AHUORA
Centre for Smart Energy Systems

Efficient Industrial Process Electrification Through Integrated Heat Pumping

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THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Overview

1. The Ahuora mission and team
2. Efficient process electrification methodology
3. Application to a milk evaporator case study – *valuable collaboration/input from Tetra Pak, Fonterra, and Piller*
4. Ways forward together for university and industry

Ahuora Mission

To help create **sustainable, net-zero-carbon** New Zealand industries that sit in harmony with **taiao** (the environment) and support **tāngata** (the people).

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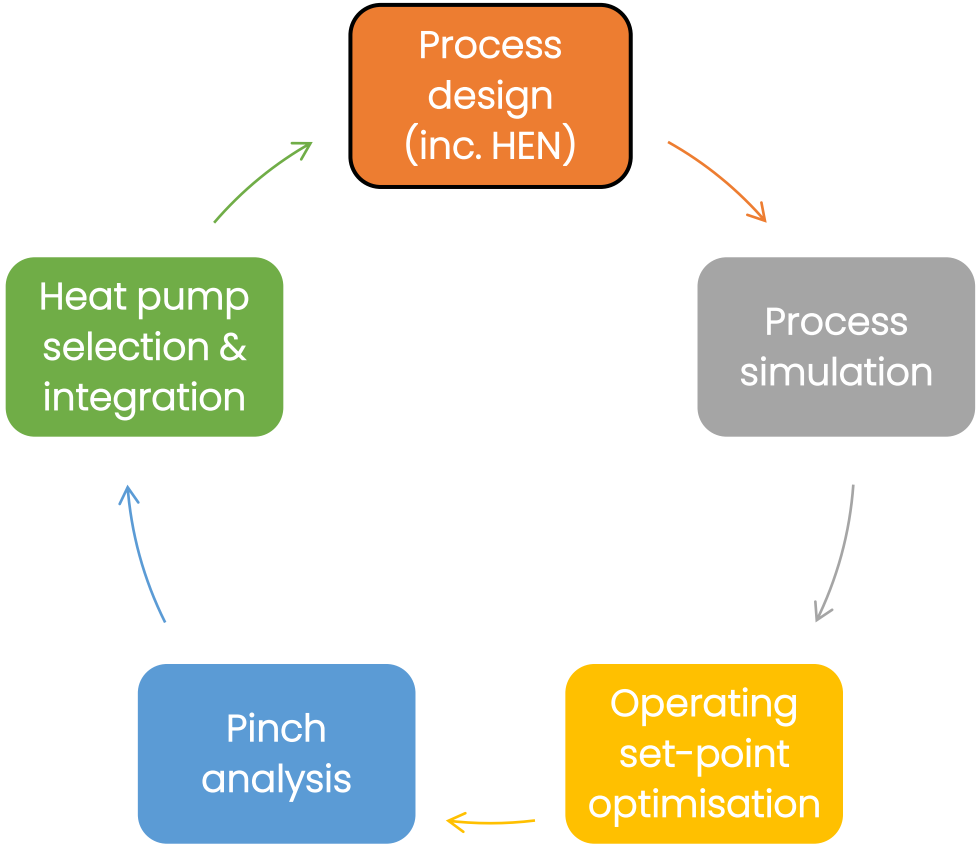
Efficient process electrification methodology



Case study goals & considerations

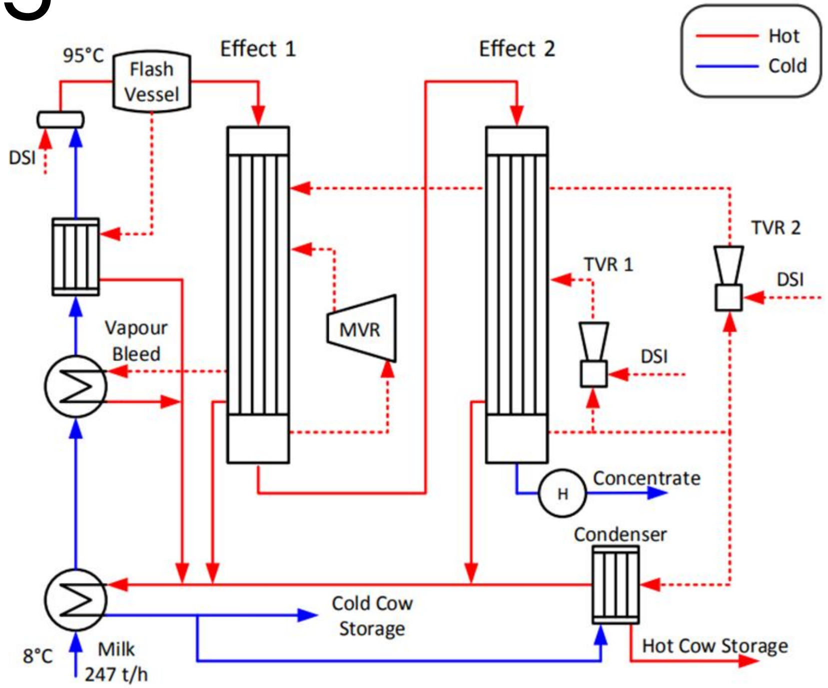
- Goal & scope: develop fully electric milk evaporator system
  - Minimise electricity use within practical constraints
  - Results in process electrification and decarbonisation
  - Initial focus on thermal processing, RO considered later
- Boundary conditions: 14.5 wt% to 52 wt% milk solids, supplies 30t/h powder dryer, milk enters at 8°C, concentrate leaves at 79°C
- Ideal solution characteristics: Localised, efficient, proven, and practical*

