2 hot streams. [e]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S13. Constant parameters to solve energy balances for Example 1 with multiple utilities.

No.	Parameter	Value (kW)
1	QH1,2^H	20
2	QH1,3^H	40
3	QH1,4^H	160
4	QH1,5^H	20
5	QH1,6^H	40
6	QS,3^H	20
7	QH2,4^H	320
8	QH2,5^H	40
9	QH2,6^H	80
10	QC1,1^C	30
11	QC1,2^C	30
12	QC1,3^C	60
13	QC1,4^C	240

14	QC2,4^C	182
15	QC2,5^C	26
16	QC2,6^C	52
17	QBFW,5^C	92
18	QW,6^C	38
19	QW,7^C	30

Table S14. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 1 with multiple utilities.

No.	Parameter	Value (kW)
1	U(MPS-C1) = min (40;60)	40
2	U(H1-C1)_above_S_pinch = min (20;30)	20
3	U(H1-C1)_above_process_pinch = min (40;60)	40
4	U(H1-C1)_above_BFW_pinch = min (160;240)	160
5	U(H1-BFW) = min (180;92)	92
6	U(H1-C2)_above_BFW_pinch = min (180;208)	180
7	U(H1-C2)_below_BFW_pinch = min (40;52)	40
8	U(H1-W) = min (40;68)	40
9	U(H2-C1)_above_BFW_pinch = min (320;240)	240

10	U(H2-C2)_above_BFW_pinch = min (360;208)	208
11	U(H2-C2)_below_BFW_pinch = min (80;52)	52
12	U(H2-BFW) = min (360;92)	92
13	U(H2-W) = min (80;68)	68
14	U(S-C1)_above_process_pinch = min (20;60)	20

Table S15. Restrictions describing heat exchangers between utilities and streams from Example 1 with multiple utilities.

No.	Heat exchanger	Restriction
1	MPS-C1	$Q_{MPS,C1,1} + Q_{MPS,C1,2} - y_{MPS-C1}U_{MPS-C1} \leq 0$
2	(H1-C1)_above_S_pinch	$Q_{H1,C1,2} - (y_{H1-C1})_{above_S_pinch}(U_{H1-C1})_{above_S_pinch} \leq 0$
3	(H1-C1)_above_process_pinch	$Q_{H1,C1,3} - (y_{H1-C1})_{above_process_pinch}(U_{H1-C1})_{above_process_pinch} \leq 0$
4	(H1-C1)_above_BFW_pinch	$Q_{H1,C1,4} - (y_{H1-C1})_{above_BFW_pinch}(U_{H1-C1})_{above_BFW_pinch} \leq 0$
5	H1-BFW	$Q_{H1,BFW,5} - y_{H1-BFW}U_{H1-BFW} \leq 0$
6	(H1-C2)_above_BFW_pinch	$Q_{H1,C2,4} + Q_{H1,C2,5} - (y_{H1-C2})_{above_BFW_pinch}(U_{H1-C2})_{above_BFW_pinch} \leq 0$
7	(H1-C2)_below_BFW_pinch	$Q_{H1,C2,6} - (y_{H1-C2})_{below_BFW_pinch}(U_{H1-C2})_{below_BFW_pinch} \leq 0$
8	(H1-W)	$Q_{H1,W,6} + Q_{H1,W,7} - y_{H1-W}U_{H1-W} \leq 0$
9	(H2-C1)_above_BFW_pinch	$Q_{H2,C1,4} - (y_{H2-C1})_{above_BFW_pinch}(U_{H2-C1})_{above_BFW_pinch} \leq 0$
10	(H2-C2)_above_BFW_pinch	$Q_{H2,C2,4} + Q_{H2,C2,5} - (y_{H2-C2})_{above_BFW_pinch}(U_{H2-C2})_{above_BFW_pinch} \leq 0$

11	(H2-C2)_below_BFW_pinch	$Q_{H2,C2,6} - (y_{H2-C2})_{below_BFW_pinch}(U_{H2-C2})_{below_BFW_pinch} \leq 0$
12	H2-BFW	$Q_{H2,BFW,5} - y_{H2-BFW}U_{H2-BFW} \leq 0$
13	H2-W	$Q_{H2,W,6} + Q_{H2,W,7} - y_{H2-W}U_{H2-W} \leq 0$
14	(S-C1)_above_process_pinch	$Q_{S,C1,3} - (y_{S-C1})_{above_procss_pinch}(U_{S-C1})_{above_process_pinch} \leq 0$

Table S16. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 1 with multiple utilities.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	MPS-C1	QMPS,C1,1	30
		QMPS,C1,2	10
1	H1-C1_before_S_pinch	QH1,C1,2	20
2	S-C1	QS,C1,3	20
3	H1-C1_before_process_pinch	QH1,C1,3	40
4	H1-C2_before_BFW_pinch	QH1,C2,4	22
5	H2-C1_before_BFW_pinch	QH2,C1,4	90
6	H2-C2_before_BFW_pinch	QH2,C2,4	30
7	H1-BFW	QH1,BFW,4	38
8	H2-C2_after_BFW_pinch	QH2,C2,5	30
		QH2,C2,6	18
9	H2-C1_after_BFW_pinch	QH2,C1,5	150
10	H1-C2_after_BFW_pinch	QH1,C2,5	100

		QH1,C2,6	60
Cooler	H2-W	QH2,W,6	80.41
		QH2,W,7	41.59

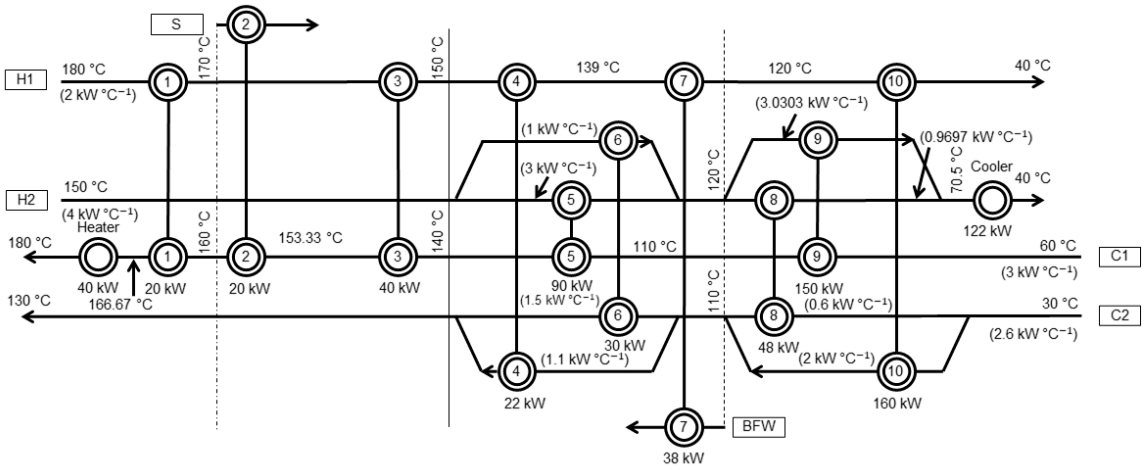


Figure S6. HEN with multiple utilities for Example 1.

Table S17. Costs for HEN with multiple utilities for Example 1.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P (\$)
1	11.59	3.89	17830.03
2	13.05	3.45	17830.03
3	13.05	6.9	17830.03
4	24.22	2.05	17830.03
5	10	20.27	15543.32
6	10	6.76	17830.03
7	17.82	4.8	17830.03
8	10.25	32.97	13555.45
9	21.71	4.98	17830.03
10	10	36.04	13287.03
Cooler	17.38	15.81	16970.85
Heater	106.53	0.85	17830.03
		Total	201996.88

Example 2 without multiple utilities

Table S18. Source and target temperatures, C value, and the multiple utilities for Example 2.

Stream	Source temperatura T^s (°C)	Target temperatura T^t (°C)	C (kW °C^{-1})	References
H1	590	400	2.376	(Seider, Seader, Lewin, & Widagdo, 2009)
H2	471	200	1.577	
H3	533	150	1.32	
C1	200	400	1.6	
C2	100	430	1.6	
C3	300	400	4.128	
C4	150	280	2.624	
Fuel	800	800		(Chang, Chen, Wang, & Feng, 2017)
HPS	230	230		

Table S19. Adjusted temperatures using the Temperature Interval method for Example 2 with ΔTmin=50 °C.

Stream	T^s (°C)	T^t (°C)	C (kW °C^{-1})	Adjusted temperatures	
				T^s (°C)	T^t (°C)
H1	590	400	2.376	540	350
H2	471	200	1.577	421	150
H3	533	150	1.32	483	100
C1	200	400	1.6	200	400
C2	100	430	1.6	100	430
C3	300	400	4.128	300	400
C4	150	280	2.624	150	280

Table S20. MER targets and the pinch value using the Temperature interval method for Example 2.

Temperature intervals (°C)		$\sum C_H$-$\sum C_C$ (kW °C^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the Fuel (kW)
					[a]217.55
540	483	2.376	135.43	135.43	352.99
483	430	3.696	195.89	331.32	548.87
430	421	2.096	18.87	350.18	567.74
421	400	3.673	77.13	427.32	644.87
400	350	-2.055	-102.75	324.57	542.12
350	300	-4.431	-221.55	103.02	320.57
300	280	-0.303	-6.06	96.96	314.51
280	200	-2.927	-234.16	-137.2	80.35
200	150	-1.327	-66.35	-203.55	14
150	[b]100	-0.28	-14	-217.55	0

[a]Fuel value

[b]Pinch temperature for cold streams

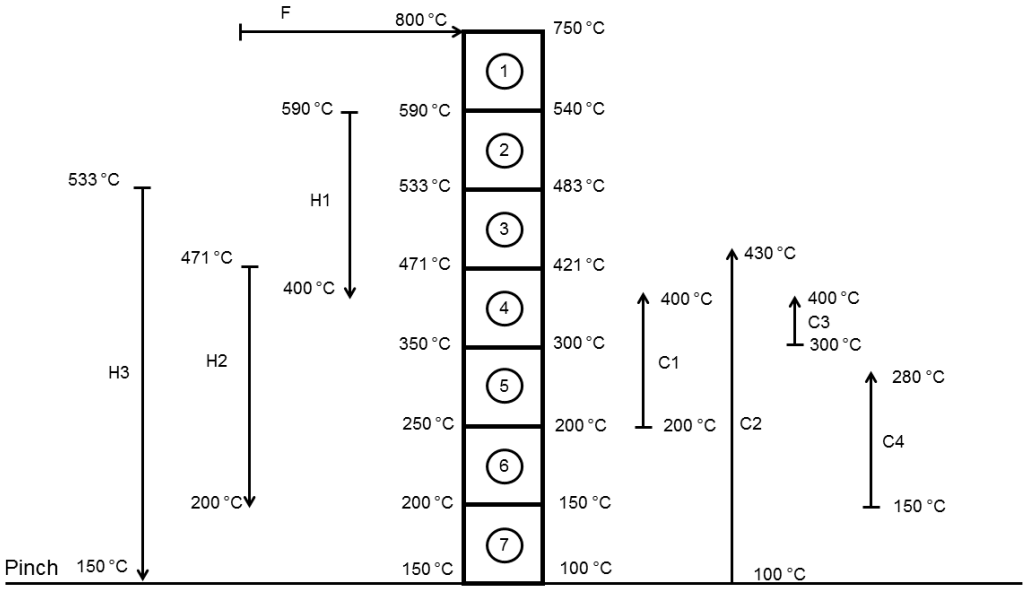


Figure S7. Temperature intervals for Example 2.

Table S21. Energy balances for Example 2.

No.	Stream	Energy balance
1	F	$R_{F,1} = Q_{F,1}^{H}$
2		$R_{F,2} - R_{F,1} = Q_{F,2}^{H}$
3		$R_{F,3} + Q_{F,C2,3} - R_{F,2} = Q_{F,3}^{H}$
4		$R_{F,4} + Q_{F,C1,4} + Q_{F,C2,4} + Q_{F,C3,4} - R_{F,3} = Q_{F,4}^{H}$
5		$R_{F,5} + Q_{F,C1,5} + Q_{F,C2,5} + Q_{F,C4,5} - R_{F,4} = Q_{F,5}^{H}$
6		$R_{F,6} + Q_{F,C2,6} + Q_{F,C4,6} - R_{F,5} = Q_{F,6}^{H}$
7		$Q_{F,C2,7} - R_{F,6} = Q_{F,7}^{H}$
8	H1	$R_{H1,2} = Q_{H1,2}^{H}$
9		$R_{H1,3} + Q_{H1,C2,3} - R_{H1,2} = Q_{H1,3}^{H}$
10		$R_{H1,4} + Q_{H1,C1,4} + Q_{H1,C2,4} + Q_{H1,C3,4} - R_{H1,3} = Q_{H1,4}^{H}$
11		$R_{H1,5} + Q_{H1,C1,5} + Q_{H1,C2,5} + Q_{H1,C4,5} - R_{H1,4} = Q_{H1,5}^{H}$
12		$R_{H1,6} + Q_{H1,C2,6} + Q_{H1,C4,6} - R_{H1,5} = Q_{H1,6}^{H}$
13		$Q_{H1,C2,7} - R_{H1,6} = Q_{H1,7}^{H}$
14	H3	$R_{H3,3} + Q_{H3,C2,3} = Q_{H3,3}^{H}$

15		$R_{H3,4} + Q_{H3,C1,4} + Q_{H3,C2,4} + Q_{H3,C3,4} - R_{H3,3} = Q^{H}_{H3,4}$
16		$R_{H3,5} + Q_{H3,C1,5} + Q_{H3,C2,5} + Q_{H3,C4,5} - R_{H3,4} = Q^{H}_{H3,5}$
17		$R_{H3,6} + Q_{H3,C2,6} + Q_{H3,C4,6} - R_{H3,5} = Q^{H}_{H3,6}$
18		$Q_{H3,C2,7} - R_{H3,6} = Q^{H}_{H3,7}$
19	H2	$R_{H2,4} + Q_{H2,C1,4} + Q_{H2,C2,4} + Q_{H2,C3,4} = Q^{H}_{H2,4}$
20		$R_{H2,5} + Q_{H2,C1,5} + Q_{H2,C2,5} + Q_{H2,C4,5} - R_{H2,4} = Q^{H}_{H2,5}$
21		$R_{H2,6} + Q_{H2,C2,6} + Q_{H2,C4,6} - R_{H2,5} = Q^{H}_{H2,6}$
22		$Q_{H2,C2,7} - R_{H2,6} = Q^{H}_{H2,7}$
23	C2	$Q_{F,C2,3} + Q_{H1,C2,3} + Q_{H3,C2,3} = Q^{C}_{C2,3}$
24		$Q_{F,C2,4} + Q_{H1,C2,4} + Q_{H2,C2,4} + Q_{H3,C2,4} = Q^{C}_{C2,4}$
25		$Q_{F,C2,5} + Q_{H1,C2,5} + Q_{H2,C2,5} + Q_{H3,C2,5} = Q^{C}_{C2,5}$
26		$Q_{F,C2,6} + Q_{H1,C2,6} + Q_{H2,C2,6} + Q_{H3,C2,6} = Q^{C}_{C2,6}$
27		$Q_{F,C2,7} + Q_{H1,C2,7} + Q_{H2,C2,7} + Q_{H3,C2,7} = Q^{C}_{C2,7}$
28	C1	$Q_{F,C1,4} + Q_{H1,C1,4} + Q_{H2,C1,4} + Q_{H3,C1,4} = Q^{C}_{C1,4}$
29		$Q_{F,C1,5} + Q_{H1,C1,5} + Q_{H2,C1,5} + Q_{H3,C1,5} = Q^{C}_{C1,5}$

30		$Q_{F,C3,4} + Q_{H1,C3,4} + Q_{H2,C3,4} + Q_{H3,C3,4} = Q^{C}_{C3,4}$
31		$Q_{F,C4,5} + Q_{H1,C4,5} + Q_{H2,C4,5} + Q_{H3,C4,5} = Q^{C}_{C4,5}$
32		$Q_{F,C4,6} + Q_{H1,C4,6} + Q_{H2,C4,6} + Q_{H3,C4,6} = Q^{C}_{C4,6}$
33		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} + Q^{H}_{F,4} + Q^{H}_{F,5} + Q^{H}_{F,6} + Q^{H}_{F,7}$ $= 217.55\ kW$

Table S22. Variables to solve the energy balances for Example 2.

No.	Parameter
1	RF,1[a]
2	QF,1^H[a]
3	RF,2[a]
4	QF,2^H[a]
5	RF,3[a]
6	QF,C2,3[a]
7	QF,3^H[a]
8	RF,4[a]
9	QF,C1,4[a]
10	QF,C2,4[a]
11	QF,C3,4[a]
12	QF,4^H[a]
13	RF,5[a]
14	QF,C1,5[a]

15	QF,C2,5[a]
16	QF,C4,5[a]
17	QF,5^H[a]
18	RF,6[a]
19	QF,C2,6[a]
20	QF,C4,6[a]
21	QF,6^H[a]
22	QF,C2,7[a]
23	QF,7^H[a]
24	RH1,2[b]
25	RH1,3[b]
26	QH1,C2,3[b]
27	RH1,4[b]
28	QH1,C1,4[b]
29	QH1,C2,4[b]

30	QH1,C3,4[b]
31	RH1,5[b]
32	QH1,C1,5[b]
33	QH1,C2,5[b]
34	QH1,C4,5[b]
35	QH1,5^H[b]
36	RH1,6[b]
37	QH1,C2,6[b]
38	QH1,C4,6[b]
39	QH1,6^H[b]
40	QH1,C2,7[b]
41	QH1,7^H[b]
42	RH3,3[c]
43	QH3,C2,3[c]
44	RH3,4[c]

45	QH3,C1,4[c]
46	QH3,C2,4[c]
47	QH3,C3,4[c]
48	RH3,5[c]
49	QH3,C1,5[c]
50	QH3,C2,5[c]
51	QH3,C4,5[c]
52	RH3,6[c]
53	QH3,C2,6[c]
54	QH3,C4,6[c]
55	QH3,C2,7[c]
56	RH2,4[d]
57	QH2,C1,4[d]
58	QH2,C2,4[d]
59	QH2,C3,4[d]

60	RH2,5[d]
61	QH2,C1,5[d]
62	QH2,C2,5[d]
63	QH2,C4,5[d]
64	RH2,6[d]
65	QH2,C2,6[d]
66	QH2,C4,6[d]
67	QH2,C2,7[d]
68	QH2,7^H[d]
69	y(H1-C1)[e]
70	y(H1-C2)[e]
71	y(H1-C3)[e]
72	y(H1-C4)[e]
73	y(H2-C1)[e]
74	y(H2-C2)[e]

75	y(H2-C3)[e]
76	y(H2-C4)[e]
77	y(H3-C1)[e]
78	y(H3-C2)[e]
79	y(H3-C3)[e]
80	y(H3-C4)[e]
81	y(F-C1)[e]
82	y(F-C2)[e]
83	y(F-C3)[e]
84	y(F-C4)[e]

Continuous variables related to [a]F utility stream, [b]H1, [c]H3, and [d]H2 hot streams. [e]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S23. Constant parameters to solve energy balances for Example 2.

No.	Parameter	Value (kW)
1	QH1,2^H	135.43
2	QH1,3^H	147.31
3	QH1,4^H	168.7
4	QH3,3^H	81.84
5	QH3,4^H	159.72
6	QH3,5^H	132
7	QH3,6^H	66
8	QH3,7^H	66
9	QH2,4^H	190.82
10	QH2,5^H	157.7
11	QH2,6^H	78.85
12	QC2,3^C	14.4
13	QC2,4^C	193.6
14	QC2,5^C	160

15	QC2,6^C	80
16	QC2,7^C	80
17	QC1,4^C	160
18	QC1,5^C	160
19	QC3,4^C	412.8
20	QC4,5^C	209.92
21	QC4,6^C	131.2

Table S24. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 2.

No.	Parameter	Value (kW)
1	U(H1-C1) = min(451.44;320)	320
2	U(H1-C2) = min(451.44;528)	451.44
3	U(H1-C3) = min(451.44;412.8)	412.8
4	U(H1-C4) = min(451.44;341.12)	341.12
5	U(H2-C1) = min(348.52;320)	320
6	U(H2-C2) = min(427.37;528)	427.37
7	U(H2-C3) = min(190.82;412.8)	190.82
8	U(H2-C4) = min(427.37;341.12)	341.12
9	U(H3-C1) = min(373.56;320)	320
10	U(H3-C2) = min(505.56;528)	505.56
11	U(H3-C3) = min(241.56;412.8)	241.56
12	U(H3-C4) = min(439.56;341.12)	341.12
13	U(F-C1) = min(217.55;320)	217.55

14	U(F-C2) = min(217.55;528)	217.55
15	U(F-C3) = min(217.55;412.8)	217.55
16	U(F-C4) = min(217.55;341.12)	217.55

Table S25. Restrictions describing heat exchangers between utilities and streams from Example 2.

No.	Heat exchanger	Restriction
1	H1-C1	$Q_{H1,C1,4} + Q_{H1,C1,5} - y_{H1,C1}U_{H1,C1} \leq 0$
2	H1-C2	$Q_{H1,C2,3} + Q_{H1,C2,4} + Q_{H1,C2,5} + Q_{H1,C2,6} + Q_{H1,C2,7} - y_{H1,C2}U_{H1,C2} \leq 0$
3	H1-C3	$Q_{H1,C3,4} - y_{H1,C3}U_{H1,C3} \leq 0$
4	H1-C4	$Q_{H1,C4,5} + Q_{H1,C4,6} - y_{H1,C4}U_{H1,C4} \leq 0$
5	H2-C1	$Q_{H2,C1,4} + Q_{H2,C1,5} - y_{H2,C1}U_{H2,C1} \leq 0$
6	H2-C2	$Q_{H2,C2,4} + Q_{H2,C2,5} + Q_{H2,C2,6} + Q_{H2,C2,7} - y_{H2,C2}U_{H2,C2} \leq 0$
7	H2-C3	$Q_{H2,C3,4} - y_{H2,C3}U_{H2,C3} \leq 0$
8	H2-C4	$Q_{H2,C4,5} + Q_{H2,C4,6} - y_{H2,C4}U_{H2,C4} \leq 0$
9	H3-C1	$Q_{H3,C1,4} + Q_{H3,C1,5} - y_{H3,C1}U_{H3,C1} \leq 0$
10	H3-C2	$Q_{H3,C2,3} + Q_{H3,C2,4} + Q_{H3,C2,5} + Q_{H3,C2,6} + Q_{H3,C2,7} - y_{H3,C2}U_{H3,C2} \leq 0$
11	H3-C3	$Q_{H3,C3,4} - y_{H3,C3}U_{H3,C3} \leq 0$

12	H3-C4	$Q_{H3,C4,5} + Q_{H3,C4,6} - y_{H3,C4}U_{H3,C4} \leq 0$
13	F-C1	$Q_{F,C1,4} + Q_{F,C1,5} - y_{F,C1}U_{F,C1} \leq 0$
14	F-C2	$Q_{F,C2,3} + Q_{F,C2,4} + Q_{F,C2,5} + Q_{F,C2,6} + Q_{F,C2,7} - y_{F,C2}U_{F,C2} \leq 0$
15	F-C3	$Q_{F,C3,4} - y_{F,C3}U_{F,C3} \leq 0$
16	F-C4	$Q_{F,C4,5} + Q_{F,C4,6} - y_{F,C4}U_{F,C4} \leq 0$

Table S26. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 2.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	F-C2	QF,C2,3	14.4
		QF,C2,4	129.7
		QF,C2,5	45.45
		QF,C2,6	23.75
		QF,C2,7	4.25
1	H1-C1	QH1,C1,5	38.64
2	H1-C3	QH1,C3,4	412.8
3	H3-C1	QH3,C1,4	160
		QH3,C1,5	35.11
4	H2-C1	QH2,C1,5	86.25
5	H3-C2	QH3,C2,4	63.9
		QH3,C2,5	114.55
		QH3,C2,6	56.25

		QH3,C2,7	75.75
6	H2-C4	QH2,C4,5	209.92
		QH2,C4,6	131.2

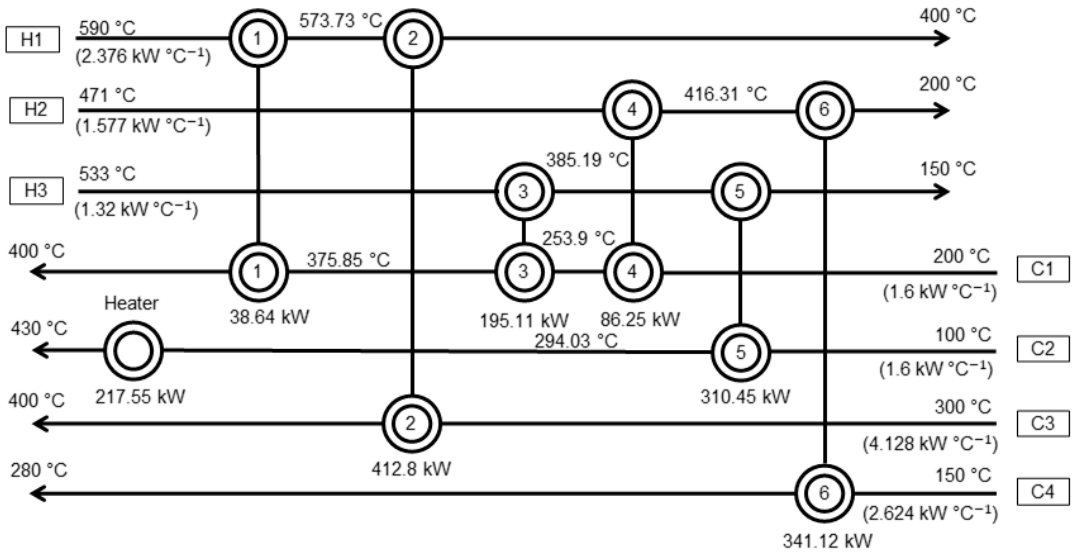


Figure S8. HEN with F for Example 2.

Table S27. Costs for HEN without multiple utilities for Example 2.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P (\$)
1	193.92	0.45	17830.03
2	133.48	6.97	17830.03
3	143.83	3.06	17830.03
4	216.7	0.9	17830.03
5	68.52	10.21	17830.03
6	85.95	8.94	17830.03
Heater	434.44	1.13	17830.03
		Total	124810.2

Example 2 with multiple utilities

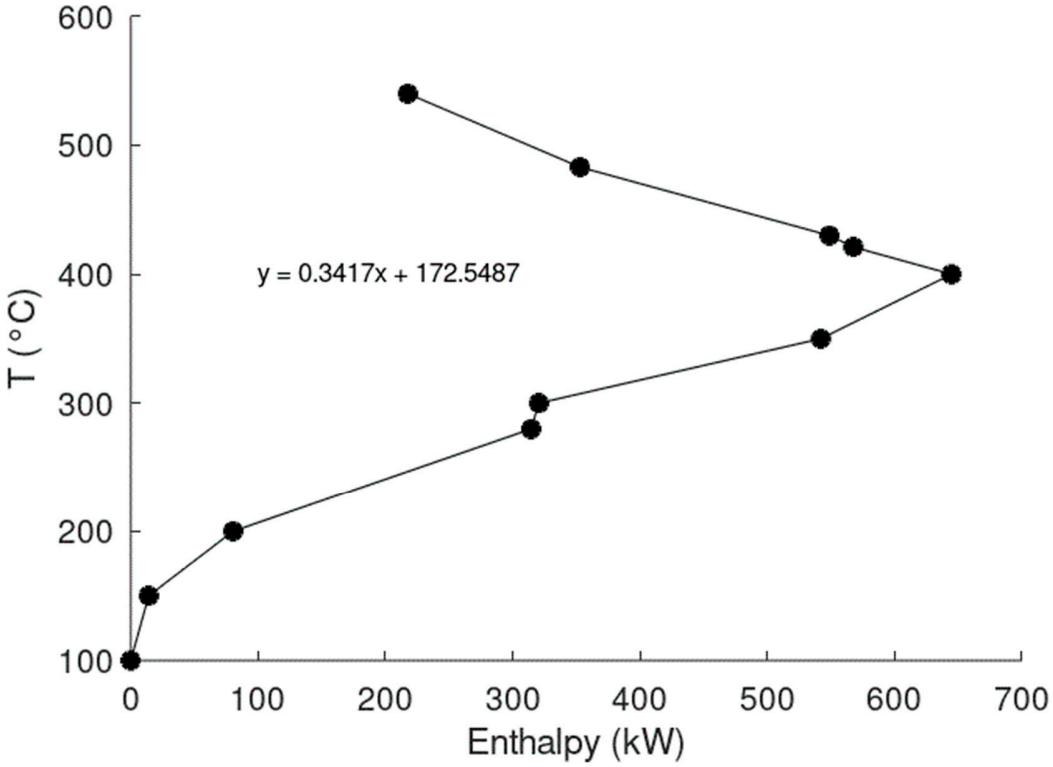


Figure S9. Grand Composite Curve for Example 2. Equation "y=0.3417x+172.5487" corresponds to the line between 280 °C and 200 °C.

