PART 8

RETROFIT

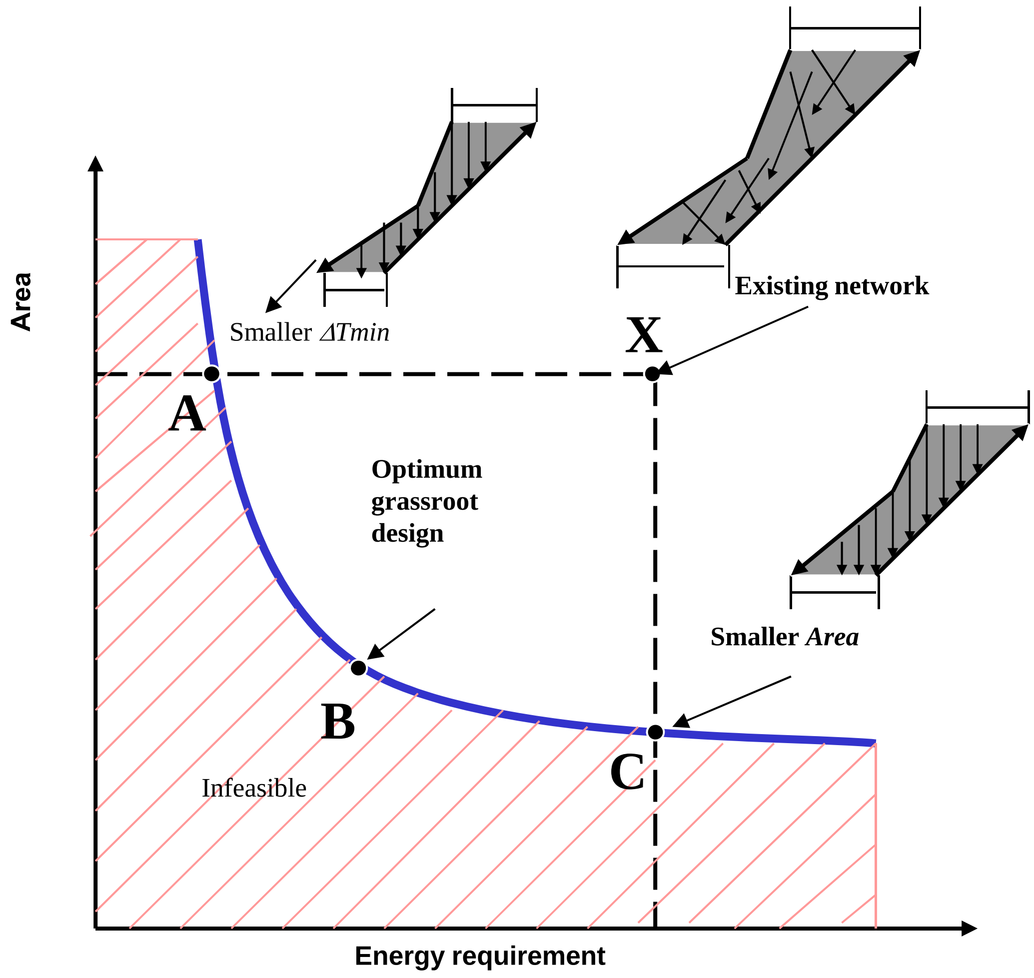
RETROFIT

RETROFIT GOAL: Reduce Energy Consumption

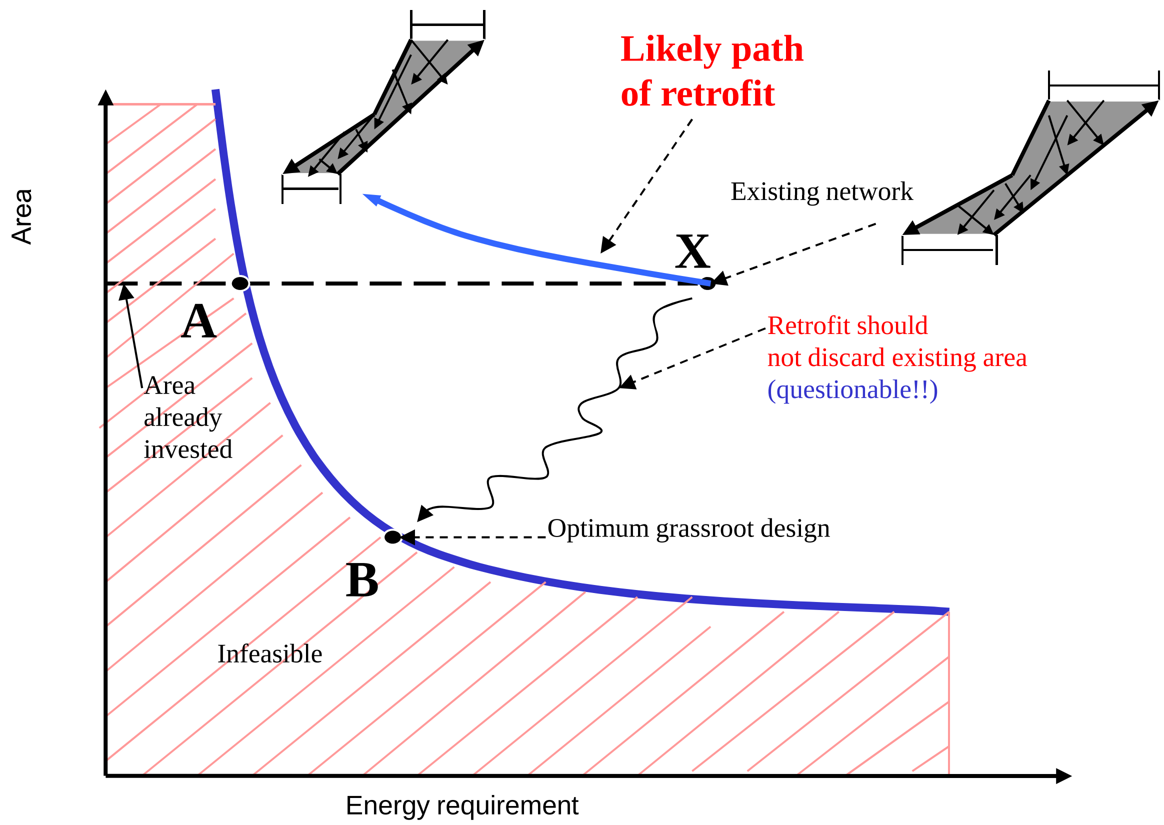
RETROFIT MECHANISMS:

