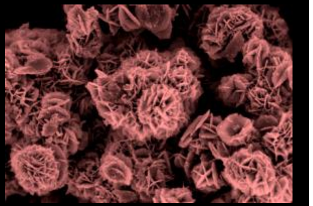



CDB 4313Z – HEAT INTEGRATION

RETROFIT OF HEAT EXCHANGER NETWORK

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Discussion time: Friday 15.00 – 17.00

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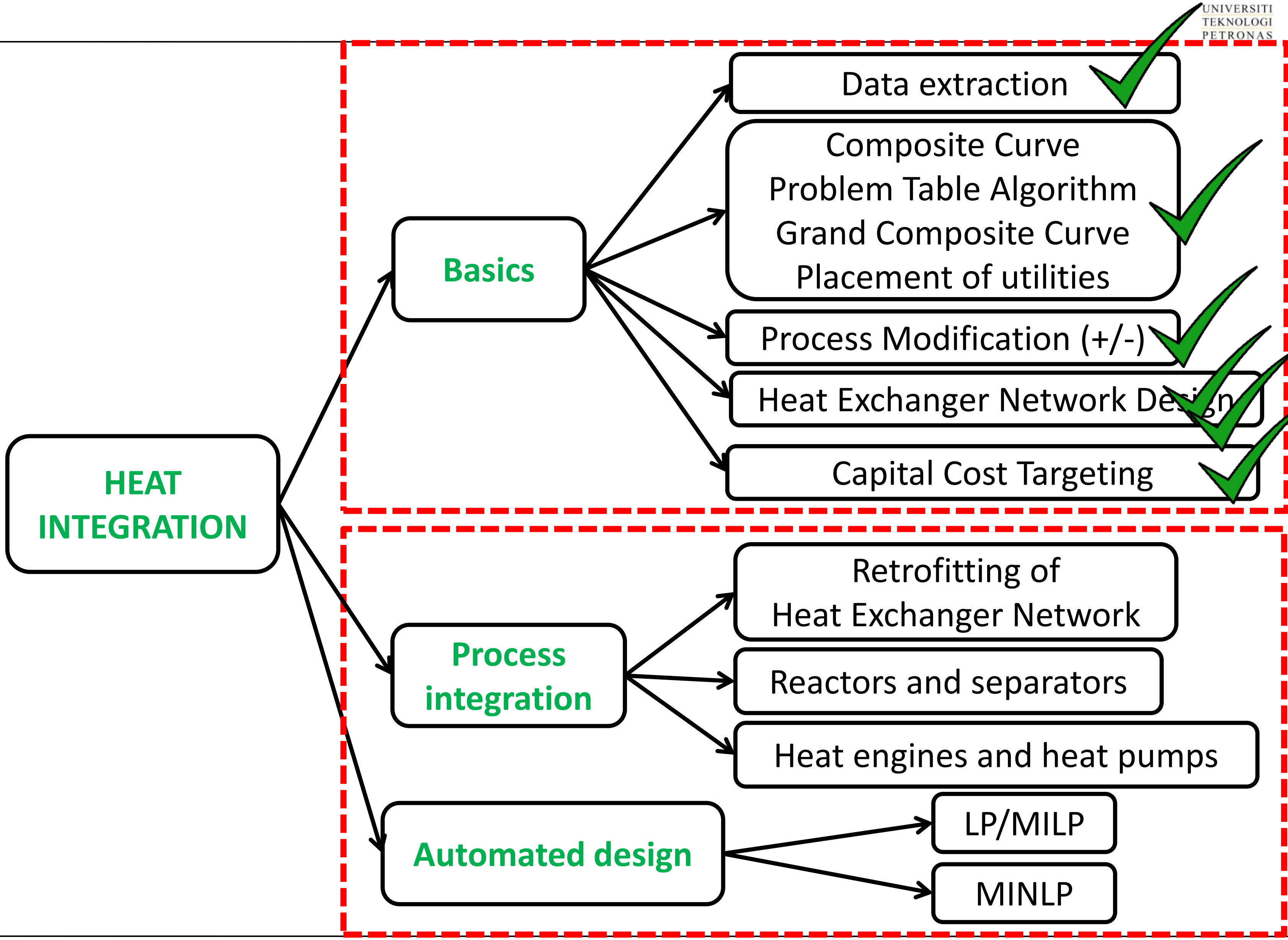
Course Overview



Course Learning Outcomes

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At the end of this course, students shall be able to:

1. Perform **targeting exercise** to determine the minimum utility requirements and maximum heat recovery possible for a process using composite curve or problem table algorithm

2. **Design heat exchanger network** for achieving maximum energy recovery or minimum total cost using pinch analysis technique

3. **Apply pinch analysis software** to perform heat integration and heat exchanger network design that is cost competitive and taking into account of sustainability factors

4. Analyze the **potential for heat and power integration** of a process and the possible implementation options, and to screen the options using cost effective strategy

5. Perform **correct data extraction** from process flowsheet for the purpose of performing pinch analysis

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RETROFIT:

THINKING OUT LOUD

What is retrofit? What is debottleneck? Are they the same?

How to retrofit heat exchanger network?

- Start from current network. Adjust it to obey pinch rules
  Note the existing ΔTmin, calculate the targets, plot existing design, and look for violations to remove

- Start from scratch. Design based on pinch rules.
  Where a choice exists, favour matches already present in current network.

- Start from current network. Identify the most critical changes required to give a significant cost reduction.

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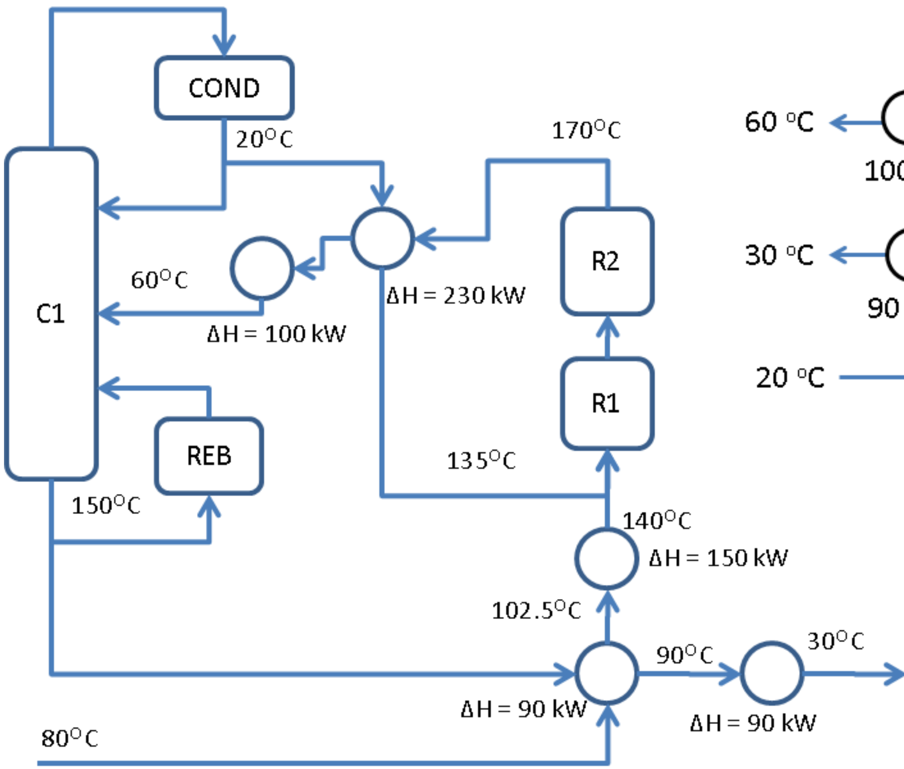
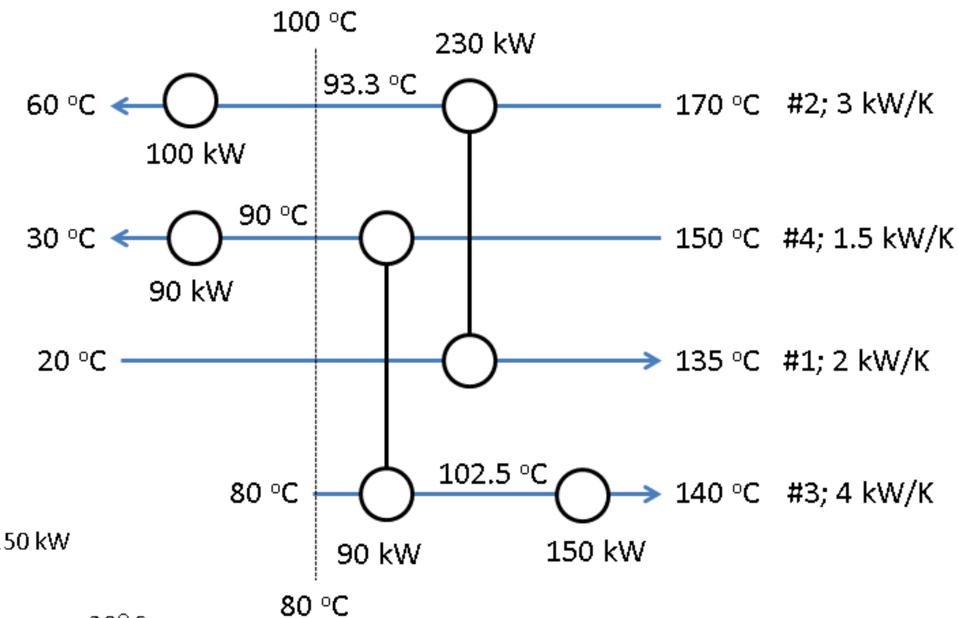
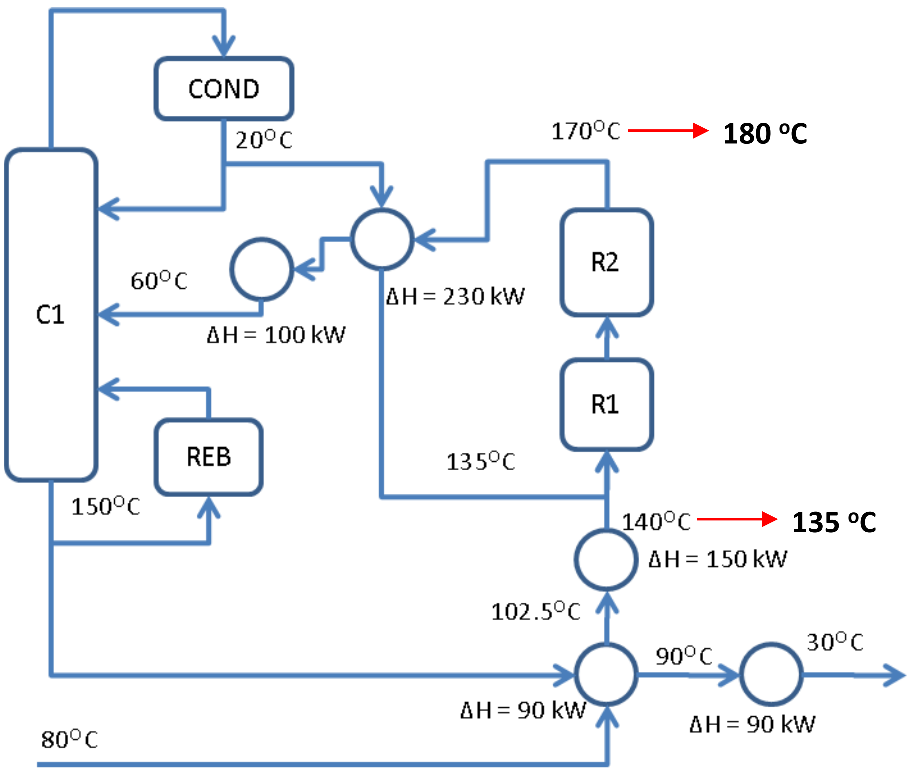
ORIGINAL CASE





THE CASE WITH PROCESS MODIFICATION AND PINCH RESULT



Process modification:

- Outlet R2 = 180 °C
- Inlet R1 = 135 °C

Pinch insight:

- Hot pinch temp. = 100 °C
- Cold pinch temp. = 80 °C
- Hot utility = 15 kW
- Cold utility = 105 kW

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THE CASE

AFTER PROCESS MODIFICATION AND EXISTING HEN

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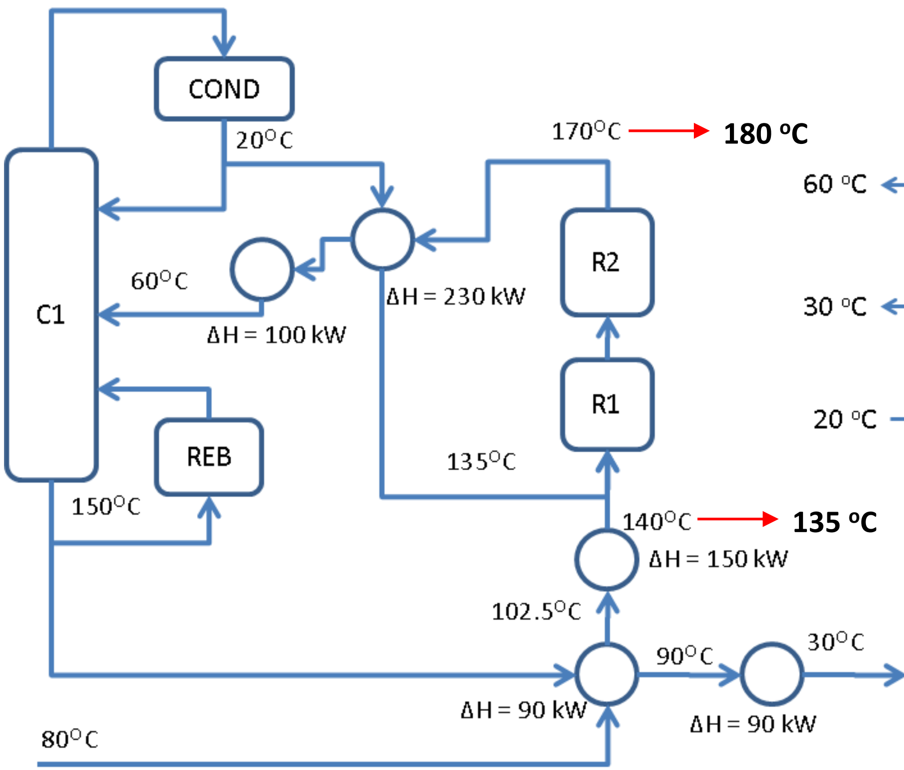

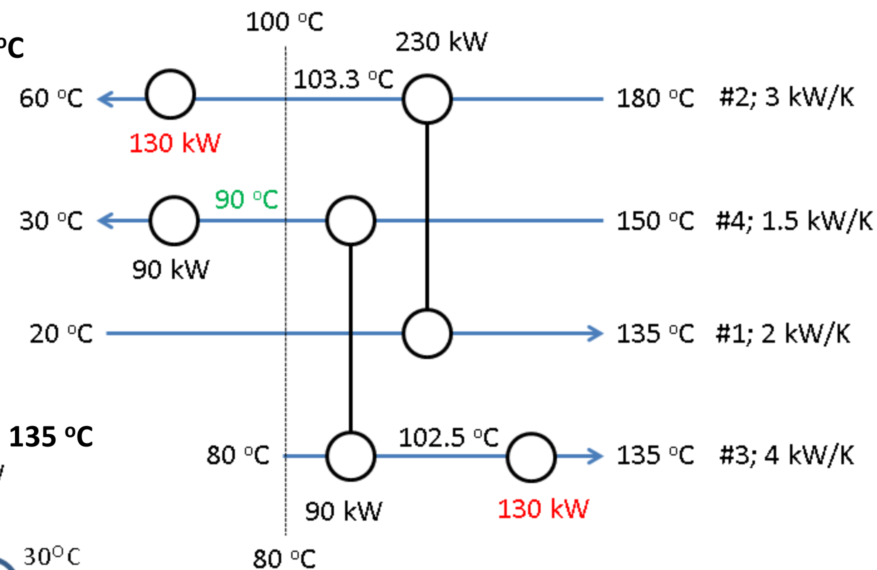

Pinch insight:

- Hot pinch temp. = 100 °C
- Cold pinch temp. = 80 °C
- Hot utility = 15 kW
- Cold utility = 105 kW

