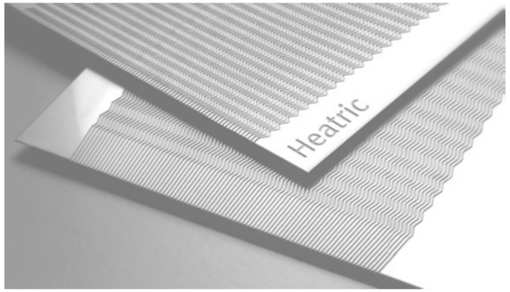
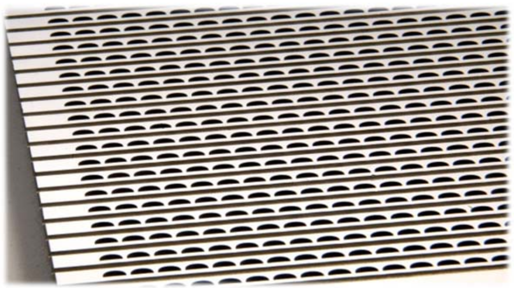
Heat Exchanger I – March 31

Economic analysis of sCO_2 cycles with PCHE Recuperator design optimisation

Dr Dereje Shiferaw, Jorge Carrero, Renaud Le Pierres

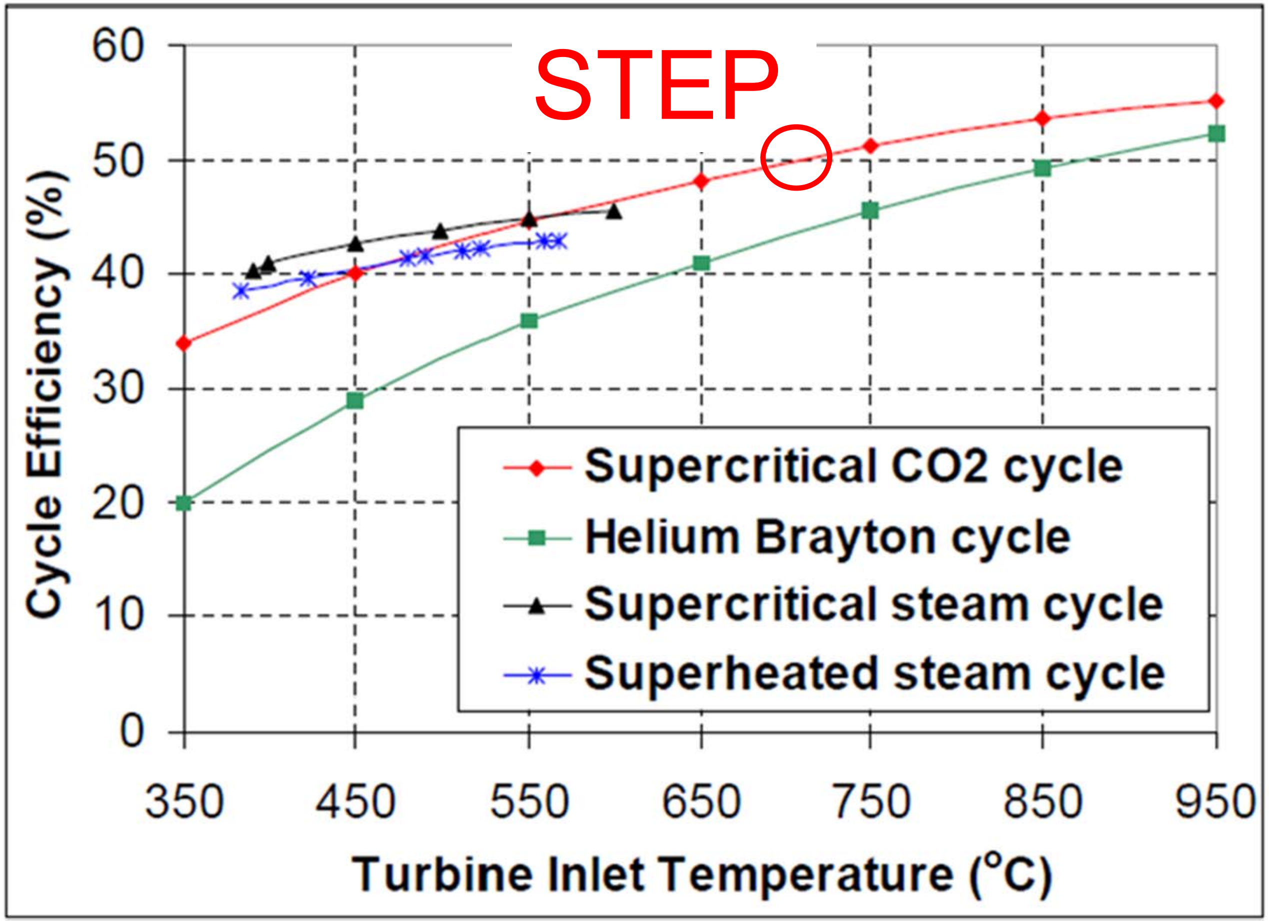




Introduction

- Increase need in clean energy systems to address global warming;
- More efficient power generation cycles are being considered to reduce carbon footprint;
- Any replacement of well established cycles (steam) will require strong technical and economic arguments;
- Supercritical CO2 cycles are considered to be some of the most promising candidates to answer these requirements;
- These cycles efficiency and cost are tightly linked to optimising the design of key components, including heat exchangers