- Addition of one or more new heat exchangers (in series or parallel)
- Relocation of existing exchangers
- Area addition to existing heat exchangers
  - –Adding a shell
  - –Exchanging the bank of tubes by one more efficient (Brown Fintube, Houston, TX)
- Area reduction to existing heat exchangers

PDM TARGETING



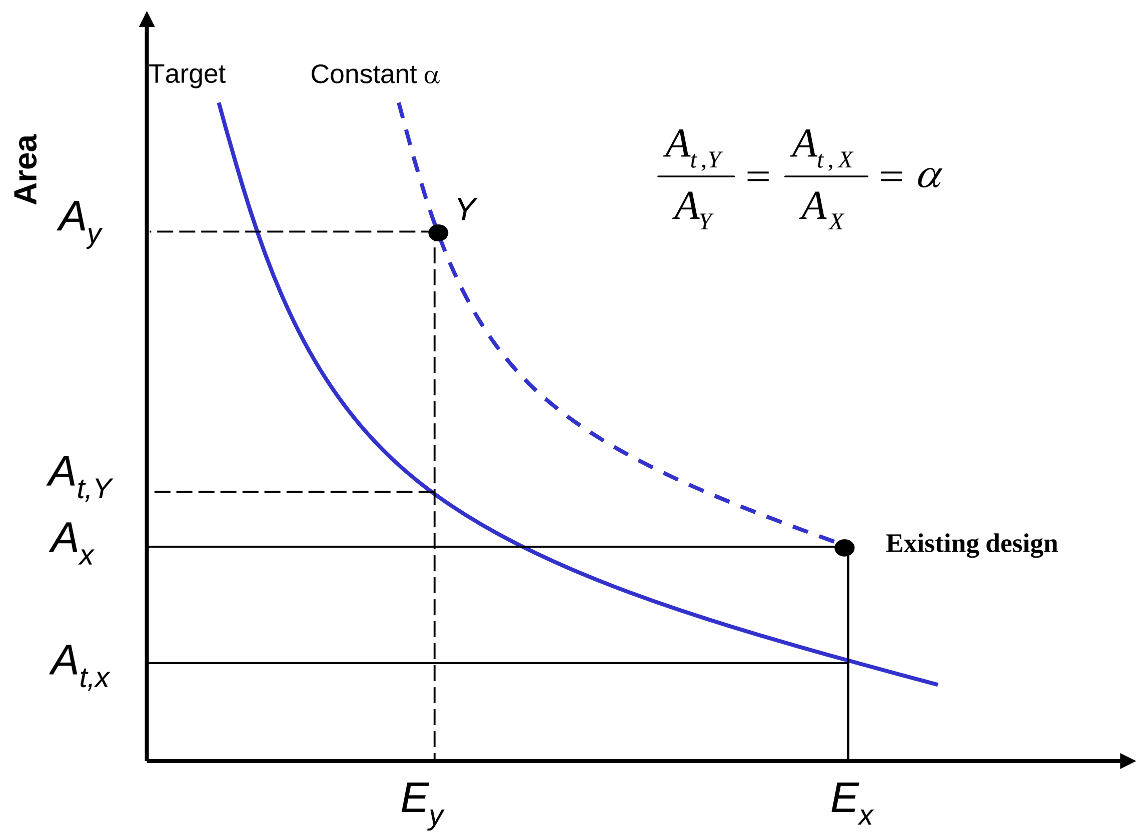
LIKELY PATH



Likely path
of retrofit
Existing network
X
A
Area
already
invested
Retrofit should
not discard existing area
(questionable!!)
Optimum grassroot design
B
Infeasible
Area
Energy requirement

