Advanced pinch curves for targeting of industrial excess heat potentials

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IEA Annex 15 – Industrial Excess Heat Recovery
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Advanced pinch curves –
Graphical tool for retrofit of heat exchanger networks

- Retrofit requires knowledge about the existing system

- The advanced curves offers new insights
    - Actual and potential temperature levels for heating and cooling – before and after retrofit
    - Information about the design of the existing network
    - Visualization of trade-off between internal or external use of excess heat
    - Visualization of potential heat recovery at different complexity levels

Theoretical Heating and Cooling Load Curves (THLC, TCLC)

Pinch curves that visualize the potential for external utilization of excess heat

Retrofit, excess heat, and basic pinch tools

Existing industrial process

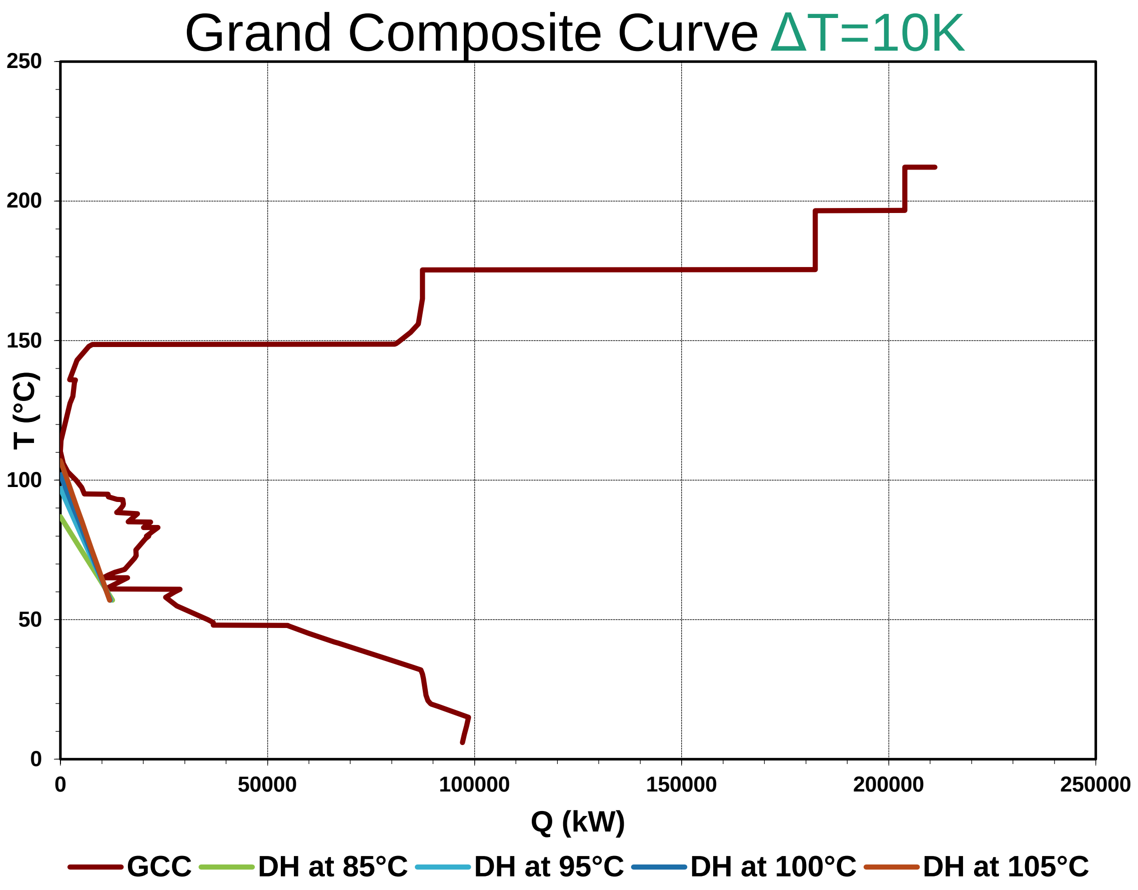
At what temperatures can excess heat be available at the current hot utility demand?

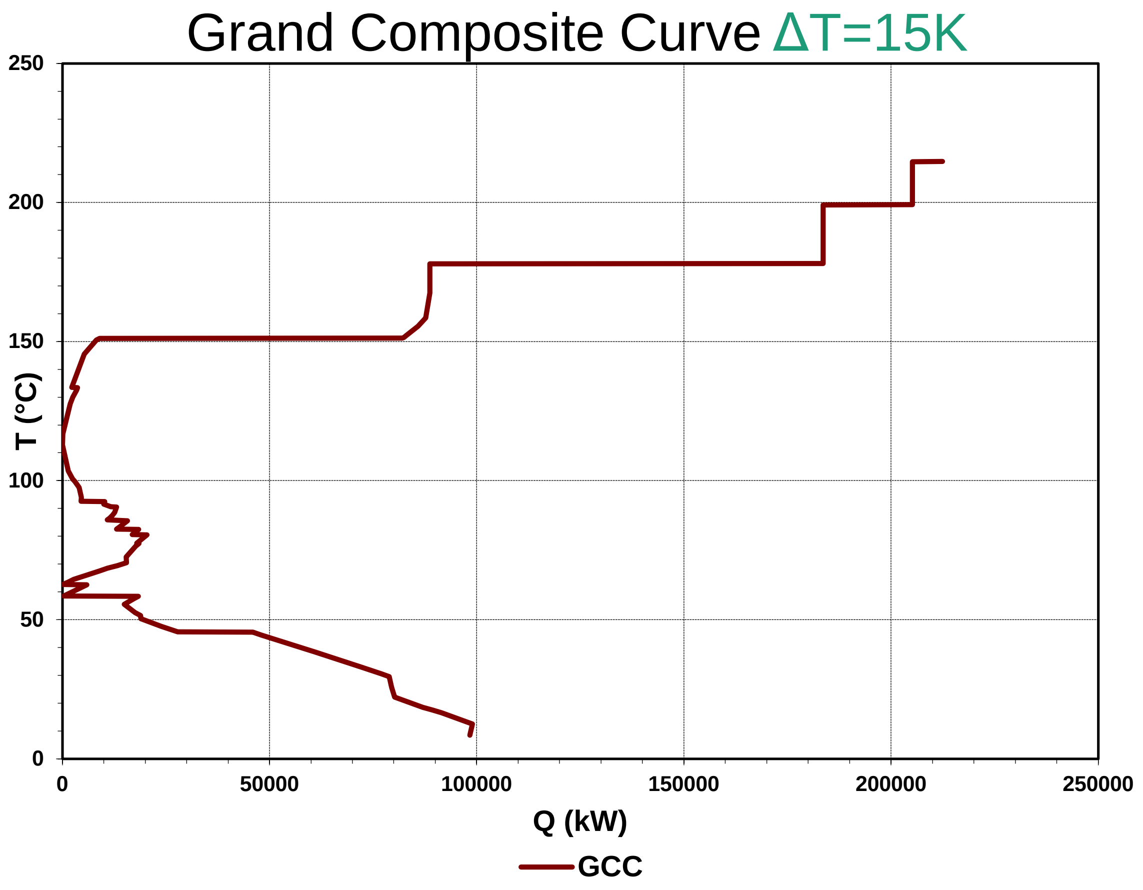
Is this heat best used internally or externally?

The GCC is not a well-suited tool to answer these questions

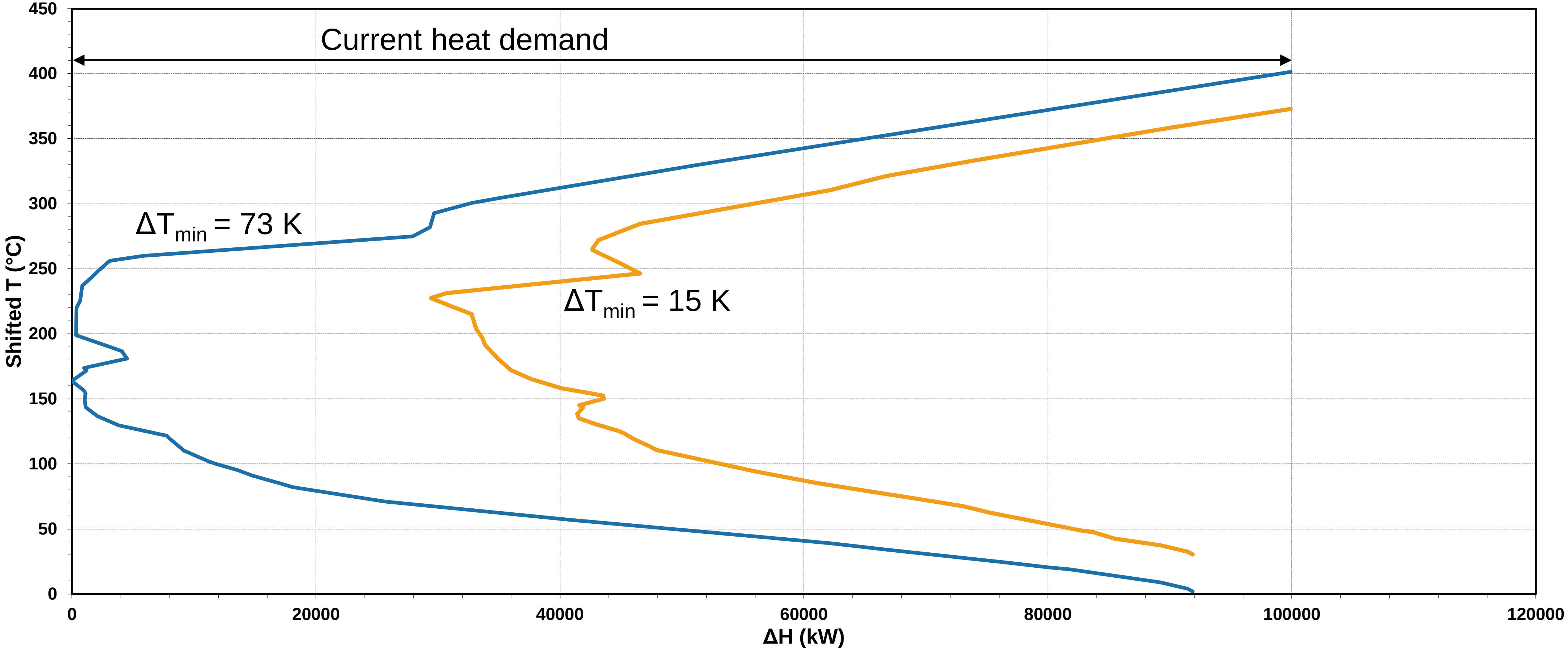
- Inadequate representation of temperatures
- Unclear trade-off between internal heat recovery and external utilization of excess heat

One illustration
Estimating excess heat potentials using GCC





Another illustration
Estimating excess heat potentials using GCC



Theoretical Heating/Cooling Load Curves THLC and TCLC

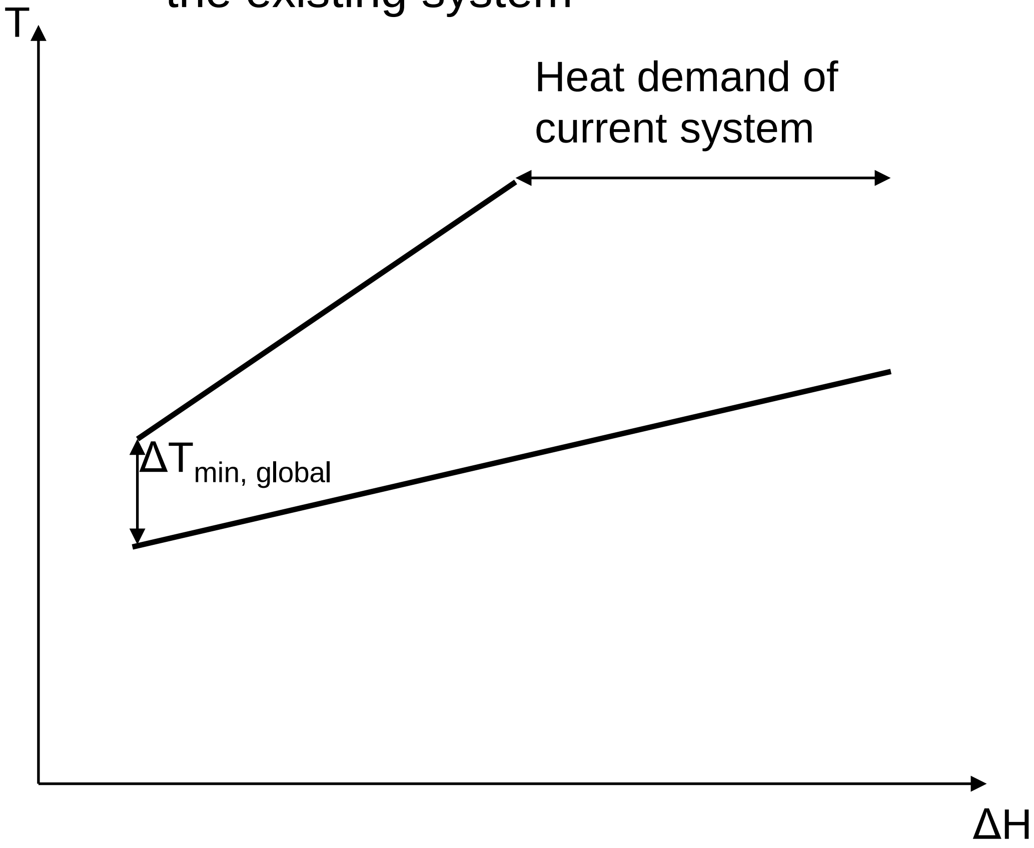
- The THLC represents the *"theoretically"* lowest temperature levels at which heat can be supplied for a given system:
  - at a given utility demand, i.e., for a given global ΔT_{min} (HRAT)
  - assuming no pinch violations