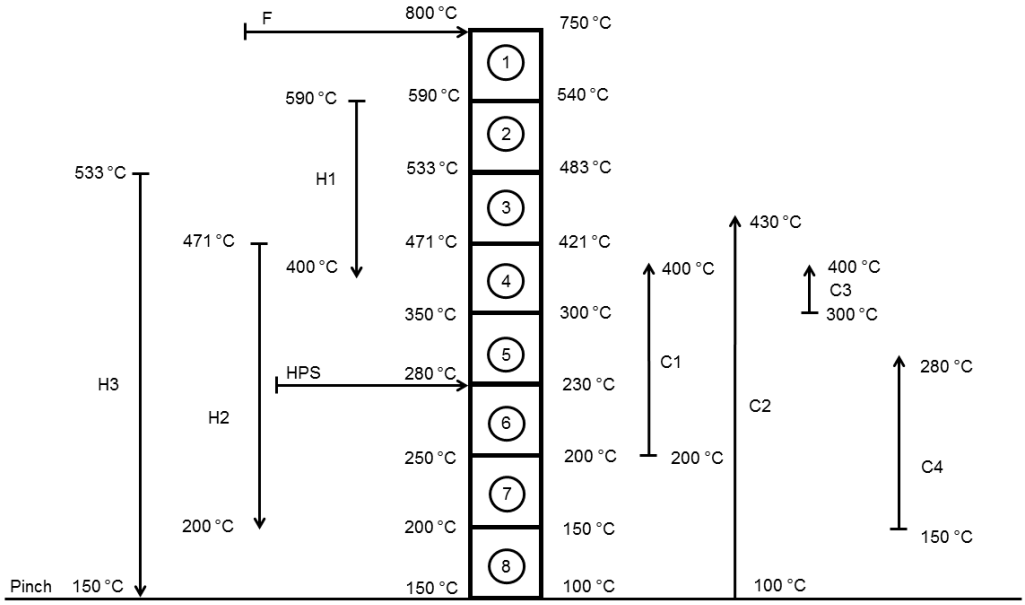


Figure S10. Temperature intervals for Example 2 with multiple utilities.

Table S28. Energy balances for Example 2 with multiple utilities.

No.	Stream	Energy balance
1	F	$R_{F,1} = Q_{F,1}^{H}$
2		$R_{F,2} - R_{F,1} = Q_{F,2}^{H}$
3		$R_{F,3} + Q_{F,C2,3} - R_{F,2} = Q_{F,3}^{H}$
4		$R_{F,4} + Q_{F,C1,4} + Q_{F,C2,4} + Q_{F,C3,4} - R_{F,3} = Q_{F,4}^{H}$
5		$Q_{F,C1,5} + Q_{F,C2,5} + Q_{F,C4,5} - R_{F,4} = Q_{F,5}^{H}$
6	H1	$R_{H1,2} = Q_{H1,2}^{H}$
7		$R_{H1,3} + Q_{H1,C2,3} - R_{H1,2} = Q_{H1,3}^{H}$
8		$R_{H1,4} + Q_{H1,C1,4} + Q_{H1,C2,4} + Q_{H1,C3,4} - R_{H1,3} = Q_{H1,4}^{H}$
9		$Q_{H1,C1,5} + Q_{H1,C2,5} + Q_{H1,C4,5} - R_{H1,4} = Q_{H1,5}^{H}$
10	H3	$R_{H3,3} + Q_{H3,C2,3} = Q_{H3,3}^{H}$
11		$R_{H3,4} + Q_{H3,C1,4} + Q_{H3,C2,4} + Q_{H3,C3,4} - R_{H3,3} = Q_{H3,4}^{H}$
12		$Q_{H3,C1,5} + Q_{H3,C2,5} + Q_{H3,C4,5} - R_{H3,4} = Q_{H3,5}^{H}$
13		$R_{H3,6} + Q_{H3,C1,6} + Q_{H3,C2,6} + Q_{H3,C4,6} = Q_{H3,6}^{H}$
14		$R_{H3,7} + Q_{H3,C2,7} + Q_{H3,C4,7} - R_{H3,6} = Q_{H3,7}^{H}$

15		$Q_{H3,C2,8} - R_{H3,7} = Q^{H}_{H3,8}$
16	H2	$R_{H2,4} + Q_{H2,C1,4} + Q_{H2,C2,4} + Q_{H2,C3,4} = Q^{H}_{H2,4}$
17		$Q_{H2,C1,5} + Q_{H2,C2,5} + Q_{H2,C4,5} - R_{H2,4} = Q^{H}_{H2,5}$
18		$R_{H2,6} + Q_{H2,C1,6} + Q_{H2,C2,6} + Q_{H2,C4,6} = Q^{H}_{H2,6}$
19		$R_{H2,7} + Q_{H2,C2,7} + Q_{H2,C4,7} - R_{H2,6} = Q^{H}_{H2,7}$
20		$Q_{H2,C2,8} - R_{H2,7} = Q^{H}_{H2,8}$
21	HPS	$R_{HPS,6} + Q_{HPS,C1,6} + Q_{HPS,C2,6} + Q_{HPS,C4,6} = Q^{H}_{HPS,6}$
22		$R_{HPS,7} + Q_{HPS,C2,7} + Q_{HPS,C4,7} - R_{HPS,6} = Q^{H}_{HPS,7}$
23		$Q_{HPS,C2,8} - R_{HPS,7} = Q^{H}_{HPS,8}$
24	C2	$Q_{F,C2,3} + Q_{H1,C2,3} + Q_{H3,C2,3} = Q^{C}_{C2,3}$
25		$Q_{F,C2,4} + Q_{H1,C2,4} + Q_{H2,C2,4} + Q_{H3,C2,4} = Q^{C}_{C2,4}$
26		$Q_{F,C2,5} + Q_{H1,C2,5} + Q_{H2,C2,5} + Q_{H3,C2,5} = Q^{C}_{C2,5}$
27		$Q_{HPS,C2,6} + Q_{H2,C2,6} + Q_{H3,C2,6} = Q^{C}_{C2,6}$
28		$Q_{HPS,C2,7} + Q_{H2,C2,7} + Q_{H3,C2,7} = Q^{C}_{C2,7}$
29		$Q_{HPS,C2,8} + Q_{H2,C2,8} + Q_{H3,C2,8} = Q^{C}_{C2,8}$

30	C1	$Q_{F,C1,4} + Q_{H1,C1,4} + Q_{H2,C1,4} + Q_{H3,C1,4} = Q^{C}_{C1,4}$
31		$Q_{F,C1,5} + Q_{H1,C1,5} + Q_{H2,C1,5} + Q_{H3,C1,5} = Q^{C}_{C1,5}$
32		$Q_{HPS,C1,6} + Q_{H2,C1,6} + Q_{H3,C1,6} = Q^{C}_{C1,6}$
33	C3	$Q_{F,C3,4} + Q_{H1,C3,4} + Q_{H2,C3,4} + Q_{H3,C3,4} = Q^{C}_{C3,4}$
34	C4	$Q_{F,C4,5} + Q_{H1,C4,5} + Q_{H2,C4,5} + Q_{H3,C4,5} = Q^{C}_{C4,5}$
35		$Q_{HPS,C4,6} + Q_{H2,C4,6} + Q_{H3,C4,6} = Q^{C}_{C4,6}$
36		$Q_{HPS,C4,7} + Q_{H2,C4,7} + Q_{H3,C4,7} = Q^{C}_{C4,7}$
37		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} + Q^{H}_{F,4} + Q^{H}_{F,5} = 49.39\ kW$
38		$Q^{H}_{HPS,6} + Q^{H}_{HPS,7} + Q^{H}_{HPS,8} = 168.16\ kW$

Table S29. Variables to solve the energy balances for Example 2 with multiple utilities.

No.	Parameter
1	$RF,1^{a}$
2	$QF,1\text{^}H^{a}$
3	$RF,2^{a}$
4	$QF,2\text{^}H^{a}$
5	$RF,3^{a}$
6	$QF,C2,3^{a}$
7	$QF,3\text{^}H^{a}$
8	$RF,4^{a}$
9	$QF,C1,4^{a}$
10	$QF,C2,4^{a}$
11	$QF,C3,4^{a}$
12	$QF,4\text{^}H^{a}$
13	$QF,C1,5^{a}$
14	$QF,C2,5^{a}$

15	QF,C4,5[a]
16	QF,5^H[a]
17	RH1,2[b]
18	RH1,3[b]
19	QH1,C2,3[b]
20	RH1,4[b]
21	QH1,C1,4[b]
22	QH1,C2,4[b]
23	QH1,C3,4[b]
24	QH1,C1,5[b]
25	QH1,C2,5[b]
26	QH1,C4,5[b]
27	QH1,5^H[b]
28	RH3,3[c]
29	QH3,C2,3[c]

30	RH3,4[c]
31	QH3,C1,4[c]
32	QH3,C2,4[c]
33	QH3,C3,4[c]
34	QH3,C1,5[c]
35	QH3,C2,5[c]
36	QH3,C4,5[c]
37	RH3,6[c]
38	QH3,C1,6[c]
39	QH3,C2,6[c]
40	QH3,C4,6[c]
41	RH3,7[c]
42	QH3,C2,7[c]
43	QH3,C4,7[c]
44	QH3,C2,8[c]

45	RH2,4^{d}
46	QH2,C1,4^{d}
47	QH2,C2,4^{d}
48	QH2,C3,4^{d}
49	QH2,C1,5^{d}
50	QH2,C2,5^{d}
51	QH2,C4,5^{d}
52	RH2,6^{d}
53	QH2,C1,6^{d}
54	QH2,C2,6^{d}
55	QH2,C4,6^{d}
56	RH2,7^{d}
57	QH2,C2,7^{d}
58	QH2,C4,7^{d}
59	QH2,C2,8^{d}

60	QH2,8^H[d]
61	RHPS,6[e]
62	QHPS,C1,6[e]
63	QHPS,C2,6[e]
64	QHPS,C4,6[e]
65	QHPS,6^H[e]
66	RHPS,7[e]
67	QHPS,C2,7[e]
68	QHPS,C4,7[e]
69	QHPS,7^H[e]
70	QHPS,C2,8[e]
71	QHPS,8^H[e]
72	y(H1-C1)[f]
73	y(H1-C2)[f]
74	y(H1-C3)[f]

75	$y(H1\text{-}C4)^f$
76	$y(H2\text{-}C1)_above_HPS_pinch^f$
77	$y(H2\text{-}C2)_above_HPS_pinch^f$
78	$y(H2\text{-}C3)_above_HPS_pinch^f$
79	$y(H2\text{-}C4)_above_HPS_pinch^f$
80	$y(H2\text{-}C1)_below_HPS_pinch^f$
81	$y(H2\text{-}C2)_below_HPS_pinch^f$
82	$y(H2\text{-}C4)_below_HPS_pinch^f$
83	$y(H3\text{-}C1)_above_HPS_pinch^f$
84	$y(H3\text{-}C2)_above_HPS_pinch^f$
85	$y(H3\text{-}C3)_above_HPS_pinch^f$
86	$y(H3\text{-}C4)_above_HPS_pinch^f$
87	$y(H3\text{-}C1)_below_HPS_pinch^f$
88	$y(H3\text{-}C2)_below_HPS_pinch^f$
89	$y(H3\text{-}C4)_below_HPS_pinch^f$

90	y(HPS-C1)[f]
91	y(HPS-C2)[f]
92	y(HPS-C4)[f]
93	y(F-C1)[f]
94	y(F-C2)[f]
95	y(F-C3)[f]
96	y(F-C4)[f]

Continuous variables related to [a]F and [e]HPS utility streams, [b]H1, [c]H3, and [d]H2 hot streams. [f]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S30. Constant parameters to solve energy balances for Example 2 with multiple utilities.

No.	Parameter	Value (kW)
1	QH1,2^H	135.43
2	QH1,3^H	147.31
3	QH1,4^H	168.7
4	QH3,3^H	81.84
5	QH3,4^H	159.72
6	QH3,5^H	92.4
7	QH3,6^H	39.6
8	QH3,7^H	66
9	QH3,8^H	66
10	QH2,4^H	190.82
11	QH2,5^H	110.39
12	QH2,6^H	47.31
13	QH2,7^H	78.85

14	QC2,3^C	14.4
15	QC2,4^C	193.6
16	QC2,5^C	112
17	QC2,6^C	48
18	QC2,7^C	80
19	QC2,8^C	80
20	QC1,4^C	160
21	QC1,5^C	112
22	QC1,6^C	48
23	QC3,4^C	412.8
24	QC4,5^C	131.2
25	QC4,6^C	78.72
26	QC4,7^C	131.2

Table S31. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 2 with multiple utilities.

No.	Parameter	Value (kW)
1	U(H1-C1) = min(451.44;272)	272
2	U(H1-C2) = min(451.44;320)	320
3	U(H1-C3) = min(451.44;412.8)	412.8
4	U(H1-C4) = min(451.44;131.2)	131.2
5	U(H2-C1)_above_HPS_pinch = min(301.21;272)	272
6	U(H2-C2)_above_HPS_pinch = min(301.21;305.6)	301.21
7	U(H2-C3)_above_HPS_pinch = min(190.82;412.8)	190.82
8	U(H2-C4)_above_HPS_pinch = min(301.21;131.2)	131.2
9	U(H2-C1)_below_HPS_pinch = min(47.31;48)	47.31
10	U(H2-C2)_below_HPS_pinch = min(126.16;208)	126.16
11	U(H2-C4)_below_HPS_pinch = min(126.16;209.92)	126.16
12	U(H3-C1)_above_HPS_pinch = min(333.96;272)	272
13	U(H3-C2)_above_HPS_pinch = min(333.96;320)	320

14	U(H3-C3)_above_HPS_pinch = min(241.56;412.8)	241.56
15	U(H3-C4)_above_HPS_pinch = min(333.96;131.2)	131.2
16	U(H3-C1)_below_HPS_pinch = min(39.6;48)	39.6
17	U(H3-C2)_below_HPS_pinch = min(171.6;208)	171.6
18	U(H3-C4)_below_HPS_pinch = min(105.6;209.92)	105.6
19	U(HPS-C1) = min(168.16;48)	48
20	U(HPS-C2) = min(168.16;208)	168.16
21	U(HPS-C4) = min(168.16;209.92)	168.16
22	U(F-C1) = min(49.39;272)	49.39
23	U(F-C2) = min(49.39;320)	49.39
24	U(F-C3) = min(49.39;412.8)	49.39
25	U(F-C4) = min(49.39;131.2)	49.39

Table S32. Restrictions describing heat exchangers between utilities and streams from Example 2 with multiple utilities.

No.	Heat exchanger	Restriction
1	H1-C1	$Q_{H1,C1,4} + Q_{H1,C1,5} - y_{H1,C1}U_{H1,C1} \leq 0$
2	H1-C2	$Q_{H1,C2,3} + Q_{H1,C2,4} + Q_{H1,C2,5} - y_{H1,C2}U_{H1,C2} \leq 0$
3	H1-C3	$Q_{H1,C3,4} - y_{H1,C3}U_{H1,C3} \leq 0$
4	H1-C4	$Q_{H1,C4,5} - y_{H1,C4}U_{H1,C4} \leq 0$
5	(H2-C1)_above_HPS_pinch	$Q_{H2,C1,4} + Q_{H2,C1,5} - (y_{H2,C1})_{above_HPS_pinch}(U_{H2,C1})_{above_HPS_pinch} \leq 0$
6	(H2-C2)_above_HPS_pinch	$Q_{H2,C2,4} + Q_{H2,C2,5} - (y_{H2,C2})_{above_HPS_pinch}(U_{H2,C2})_{above_HPS_pinch} \leq 0$
7	H2-C3	$Q_{H2,C3,4} - y_{H2,C3}U_{H2,C3} \leq 0$
8	(H2-C4)_above_HPS_pinch	$Q_{H2,C4,5} - (y_{H2,C4})_{above_HPS_pinch}(U_{H2,C4})_{above_HPS_pinch} \leq 0$
9	(H2-C1)_below_HPS_pinch	$Q_{H2,C1,6} - (y_{H2,C1})_{below_HPS_pinch}(U_{H2,C1})_{below_HPS_pinch} \leq 0$

10	(H2-C2)_below_HPS_pinch	$Q_{H2,C2,6} + Q_{H2,C2,7} + Q_{H2,C2,8} - \left(y_{H2,C2}\right)_{below_HPS_pinch}\left(U_{H2,C2}\right)_{below_HPS_pinch} \leq 0$
11	(H2-C4)_below_HPS_pinch	$Q_{H2,C4,6} + Q_{H2,C4,7} - \left(y_{H2,C4}\right)_{below_HPS_pinch}\left(U_{H2,C4}\right)_{below_HPS_pinch} \leq 0$
12	(H3-C1)_above_HPS_pinch	$Q_{H3,C1,4} + Q_{H3,C1,5} - \left(y_{H3,C1}\right)_{above_HPS_pinch}\left(U_{H3,C1}\right)_{above_HPS_pinch} \leq 0$
13	(H3-C2)_above_HPS_pinch	$Q_{H3,C2,3} + Q_{H3,C2,4} + Q_{H3,C2,5} - \left(y_{H3,C2}\right)_{above_HPS_pinch}\left(U_{H3,C2}\right)_{above_HPS_pinch} \leq 0$
14	H3-C3	$Q_{H3,C3,4} - y_{H3,C3}U_{H3,C3} \leq 0$
15	(H3-C4)_above_HPS_pinch	$Q_{H3,C4,5} - \left(y_{H3,C4}\right)_{above_HPS_pinch}\left(U_{H3,C4}\right)_{above_HPS_pinch} \leq 0$
16	(H3-C1)_below_HPS_pinch	$Q_{H3,C1,6} - \left(y_{H3,C1}\right)_{below_HPS_pinch}\left(U_{H3,C1}\right)_{below_HPS_pinch} \leq 0$
17	(H3-C2)_below_HPS_pinch	$Q_{H3,C2,6} + Q_{H3,C2,7} + Q_{H3,C2,8} - \left(y_{H3,C2}\right)_{below_HPS_pinch}\left(U_{H3,C2}\right)_{below_HPS_pinch} \leq 0$
18	(H3-C4)_below_HPS_pinch	$Q_{H3,C4,6} + Q_{H3,C4,7} - \left(y_{H3,C4}\right)_{below_HPS_pinch}\left(U_{H3,C4}\right)_{below_HPS_pinch} \leq 0$

19	HPS-C1	$Q_{HPS,C1,6} - y_{HPS,C1}U_{HPS,C1} \leq 0$
20	HPS -C2	$Q_{HPS,C2,6} + Q_{HPS,C2,7} + Q_{HPS,C2,8} - y_{HPS,C2}U_{HPS,C2} \leq 0$
21	HPS -C4	$Q_{HPS,C4,6} + Q_{HPS,C4,7} - y_{HPS,C4}U_{HPS,C4} \leq 0$
22	F-C1	$Q_{F,C1,4} + Q_{F,C1,5} - y_{F,C1}U_{F,C1} \leq 0$
23	F-C2	$Q_{F,C2,3} + Q_{F,C2,4} + Q_{F,C2,5} - y_{F,C2}U_{F,C2} \leq 0$
24	F-C3	$Q_{F,C3,4} - y_{F,C3}U_{F,C3} \leq 0$
25	F-C4	$Q_{F,C4,5} - y_{F,C4}U_{F,C4} \leq 0$

Table S33. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 2 with multiple utilities employed to devise de HEN.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	F-C4	QS,C4,5	49.39
1	H1-C2	QH1,C2,3	14.4
		QH1,C2,4	2.78
		QH1,C2,5	1.61
2	H1-C1	QH1,C1,4	13.23
		QH1,C1,5	6.62
3	H1-C3	QH1,C3,4	412.8
4	H3-C1	QH3,C1,4	146.77
		QH3,C1,5	105.38
5	H3-C4	QH3,C4,5	81.81
6	H2-C2	QH2,C2,4	190.82
		QH2,C2,5	110.39

7	HPS-C1	QHPS,C1,6	48
8	HPS-C4	QHPS,C4,6	61.19
		QHPS,C4,7	58.98
9	H2-C2	QH2,C2,6	32.16
		QH2,C2,7	80
		QH2,C2,8	14
10	H3-C2	QH3,C2,6	15.84
11	H3-C4	QH3,C4,6	17.54
		QH3,C4,7	72.23
12	H3-C2	QH3,C2,8	66

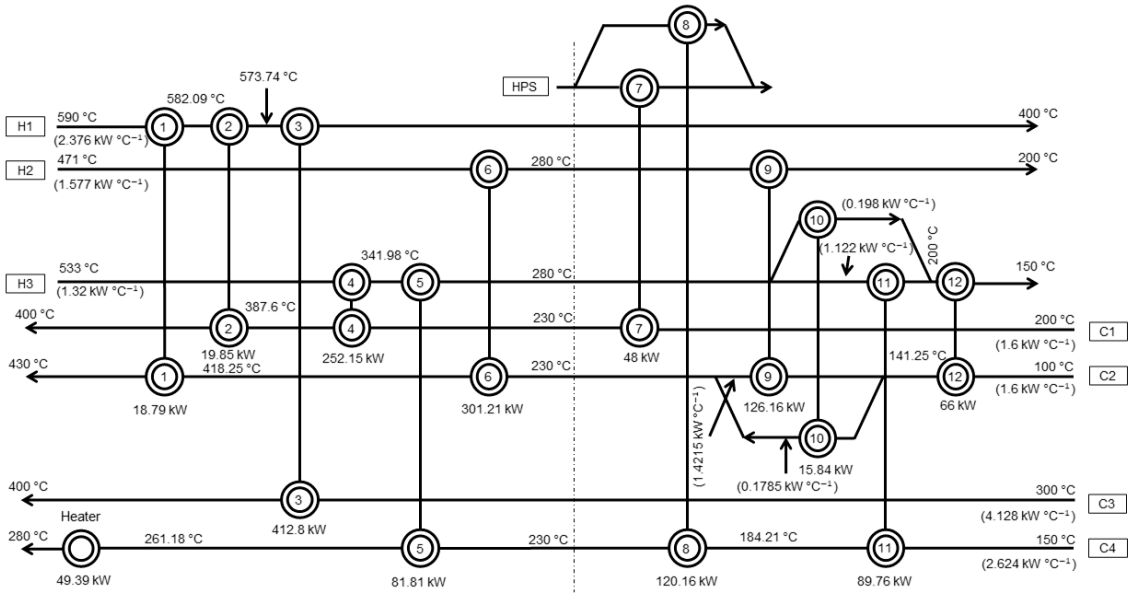


Figure S11. HEN with multiple utilities for Example 2.

Table S34. Costs for HEN with multiple utilities for Example 2.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P ($)
1	161.91	0.26	17830.03
2	184.11	0.24	17830.03
3	133.48	6.97	17830.03
4	127.96	4.44	17830.03
5	64.17	2.87	17830.03
6	51.36	13.21	17830.03
7	63.83	1.69	17830.03
8	70.42	3.84	17830.03
9	54.26	5.24	17830.03
10	54.26	0.66	17830.03
11	70.42	2.87	17830.03

12	54.26	2.74	17830.03
Heater	529.36	0.21	17830.03
		Total	231790.37

Example 3 without multiple utilities

Table S35. Source and target temperatures, C value, and the multiple utilities for Example 3.

Stream	Source temperatura T^s (K)	Target temperatura T^t (K)	C (kW K^{-1})	References
H1	413	313	328.84	(Mizutani, Pessoa, Queiroz, Hauan, & Grossmann, 2003)
H2	433	393	576.69	
H3	483	318	29.69	
H4	533	333	69.94	
H5	553	483	250.31	
H6	623	443	34.85	
H7	653	433	95.46	
C1	543	658	576.69	
C2	403	543	350.92	
C3	293	403	255.22	
Fuel	1073.15	1073.15		(Chang et al., 2017)
Steam	605.4	605.4		(Seider, Seader, Lewin, &

				Widagdo, 2009)
BFW	383.15	383.15		(Seider et al., 2009)
W	288.15			(Chang et al., 2017)

Table S36. Adjusted temperatures using the Temperature Interval method for Example 3 with ΔT_{min}=10 K.

Stream	T^s (K)	T^t (K)	C (kW K^{-1})	Adjusted temperatures	
				T^s (K)	T^t (K)
H1	413	313	328.836	403	303
H2	433	393	576.69	423	383
H3	483	318	29.6934	473	308
H4	533	333	69.939	523	323
H5	553	483	250.308	543	473
H6	623	443	34.8468	613	433
H7	653	433	95.4606	643	423
C1	543	658	576.69	533	648
C2	403	543	350.922	393	533
C3	293	403	255.216	283	393

Table S37. MER targets and the pinch value using the Temperature interval method for Example 3.

Temperature intervals (K)		$\sum C_H$-$\sum C_C$ (kW K^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the Fuel (kW)
					[a]51646.88
648	643	-576.69	-2883.45	-2883.45	48763.43
643	613	-481.2294	-14436.88	-17320.33	34326.55
613	543	-446.3826	-31246.78	-48567.11	3079.77
543	533	-196.0746	-1960.75	-50527.86	1119.02
533	523	29.6934	296.94	-50230.93	1415.96
523	473	99.6324	4981.62	-45249.31	6397.58
473	433	-120.9822	-4839.29	-50088.59	1558.29
433	[b]423	-155.829	-1558.29	-51646.88	0
423	403	325.4004	6508.01	-45138.88	6508.01
403	393	654.2364	6542.36	-38596.51	13050.37
393	383	749.9424	7499.42	-31097.09	20549.8

383	323	173.2524	10395.14	-20701.94	30944.94
323	308	103.3134	1549.7	-19152.24	32494.64
308	303	73.62	368.1	-18784.14	32862.74
303	283	-255.216	-5104.32	-23888.46	[c]27758.42

[a]Fuel value

[b]Pinch temperature for cold streams

[c]Water value

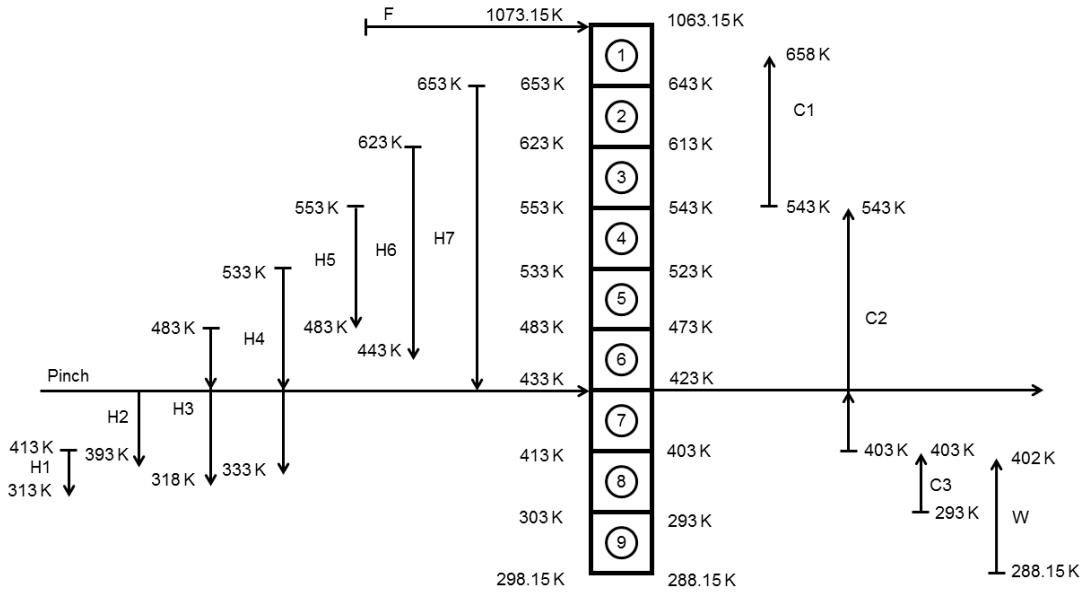


Figure S12. Temperature intervals for Example 3.