Practical considerations

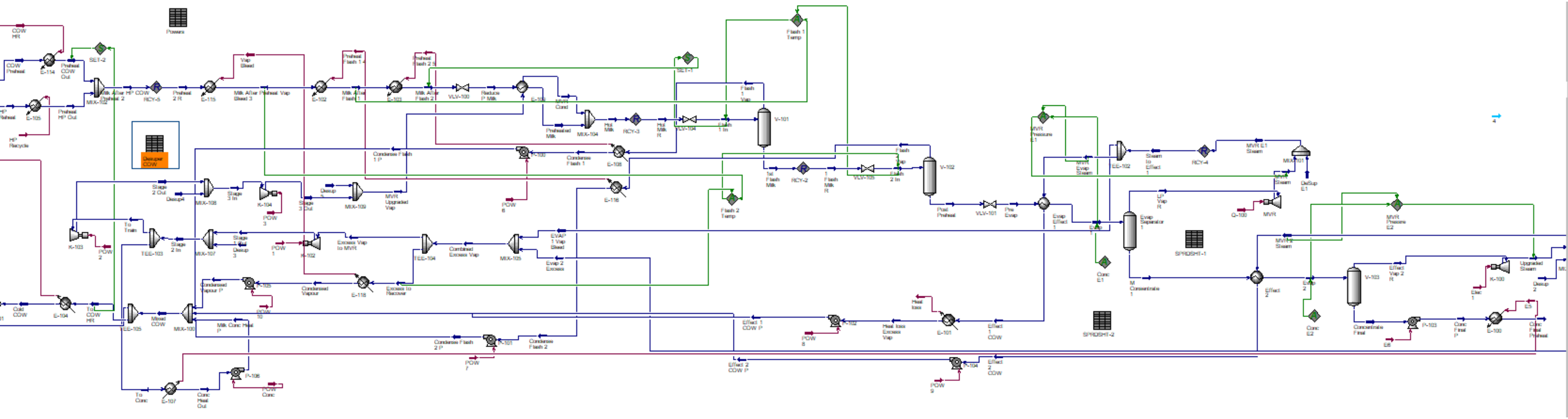
- **Product safety:** No direct heat exchange between synthetic refrigerants and milk flows
- **Product quality:** Achieve high heating rates (e.g., direct contact heating) or parallel heat exchange
- **Operability and control:** Use localised heat integration and heat pumps
- **Operating cost:** Set constraints and optimise operating set-points to minimise work

1. Initial process design

- Two-effect evaporator
- MVR on the first effect
- TVR finisher
- Basis: 30 t/h of powder
- About 30kW/t heat loss



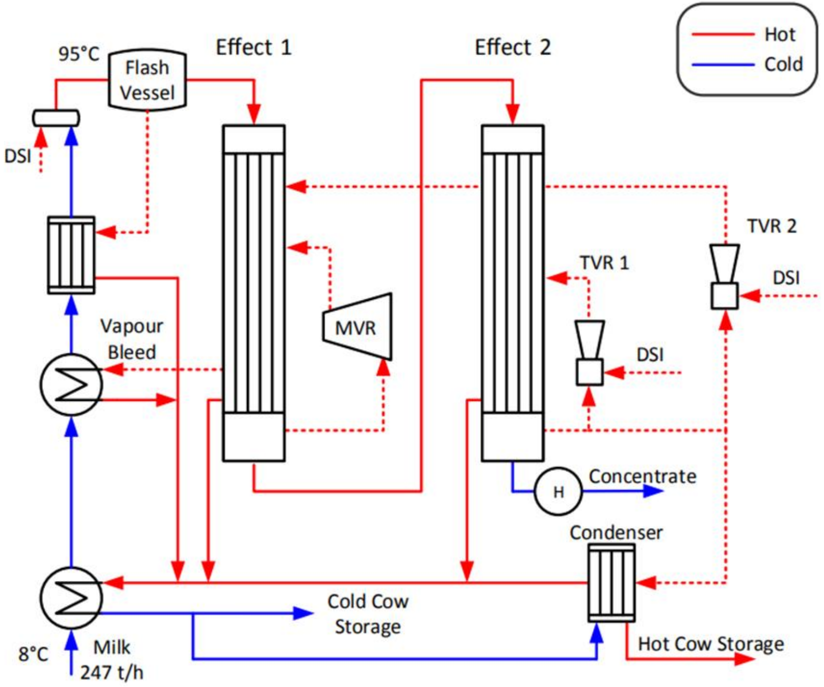
2. Process simulation



3. Operating set-point optimisation

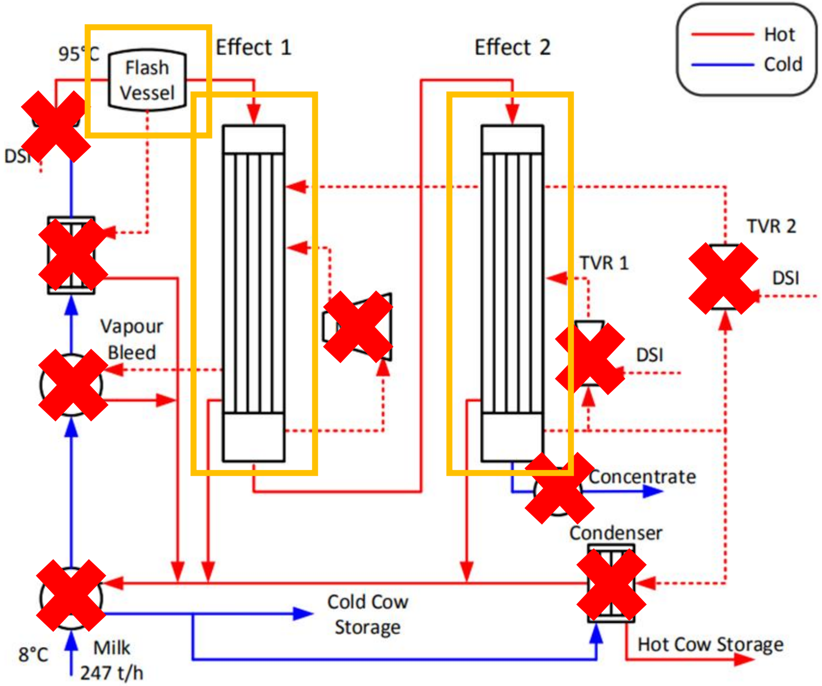
- Can we optimise the operating pressures of:
    - milk flash ?
    - effect 1 ?
    - effect 2 ?
- What effect does 95ºC milk heat treatment T have on energy use?