Cycles comparison



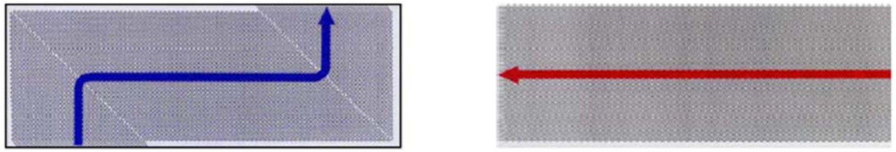
Heat exchangers for Supercritical CO2 Cycles

» sCO2 cycles recuperators must provide:
  - High mechanical integrity (between 260-330 bar HP side);
  - High differential pressure capabilities;
  - Able to manage large number of NTUs;
  - Contribute to a lower BOP cost;

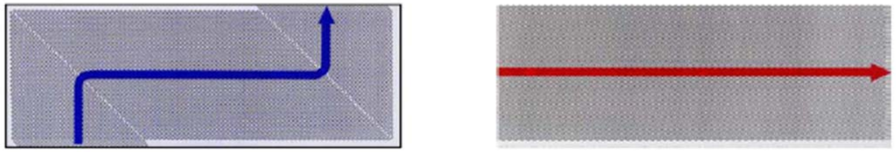
» Printed Circuit Heat Exchangers (PCHE) have been used for more than 10 years with sCO2 cycles as they closely match requirements;

» But PCHE cost is still being debated;

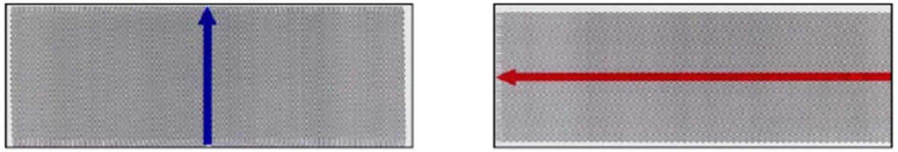
Example of PCHE configurations



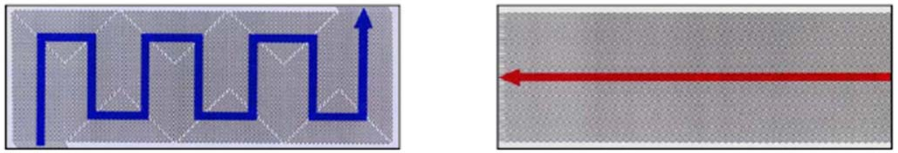
Counterflow example with side-side and end -end flows.