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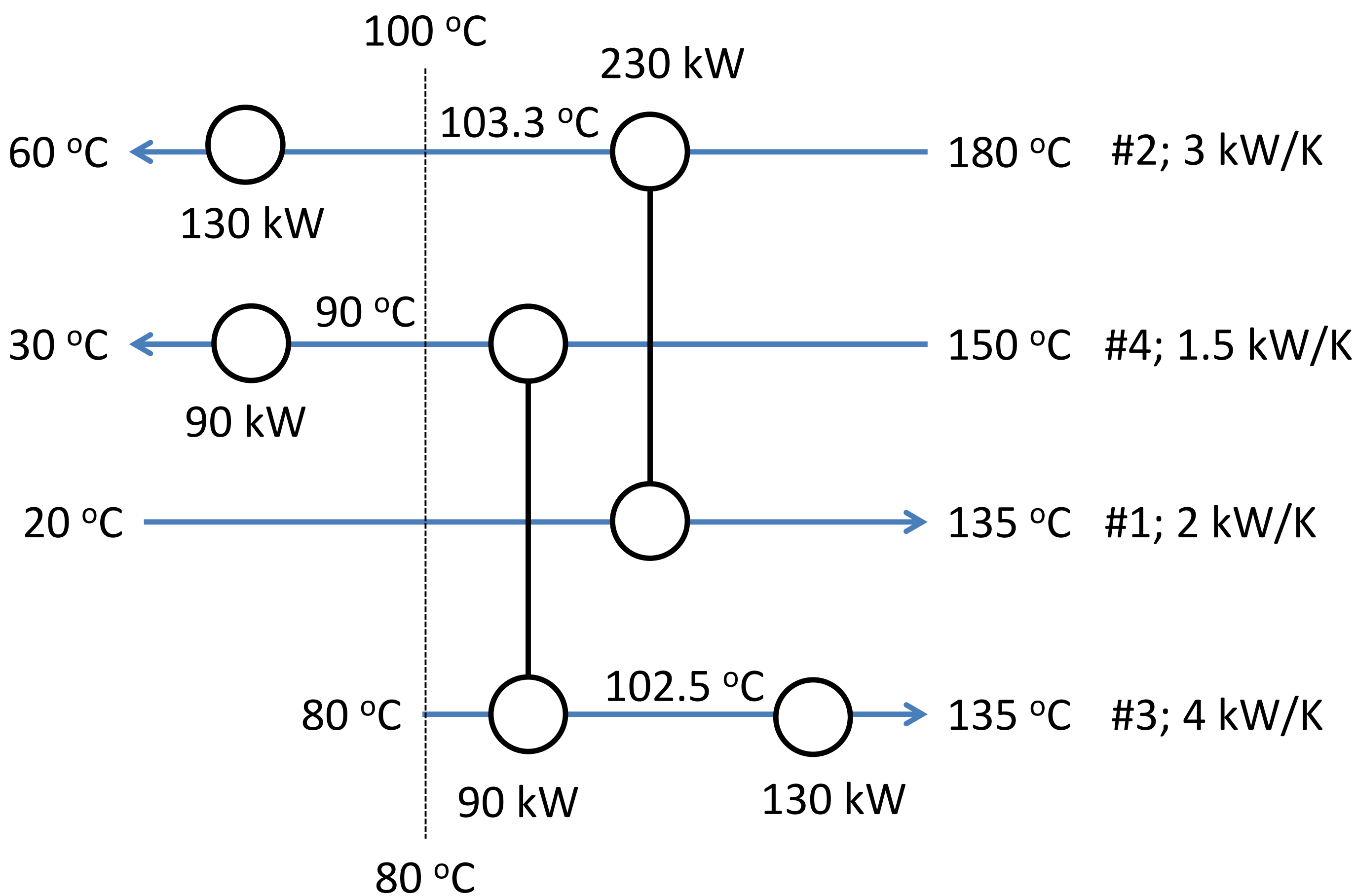
1. EXISTING TO ADAPT TO PINCH RULE



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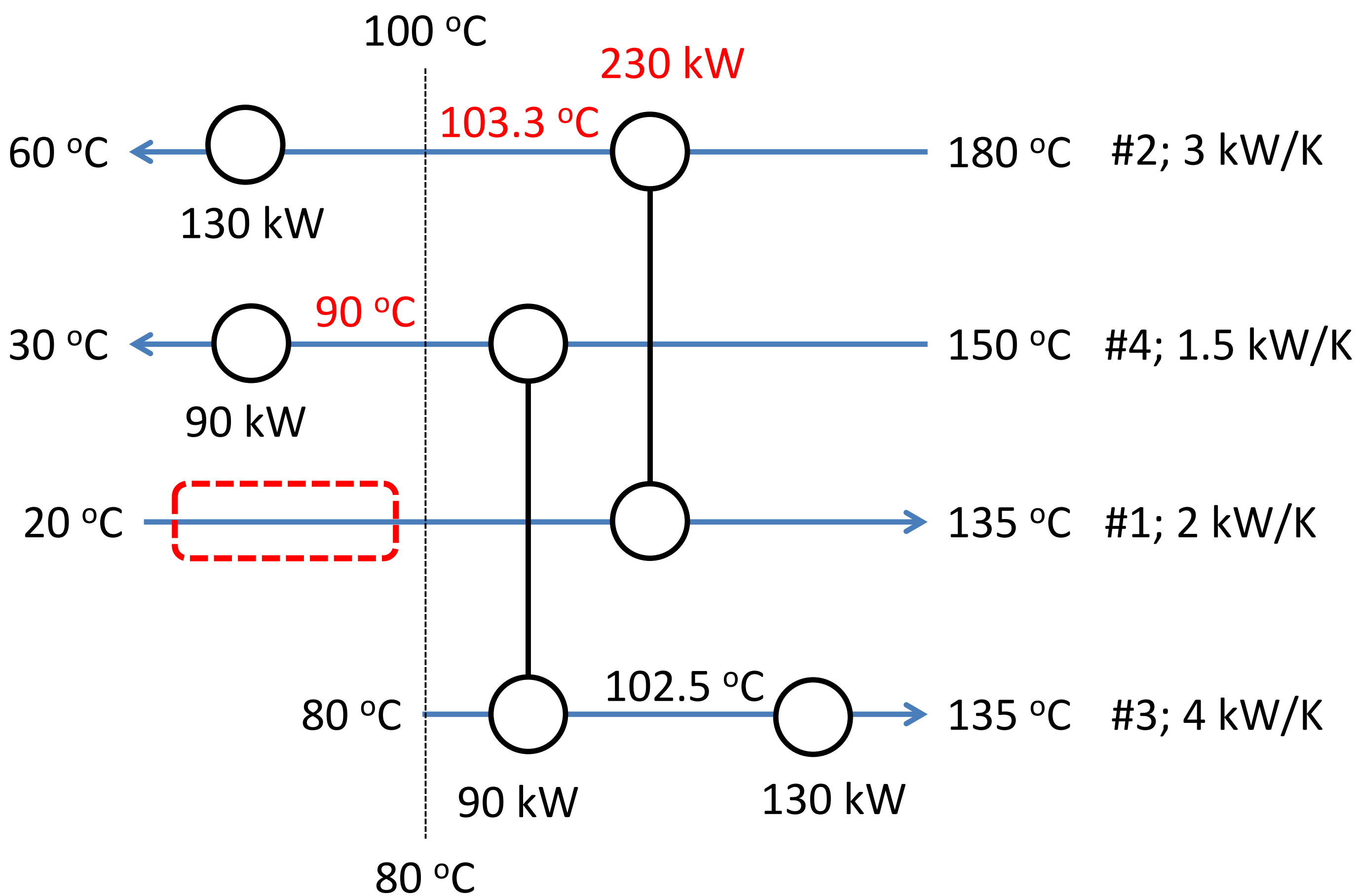
1.1 Identifications of Rule Violations

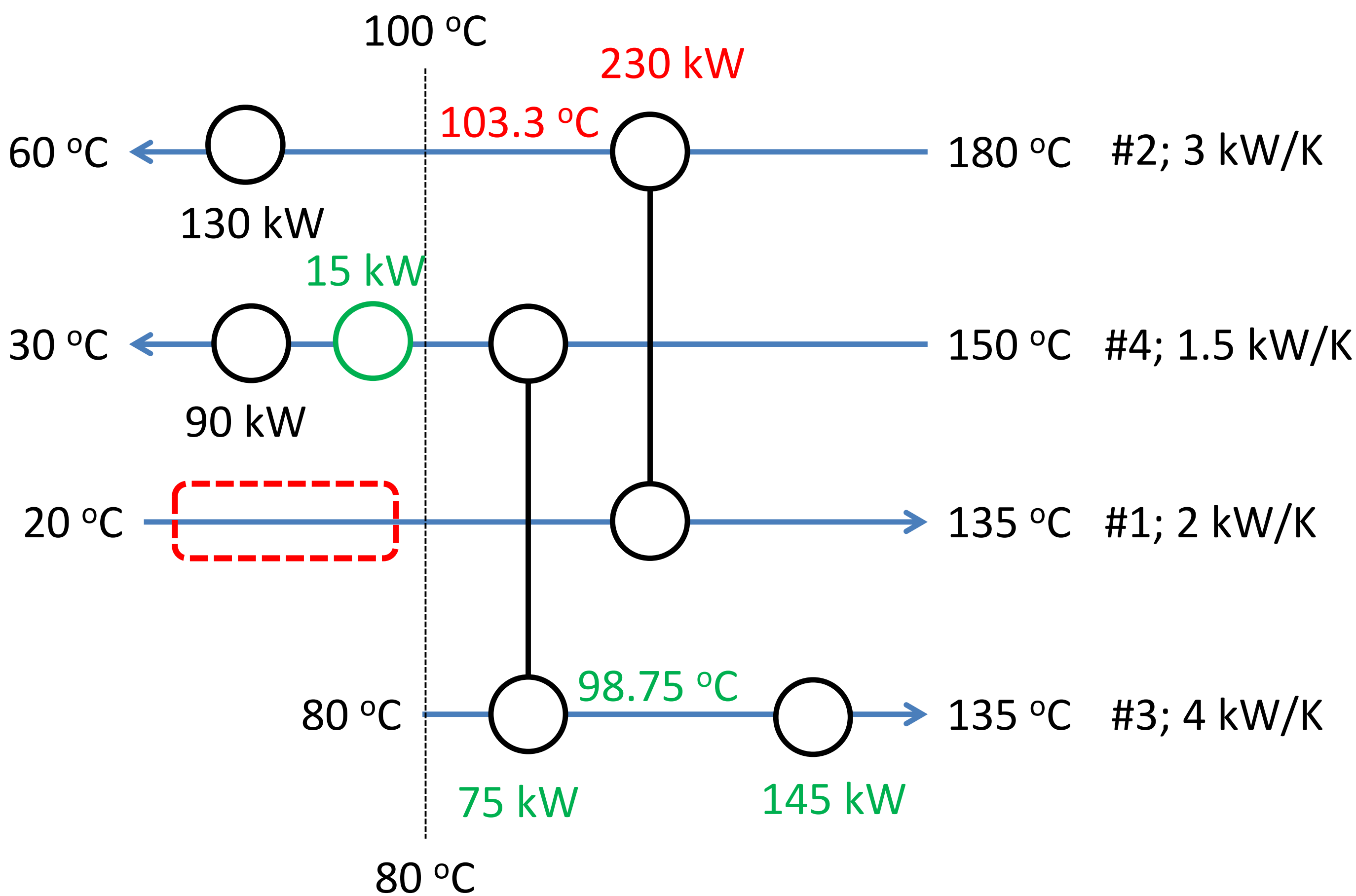


Remember!

Target hot is 15 kW and target cold is 105 kW

1.2 Increase cooling duty below pinch for #4

1. Additional area on cooler #4



Now we get our 105 kW of cooling duty by increasing the cooler area
From 90 kW to 105 kW

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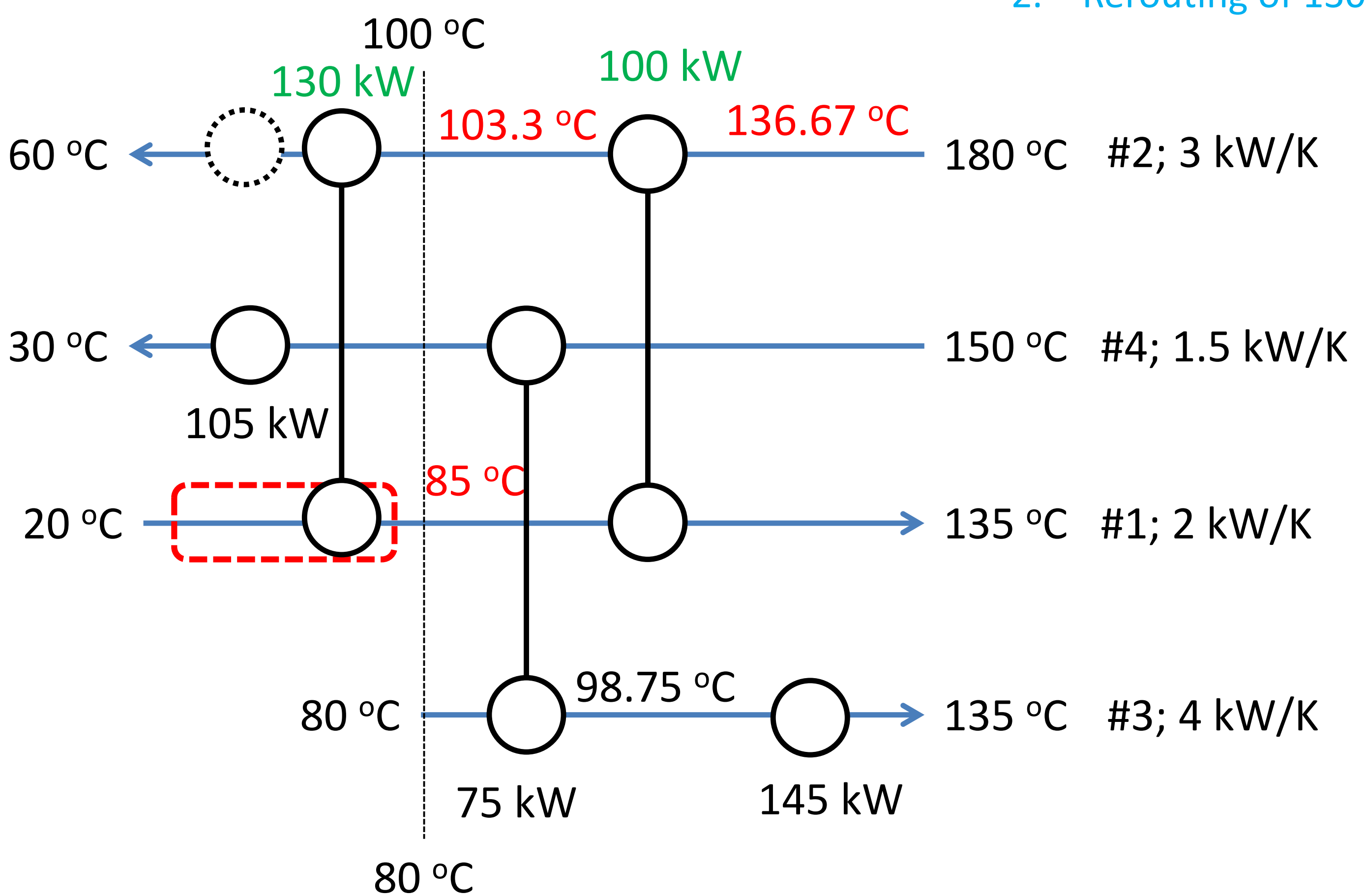
1.3 Make the heat available from #2

1. Additional area on cooler #4
2. Rerouting of 130 kW cooler



Replace cooling water in the cooler in #2 with cold stream #1.
Target cold of 105 kW is achieved

