On identification of ammonia synthesis technology based on process energy requirements

PRESENTER

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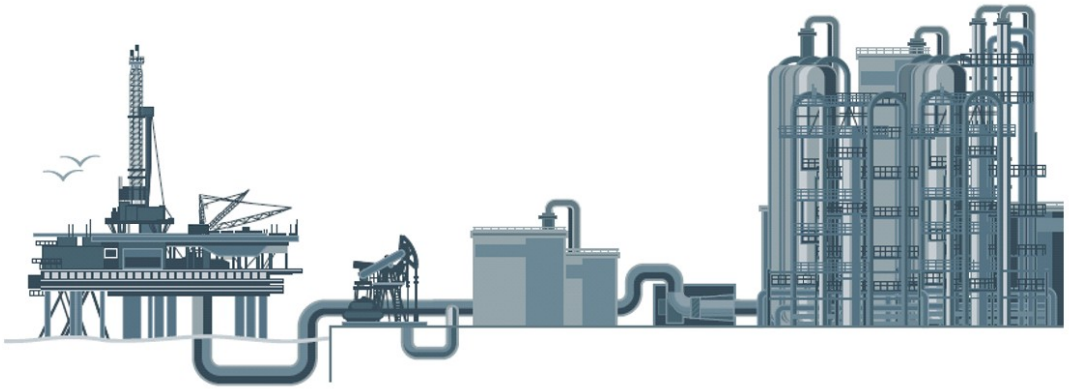
Why is ammonia important?

farming

chemical industry & biotechnology

household

refrigerant



How is ammonia produced?