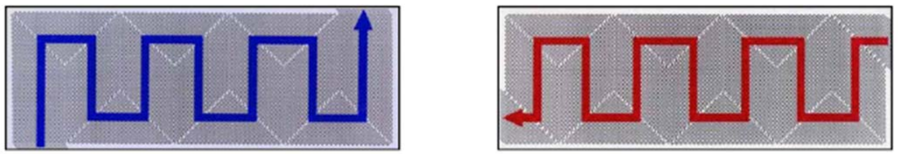
Co-current parallel flow example with side-side and end-end flows.



Cross flow example with end-end flows.



Cross counter flow example with multi-pass on one side.



Multipass counter flow example with equal multi passes on both sides.

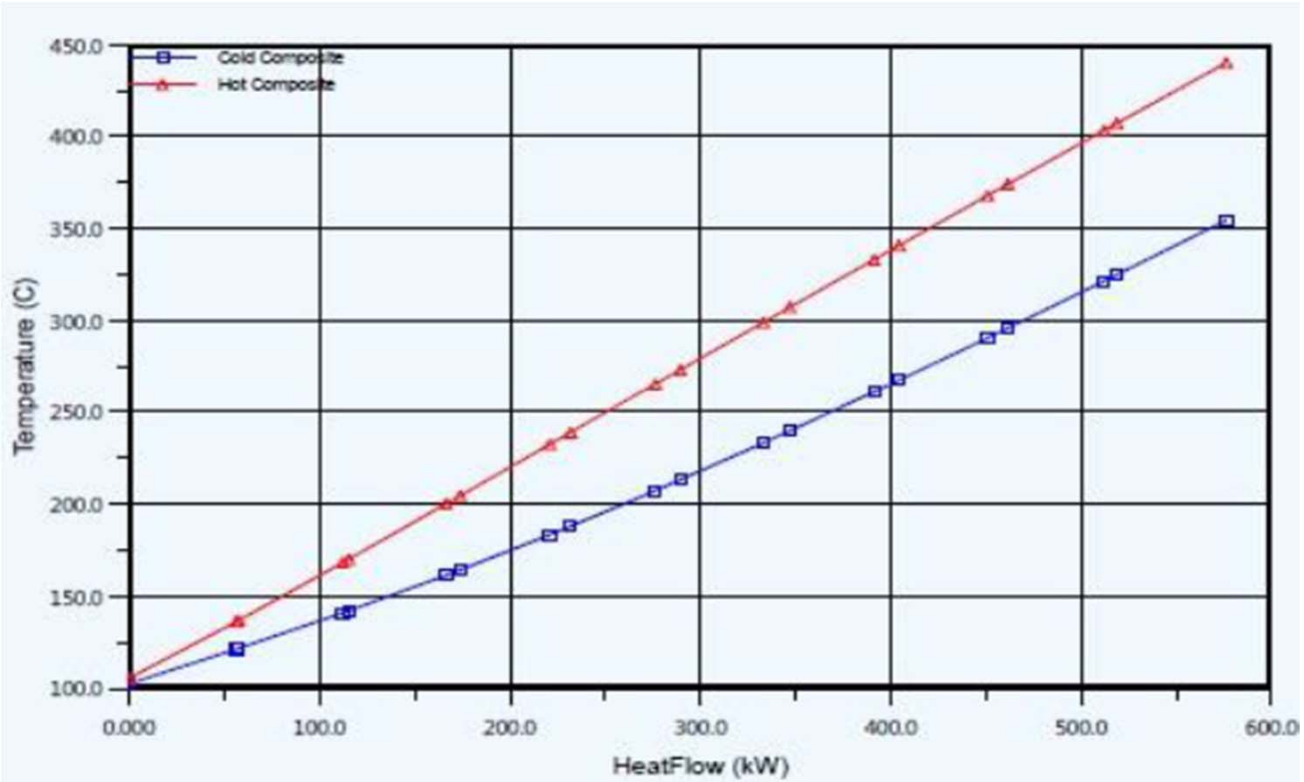
Heat exchangers for Supercritical CO2 Cycles

» Q=U*A*TD
   - Q (heat duty)
   - U (Overal heat transfer coefficient)
   - A (heat transfer area);
   - TD (mean temperature difference);