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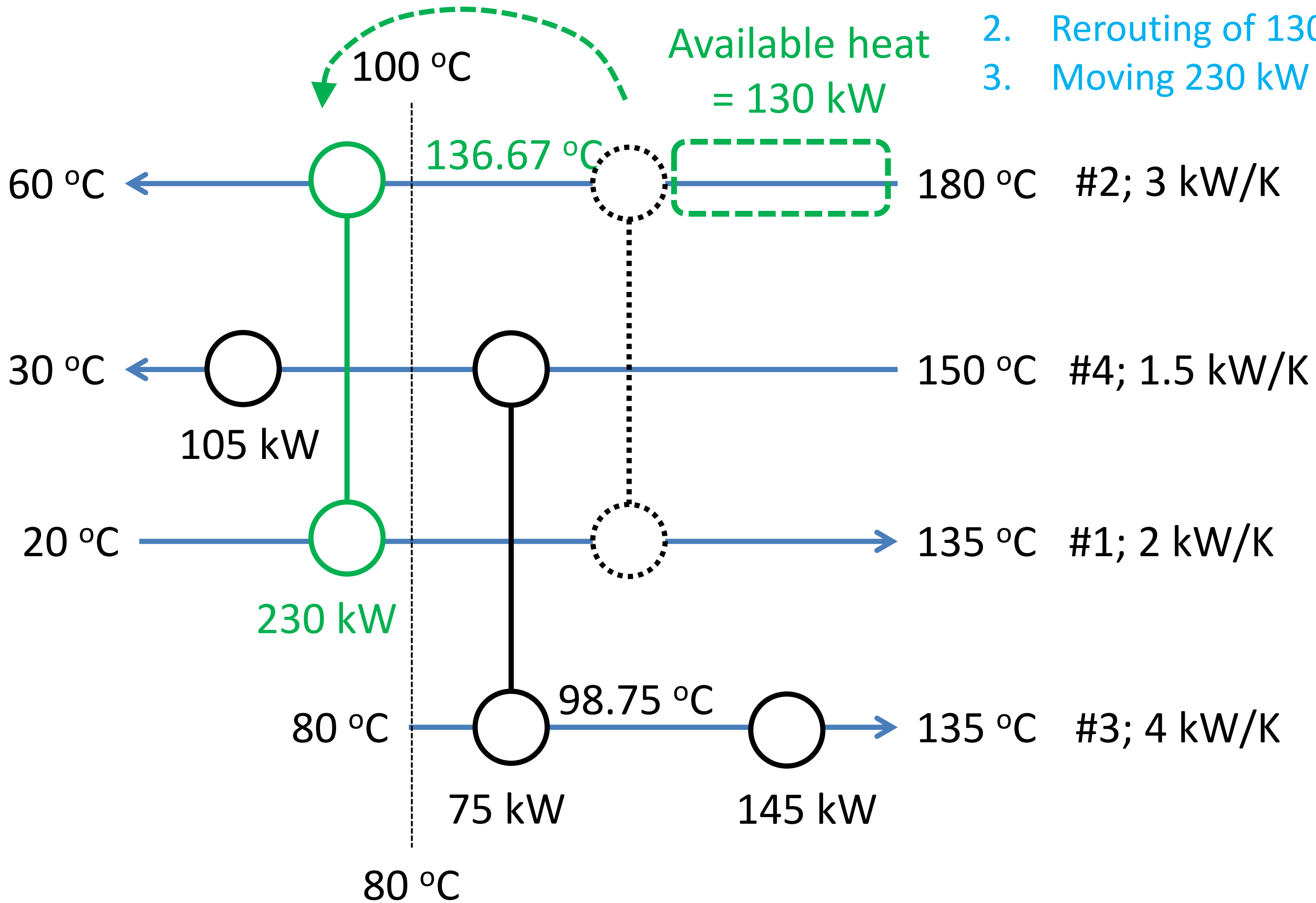
1.4 REMOVE LOOP

1. Additional area on cooler #4
2. Rerouting of 130 kW cooler
3. Moving 230 kW HE



Remove the loop

Target cold is 105 kW is achieved. 130 kW of heat is available above pinch

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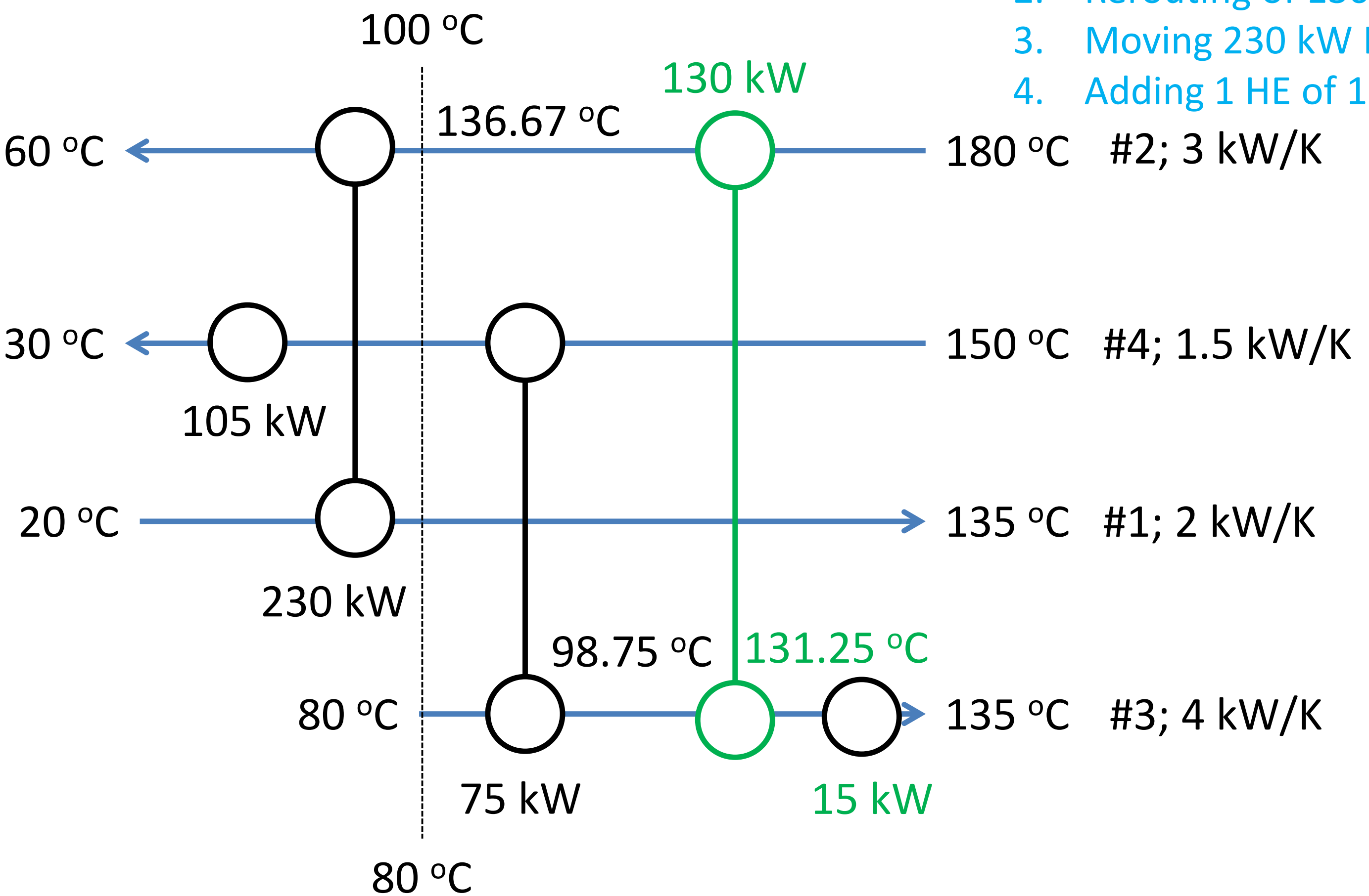
1.5 ADD 1 HE

1. Additional area on cooler #4
2. Rerouting of 130 kW cooler
3. Moving 230 kW HE
4. Adding 1 HE of 130 kW



Both targets are achieved!

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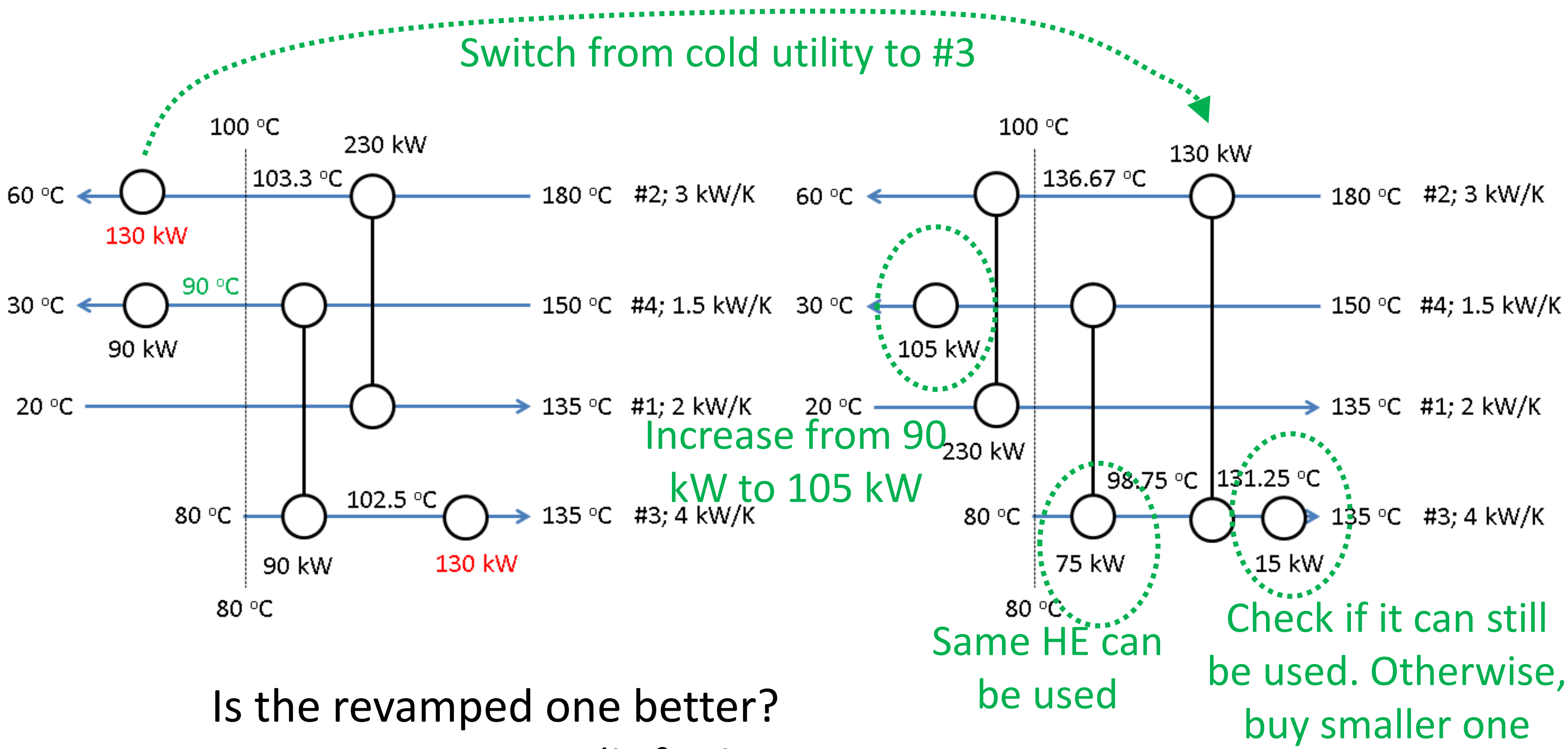
1.6 RESULT COMPARISON



Is the revamped one better?

Use U = 1000 W/(m^2.°C)

Annual heat exchanger cost (RM/yr) = $80000 + 5000 \cdot A^{0.75}$

Hot utility cost = 200 RM/kWyr

Cold utility cost = 20 RM/kWyr

Calculate total annual cost and the payback period!

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1.7 Result

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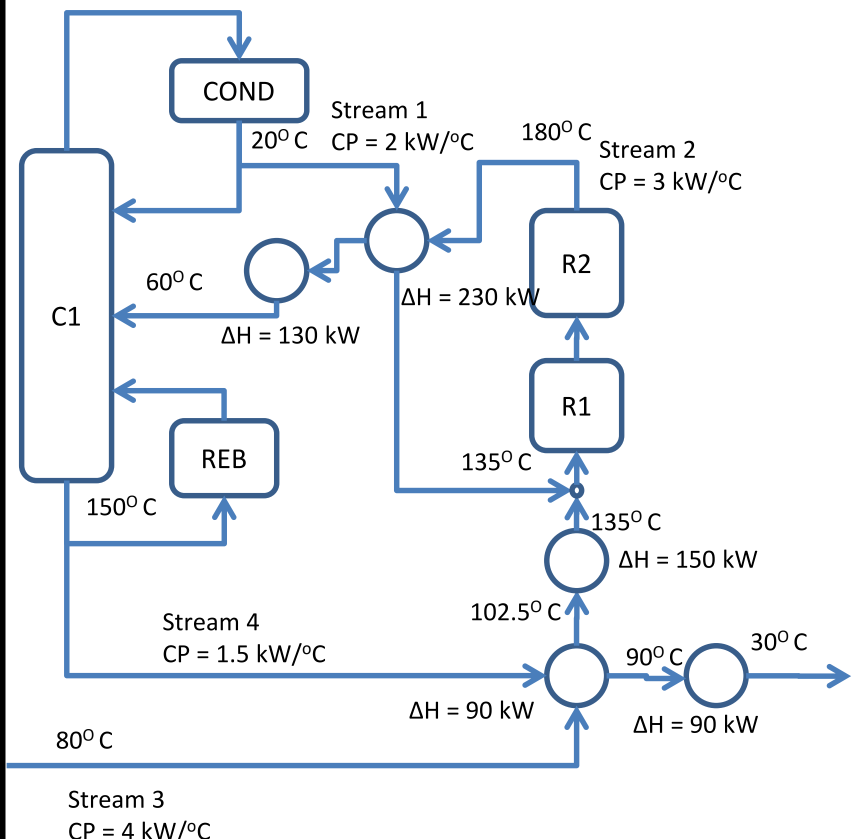
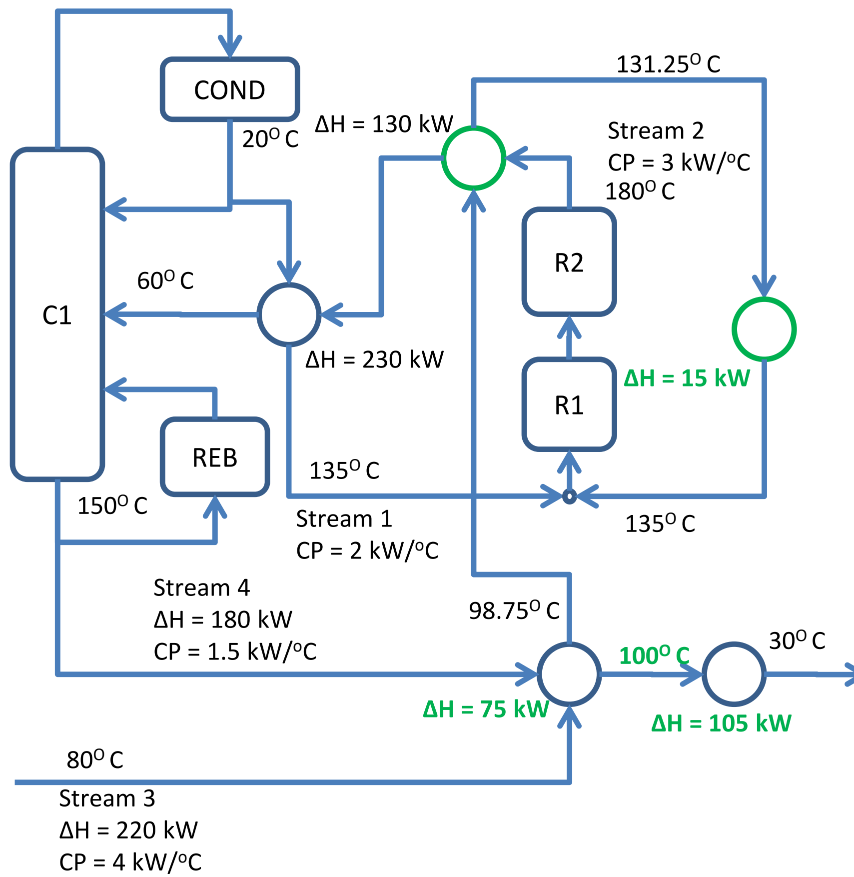
Existing



Revamped network



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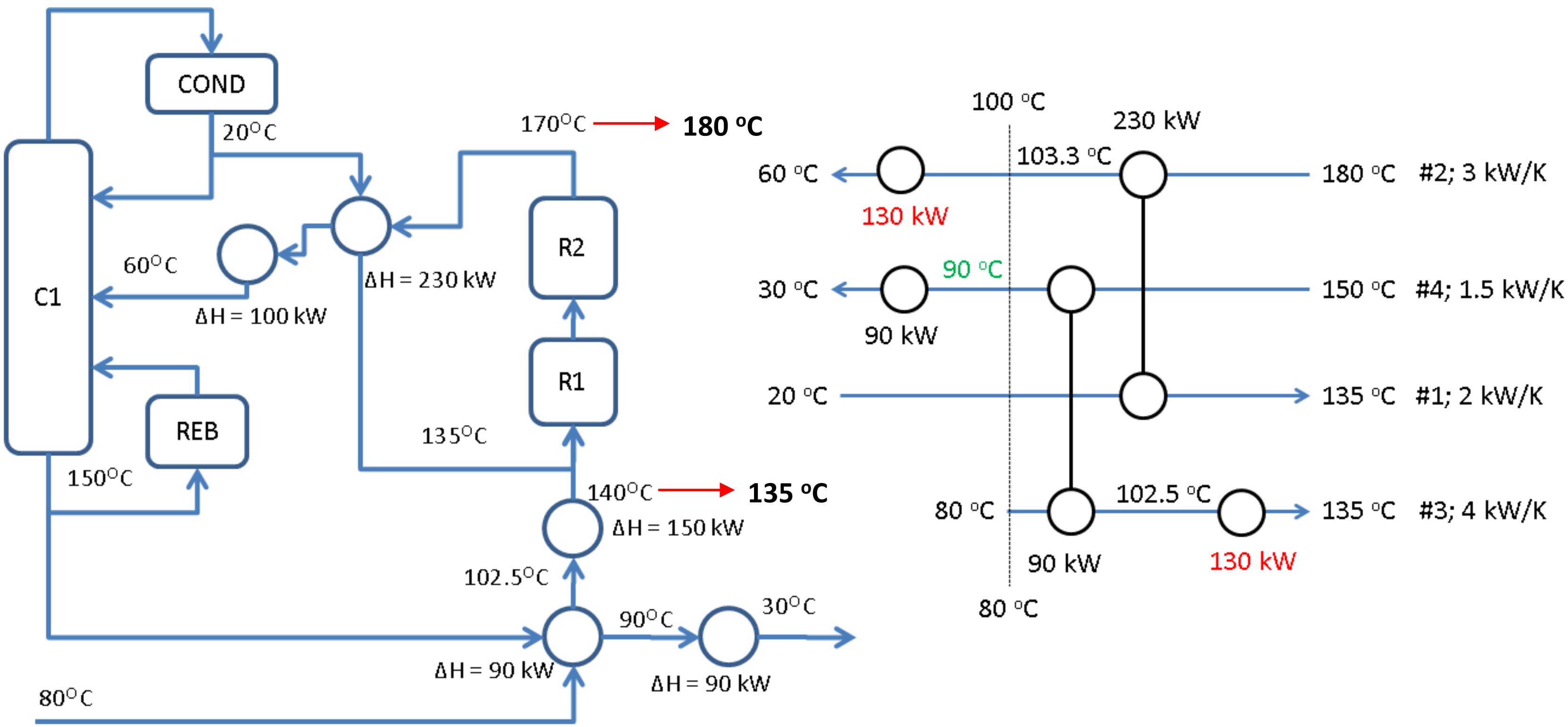
2 Design from scratch and adjust existing