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$

1)Steam reforming

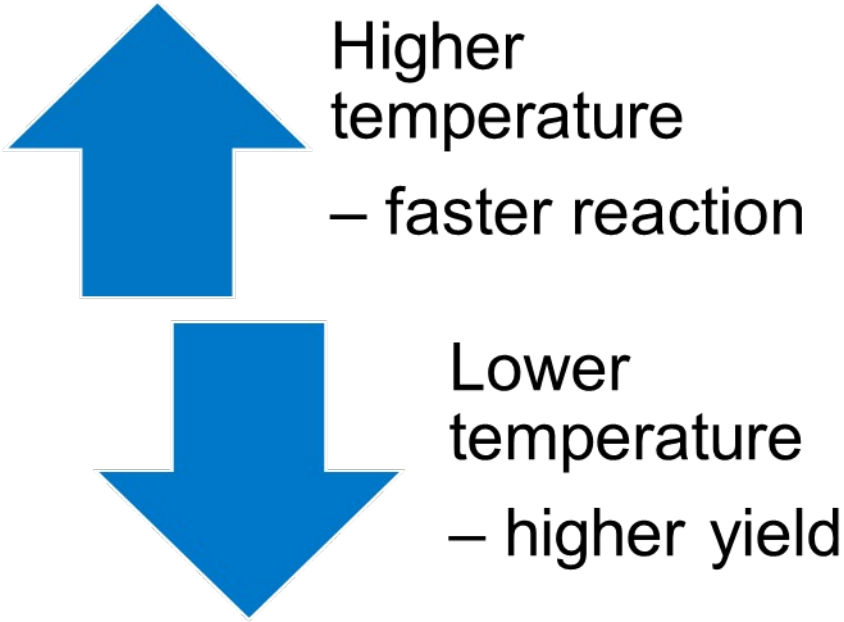
2)Cryogenic distillation

3)Ammonia synthesis

Ammonia synthesis

- Haber-Bosch process

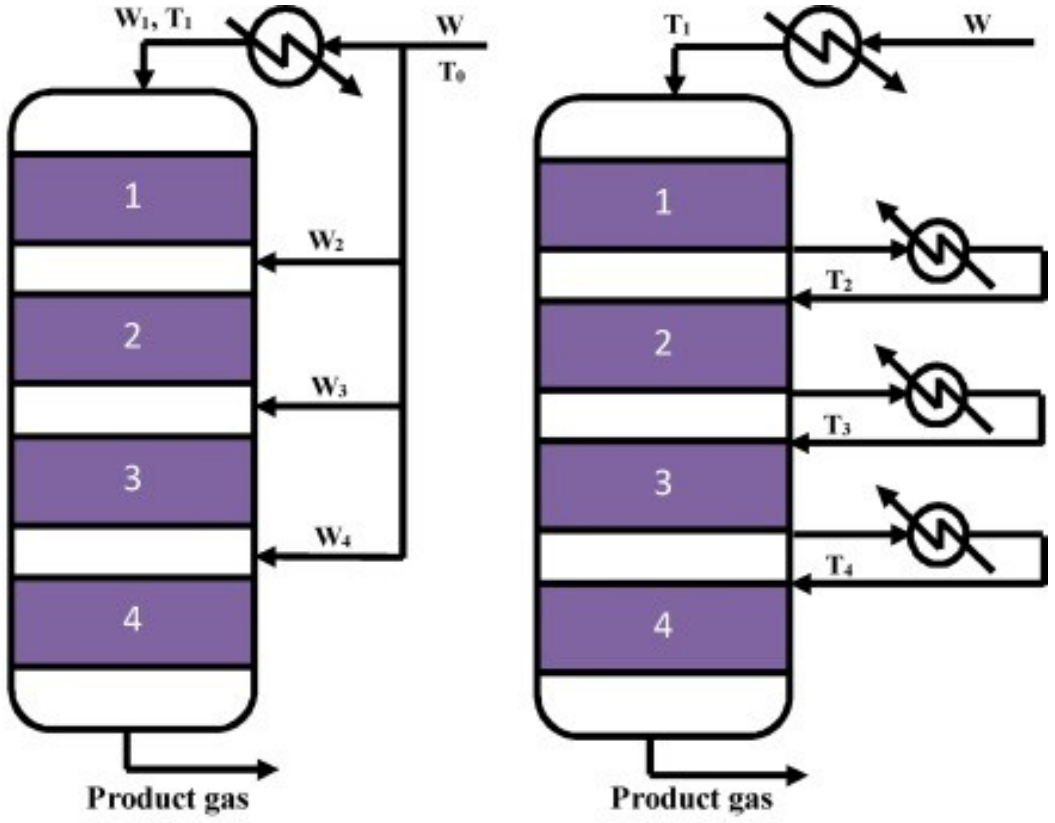
- High temperature and pressure
- Exothermic chemical reaction
- Optimal temperature regime



Two technologies

Multi-bed reactor with inter-stage cooling:
a)Direct cooling (quench)
b)Indirect cooling (HE)

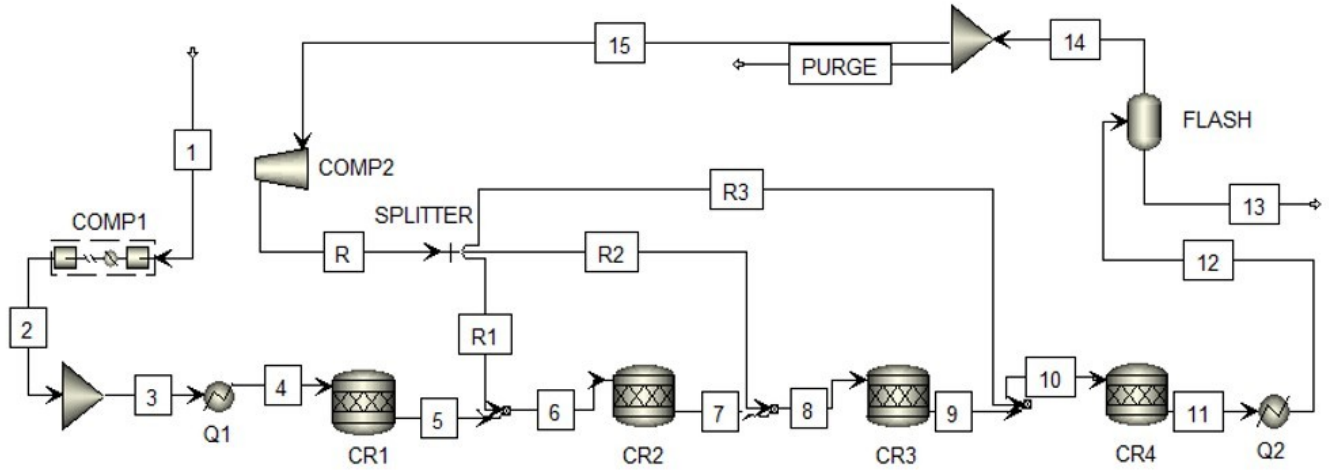
- Production rate is fixed
- Energy requirements are different