Table S38. Energy balances for Example 3.

No.	Stream	Energy balances
1	F	$R_{F,1} + Q_{F,C1,1} = Q_{F,1}^{H}$
2		$R_{F,2} + Q_{F,C1,2} - R_{S,1} = Q_{F,2}^{H}$
3		$R_{F,3} + Q_{F,C1,3} - R_{F,2} = Q_{F,3}^{H}$
4		$R_{F,4} + Q_{F,C2,4} - R_{F,3} = Q_{F,4}^{H}$
5		$R_{F,5} + Q_{F,C2,5} - R_{F,4} = Q_{F,5}^{H}$
6		$Q_{F,C2,6} - R_{F,5} = Q_{F,6}^{H}$
7	H7	$R_{H7,2} + Q_{H7,C1,2} = Q_{H7,2}^{H}$
8		$R_{H7,3}+Q_{H7,C1,3} - R_{H7,2} = Q_{H7,3}^{H}$
9		$R_{H7,4}+Q_{H7,C2,4} - R_{H7,3} = Q_{H7,4}^{H}$
10		$R_{H7,5}+Q_{H7,C2,5} - R_{H7,4} = Q_{H7,5}^{H}$
11		$Q_{H7,C2,6} - R_{H7,5} = Q_{H7,6}^{H}$
12	H6	$R_{H6,3} + Q_{H6,C1,3} = Q_{H6,3}^{H}$
13		$R_{H6,4} + Q_{H6,C2,4} - R_{H6,3} = Q_{H6,4}^{H}$
14		$R_{H6,5} + Q_{H6,C2,5} - R_{H6,4} = Q_{H6,5}^{H}$

15		$Q_{H6,C2,6} - R_{H6,5} = Q^{H}_{H6,6}$
16	H5	$R_{H5,4} + Q_{H5,C2,4} = Q^{H}_{H5,4}$
17		$R_{H5,5} + Q_{H5,C2,5} - R_{H5,4} = Q^{H}_{H5,5}$
18		$Q_{H5,C2,6} - R_{H5,5} = Q^{H}_{H5,6}$
19	H4	$R_{H4,5} + Q_{H4,C2,5} = Q^{H}_{H4,5}$
20		$Q_{H4,C2,6} - R_{H4,5} = Q^{H}_{H4,6}$
21		$R_{H4,7} + Q_{H4,C2,7} = Q^{H}_{H4,7}$
22		$R_{H4,8} + Q_{H4,C3,8} + Q_{H4,W,8} - R_{H4,7} = Q^{H}_{H4,8}$
23		$Q_{H4,W,9} - R_{H4,8} = Q^{H}_{H4,9}$
24	H3	$R_{H3,6} + Q_{H3,C2,6} = Q^{H}_{H3,6}$
25		$R_{H3,7} + Q_{H3,C2,7} = Q^{H}_{H3,7}$
26		$R_{H3,8} + Q_{H3,C3,8} + Q_{H3,W,8} - R_{H3,7} = Q^{H}_{H3,8}$
27		$Q_{H3,W,9} - R_{H3,8} = Q^{H}_{H3,9}$
28	H2	$R_{H2,7} + Q_{H2,C2,7} = Q^{H}_{H2,7}$
29		$R_{H2,8} + Q_{H2,C3,8} + Q_{H2,W,8} - R_{H2,7} = Q^{H}_{H2,8}$

30		$Q_{H2,W,9} - R_{H2,8} = Q^{H}_{H2,9}$
31	H1	$R_{H1,8} + Q_{H1,C3,8} + Q_{H1,W,8} = Q^{H}_{H1,8}$
32		$Q_{H1,W,9} - R_{H1,8} = Q^{H}_{H1,9}$
33	C1	$Q_{F,C1,1} = Q^{C}_{C1,1}$
34		$Q_{H7,C1,2} + Q_{F,C1,2} = Q^{C}_{C1,2}$
35		$Q_{H6,C1,3} + Q_{H7,C1,3} + Q_{F,C1,3} = Q^{C}_{C1,3}$
36	C2	$Q_{H5,C2,4} + Q_{H6,C2,4} + Q_{H7,C2,4} + Q_{F,C2,4} = Q^{C}_{C2,4}$
37		$Q_{H4,C2,5} + Q_{H5,C2,5} + Q_{H6,C2,5} + Q_{H7,C2,5} + Q_{F,C2,5} = Q^{C}_{C2,5}$
38		$Q_{H3,C2,6} + Q_{H4,C2,6} + Q_{H5,C2,6} + Q_{H6,C2,6} + Q_{H7,C2,6} + Q_{F,C2,6} = Q^{C}_{C2,6}$
39		$Q_{H2,C2,7} + Q_{H3,C2,7} + Q_{H4,C2,7} = Q^{C}_{C2,7}$
40	C3	$Q_{H1,C3,8} + Q_{H2,C3,8} + Q_{H3,C3,8} + Q_{H4,C3,8} = Q^{C}_{C3,8}$
41	W	$Q_{H1,W,8} + Q_{H2,W,8} + Q_{H3,W,8} + Q_{H4,W,8} = Q^{C}_{W,8}$
42		$Q_{H1,W,9} + Q_{H2,W,9} + Q_{H3,W,9} + Q_{H4,W,9} = Q^{C}_{W,9}$
43		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} + Q^{H}_{F,4} + Q^{H}_{F,5} + Q^{H}_{F,6} = 55156.1\ kW$

Table S39. Variables to solve the energy balances for Example 3.

No.	Parameter
1	RF,1[a]
2	QF,C1,1[a]
3	QF,1^H[a]
4	QF,C1,2[a]
5	RF,2[a]
6	QF,2^H[a]
7	QF,C1,3[a]
8	RF,3[a]
9	QF,3^H[a]
10	QF,C2,4[a]
11	RF,4[a]
12	QF,4^H[a]
13	QF,C2,5[a]

14	RF,5[a]
15	QF,5^H[a]
16	QF,C2,6[a]
17	QF,6^H[a]
18	QH7,C1,2[b]
19	RH7,2[b]
20	QH7,C1,3[b]
21	RH7,3[b]
22	QH7,C2,4[b]
23	RH7,4[b]
24	QH7,C2,5[b]
25	RH7,5[b]
26	QH7,C2,6[b]
27	QH6,C1,3[c]
28	RH6,3[c]

29	QH6,C2,4[c]
30	RH6,4[c]
31	QH6,C2,5[c]
32	RH6,5[c]
33	QH6,C2,6[c]
34	QH5,C2,4[d]
35	RH5,4[d]
36	QH5,C2,5[d]
37	RH5,5[d]
38	QH5,C2,6[d]
39	QH5,6^H[d]
40	QH4,C2,5[e]
41	RH4,5[e]
42	QH4,C2,6[e]
43	QH4,C2,7[e]

44	RH4,7[e]
45	QH4,C3,8[e]
46	QH4,W,8[e]
47	RH4,8[e]
48	QH4,W,9[e]
49	QH4,9^H[e]
50	QH3,C2,6[f]
51	RH3,6[f]
52	QH3,C2,7[f]
53	RH3,7[f]
54	QH3,C3,8[f]
55	QH3,W,8[f]
56	RH3,8[f]
57	QH3,W,9[f]
58	QH3,9^H[f]

59	QH2,C2,7[g]
60	RH2,7[g]
61	QH2,C3,8[g]
62	QH2,W,8[g]
63	RH2,8[g]
64	QH2,W,9[g]
65	QH2,9^H[g]
66	QH1,C3,8[h]
67	QH1,W,8[h]
68	RH1,8[h]
69	QH1,W,9[h]
70	QH1,9^H[h]
71	Y(F-C1)[i]
72	Y(F-C2)[i]
73	Y(H7-C1)[i]

74	$Y(H7\text{-}C2)^{i}$
75	$Y(H6\text{-}C1)^{i}$
76	$Y(H6\text{-}C2)^{i}$
77	$Y(H5\text{-}C2)^{i}$
78	$Y(H4\text{-}C2)^{i}$
79	$Y(H4\text{-}C2)^{i}$
80	$Y(H4\text{-}C3)^{i}$
81	$Y(H4\text{-}W)^{i}$
82	$Y(H3\text{-}C2)^{i}$
83	$Y(H3\text{-}C2)^{i}$
84	$Y(H3\text{-}C3)^{i}$
85	$Y(H3\text{-}W)^{i}$
86	$Y(H2\text{-}C2)^{i}$
87	$Y(H2\text{-}C3)^{i}$
88	$Y(H2\text{-}W)^{i}$

89	Y(H1-C3)[i]
90	Y(H1-W)[i]

Continuous variables related to [a]F utility stream, [b]H7, [c]H6, [d]H5, [e]H4, [f]H3, [g]H2, and [h]H1 hot streams. [i]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S40. Constant parameters to solve energy balances for Example 3.

No.	Parameter	Value (kW)
1	QH7,2^H	2863.82
2	QH7,3^H	6682.24
3	QH7,4^H	1909.21
4	QH7,5^H	4773.03
5	QH7,6^H	4773.03
6	QH6,3^H	2439.28
7	QH6,4^H	696.94
8	QH6,5^H	1742.34
9	QH6,6^H	1393.87
10	QH5,4^H	5006.16
11	QH5,5^H	12515.4
12	QH4,5^H	3496.95
13	QH4,6^H	3496.95
14	QH4,7^H	1398.78

15	QH4,8^H	5595.12
16	QH3,6^H	1484.67
17	QH3,7^H	593.87
18	QH3,8^H	2820.87
19	QH2,7^H	11533.8
20	QH2,8^H	11533.8
21	QH1,8^H	32883.6
22	QC1,1^C	8650.35
23	QC1,2^C	17300.7
24	QC1,3^C	40368.3
25	QC2,4^C	7018.44
26	QC2,5^C	17546.1
27	QC2,6^C	17546.1
28	QC2,7^C	7018.44
29	QC3,8^C	28073.76
30	QW,8^C	29935.64

31	QW,9^C	1332

Table S41. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 3.

No.	Parameter	Value (kW)
1	U(F-C1) = min(55156.1;66319.35)	55156.1
2	U(F-C2) = min(55156.1;42110.64)	42110.64
3	U(H7-C1) = min(9546.06;57669)	9546.06
4	U(H7-C2) = min(21001.33;42110.64)	21001.33
5	U(H6-C1) = min(2439.28;40368.3)	2439.28
6	U(H6-C2) = min(6272.42;42110.64)	6272.42
7	U(H5-C2) = min(17521.56;42110.64)	17521.56
8	U(H4-C2) = min(6993.9;35092.2)	6993.9
9	U(H4-C2) = min(1398.78;7018.44)	1398.78
10	U(H4-C3) = min(6993.9;28073.76)	6993.9
11	U(H4-W) = min(6993.9;31267.64)	6993.9
12	U(H3-C2) = min(1484.67;17546.1)	1484.67
13	U(H3-C2) = min(593.87;7018.44)	593.87

14	U(H3-C3) = min(3414.74;28073.76)	3414.74
15	U(H3-W) = min(3414.74;31267.641)	3414.74
16	U(H2-C2) = min(11533.8;7018.44)	7018.44
17	U(H2-C3) = min(23067.6;28073.76)	23067.6
18	U(H2-W) = min(23067.6;31267.64)	23067.6
19	U(H1-C3) = min(32883.6;28073.76)	28073.76
20	U(H1-W) = min(32883.6;31267.64)	31267.64

Table S42. Restrictions describing heat exchangers between utilities and streams from Example 3.

No.	Heat Exchanger	Restriction
1	F-C1	$Q_{F,C1,1} + Q_{F,C1,2} + Q_{F,C1,3} - y_{F-C1}U_{F-C1} \leq 0$
2	F-C2	$Q_{F,C2,4} + Q_{F,C2,5} + Q_{F,C2,6} - y_{F-C2}U_{F-C2} \leq 0$
3	H7-C1	$Q_{H7,C1,2} + Q_{H7,C1,3} - y_{H7-C1}U_{H1-C1} \leq 0$
4	H7-C2	$Q_{H7,C2,4} + Q_{H7,C2,5} + Q_{H7,C2,6} - y_{H7-C2}U_{H1-C2} \leq 0$
5	H6-C1	$Q_{H6,C1,3} - y_{H6-C1}U_{H6-C1} \leq 0$
6	H6-C2	$Q_{H6,C2,4} + Q_{H6,C2,5} + Q_{H6,C2,6} - y_{H6-C2}U_{H6-C2} \leq 0$
7	H5-C2	$Q_{H5,C2,4} + Q_{H5,C2,5} + Q_{H5,C2,6} - y_{H5-C2}U_{H5-C2} \leq 0$
8	(H4-C2)_above_process_pinch	$Q_{H4,C2,5} + Q_{H4,C2,6} - (y_{H4-C2})_{above_process_pinch}(U_{H4-C2})_{above_process_pinch} \leq 0$
9	(H4-C2)_below_process_pinch	$Q_{H4,C2,7} - (y_{H2-C2})_{below_process_pinch}(U_{H4-C2})_{below_process_pinch} \leq 0$
10	H4-C3	$Q_{H4,C3,8} - y_{H4-C3}U_{H4-C3} \leq 0$
11	H4-W	$Q_{H4,W,8} + Q_{H4,W,9} - y_{H4-W}U_{H4-W} \leq 0$

12	(H3-C2)_above_process_pinch	$Q_{H3,C2,6} - (y_{H3-C2})_{above_process_pinch}(U_{H3-C2})_{above_process_pinch} \leq 0$
13	(H3-C2)_below_process_pinch	$Q_{H3,C2,7} - (y_{H3-C2})_{below_process_pinch}(U_{H3-C2})_{below_process_pinch} \leq 0$
14	H3-C3	$Q_{H3,C3,8} - y_{H3-C3}U_{H3-C3} \leq 0$
15	H3-W	$Q_{H3,W,8} + Q_{H3,W,9} - y_{H3-W}U_{H3-W} \leq 0$
16	H2-C2	$Q_{H2,C2,7} - y_{H2-C2}U_{H2-C2} \leq 0$
17	H2-C3	$Q_{H2,C3,8} - y_{H2-C3}U_{H2-C3} \leq 0$
18	H2-W	$Q_{H2,W,8} + Q_{H2,W,9} - y_{H2-W}U_{H2-W} \leq 0$
19	H1-C3	$Q_{H1,C3,8} - y_{H1-C3}U_{H1-C3} \leq 0$
20	H1-W	$Q_{H1,W,8} + Q_{H1,W,9} - y_{H1-W}U_{H1-W} \leq 0$

Table S43. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 3.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater-1	F-C1	QF,C1,1	8650.35
		QF,C1,2	17300.7
		QF,C1,3	28880.93
Heater-2	F-C2	QF,C2,4	0
		QF,C2,5	60.67
		QF,C2,6	263.46
1	H7-C1	QH7,C1,2	0
		QH7,C1,3	9161.63
2	H5-C2	QH5,C2,4	4724.8
	H5-C2	QH5,C2,5	6753.92
	H5-C2	QH5,C2,6	6042.84
3	H7-C2	QH7,C2,4	2293.64
	H7-C2	QH7,C2,5	4773.03

	H7-C2	QH7,C2,6	4773.03
4	H6-C1	QH6,C1,3	2325.74
5	H4-C2	QH4,C2,5	3496.95
	H4-C2	QH4,C2,6	3496.95
6	H6-C2	QH6,C2,4	0
	H6-C2	QH6,C2,5	2461.53
	H6-C2	QH6,C2,6	1485.16
7	H3-C2	QH3,C2,6	1484.67
8	H2-C2	QH2,C2,7	7018.44
9	H1-C3	QH1,C3,8	21079.86
10	H4-C3	QH4,C3,8	6993.9
Cooler-1	H3-W	QH3,W,8	2082.74
		QH3,W,9	1332
Cooler-2	H2-W	QH2,W,8	16049.16
		QH2,W,9	0

Cooler-3	H1-W	QH1,W,8	11803.74
		QH1,W,9	0

Table S44. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 3 employed to devise the HEN.

No.	Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
1	Heater-1	F-C1	QF,C1,1	8650.35
			QF,C1,2	17300.7
			QF,C1,3	28880.93
2	Heater-2	F-C2	QF,C2,4	0
			QF,C2,5	60.67
3	Heater-3	F-C2	QF,C2,6	263.46
4	1	H7-C1	QH7,C1,2	0
			QH7,C1,3	9161.63
5	2	H5-C2	QH5,C2,4	4724.8
6	3	H7-C2	QH7,C2,4	2293.64
7	4	H6-C1	QH6,C1,3	2325.74
8	5	H4-C2	QH4,C2,5	3496.95

9	6	H6-C2	QH6,C2,4	0
		H6-C2	QH6,C2,5	2461.53
10	7	H7-C2	QH7,C2,5	4773.03
11	8	H5-C2	QH5,C2,5	6753.92
12	9	H7-C2	QH7,C2,6	4773.03
13	10	H5-C2	QH5,C2,6	6042.84
14	11	H6-C2	QH6,C2,6	1485.16
15	12	H4-C2	QH4,C2,6	3496.95
16	13	H3-C2	QH3,C2,6	1484.67
17	14	H2-C2	QH2,C2,7	7018.44
18	15	H1-C3	QH1,C3,8	21079.86
19	16	H4-C3	QH4,C3,8	6993.9
20	Cooler-3	H3-W	QH3,W,8	2082.74
			QH3,W,9	1332
21	Cooler-2	H2-W	QH2,W,8	16049.16

			QH2,W,9	0
22	Cooler-1	H1-W	QH1,W,8	11803.74
			QH1,W,9	0

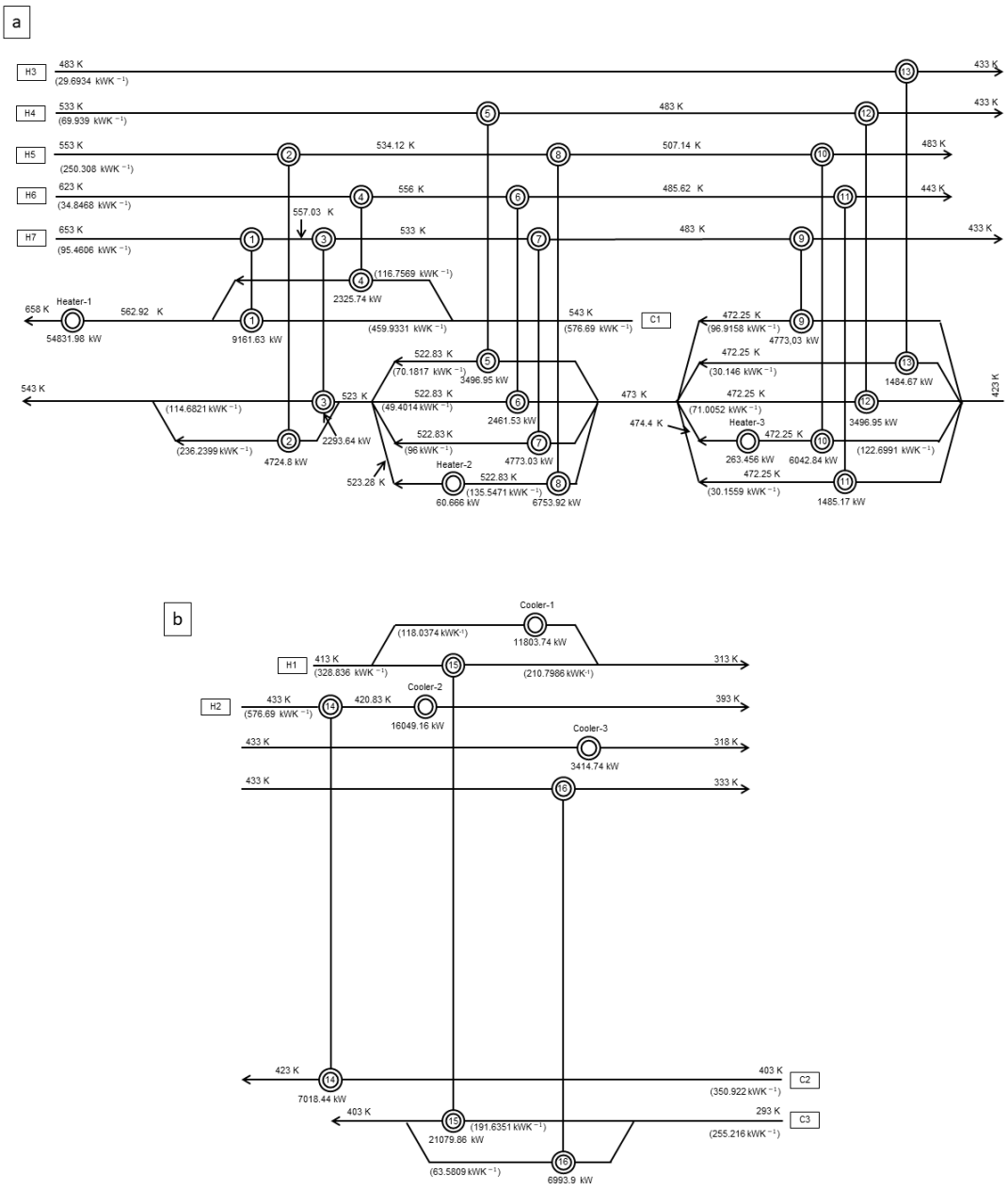


Figure S13. HEN with F and W for Example 3. (a) Heat and (b) cold process pinch side.

Table S45. Costs for HEN without multiple utilities for Example 3.

Unit name	ΔT_{LM} (K)	A (m^2)	C_P (\$)
1	40.37	511.18	14998.05
2	10.55	1008.47	19340.17
3	11.9	434.11	14301.26
4	30.8	170.09	12052.54
5	10.09	780.87	17388.04
6	21.34	259.83	12745.66
7	10.09	1065.82	19823.92
8	20.62	737.84	17012.49
9	10.37	1036.57	19577.53
10	46.31	293.88	13040.76
11	16.46	203.18	12285.59
12	10.37	759.44	17201.27
13	10.37	322.43	13293.7
14	13.54	1167.66	32647.07

15	14.42	3291.88	60263.69
16	34.76	453.16	14473.84
Heater-1	461.06	267.85	12814.37
Heater-2	550.1	0.25	17830.03
Heater-3	599.83	0.99	17830.03
Cooler-1	16.99	1565.23	34683.81
Cooler-2	49.61	728.63	16931.88
Cooler-3	30.42	252.81	12686.11
		Total	423221.79

Example 3 with multiple utilities

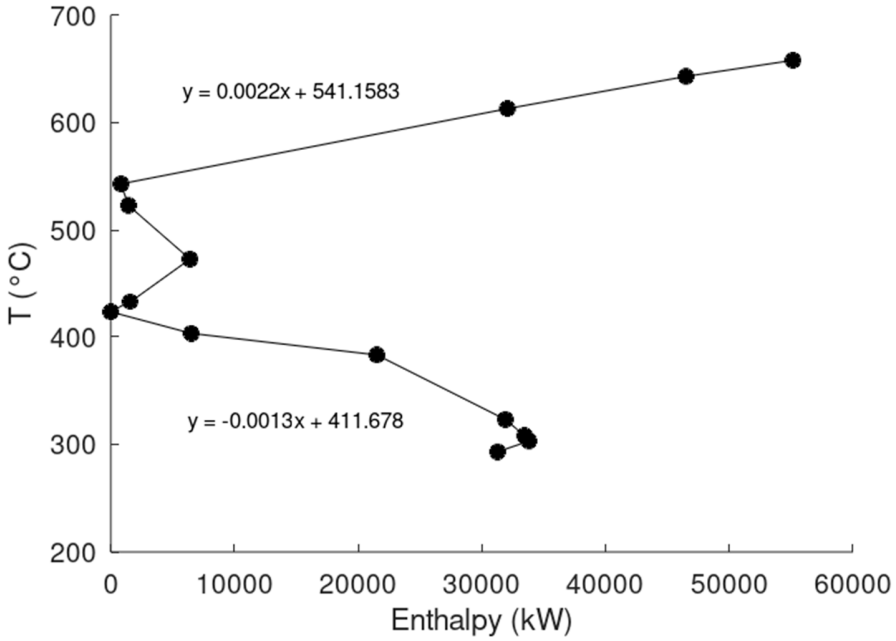


Figure S14. Grand Composite Curve for Example 3. Equation "y=0.0022x+541.1583" corresponds to the 613 K and 543 K line. Moreover, the equation "y= -0.0013x+411.678" describes the line between 403 K and 383 K.

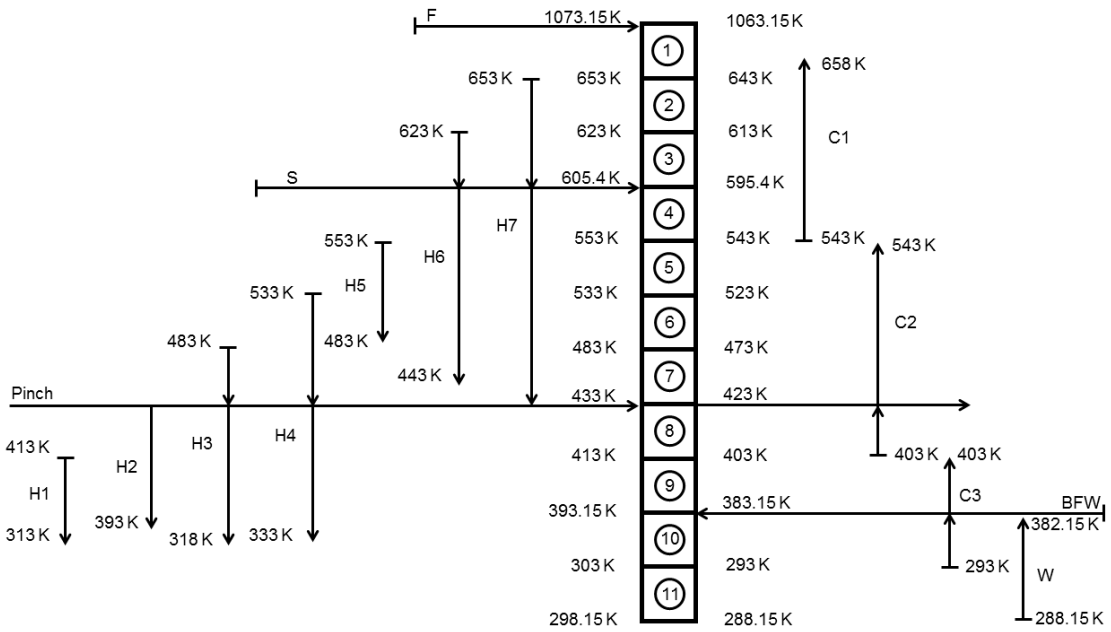


Figure S15. Temperature intervals for Example 3 with multiple utilities.

Table S46. Energy balances for Example 3 with multiple utilities.