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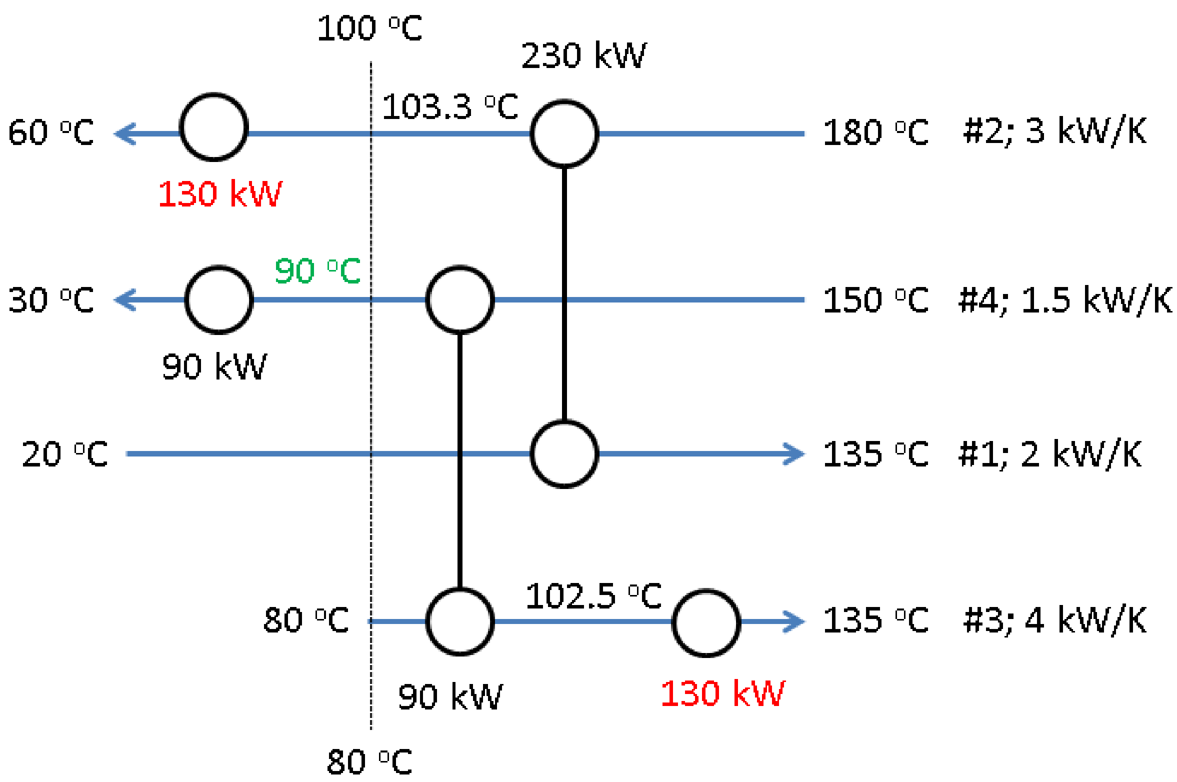
2.1 Design from scratch

and, if exists, favor existing matches

Existing network



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2.2 DESIGN FROM SCRATCH

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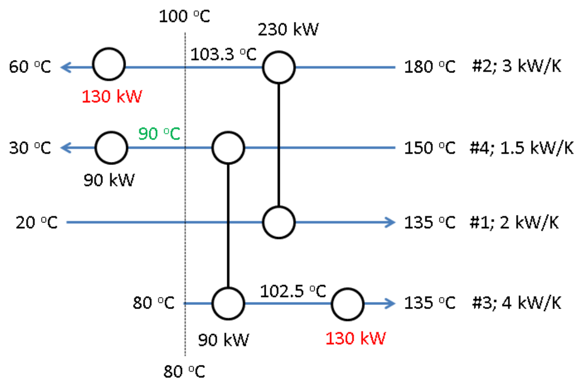
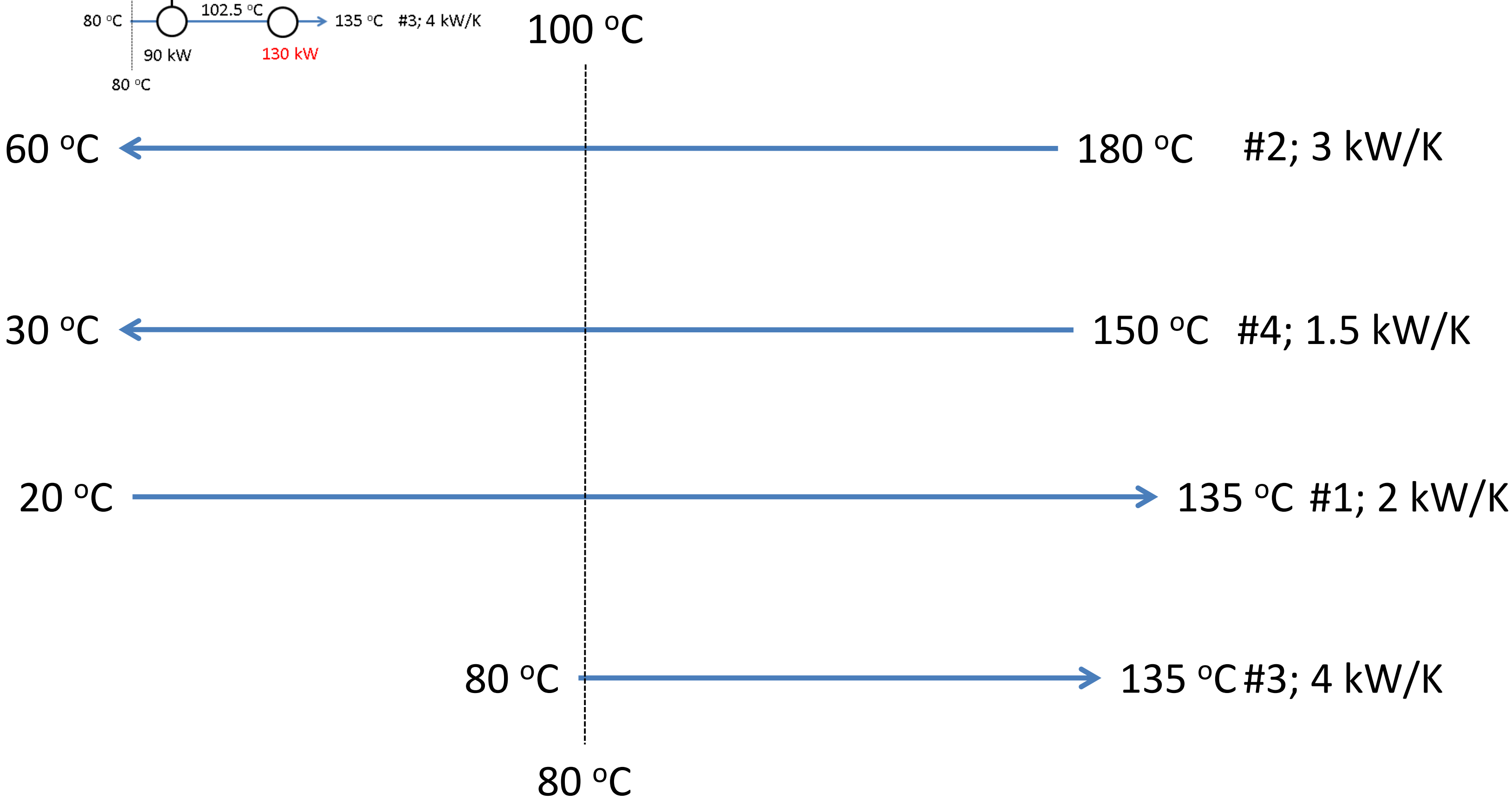


Pinch matches?



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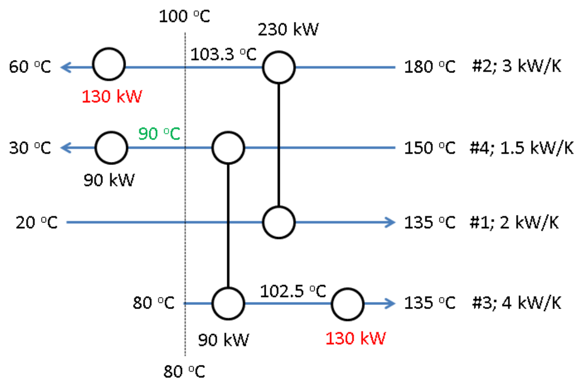
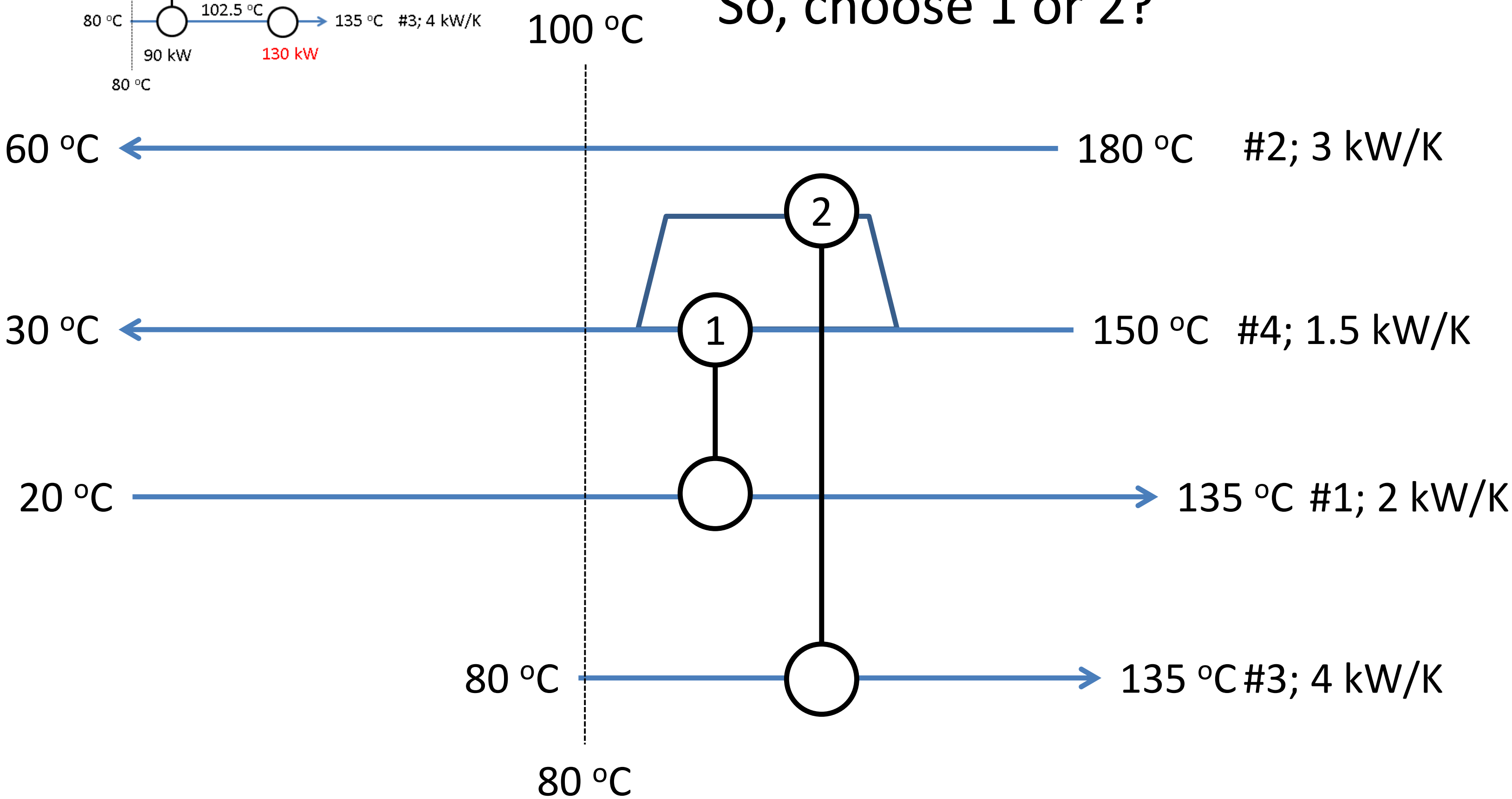
2.3 Design from scratch: Pinch rule above pinch, $CP_{HOT} \leq CP_{COLD}$



So, choose 1 or 2?



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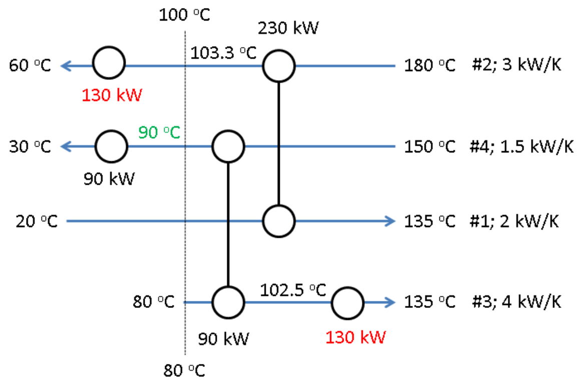
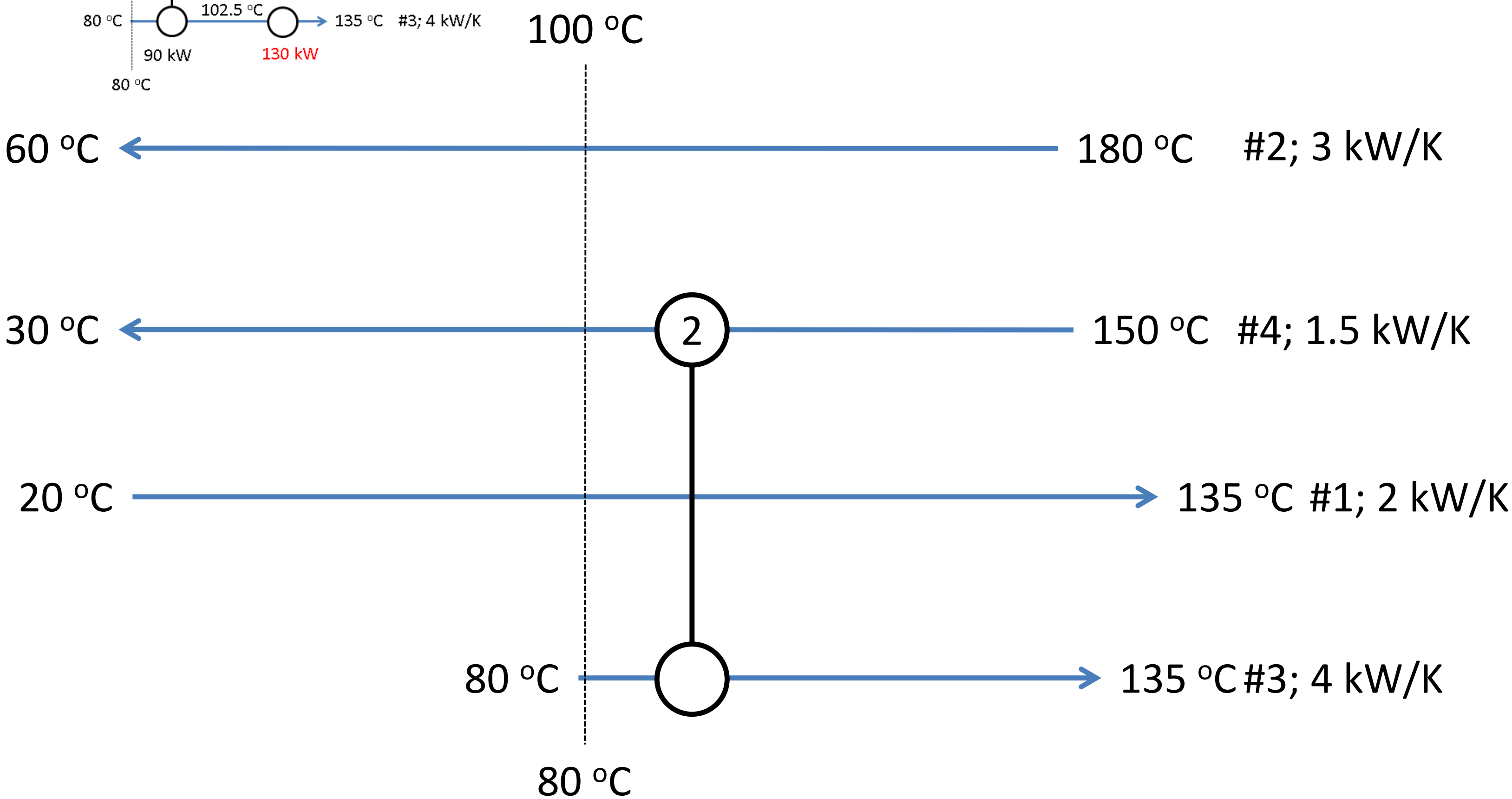
2.4 Design from scratch: Pinch rule above pinch, $CP_{HOT} \leq CP_{COLD}$



2 is chosen, as it favors current design

90 kW or 75 kW?