TARGETING

CONSTANT AREA EFFICIENCY

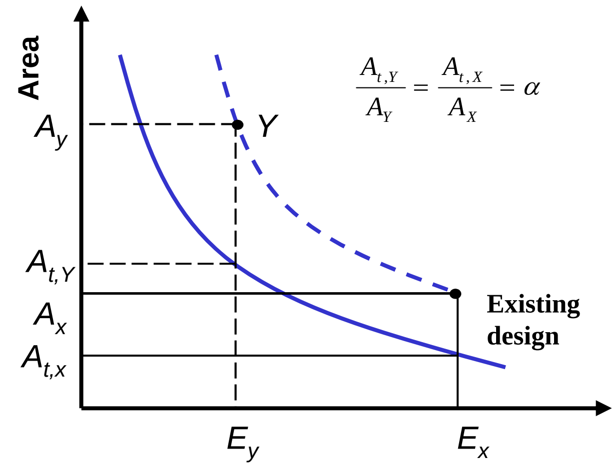


TARGETING

CONSTANT AREA EFFICIENCY

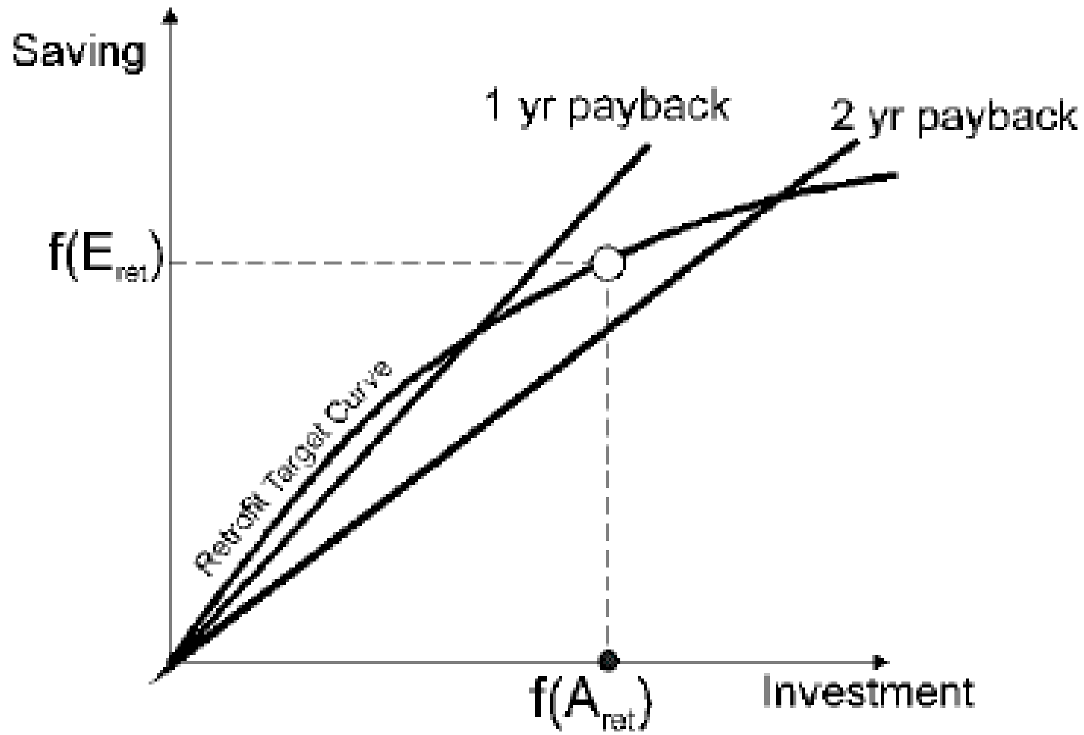
PROCEDURE

- Start with existing system. Obtain its ideal area (use vertical heat transfer) ($A_{t,X}$)
- Compute $\alpha = A_{t,X} / A_X$
- Pick a value of $E_Y < E_X$
- Obtain its ideal area (use vertical heat transfer) ($A_{t,Y}$)
- Obtain "real" area estimate $A_Y = A_{t,Y} / \alpha$
- Obtain the number of exchangers (use minimum number of exchangers)
- Compute the capital cost= Cost of additional area ($A_Y - A_X$) and fixed cost new exchangers ($N_Y - N_X$)
- Obtain Payout (ROI and NPV could also be used) (Payout= Capital investment/ savings over a year)



TARGETING

Determinee retrofit area based on Payout



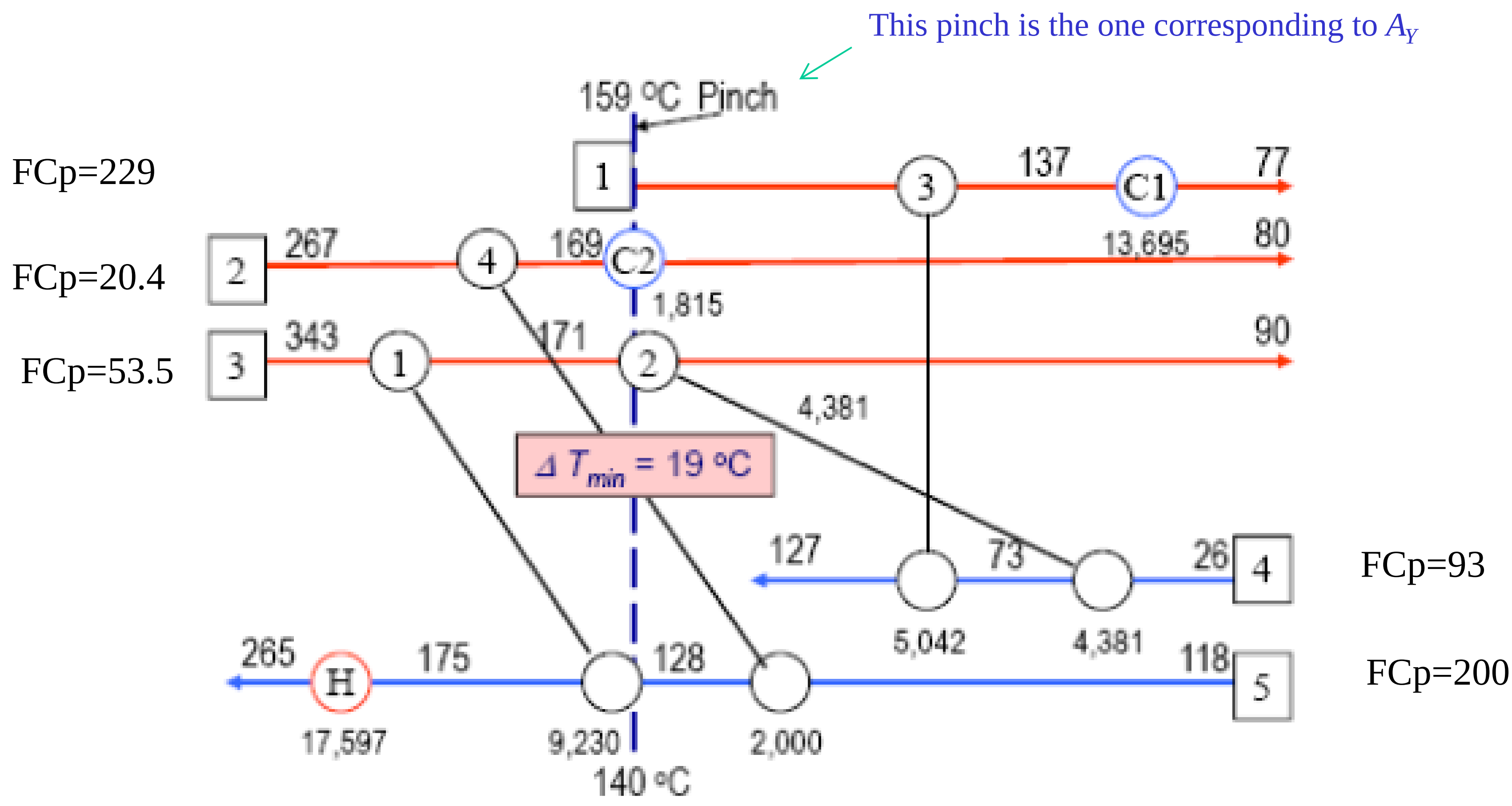
HEN Retrofit

NEXT STEP:

- Obtain a new grassroots design and maximize the use of existing exchangers
- Correct Cross-Pinch Exchangers
- Use Network Loops and Paths to minimize area reduction