No.	Stream	Energy balance
1	F	$R_{F,1} + Q_{F,C1,1} = Q^H_{F,1}$
2		$R_{F,2} + Q_{F,C1,2} - R_{F,1} = Q^H_{F,2}$
3		$R_{F,3} + Q_{F,C1,3} - R_{F,2} = Q^H_{F,3}$
4	H7	$R_{H7,2} + Q_{H7,C1,2} = Q^H_{H7,2}$
5		$Q_{H7,C1,3} - R_{H7,2} = Q^H_{H7,3}$
6		$R_{H7,4}+Q_{H7,C1,4} = Q^H_{H7,4}$
7		$R_{H7,5}+Q_{H7,C2,5} - R_{H7,4} = Q^H_{H7,5}$
8		$R_{H7,6}+Q_{H7,C2,6} - R_{H7,5} = Q^H_{H7,6}$
9		$Q_{H7,C2,7} - R_{H7,6} = Q^H_{H7,7}$
10	H6	$R_{H6,3} + Q_{H6,C1,3} = Q^H_{H6,3}$
11		$R_{H6,4} + Q_{H6,C1,4} = Q^H_{H6,4}$
12		$R_{H6,5}+Q_{H6,C2,5} - R_{H6,4} = Q^H_{H6,5}$
13		$R_{H6,6}+Q_{H6,C2,6} - R_{H6,5} = Q^H_{H6,6}$
14		$Q_{H6,C2,7} - R_{H6,6} = Q^H_{H6,7}$

15	S	$R_{S,4}+Q_{S,C1,4} = Q^H_{S,4}$
16		$R_{S,5}+Q_{S,C2,5} - R_{S,4} = Q^H_{S,5}$
17		$R_{S,6}+Q_{S,C2,6} - R_{S,5} = Q^H_{S,6}$
18		$R_{S,7}+Q_{S,C2,7} - R_{S,6} = Q^H_{S,7}$
19	H5	$R_{H5,5} + Q_{H5,C2,5} = Q^H_{H5,5}$
20		$R_{H5,6} + Q_{H5,C2,6} - R_{H5,5} = Q^H_{H5,6}$
21		$R_{H5,7} + Q_{H5,C2,7} - R_{H5,6} = Q^H_{H5,7}$
22	H4	$R_{H4,6} + Q_{H4,C2,6} = Q^H_{H4,6}$
23		$Q_{H4,C2,7} - R_{H4,6} = Q^H_{H4,7}$
24		$R_{H4,8} + Q_{H4,C2,8} + Q_{H4,BFW,8} = Q^H_{H4,8}$
25		$Q_{H4,C3,9} + Q_{H4,BFW,9} - R_{H4,8} = Q^H_{H4,9}$
26		$R_{H4,10} + Q_{H4,C3,10}+Q_{H4,W,10} = Q^H_{H4,10}$
27		$Q_{H4,W,11}-R_{H4,10} = Q^H_{H4,11}$
28	H3	$R_{H3,7} + Q_{H3,C2,7} = Q^H_{H3,7}$
29		$R_{H3,8} + Q_{H3,C2,8} + Q_{H3,BFW,8} = Q^H_{H3,8}$

30		$Q_{H3,C3,9} + Q_{H3,BFW,9} - R_{H3,8} = Q^{H}_{H3,9}$
31		$R_{H3,10} + Q_{H3,C3,10} + Q_{H3,W,10} = Q^{H}_{H3,10}$
32		$Q_{H3,W,11} - R_{H3,10} = Q^{H}_{H3,11}$
33	H2	$R_{H2,8} + Q_{H2,C2,8} + Q_{H2,BFW,8} = Q^{H}_{H2,8}$
34		$Q_{H2,C3,9} + Q_{H2,BFW,9} - R_{H2,8} = Q^{H}_{H2,9}$
35		$R_{H2,10} + Q_{H2,C3,10} + Q_{H2,W,10} = Q^{H}_{H2,10}$
36		$Q_{H2,W,11} - R_{H2,10} = Q^{H}_{H2,11}$
37	H1	$R_{H1,9} + Q_{H1,C3,9} + Q_{H1,BFW,9} = Q^{H}_{H1,9}$
38		$R_{H1,10} + Q_{H1,C3,10} + Q_{H1,W,10} = Q^{H}_{H1,10}$
39		$Q_{H1,W,11} - R_{H1,10} = Q^{H}_{H1,11}$
40	C1	$Q_{F,C1,1} = Q^{C}_{C1,1}$
41		$Q_{H7,C1,2} + Q_{F,C1,2} = Q^{C}_{C1,2}$
42		$Q_{H6,C1,3} + Q_{H7,C1,3} + Q_{F,C1,3} = Q^{C}_{C1,3}$
43		$Q_{S,C1,4} + Q_{H6,C1,4} + Q_{H7,C1,4} = Q^{C}_{C1,4}$
44	C2	$Q_{H5,C2,5} + Q_{H6,C2,5} + Q_{H7,C2,5} + Q_{S,C2,5} = Q^{C}_{C2,5}$

45		$Q_{H4,C2,6} + Q_{H5,C2,6} + Q_{H6,C2,6} + Q_{H7,C2,6} + Q_{S,C2,6} = Q^{C}_{C2,6}$
46		$Q_{H3,C2,7} + Q_{H4,C2,7} + Q_{H5,C2,7} + Q_{H6,C2,7} + Q_{H7,C2,7} + Q_{S,C2,7} = Q^{C}_{C2,7}$
47		$Q_{H2,C2,8} + Q_{H3,C2,8} + Q_{H4,C2,8} = Q^{C}_{C2,8}$
48	C3	$Q_{H1,C3,9} + Q_{H2,C3,9} + Q_{H3,C3,9} + Q_{H4,C3,9} = Q^{C}_{C3,9}$
49		$Q_{H1,C3,10} + Q_{H2,C3,10} + Q_{H3,C3,10} + Q_{H4,C3,10} = Q^{C}_{C3,10}$
50	BFW	$Q_{H2,BFW,8} + Q_{H3,BFW,8} + Q_{H4,BFW,8} = Q^{C}_{BFW,8}$
51		$Q_{H1,BFW,9} + Q_{H2,BFW,9} + Q_{H3,BFW,9} + Q_{H4,BFW,9} = Q^{C}_{BFW,9}$
52	W	$Q_{H1,W,10} + Q_{H2,W,10} + Q_{H3,W,10} + Q_{H4,W,10} = Q^{C}_{W,10}$
53		$Q_{H1,W,11} + Q_{H2,W,11} + Q_{H3,W,11} + Q_{H4,W,11} = Q^{C}_{W,11}$
54		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} = 30943.57$
55		$Q^{H}_{S,4} + Q^{H}_{S,5} + Q^{H}_{S,6} + Q^{H}_{S,7} = 24212.54$
56		$Q^{C}_{BFW,8} + Q^{C}_{BFW,9} = 21394.37$

Table S47. Variables to solve the energy balances for Example 3 with multiple utilities.

No.	Continuous variables
1	RS,1[a]
2	QF,C1,1[a]
3	QF,1^H[a]
4	QF,C1,2[a]
5	RF,2[a]
6	QF,2^H[a]
7	QF,C1,3[a]
8	QF,3^H[a]
9	QS,C1,4[b]
10	RS,4[b]
11	QS,4^H[b]
12	QS,C2,5[b]
13	RS,5[b]
14	QS,5^H[b]

15	QS,C2,6[b]
16	RS,6[b]
17	QS,6^H[b]
18	QS,C2,7[b]
19	QS,7^H[b]
20	QH7,C1,2[c]
21	RH7,2[c]
22	QH7,C1,3[c]
23	QH7,C1,4[c]
24	RH7,4[c]
25	QH7,C2,5[c]
26	RH7,5[c]
27	QH7,C2,6[c]
28	RH7,6[c]
29	QH7,C2,7[c]

30	QH6,C1,3[d]
31	RH6,3[d]
32	QH6,C1,4[d]
33	RH6,4[d]
34	QH6,C2,5[d]
35	RH6,5[d]
36	QH6,C2,6[d]
37	RH6,6[d]
38	QH6,C2,7[d]
39	QH5,C2,5[e]
40	RH5,5[e]
41	QH5,C2,6[e]
42	RH5,6[e]
43	QH5,C2,7[e]
44	QH5,7^H[e]

45	QH4,C2,6[f]
46	RH4,6[f]
47	QH4,C2,7[f]
48	QH4,C2,8[f]
49	QH4,BFW,8[f]
50	RH4,8[f]
51	QH4,C3,9[f]
52	QH4,BFW,9[f]
53	QH4,C3,10[f]
54	QH4,W,10[f]
55	RH4,10[f]
56	QH4,W,11[f]
57	QH4,11^H[f]
58	QH3,C2,7[g]
59	RH3,7[g]

60	QH3,C2,8[g]
61	QH3,BFW,8[g]
62	RH3,8[g]
63	QH3,C3,9[g]
64	QH3,BFW,9[g]
65	QH3,C3,10[g]
66	QH3,W,10[g]
67	RH3,10[g]
68	QH3,W,11[g]
69	QH3,11^H[g]
70	QH2,C2,8[h]
71	QH2,BFW,8[h]
72	RH2,8[h]
73	QH2,C3,9[h]
74	QH2,BFW,9[h]

75	QH2,C3,10[h]
76	QH2,W,10[h]
77	RH2,10[h]
78	QH2,W,11[h]
79	QH2,11^H[h]
80	QH1,C3,9[i]
81	QH1,BFW,9[i]
82	RH1,9[i]
83	QH1,C3,10[i]
84	QH1,W,10[i]
85	RH1,10[i]
86	QH1,W,11[i]
87	QH1,11^H[i]
88	QBFW,8^C[j]
89	QBFW,9^C[j]

90	$Y(F\text{-}C1)^k$
91	$Y(S\text{-}C1)^k$
92	$Y(S\text{-}C2)^k$
93	$Y(H7\text{-}C1)_above_S_pinch^k$
94	$Y(H7\text{-}C1)_above_process_pinch^k$
95	$Y(H7\text{-}C2)^k$
96	$Y(H6\text{-}C1)_above_S_pinch^k$
97	$Y(H6\text{-}C1)_above_process_pinch^k$
98	$Y(H6\text{-}C2)^k$
99	$Y(H5\text{-}C2)^k$
100	$Y(H4\text{-}C2)_above_process_pinch^k$
101	$Y(H4\text{-}C2)_above_BFW_pinch^k$
102	$Y(H4\text{-}C3)_above_BFW_pinch^k$
103	$Y(H4\text{-}C3)_below_BFW_pinch^k$
104	$Y(H4\text{-}BFW)_8^k$

105	$Y(H4\text{-}BFW)_9^k$
106	$Y(H4\text{-}W)^k$
107	$Y(H3\text{-}C2)_above_process_pinch^k$
108	$Y(H3\text{-}C2)_above_BFW_pinch^k$
109	$Y(H3\text{-}C3)_above_BFW_pinch^k$
110	$Y(H3\text{-}C3)_below_BFW_pinch^k$
111	$Y(H3\text{-}BFW)_8^k$
112	$Y(H3\text{-}BFW)_9^k$
113	$Y(H3\text{-}W)^k$
114	$Y(H2\text{-}C2)^k$
115	$Y(H2\text{-}C3)^k$
116	$Y(H2\text{-}C3)^k$
117	$Y(H2\text{-}BFW)_8^k$
118	$Y(H2\text{-}BFW)_9^k$
119	$Y(H2\text{-}W)^k$

120	Y(H1-C3)_above_BFW_pinch[k]
121	Y(H1-C3)_below_BFW_pinch[k]
122	Y(H1-BFW)[k]
123	Y(H1-W)[k]

Continuous variables related to [a]F, [b]S, and [j]BFW utility streams, [c]H7, [d]H6, [e]H5, [f]H4, [g]H3, [h]H2, and [i]H1 hot streams. [k]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S48. Constant parameters to solve energy balances for Example 3 with multiple utilities.

No.	Parameter	Value (kW)
1	QH7,2^H	2863.82
2	QH7,3^H	1680.11
3	QH7,4^H	5002.14
4	QH7,5^H	1909.21
5	QH7,6^H	4773.03
6	QH7,7^H	4773.03
7	QH6,3^H	613.3
8	QH6,4^H	1825.97
9	QH6,5^H	696.94
10	QH6,6^H	1742.34
11	QH6,7^H	1393.87
12	QH5,5^H	5006.16
13	QH5,6^H	12515.4

14	QH4,6^H	3496.95
15	QH4,7^H	3496.95
16	QH4,8^H	1398.78
17	QH4,9^H	1388.29
18	QH4,10^H	4206.83
19	QH3,7^H	1484.67
20	QH3,8^H	593.87
21	QH3,9^H	589.41
22	QH3,10^H	2231.46
23	QH2,8^H	11533.8
24	QH2,9^H	11447.3
25	QH2,10^H	86.5
26	QH1,9^H	6527.4
27	QH1,10^H	26356.21
28	QC1,1^C	8650.35

29	QC1,2^C	17300.7
30	QC1,3^C	10149.74
31	QC1,4^C	30218.56
32	QC2,5^C	7018.44
33	QC2,6^C	17546.1
34	QC2,7^C	17546.1
35	QC2,8^C	7018.44
36	QC3,9^C	5066.04
37	QC3,10^C	23007.72
38	QW,10^C	9363.86
39	QW,11^C	509.42

Table S49. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 3 with multiple utilities.

No.	Parameter	Value (kW)
1	U(F-C1) = min(30943.57; 36100.79)	30943.57
2	U(S-C1) = min(24212.54; 30218.56)	24212.54
3	U(S-C2) = min(24212.54; 42110.64)	24212.54
4	U(H7-C1)_above_S_pinch = min (4543.92; 27450.44)	4543.92
5	U(H7-C1)_above_process_pinch = min(5002.14; 30218.56)	5002.14
6	U(H7-C2) = min(16457.41; 42110.64)	16457.41
7	U(H6-C1)_above_S_pinch = min(613.3; 10149.74)	613.3
8	U(H6-C1)_above_process_pinch = min(1825.97; 30218.56)	1825.97
9	U(H6-C2) = min(5659.12; 42110.64)	5659.12
10	U(H5-C2) = min(17521.56; 42110.64)	17521.56
11	U(H4-C2)_above_process_pinch = min(6993.9; 35092.2)	6993.9
12	U(H4-C2)_above_BFW_pinch = min(1398.78; 7018.44)	1398.78
13	U(H4-C3)_above_BFW_pinch = min(2787.07; 5066.04)	2787.07

14	U(H4-C3)_below_BFW_pinch = (4206.83; 23007.72)	4206.83
15	U(H4-BFW)_8 = min(1398.78; 21394.37)	1398.78
16	U(H4-BFW)_9 = min(1388.29; 21394.37)	1388.29
17	U(H4-W) = min(4206.83; 9873.28)	4206.83
18	U(H3-C2)_above_process_pinch = min(1484.67; 17546.1)	1484.67
19	U(H3-C2)_above_BFW_pinch = min(593.87; 7018.44)	593.87
20	U(H3-C3)_above_BFW_pinch = min(1183.28; 5066.04)	1183.28
21	U(H3-C3)_below_BFW_pinch = min(2231.46; 23007.72)	2231.46
22	U(H3-BFW)_8 = min(593.87; 21394.37)	593.87
23	U(H3-BFW)_9 = min(589.41; 21394.37)	589.41
24	U(H3-W) = min(2231.46; 9873.28)	2231.46
25	U(H2-C2) = min(11533.8; 7018.44)	7018.44
26	U(H2-C3) = min(22981.1;5066.04)	5066.04
27	U(H2-C3) = min(86.5;23007.72)	86.5
28	U(H2-BFW)_8 = min(11533.8; 21394.37)	11533.8

29	U(H2-BFW)_9 = min(11447.3; 21394.37)	11447.3
30	U(H2-W) = min(86.5;9873.28)	86.5
31	U(H1-C3)_above_BFW_pinch = min(6527.4; 5066.04)	5066.04
32	U(H1-C3)_below_BFW_pinch = min(26356.21; 23007.72)	23007.72
33	U(H1-BFW) = min(6527.4;21394.37)	6527.4
34	U(H1-W) = min(26356.2; 9873.28)	9873.28

Table S50. Restrictions describing heat exchangers between utilities and streams from Example 3 with multiple utilities.

No.	Heat Exchanger	Restriction
1	F-C1	$Q_{F,C1,1} + Q_{F,C1,2} + Q_{F,C1,3} - y_{F-C1}U_{F-C1} \leq 0$
2	S-C1	$Q_{S,C1,4} - y_{S-C1}U_{S-C1} \leq 0$
3	S-C2	$Q_{S,C2,5} + Q_{S,C2,6} + Q_{S,C2,7} - y_{S-C2}U_{S-C2} \leq 0$
4	(H7-C1)_above_S_pinch	$Q_{H7,C1,2} + Q_{H7,C1,3} - (y_{H7-C1})_{above_S_pinch}(U_{H7-C1})_{above_S_pinch} \leq 0$
5	(H7-C1)_above_process_pinch	$Q_{H7,C1,4} - (y_{H7-C1})_{above_process_pinch}(U_{H7-C1})_{above_process_pinch} \leq 0$
6	H7-C2	$Q_{H7,C2,5} + Q_{H7,C2,6} + Q_{H7,C2,7} - y_{H7-C2}U_{H7-C2} \leq 0$
7	(H6-C1)_above_S_pinch	$Q_{H6,C1,3} - (y_{H6-C1})_{above_S_pinch}(U_{H6-C1})_{above_S_pinch} \leq 0$
8	(H6-C1)_above_process_pinch	$Q_{H6,C1,4} - (y_{H6-C1})_{above_process_pinch}(U_{H6-C1})_{above_process_pinch} \leq 0$
9	H6-C2	$Q_{H6,C2,5} + Q_{H6,C2,6} + Q_{H6,C2,7} - y_{H6-C2}U_{H6-C2} \leq 0$

10	H5-C2	$Q_{H5,C2,5} + Q_{H5,C2,6} + Q_{H5,C2,7} - y_{H5-C2}U_{H5-C2} \leq 0$
11	(H4-C2)_above_process_pinch	$Q_{H4,C2,6} + Q_{H4,C2,7} - (y_{H4-C2})_{above_process_pinch}(U_{H4-C2})_{above_process_pinch} \leq 0$
12	(H4-C2) _above_BFW_pinch	$Q_{H4,C2,8} - (y_{H4-C2})_{above_BFW_pinch}(U_{H4-C2})_{above_BFW_pinch} \leq 0$
13	(H4-C3)_above_BFW_pinch	$Q_{H4,C3,9} - (y_{H4-C3})_{above_BFW_pinch}(U_{H4-C3})_{above_BFW_pinch} \leq 0$
14	(H4-C3)_below_BFW_pinch	$Q_{H4,C3,10} - (y_{H4-C3})_{below_BFW_pinch}(U_{H4-C3})_{below_BFW_pinch} \leq 0$
15	(H4-BFW)_8	$Q_{H4,BFW,8} - (y_{H4-BFW})_8(U_{H4-BFW})_8 \leq 0$
16	(H4-BFW)_9	$Q_{H4,BFW,9} - (y_{H4-BFW})_9(U_{H4-BFW})_9 \leq 0$
17	H4-W	$Q_{H4,W,10} + Q_{H4,W,11} - y_{H4-W}U_{H4-W} \leq 0$
18	(H3-C2)_above_process_pinch	$Q_{H3,C2,7} - (y_{H3-C2})_{above_process_pinch}(U_{H3-C2})_{above_process_pinch} \leq 0$

19	(H3-C2)_above_BFW_pinch	$Q_{H3,C2,8} - (y_{H3-C2})_{above_BFW_pinch}(U_{H3-C2})_{above_BFW_pinch} \leq 0$
20	(H3-C3)_above_BFW_pinch	$Q_{H3,C3,9} - (y_{H3-C3})_{above_BFW_pinch}(U_{H3-C3})_{above_BFW_pinch} \leq 0$
21	(H3-C3)_below_BFW_pinch	$Q_{H3,C3,10} - (y_{H3-C3})_{below_BFW_pinch}(U_{H3-C3})_{below_BFW_pinch} \leq 0$
22	(H3-BFW)$_8$	$Q_{H3,BFW,8} - (y_{H3-BFW})_8(U_{H3-BFW})_8 \leq 0$
23	(H3-BFW)$_9$	$Q_{H3,BFW,9} - (y_{H3-BFW})_9(U_{H3-BFW})_9 \leq 0$
24	H3-W	$Q_{H3,W,10} + Q_{H3,W,11} - y_{H3-W}U_{H3-W} \leq 0$
25	H2-C2	$Q_{H2,C2,8} - y_{H2-C2}U_{H2-C2} \leq 0$
26	(H2-C3)_above_BFW_pinch	$Q_{H2,C3,9} - (y_{H2-C3})_{above_BFW_pinch}(U_{H2-C3})_{above_BFW_pinch} \leq 0$

27	(H2-C3)_below_BFW_pinch	$Q_{H2,C3,10} - (y_{H2-C3})_{\text{below_}BFW_pinch}(U_{H2-C3})_{\text{below_}BFW_pinch} \leq 0$
28	$(\text{H2-BFW})_8$	$Q_{H2,BFW,8} - (y_{H2-BFW})_8(U_{H2-BFW})_8 \leq 0$
29	$(\text{H2-BFW})_9$	$Q_{H2,BFW,9} - (y_{H2-BFW})_9(U_{H2-BFW})_9 \leq 0$
30	H2-W	$Q_{H2,W,10} + Q_{H2,W,11} - y_{H2-W}U_{H2-W} \leq 0$
31	(H1-C3)_above_BFW_pinch	$Q_{H1,C3,9} - (y_{H1-C3})_{above_BFW_pinch}(U_{H1-C3})_{above_BFW_pinch} \leq 0$
32	(H1-C3)_below_BFW_pinch	$Q_{H1,C3,10} - (y_{H1-C3})_{\text{below_}BFW_pinch}(U_{H1-C3})_{\text{below_}BFW_pinch} \leq 0$
33	H1-BFW	$Q_{H1,BFW,9} - y_{H1-BFW}U_{H1-BFW} \leq 0$
34	H1-W	$Q_{H1,W,10} + Q_{H1,W,11} - y_{H1-W}U_{H1-W} \leq 0$

Table S51. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 3 with multiple utilities.

Unit name	Heat exchanging streams	Heat Exchange interval	Q(kW)
Heater	F-C1	QF,C1,1	8650.35
		QF,C1,2	14436.88
		QF,C1,3	7856.33
1	(H7-C1)_ above_S_pinch	QH7,C1,2	2863.82
		QH7,C1,3	1680.11
2	(H6-C1)__ above_S_pinch	QH6,C1,3	613.3
3	S-C1	QS,C1,4	24212.54
4	H5-C2	QH5,C2,5	4771.96
		QH5,C2,6	6580.2
		QH5,C2,7	6169.4
5	(H6-C1)__ above_process_pinch	QH6,C1,4	1488.70
6	(H7-C1)_ above_process_pinch	QH7,C1,4	4517.31

7	H7-C2	QH7,C2,5	2246.48
		QH7,C2,6	4879.26
		QH7,C2,7	4814.35
8	H6-C2	QH6,C2,5	0
		QH6,C2,6	2589.68
		QH6,C2,7	1580.73
9	(H4-C2)_above_process_pinch	QH4,C2,6	3496.95
		QH4,C2,7	3496.95
10	(H3-C2)_above_process_pinch	QH3,C2,7	1484.67
11	H2-C2	QH2,C2,8	7018.44
12	(H1-C3)_above_BFW_pinch	QH1,C3,9	1095.69
13	(H3-C3)_above_BFW_pinch	QH3,C3,9	1183.28

14	(H4-C3)_above_BFW_pinch	QH4,C3,9	2787.07
15	H1-BFW	QH1,BFW,9	5431.71
16	(H2-BFW)_8	QH2,BFW,8	4515.36
17	(H2-BFW)_9	QH2,BFW,9	11447.3
18	(H1-C3)_below_BFW_pinch	QH1,C3,10	23007.72
Cooler-1	H4-W	QH4,W,10	3704.51
		QH4,W,11	502.33
Cooler-2	H3-W	QH3,W,10	2231.46
		QH3,W,11	0
Cooler-3	H2-W	QH2,W,10	79.41
		QH2,W,11	7.09
Cooler-4	H1-W	QH1,W,10	3348.48
		QH1,W,11	0

Table S52. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 3 with multiple utilities employed to devise the HEN.

Unit name	Heat exchanging streams	Heat Exchange interval	Q (kW)
Heater	F-C1	QF,C1,1	8650.35
		QF,C1,2	14436.88
		QF,C1,3	7856.33
1	(H7-C1)_ above_S_pinch	QH7,C1,2	2863.82
		QH7,C1,3	1680.11
2	(H6-C1)__ above_S_pinch	QH6,C1,3	613.3
3	S-C1	QS,C1,4	24212.54
4	H5-C2	QH5,C2,5	4771.96
5	(H6-C1)__ above_process_pinch	QH6,C1,4	1488.7
6	(H7-C1)_ above_process_pinch	QH7,C1,4	4517.32
7	H7-C2	QH7,C2,5	2246.48
8	H6-C2	QH6,C2,5	0

	H6-C2	QH6,C2,6	2589.68
9	H7-C2	QH7,C2,6	4879.26
10	H5-C2	QH5,C2,6	6580.2
11	(H4-C2)_above_process_pinch	QH4,C2,6	3496.95
12	H5-C2	QH5,C2,7	6169.4
13	H6-C2	QH6,C2,7	1580.73
14	H7-C2	QH7,C2,7	4814.35
15	(H4-C2)_above_process_pinch	QH4,C2,7	3496.95
16	(H3-C2)_above_process_pinch	QH3,C2,7	1484.67
17	H2-C2	QH2,C2,8	7018.44
18	(H1-C3)_above_BFW_pinch	QH1,C3,9	1095.69
19	(H3-C3)_above_BFW_pinch	QH3,C3,9	1183.28

20	(H4-C3)_above_BFW_pinch	QH4,C3,9	2787.07
21	(H2-BFW)_8	QH2,BFW,8	4515.36
	(H2-BFW)_9	QH2,BFW,9	11447.3
22	H1-BFW	QH1,BFW,9	5431.71
23	(H1-C3)_below_BFW_pinch	QH1,C3,10	23007.72
Cooler-4	H4-W	QH4,W,10	3704.51
		QH4,W,11	502.33
Cooler-3	H3-W	QH3,W,10	2231.46
		QH3,W,11	0
Cooler-2	H2-W	QH2,W,10	79.41
		QH2,W,11	7.09
Cooler-1	H1-W	QH1,W,10	3348.48
		QH1,W,11	0

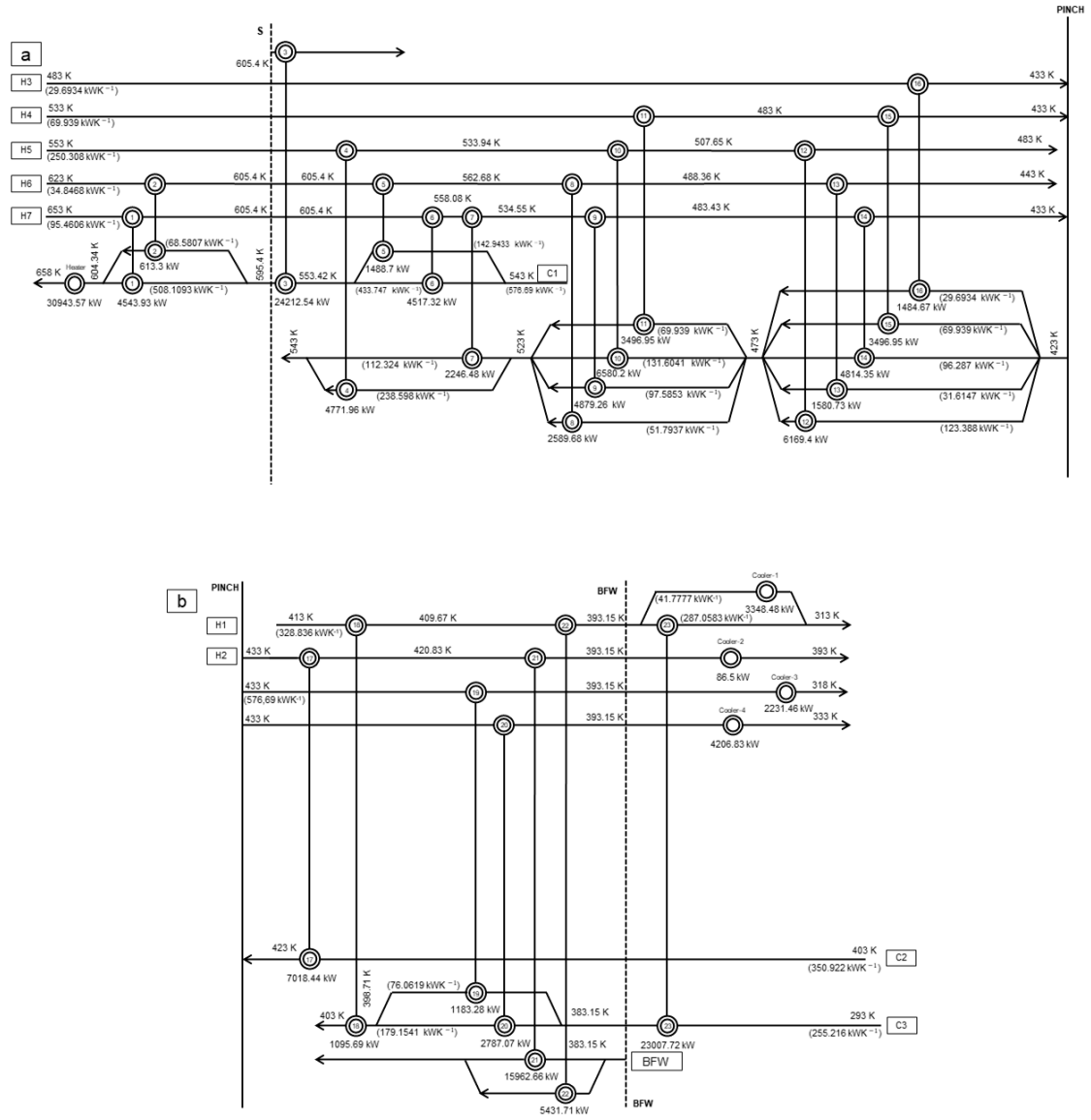


Figure S16. HEN with multiple utilities for Example 3. (a) Heat and (b) cold process pinch side.