1 tone of ammonia:
≈ 0.61 MWh of electrical energy
≈ 1.87 MWh of heating & cooling

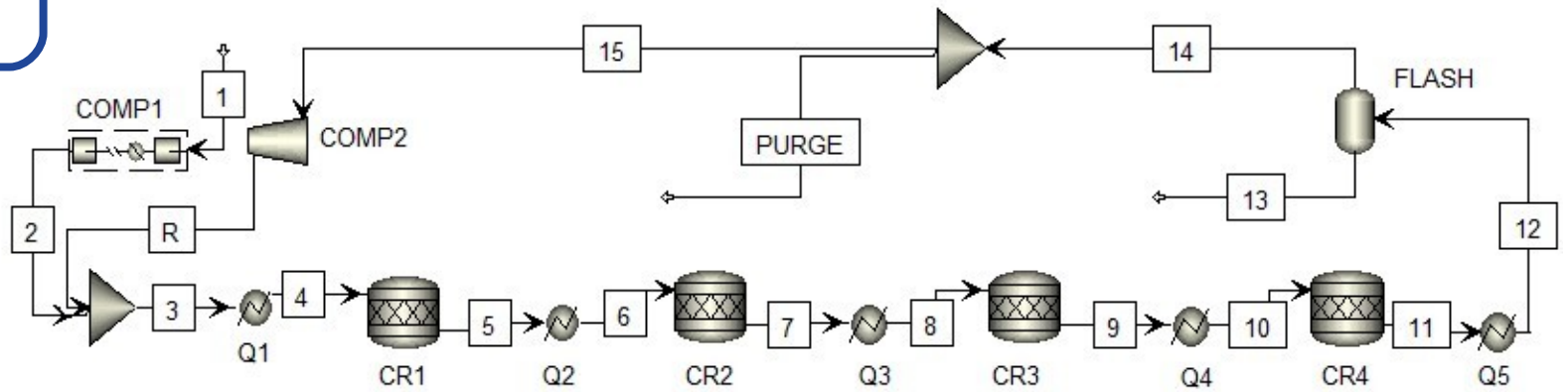
Simulation

Direct cooling (quench)