HEN Retrofit

Identify Cross-Pinch Exchangers



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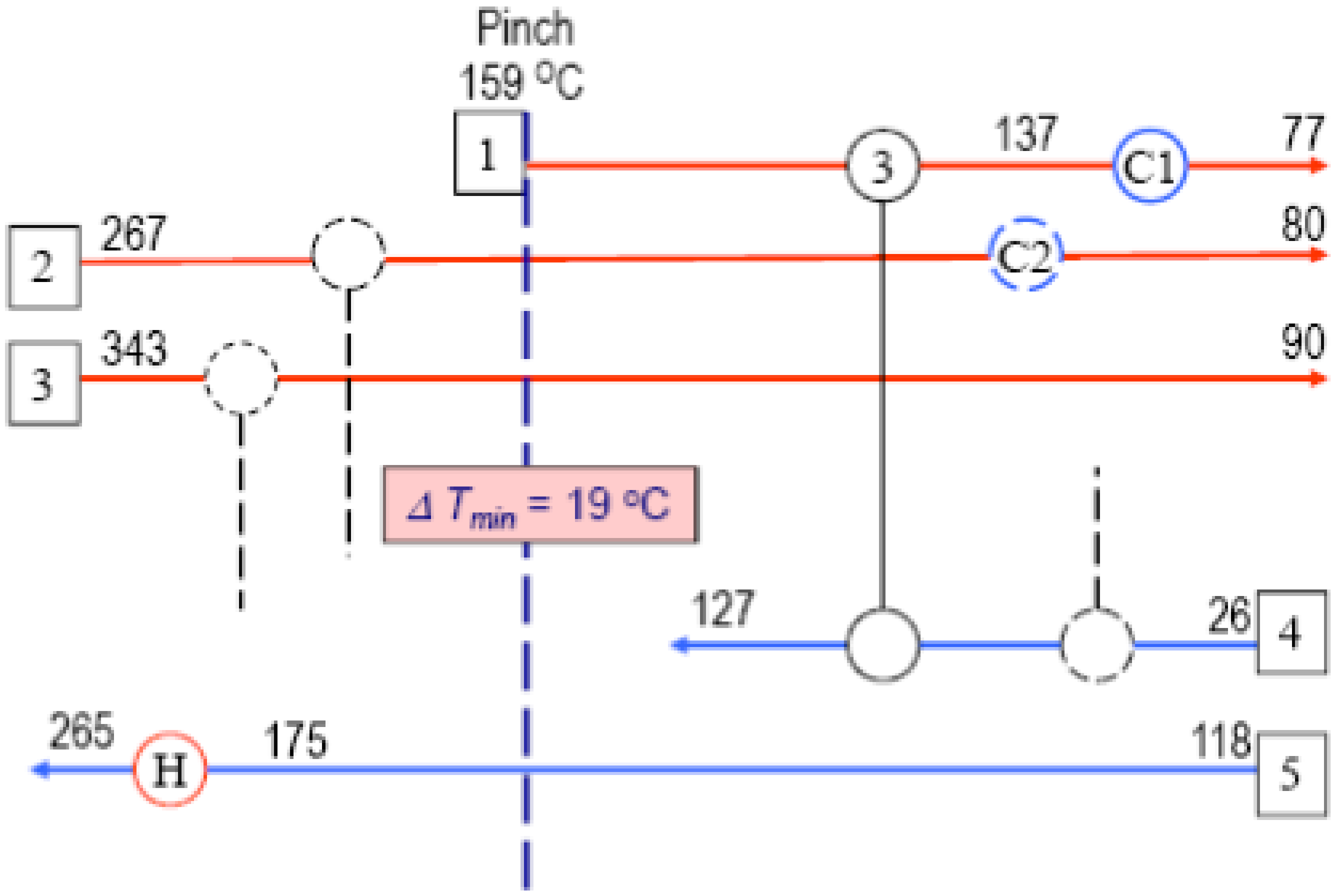
Remove Cross-Pinch Exchangers



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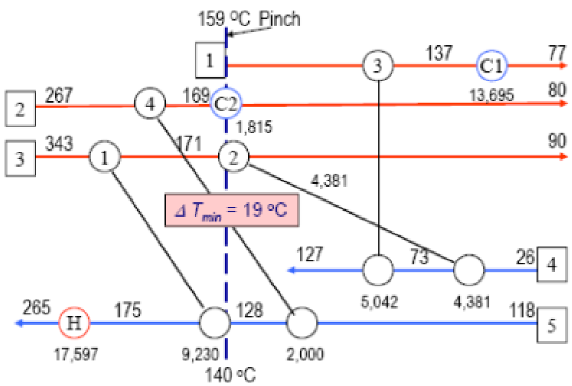
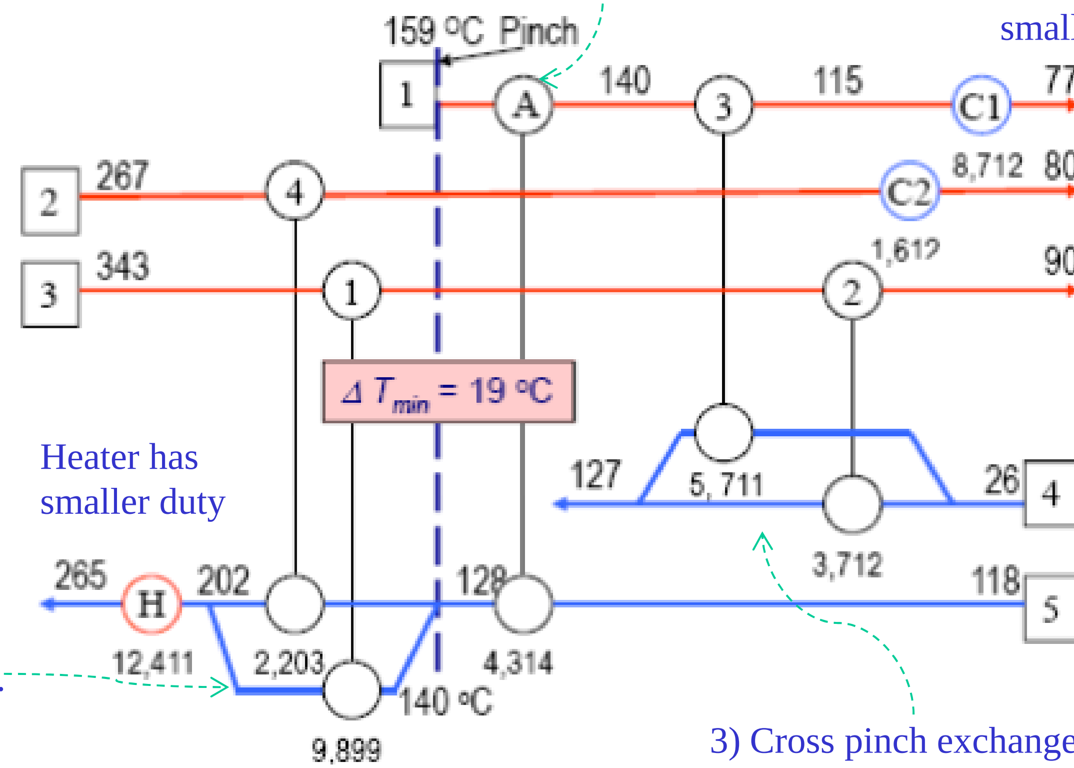
Add exchangers to meet energy targets