Heat exchangers for Supercritical CO_2 Cycles

- TD = Fhc*Fgeom*Fsc*Flong-c*LMTD
  - Fhc (heat curve factor)
  - Fgeom (geometry factor)
  - Fsc (short circuit factor)
  - Flong (longitudinal conduction factor)
  - LMTD (logarithmic mean temperature difference)

Heat exchangers for Supercritical CO2 Cycles



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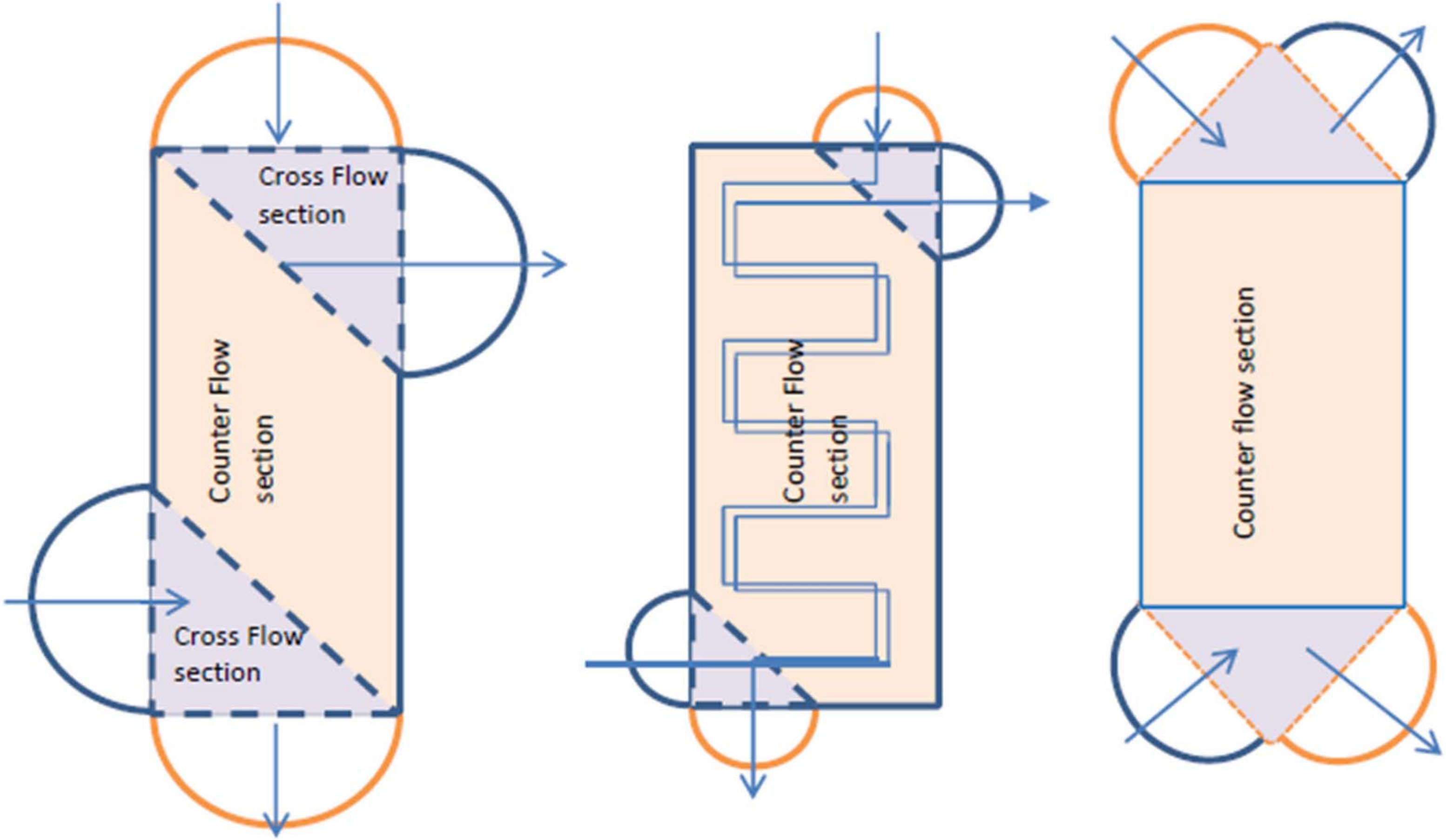
Heat exchangers for Supercritical CO2 Cycles



