# IDRIST – Temporal pinch-point analysis for energy demand reduction in batch production

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# Content

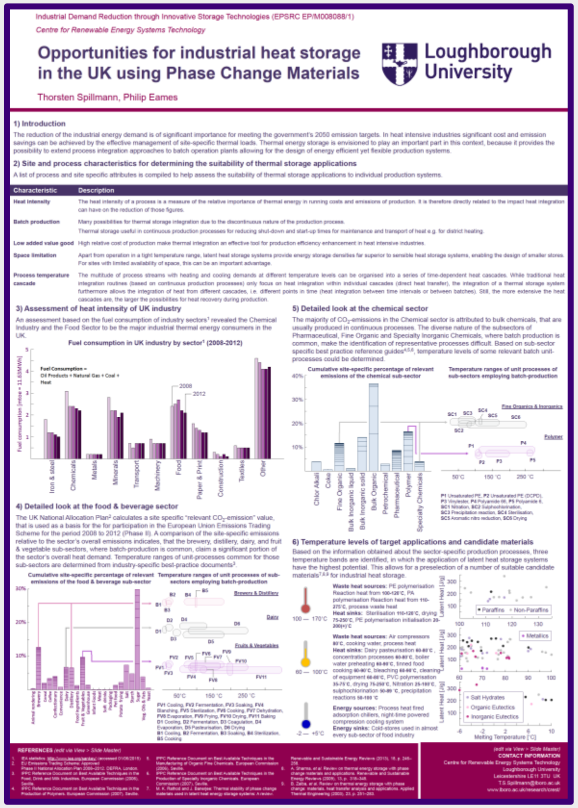
- Introduction to IDRIST project
- Importance of pinch-methodology for energy demand reduction
- Challenges of thermal integration in batch processes
- Summary of approach taken
- Outlook

# IDRIST Project Phases

***Poster presented at 2015 UKES Conference***

**Industrial Demand Reduction through Innovative Storage Technologies**

1. Market Potential Assessment
    1. Identify industry needs and market potential
2. Investigation of Integrated PCM thermal storage systems
    1. Identify and characterise candidate PCMs
    2. Design laboratory tests and simulation
    3. Experimental evaluation & model validation
    4. System modelling for industrial applications
3. Investigation of Thermo-chemical heat storage and transformation
    1. Short list salt-refrigerant working pairs using ideal thermodynamics
4. Whole systems modelling
    1. Business models, techno-economic assessments
    2. Whole system performance modelling




*online at: http://i-stute.org/*

# Pinch methodology for energy demand reduction (1)

- Pinch Analysis is a discipline of Process Integration, which emphasises on the *“efficient use of energy and reducing environmental effects“* ***(IEA)*****.**

- Developed for heat recovery in continuous production processes, but also used in other areas (e.g. waste water minimisation, hydrogen distribution in oil refineries)

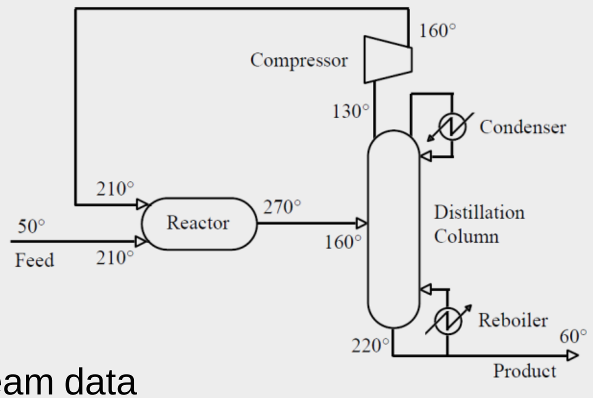
- Central Aspect is the identification of the point of smallest driving force for network integration

- Pinch Concept: Establishment of performance targets before design

- 4-Phase Approach:

# Pinch methodology for energy demand reduction (2)

Block diagram




- Necessary stream data from energy audit:
  - Mass flow rate
  - Specific heat capacity
  - Supply & Target temperatures
  - Start and stop times
  - Heat of vaporisation
- Decision if heat integration of certain units is not desired
  - Costly piping
  - Safety, product purity
  - operability