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2.5 Design from scratch: Pinch rule above pinch, $CP_{HOT} \le CP_{COLD}$

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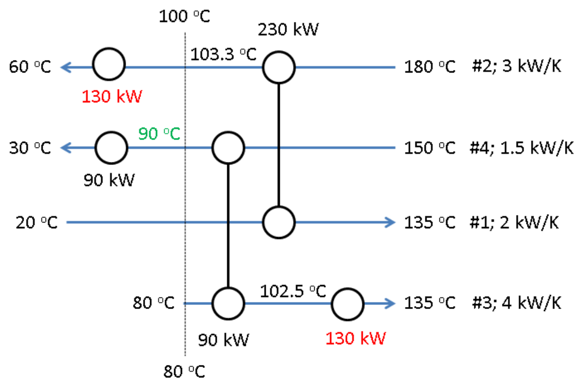
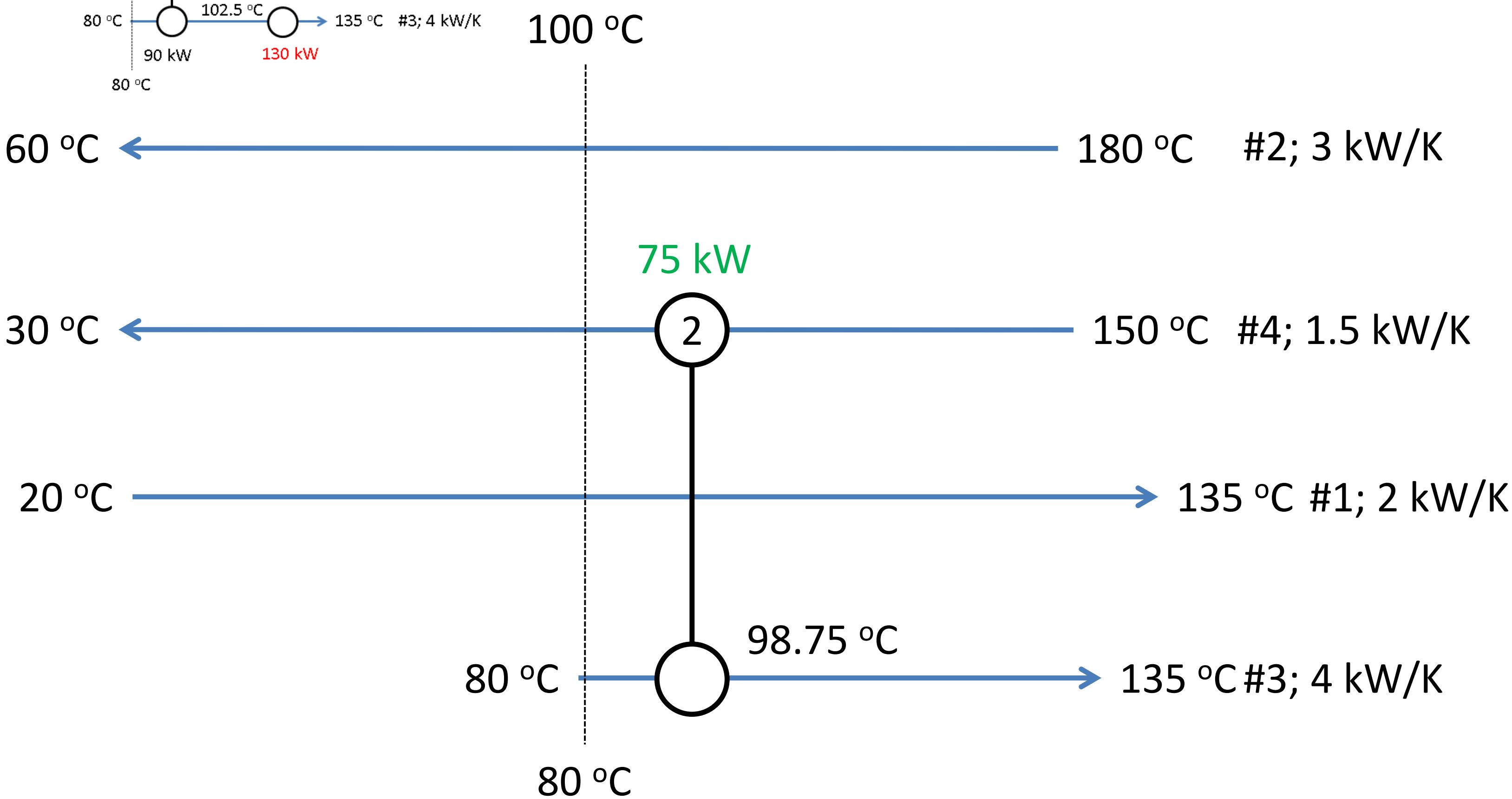


2 is chosen, as it favors current design

Try 75 kW (follow design rule)



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2.6 Design from scratch: Pinch rule above pinch, $CP_{HOT} \leq CP_{COLD}$

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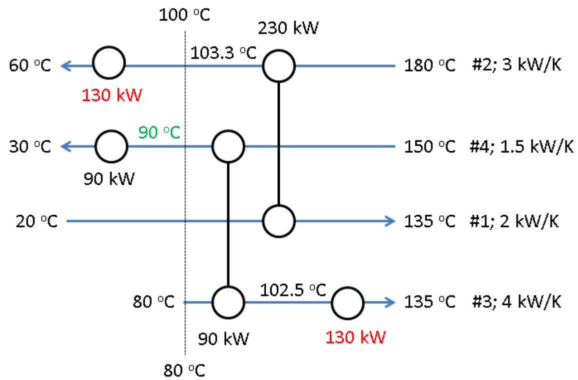
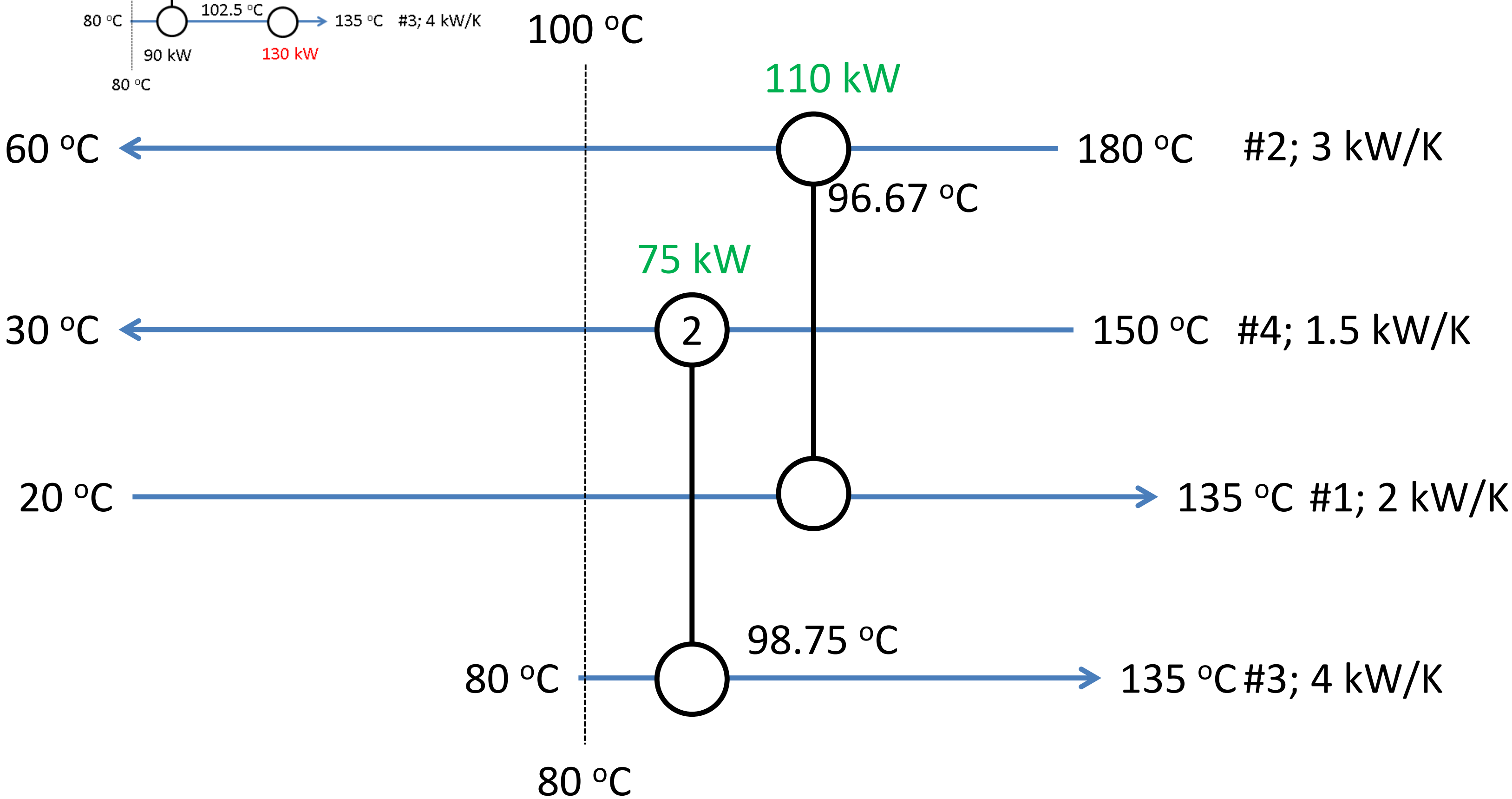
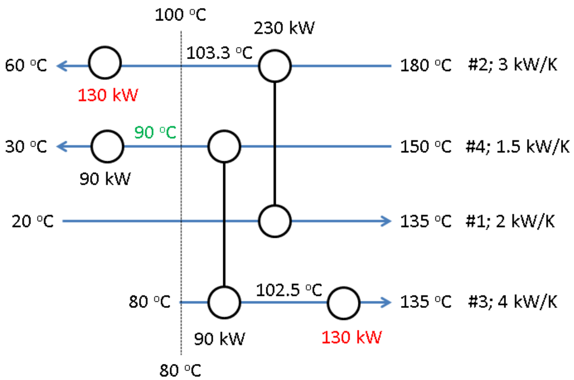


HE-2 (75 kW) is chosen

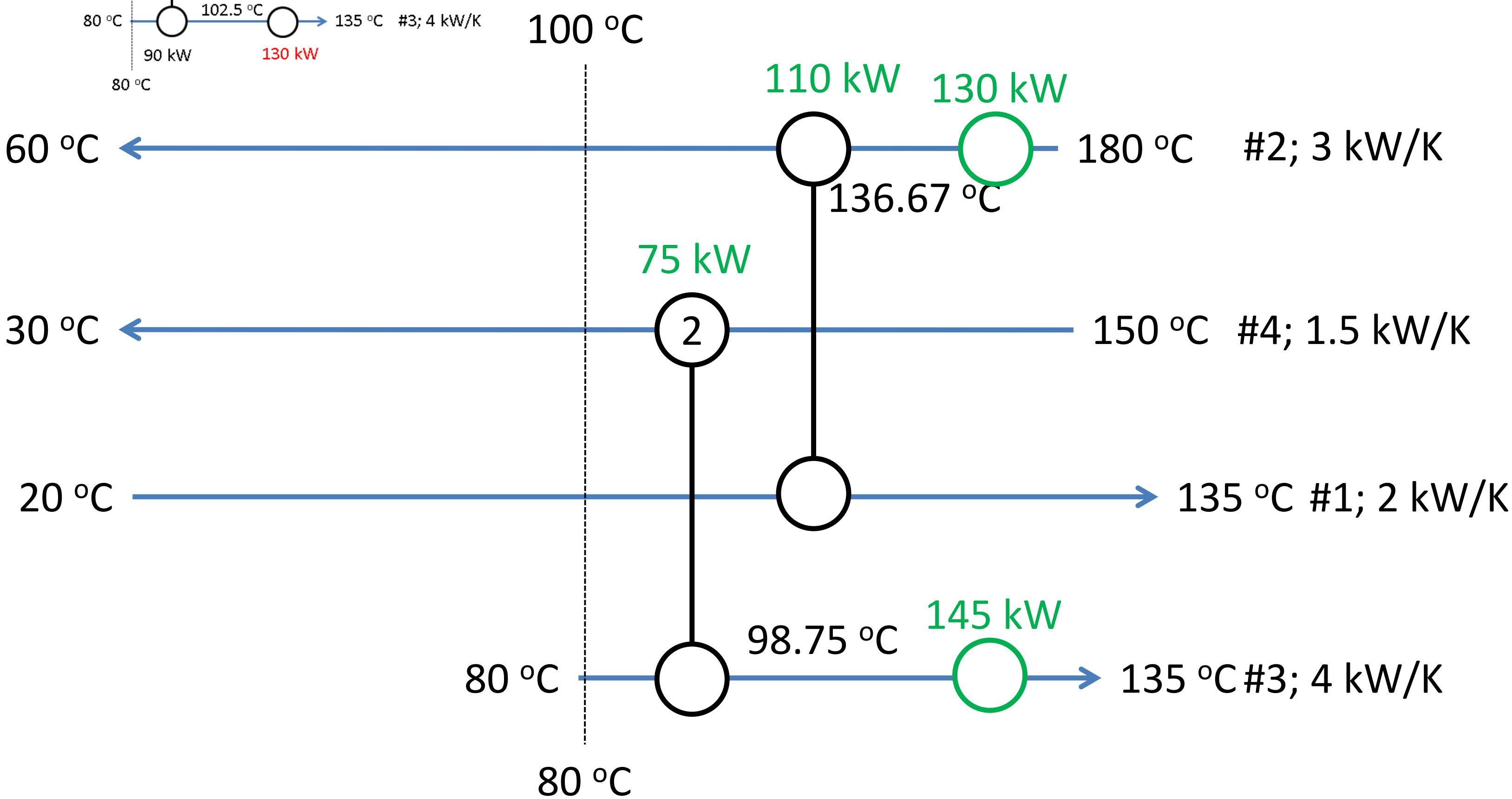
Another match (110 kW) is chosen



2.7 Design from scratch: Pinch rule above pinch, $CP_{HOT} \le CP_{COLD}$



HE-2 (75 kW) is chosen
Another match (110 kW) is chosen
Extra energies are identified