1) New exchanger: Fixes cross pinch of exchanger 1 and 4

Coolers have smaller duty



Heater has smaller duty

2) Split is needed after cross pinch for exchangers 1 and 4 is removed.

We note that areas needed in 1 and 4 may be much larger than existing areas

3) Cross pinch exchanger 2 is fixed when area was added . Load of exchanger 1 increased. However, a split is now needed.

HEN Retrofit

Loop and Path Analysis

- Choose a value for EMAT (Exchanger Minimum Approach Temperature).

- Increase the duty of the process-process exchangers along a loop until one or more of the exchangers becomes a bottleneck

- If the full savings potential has not been achieved, try to remove the bottleneck by
  (1) modifying branch flow fractions in split regions.
  (2) Re-sequence exchangers if one has excess driving force and another is the bottleneck or insert a split so that the driving forces are more even.

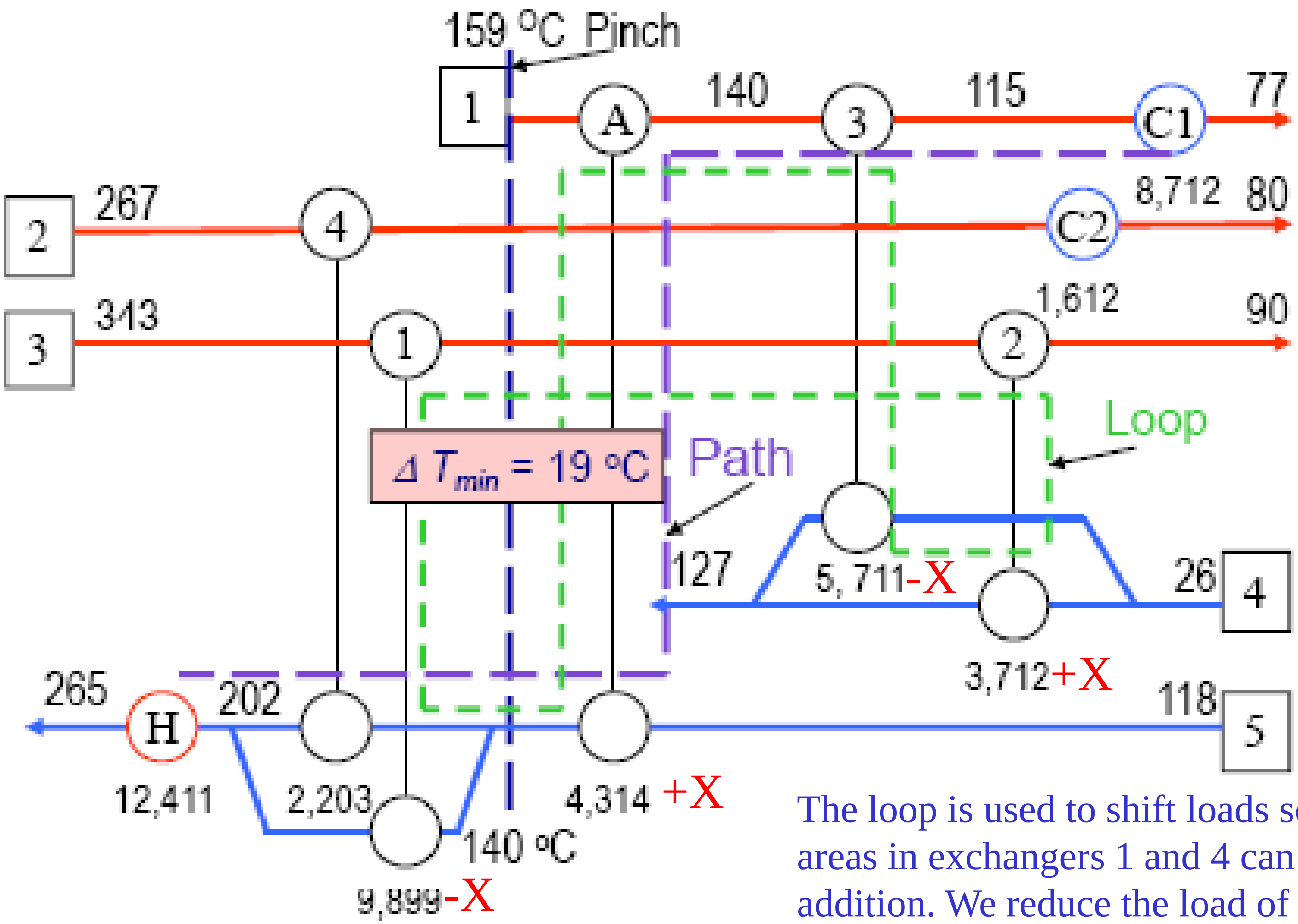
- Increase the duty of exchangers on the loop again until the full savings potential has been achieved.

- Use heat load loops to re-distribute the driving forces in the network, thereby reducing overall area requirement.

- Explore the use of paths to perform energy relaxations to also adjust area.