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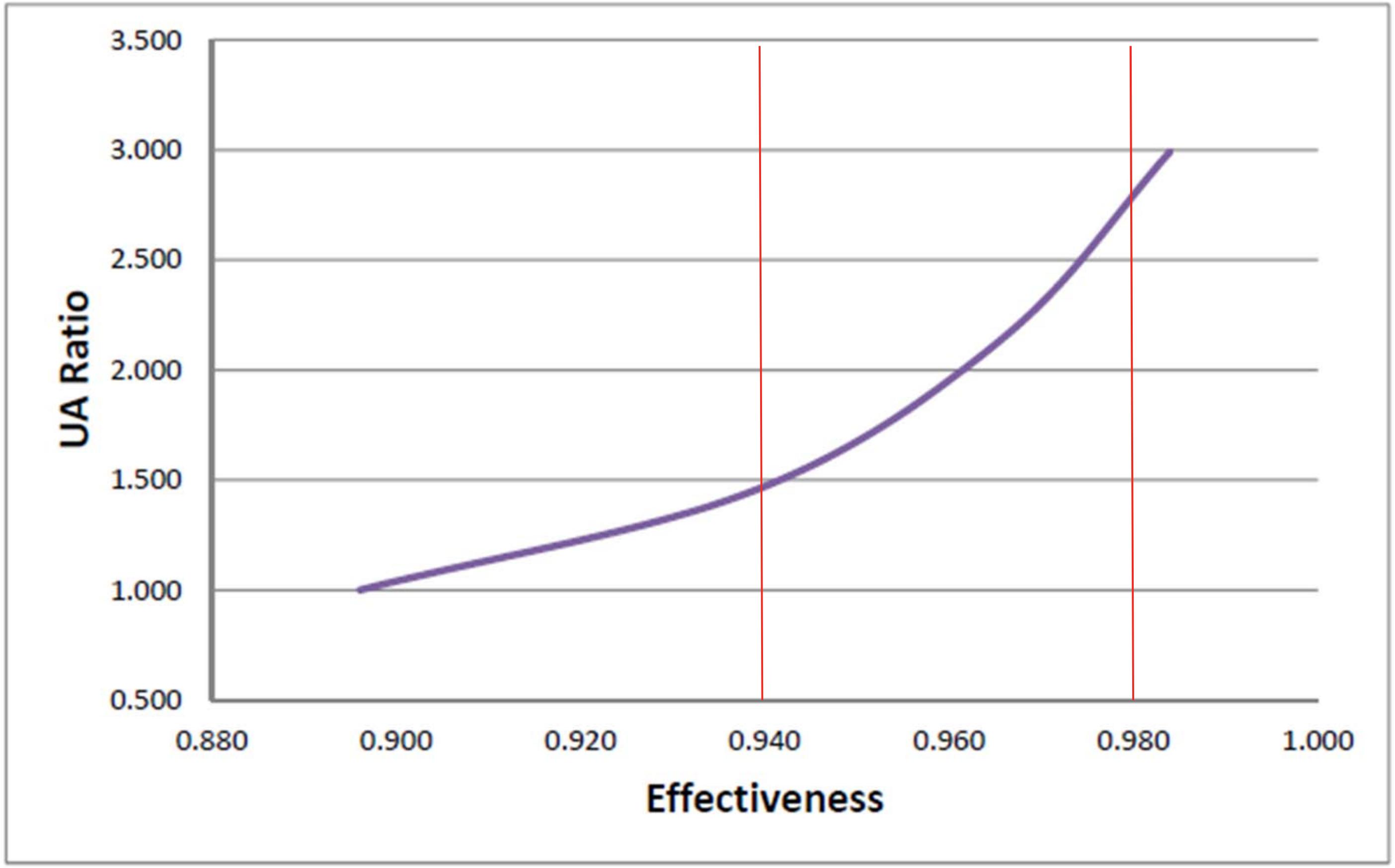
Economic feasibility