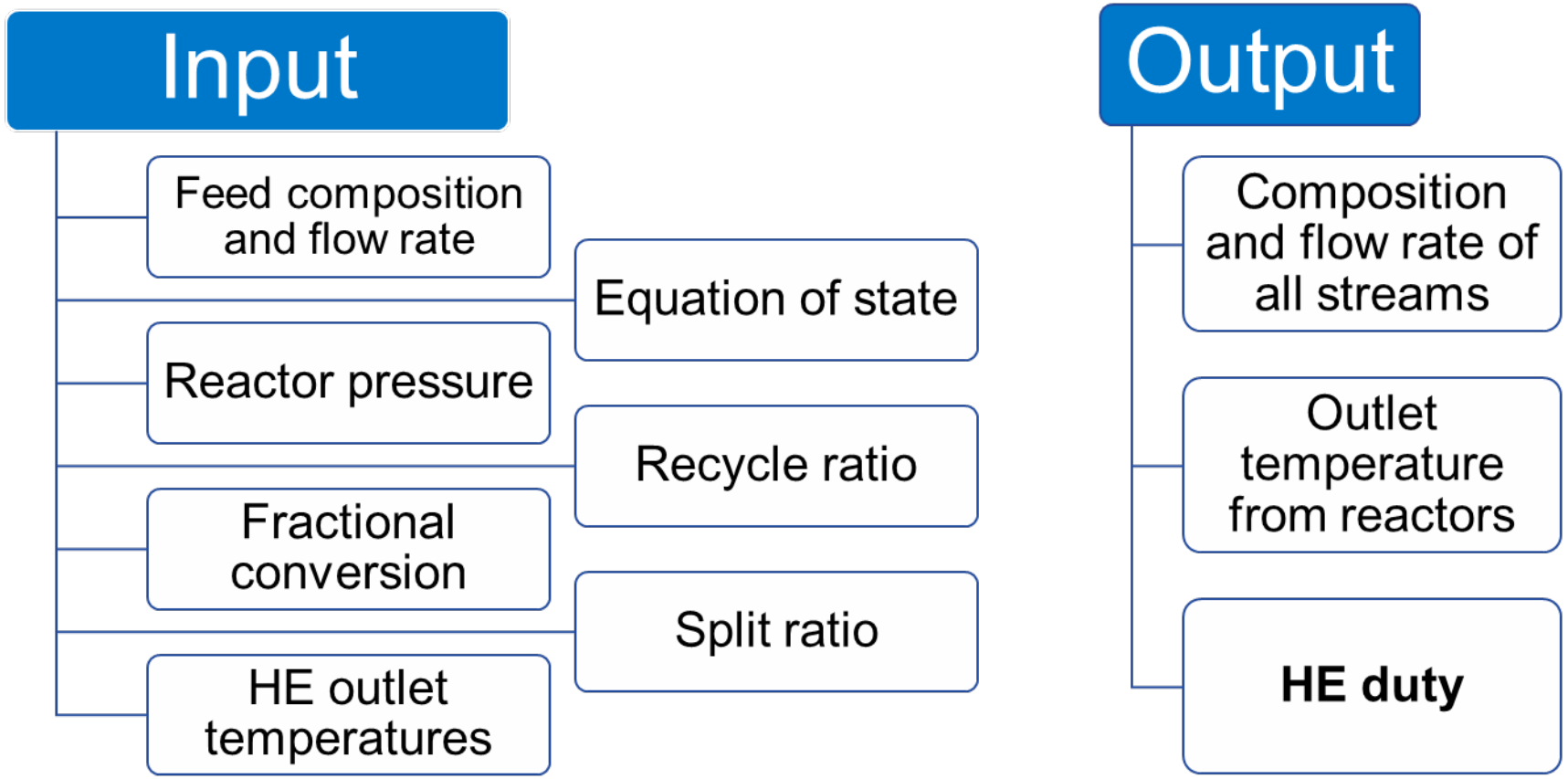


Which technology requires less energy?

Indirect cooling (HE)



Simulation


Input
Feed composition and flow rate
Reactor pressure
Fractional conversion
HE outlet temperatures
Equation of state
Recycle ratio
Split ratio
Output
Composition and flow rate of all streams
Outlet temperature from reactors
HE duty