- Similarly, the TCLC represents the *"theoretically"* highest temperature level of cooling

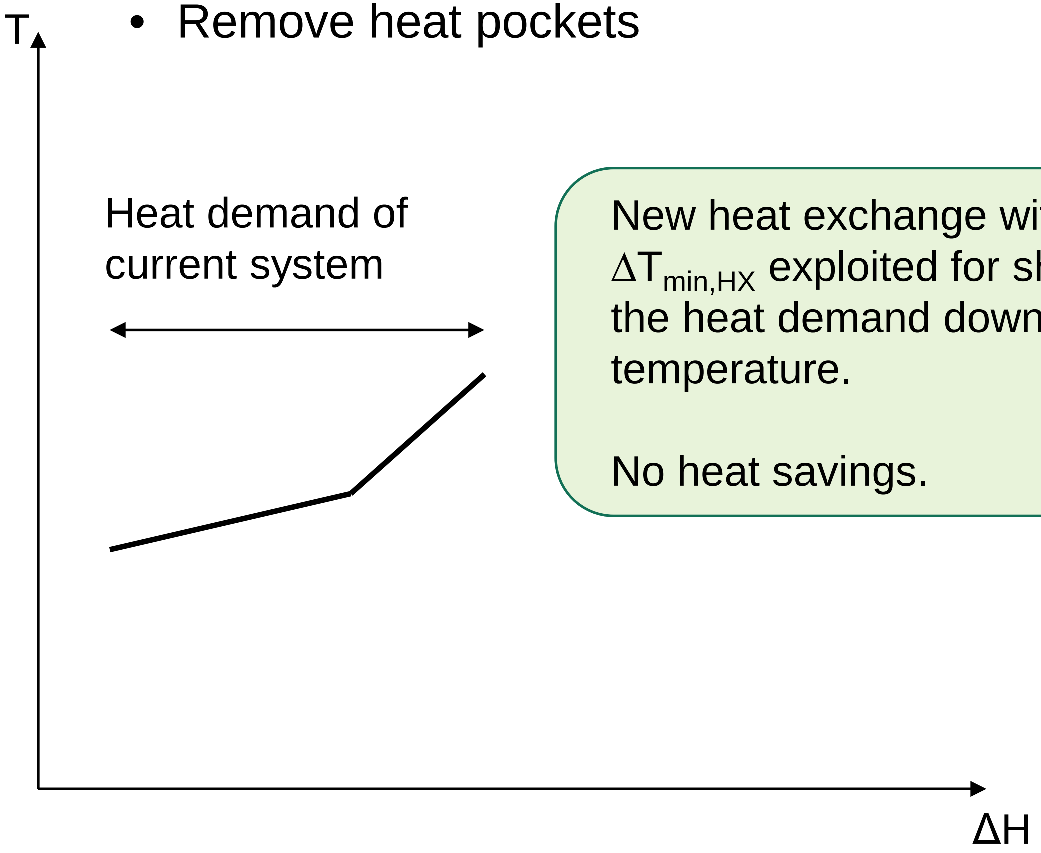
⇒TCLC shows highest temperature where excess heat can be extracted (below the pinch)

Construction of THLC

- Divide the system at the pinch, with a ΔT_{min} representing the heat demand of the existing system



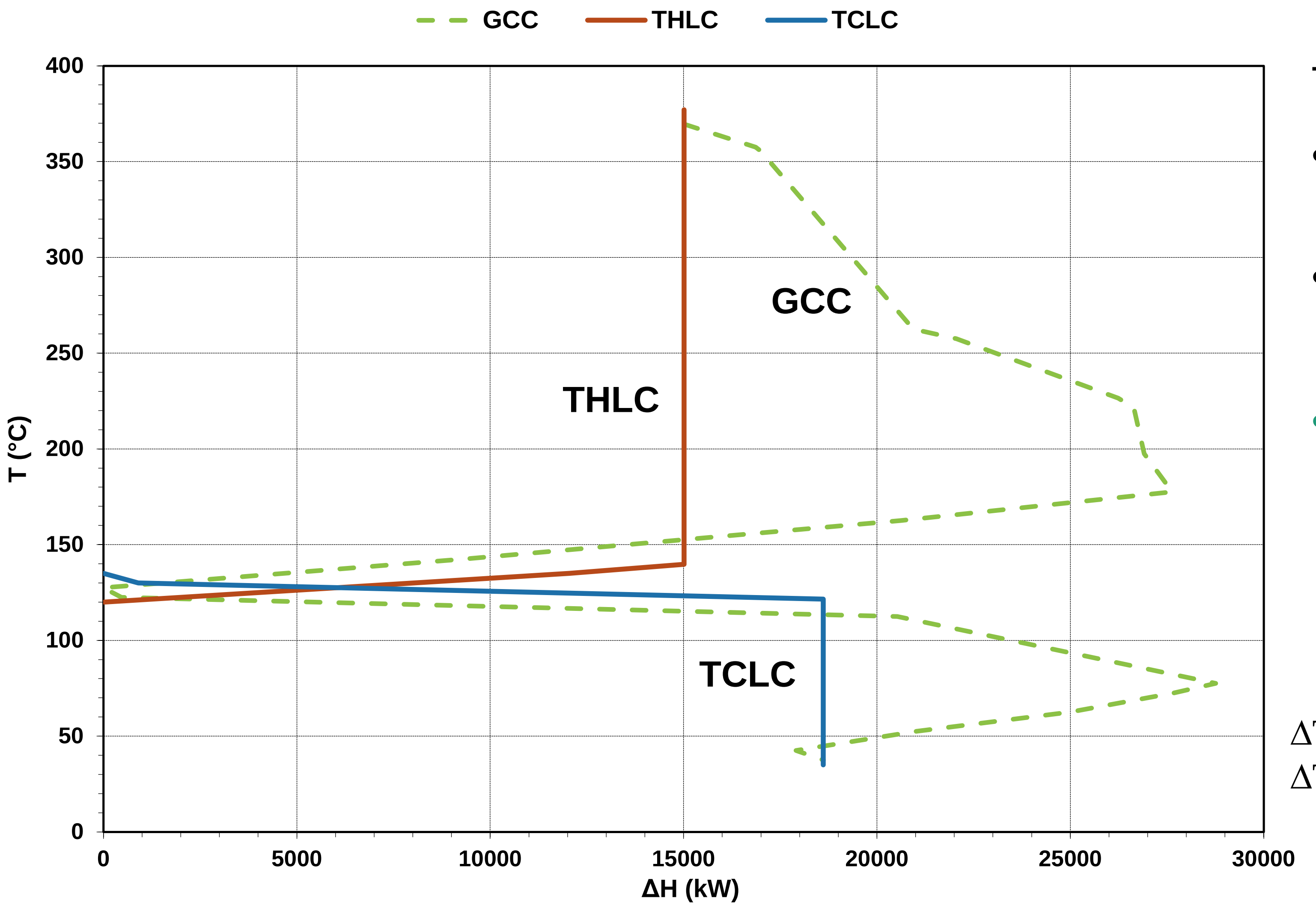
- Calculate a new heat cascade with $\Delta T_{min,HX} < \Delta T_{min,global}$ (e.g. $\Delta T_{min,HX} = 0$ K)
- Remove heat pockets



New heat exchange with $\Delta T_{min,HX}$ exploited for shifting the heat demand down in temperature.

No heat savings.

Comparison GCC and THLC / TCLC



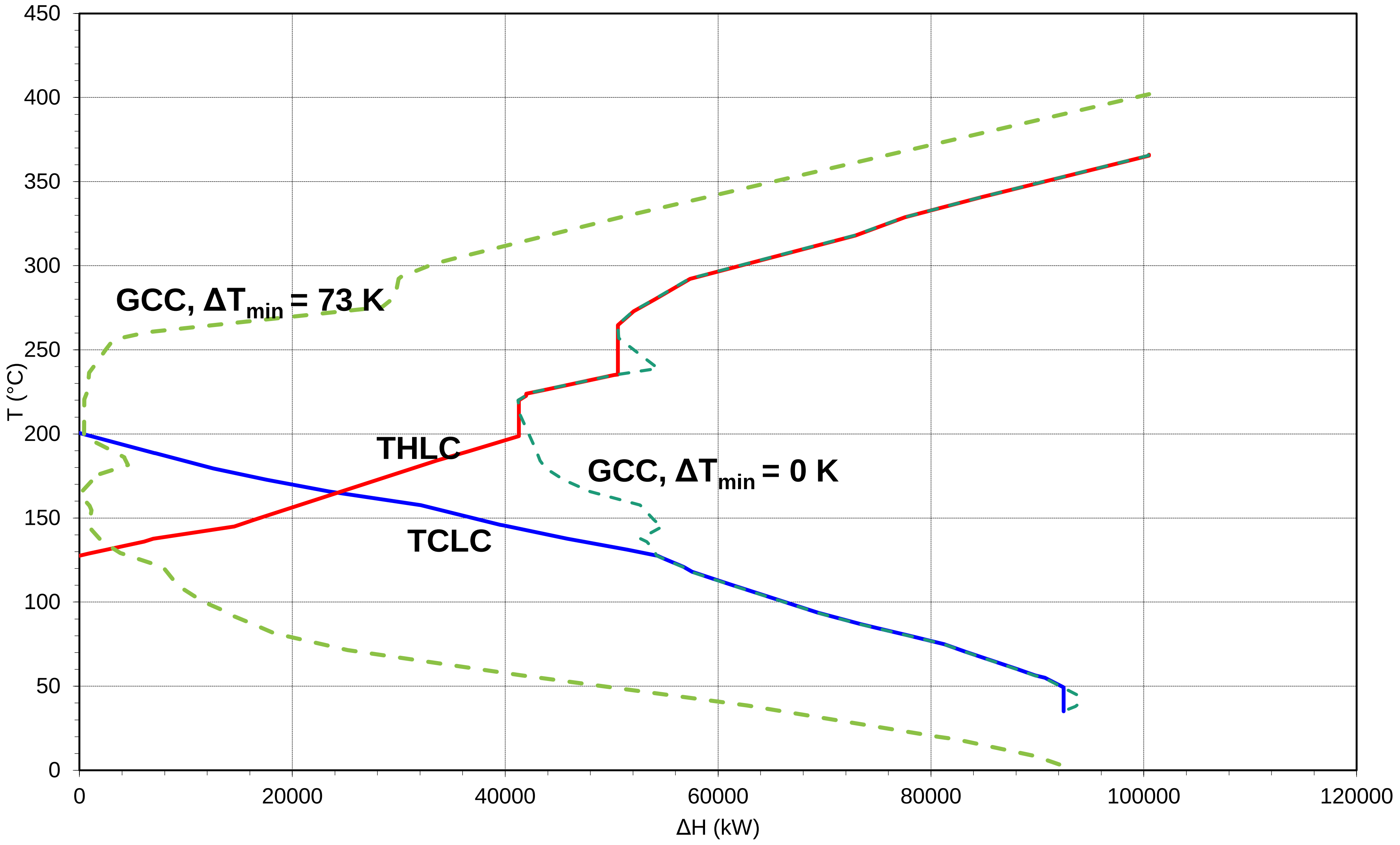
THLC/TCLC…

- shows heat surplus and demands at real temperatures
- removes the pockets in the GCC