Caution: need to ensure consistent boundary conditions



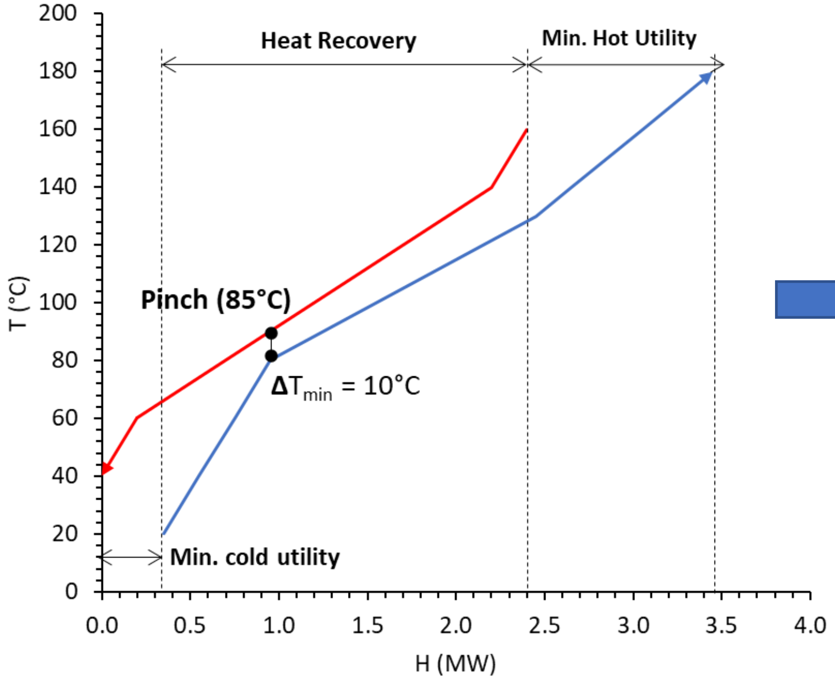
4. Pinch analysis: stream data

- Identify key processing elements of the flowsheet: Effects 1 and 2, flash
- “Remove” existing heat exchangers and other integration (e.g., TVR ejectors)
- Identify “supply” and “target” temperatures with heat added (sink) or removed (source)



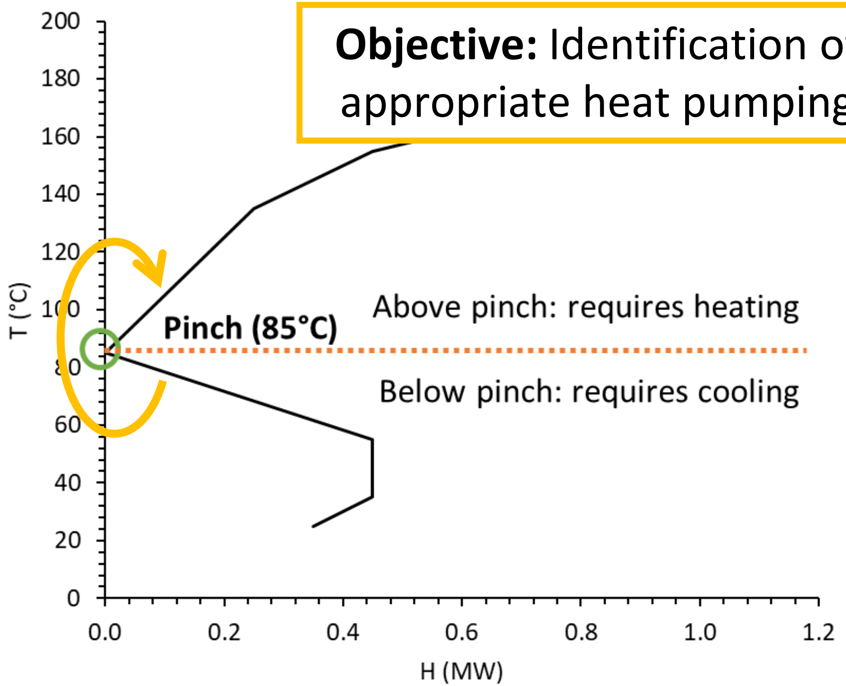
4. Pinch Analysis: targeting (example)

Composite curve:

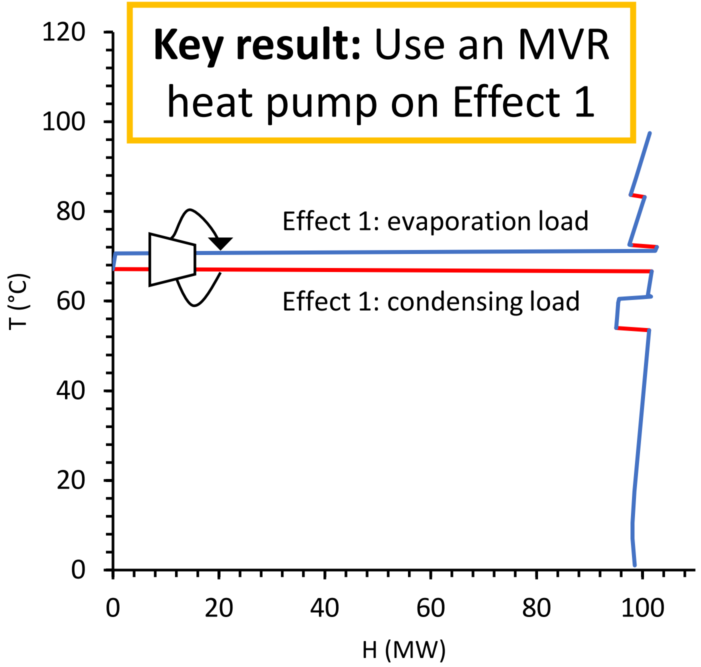


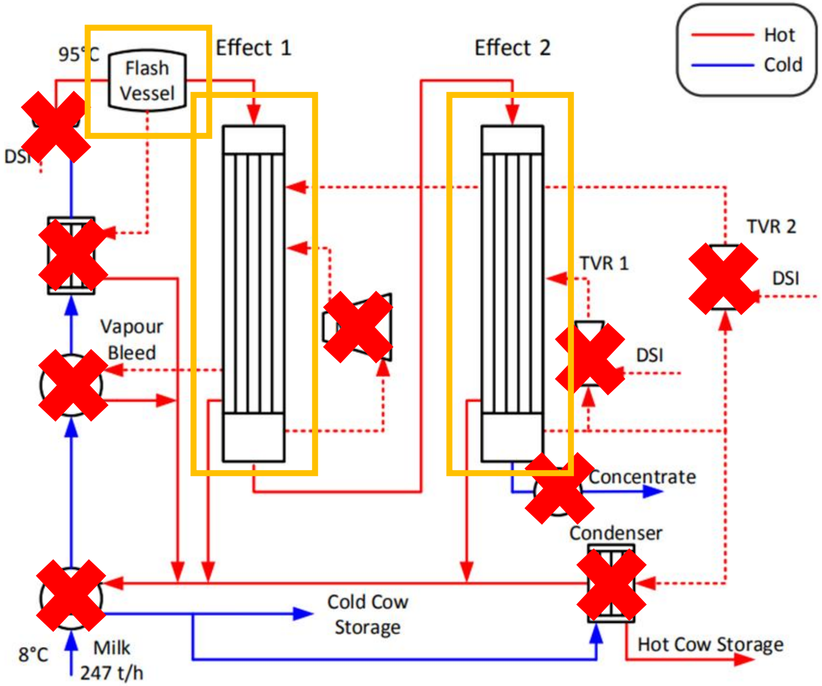
Grand Composite curve:

Objective: Identification of appropriate heat pumping



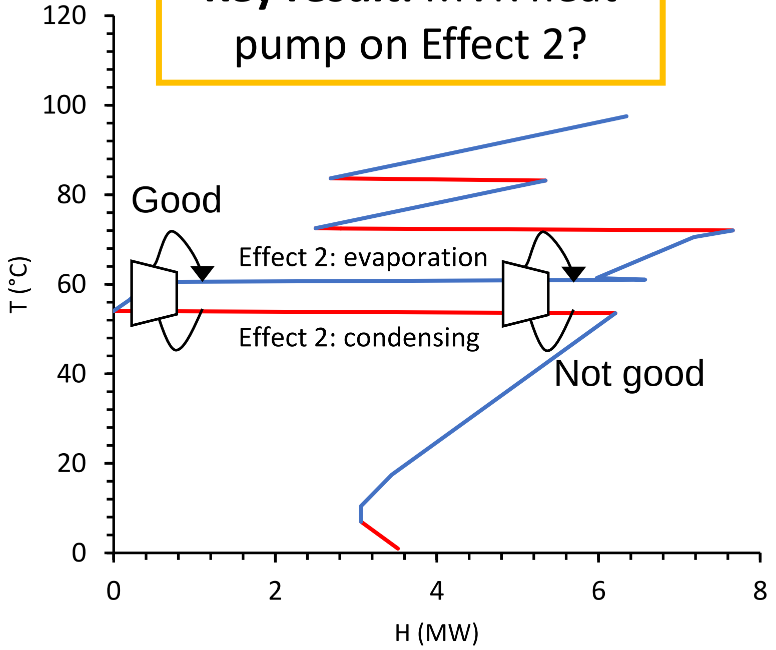
4. Pinch analysis: iteration 1

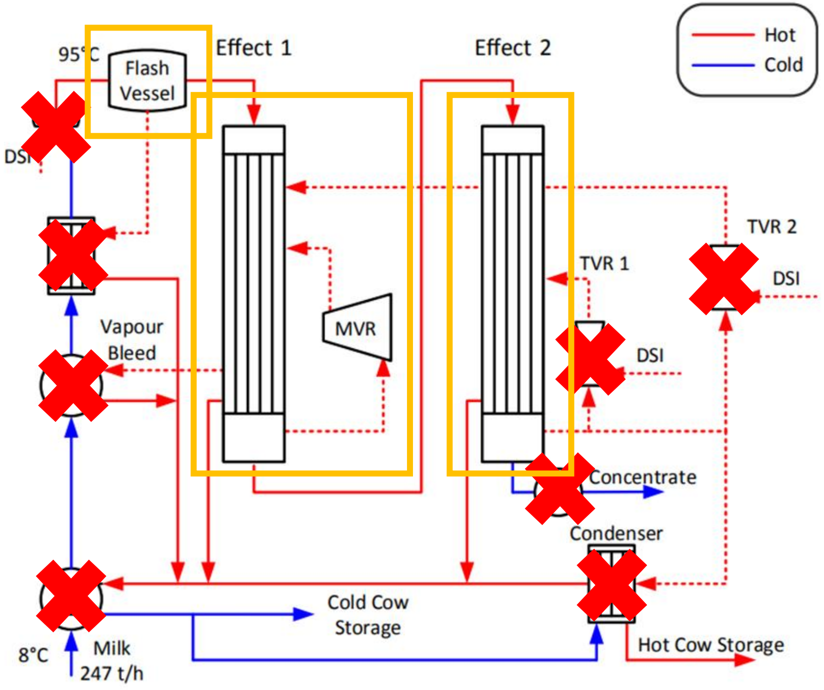




4. Pinch analysis: iteration 2

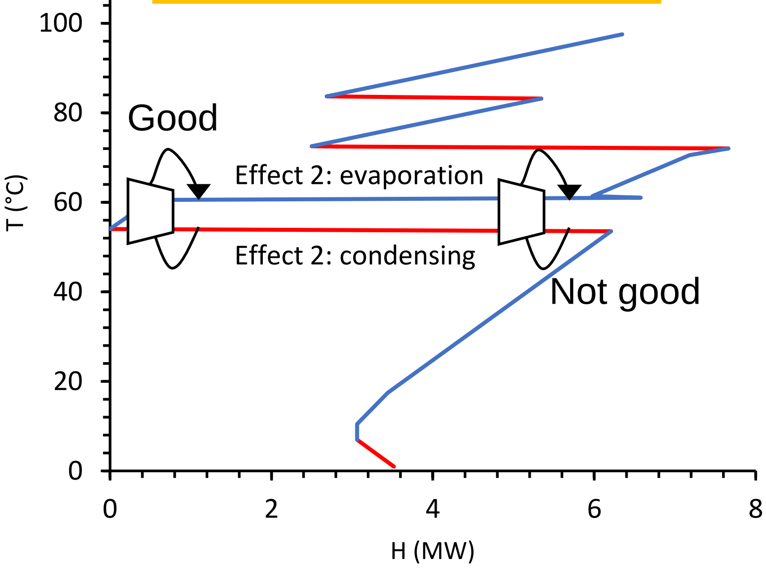
Key result: MVR heat pump on Effect 2?