» Temperature approach analysis basis:

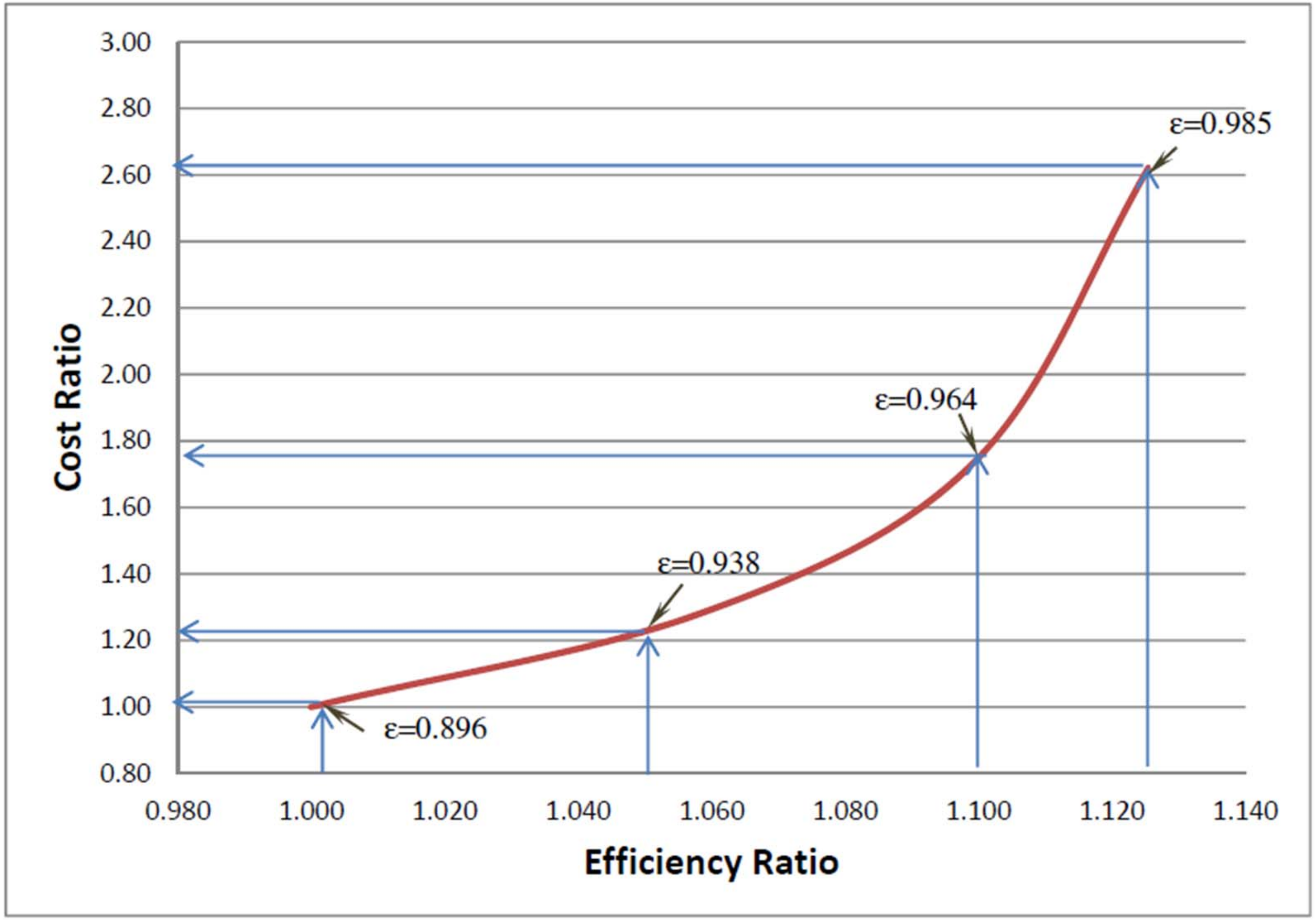
- 10 MWth plant size;
- High temperature recuperator;
- Constant pressure drop;
- From 2 to 18 degree Celsius approach;
- Base case is 18 degree Celsius approach;