- gives an *idea* of the trade-off between internal heat recovery and external utilization of excess heat

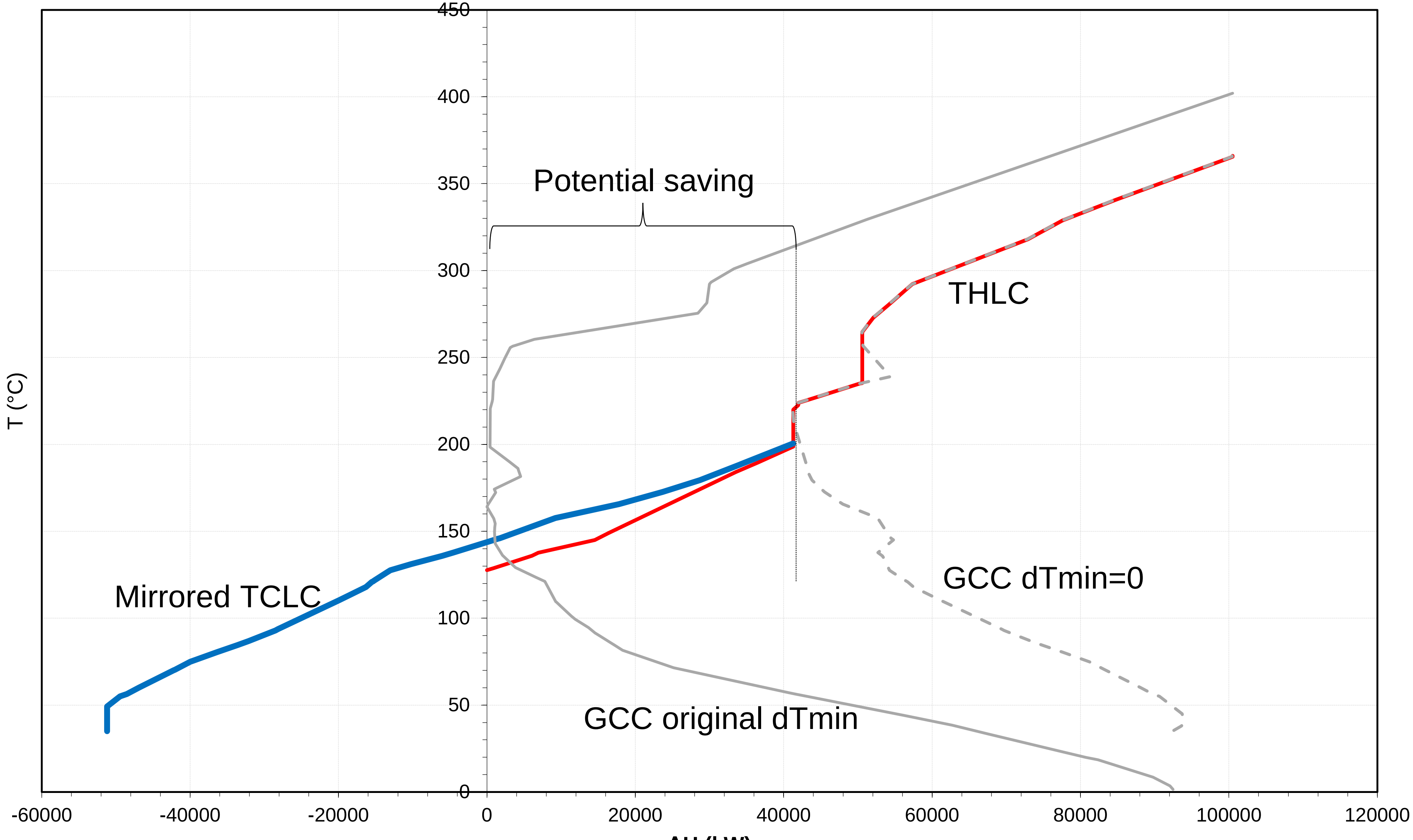
$\Delta T_{min, global} = 15$ K
$\Delta T_{min, HX} = 0$ K

Comparison GCC and THLC / TCLC



THLC/TCLC
$\Delta T_{min,\ global} = 73$ K
$\Delta T_{min,\ HX} = 0$ K

Comparison GCC and THLC / TCLC



THLC/TCLC

$\Delta T_{min,\ global}$ = 73 K

$\Delta T_{min,\ HX}$ = 0 K

Not enough for retrofit situations

THLC/TCLC…

- illustrate potentials for excess heat at certain temperatures
- but do **not** illustrate how difficult it is to retrofit the existing HEN for
  - internal heat recovery
  - releasing excess heat for external use or new processes

Retrofit of heat exchanger networks

Cost and complexity of HEN retrofit depend on existing HEN design, e.g., the placement of heaters and coolers

HEN retrofit

The cost and complexity of retrofitting a HEN to reach a certain heat saving depends on:

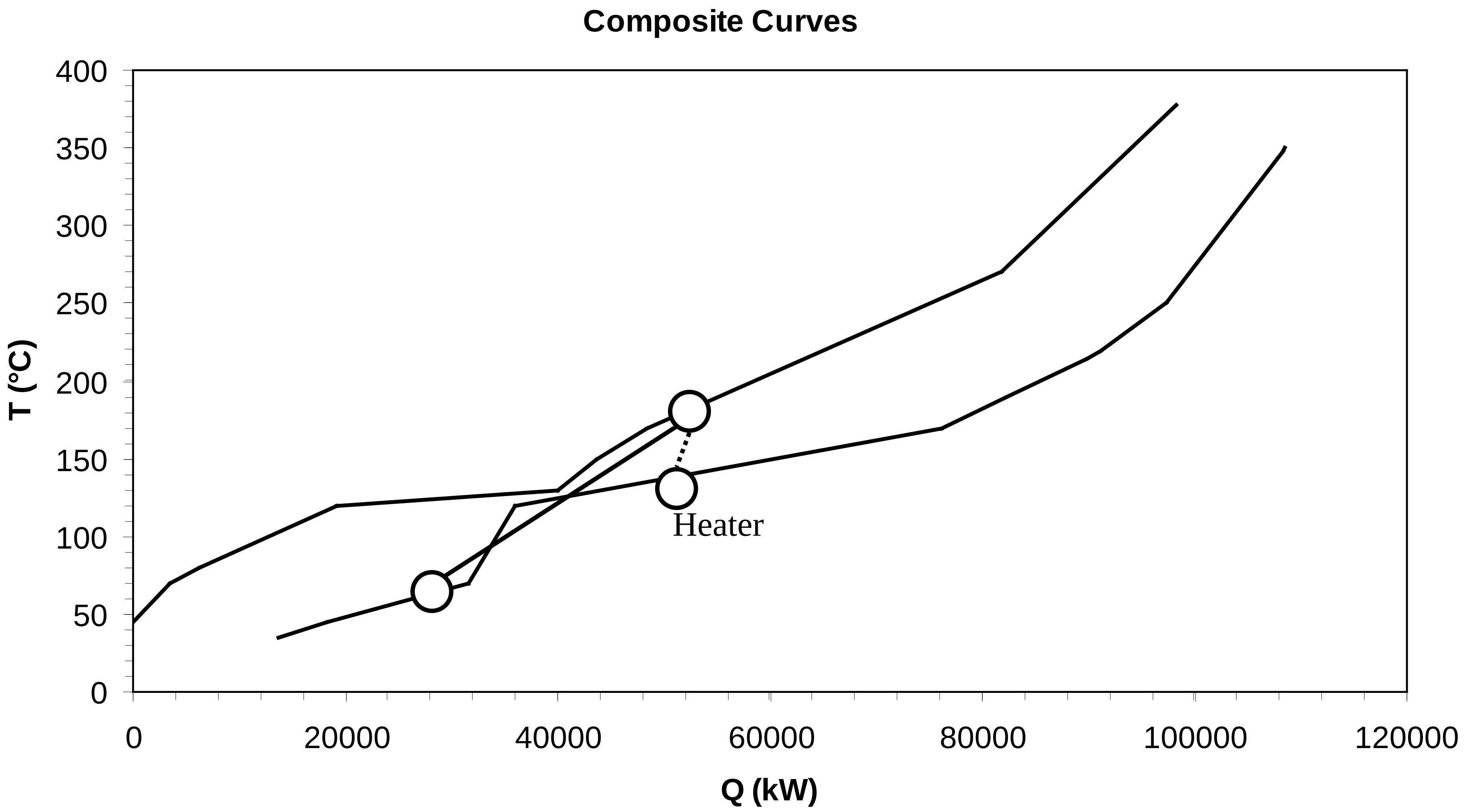
- The placement, in terms of temperature level, of the heaters and the coolers in the HEN
- The degree of criss-cross heat exchange, resulting in heaters placed low and coolers placed high

Composite Curves (CC:s) and Grand Composite Curves (GCC:s) are based only on stream data

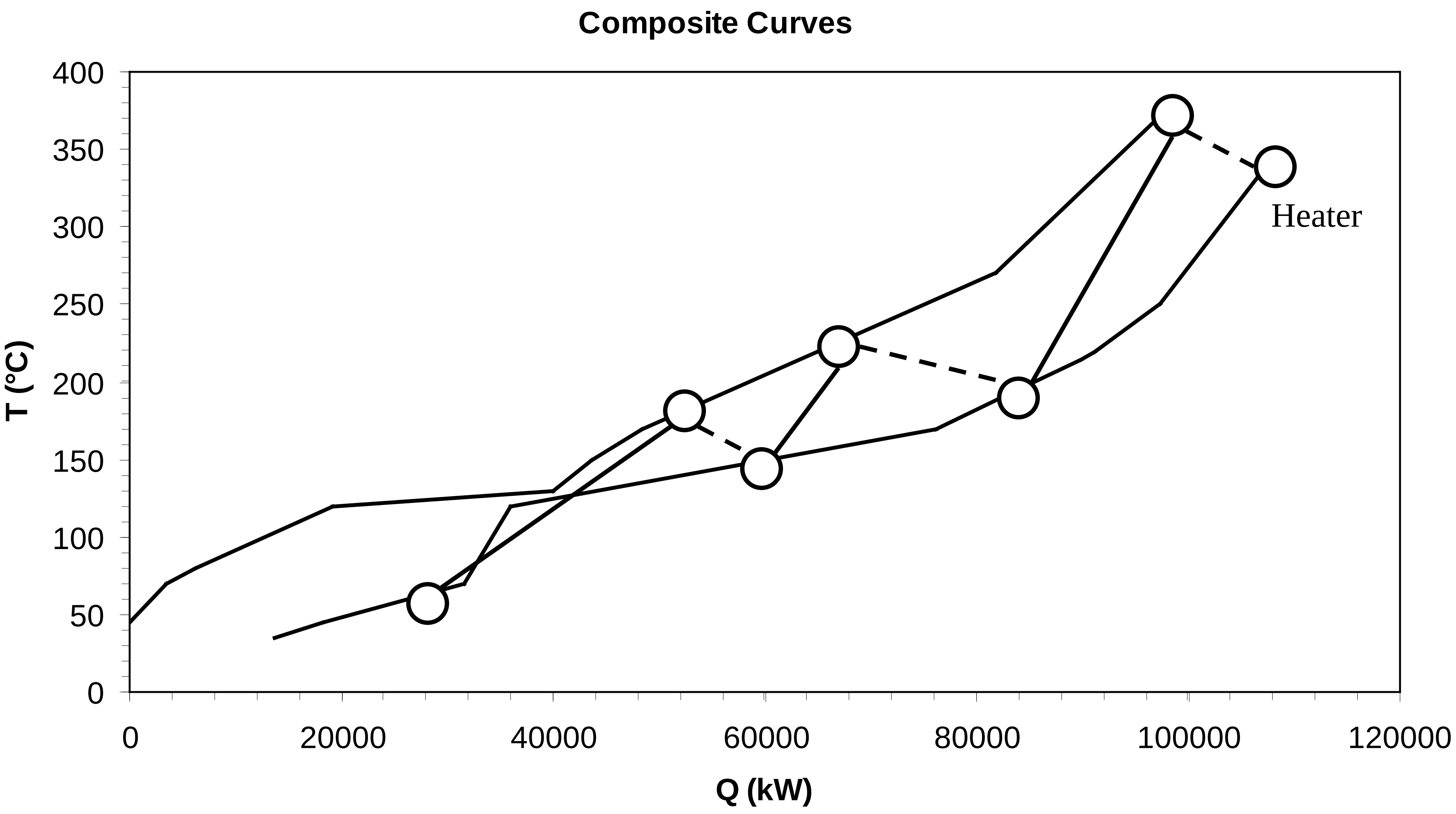
$\Rightarrow$ No information about existing heat exchanger network (HEN) design in the curves