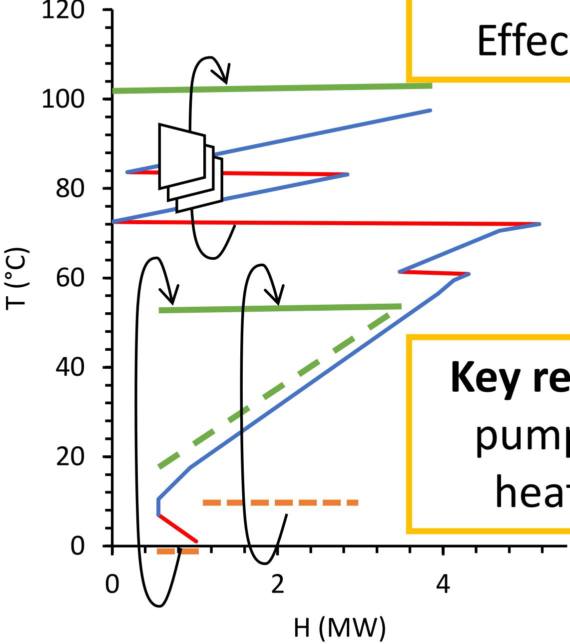


4. Pinch analysis: iteration 3

Key result: MVR heat pump on Effect 2?

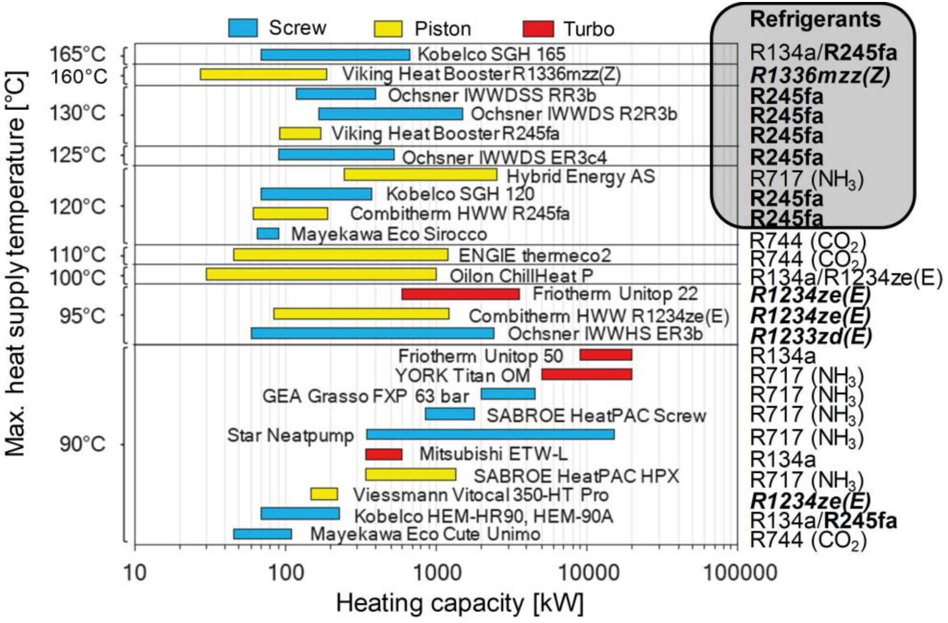


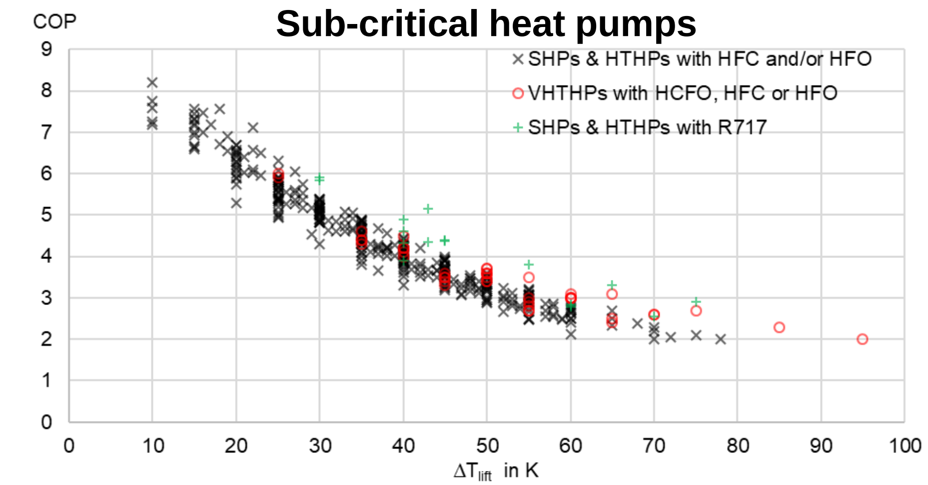
Key result 1: Use an MVR on a vapour bleed from Effect 1 to replace DSI