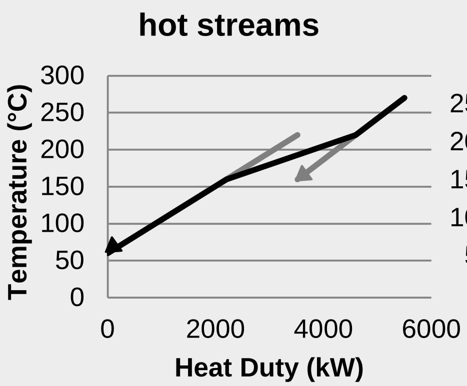
Stream data

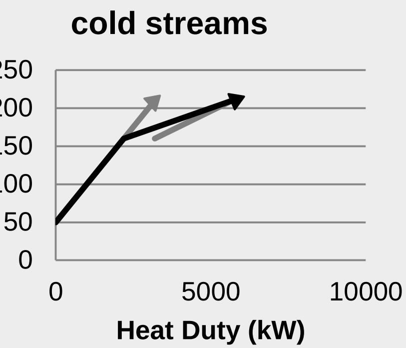
| Stream | ID | $T_s$(°C) | $T_t$(°C) | $T^*_s$(°C) | $T^*_t$(°C) | MCp(kW/°C) | ΔQ(kW) | $\Delta T_{min}$(°C) |
|---|---|---|---|---|---|---|---|---|
| Reactor Outlet | H1 | 270 | 160 | 280 | 170 | 18 | 1980 | 20 |
| Product | H2 | 220 | 60 | 230 | 70 | 22 | 3520 | |
| Feed | C1 | 50 | 210 | 40 | 200 | 20 | 3200 | |
| Recycle | C2 | 160 | 210 | 150 | 200 | 50 | 2500 | |

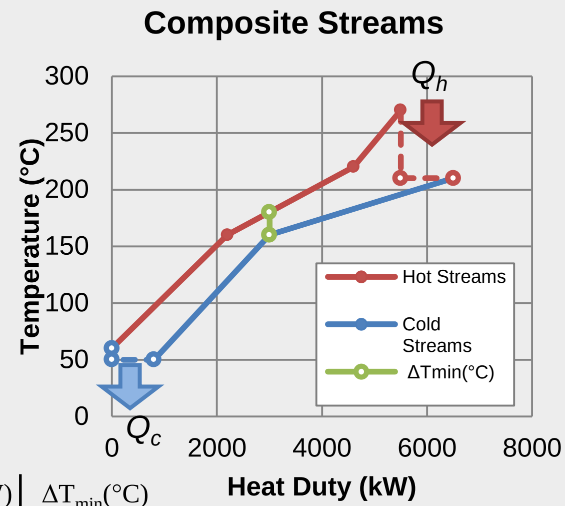
- 4-Phase Approach:

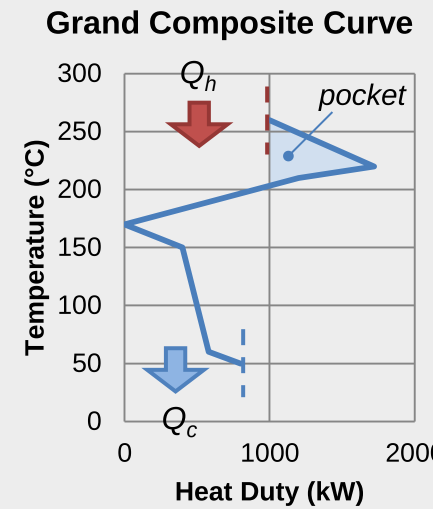
**Data Collection** → Performance Targeting → Network Design → Network Optimisation