Some examples…

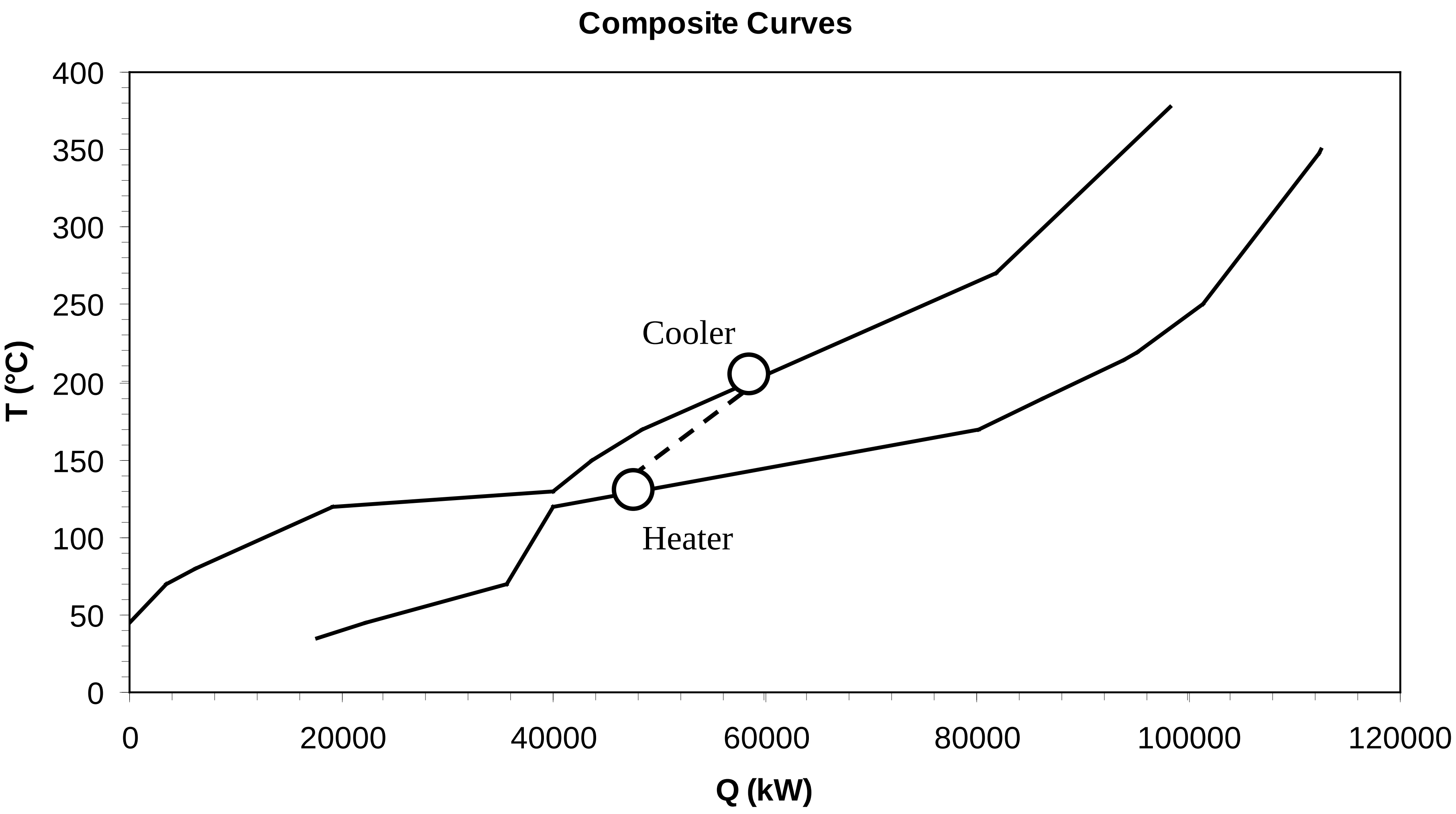
Heater placed low



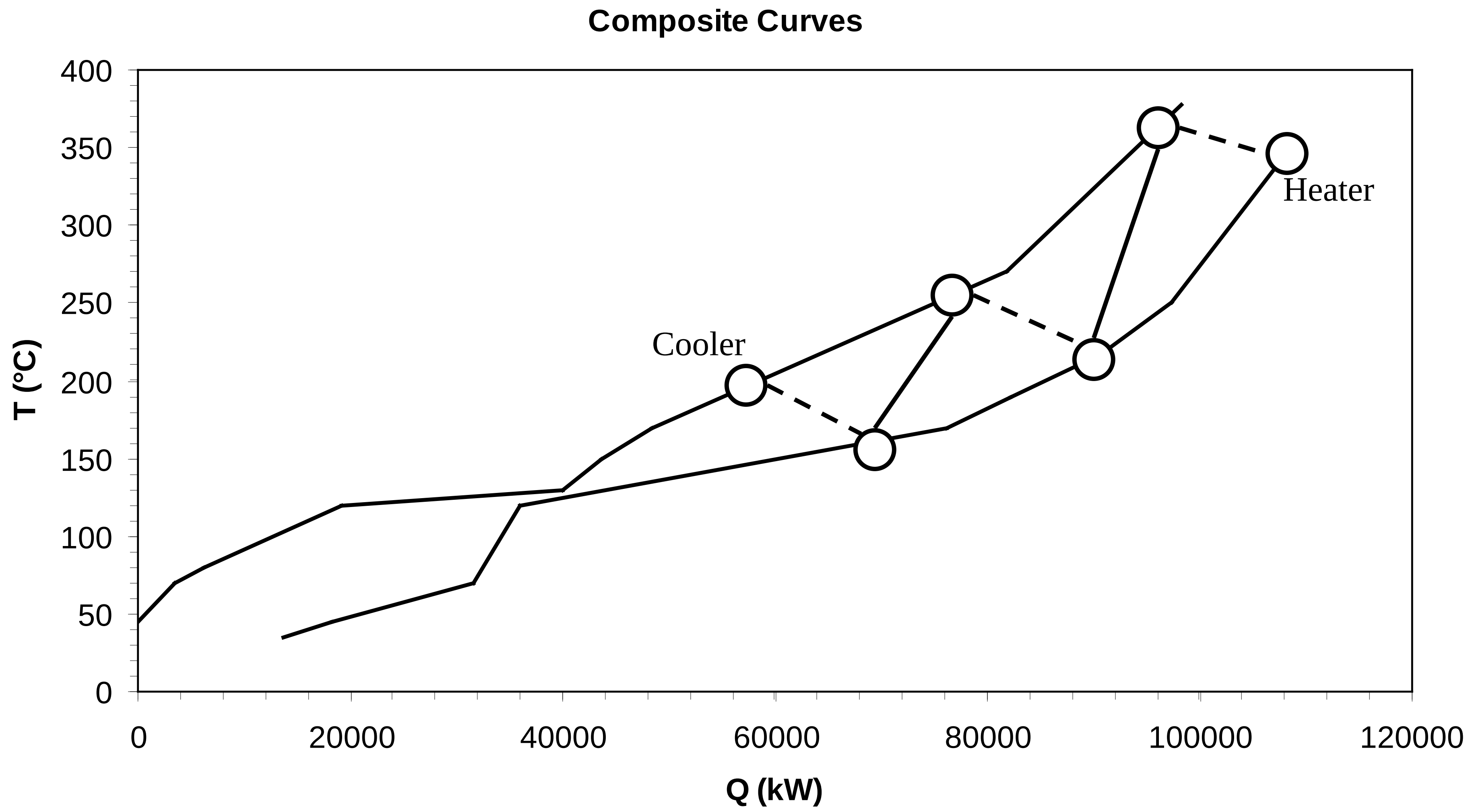
Heater placed high



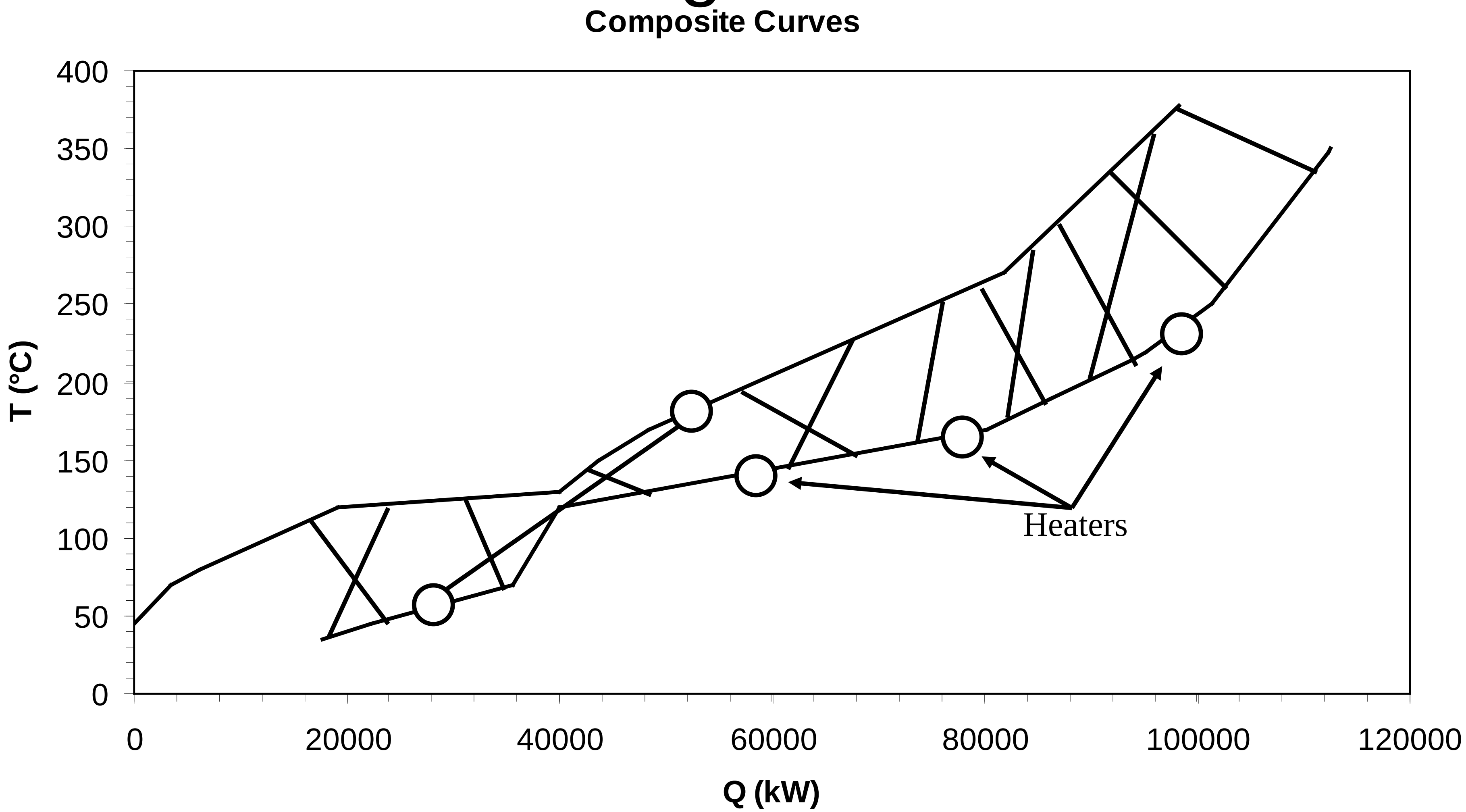
Cooler placed high (above pinch) and heater placed low