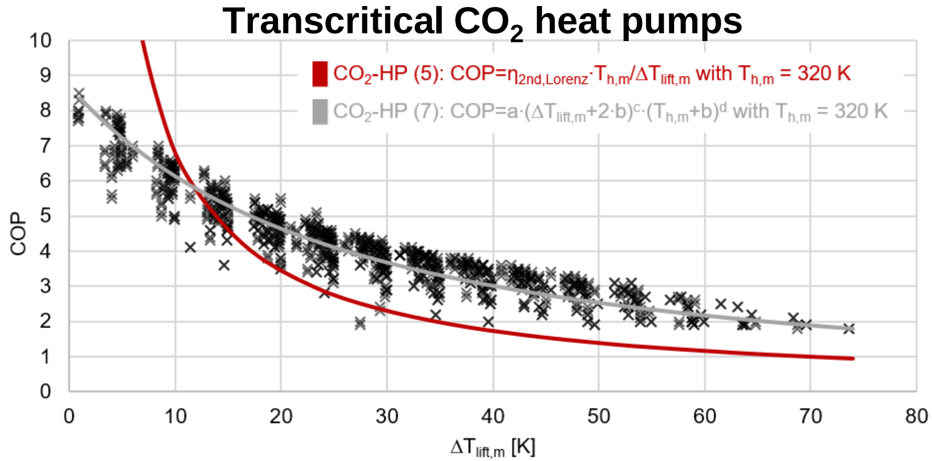


Key result 2: Chiller heat pump and air-sourced heat pumps needed

5. Heat pump integration & selection







Heat pump selection summary

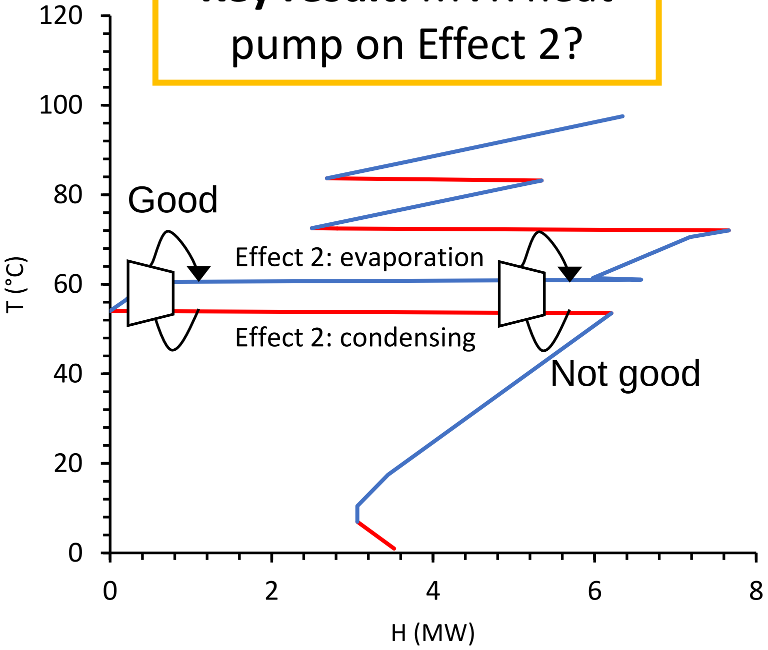
	CO_2 HP (CIP Water)	CO_2 HP (COW Water)	CO_2 HP (Site hot water)	3-stage Vapofan MVR	Ammonia HP (Milk conc.)
Condenser duty (kW)	608	2627	525	3274	497.6
Evaporator load (kW)	403	2062	414	2947	307
Work (kW)	205	566	111	327	191
COP	2.97	4.65	4.74	10.0	2.61

VapoFan by Piller

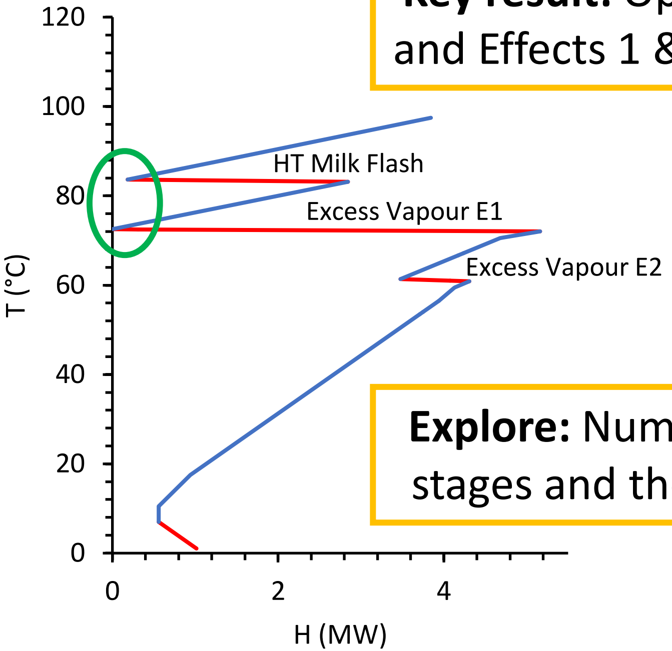
- 2 + 1 stage VapoFan to get a temperature rise of 27K
- Mass flowrate - 3 trains of 1.5t/h
- Compact design
    - 1.5m by 2.5m for a standard 2-stage VapoFan

4. Pinch analysis: iteration 3 (re-visited)

Key result: MVR heat pump on Effect 2?



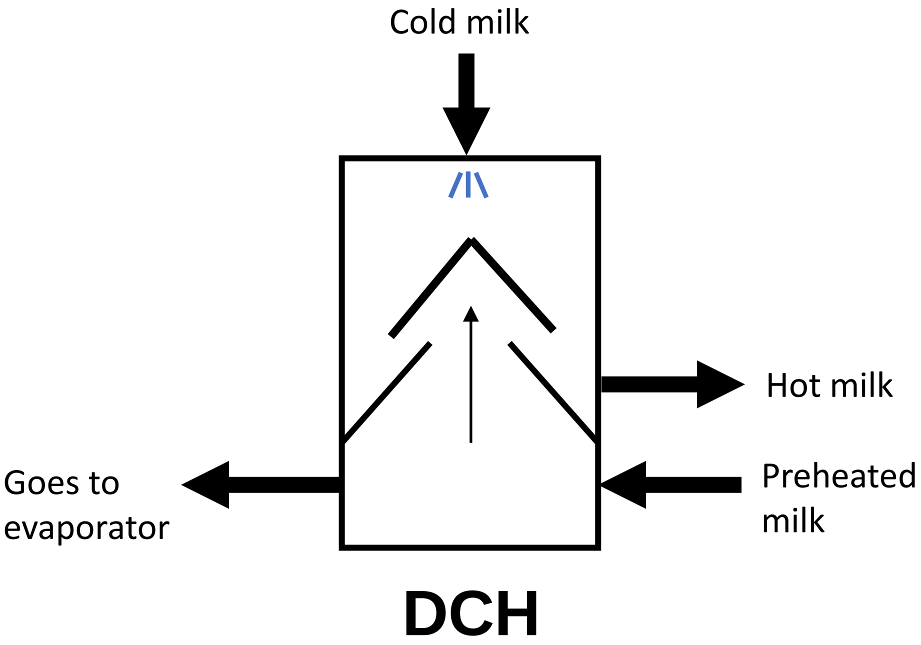
Key result: Optimise Flash and Effects 1 & 2 pressures