Optimization

Variables

Fractional conversion

Split fraction

Constraints

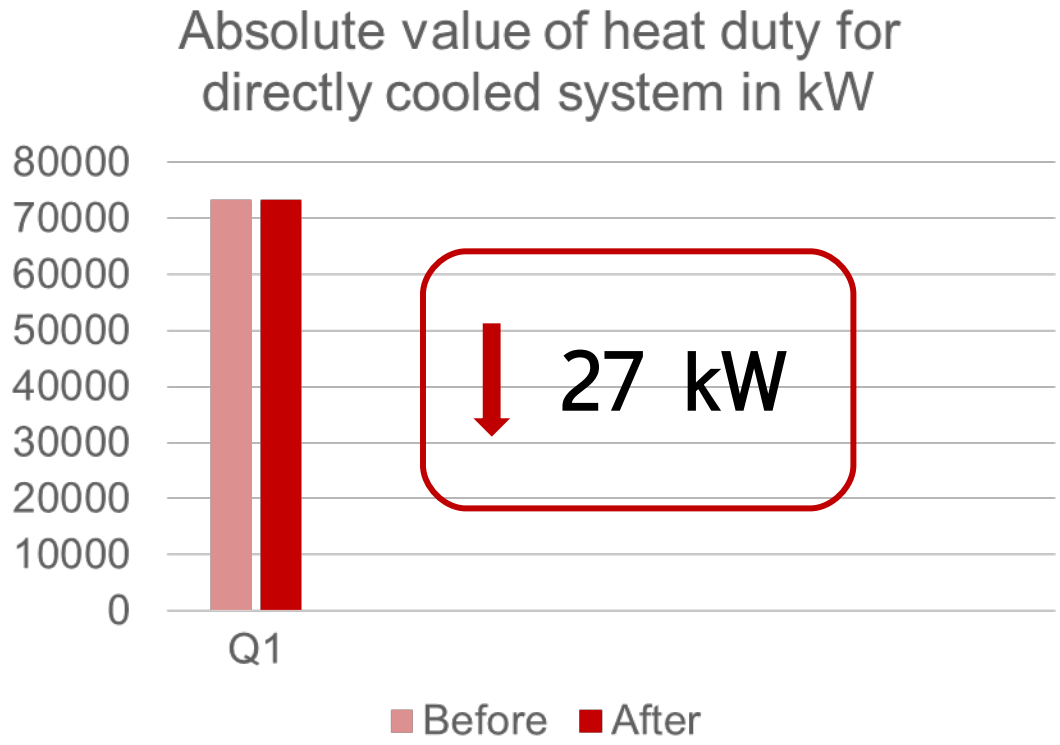
Reactor outlet temperature

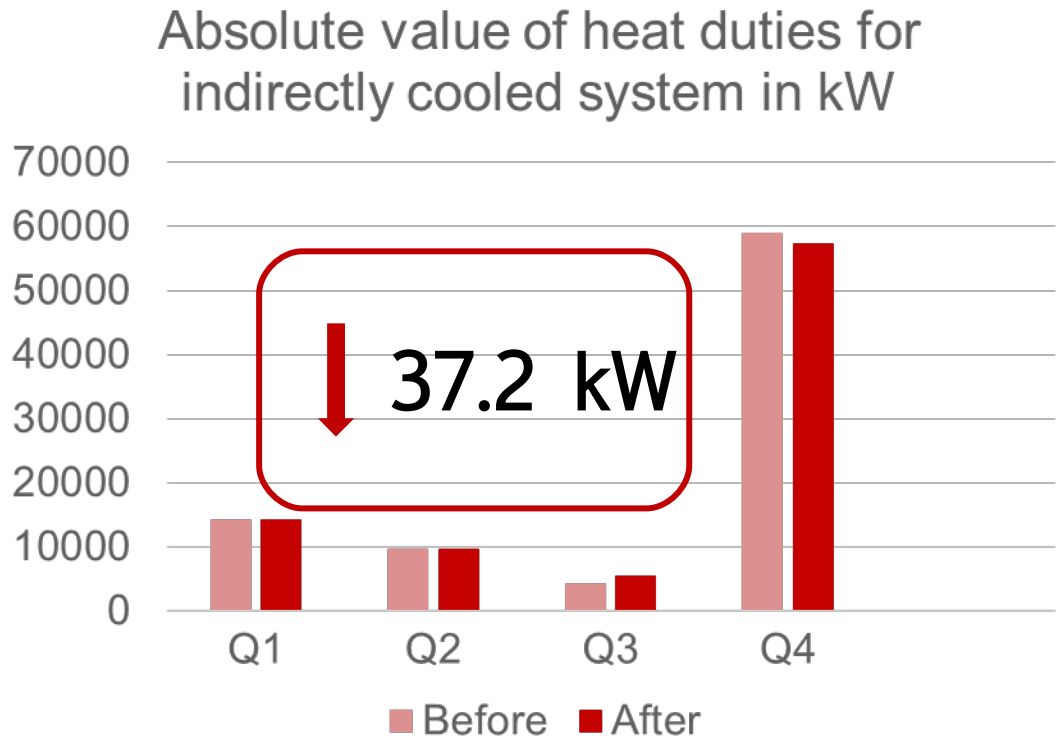
Ammonia flow rate in the product stream

Minimized values

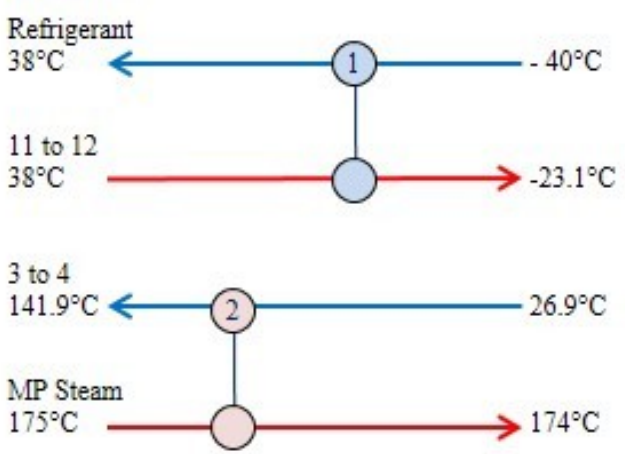
Total heat duty

Optimization results

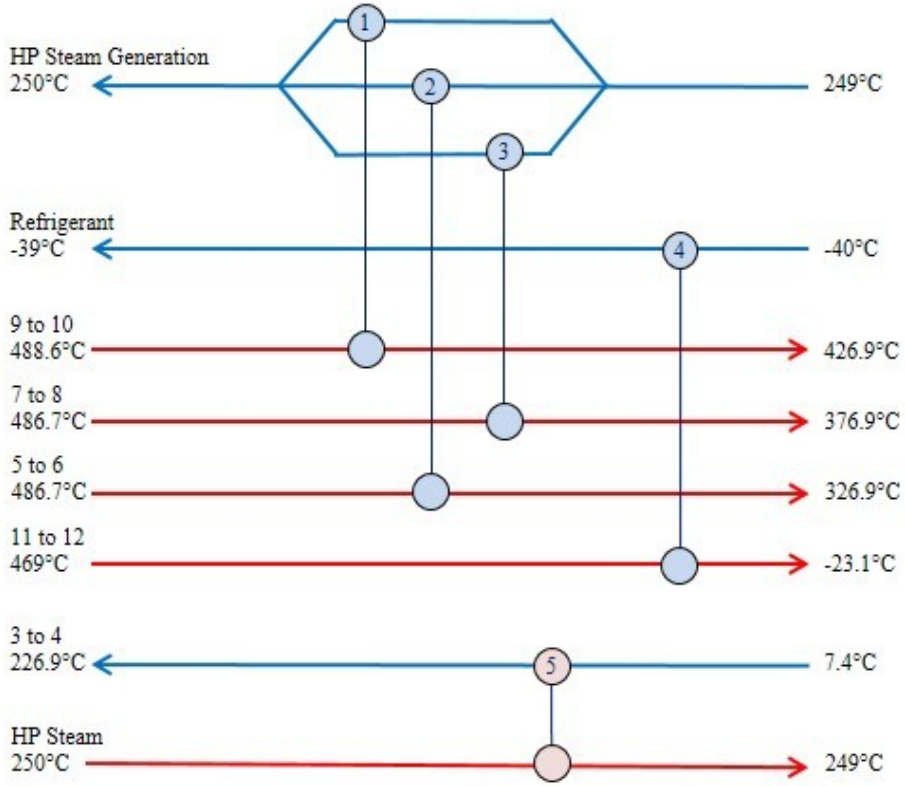