Cooler placed high (above pinch) and heater placed high



Criss-cross heat exchange



Summary: Placement of heaters and coolers

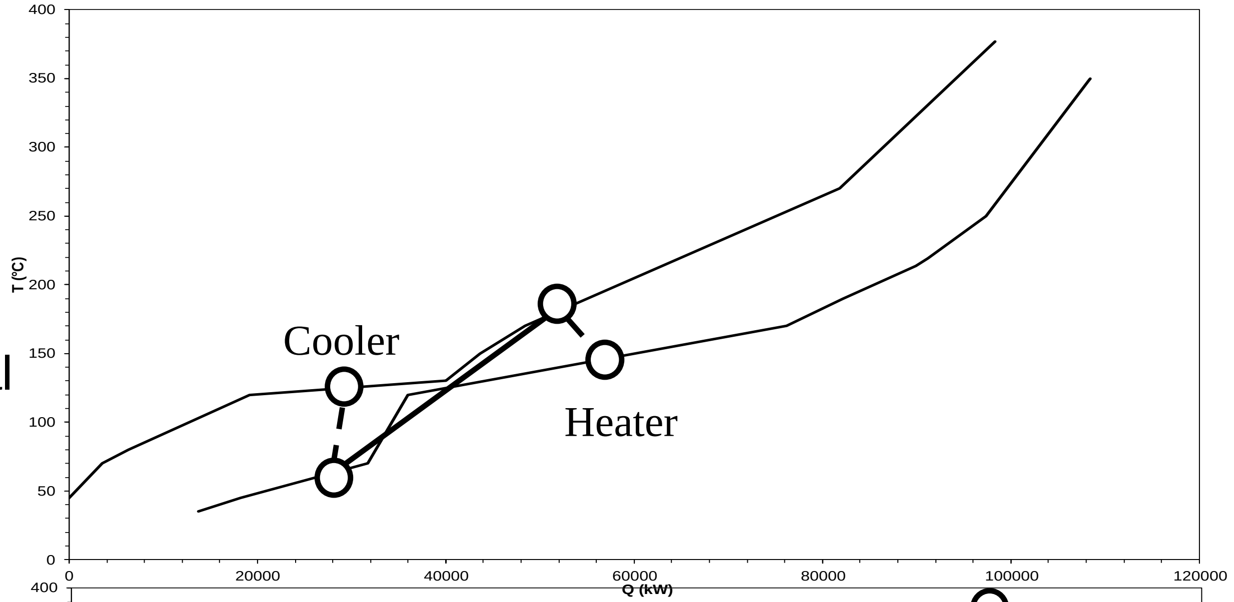
- A ”badly” designed HEN (much criss-cross) has an excess of heat transfer area and, consequently, a higher potential for cost-efficient retrofits.
- The potential for cost-efficient retrofits is better when
  - existing heaters are placed low and
  - existing coolers are placed high

$\Rightarrow$ There is a need for visualizing information about the placement of heaters and coolers

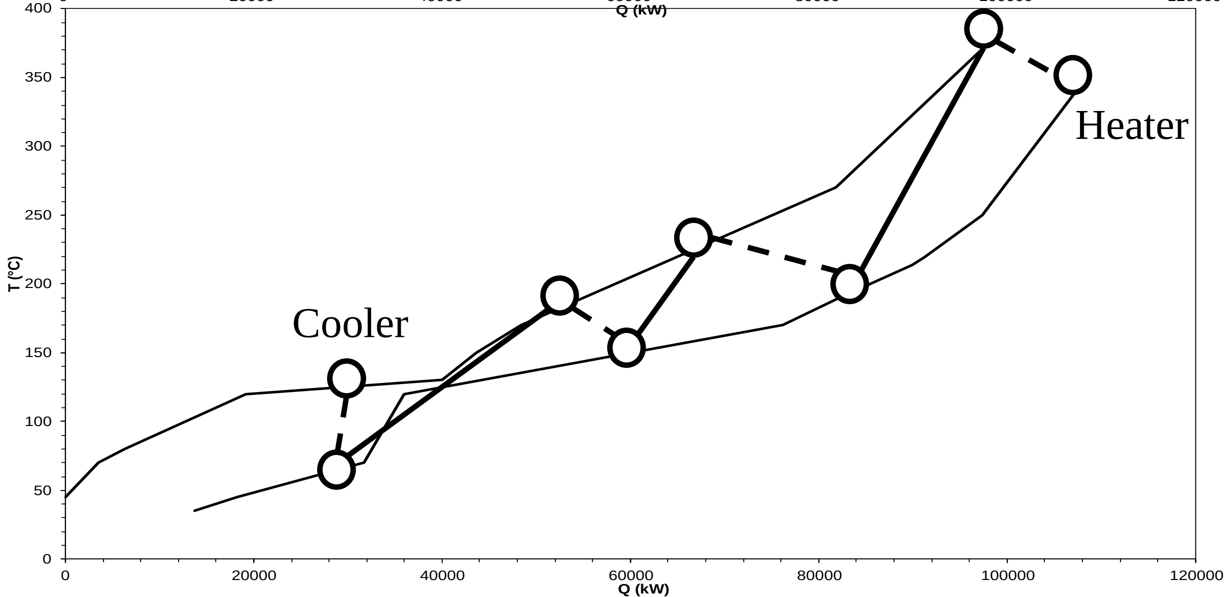
Placement of heaters and coolers
Relevance for excess heat

Releasing excess heat is – obviously – easier when coolers are placed high

- Coolers placed high and heaters placed low
  Beneficial also for internal heat recovery projects
  ⇒Competition between internal and external use of excess heat



- Coolers placed high and heaters placed high
  ⇒External use of excess heat is likely to be less complex and more cost-efficient than internal heat recovery

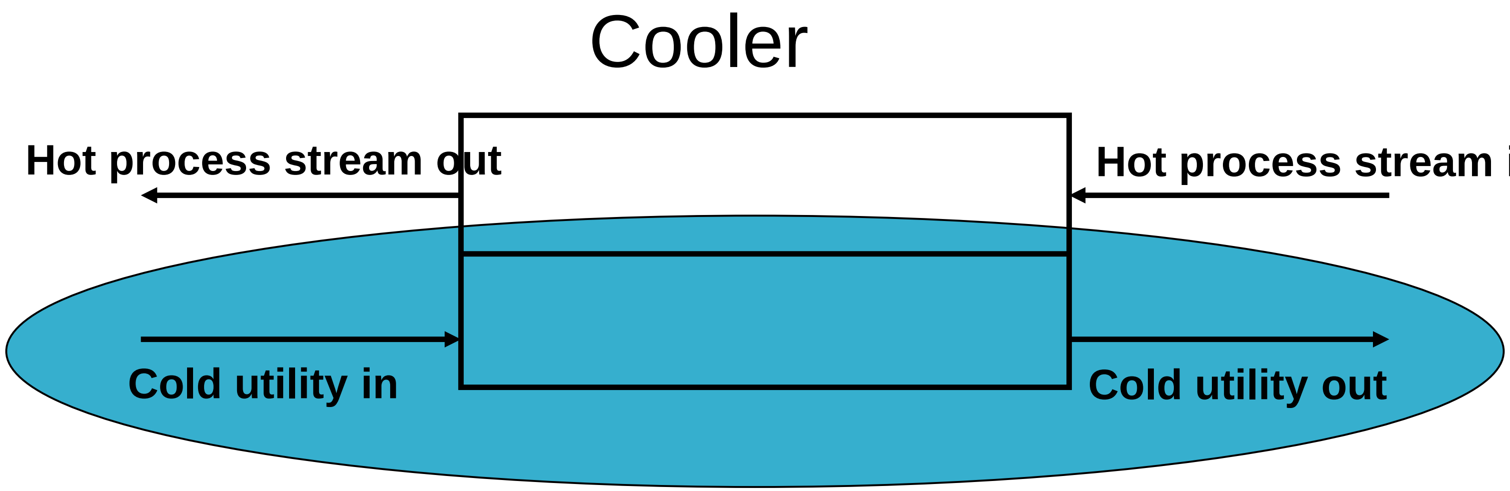


Most cost-efficient solution depends on utility price, value of excess heat and investment costs

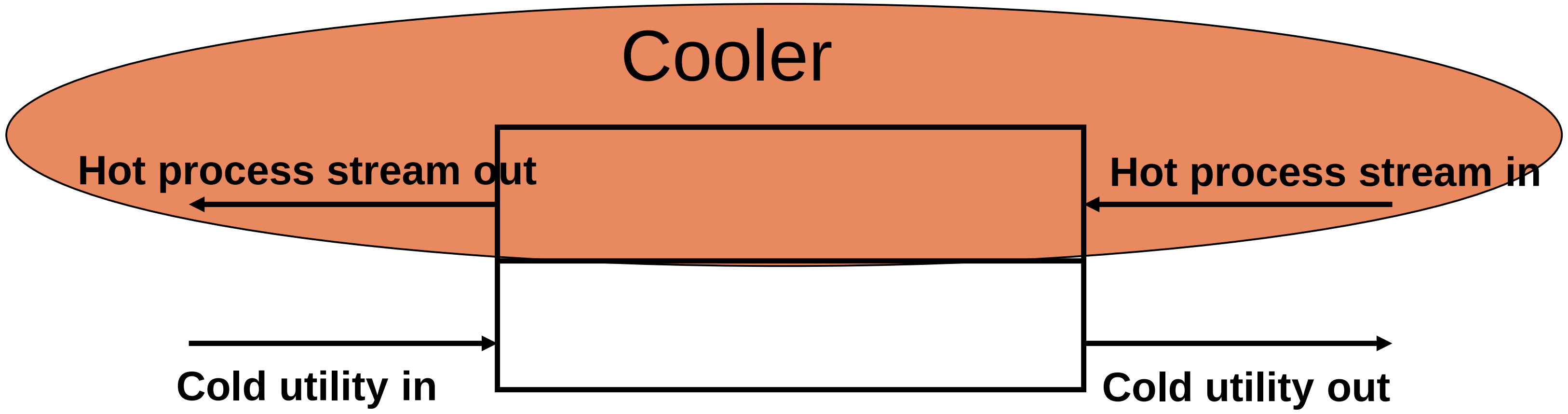
Hot and Cold Utility Curves (HUC, CUC)
Actual Heating and Cooling Load Curves (AHLC, ACLC)
Extreme Heating and Cooling Load Curves (EHLC, ECLC)

Curves representing utility heat exchangers add information about the placement of heaters and coolers in the existing network