# Pinch methodology for energy demand reduction (3)




<u>Stream data</u>

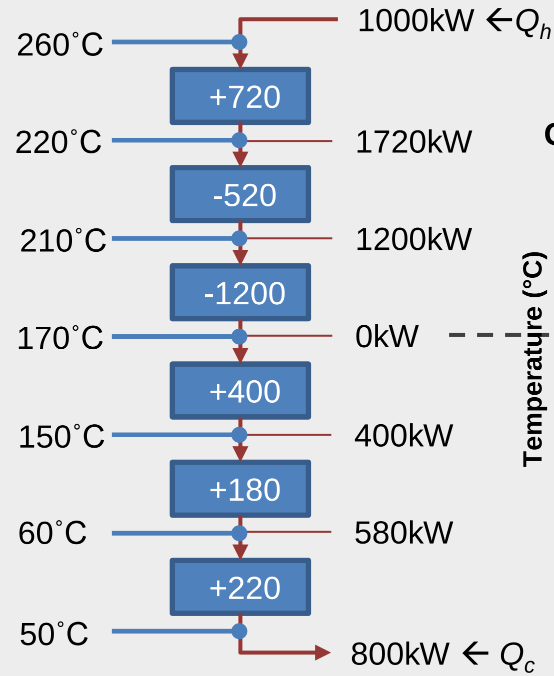
| Stream | ID | $T_s$(°C) | $T_t$(°C) | $T^*_s$(°C) | $T^*_t$(°C) | MCp(kW/°C) | ΔQ(kW) | $\Delta T_{min}$(°C) |
|---|---|---|---|---|---|---|---|---|
| Reactor Outlet | H1 | 270 | 160 | 250 | 140 | 18 | 1980 | 20 |
| Product | H2 | 220 | 60 | 210 | 40 | 22 | 3520 | |
| Feed | C1 | 50 | 210 | 70 | 230 | 20 | 3200 | |
| Recycle | C2 | 160 | 210 | 180 | 230 | 50 | 2500 | |

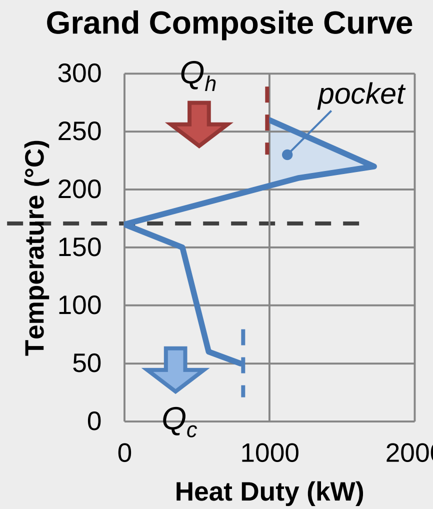
- 4-Phase Approach:

Data Collection → **Performance Targeting** → Network Design → Network Optimisation

# Pinch methodology for energy demand reduction (3)

- Streams are grouped together into subnetworks based on their temperatures
- A minimum $\Delta T_{min}$ for heat exchange is defined that represents the physical constraint to heat transfer and is related to heat exchanger surface area and costs.
- The pinch point represents the location in the network, where the driving force for heat transfer is minimal



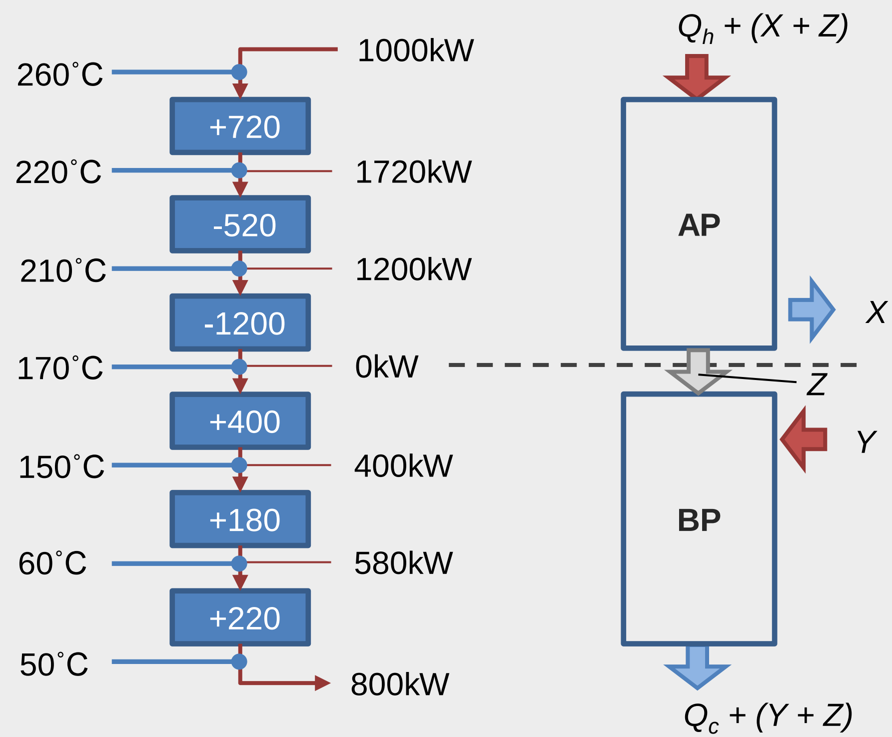




- 4-Phase Approach:

Data Collection → **Performance Targeting** → Network Design → Network Optimisation

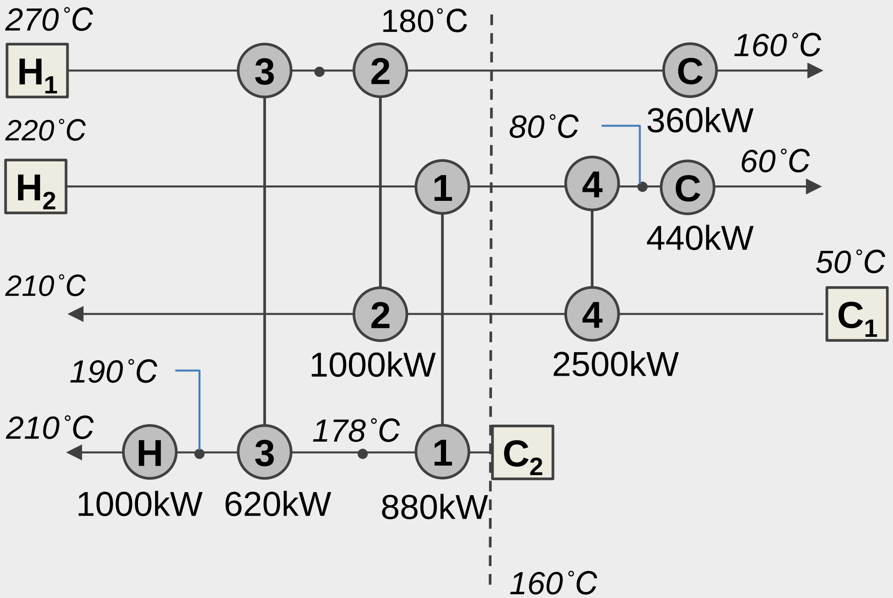
# Pinch methodology for energy demand reduction (3)

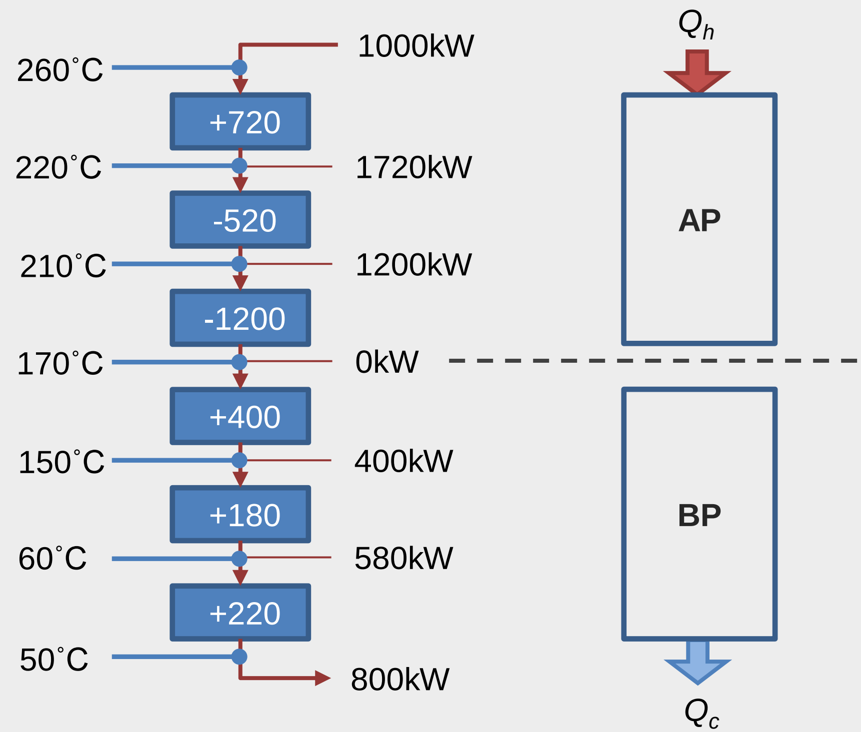
- The pinch divides the network into a high temperature region, that only requires hot utility supply, and a low temperature region, that only requires cold utility.
- Heat transfer between the two regions results in increased utility demands.
- This means that subnetworks for the two regions can be designed independently from one another
- Pockets of the Grand Composite Curve represent internal heat transfer between subnetworks
  - 4-Phase Approach:




Data Collection → **Performance Targeting** → Network Design → Network Optimisation

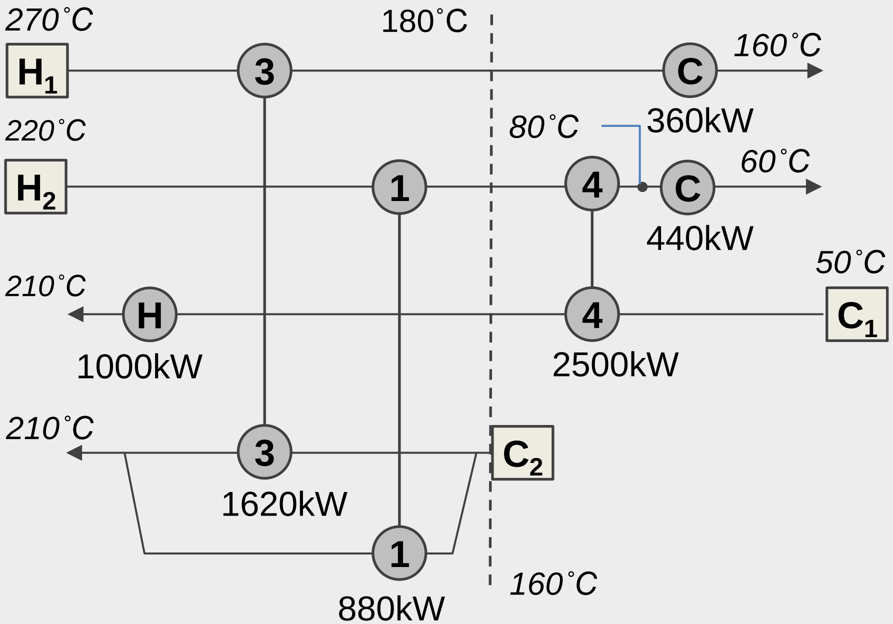
# Pinch methodology for energy demand reduction (4)

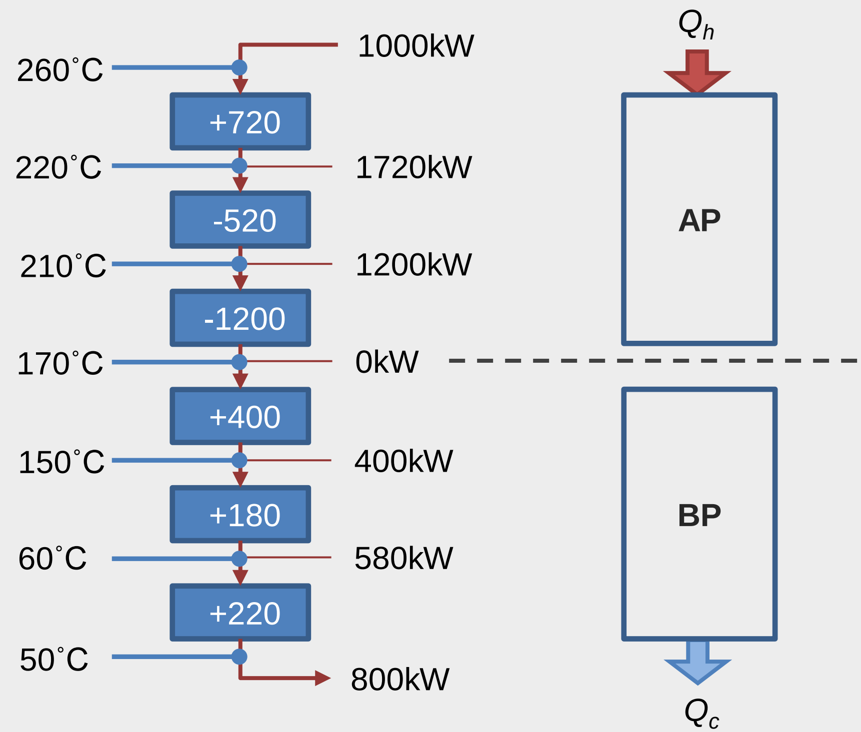



- 4-Phase Approach:

# Pinch methodology for energy demand reduction (5)

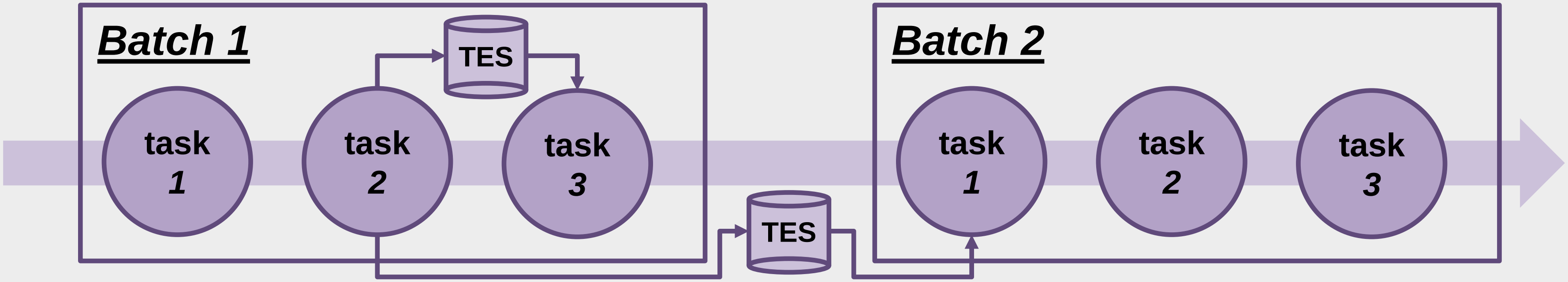



- 4-Phase Approach:

# Thermal integration in batch processes

- Process Integration becomes more complex with the time-dependence of process streams, i.e. heat transfer possibilities are now constrained not only by temperature, but also by time
- Heat exchange can occur direct, when processes occur at the same time, or indirect when heat is exchanged with a storage medium to be used at a later point in time
- Limited implementation due to lack of established methods and design tools. Approaches suggested in literature differ according to simplifying assumption made and degree of complexity
- Two types of thermal integration: within batches, between batches

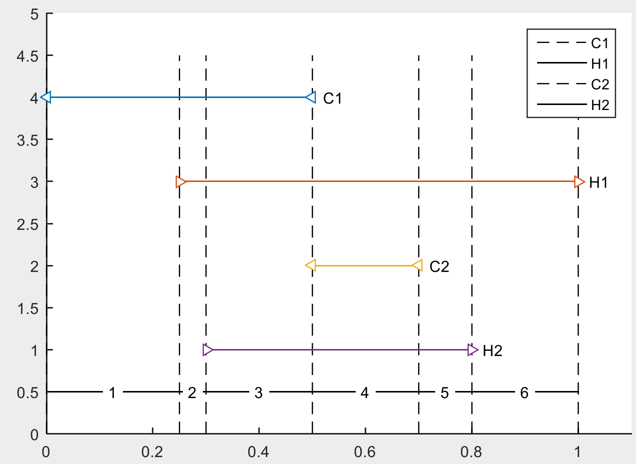


# Approach taken (1)

- Division of time horizon into intervals with pseudo-continuous streams
- Composition of interval specific heat cascades identifying utility demand reduction through direct heat integration (within individual intervals).
- Composition of modified heat cascades identifying further reductions in utility requirements due to indirect heat integration (between intervals).
- Initial Heat Exchange Network Design based on Pinch Design Method

**Literature Example: Chaturvedi (2014)**

| Name | $T_{supply}$ | $T_{target}$ | MCp | $t_{start}$ | $t_{stop}$ | $\Delta T_{min}$ |
|---|---|---|---|---|---|---|
| C1 | 80 | 140 | 8 | 0 | 0.5 | 10 |
| H1 | 170 | 60 | 4 | 0.25 | 1 | 10 |
| C2 | 20 | 135 | 10 | 0.5 | 0.7 | 10 |
| H2 | 150 | 30 | 3 | 0.3 | 0.8 | 10 |