Heat Exchanger Networks



-73.3 MW



-86.6 MW

Heat Integration

Goal

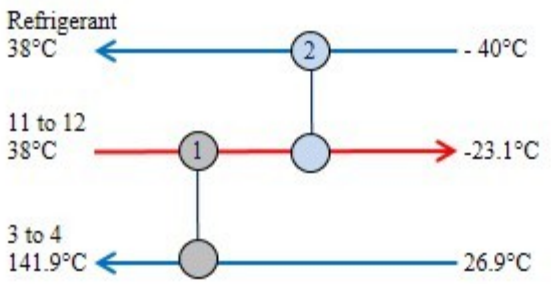
Heat Exchanger Network

- Minimum costs
- 20 years lifespan

Basic – Utility streams

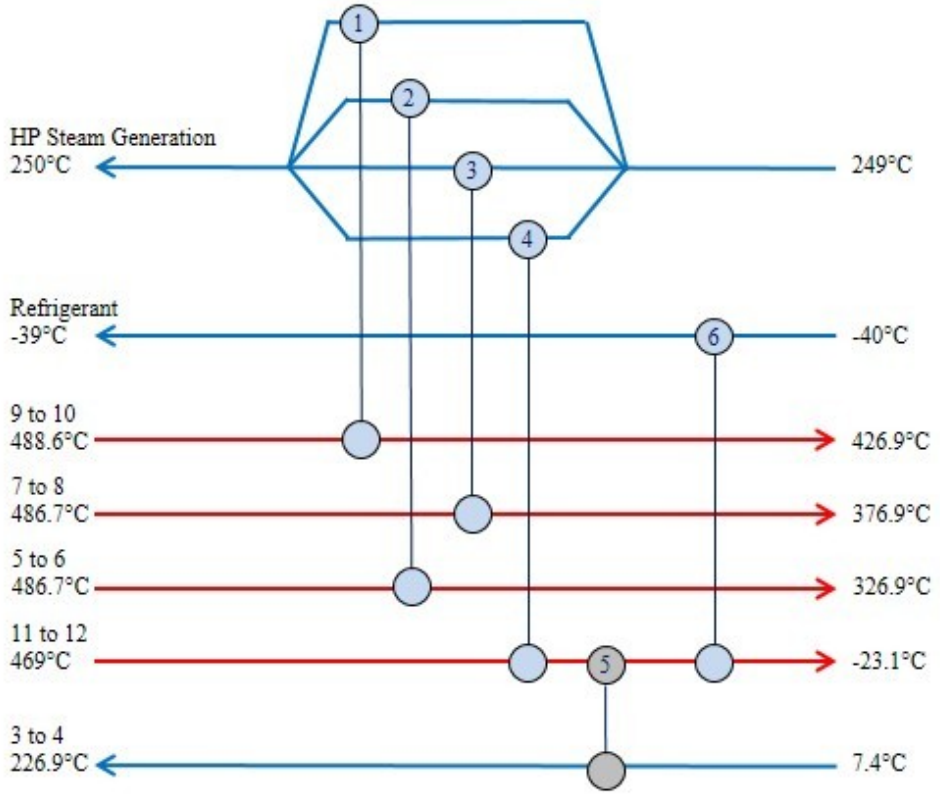
Target – HE & utility streams

Heat Integration - Results



Before	After
80.24 MW	**66.39** MW