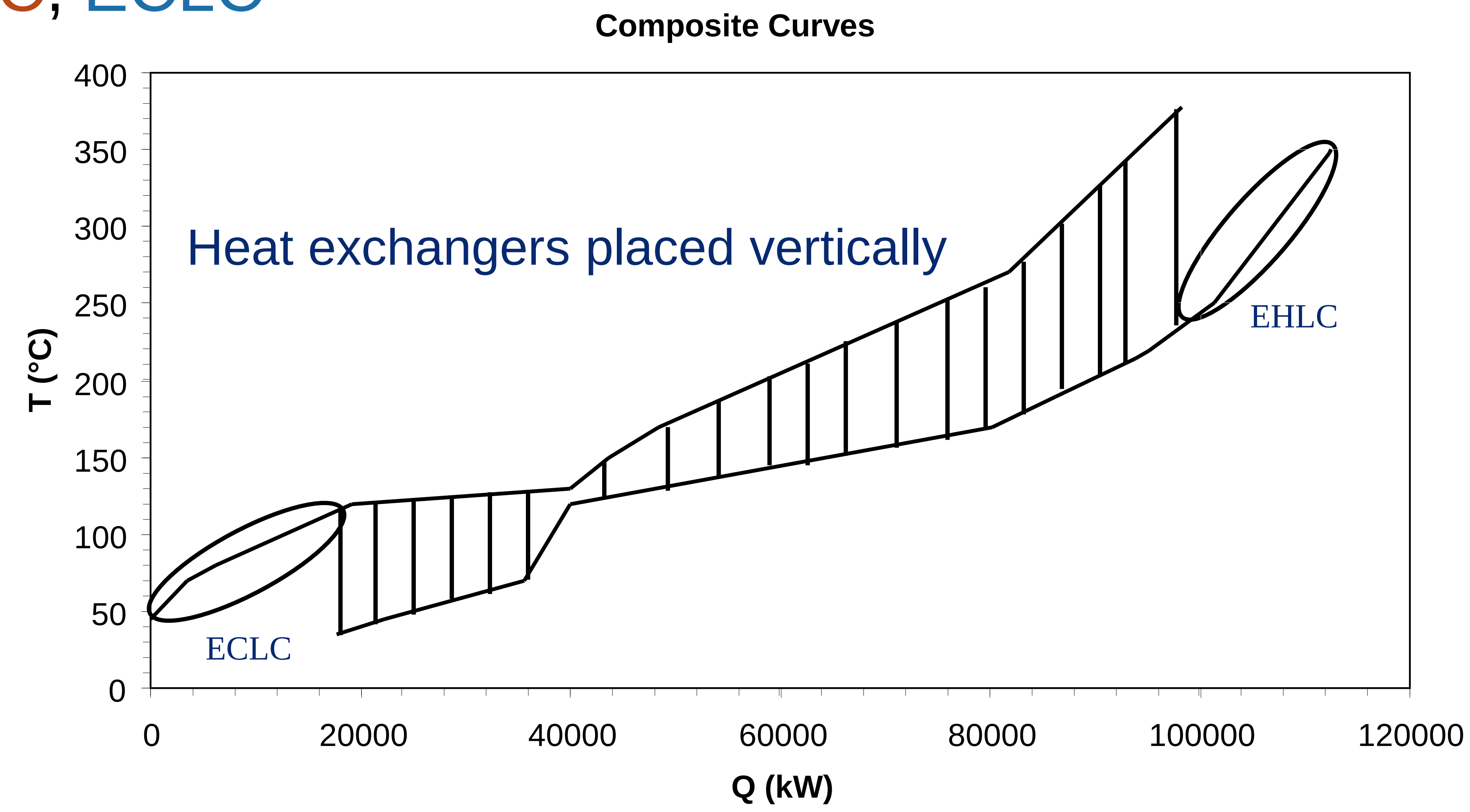
Hot and Cold Utility Curves
HUC, CUC



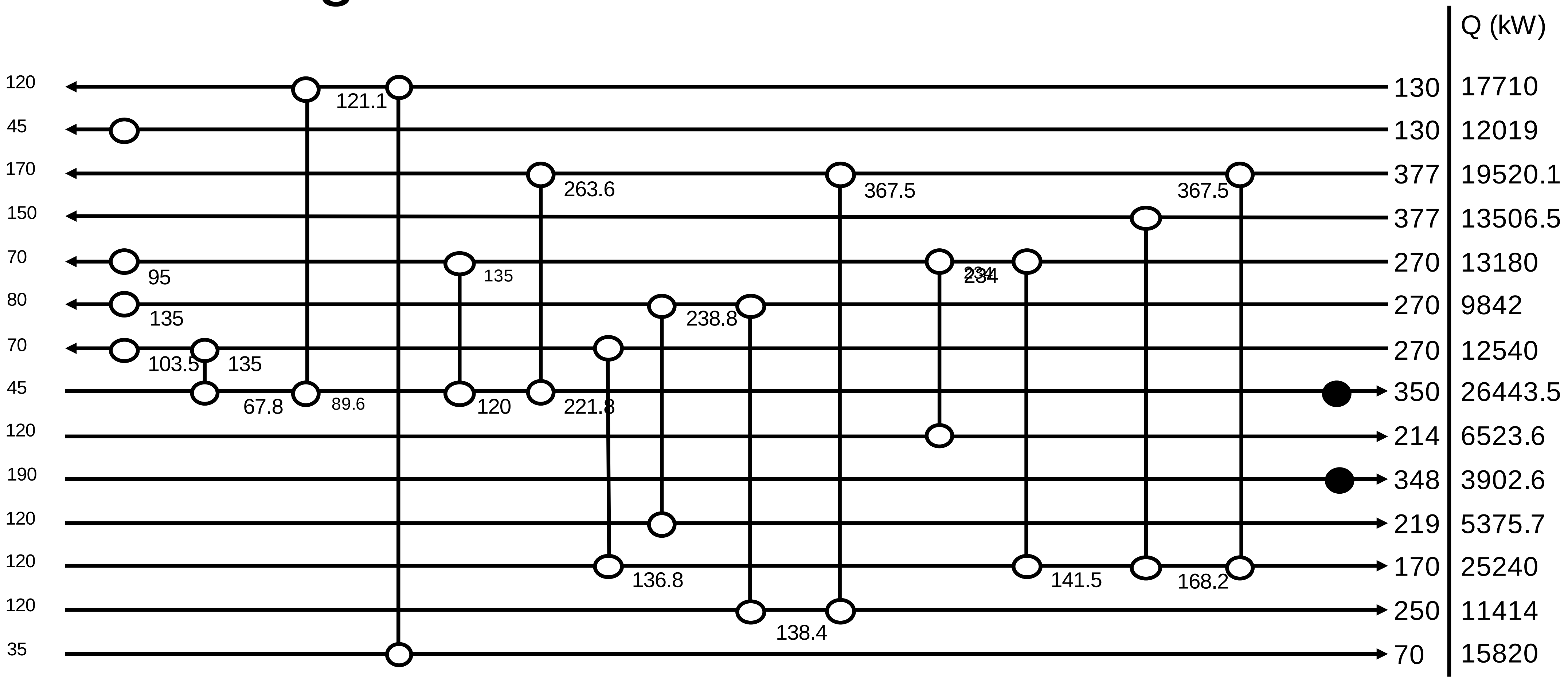
Actual Heating and Cooling Load Curves
AHLC, ACLC



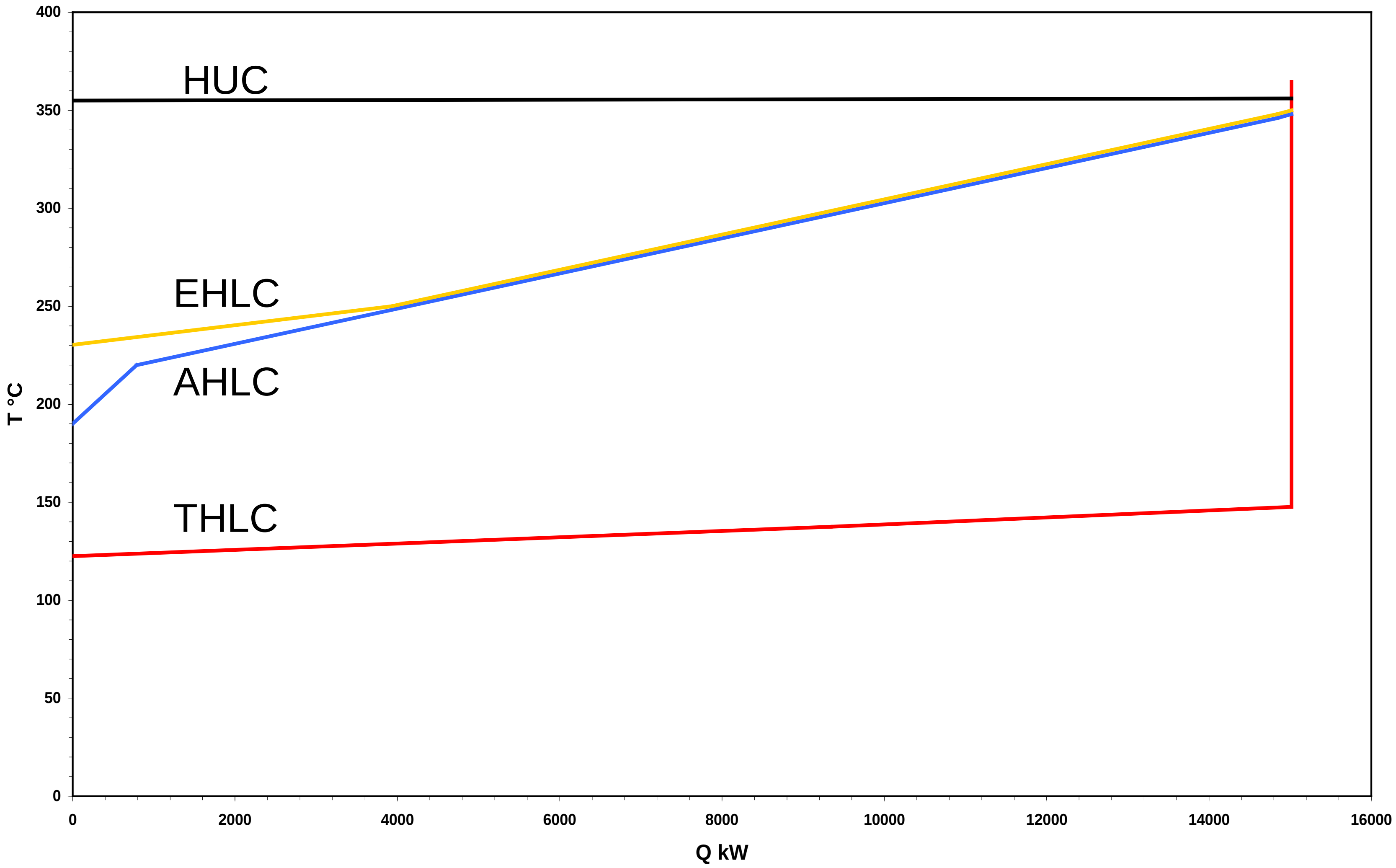
Extreme Heating and Cooling Load Curves
EHLC, ECLC