# Approach taken (2)

**Direct Heat Transfer**

Divide streams into time slices

↓

Use conventional pinch methodology (PTA) to calculate utility targets

**Indirect Heat Transfer**

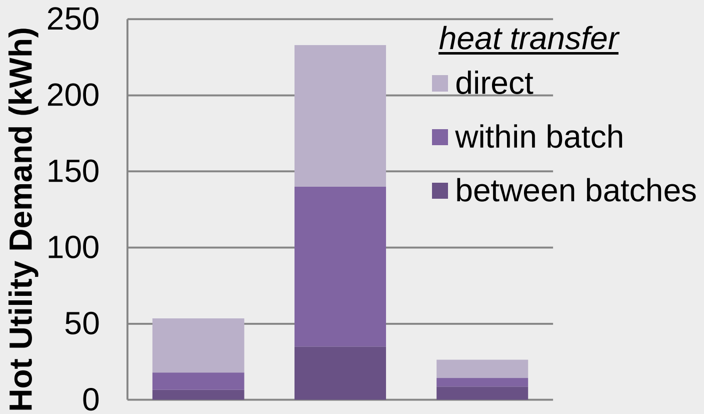
Modify GCC to determine thermal energy available for integration with subsequent intervals

↓

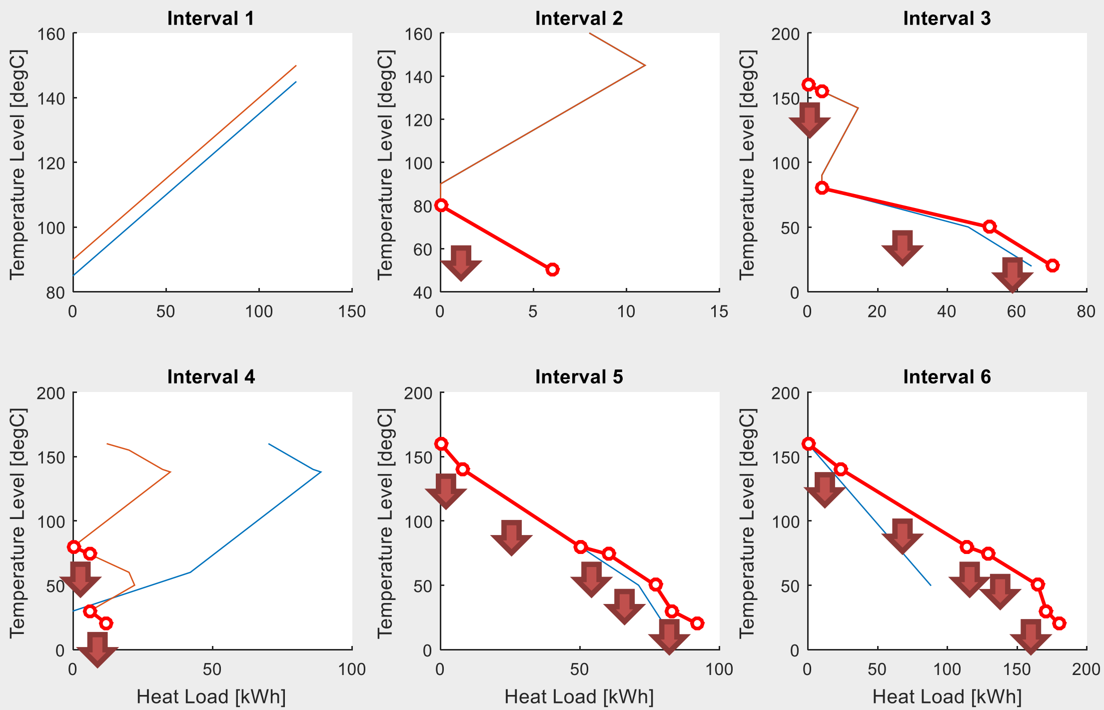
Repeat Integration Procedure for subsequent interval with shifted temperatures including pseudo hot streams

= *heat available from subnetworks for integration with subsequent intervals*

## Results for 3 example cases




## Grand Composite Curves



# Outlook

- Complete Computerised Initial Network Design Method
- Adapt targeting routine to represent different thermal store/ heat exchanger designs
- Utilise routine on further example cases from literature and industry

# THANK YOU!