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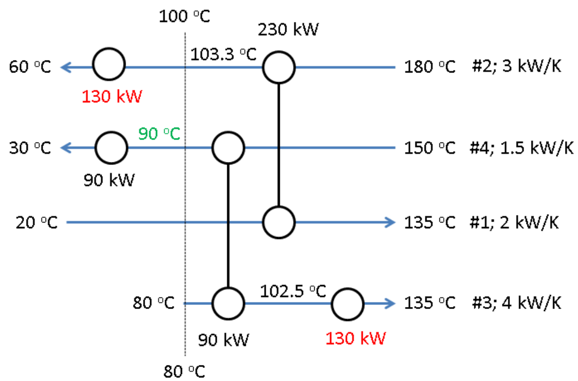
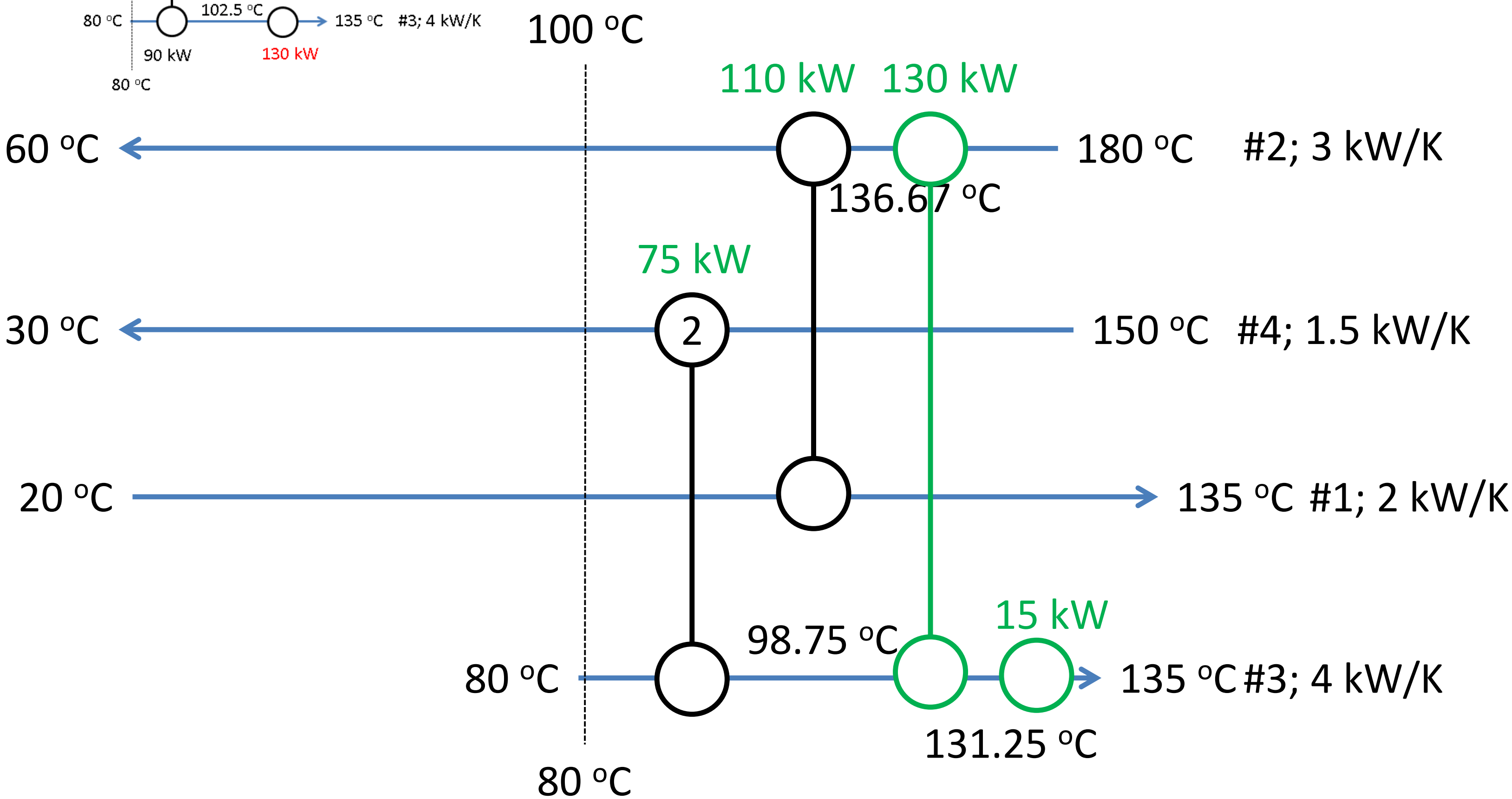
2.8 DESIGN FROM SCRATCH:
PINCH RULE ABOVE PINCH, $CP_{HOT} \le CP_{COLD}$



HE-2 (75 kW) is chosen
Another match (110 kW) is chosen
New match is added. Above pinch is complete



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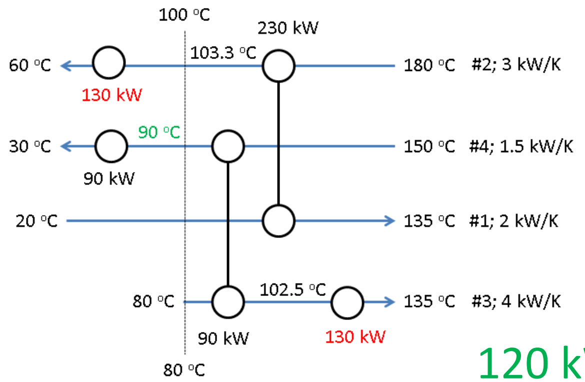
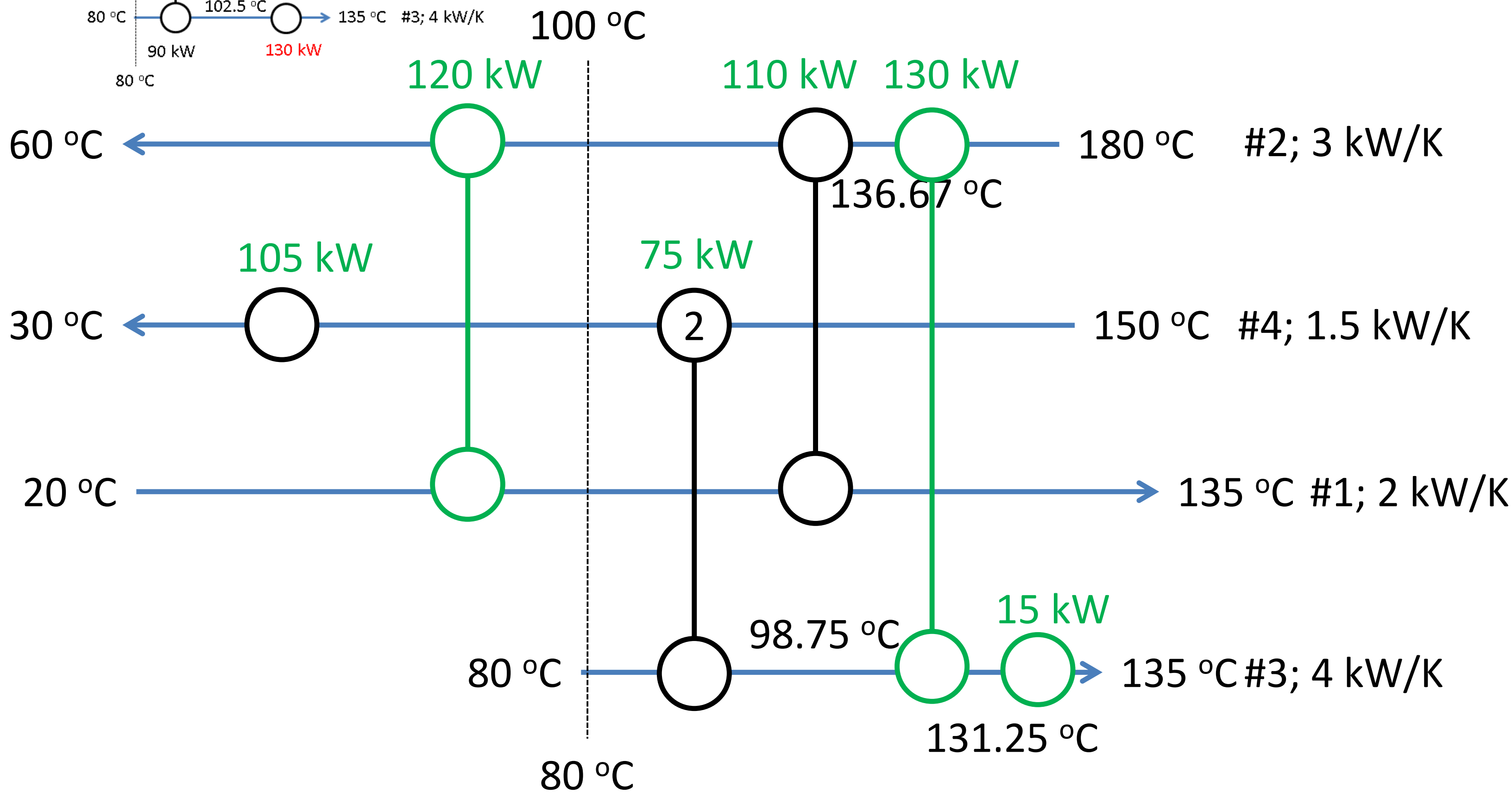
2.9 DESIGN FROM SCRATCH: PINCH RULE BELOW PINCH, $CP_{HOT} \geq CP_{COLD}$



HE-2 (75 kW) is chosen
Another match (110 kW) is chosen
New match is added. Above pinch is complete
Only 1 match in below pinch



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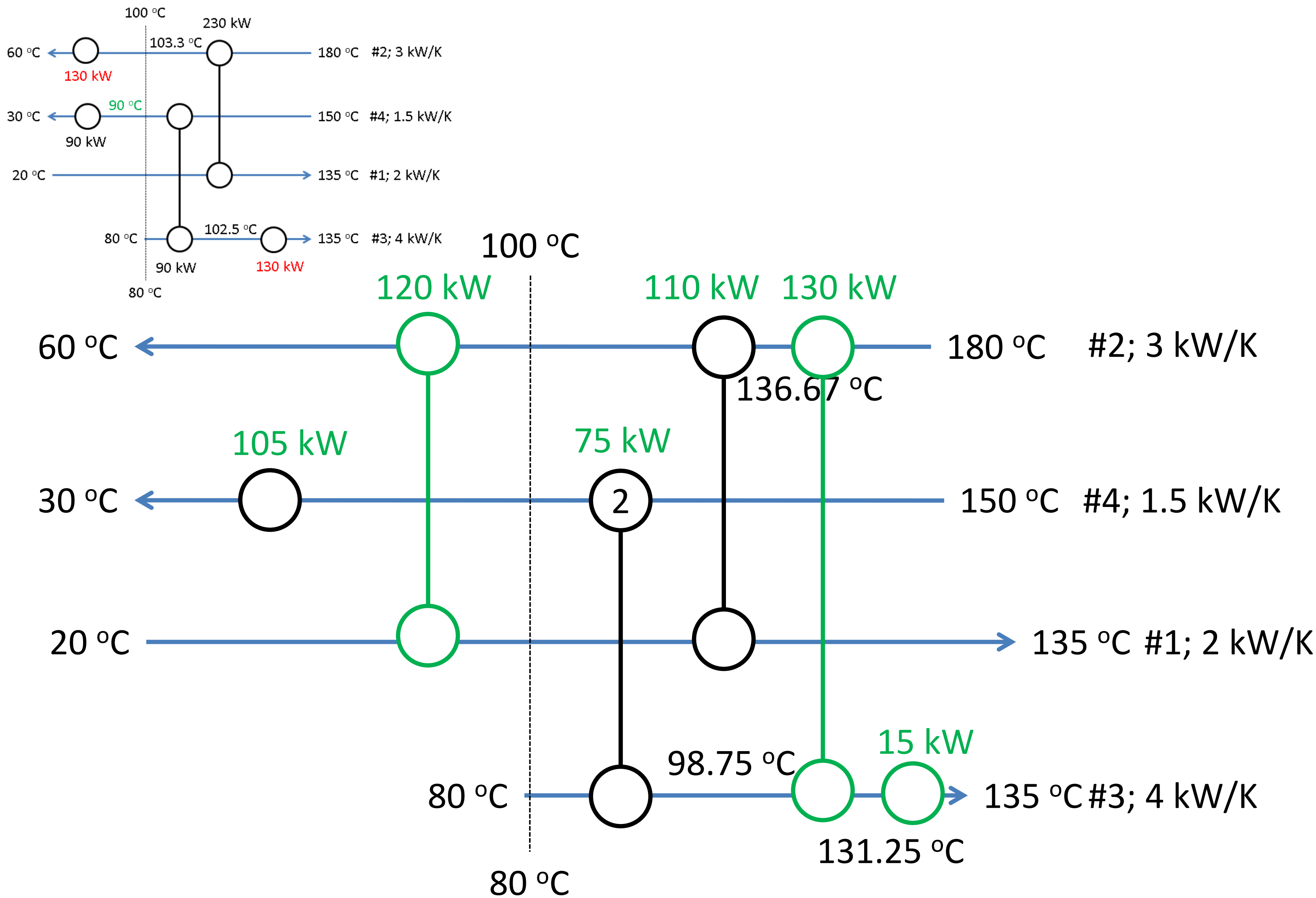
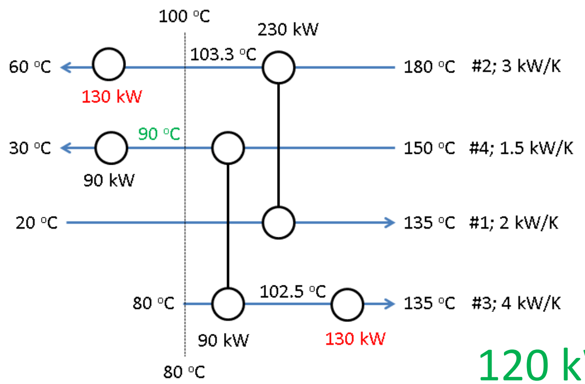
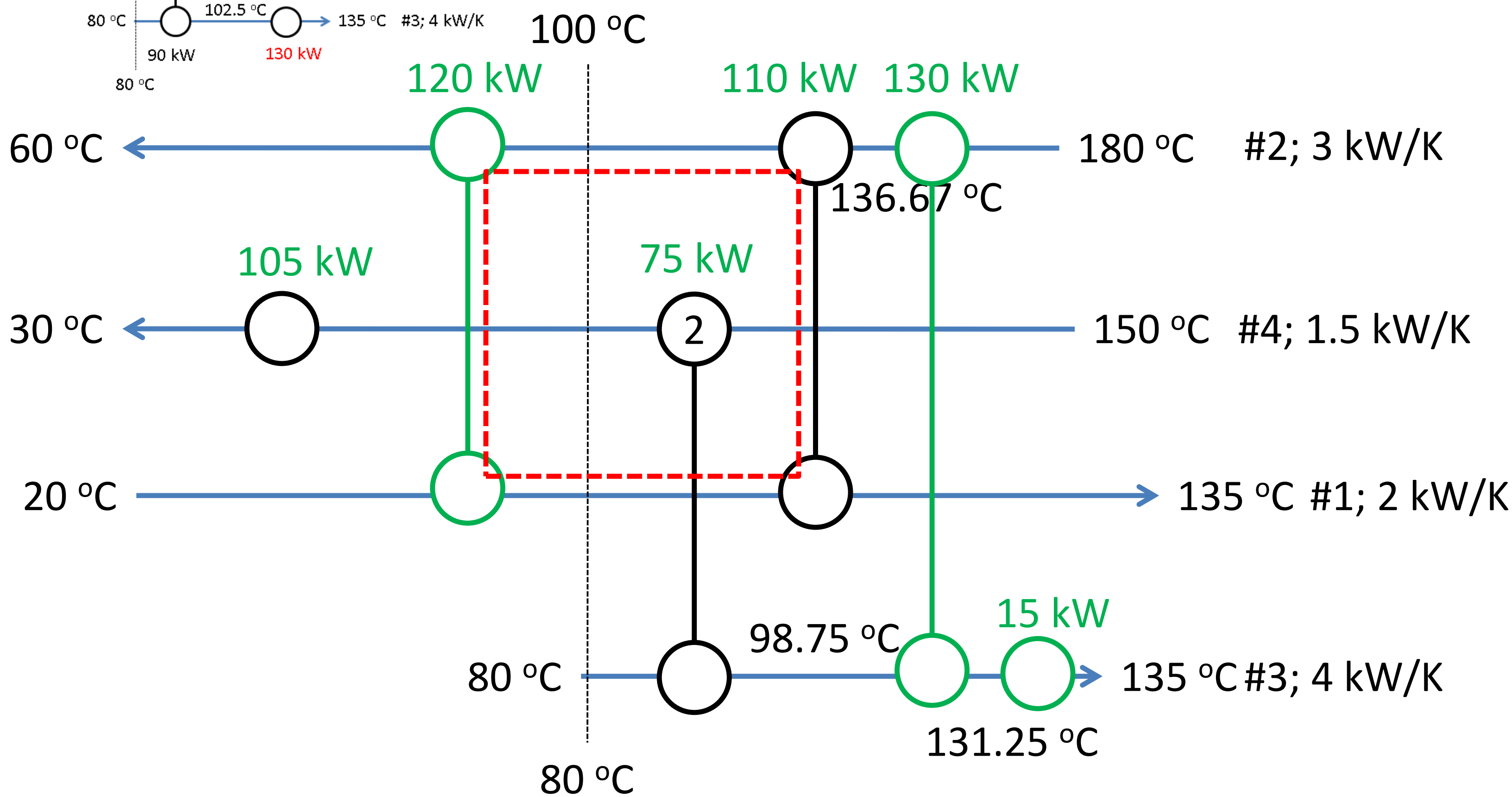
2.10 Then what? Let's simplify it