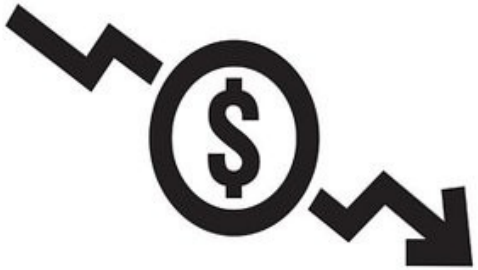
108.7 % bigger area of HE



Before	After
106.9 MW	**66.3** MW

226.2 % bigger area of HE

Costs

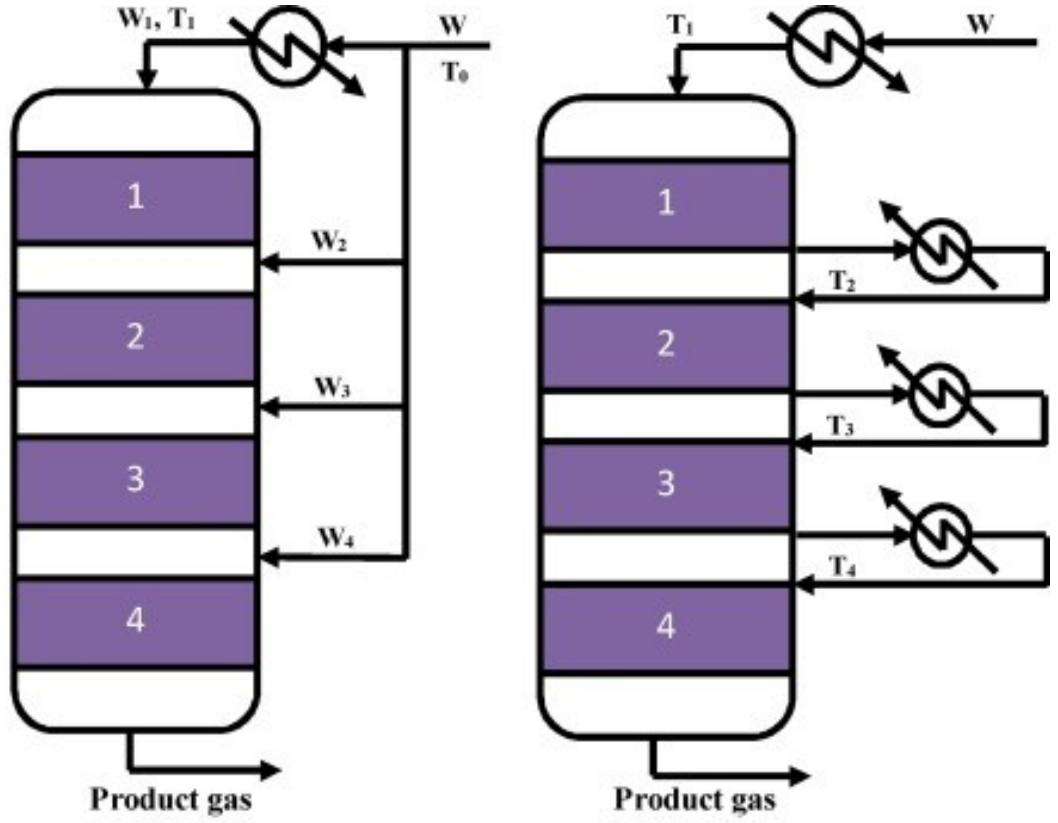


	Direct cooling	**Indirect** cooling
Capital costs	+ 0.7 %	+ 89 %
Operational costs	- 14.6 %	- 150 %
Cost/s	0.2244	-0.0863

Conclusion

Directly cooled system **Indirectly** cooled system

- Simplicity
- Doesn't depend on HPS usage and sale



- Great potential for generation of HPS
- Usage or sale
- Cheaper even without selling HPS

Methodology review

- Fast and reliable analysis of the process
- Quick optimization
- Designed the target HENs
- Demonstrated the benefits of direct cooling through the cost estimates