Table S53. Costs for HEN with multiple utilities for Example 3.

Unit name	ΔT_{LM} (K)	A (m^2)	C_P (\$)
1	24.26	421.93	14190.91
2	13.88	99.53	11813.77
3	25.26	2159.12	39877.69
4	10.46	1027.42	19500.31
5	33.22	100.94	11811.42
6	29.73	342.19	13470.53
7	13.23	382.33	13832.44
8	25.6	227.85	12479.28
9	10.98	1000.86	19275.77
10	20.52	722.37	16877.01
11	10	787.6	17446.58
12	46.16	301	13103.48
13	17.58	202.52	12280.6
14	10.22	1061.5	19787.6

15	10	787.6	17446.58
16	10	334.39	13400.58
17	13.54	1167.66	32647.07
18	10.47	235.63	12542.77
19	19.66	135.58	11868.61
20	19.66	319.35	13266.22
21	16.92	723.13	16883.62
22	20.79	1729.49	36160.24
23	14.42	3592.94	44499.58
Heater	441.44	157.88	11978.4
Cooler-1	16.99	444.02	14391.09
Cooler-2	40.58	4.8	30645.7
Cooler-3	18.86	266.51	12802.78
Cooler-4	23.97	395.24	13949.18
		Total	518229.77

Example 4 without multiple utilities

Table S54. Source and target temperatures, C value, and the multiple utilities for Example 4.

Stream	Source Temperature T^s(K)	Target Temperature T^t(K)	C (kW K^{-1})	Reference
C1	269.3	488.7	36.93	(Seider, Seader, Lewin, & Widagdo, 2009)
H1	533.2	316.5	10.55	
H2	494.3	383.2	26.38	
H3	477.5	316.5	15.83	
HPS	553.15	553.15		(Chang et al., 2017)
S	500	500		(Biegler et al., 1999)

Table S55. Adjusted temperatures using the Temperature Interval method for Example 4 with ΔT_{min}=25.833 K.

Stream	T^s(K)	T^t(K)	C (kW K^{-1})	Adjusted temperaturas	
				T^s(K)	T^t(K)
C1	269.3	488.7	36.93	269.3	488.7
H1	533.2	316.5	10.55	507.37	290.67
H2	494.3	383.2	26.38	468.47	357.37
H3	477.5	316.5	15.83	451.67	290.67

Table S56. MER targets and the pinch values using the Temperature interval method for Example 4.

Intervals		$\sum C_H$-$\sum C_C$ (kW K^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the High-pressure steam (kW)
					[a]336.81
507.37	488.7	10.55	196.94	196.94	533.75
488.7	[b]468.47	-26.38	-533.75	-336.81	0
468.47	[c]451.67	0	0	-336.81	0
451.67	357.37	15.83	1492.77	1155.96	1492.77
357.37	290.67	-10.55	-703.69	452.27	789.08
290.67	269.3	-36.93	-789.08	-336.81	[d] 0

[a]High-pressure steam value
[b]First pinch temperature for cold streams
[c]Second pinch temperature for cold streams
[d]Water value

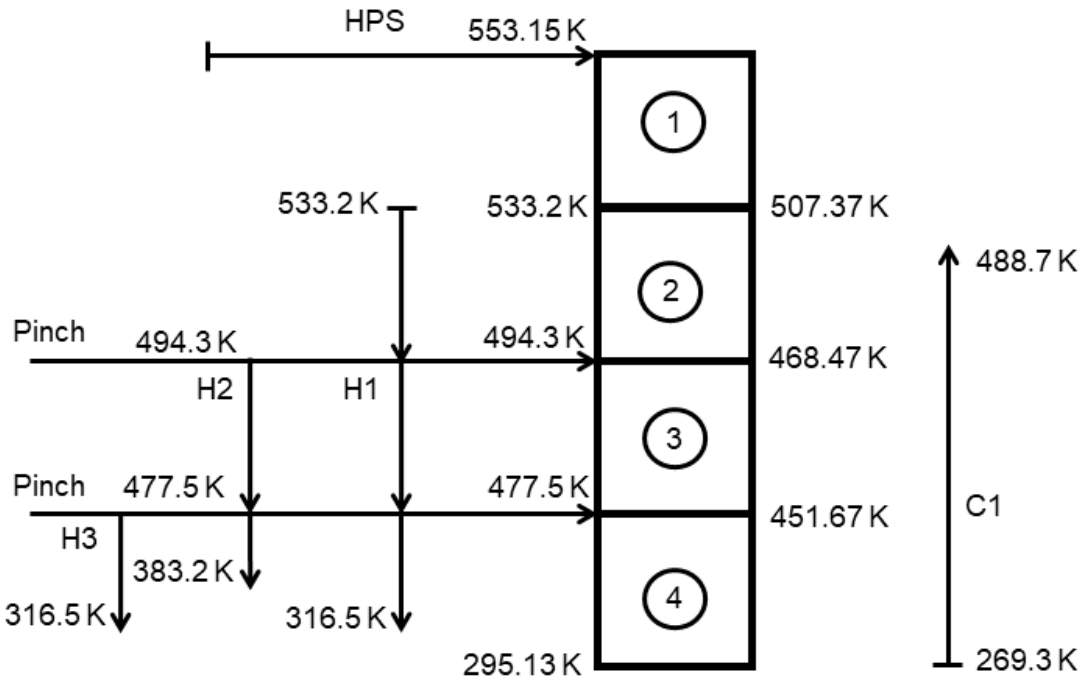


Figure S17. Temperature intervals for Example 4.

Table S57. Energy balances for Example 4.

No.	Stream	Energy balances
1	HPS	$R_{HPS,1} = Q^{H}_{HPS,1}$
2		$Q_{HPS,C1,2} - R_{HPS,1} = Q^{H}_{HPS,2}$
3	H1	$R_{H1,2} + Q_{H1,C1,2} = Q^{H}_{H1,2}$
4		$R_{H1,3} + Q_{H1,C1,3} = Q^{H}_{H1,3}$
5		$R_{H1,4} + Q_{H1,C1,4} = Q^{H}_{H1,4}$
6	H2	$R_{H2,3} + Q_{H2,C1,3} = Q^{H}_{H2,3}$
7		$R_{H2,4} + Q_{H2,C1,4} = Q^{H}_{H2,4}$
8	H3	$R_{H3,4} + Q_{H3,C1,4} = Q^{H}_{H3,4}$
9	C1	$Q_{HPS,C1,2} + Q_{H1,C1,2} = Q^{C}_{C1,2}$
10		$Q_{H1,C1,3} + Q_{H2,C1,3} = Q^{C}_{C1,3}$
11		$Q_{H1,C1,4} + Q_{H2,C1,4} + Q_{H3,C1,4} = Q^{C}_{C1,4}$
12		$Q^{H}_{HPS,1} + Q^{H}_{HPS,2} = 336.81$

Table S58. Variables to solve the energy balances for Example 4.

No.	Variable
1	RHPS,1[a]
2	QHPS,1^H[a]
3	QHPS,C1,2[a]
4	QHPS,2^H[a]
5	RH1,2[b]
6	QH1,C1,2[b]
7	RH1,3[b]
8	QH1,C1,3[b]
9	RH1,4[b]
10	QH1,C1,4[b]
11	RH2,3[c]
12	QH2,C1,3[c]
13	RH2,4[c]
14	QH2,C1,4[c]

15	RH3,4[d]
16	QH3,C1,4[d]
17	y(HPS-C1)[e]
18	y(H1-C1)_above_pinch_1[e]
19	y(H1-C1)_above_pinch_2[e]
20	y(H1-C1)_below_pinch_2[e]
21	y(H2-C1)_above_pinch_2[e]
22	y(H2-C1)_below_pinch_2[e]
23	y(H3-C1)_below_pinch_2[e]

Continuous variables related to [a]HPS utility stream, [b]H1, [c]H2 and [d]H3 hot streams. [e]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S59. Constant parameters to solve energy balances for Example 4.

No.	Parameter	Value (kW)
1	QH1,2^H	410.4
2	QH1,3^H	177.24
3	QH1,4^H	1698.55
4	QH2,3^H	443.18
5	QH2,4^H	2487.63
6	QH3,4^H	2548.63
7	QC1,2^C	747.21
8	QC1,3^C	620.42
9	QC1,4^C	6734.81

Table S60. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 4.

No.	Parameter	Value (kW)
1	U(HPS-C1)=min(336.81;747.21)	336.81
2	U(H1-C1)_above_pinch_1=min(410.4;747.21)	410.4
3	U(H1-C1)_above_pinch_2=min(177.24;620.42)	177.24
4	U(H1-C1)_below_pinch_2=min(1698.55;6734.81)	1698.55
5	U(H2-C1)_above_pinch_2=min(443.18;620.42)	443.18
6	U(H2-C1)_below_pinch_2=min(2487.63;6734.81)	2487.63
7	U(H3-C1)_below_pinch_2=min(2548.63;6734.81)	2548.63

Table S61. Restrictions describing heat exchangers between utilities and streams from Example 4.

No.	Heat exchanger	Restrictions
1	(HPS-C1)	$Q_{HPS,C1,2} - y_{HPS,C1} U_{HPS,C1} \leq 0$
2	(H1-C1)_above_pinch_1	$Q_{H1,C1,2} - (y_{H1,C1})_above_pinch_1 (U_{H1,C1})_above_pinch_1 \leq 0$
3	(H1-C1)_above_pinch_2	$Q_{H1,C1,3} - (y_{H1,C1})_above_pinch_2 (U_{H1,C1})_above_pinch_2 \leq 0$
4	(H1-C1) _below_pinch_2	$Q_{H1,C1,4} - (y_{H1,C1})_below_pinch_2 (U_{H1,C1})_below_pinch_2 \leq 0$
5	(H2-C1) _above_pinch_2	$Q_{H2,C1,3} - (y_{H2,C1})_above_pinch_2 (U_{H2,C1})_above_pinch_2 \leq 0$
6	(H2-C1) _below_pinch_2	$Q_{H2,C1,4} - (y_{H2,C1})_below_pinch_2 (U_{H2,C1})_below_pinch_2 \leq 0$
7	(H3-C1) _below_pinch_2	$Q_{H3,C1,4} - (y_{H3,C1})_below_pinch_2 (U_{H3,C1})_below_pinch_2 \leq 0$

Table S62. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 4.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	HPS-C1	QHPS,C1,2	336.81
1	H1-C1	QH1,C1,2	410.4
2	H1-C1	QH1,C1,3	177.24
3	H2-C1	QH2,C1,3	443.18
4	H1-C1	QH1,C1,4	1698.55
5	H2-C1	QH2,C1,4	2487.63
6	H3-C1	QH3,C1,4	2548.63

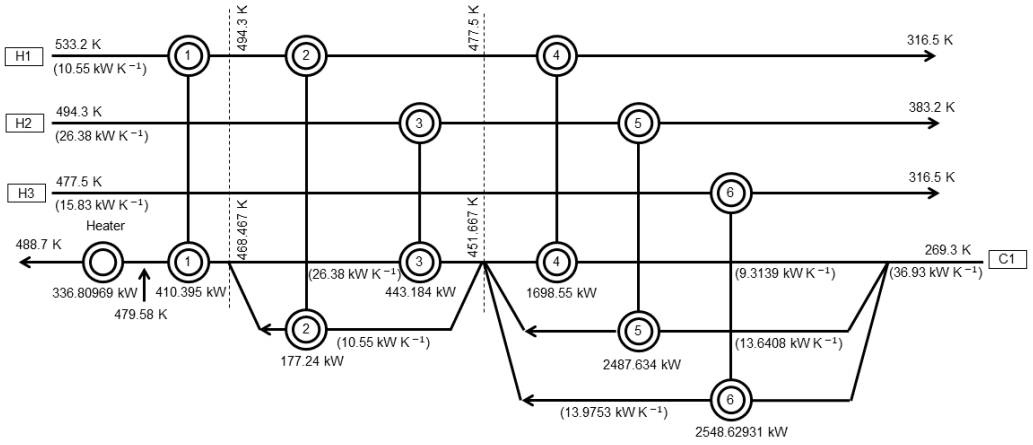


Figure S18. HEN with HPS for Example 4.

Table S63. Costs for HEN without multiple utilities for Example 4.

Unit name	ΔT_{LM}(K)	A (m^2)	C_P (\$)
1	38.04	24.3	14689.69
2	25.84	15.45	17120.31
3	25.83	38.64	13094.77
4	35.44	107.93	11806.58
5	59.02	94.93	11825.03
6	35.44	161.95	12002.23
Heater	68.91	11.01	17830.03
		Total	98368.64

Example 4 with multiple utilities

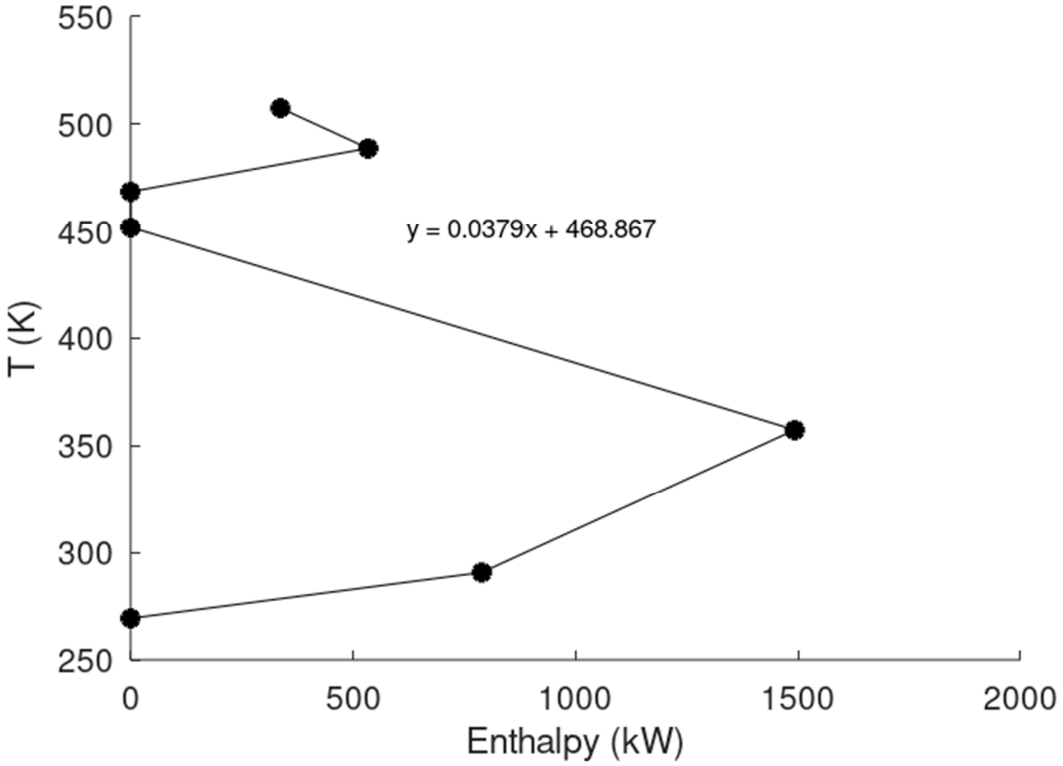


Figure S19. Grand Composite Curve for Example 4. Equation “y=0.0379x+468.867” corresponds to the line between 488.7 K and 451.67 K.

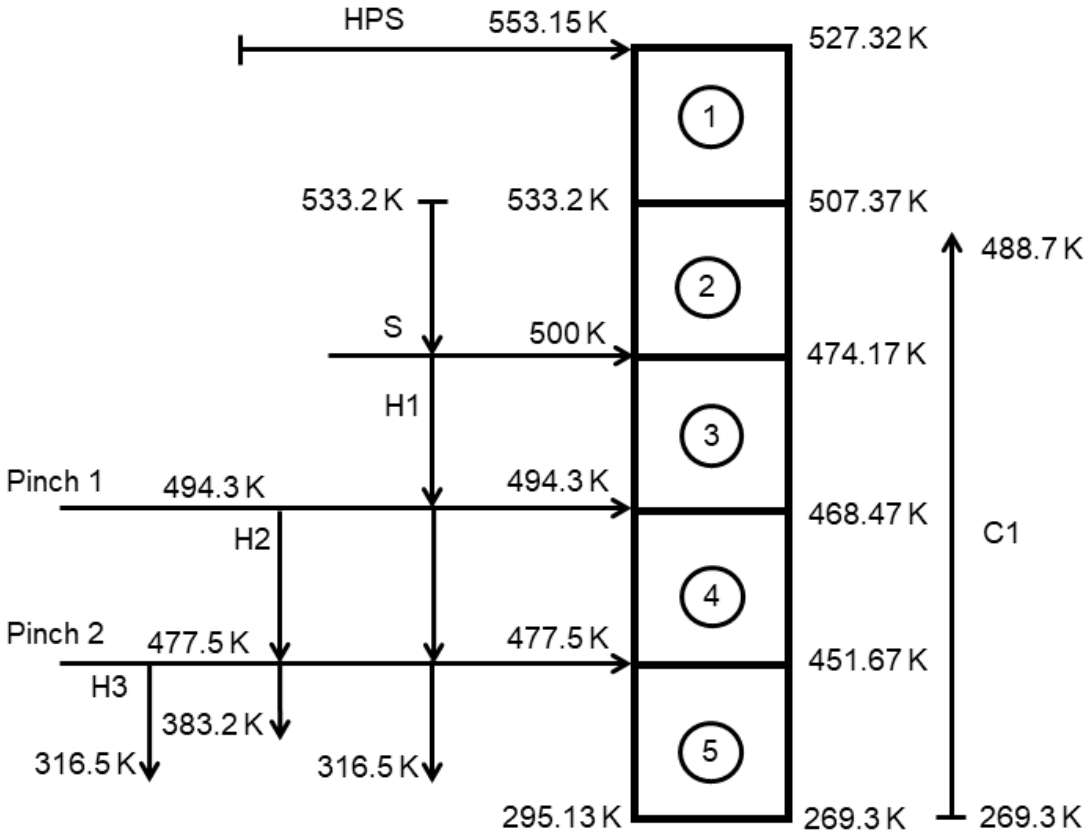


Figure S20. Temperature intervals for Example 4 with multiple utilities.

Table S64. Energy balances for Example 4 with multiple utilities.

No.	Stream	Energy balance
1	HPS	$R_{HPS,1} = Q^H_{HPS,1}$
2		$Q_{HPS,C1,2} - R_{HPS,1} = Q^H_{HPS,2}$
3	H1	$R_{H1,2} + Q_{H1,C1,2} = Q^H_{H1,2}$
4		$R_{H1,3} + Q_{H1,C1,3} = Q^H_{H1,3}$
5		$R_{H1,4} + Q_{H1,C1,4} = Q^H_{H1,4}$
6		$R_{H1,5} + Q_{H1,C1,5} = Q^H_{H1,5}$
7	S	$R_{S,3} + Q_{S,C1,3} = Q^H_{S,3}$
8	H2	$R_{H2,4} + Q_{H2,C1,4} = Q^H_{H2,4}$
9		$R_{H2,5} + Q_{H2,C1,5} = Q^H_{H2,5}$
10	H3	$R_{H3,5} + Q_{H3,C1,5} = Q^H_{H3,5}$
11	C1	$Q_{HPS,C1,2} + Q_{H1,C1,2} = Q^C_{C1,2}$
12		$Q_{S,C1,3} + Q_{H1,C1,3} = Q^C_{C1,3}$
13		$Q_{H1,C1,4} + Q_{H2,C1,4} = Q^C_{C1,4}$
14		$Q_{H1,C1,5} + Q_{H2,C1,5} + Q_{H3,C1,5} = Q^C_{C1,5}$

15		$Q_{HPS,1}^{H} + Q_{HPS,2}^{H} = 186.44$

Table S65. Variables to solve the energy balances for Example 4 with multiple utilities.

No.	Variable
1	RHPS,1[a]
2	QHPS,1^H[a]
3	QHPS,C1,2[a]
4	QHPS,2^H[a]
5	RH1,2[b]
6	QH1,C1,2[b]
7	RH1,3[b]
8	QH1,C1,3[b]
9	RH1,4[b]
10	QH1,C1,4[b]
11	RH1,5[b]
12	QH1,C1,5[b]
13	RS,3[c]
14	QS,C1,3[c]
15	RH2,4[d]

16	QH2,C1,4[d]
17	RH2,5[d]
18	QH2,C1,5[d]
19	RH3,5[e]
20	QH3,C1,5[e]
21	y(HPS-C1)[f]
22	y(H1-C1)_above_S_pinch_1[f]
23	y(H1-C1)_above_pinch_1[f]
24	y(H1-C1)_above_pinch_2[f]
25	y(H1-C1)_below_pinch_2[f]
26	y(S-C1)_above_pinch_1[f]
27	y(H2-C1)_above_pinch_2[f]
28	y(H2-C1)_below_pinch_2[f]
29	y(H3-C1)_below_pinch_2[f]

Continuous variables related to [a]HPS and [c]S utility streams, [b]H1, and [d]H2, and [e]H3 hot streams. [f]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S66. Constant parameters to solve energy balances for Example 4 with multiple utilities.

No.	Parameter	Value (kW)
1	QH1,2^H	350.26
2	QH1,3^H	60.14
3	QH1,4^H	177.24
4	QH1,5^H	1698.55
5	QS,3^H	150.37
6	QH2,4^H	443.18
7	QH2,5^H	2487.63
8	QH3,5^H	2548.63
9	QC1,2^C	536.7
10	QC1,3^C	210.5
11	QC1,4^C	620.42
12	QC1,5^C	6734.81

Table S67. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 4 with multiple utilities.

No.	Parameter	Value (kW)
1	U(HPS-C1)=min(186.44;536.7)	186.44
2	U(H1-C1)_above_S_pinch_1=min(350.26;536.7)	350.26
3	U(H1-C1)_above_pinch_1=min(60.14;210.5)	60.14
4	U(H1-C1)_above_pinch_2=min(177.24;620.42)	177.24
5	U(H1-C1)_below_pinch_2=min(1698.55;6734.81)	1698.55
6	U(S-C1)_above_pinch_1=min(150.37;210.5)	150.37
7	U(H2-C1)_above_pinch_2=min(443.18;620.42)	443.18
8	U(H2-C1)_below_pinch_2=min(2487.63;6734.81)	2487.63
9	U(H3-C1)_below_pinch_2=min(2548.63;6734.81)	2548.63

Table S68. Restrictions describing heat exchangers between utilities and streams from Example 4 with multiple utilities.

No.	Heat exchanger	Restriction
1	HPS-C1	$Q_{HPS,C1,2} - y_{HPS,C1} U_{HPS,C1} \leq 0$
2	(H1-C1)_above_S_pinch	$Q_{H1,C1,2} - (y_{H1,C1})_above_pinch_1 (U_{H1,C1})_above_pinch_1 \leq 0$
3	(H1-C1)_above_pinch_1	$Q_{H1,C1,3} - (y_{H1,C1})_above_pinch_1 (U_{H1,C1})_above_pinch_1 \leq 0$
4	(H1-C1)_above_pinch_2	$Q_{H1,C1,4} - (y_{H1,C1})_above_pinch_2 (U_{H1,C1})_above_pinch_2 \leq 0$
5	(H1-C1) _below_pinch_2	$Q_{H1,C1,5} - (y_{H1,C1})_below_pinch_2 (U_{H1,C1})_below_pinch_2 \leq 0$
6	(S-C1)_above_pinch_1	$Q_{S,C1,3} - (y_{S,C1})_above_pinch_1 (U_{S,C1})_above_pinch_1 \leq 0$

7	(H2-C1) _above_pinch_2	$Q_{H2,C1,4} - (y_{H2,C1})__above_pinch_2(U_{H2,C1})__above_pinch_2 \leq 0$
8	(H2-C1) _below_pinch_2	$Q_{H2,C1,5} - (y_{H2,C1})__below_pinch_2(U_{H2,C1})__below_pinch_2 \leq 0$
9	(H3-C1) _below_pinch_2	$Q_{H3,C1,5} - (y_{H3,C1})__below_pinch_2(U_{H3,C1})_below_pinch_2 \leq 0$

Table S69. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 4 with multiple utilities.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	HPS-C1	QHPS,C1,2	186.44
1	H1-C1	QH1,C1,2	350.26
2	S-C1	QS,C1,3	150.37
3	H1-C1	QH1,C1,3	60.14
4	H1-C1	QH1,C1,4	177.24
5	H2-C1	QH2,C1,4	443.18
6	H1-C1	QH1,C1,5	1698.55
7	H2-C1	QH2,C1,5	2487.63
8	H3-C1	QH3,C1,5	2548.63

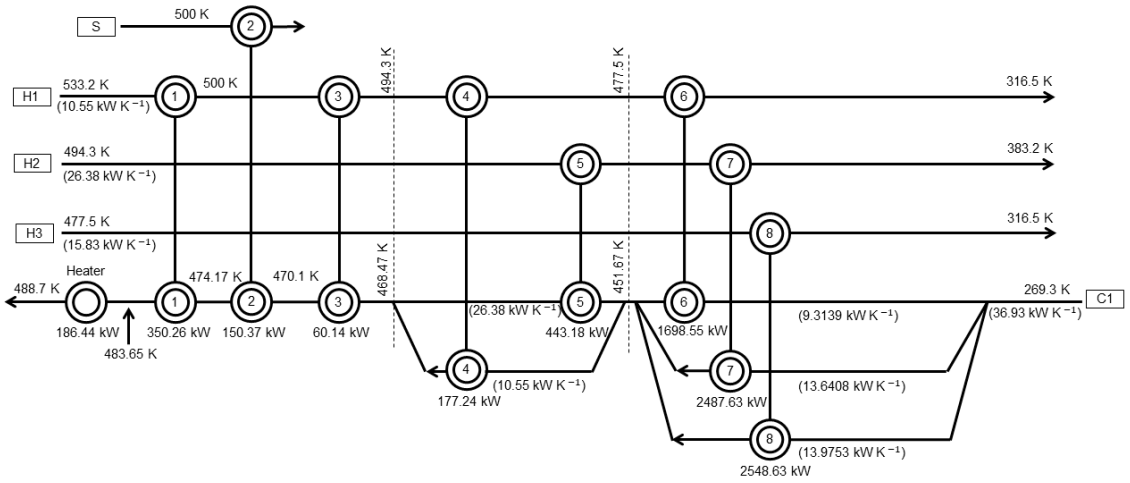


Figure S21. HEN with multiple utilities for Example 4.

Table S70. Costs for HEN with multiple utilities for Example 4.

Unit name	ΔT_{LM}(K)	A (m^2)	C_P (\$)
1	36.40	21.67	15211.91
2	27.82	12.17	17830.03
3	27.82	4.87	17830.03
4	25.83	15.45	17120.31
5	25.83	19.32	15794.79
6	35.44	35.98	13291.64
7	59.02	23.73	14792.84
8	35.44	32.39	13611.73
Heater	66.94	6.27	17830.03
		Total	143313.31

Example 5 without multiple utilities

Table S71. Source and target temperatures, C value, and the multiple utilities for Example 5.