HEN Retrofit

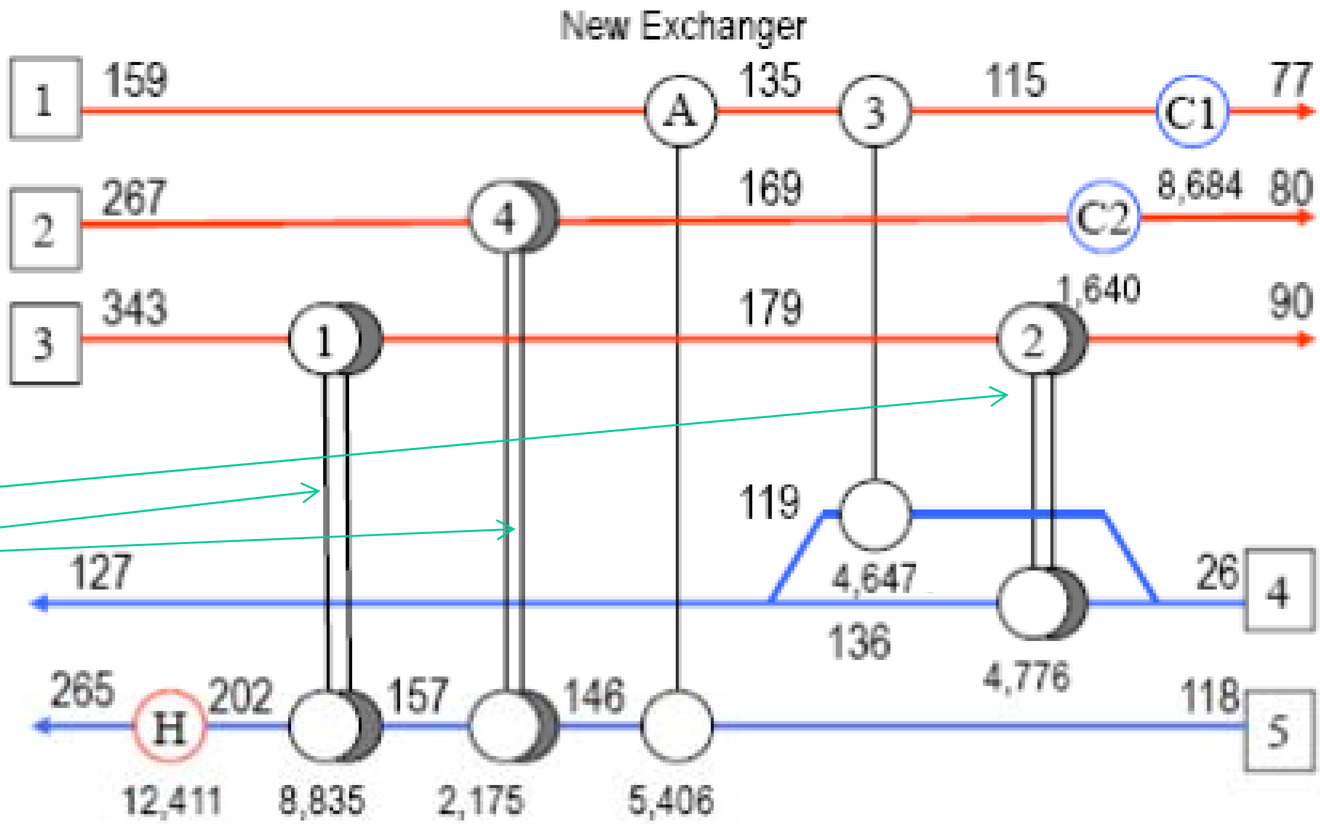
Loops and Paths



The loop is used to shift loads so that areas in exchangers 1 and 4 can be utilized without addition. We reduce the load of exchanger 1 by X and adjust all others accordingly. Optimum X is obtained when area is enough. 4 and 3 will change its duty accordingly

HEN Retrofit

Loop Analysis Result



Need area Addition

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CONCLUSIONS for PDM Method

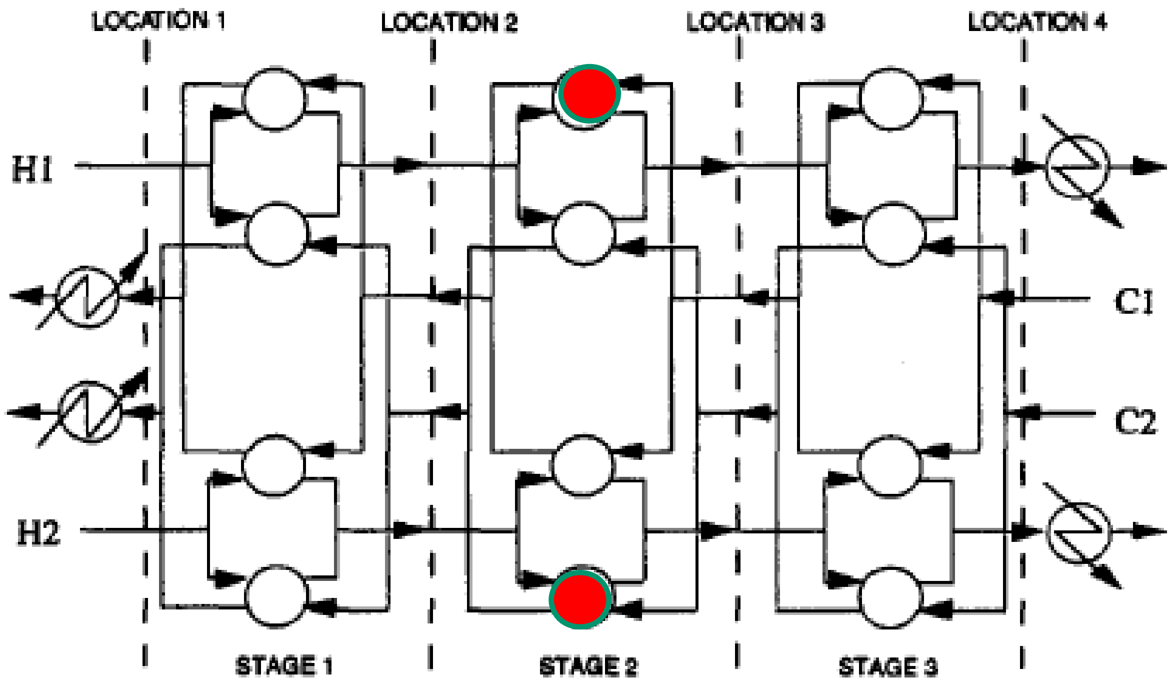
- A Targeting procedure is based on uncertain economical predictions
- Changes are made by inspection
- Loops and Path analysis require to build expertise
- Not completely systematic and not automatic
- May work well for small problems
- Combinatorial choices in large problems may increase substantially.