Explore: Number of Flash stages and their pressure

Milk flashing: Direct Contact Heaters

- Flash the heated milk, rapidly drop temperature, creates vapour
- Provides high heating rate to cold milk
- Investigate different DCH arrangements



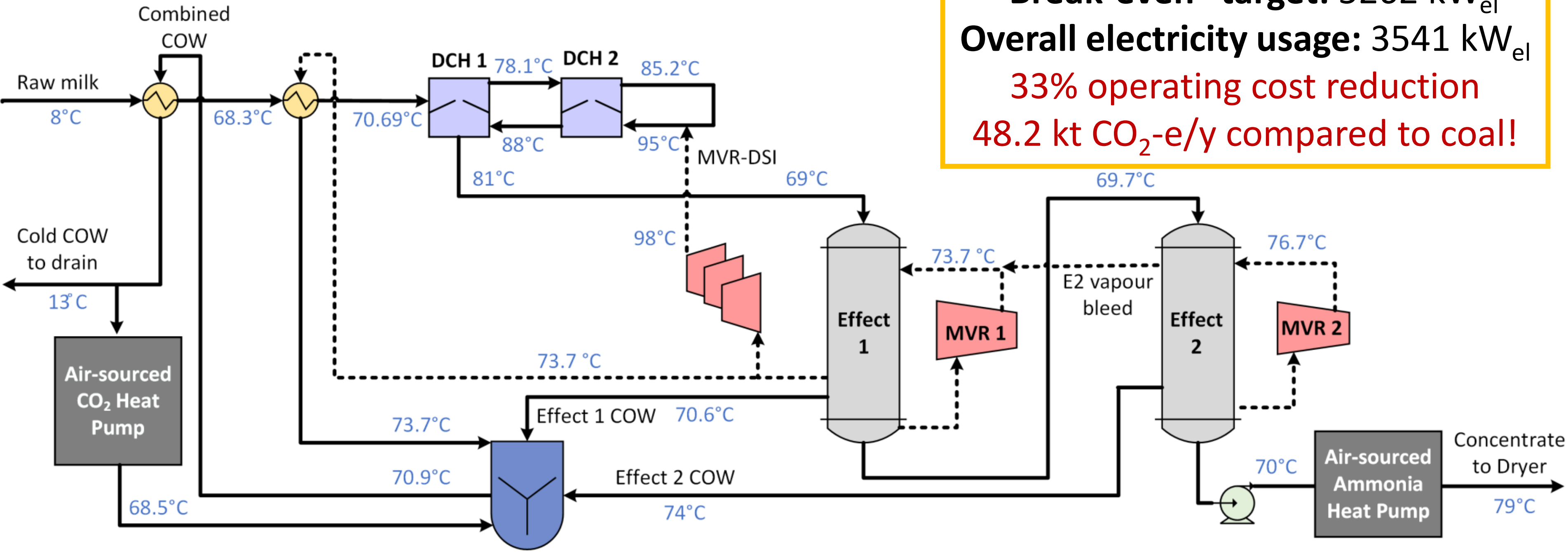
Process simulation of multiple DCHs

Investigated cases	Direct steam injection required
1 DCH	3195 kW
2 DCH in series	2648 kW
3 DCH in series	2170 kW
HX (lower heating rates)	1315 kW

Key question: How do these DSI values translate to total electricity required?

5. Final process design

“Break-even” target: 5262 kW_{el}
Overall electricity usage: 3541 kW_{el}
33% operating cost reduction
48.2 kt CO_2-e/y compared to coal!



Final process design options summary

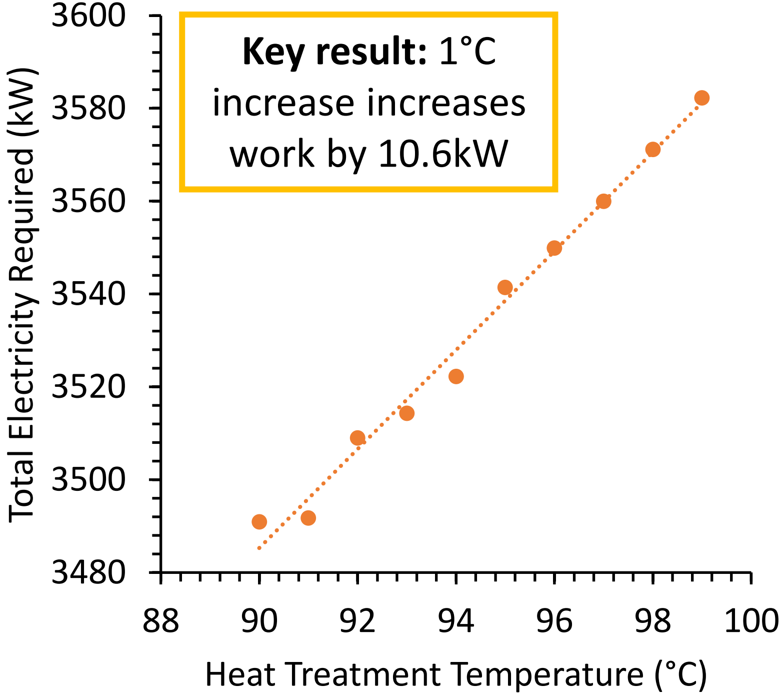
Options	Design features	Power requirements
1	MVR Effect 1 + MVR Effect 2 + Simple HP	4844 kW
2	1 DCH + Integrated concentrate heating	3929 kW
3	2 DCH + Integrated concentrate heating	3535 kW
4	3 DCH + Integrated concentrate heating	3530 kW
5	HX (no DCH) + Integrated concentrate heating	3498 kW
6	HX (no DCH) +Separate HP for concentrate heating	3477 kW
7	2DCH + Separate HP for concentrate heating	3541 kW