Stream	Source Temperature T^s(°C)	Target Temperature T^t(°C)	C (kW °C^{-1})	Reference
C1	52	360	143.9	(Jiang et al., 2014)
H1	310	95	86	
H2	299	120	21.4	
H3	273	250	184.7	
H4	230	95	23.5	
H5	206	178	129.4	
F	800	800		(Chang et al., 2017)
S	332.25	332.25		(Seider, Seader, Lewin, & Widagdo, 2009)

Table S72. Adjusted temperatures using the Temperature Interval method for Example 5 with ΔT_{min}=10 °C.

Stream	T^s(°C)	T^t(°C)	C(kW °C^{-1})	Adjusted temperaturas	
				T^s(°C)	T^t(°C)
C1	52	360	143.9	52	360
H1	310	95	86	300	85
H2	299	120	21.4	289	110
H3	273	250	184.7	263	240
H4	230	95	23.5	220	85
H5	206	178	129.4	196	168

Table S73. MER targets and the pinch value using the Temperature interval method for Example 5.

Intervals		$\sum C_H$-$\sum C_C$ (kW °C^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the Fuel (kW)
					10956.8[a]
360	300	-143.9	-8634	-8634	2322.8
300	289	-57.9	-636.9	-9270.9	1685.9
289	263	-36.5	-949	-10219.9	736.9
263	240	148.2	3408.6	-6811.3	4145.5
240	220	-36.5	-730	-7541.3	3415.5
220	196	-13	-312	-7853.3	3103.5
196	168	116.4	3259.2	-4594.1	6362.7
168	110	-13	-754	-5348.1	5608.7
110	85	-34.4	-860	-6208.1	4748.7
85	52[b]	-143.9	-4748.7	-10956.8	0

[a]Fuel value

[b]Pinch temperature for cold streams

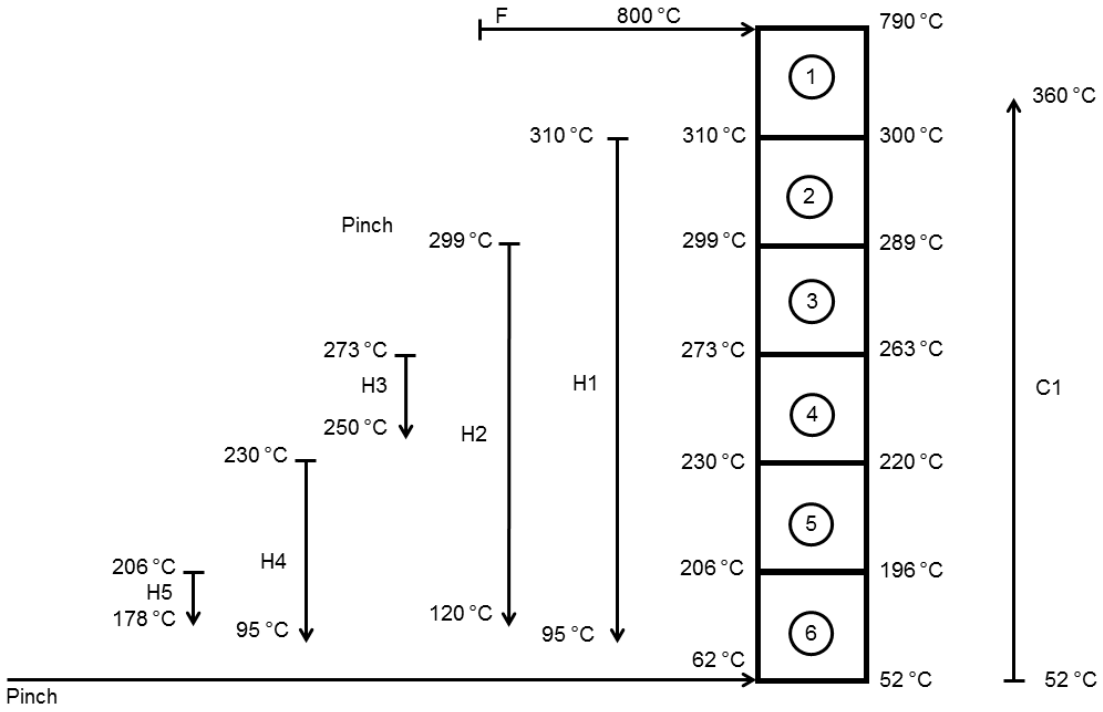


Figure S22. Temperature intervals for Example 5.

Table S74. Energy balances for Example 5.

No.	Stream	Energy balances
1	F	$R_{F,1} + Q_{F,C1,1} = Q_{F,1}^{H}$
2		$R_{F,2} + Q_{F,C1,2} - R_{F,1} = Q_{F,2}^{H}$
3		$R_{F,3} + Q_{F,C1,3} - R_{F,2} = Q_{F,3}^{H}$
4		$R_{F,4} + Q_{F,C1,4} - R_{F,3} = Q_{F,4}^{H}$
5		$R_{F,5} + Q_{F,C1,5} - R_{F,4} = Q_{F,5}^{H}$
6		$Q_{F,C1,6} - R_{F,5} = Q_{F,6}^{H}$
7	H1	$R_{H1,2} + Q_{H1,C1,2} = Q_{H1,2}^{H}$
8		$R_{H1,3} + Q_{H1,C1,3} - R_{H1,2} = Q_{H1,3}^{H}$
9		$R_{H1,4} + Q_{H1,C1,4} - R_{H1,3} = Q_{H1,4}^{H}$
10		$R_{H1,5} + Q_{H1,C1,5} - R_{H1,4} = Q_{H1,5}^{H}$
11		$Q_{H1,C1,6} - R_{H1,5} = Q_{H1,6}^{H}$
12	H2	$R_{H2,3} + Q_{H2,C1,3} = Q_{H2,3}^{H}$

13		$R_{H2,4} + Q_{H2,C1,4} - R_{H2,3} = Q^H_{H2,4}$
14		$R_{H2,5} + Q_{H2,C1,5} - R_{H2,4} = Q^H_{H2,5}$
15		$Q_{H2,C1,6} - R_{H2,5} = Q^H_{H2,6}$
16	H3	$R_{H3,4} + Q_{H3,C1,4} = Q^H_{H3,4}$
17		$R_{H3,5} + Q_{H3,C1,5} - R_{H3,4} = Q^H_{H3,5}$
18		$Q_{H3,C1,6} - R_{H3,5} = Q^H_{H3,6}$
19	H4	$R_{H4,5} + Q_{H4,C1,5} = Q^H_{H4,5}$
20		$Q_{H4,C1,6} - R_{H4,5} = Q^H_{H4,6}$
21	H5	$R_{H5,6} + Q_{H5,C1,6} = Q^H_{H5,6}$
22	C1	$Q_{F,C1,1} = Q^C_{C1,1}$
23		$Q_{F,C1,2} + Q_{H1,C1,2} = Q^C_{C1,2}$
24		$Q_{F,C1,3} + Q_{H1,C1,3} + Q_{H2,C1,3} = Q^C_{C1,3}$

25		$Q_{F,C1,4} + Q_{H1,C1,4} + Q_{H2,C1,4} + Q_{H3,C1,4} = Q_{C1,4}^{C}$
26		$Q_{F,C1,5} + Q_{H1,C1,5} + Q_{H2,C1,5} + Q_{H3,C1,5} + Q_{H4,C1,5} = Q_{C1,5}^{C}$
27		$Q_{F,C1,6} + Q_{H1,C1,6} + Q_{H2,C1,6} + Q_{H3,C1,6} + Q_{H4,C1,6} + Q_{H5,C1,6} = Q_{C1,6}^{C}$
28		$Q_{F,1}^{H} + Q_{F,2}^{H} + Q_{F,3}^{H} + Q_{F,4}^{H} + Q_{F,5}^{H} + Q_{F,6}^{H} = 10956.8$

Table S75. Variables to solve the energy balances for Example 5.

No.	Variable
1	RF,1[a]
2	QF,C1,1[a]
3	QF,1^H[a]
4	RF,2[a]
5	QF,C1,2[a]
6	QF,2^H[a]
7	RF,3[a]
8	QF,C1,3[a]
9	QF,3^H[a]
10	RF,4[a]
11	QF,C1,4[a]
12	QF,4^H[a]
13	RF,5[a]
14	QF,C1,5[a]

15	QF,5^H[a]
16	QF,C1,6[a]
17	QF,6^H[a]
18	RH1,2[b]
19	QH1,C1,2[b]
20	RH1,3[b]
21	QH1,C1,3[b]
22	RH1,4[b]
23	QH1,C1,4[b]
24	RH1,5[b]
25	QH1,C1,5[b]
26	QH1,C1,6[b]
27	RH2,3[c]
28	QH2,C1,3[c]
29	RH2,4[c]
30	QH2,C1,4[c]

31	RH2,5[c]
32	QH2,C1,5[c]
33	QH2,C1,6[c]
34	RH3,4[d]
35	QH3,C1,4[d]
36	RH3,5[d]
37	QH3,C1,5[d]
38	QH3,5^H[d]
39	QH3,C1,6[d]
40	QH3,6^H[d]
41	RH4,5[e]
42	QH4,C1,5[e]
43	QH4,C1,6[e]
44	RH5,6[f]
45	QH5,C1,6[f]
46	y(S-C1)[g]

47	y(H1-C1)[g]
48	y(H2-C1)[g]
49	y(H3-C1)[g]
50	y(H4-C1)[g]
51	y(H5-C1)[g]

Continuous variables related to [a]F utility stream, [b]H1, [c]H2, [d]H3, [e]H4, and [f]H5 hot streams. [g]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S76. Constant parameters to solve energy balances for Example 5.

No.	Parameter	Value (kW)
1	QH1,2^H	946
2	QH1,3^H	2236
3	QH1,4^H	3698
4	QH1,5^H	2064
5	QH1,6^H	9546
6	QH2,3^H	556.4
7	QH2,4^H	920.2
8	QH2,5^H	513.6
9	QH2,6^H	1840.4
10	QH3,4^H	4248.1
11	QH4,5^H	564
12	QH4,6^H	2608.5
13	QH5,6^H	3623.2
14	QC1,1^C	8634

15	QC1,2^C	1582.9
16	QC1,3^C	3741.4
17	QC1,4^C	6187.7
18	QC1,5^C	3453.6
19	QC1,6^C	20721.6

Table S77. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 5.

No.	Heat exchanger	Restriction
1	U(S-C1)=min(10956.8;44321.2)	10956.8
2	U(H1-C1)=min(18490;35687.2)	18490
3	U(H2-C1)=min(3830.6;34104.3)	3830.6
4	U(H3-C1)=min(4248.1;30362.9)	4248.1
5	U(H4-C1)=min(3172.5;24175.2)	3172.5
6	U(H5-C1)=min(3623.2;20721.6)	3623.2

Table S78. Restrictions describing heat exchangers between utilities and streams from Example 5.

No.	Heat exchanger	Restriction
1	S-C1	$Q_{S,C1,1} + Q_{S,C1,2} + Q_{S,C1,3} + Q_{S,C1,4} + Q_{S,C1,5} + Q_{S,C1,6} - y_{S,C1}U_{S,C1} \leq 0$
2	H1-C1	$Q_{H1,C1,2} + Q_{H1,C1,3} + Q_{H1,C1,4} + Q_{H1,C1,5} + Q_{H1,C1,6} - y_{H1,C1}U_{H1,C1} \leq 0$
3	H2-C1	$Q_{H2,C1,3} + Q_{H2,C1,4} + Q_{H2,C1,5} + Q_{H2,C1,6} - y_{H2,C1}U_{H2,C1} \leq 0$
4	H3-C1	$Q_{H3,C1,4} + Q_{H3,C1,5} + Q_{H3,C1,6} - y_{H3,C1}U_{H3,C1} \leq 0$
5	H4-C1	$Q_{H4,C1,5} + Q_{H4,C1,6} - y_{H4,C1}U_{H4,C1} \leq 0$
6	H5-C1	$Q_{H5,C1,6} - y_{H5,C1}U_{H5,C1} \leq 0$

Table S79. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 5.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	F-C1	QF,C1,1	8634
		QF,C1,2	636.9
		QF,C1,3	972.89
		QF,C1,4	635.85
		QF,C1,6	77.16
1	H1-C1	QH1,C1,2	946
		QH1,C1,3	2236
		QH1,C1,4	3149.5
		QH1,C1,5	2612.51
		QH1,C1,6	9546
2	H2-C1	QH2,C1,3	532.51
		QH2,C1,4	944.09
		QH2,C1,6	2354

3	H3-C1	QH3,C1,4	1458.27
		QH3,C1,5	500.69
		QH3,C1,6	2289.15
4	H4-C1	QH4,C1,5	340.41
		QH4,C1,6	2832.09
5	H5-C1	QH5,C1,6	3623.2

Table S80. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 5 employed to devise the HEN.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater-1	F-C1	QF,C1,1	8634
		QF,C1,2	636.9
		QF,C1,3	972.89
		QF,C1,4	635.85
Heater-2	F-C1	QF,C1,6	77.16
1	H1-C1	QH1,C1,2	946
		QH1,C1,3	2236
		QH1,C1,4	3149.5
2	H2-C1	QH2,C1,3	532.51
		QH2,C1,4	944.09
3	H3-C1	QH3,C1,4	1458.27
4	H1-C1	QH1,C1,5	2612.51
5	H3-C1	QH3,C1,5	500.69

6	H4-C1	QH4,C1,5	340.41
7	H1-C1	QH1,C1,6	9546
8	H2-C1	QH2,C1,6	2354
9	H3-C1	QH3,C1,6	2289.15
10	H4-C1	QH4,C1,6	2832.09
11	H5-C1	QH5,C1,6	3623.2

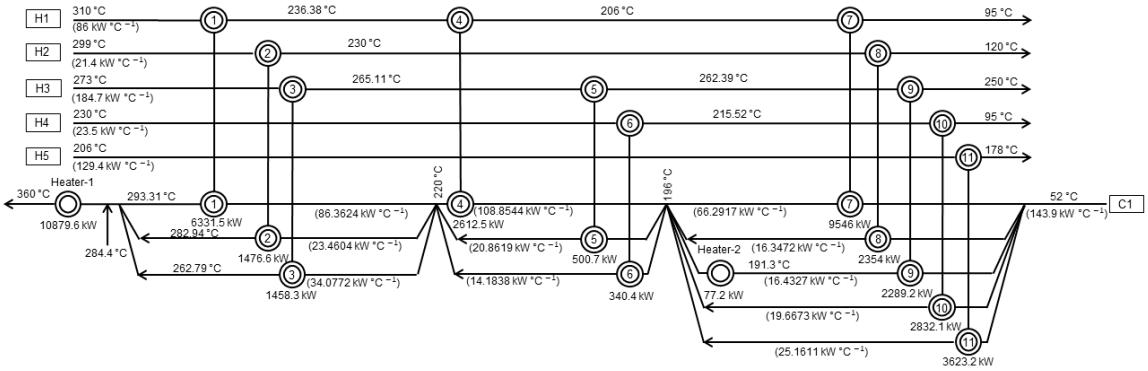


Figure S23. HEN with F for Example 5.

Table S81. Costs for HEN without multiple utilities for Example 5.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P ($)
1	16.53	862.58	18095.21
2	12.79	260.01	12747.17
3	23.35	140.65	11890.03
4	12.93	455.18	14492.11
5	55.06	10.24	17830.03
6	14.23	17.96	16197.71
7	22.5	238.86	12569.43
8	49.04	21.62	15222.18
9	123.72	6.95	17830.03
10	29.71	30.67	13793.03
11	44.09	23.14	14906.24
Heater-1	476.8	51.39	17830.03

Heater-2	606.35	0.29	17830.03
		Total	201233.22

Example 5 with multiple utilities

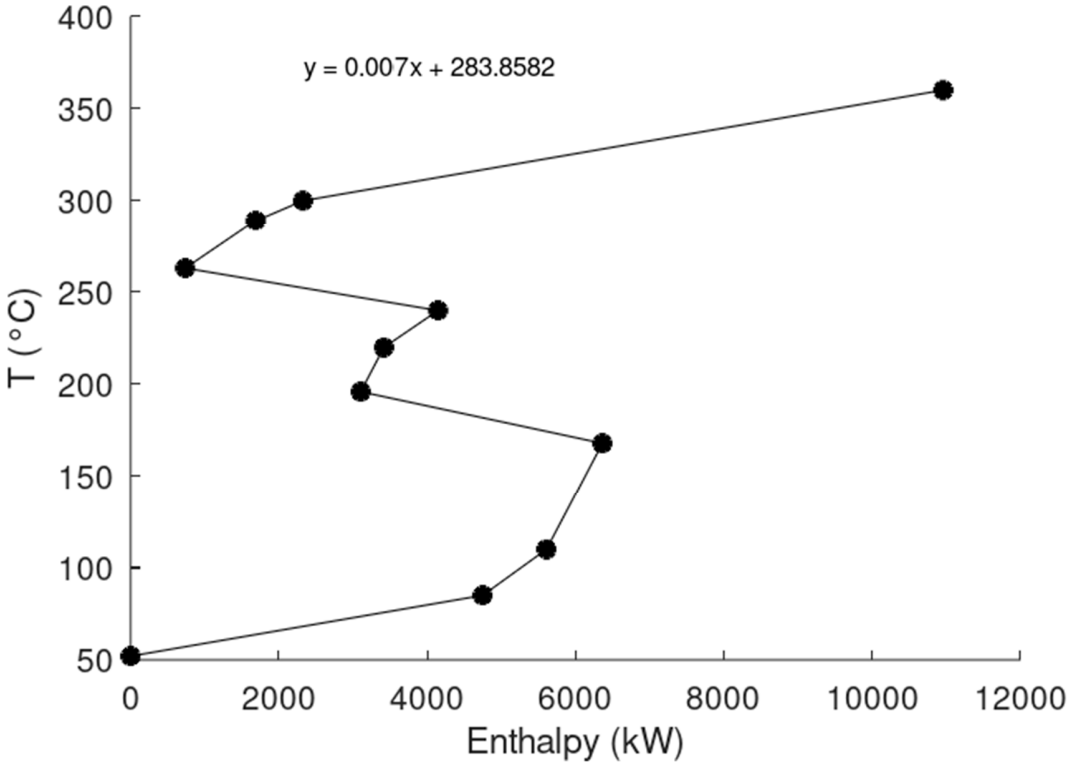


Figure S24. Grand Composite Curve for Example 5. Equation “y=0.007x+283.8582” corresponds to the line between 360 °C and 300 °C.

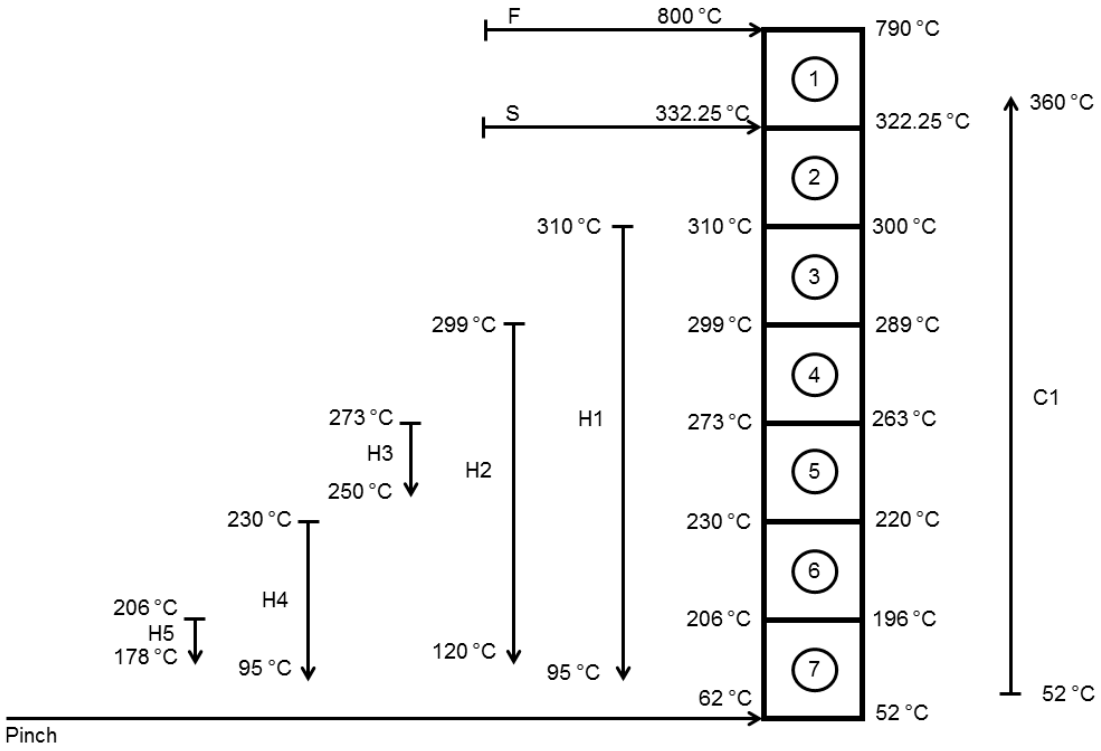


Figure S25. Temperature intervals for Example 5 with multiple utilities.

Table S82. Energy balances for Example 5 with multiple utilities.

No.	Stream	Energy balance
1	F	$R_{F,1} + Q_{F,C1,1} = Q_{F,1}^{H}$
2	S	$R_{S,2} + Q_{S,C1,2} = Q_{S,2}^{H}$
3		$R_{S,3} + Q_{S,C1,3} - R_{S,2} = Q_{S,3}^{H}$
4		$R_{S,4} + Q_{S,C1,4} - R_{S,3} = Q_{S,4}^{H}$
5		$R_{S,5} + Q_{S,C1,5} - R_{S,4} = Q_{S,5}^{H}$
6		$R_{S,6} + Q_{S,C1,6} - R_{S,5} = Q_{S,6}^{H}$
7		$Q_{S,C1,7} - R_{S,6} = Q_{S,7}^{H}$
8	H1	$R_{H1,3} + Q_{H1,C1,3} = Q_{H1,3}^{H}$
9		$R_{H1,4} + Q_{H1,C1,4} - R_{H1,3} = Q_{H1,4}^{H}$
10		$R_{H1,5} + Q_{H1,C1,5} - R_{H1,4} = Q_{H1,5}^{H}$
11		$R_{H1,6} + Q_{H1,C1,6} - R_{H1,5} = Q_{H1,6}^{H}$
12		$Q_{H1,C1,7} - R_{H1,6} = Q_{H1,7}^{H}$
13	H2	$R_{H2,4} + Q_{H2,C1,4} = Q_{H2,4}^{H}$
14		$R_{H2,5} + Q_{H2,C1,5} - R_{H2,4} = Q_{H2,5}^{H}$

15		$R_{H2,6} + Q_{H2,C1,6} - R_{H2,5} = Q^{H}_{H2,6}$
16		$Q_{H2,C1,7} - R_{H2,6} = Q^{H}_{H2,7}$
17	H3	$R_{H3,5} + Q_{H3,C1,5} = Q^{H}_{H3,5}$
18		$R_{H3,6} + Q_{H3,C1,6} - R_{H3,5} = Q^{H}_{H3,6}$
19		$Q_{H3,C1,7} - R_{H3,6} = Q^{H}_{H3,7}$
20	H4	$R_{H4,6} + Q_{H4,C1,6} = Q^{H}_{H4,6}$
21		$Q_{H4,C1,7} - R_{H4,6} = Q^{H}_{H4,7}$
22	H5	$R_{H5,7} + Q_{H5,C1,7} = Q^{H}_{H5,7}$
23	C1	$Q_{F,C1,1} = Q^{C}_{C1,1}$
24		$Q_{S,C1,2} = Q^{C}_{C1,2}$
25		$Q_{S,C1,3} + Q_{H1,C1,3} = Q^{C}_{C1,3}$
26		$Q_{S,C1,4} + Q_{H1,C1,4} + Q_{H2,C1,4} = Q^{C}_{C1,4}$
27		$Q_{S,C1,5} + Q_{H1,C1,5} + Q_{H2,C1,5} + Q_{H3,C1,5} = Q^{C}_{C1,5}$
28		$Q_{S,C1,6} + Q_{H1,C1,6} + Q_{H2,C1,6} + Q_{H3,C1,6} + Q_{H4,C1,6} = Q^{C}_{C1,6}$

29		$Q_{S,C1,7} + Q_{H1,C1,7} + Q_{H2,C1,7} + Q_{H3,C1,7} + Q_{H4,C1,7} + Q_{H5,C1,7} = Q_{C1,7}^{C}$
30		$Q_{S,2}^{H} + Q_{S,3}^{H} + Q_{S,4}^{H} + Q_{S,5}^{H} + Q_{S,6}^{H} + Q_{S,7}^{H} = 5524.58$

Table S83. Variables to solve the energy balances for Example 5 with multiple utilities.

No.	Variables
1	RF,1[a]
2	QF,C1,1[a]
3	RS,2[b]
4	QS,C1,2[b]
5	QS,2^H[b]
6	RS,3[b]
7	QS,C1,3[b]
8	QS,3^H[b]
9	RS,4[b]
10	QS,C1,4[b]
11	QS,4^H[b]
12	RS,5[b]
13	QS,C1,5[b]
14	QS,5^H[b]

15	RS,6[b]
16	QS,C1,6[b]
17	QS,6^H[b]
18	QS,C1,7[b]
19	QS,7^H[b]
20	RH1,3[c]
21	QH1,C1,3[c]
22	RH1,4[c]
23	QH1,C1,4[c]
24	RH1,5[c]
25	QH1,C1,5[c]
26	RH1,6[c]
27	QH1,C1,6[c]
28	QH1,C1,7[c]
29	RH2,4[d]
30	QH2,C1,4[d]

31	RH2,5[d]
32	QH2,C1,5[d]
33	RH2,6[d]
34	QH2,C1,6[d]
35	QH2,C1,7[d]
36	RH3,5[e]
37	QH3,C1,5[e]
38	RH3,6[e]
39	QH3,C1,6[e]
40	QH3,6^H[e]
41	QH3,C1,7[e]
42	QH3,7^H[e]
43	RH4,6[f]
44	QH4,C1,6[f]
45	QH4,C1,7[f]
46	RH5,7[g]

47	QH5,C1,7[g]
48	y(F-C1)[h]
49	y(S-C1)[h]
50	y(H1-C1)[h]
51	y(H2-C1)[h]
52	y(H3-C1)[h]
53	y(H4-C1)[h]
54	y(H5-C1)[h]

Continuous variables related to [a]F and [b]S utility streams, [c]H1, and [d]H2, [e]H3, [f]H4, and [g]H5 hot streams. [h]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S84. Constant parameters to solve energy balances for Example 5 with multiple utilities.

No.	Parameter	Value (kW
1	QS,1^H	5432.23
2	QH1,3^H	946
3	QH1,4^H	2236
4	QH1,5^H	3698
5	QH1,6^H	2064
6	QH1,7^H	9546
7	QH2,4^H	556.4
8	QH2,5^H	920.2
9	QH2,6^H	513.6
10	QH2,7^H	1840.4
11	QH3,5^H	4248.1
12	QH4,6^H	564
13	QH4,7^H	2608.5

14	QH5,7^H	3623.2
15	QC1,1^C	5432.23
16	QC1,2^C	3201.78
17	QC1,3^C	1582.9
18	QC1,4^C	3741.4
19	QC1,5^C	6187.7
20	QC1,6^C	3453.6
21	QC1,7^C	20721.6

Table S85. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 5 with multiple utilities.

No.	Parameter	Value (kW)
1	U(F-C1)=min(5432.23; 5432.23)	5432.23
2	U(S-C1)=min(5524.58; 38888.98)	5524.58
3	U(H1-C1)=min(18490; 35687.2)	18490
4	U(H2-C1)=min(3830.6; 34104.3)	3830.6
5	U(H3-C1) =min(4248.1; 30362.9)	4248.1
6	U(H4-C1) =min(3172.5; 24175.2)	3172.5
7	U(H5-C1)=min(3623.2; 20721.6)	3623.2

Table S86. Restrictions describing heat exchangers between utilities and streams from Example 5 with multiple utilities.