A ONE STEP SYSTEMATIC & AUTOMATIC METHOD IS SHOWN NEXT

HEN Retrofit

Additional equations to Stages Model

Some exchangers exist (in red)



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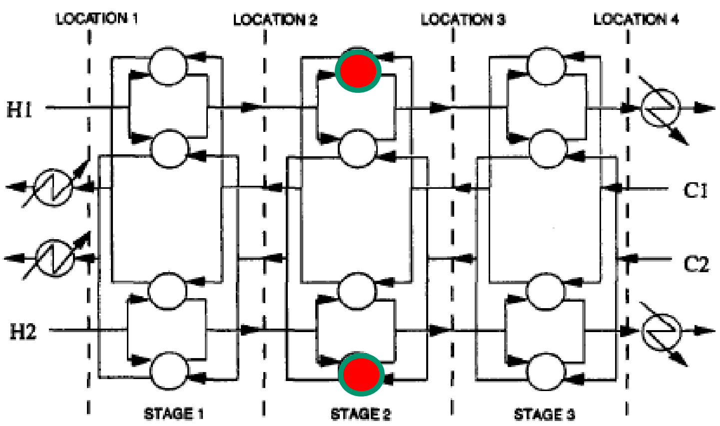
Additional equations to Stages Model

Some exchangers exist (in red). Order must be respected.



Adding Area, Shells and new units

$$A_{i,j,k} \leq A^0_{i,j,k} + A^A_{i,j,k} + A^{AN}_{i,j,k}$$

$$A^A_{i,j,k} \leq \Gamma \cdot Z^A_{i,j,k}$$

$$A^{AN}_{i,j,k} \leq \Gamma \cdot Z^{AN}_{i,j,k}$$

$$Q_{i,j,k} - A_{i,j,k} U_{i,j,k} \sqrt[3]{\Delta Th_{i,j,k} \Delta Tc_{i,j,k} \frac{\left[\Delta Th_{i,j,k} + \Delta Tc_{i,j,k}\right]}{2}} \leq 0$$

Reducing Area

$$A_{i,j,k} \geq A^0_{i,j,k} - A^R_{i,j,k}$$

HEN Retrofit

MILP Transportation Model

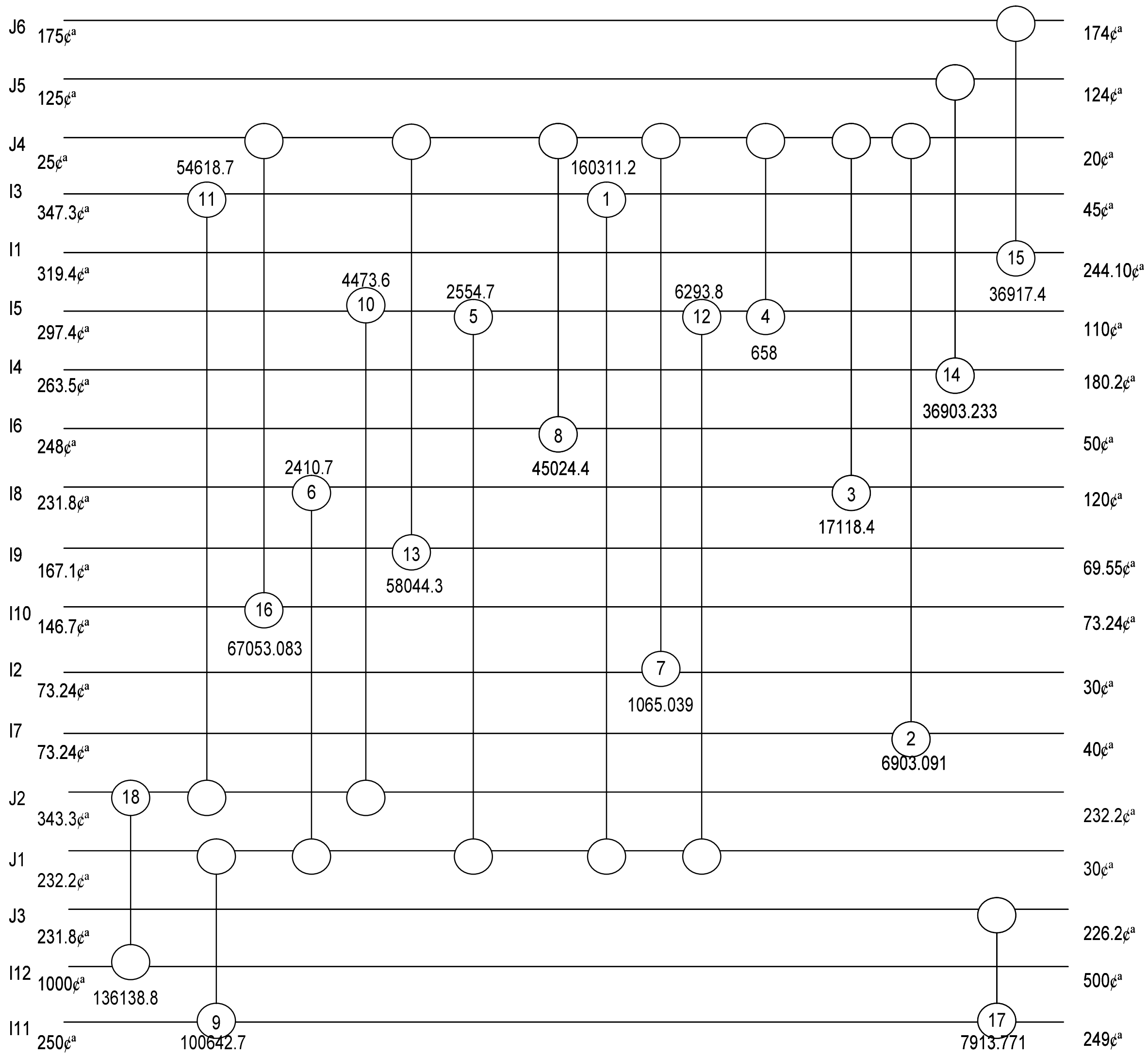
THIS IS A LINEAR MODEL THAT CONSIDERS

- Exchanger addition
- Area addition through new shells.
- Area addition through new tube arrangements.
- Relocation and re-piping