2.11 Remove loop





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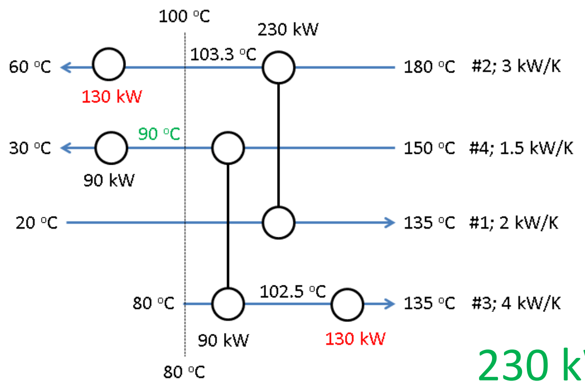
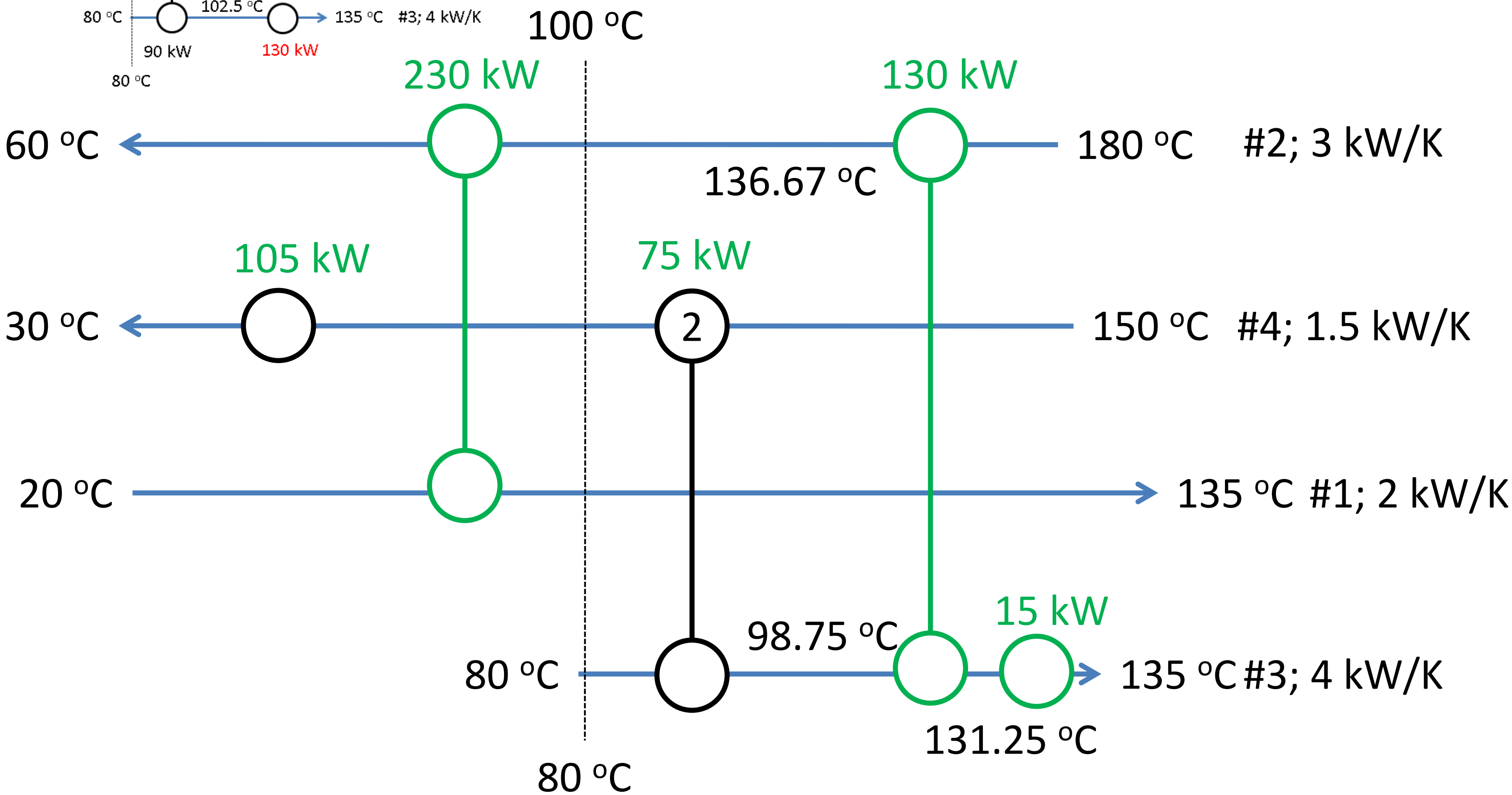
2.12 Remove loop





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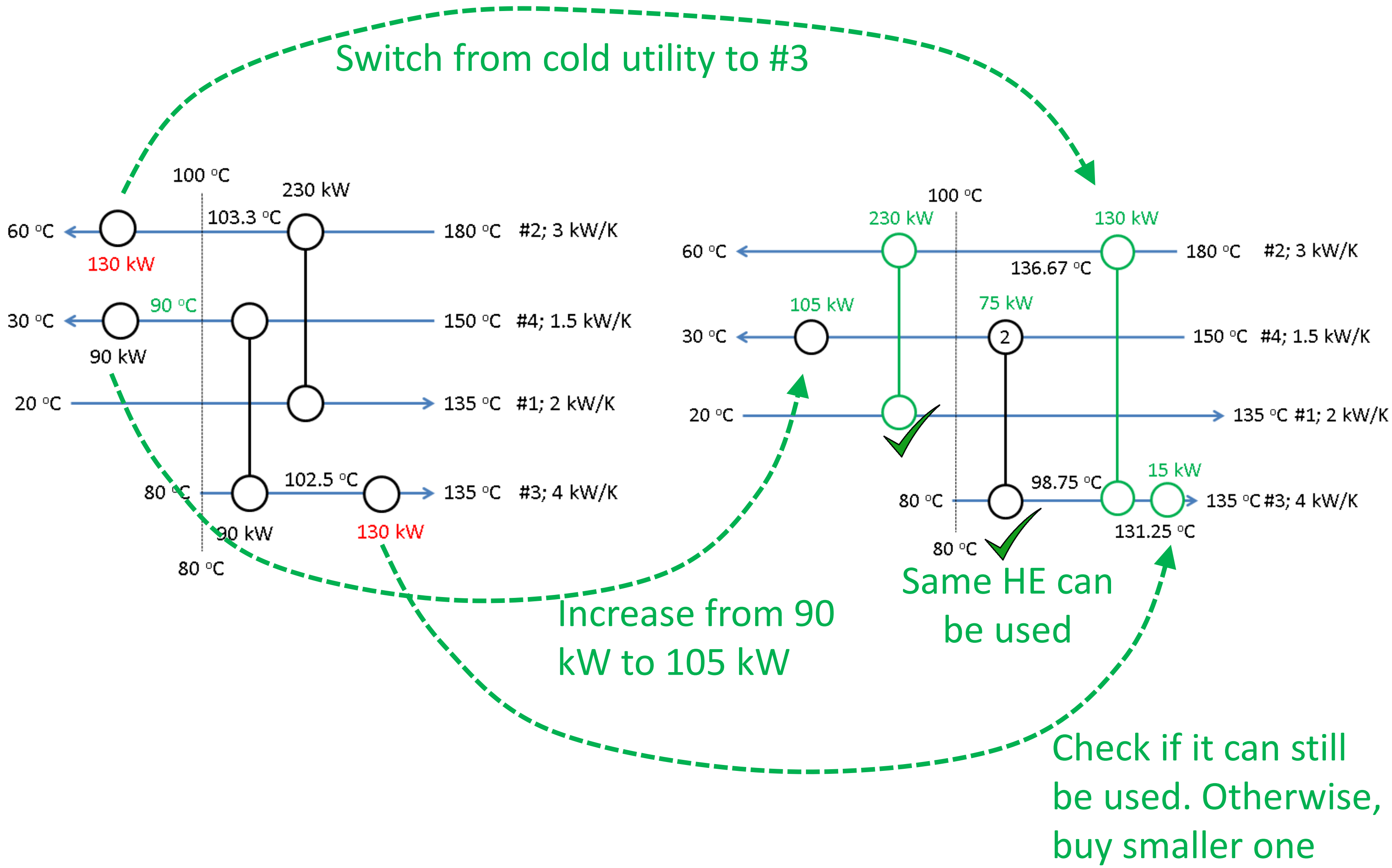
2.13 What needs to be changed?



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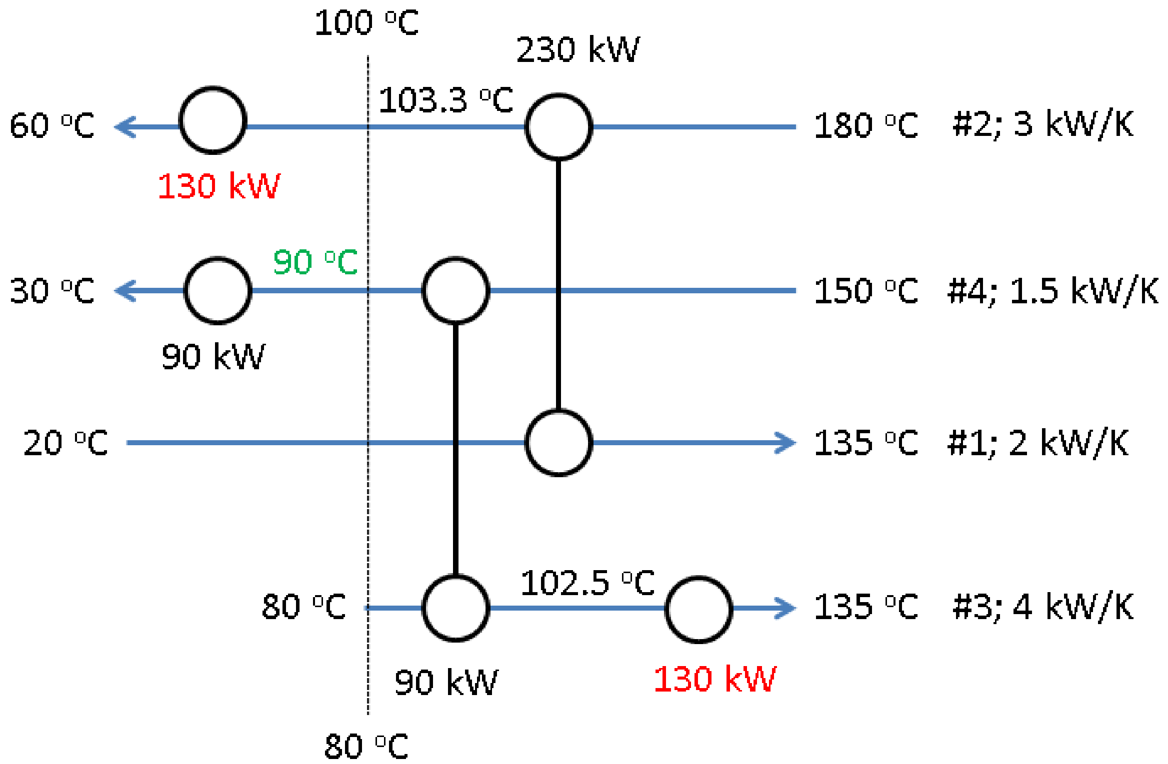
3. START FROM CURRENT DESIGN.

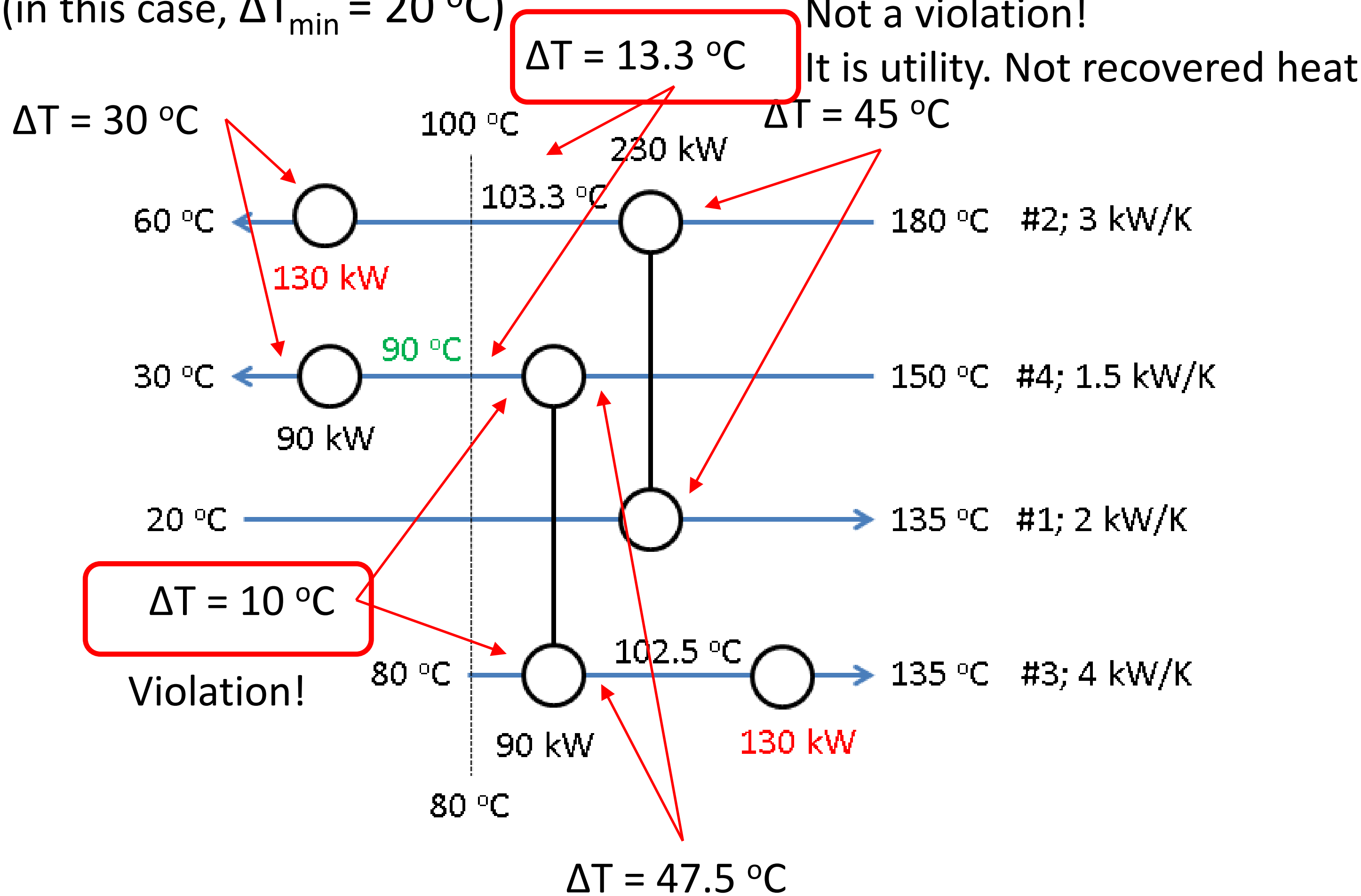
IDENTIFY CHANGES WITH SIGNIFICANT COST IMPACT



3.1 Network Pinch

Network pinch → point where existing exchangers reach ΔT_{min}

(in this case, ΔT_{min} = 20 °C)



If the ΔT is still higher than the ΔT_{min}, the heat load can be increased until ΔT_{min}

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3.2 4 POSSIBLE APPROACHES

Asante and Zhu (1996) provided 4 possible approaches for the network pinch:

1. **Resequencing**: Order of exchangers can be reversed, and this sometimes allows for better heat recovery
2. **Repiping**: Similar to resequencing, but one of both of the matched streams can be different to current situation
3. **Adding a new match**
4. **Splitting**