No.	Heat exchanger	Restriction
1	F-C1	$Q_{F,C1,1} - y_{F,C1}U_{F,C1} \leq 0$
2	S-C1	$Q_{S,C1,2} + Q_{S,C1,3} + Q_{S,C1,4} + Q_{S,C1,5} + Q_{S,C1,6} + Q_{S,C1,7} - y_{S,C1}U_{S,C1} \leq 0$
3	H1-C1	$Q_{H1,C1,3} + Q_{H1,C1,4} + Q_{H1,C1,5} + Q_{H1,C1,6} + Q_{H1,C1,7} - y_{H1,C1}U_{H1,C1} \leq 0$
4	H2-C1	$Q_{H2,C1,4} + Q_{H2,C1,5} + Q_{H2,C1,6} + Q_{H2,C1,7} - y_{H2,C1}U_{H2,C1} \leq 0$
5	H3-C1	$Q_{H3,C1,5} + Q_{H3,C1,6} + Q_{H3,C1,7} - y_{H3,C1}U_{H3,C1} \leq 0$

6	H4-C1	$Q_{H4,C1,6} + Q_{H4,C1,7} - y_{H4,C1}U_{H4,C1} \leq 0$
7	H5-C1	$Q_{H5,C1,7} - y_{H5,C1}U_{H5,C1} \leq 0$

Table S87. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 5 with multiple utilities.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	F-C1	QF,C1,1	5432.23
1	S-C1	QS,C1,2	3201.78
		QS,C1,3	636.95
		QS,C1,4	948.95
		QS,C1,7	736.9
2	H1-C1	QH1,C1,3	945.95
		QH1,C1,4	2236.05
		QH1,C1,5	2829.27
		QH1,C1,6	2932.68
		QH1,C1,7	9546.05
3	H2-C1	QH2,C1,4	556.4
		QH2,C1,5	822.47
		QH2,C1,7	2451.74

4	H3-C1	QH3,C1,5	2535.97
		QH3,C1,6	79.95
		QH3,C1,7	1632.18
5	H4-C1	QH4,C1,6	440.97
		QH4,C1,7	2731.54
6	H5-C1	QH5,C1,7	3623.2

Table S88. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 5 with multiple utilities employed to devise the HEN.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater	F-C1	QF,C1,1	5432.23
1	S-C1	QS,C1,2	3201.78
		QS,C1,3	636.95
		QS,C1,4	948.95
2	H1-C1	QH1,C1,3	945.95
		QH1,C1,4	2236.05
3	H2-C1	QH2,C1,4	556.4
4	H1-C1	QH1,C1,5	2829.27
5	H2-C1	QH2,C1,5	822.47
6	H3-C1	QH3,C1,5	2535.97
7	H1-C1	QH1,C1,6	2932.68
8	H3-C1	QH3,C1,6	79.95
9	H4-C1	QH4,C1,6	440.97

10		QS,C1,7	736.9
11	H1-C1	QH1,C1,7	9546.05
12	H2-C1	QH2,C1,7	2451.74
13	H3-C1	QH3,C1,7	1632.18
14	H4-C1	QH4,C1,7	2731.54
15	H5-C1	QH5,C1,7	3623.2

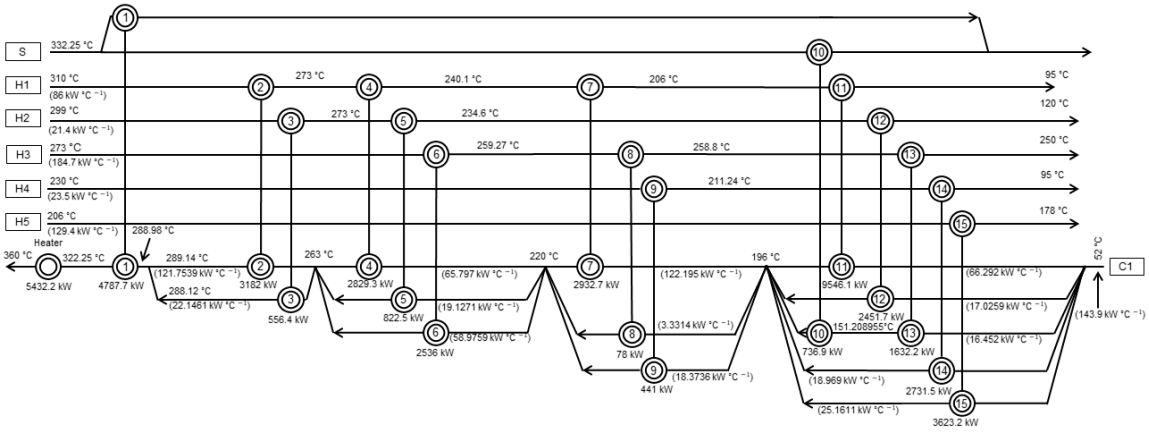


Figure S26. HEN with multiple utilities for Example 5.

Table S89. Costs for HEN with multiple utilities for Example 5.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P ($)
1	22.59	477.37	14692.86
2	14.77	485.32	14764.7
3	10.43	120.13	11820.54
4	14.46	440.58	14359.94
5	12.14	76.29	23891.09
6	21.31	89.35	35541.35
7	14.46	114.17	47242.3
8	50.13	0.72	89150.14
9	12.43	13.31	106980.17
10	199.6	1.19	124810.2
11	22.5	119.43	94552.71
12	51.89	11.82	160470.26
13	148.22	2.48	178300.28

14	26.72	20.93	169195.43
15	44.09	185.1	12153.43
Heater	458.49	26.69	17830.03
		Total	1115755.43

Example 6 without multiple utilities

Table S90. Source and target temperatures, C value, and the multiple utilities for Example 6.

Stream	Source Temperature T^s(°C)	Target Temperature T^t(°C)	C (kW °C^{-1})	Reference
H1	500	50	5	(Seider, Seader, Lewin, & Widagdo, 2009)
H2	400	100	4	
H3	400	100	3	
H4	200	50	2	
C1	250	450	10	
C2	30	430	6	
F	800	800		(Chang et al., 2017)
S	332.25	332.25		(Seider, Seader, Lewin, & Widagdo, 2009)
BFW	110	110		(Seider, Seader, Lewin, & Widagdo, 2009)
W	15			(Chang et al., 2017)

Table S91. Adjusted temperatures using the Temperature Interval method for Example 6 with ΔT_{min}=10 °C.

Stream	T^s(°C)	T^t(°C)	C (kW °C^{-1})	Adjusted temperatures	
				T^s(°C)	T^t(°C)
H1	500	50	5	490	40
H2	400	100	4	390	90
H3	400	100	3	390	90
H4	200	50	2	190	40
C1	250	450	10	250	450
C2	30	430	6	30	430

Table S92. MER targets and the pinch value using the Temperature interval method for Example 6.

Intervals		$\sum C_H$-$\sum C_C$ (kW °C^{-1})	Enthalpy (kW)	Cascaded enthalpy (kW)	Cascaded enthalpy with the heat value for the Fuel (kW)
					900[a]
490	450	5	200	200	1100
450	430	-5	-100	100	1000
430	390	-11	-440	-340	560
390	250[b]	-4	-560	-900	0
250	190	6	360	-540	360
190	90	8	800	260	1160
90	40	1	50	310	1210
40	30	-6	-60	250	1150[c]

[a]Fuel value
[b]Pinch temperature for cold streams
[c]Water value

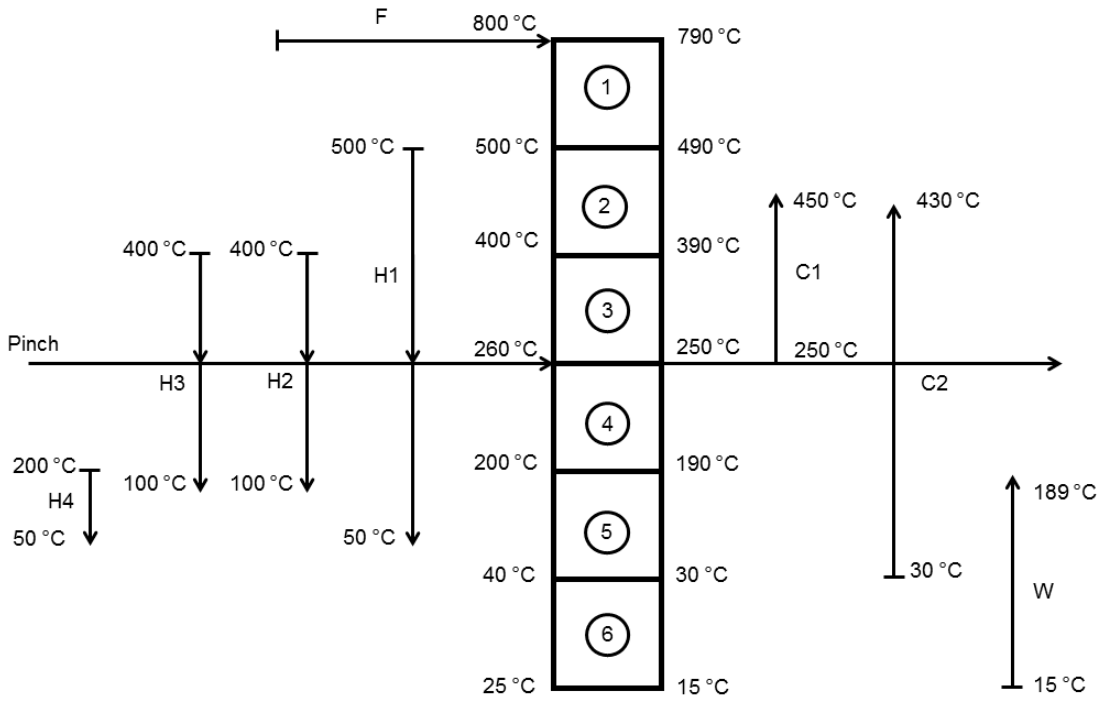


Figure S27. Temperature intervals for Example 6.

Table S93. Energy balances for Example 6.

No.	Stream	Energy balances
1	F	$R_{F,1} = Q_{F,1}^{H}$
2		$R_{F,2} + Q_{F,C1,2} + Q_{F,C2,2} - R_{F,1} = Q_{F,2}^{H}$
3		$Q_{F,C1,3} + Q_{F,C2,3} - R_{F,2} = Q_{F,3}^{H}$
4	H1	$R_{H1,2} + Q_{H1,C1,2} + Q_{H1,C2,2} = Q_{H1,2}^{H}$
5		$Q_{H1,C1,3} + Q_{H1,C2,3} - R_{H1,2} = Q_{H1,3}^{H}$
6		$R_{H1,4} + Q_{H1,C2,4} = Q_{H1,4}^{H}$
7		$R_{H1,5} + Q_{H1,C2,5} + Q_{H1,W,5} - R_{H1,4} = Q_{H1,5}^{H}$
8		$Q_{H1,W,6} - R_{H1,5} = Q_{H1,6}^{H}$
9	H2	$R_{H2,3} + Q_{H2,C1,3} + Q_{H2,C2,3} = Q_{H2,3}^{H}$
10		$R_{H2,4} + Q_{H2,C2,4} = Q_{H2,4}^{H}$
11		$R_{H2,5} + Q_{H2,C2,5} + Q_{H2,W,5} - R_{H2,4} = Q_{H2,5}^{H}$
12		$Q_{H2,W,6} - R_{H2,5} = Q_{H2,6}^{H}$
13	H3	$R_{H3,3} + Q_{H3,C1,3} + Q_{H3,C2,3} = Q_{H3,3}^{H}$
14		$R_{H3,4} + Q_{H3,C2,4} = Q_{H3,4}^{H}$

15		$R_{H3,5} + Q_{H3,C2,5} + Q_{H3,W,5} - R_{H3,4} = Q^{H}_{H3,5}$
16		$Q_{H3,W,6} - R_{H3,5} = Q^{H}_{H3,6}$
17	H4	$R_{H4,5} + Q_{H4,C2,5} + Q_{H4,W,5} = Q^{H}_{H4,5}$
18		$Q_{H4,W,6} - R_{H4,5} = Q^{H}_{H4,6}$
19	C1	$Q_{F,C1,2} + Q_{H1,C1,2} = Q^{C}_{C1,2}$
20		$Q_{F,C1,3} + Q_{H1,C1,3} + Q_{H2,C1,3} + Q_{H3,C1,3} = Q^{C}_{C1,3}$
21	C2	$Q_{F,C2,2} + Q_{H1,C2,2} = Q^{C}_{C2,2}$
22		$Q_{F,C2,3} + Q_{H1,C2,3} + Q_{H2,C2,3} + Q_{H3,C2,3} = Q^{C}_{C2,3}$
23		$Q_{H1,C2,4} + Q_{H2,C2,4} + Q_{H3,C2,4} = Q^{C}_{C2,4}$
24		$Q_{H1,C2,5} + Q_{H2,C2,5} + Q_{H3,C2,5} + Q_{H4,C2,5} = Q^{C}_{C2,5}$
25	W	$Q_{H1,W,5} + Q_{H2,W,5} + Q_{H3,W,5} + Q_{H4,W,5} = Q^{C}_{W,5}$
26		$Q_{H1,W,6} + Q_{H2,W,6} + Q_{H3,W,6} + Q_{H4,W,6} = Q^{C}_{W,6}$
27		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} = 900\ kW$

Table S94. Variables to solve the energy balances for Example 6.

No.	Variable
1	RS,1[a]
2	QS,1^H[a]
3	RS,2[a]
4	QS,C1,2[a]
5	QS,C2,2[a]
6	QS,2^H[a]
7	QS,C1,3[a]
8	QS,C2,3[a]
9	QS,3^H[a]
10	RH1,2[b]
11	QH1,C1,2[b]
12	QH1,C2,2[b]
13	QH1,C1,3[b]
14	QH1,C2,3[b]

15	RH1,4[b]
16	QH1,C2,4[b]
17	RH1,5[b]
18	QH1,C2,5[b]
19	QH1,W,5[b]
20	QH1,W,6[b]
21	QH1,6^H[b]
22	RH2,3[c]
23	QH2,C1,3[c]
24	QH2,C2,3[c]
25	RH2,4[c]
26	QH2,C2,4[c]
27	RH2,5[c]
28	QH2,C2,5[c]
29	QH2,W,5[c]
30	QH2,W,6[c]

31	QH2,6^H[c]
32	RH3,3[d]
33	QH3,C1,3[d]
34	QH3,C2,3[d]
35	RH3,4[d]
36	QH3,C2,4[d]
37	RH3,5[d]
38	QH3,C2,5[d]
39	QH3,W,5[d]
40	QH3,W,6[d]
41	QH3,6^H[d]
42	RH4,5[e]
43	QH4,C2,5[e]
44	QH4,W,5[e]
45	QH4,W,6[e]
46	QH4,6^H[e]

47	$y(S\text{-}C1)^f$
48	$y(S\text{-}C2)^f$
49	$y(H1\text{-}C1)^f$
50	$y(H1\text{-}C2)_above_pinch^f$
51	$y(H1\text{-}C2)_below_pinch^f$
52	$y(H1\text{-}W)^f$
53	$y(H2\text{-}C1)^f$
54	$y(H2\text{-}C2)_above_pinch^f$
55	$y(H2\text{-}C2)_below_pinch^f$
56	$y(H2\text{-}W)^f$
57	$y(H3\text{-}C1)^f$
58	$y(H3\text{-}C2)_above_pinch^f$
59	$y(H3\text{-}C2)_below_pinch^f$
60	$y(H3\text{-}W)^f$
61	$y(H4\text{-}C2)^f$
62	$y(H4\text{-}W)^f$

Continuous variables related to [a]F utility stream, [b]H1, [c]H2, [d]H3 and [e]H4 hot streams. [f]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S95. Constant parameters to solve energy balances for Example 6.

No.	Parameter	Value (kW)
1	QH1,2^H	500
2	QH1,3^H	700
3	QH1,4^H	300
4	QH1,5^H	750
5	QH2,3^H	560
6	QH2,4^H	240
7	QH2,5^H	400
8	QH3,3^H	420
9	QH3,4^H	180
10	QH3,5^H	300
11	QH4,5^H	300
12	QC1,2^C	600
13	QC1,3^C	1400
14	QC2,2^C	240

15	QC2,3^C	840
16	QC2,4^C	360
17	QC2,5^C	960
18	QW,5^C	1050.86
19	QW,6^C	99.14

Table S96. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 6.

No.	Parameter	Value (kW)
1	U(S-C1)=min (900; 2000)	900
2	U(S-C2) =min(900; 1080)	900
3	U(H1-C1) =min(1200; 2000)	1200
4	U(H1-C2)_above_pinch=min(1200; 1080)	1080
5	U(H1-C2)_below_pinch=min(1050; 1320)	1050
6	U(H1-W) =min(1050; 1150)	1050
7	U(H2-C1) =min(560; 1400)	560
8	U(H2-C2)_above_pinch=min(560; 840)	560
9	U(H2-C2)_below_pinch=min(640; 1320)	640
10	U(H2-W) =min(640; 1150)	640
11	U(H3-C1) =min(420; 1400)	420
12	U(H3-C2)_above_pinch=min(420; 840)	420
13	U(H3-C2)_below_pinch=min(480; 1320)	480

14	U(H3-W) =min(480; 1150)	480
15	U(H4-C2) =min(300; 960)	300
16	U(H4-W) =min(300; 1150)	300

Table S97. Restrictions describing heat exchangers between utilities and streams from Example 6.

No.	Heat exchanger	Restriction
1	S-C1	$Q_{S,C1,2} + Q_{S,C1,3} - y_{S,C1}U_{S,C1} \leq 0$
2	S-C2	$Q_{S,C2,2} + Q_{S,C2,3} - y_{S,C2}U_{S,C2} \leq 0$
3	H1-C1	$Q_{H1,C1,2} + Q_{H1,C1,3} - y_{H1,C1}U_{H1,C1} \leq 0$
4	(H1-C2)_above_pinch	$Q_{H1,C2,2} + Q_{H1,C2,3} - \left(y_{H1,C2}\right)_{above_pinch}\left(U_{H1,C2}\right)_{above_pinch} \leq 0$
5	(H1-C2)_below_pinch	$Q_{H1,C2,4} + Q_{H1,C2,5} - \left(y_{H1,C2}\right)_{below_pinch}\left(U_{H1,C2}\right)_{below_pinch} \leq 0$
6	H1-W	$Q_{H1,W,5} + Q_{H1,W,6} - y_{H1,W}U_{H1,W} \leq 0$
7	H2-C1	$Q_{H2,C1,3} - y_{H2,C1}U_{H2,C1} \leq 0$
8	(H2-C2)_above_pinch	$Q_{H2,C2,3} - \left(y_{H2,C2}\right)_{above_pinch}\left(U_{H2,C2}\right)_{above_pinch} \leq 0$
9	(H2-C2)_below_pinch	$Q_{H2,C2,4} + Q_{H2,C2,5} - \left(y_{H2,C2}\right)_{below_pinch}\left(U_{H2,C2}\right)_{below_pinch} \leq 0$
10	H2-W	$Q_{H2,W,5} + Q_{H2,W,6} - y_{H2,W}U_{H2,W} \leq 0$

11	H3-C1	$Q_{H3,C1,3} - y_{H3,C1}U_{H3,C1} \leq 0$
12	(H3-C2)_above_pinch	$Q_{H3,C2,3}$ $-\left(y_{H3,C2}\right)_{above_pinch}\left(U_{H3,C2}\right)_{above_pinch} \leq 0$
13	(H3-C2)_below_pinch	$Q_{H3,C2,4} + Q_{H3,C2,5}$ $-\left(y_{H3,C2}\right)_{below_pinch}\left(U_{H3,C2}\right)_{below_pinch} \leq 0$
14	H3-W	$Q_{H3,W,5} + Q_{H3,W,6} - y_{H3,W}U_{H3,W} \leq 0$
15	H4-C2	$Q_{H4,C2,5} - y_{H4,C2}U_{H4,C2} \leq 0$
16	H4-W	$Q_{H4,W,5} + Q_{H4,W,6} - y_{H4,W}U_{H4,W} \leq 0$

Table S98. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 6.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater-1	S-C1	QS,C1,2	100
Heater-2	S-C2	QS,C2,2	240
		QS,C2,3	560
1	H1-C1	QH1,C1,2	500
		QH1,C1,3	700
2	H1-C2	QH1,C2,4	300
3	H2-C1	QH2,C1,3	560
4	H2-C2	QH2,C2,4	60
		QH2,C2,5	580
5	H3-C1	QH3,C1,3	140
6	H3-C2	QH3,C2,3	280
7	H3-C2	QH3,C2,5	380
Cooler-1	H1-W	QH1,W,5	750

Cooler-2	H3-W	QH3,W,5	100
Cooler-3	H4-W	QH4,W,5	200.86
		QH4,W,6	99.14

Table S99. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 6 employed to devise the HEN.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater-1	S-C1	QS,C1,2	100
Heater-2	S-C2	QS,C2,2	240
		QS,C2,3	560
1	H1-C1	QH1,C1,2	500
2	H1-C1	QH1,C1,3	700
3	H2-C1	QH2,C1,3	560
4	H3-C1	QH3,C1,3	140
5	H3-C2	QH3,C2,3	280
6	H1-C2	QH1,C2,4	300
7	H2-C2	QH2,C2,4	60
		QH2,C2,5	580
8	H3-C2	QH3,C2,5	380
Cooler-1	H1-W	QH1,W,5	750

Cooler-2	H3-W	QH3,W,5	100
Cooler-3	H4-W	QH4,W,5	200.86
		QH4,W,6	99.14

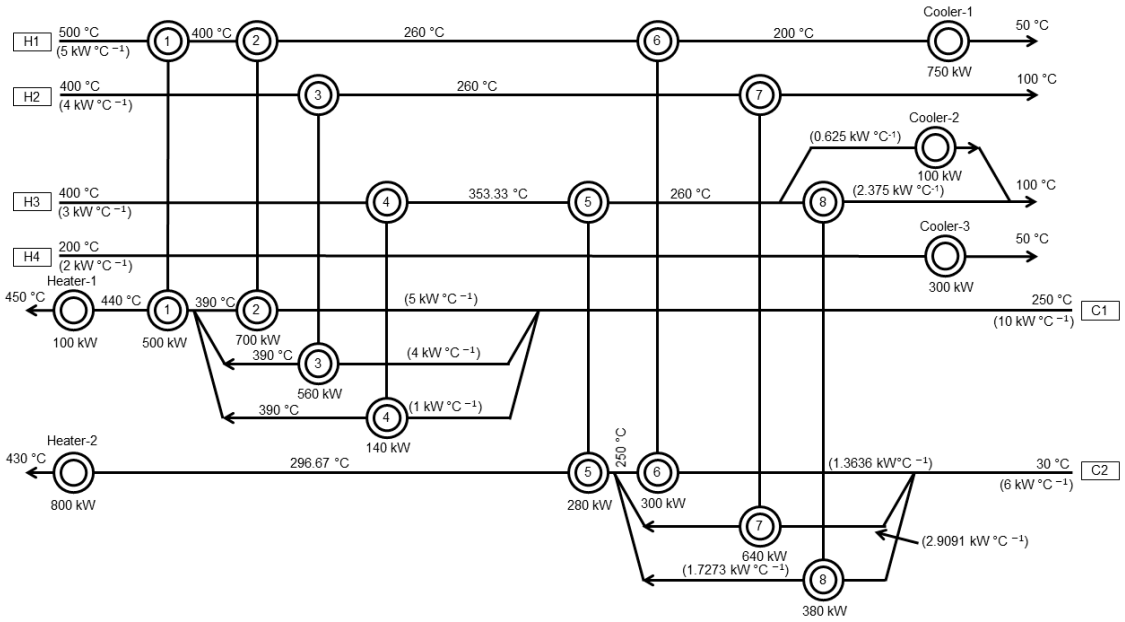


Figure S28. HEN with F and W for Example 6.

Table S100. Costs for HEN without multiple utilities for Example 6.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P (\$)
1	27.59	40.82	12954.25
2	10	157.66	11977.14
3	10	126.13	11835.76
4	38.83	8.12	17830.03
5	26.63	11.84	17830.03
6	53.49	4.21	17830.03
7	30.37	11.87	17830.03
8	30.37	5.64	17830.03
Cooler-1	20.69	13.61	17830.03
Cooler-2	77.79	0.41	17830.03
Cooler-3	20.69	4.08	17830.03
Heater-1	354.98	0.07	17830.03
Heater-2	433.25	0.42	17830.03
		Total	197237.41

Example 6 with multiple utilities

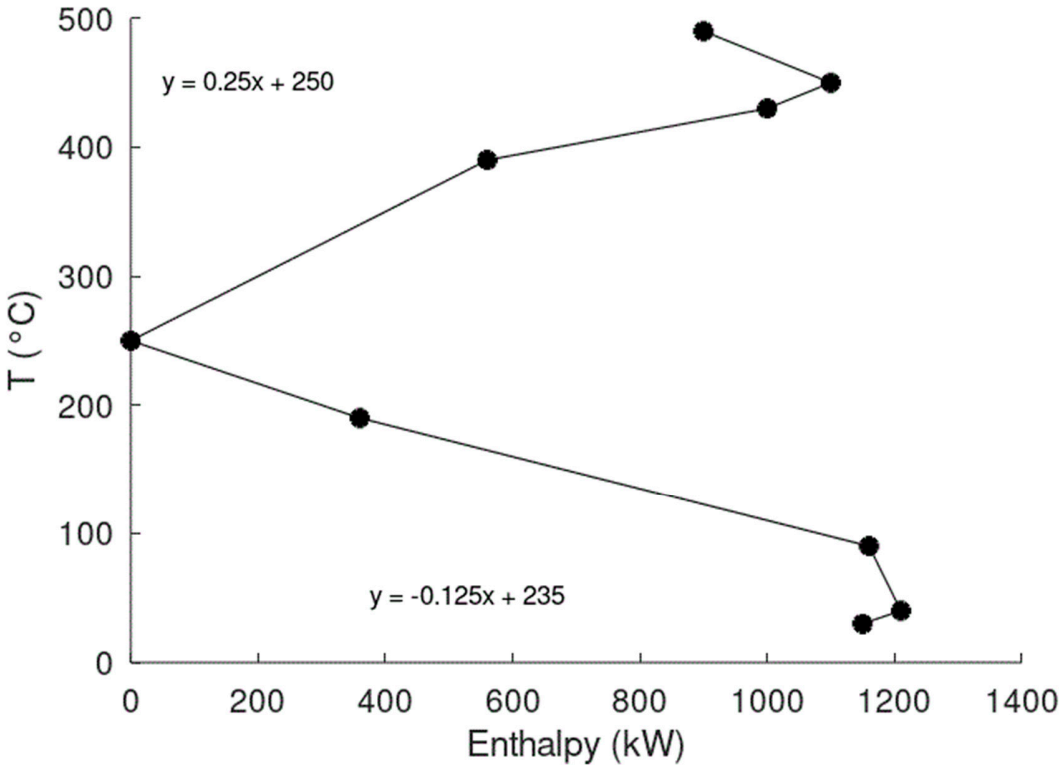


Figure S29. Grand Composite Curve for Example 6. Equation "y=0.25x+250" correspond to the 400 °C and 250 °C line. Moreover, the equation "y=-0.125x+235" describes the line between 190 °C and 90 °C.