Investigating more operating states

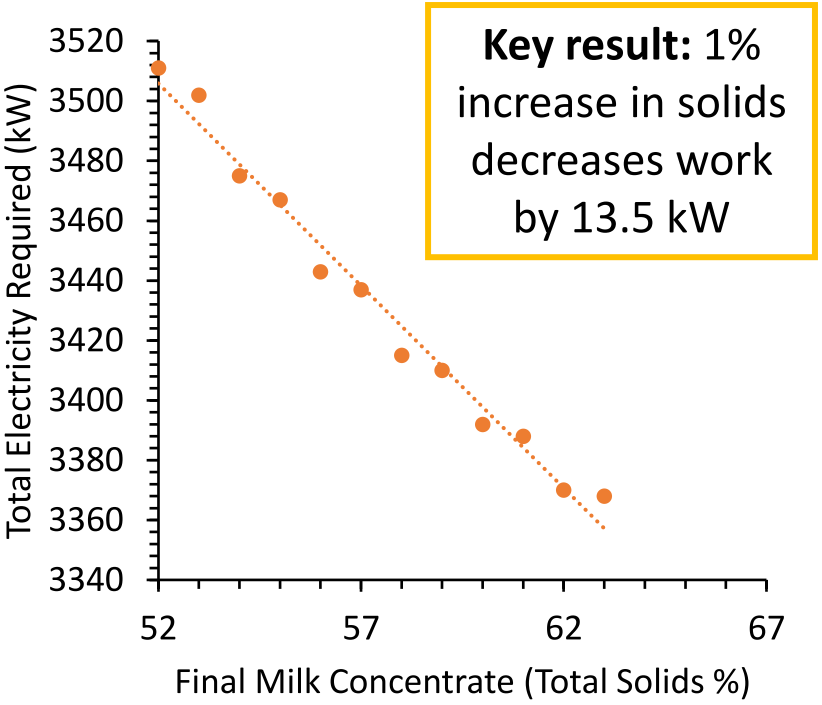
Using process simulation, the robustness of the design and effect of different operating states can be understood, e.g.,

1. Evaporator tube-side temperature
2. Milk heat treatment temperature
3. High-concentrate solid, e.g., up to 62%
4. RO pre-concentrating of milk, up to 30%

Investigations via simulation

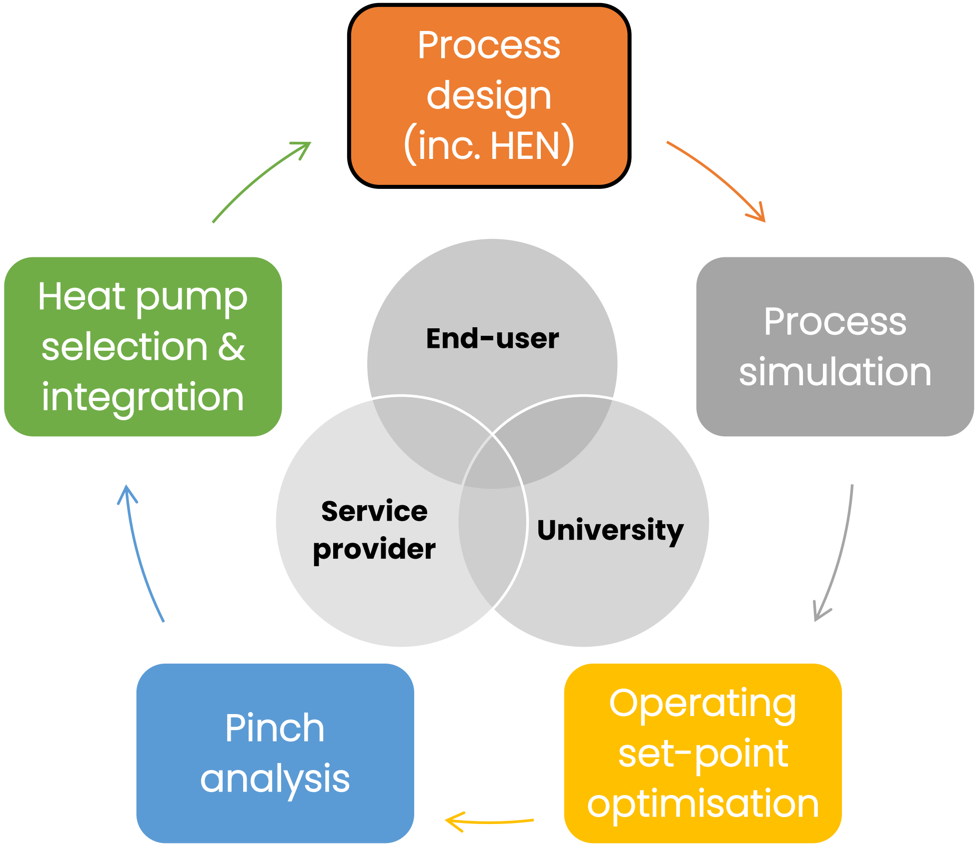


Key result: 1°C increase increases work by 10.6kW



Key result: 1% increase in solids decreases work by 13.5 kW

Efficient process electrification



Closing points

Towards a net-zero-carbon future, together:

1. Need to extend the operating temperature lifts of heat pumps, e.g. transcritical, to >100°C for great decarbonisation potential
2. Need to identify ways to retrofit and evolve current assets to integrate heat pumps
3. Need to collaborate across end-users, service providers, and universities

Want to collaborate?
Connect on LinkedIn

Or email me directly:
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