Heaters High

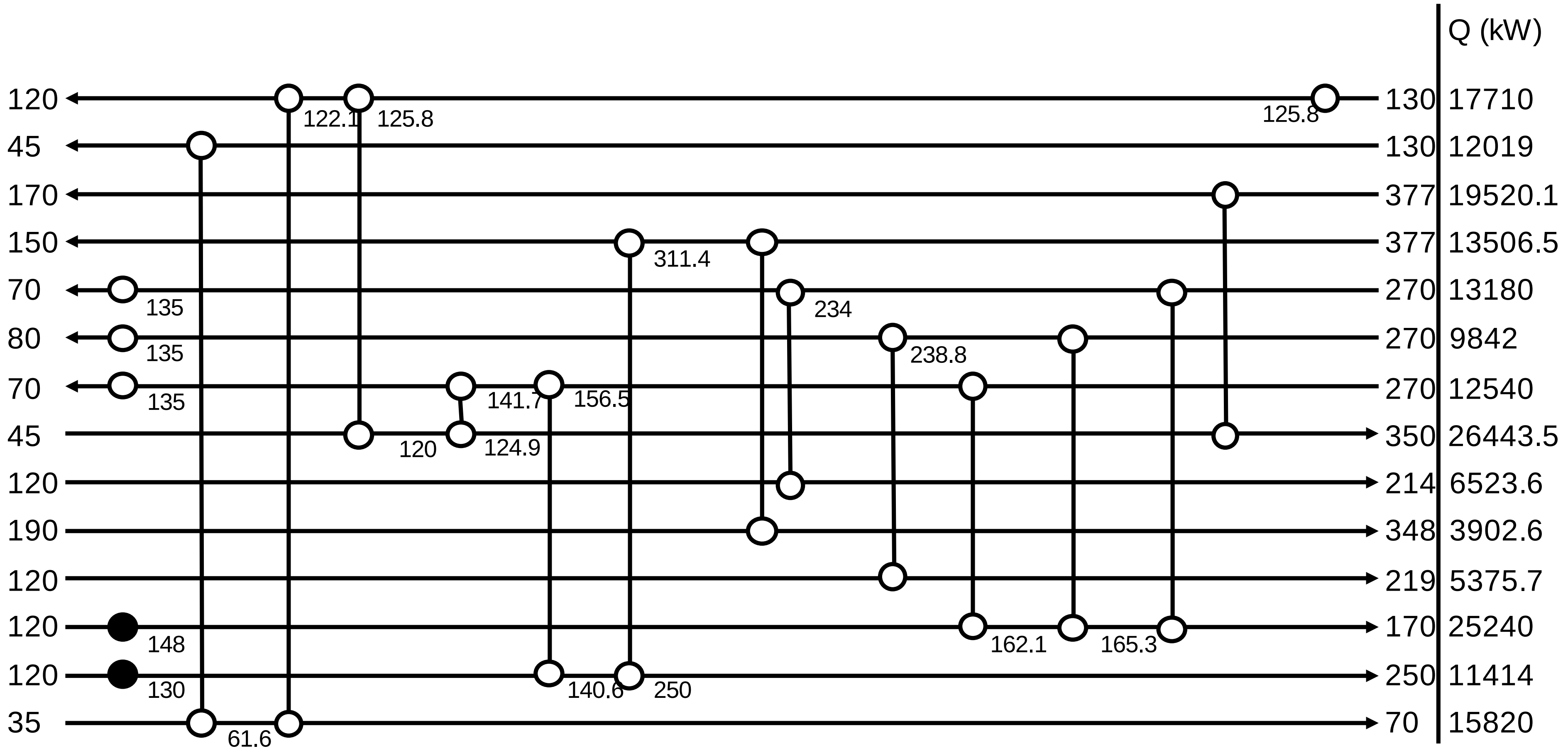


Heaters High

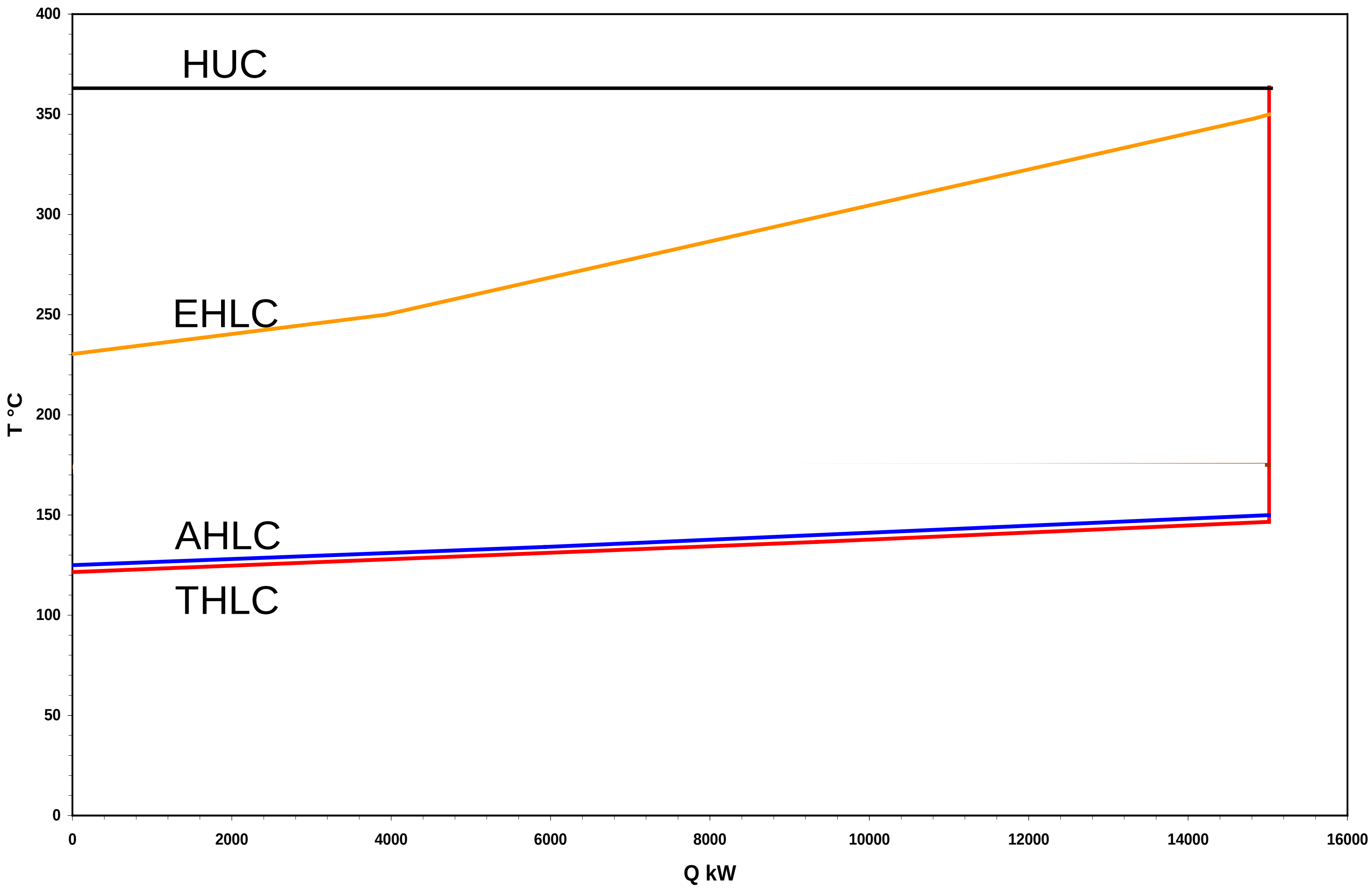


AHLC close to EHLC

Heaters Low

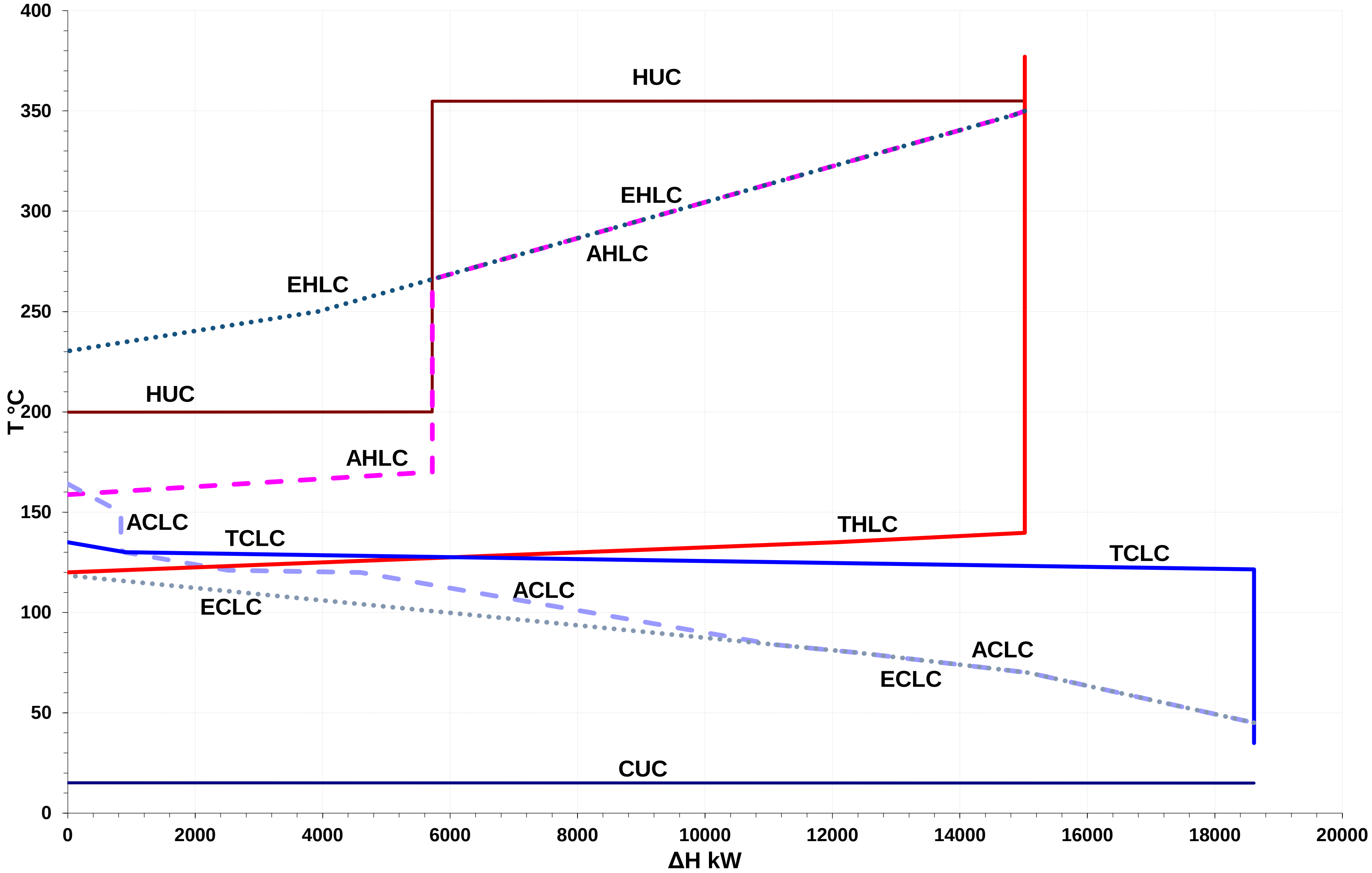

Q (kW)
120
45
170
150
70
80
70
45
120
190
120
120
120
35
130 17710
130 12019
377 19520.1
377 13506.5
270 13180
270 9842
270 12540
350 26443.5
214 6523.6
348 3902.6
219 5375.7
170 25240
250 11414
70 15820
122.1
125.8
125.8
311.4
135
234
135
238.8
135
141.7
156.5
120
124.9
148
162.1
165.3
130
140.6
250
61.6

Heaters Low



AHLC close to THLC

Example

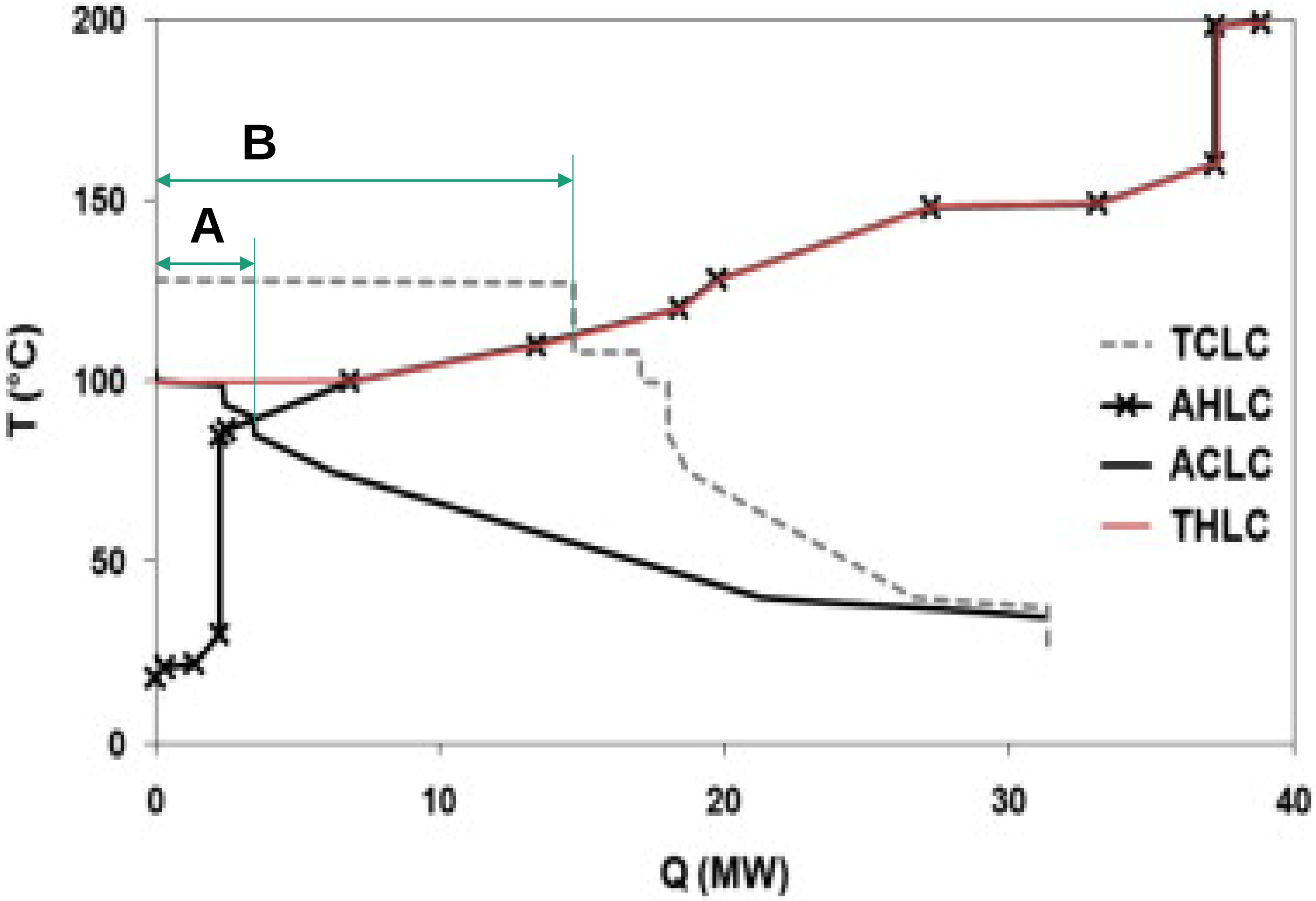


ACLC above AHLC = Coolers placed above heaters

ACLC above TCLC = Cooler above pinch

TCLC above THLC = Potential for internal heat recovery

Another example



A: ACLC above AHLC
Internal heat recovery by replacing heaters+coolers with new HXs