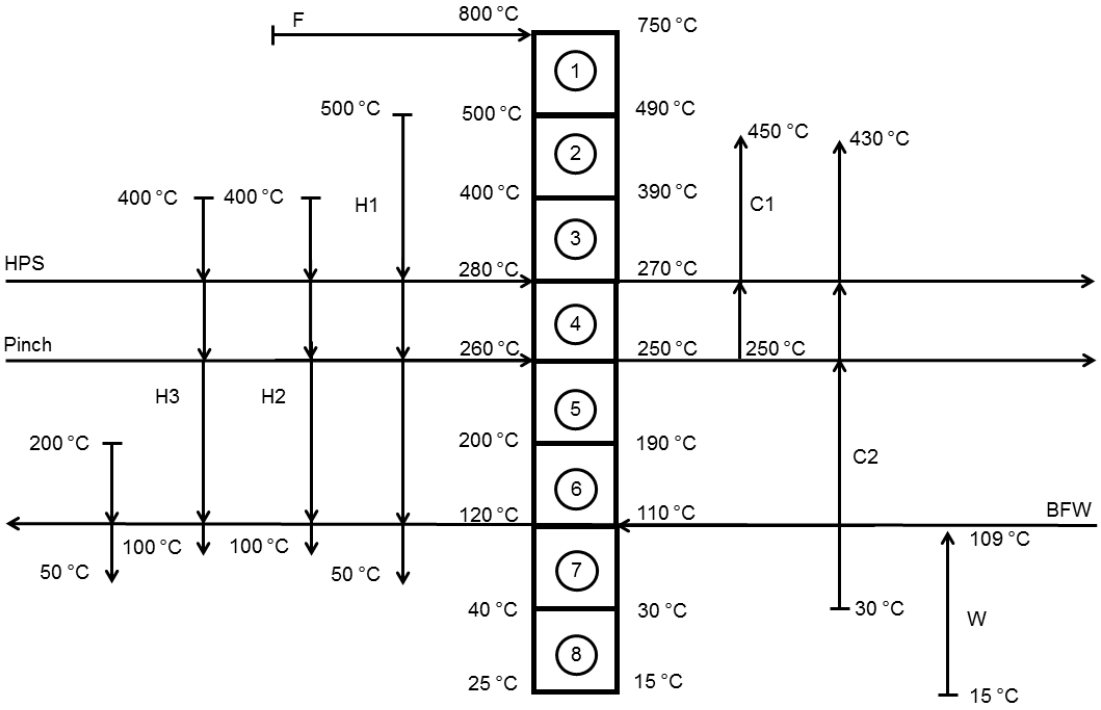


Figure S30. Temperature intervals for Example 6 with multiple utilities.

Table S101. Energy balances for Example 6 with multiple utilities.

No.	Stream	Energy balances
1	F	$R_{F,1} = Q_{F,1}^{H}$
2		$R_{F,2} + Q_{F,C1,2} + Q_{F,C2,2} - R_{F,1} = Q_{F,2}^{H}$
3		$Q_{F,C1,3} + Q_{F,C2,3} - R_{F,2} = Q_{F,3}^{H}$
4	H1	$R_{H1,2} + Q_{H1,C1,2} + Q_{H1,C2,2} = Q_{H1,2}^{H}$
5		$Q_{H1,C1,3} + Q_{H1,C2,3} - R_{H1,2} = Q_{H1,3}^{H}$
6		$R_{H1,4} + Q_{H1,C1,4} + Q_{H1,C2,4} = Q_{H1,4}^{H}$
7		$R_{H1,5} + Q_{H1,C2,5} + Q_{H1,BFW,5} = Q_{H1,5}^{H}$
8		$Q_{H1,C2,6} + Q_{H1,BFW,6} - R_{H1,5} = Q_{H1,6}^{H}$
9		$R_{H1,7} + Q_{H1,C2,7} + Q_{H1,W,7} = Q_{H1,7}^{H}$
10		$Q_{H1,W,8} - R_{H1,7} = Q_{H1,8}^{H}$
11	H2	$R_{H2,3} + Q_{H2,C1,3} + Q_{H2,C2,3} = Q_{H2,3}^{H}$
12		$R_{H2,4} + Q_{H2,C1,4} + Q_{H2,C2,4} = Q_{H2,4}^{H}$
13		$R_{H2,5} + Q_{H2,C2,5} + Q_{H2,BFW,5} = Q_{H2,5}^{H}$
14		$Q_{H2,C2,6} + Q_{H2,BFW,6} - R_{H2,5} = Q_{H2,6}^{H}$

15		$R_{H2,7} + Q_{H2,W,7} + Q_{H2,C2,7} = Q^{H}_{H2,7}$
16		$Q_{H2,W,8} - R_{H2,7} = Q^{H}_{H2,8}$
17	H3	$R_{H3,3} + Q_{H3,C1,3} + Q_{H3,C2,3} = Q^{H}_{H3,3}$
18		$R_{H3,4} + Q_{H3,C1,4} + Q_{H3,C2,4} = Q^{H}_{H3,4}$
19		$R_{H3,5} + Q_{H3,C2,5} + Q_{H3,BFW,5} = Q^{H}_{H3,5}$
20		$Q_{H3,C2,6} + Q_{H3,BFW,6} - R_{H3,5} = Q^{H}_{H3,6}$
21		$R_{H3,7} + Q_{H3,W,7} + Q_{H3,C2,7} = Q^{H}_{H3,7}$
22		$Q_{H3,W,8} - R_{H3,7} = Q^{H}_{H3,8}$
23	HPS	$R_{HPS,4} + Q_{HPS,C1,4} + Q_{HPS,C2,4} = Q^{H}_{HPS,4}$
24	H4	$R_{H4,6} + Q_{H4,C2,6} + Q_{H4,BFW,6} = Q^{H}_{H4,6}$
25		$R_{H4,7} + Q_{H4,W,7} + Q_{H4,C2,7} = Q^{H}_{H4,7}$
26		$Q_{H4,W,8} - R_{H4,7} = Q^{H}_{H4,8}$
27	C1	$Q_{F,C1,2} + Q_{H1,C1,2} = Q^{C}_{C1,2}$
28		$Q_{F,C1,3} + Q_{H1,C1,3} + Q_{H2,C1,3} + Q_{H3,C1,3} = Q^{C}_{C1,3}$
29		$Q_{HPS,C1,4} + Q_{H1,C1,4} + Q_{H2,C1,4} + Q_{H3,C1,4} = Q^{C}_{C1,4}$
30	C2	$Q_{F,C2,2} + Q_{H1,C2,2} = Q^{C}_{C2,2}$

31		$Q_{F,C2,3} + Q_{H1,C2,3} + Q_{H2,C2,3} + Q_{H3,C2,3} = Q^{C}_{C2,3}$
32		$Q_{HPS,C2,4} + Q_{H1,C2,4} + Q_{H2,C2,4} + Q_{H3,C2,4} = Q^{C}_{C2,4}$
33		$Q_{H1,C2,5} + Q_{H2,C2,5} + Q_{H3,C2,5} = Q^{C}_{C2,5}$
34		$Q_{H1,C2,6} + Q_{H2,C2,6} + Q_{H3,C2,6} + Q_{H4,C2,6} = Q^{C}_{C2,6}$
35		$Q_{H1,C2,7} + Q_{H2,C2,7} + Q_{H3,C2,7} + Q_{H4,C2,7} = Q^{C}_{C2,7}$
36	BFW	$Q_{H1,BFW,5} + Q_{H2,BFW,5} + Q_{H3,BFW,5} = Q^{C}_{BFW,5}$
37		$Q_{H1,BFW,6} + Q_{H2,BFW,6} + Q_{H3,BFW,6} + Q_{H4,BFW,6} = Q^{C}_{BFW,6}$
38	W	$Q_{H1,W,7} + Q_{H2,W,7} + Q_{H3,W,7} + Q_{H4,W,7} = Q^{C}_{W,7}$
39		$Q_{H1,W,8} + Q_{H2,W,8} + Q_{H3,W,8} + Q_{H4,W,8} = Q^{C}_{W,8}$
40		$Q^{H}_{F,1} + Q^{H}_{F,2} + Q^{H}_{F,3} = 820\ kW$
41		$Q^{C}_{BFW,5} + Q^{C}_{BFW,6} = 1000\ kW$

Table S102. Variables to solve the energy balances for Example 6 with multiple utilities.

No.	Variable
1	RF,1[a]
2	QF,1^H[a]
3	RF,2[a]
4	QF,C1,2[a]
5	QF,C2,2[a]
6	QF,2^H[a]
7	QF,C1,3[a]
8	QF,C2,3[a]
9	QF,3^H[a]
10	RH1,2[b]
11	QH1,C1,2[b]
12	QH1,C2,2[b]
13	QH1,C1,3[b]
14	QH1,C2,3[b]

15	RH1,4[b]
16	QH1,C1,4[b]
17	QH1,C2,4[b]
18	RH1,5[b]
19	QH1,C2,5[b]
20	QH1,C2,6[b]
21	QH1,BFW,5[b]
22	QH1,BFW,6[b]
23	RH1,7[b]
24	QH1,C2,7[b]
25	QH1,W,7[b]
26	QH1,W,8[b]
27	QH1,8^H[b]
28	RH2,3[c]
29	QH2,C1,3[c]

30	QH2,C2,3[c]
31	RH2,4[c]
32	QH2,C1,4[c]
33	QH2,C2,4[c]
34	RH2,5[c]
35	QH2,C2,5[c]
36	QH2,C2,6[c]
37	QH2,BFW,5[c]
38	QH2,BFW,6[c]
39	RH2,7[c]
40	QH2,W,7[c]
41	QH2,C2,7[c]
42	QH2,W,8[c]
43	QH2,8^H[c]
44	RH3,3[d]

45	QH3,C1,3[d]
46	QH3,C2,3[d]
47	RH3,4[d]
48	QH3,C1,4[d]
49	QH3,C2,4[d]
50	RH3,5[d]
51	QH3,C2,[5]
52	QH3,C2,6[d]
53	QH3,BFW,5[d]
54	QH3,BFW,6[d]
55	RH3,7[d]
56	QH3,W,7[d]
57	QH3,C2,7[d]
58	QH3,W,8[d]
59	QH3,8^H[d]

60	RHPS,4[e]
61	QHPS,C1,4[e]
62	QHPS,C2,4[e]
63	RH4,6[f]
64	QH4,C2,6[f]
65	QH4,BFW,6[f]
66	RH4,7[f]
67	QH4,W,7[f]
68	QH4,C2,7[f]
69	QH4,W,8[f]
70	QH4,8^H[f]
71	QBFW,5^C[f]
72	QBFW,6^C[f]
73	y(F-C1)[g]
74	y(F-C2)[g]

75	$y(H1\text{-}C1)_above_HPS_pinch^{g}$
76	$y(H1\text{-}C1)_above_process_pinch^{g}$
77	$y(H1\text{-}C2)_above_HPS_pinch^{g}$
78	$y(H1\text{-}C2)_above_process_pinch^{g}$
79	$y(H1\text{-}C2)_above_BFW_pinch^{g}$
80	$y(H1\text{-}C2)_below_BFW_pinch^{g}$
81	$y(H1\text{-}W)^{g}$
82	$y(H2\text{-}C1)_above_HPS_pinch^{g}$
83	$y(H2\text{-}C1)_above_process_pinch^{g}$
84	$y(H2\text{-}C2)_above_HPS_pinch^{g}$
85	$y(H2\text{-}C2)_above_process_pinch^{g}$
86	$y(H2\text{-}C2)_above_BFW_pinch^{g}$
87	$y(H2\text{-}C2)_below_BFW_pinch^{g}$
88	$y(H2\text{-}W)^{g}$
89	$y(H3\text{-}C1)_above_HPS_pinch^{g}$

90	$y(H3\text{-}C1)_above_process_pinch^{g}$
91	$y(H3\text{-}C2)_above_HPS_pinch^{g}$
92	$y(H3\text{-}C2)_above_process_pinch^{g}$
93	$y(H3\text{-}C2)_above_BFW_pinch^{g}$
94	$y(H3\text{-}C2)_below_BFW_pinch^{g}$
95	$y(H3\text{-}W)^{g}$
96	$y(H4\text{-}C2)_above_BFW_pinch^{g}$
97	$y(H4\text{-}C2)_below_BFW_pinch^{g}$
98	$y(H4\text{-}W)^{g}$
99	$y(H1\text{-}BFW)_5^{g}$
100	$y(H1\text{-}BFW)_6^{g}$
101	$y(H2\text{-}BFW)_5^{g}$
102	$y(H2\text{-}BFW)_6^{g}$
103	$y(H3\text{-}BFW)_5^{g}$
104	$y(H3\text{-}BFW)_6^{g}$

105	y(H4-BFW)[g]
106	y(HPS-C1)[g]
107	y(HPS-C2)[g]

Continuous variables related to [a]F and [e]S utility streams, [b]H1, [c]H2, [d]H3 and [f]H4 hot streams. [g]Discrete variables regarding possible heat exchange between the streams involved in the HEN. The objective function is the minimization of the sum of the discrete variables mentioned above.

Table S103. Constant parameters to solve energy balances for Example 6 with multiple utilities.

No.	Parameter	Value (kW)
1	QH1,2^H	500
2	QH1,3^H	600
3	QH1,4^H	100
4	QH1,5^H	300
5	QH1,6^H	400
6	QH1,7^H	350
7	QH2,3^H	480
8	QH2,4^H	80
9	QH2,5^H	240
10	QH2,6^H	320
11	QH2,7^H	80
12	QH3,3^H	360
13	QH3,4^H	60

14	QH3,5^H	180
15	QH3,6^H	240
16	QH3,7^H	60
17	QHPS,4^H	80
18	QH4,6^H	160
19	QH4,7^H	140
20	QC1,2^C	600
21	QC1,3^C	1200
22	QC1,4^C	200
23	QC2,2^C	240
24	QC2,3^C	720
25	QC2,4^C	120
26	QC2,5^C	360
27	QC2,6^C	480
28	QC2,7^C	480

29	QW,7^C	126.06
30	QW,8^C	23.94

Table S104. Parameter describing the minimum feasible heat value exchanged between the utilities and the streams from Example 6 with multiple utilities.

No.	Parameter	Value (kW)
1	U(S-C1)=min(820; 1800)	820
2	U(S-C2) =min(820; 960)	820
3	U(H1-C1)_above_HPS_pinch=min(1100; 1800)	1100
4	U(H1-C1)_above_process_pinch=min(100; 200)	100
5	U(H1-C2)_above_HPS_pinch=min(1100; 960)	960
6	U(H1-C2)_above_process_pinch=min(100; 120)	100
7	U(H1-C2)_above_BFW_pinch=min(700; 840)	700
8	U(H1-C2)_below_BFW_pinch=min(350; 480)	350
9	U(H1-W) =min(350; 150)	150
10	U(H2-C1)_above_HPS_pinch=min(480; 1200)	480
11	U(H2-C1)_above_process_pinch=min(80; 200)	80
12	U(H2-C2)_above_HPS_pinch=min(480; 720)	480
13	U(H2-C2)_above_process_pinch=min(80; 120)	80

14	U(H2-C2)_above_BFW_pinch=min(560; 840)	560
15	U(H2-C2)_below_BFW_pinch=min(80; 480)	80
16	U(H2-W) =min(80; 150)	80
17	U(H3-C1)_above_HPS_pinch=min(360; 1200)	360
18	U(H3-C1)_above_process_pinch=min(60; 200)	60
19	U(H3-C2)_above_HPS_pinch=min(360; 720)	360
20	U(H3-C2)_above_process_pinch=min(60; 120)	60
21	U(H3-C2)_above_BFW_pinch=min(420; 840)	420
22	U(H3-C2)_below_BFW_pinch=min(60; 480)	60
23	U(H3-W) =min(60; 150)	60
24	U(H4-C2)_above_BFW_pinch=min(160; 480)	160
25	U(H4-C2)_below_BFW_pinch=min(140; 480)	140
26	U(H4-W) =min(140; 150)	140
27	U(H1-BFW)_5=min(300; 1000)	300
28	U(H1-BFW)_6=min(400; 1000)	400

29	U(H2-BFW)_5=min(240; 1000)	240
30	U(H2-BFW)_6=min(320; 1000)	320
31	U(H3-BFW)_5=min(180; 1000)	180
32	U(H3-BFW)_6=min(240; 1000)	240
33	U(H4-BFW) =min(160; 1000)	160
34	U(HPS-C1) =min(80; 200)	80
35	U(HPS-C2) =min(80; 120)	80

Table S105. Restrictions describing heat exchangers between utilities and streams from Example 6 with multiple utilities.

No.	Heat exchanger	Restriction
1	F-C1	$Q_{F,C1,2} + Q_{F,C1,3} - y_{F,C1}U_{F,C1} \leq 0$
2	F-C2	$Q_{F,C2,2} + Q_{F,C2,3} - y_{F,C2}U_{F,C2} \leq 0$
3	(H1-C1)_above_HPS_pinch	$Q_{H1,C1,2} + Q_{H1,C1,3} - (y_{H1,C1})_{above_HPS_pinch}(U_{H1,C1})_{above_HPS_pinch} \leq 0$
4	(H1-C1)_above_process_pinch	$Q_{H1,C1,4} - (y_{H1,C1})_{above_process_pinch}(U_{H1,C1})_{above_process_pinch} \leq 0$
5	(H1-C2)_above_HPS_pinch	$Q_{H1,C2,2} + Q_{H1,C2,3} - (y_{H1,C2})_{above_HPS_pinch}(U_{H1,C2})_{above_HPS_pinch} \leq 0$
6	(H1-C2)_above_process_pinch	$Q_{H1,C2,4} - (y_{H1,C2})_{above_process_pinch}(U_{H1,C2})_{above_process_pinch} \leq 0$
7	(H1-C2)_above_BFW_pinch	$Q_{H1,C2,5} + Q_{H1,C2,6} - (y_{H1,C2})_{above_BFW_pinch}(U_{H1,C2})_{above_BFW_pinch} \leq 0$

8	(H1-C2)_below_BFW_pinch	$Q_{H1,C2,7} - (y_{H1,C2})_{below_BFW_pinch}(U_{H1,C2})_{below_BFW_pinch} \leq 0$
9	H1-W	$Q_{H1,W,7} + Q_{H1,W,8} - y_{H1,W}U_{H1,W} \leq 0$
10	(H2-C1)_above_HPS_pinch	$Q_{H2,C1,3} - (y_{H2,C1})_{above_HPS_pinch}(U_{H2,C1})_{above_HPS_pinch} \leq 0$
11	(H2-C1)_above_process_pinch	$Q_{H2,C1,4} - (y_{H2,C1})_{above_process_pinch}(U_{H2,C1})_{above_process_pinch} \leq 0$
12	(H2-C2)_above_HPS_pinch	$Q_{H2,C2,3} - (y_{H2,C2})_{above_HPS_pinch}(U_{H2,C2})_{above_HPS_pinch} \leq 0$
13	(H2-C2)_above_process_pinch	$Q_{H2,C2,4} - (y_{H2,C2})_{above_process_pinch}(U_{H2,C2})_{above_process_pinch} \leq 0$
14	(H2-C2)_above_BFW_pinch	$Q_{H2,C2,5} + Q_{H2,C2,6} - (y_{H2,C2})_{above_BFW_pinch}(U_{H2,C2})_{above_BFW_pinch} \leq 0$

15	(H2-C2)_below_BFW_pinch	$Q_{H2,C2,7} - (y_{H2,C2})_{below_BFW_pinch}(U_{H2,C2})_{below_BFW_pinch} \leq 0$
16	H2-W	$Q_{H2,W,7} + Q_{H2,W,8} - y_{H2,W}U_{H2,W} \leq 0$
17	(H3-C1)_above_HPS_pinch	$Q_{H3,C1,3} - (y_{H3,C1})_{above_HPS_pinch}(U_{H3,C1})_{above_HPS_pinch} \leq 0$
18	(H3-C1)_above_process_pinch	$Q_{H3,C1,4} - (y_{H3,C1})_{above_process_pinch}(U_{H3,C1})_{above_process_pinch} \leq 0$
19	(H3-C2)_above_HPS_pinch	$Q_{H3,C2,3} - (y_{H3,C2})_{above_HPS_pinch}(U_{H3,C2})_{above_HPS_pinch} \leq 0$
20	(H3-C2)_above_process_pinch	$Q_{H3,C2,4} - (y_{H3,C2})_{above_process_pinch}(U_{H3,C2})_{above_process_pinch} \leq 0$
21	(H3-C2)_above_BFW_pinch	$Q_{H3,C2,5} + Q_{H3,C2,6} - (y_{H3,C2})_{above_BFW_pinch}(U_{H3,C2})_{above_BFW_pinch} \leq 0$

22	(H3-C2)_below_BFW_pinch	$Q_{H3,C2,7} - \left(y_{H3,C2}\right)_{below_BFW_pinch}\left(U_{H3,C2}\right)_{below_BFW_pinch} \leq 0$
23	H3-W	$Q_{H3,W,7} + Q_{H3,W,8} - y_{H3,W}U_{H3,W} \leq 0$
24	(H4-C2)_above_BFW_pinch	$Q_{H4,C2,6} - \left(y_{H4,C2}\right)_{above_BFW_pinch}\left(U_{H4,C2}\right)_{above_BFW_pinch} \leq 0$
25	(H4-C2)_below_BFW_pinch	$Q_{H4,C2,7} - \left(y_{H4,C2}\right)_{below_BFW_pinch}\left(U_{H4,C2}\right)_{below_BFW_pinch} \leq 0$
26	H4-W	$Q_{H4,W,7} + Q_{H4,W,8} - y_{H4,W}U_{H4,W} \leq 0$
27	(H1-BFW)_5	$Q_{H1,BFW,5} - \left(y_{H1,BFW}\right)_5\left(U_{H1,BFW}\right)_5 \leq 0$
28	(H1-BFW)_6	$Q_{H1,BFW,6} - \left(y_{H1,BFW}\right)_6\left(U_{H1,BFW}\right)_6 \leq 0$
29	(H2-BFW)_5	$Q_{H2,BFW,5} - \left(y_{H2,BFW}\right)_5\left(U_{H2,BFW}\right)_5 \leq 0$
30	(H2-BFW)_6	$Q_{H2,BFW,6} - \left(y_{H2,BFW}\right)_6\left(U_{H2,BFW}\right)_6 \leq 0$
31	(H3-BFW)_5	$Q_{H3,BFW,5} - \left(y_{H3,BFW}\right)_5\left(U_{H3,BFW}\right)_5 \leq 0$
32	(H3-BFW)_6	$Q_{H3,BFW,6} - \left(y_{H3,BFW}\right)_6\left(U_{H3,BFW}\right)_6 \leq 0$
33	H4-BFW	$Q_{H4,BFW,6} - y_{H4,BFW}U_{H4,BFW} \leq 0$

34	HPS-C1	$Q_{HPS,C1,4} - y_{HPS,C1} U_{HPS,C1} \leq 0$
35	HPS-C2	$Q_{HPS,C2,4} - y_{HPS,C2} U_{HPS,C2} \leq 0$

Table S106. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 6 with multiple utilities.

No.	Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
1	Heater-1	F-C1	QF,C1,2	340
2	Heater-2	F-C2	QF,C2,2	240
3			QF,C2,3	240
4	1	H1-C1	QH1,C1,2	260
5			QH1,C1,3	840
6	2	H1-C1	QH1,C1,4	100
7	3	H1-C2	QH1,C2,7	340
8	4	H2-C2	QH2,C2,3	480
9	5	H2-C2	QH2,C2,4	80
10	6	H2-C2	QH2,C2,5	200
11			QH2,C2,6	360
12	7	H3-C1	QH3,C1,3	360
13	8	H3-C1	QH3,C1,4	60

14	9	H3-C2	QH3,C2,5	160
15			QH3,C2,6	120
16	10	H4-C2	QH4,C2,7	140
17	11	H1-BFW	QH1,BFW,5	300
18	12	H1-BFW	QH1,BFW,6	400
19	13	H3-BFW	QH3,BFW,6	140
20	14	H4-BFW	QH4,BFW,6	160
21	15	HPS-C1	QHPS,C1,4	40
22	16	HPS-C2	QHPS,C2,4	40
23	Cooler-1	H1-W	QH1,W,7	5
24			QH1,W,8	5
25	Cooler-2	H2-W	QH2,W,7	61.06
26			QH2,W,8	18.94
27	Cooler-3	H3-W	QH3,W,7	60
28			QH3,W,8	0

Table S107. Unit name, heat exchanging streams, interval, and the value found using the Solver tool from Microsoft Excel® for Example 6 with multiple utilities employed to devise the HEN.

Unit name	Heat exchanging streams	Heat exchange Interval	Value (kW)
Heater-1	F-C1	QF,C1,2	340
Heater-2	F-C2	QF,C2,2	240
		QF,C2,3	240
1	H1-C1	QH1,C1,2	260
2	H1-C1	QH1,C1,3	840
3	H3-C1	QH3,C1,3	360
4	H2-C2	QH2,C2,3	480
5	HPS-C1	QHPS,C1,4	40
6	HPS-C2	QHPS,C2,4	40
7	H1-C1	QH1,C1,4	100
8	H2-C2	QH2,C2,4	80
9	H3-C1	QH3,C1,4	60
10	H2-C2	QH2,C2,5	200

		QH2,C2,6	360
11	H3-C2	QH3,C2,5	160
		QH3,C2,6	120
12	H1-BFW	QH1,BFW,5	300
		QH1,BFW,6	400
13	H3-BFW	QH3,BFW,6	140
14	H4-BFW	QH4,BFW,6	160
15	H1-C2	QH1,C2,7	340
16	H4-C2	QH4,C2,7	140
Cooler-1	H1-W	QH1,W,7	5
		QH1,W,8	5
Cooler-2	H2-W	QH2,W,7	61.06
		QH2,W,8	18.94
Cooler-3	H3-W	QH3,W,7	60

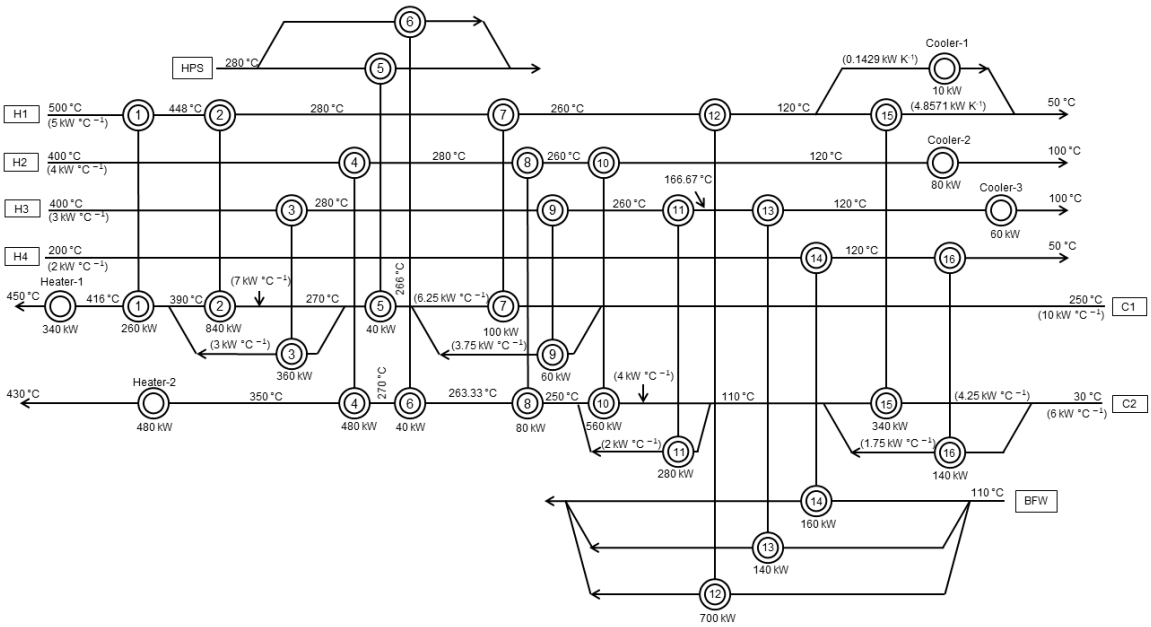


Figure S31. HEN with multiple utilities for Example 6.

Table S108. Costs for HEN with multiple utilities for Example 6.

Unit name	ΔT_{LM} (°C)	A (m^2)	C_P ($)
1	70.2	8.34	17830.03
2	27.02	70.03	12023.99
3	10	81.08	11900.58
4	24.66	43.84	12785.1
5	11.89	3.79	17830.03
6	13.05	2.30	17830.03
7	11.89	4.74	17830.03
8	13.05	2.76	17830.03
9	11.89	1.9	17830.03
10	10	18.02	16180.22
11	26.63	2.96	17830.03
12	49.32	3.55	17830.03
13	26.63	1.18	17830.03

14	35.57	0.92	17830.03
15	14.42	4.43	17830.03
16	14.42	1.68	17830.03
Cooler-1	20.69	0.08	17830.03
Cooler-2	35.54	5.07	17830.03
Cooler-3	35.54	1.9	17830.03
Heater-1	366.74	0.7	17830.03
Heater-2	408.7	2.65	17830.03
		Total	356000.36

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