HEN Retrofit

MILP Transportation Model -Example

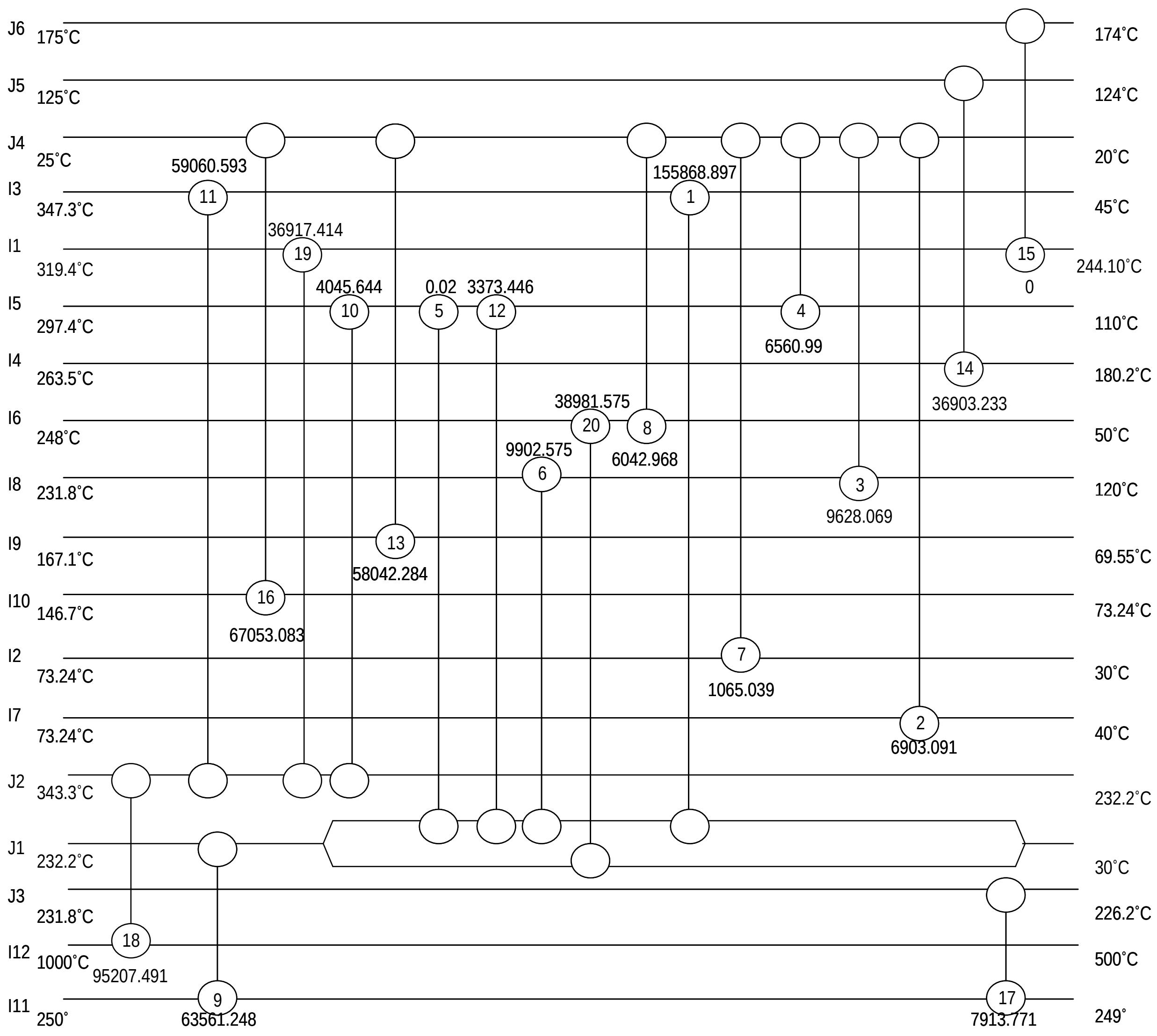
Before



HEN Retrofit

MILP Transportation Model- Example

After



HEN Retrofit

MILP Transportation Model-Example

HE	Original Load MJ/hr	Retrofit Load MJ/hr	Original Area m2	Retrofit Area m2	Area Addition m2	Shell Addition	Cost $
1	160,311.20	155,868.90	4,303.20	3,926.25			
2	6,903.09	6,903.09	59.40	63.80	4.40		342.03
3	17,118.40	9,628.07	33.40	21.53			
4	658.00	6,560.99	2.30	16.63	14.33	YES	6,406.84
5	2,554.70	0.02	26.30	28.93	2.63		204.58
6	2,410.70	9,902.58	24.60	398.53	373.93	YES	34,379.01
7	1,065.04	1,065.04	5.50	5.87	0.37		28.70
8	45,024.40	6,042.97	145.00	41.66			
9	100,642.70	63,561.25	1,212.70	962.01			
10	4,473.60	4,045.64	93.70	93.70			
11	54,618.70	59,060.59	685.70	1,239.90	554.20	YES	48,402.09
12	6,293.80	3,373.45	40.00	44.00	4.00		311.15
13	58,044.30	58,042.28	183.30	182.39			
14	36,903.20	36,903.23	101.60	101.47			
15	36,917.40	0	93.90	0			
16	67,053.08	67,053.08	278.10	288.97	10.87		845.32
17	7,913.77	7,913.77	53.50	52.24			
18	136,138.80	95,207.49	976.40	709.00			
19		36,917.41		727.96			61,918.53
20		38,981.58		651.93			56,004.54
			8,318.60	9,556.76	14.88%	3	208,842.80

HEN Retrofit

MILP Transportation Model-Example

Costs	Existing	Retrofitted
Total utility cost	$ 6,865,616/yr	$ 5,004,800/yr
Total fixed and area cost	-	$ 208,842/yr
Total cost	$ 6,865,616/yr	$ 5,213,643/yr
Savings		~24%