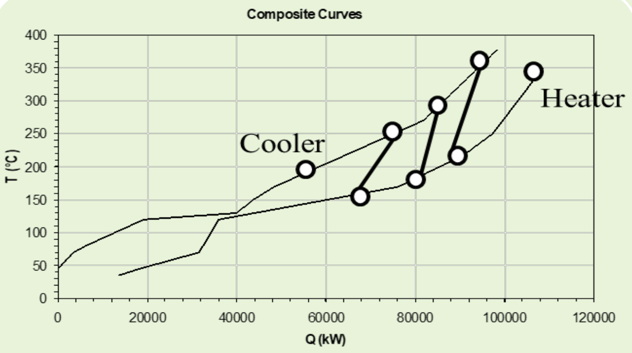
B: Full potential for internal heat recovery

Large potential for releasing excess heat at high temperature (TCLC)

But difficult retrofit (ACLC far from TCLC = Coolers placed low)

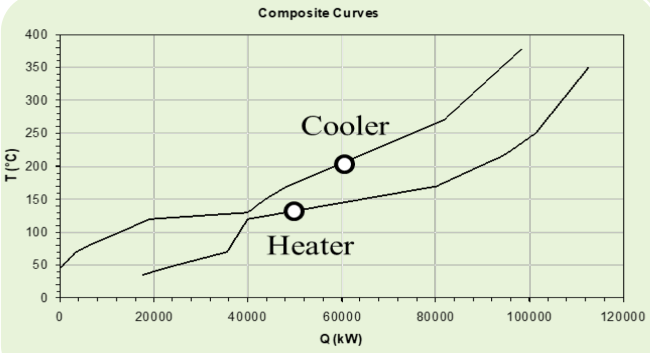
Placement of heaters and coolers
Relevance for excess heat

Releasing excess heat is easier when coolers are placed high
= ACLC close to (or even above!) TCLC (i.e. far from ECLC)



Coolers placed high and heaters placed high

- External use of excess heat is likely to be less complex and more cost-efficient than internal heat recovery
- ACLC close to TCLC and AHLC close to EHLC



Coolers placed high and heaters placed low

- Competition with internal use of excess heat
- ACLC close to TCLC and AHLC close to THLC
- Extreme case: ACLC above AHLC => Cooler+Heater can be directly replaced by HX

Applications

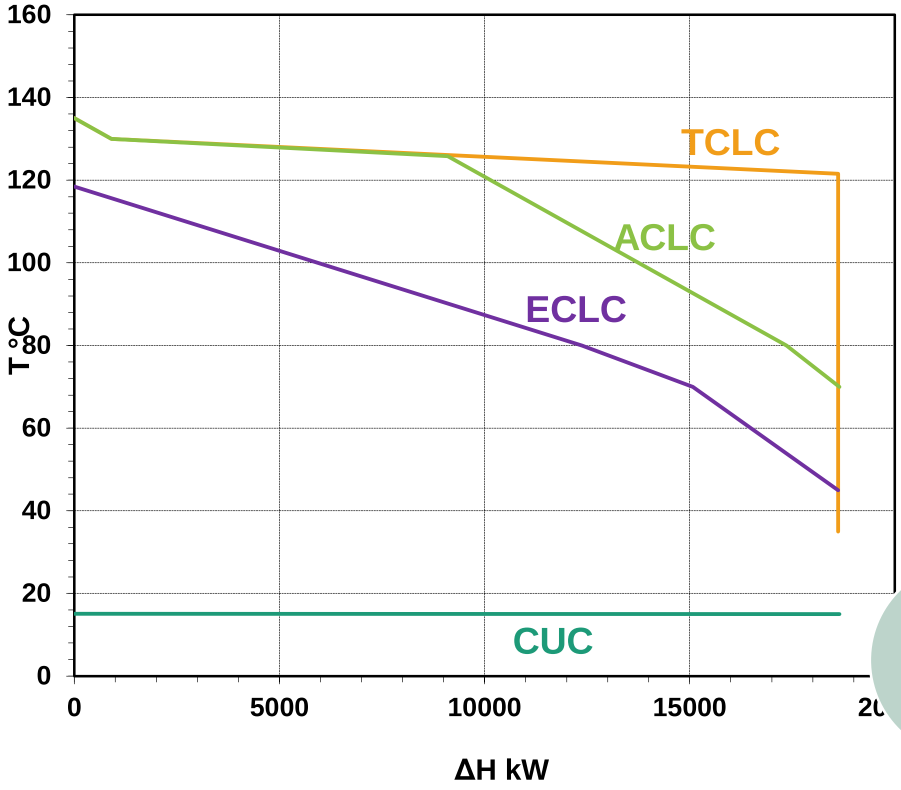
Examples of how the advanced curves can be used to analyze different options for excess heat utilization

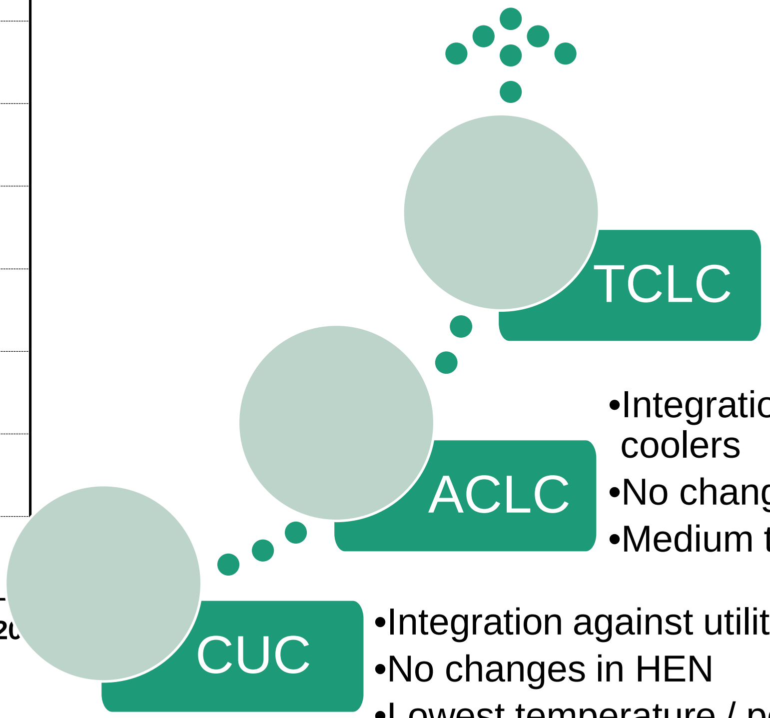
Examples of applications

- Integration of heat pumps
- External deliveries of excess heat, e.g. district heating
- Low-temperature drying

Utilization of excess heat at different levels of complexity

Utilization of excess heat can be achieved at different levels of complexity corresponding to integration against different curves





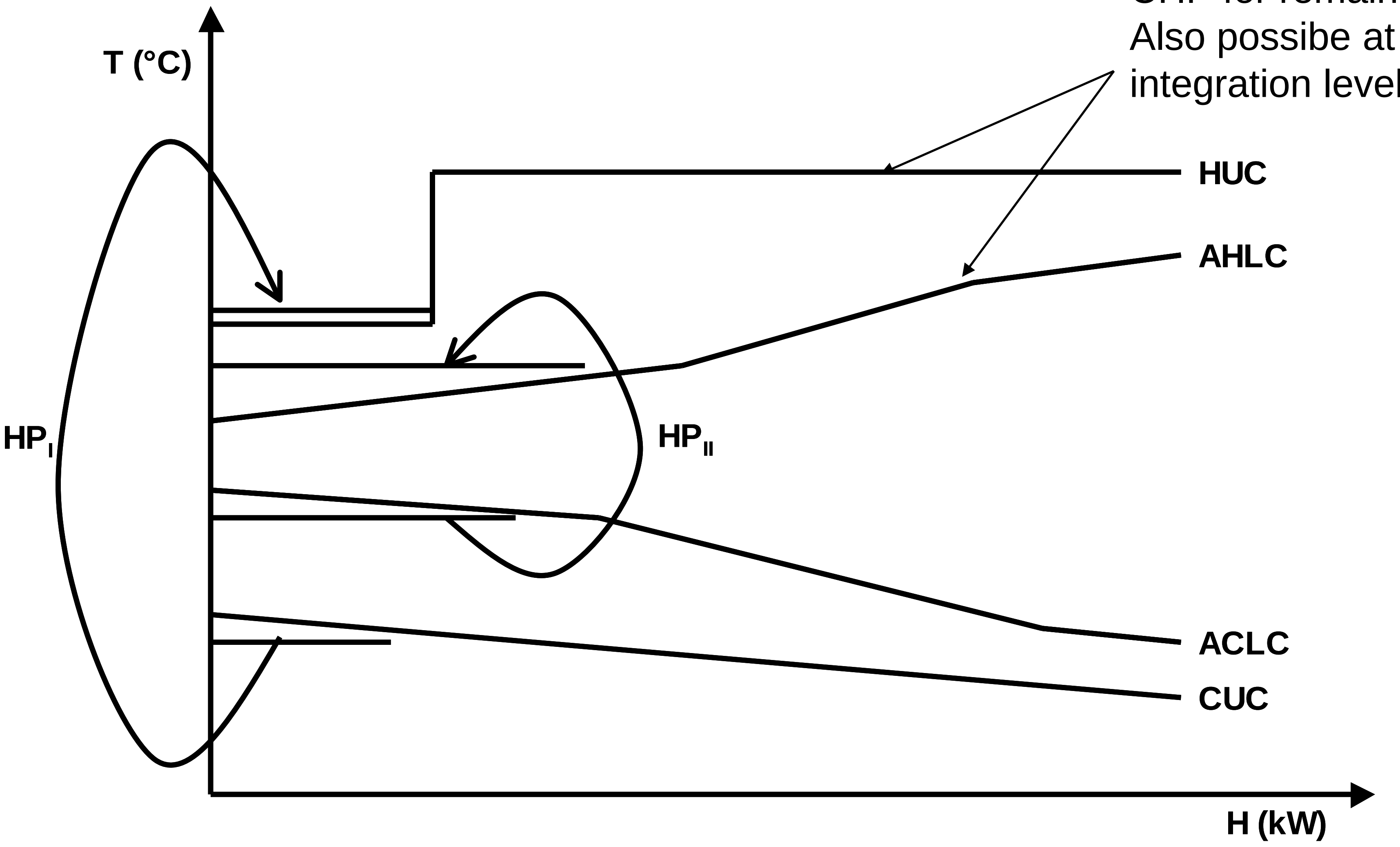
- Integration against any process stream
- Changes in HEN needed (Complexity depend on placement of ACLC relative to TCLC/ECLC)
- Highest temperature / potential

- Integration against process streams in existing coolers
- No changes in process HX
- Medium temperature / potential

- Integration against utility only
- No changes in HEN
- Lowest temperature / potential

Potential as function of complexity
Example: Integration of heat pump

CHP for remaining heat demand
Also possibe at different
integration levels



Summary

The curves

HUC/CUC	Hot/Cold Utility Curve	Composite curves consisting of utility streams in heaters/coolers
AHLC/ACLC	Actual Heating/Cooling Load Curve	Composite curves consisting of process streams in heaters/coolers
THLC/TCLC	Theoretical Heating/Cooling Load Curve	This composite curve shows the theoretically lowest levels at which utility can be supplied, at a certain heat demand. The curve is constructed from the process streams in the heat exchanger network
EHLC/ECLC	Extreme Heating/Cooling Load Curve	This curve represents the composite of heat demand, when vertical heat exchange is used within the HEN, i.e. when minimum area is installed

Benefits of advanced composite curves

- Visualizes the ”theoretical” highest and lowest levels of heating/cooling for a given system
- Illustrates the utility temperature levels used in the network
- Provides information about where existing heaters and coolers are placed in relation to these temperature extremes