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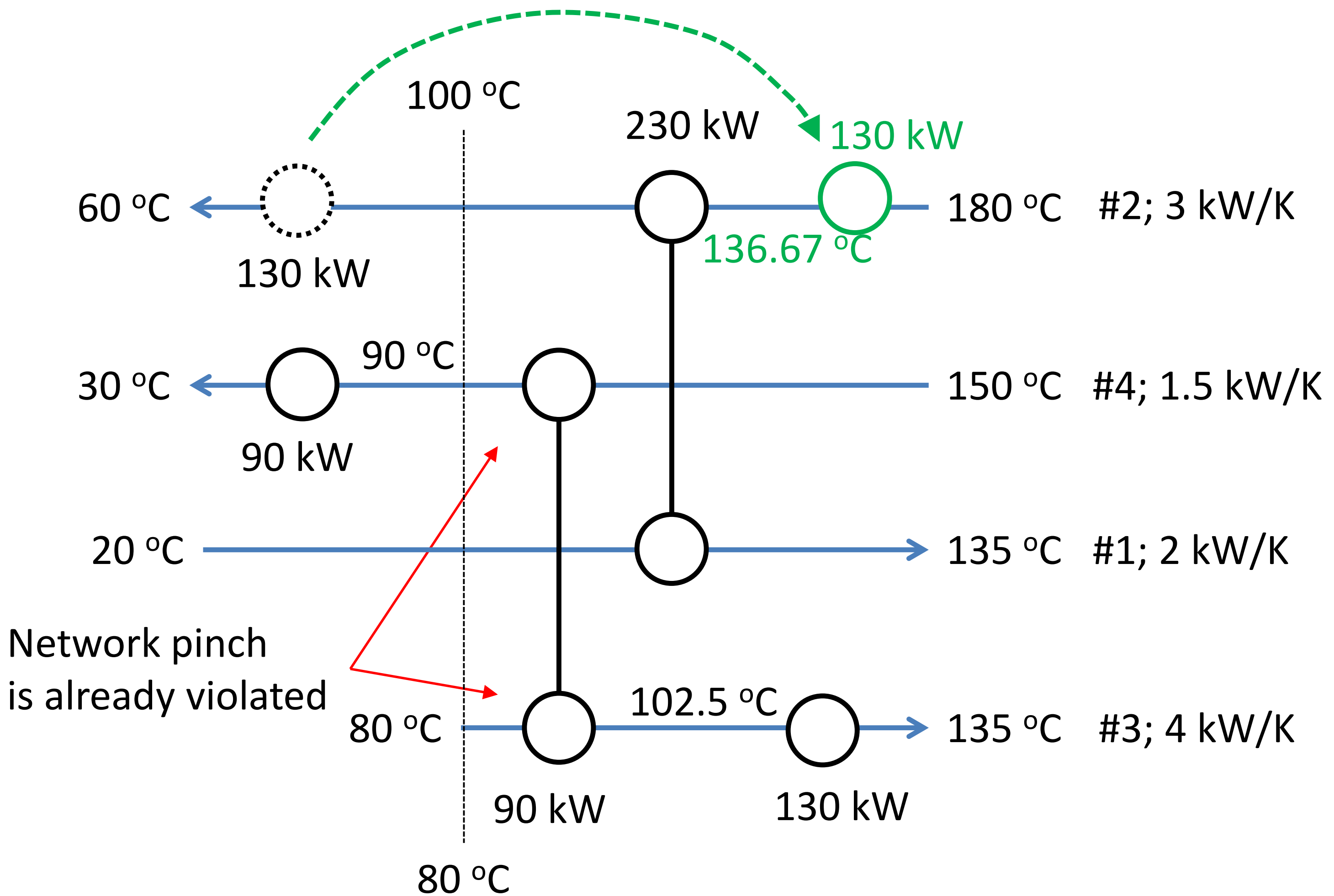
3.3 RESEQUENCING: TO MAKE HEAT AVAILABLE AT HIGHER TEMP



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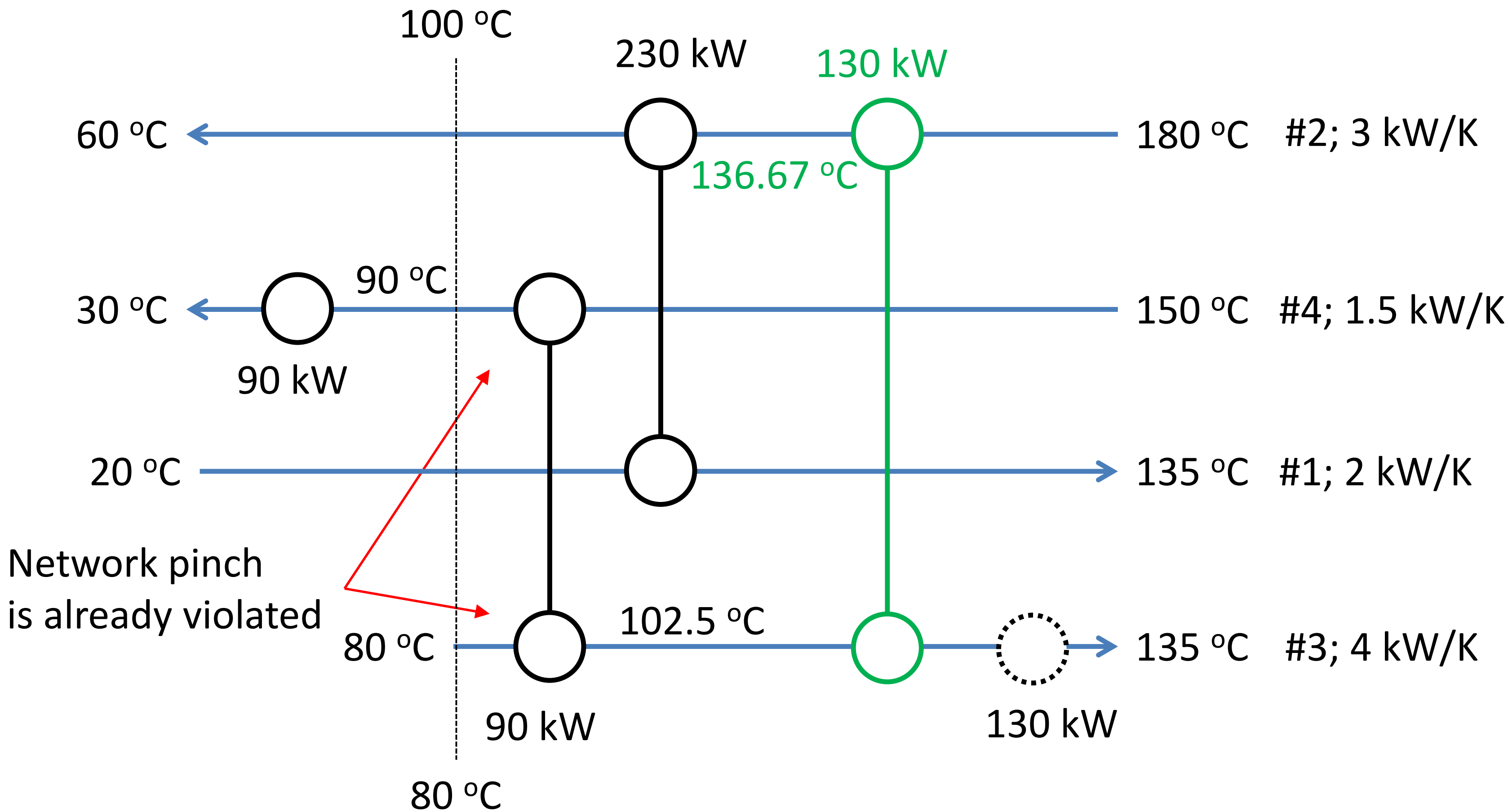
3.3 Repiping: to switch cold utility with #3



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3.4 Result

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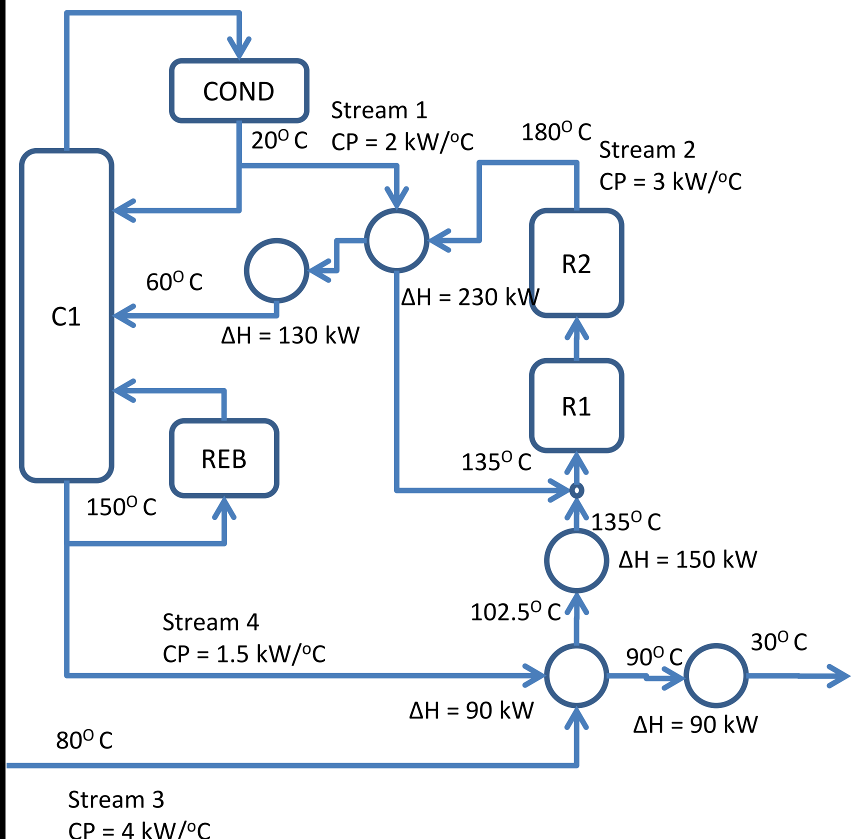
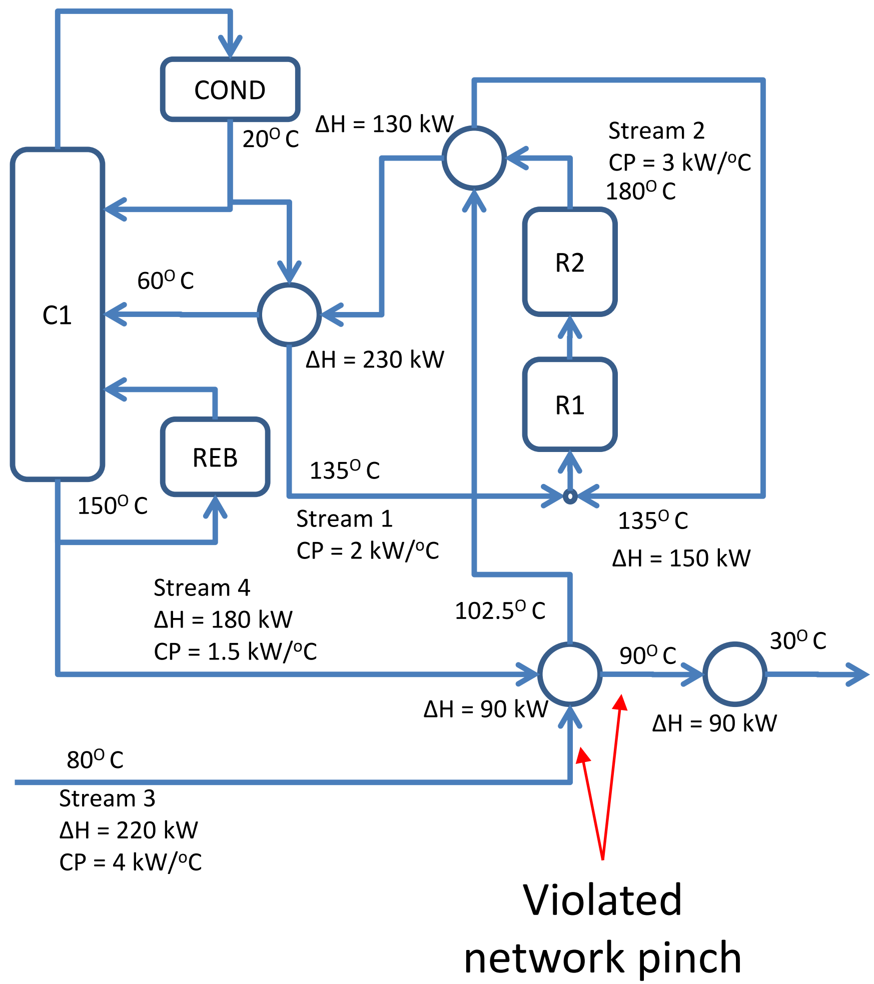
Existing



Revamped network



Summary

To find the best potential energy improvement schemes, one should:

- Check the existing network and identify pinch violators
- Obtain as many similar matches as possible with the existing network
- Favor matches which already exist if a choice exists on matches, especially away from the pinch region
- Identify the network pinch and pinching match for the existing network
- Consider working in two directions, from:
  - new design by loop breaking and energy relaxation (path), and
  - existing network by eliminating violations
- Perform a crude evaluation of all alternatives by comparing the UA values. Restore A values of existing units as far as possible (for reuse)
- Perform detailed simulation and optimization of the "best bets"
- "There are always options to choose"

FINAL QUESTION:
WHICH REVAMPED NETWORK IS BETTER?

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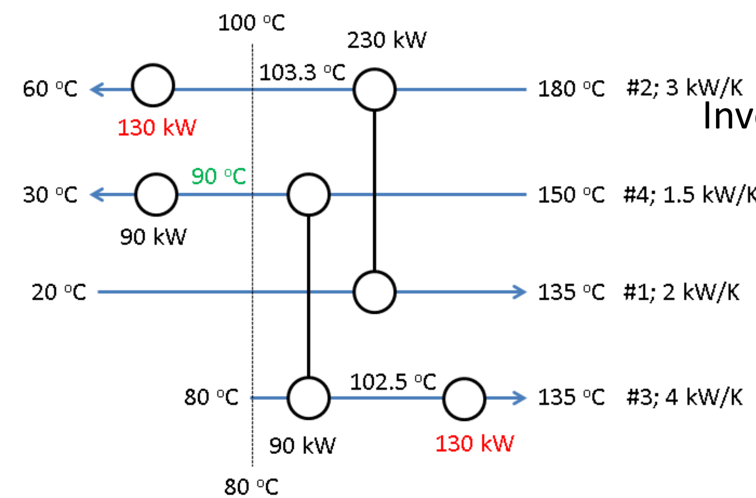
Existing



Use U = 1000 W/(m^2.°C)

T hot utility = 150 °C (condensing steam),

T cold utility = 10 – 20 °C (in – out)

Investment new heat exchanger (RM) = 80000 + 5000·$A^{0.75}$

Additional area only (RM) = 5000·$A^{0.75}$

Piping negligible

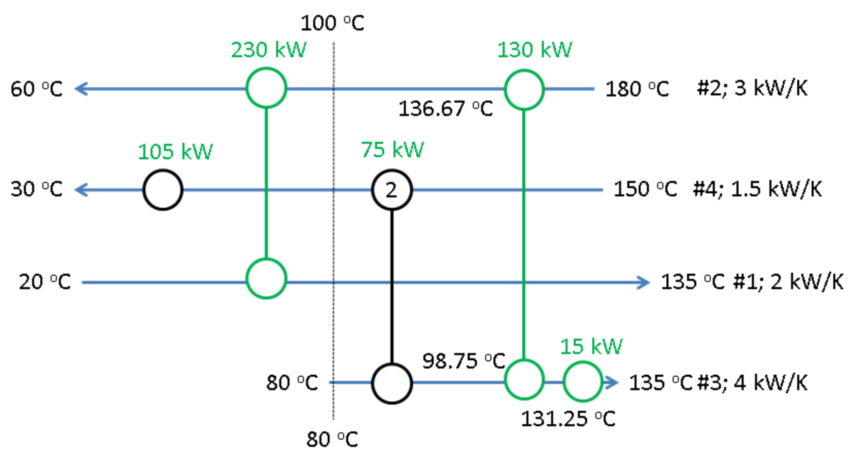
Demolition 10000 RM

Hot utility cost = 200 RM/kWyr

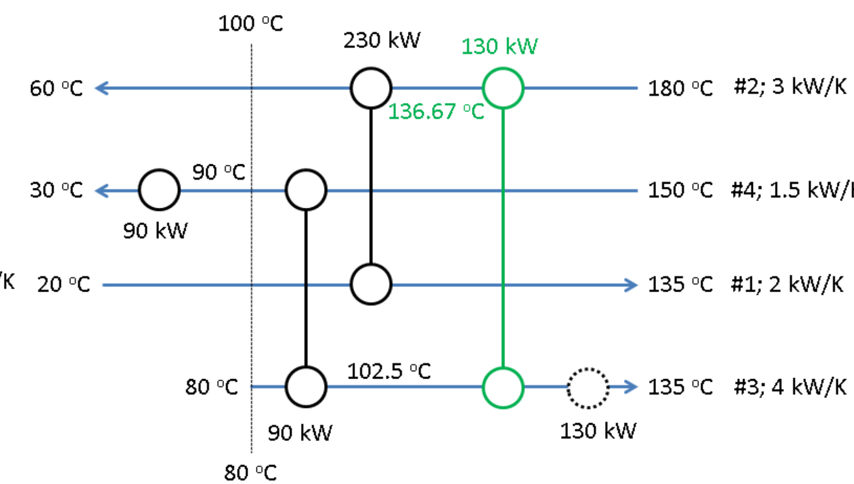
Cold utility cost = 20 RM/kWyr

Calculate the payback period!

Option 1



Option 2



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