Economic feasibility

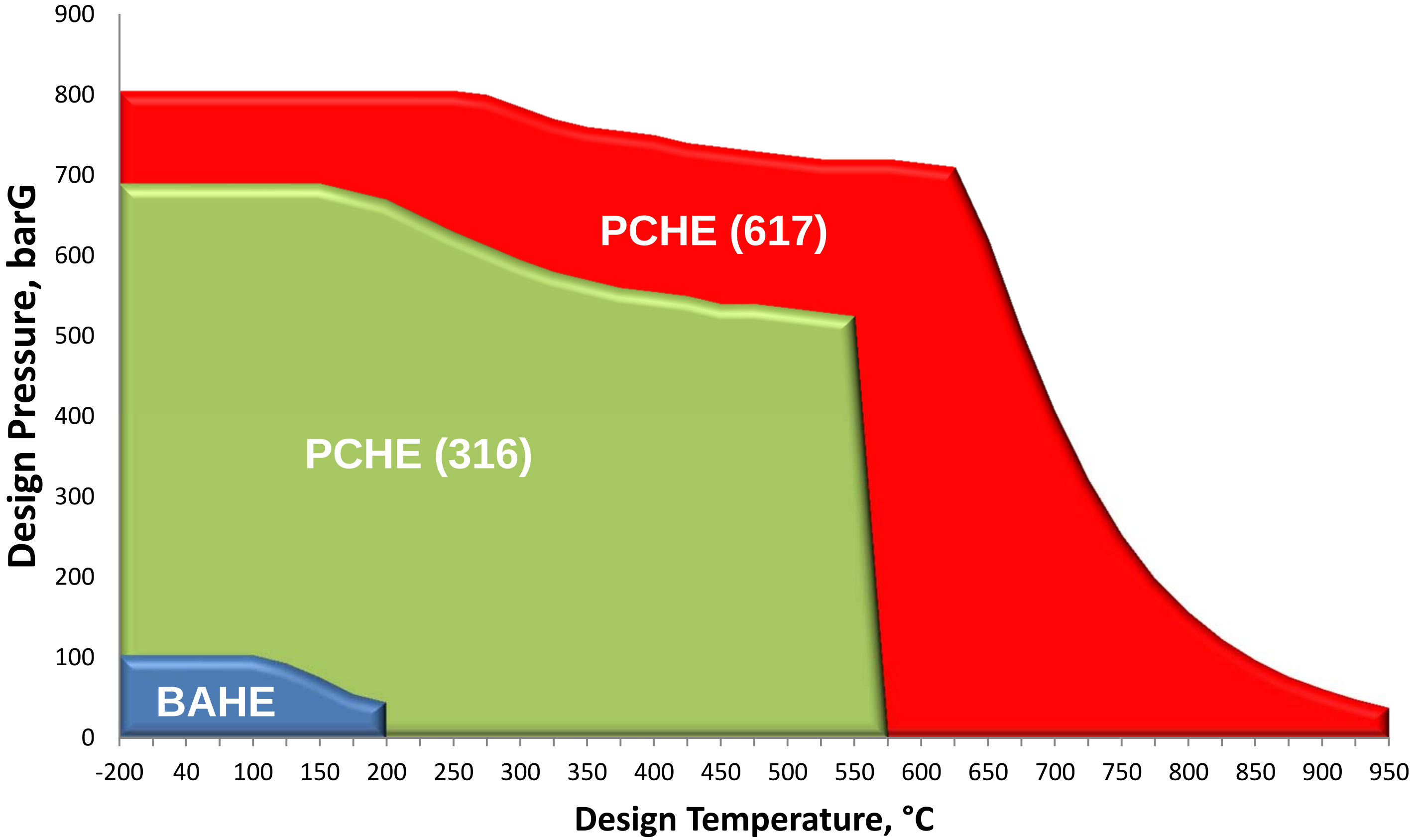


$$Effectiveness = 1 - \frac{\Delta T_{approach}}{T_{hot\ in} - T_{cold\ in}}$$

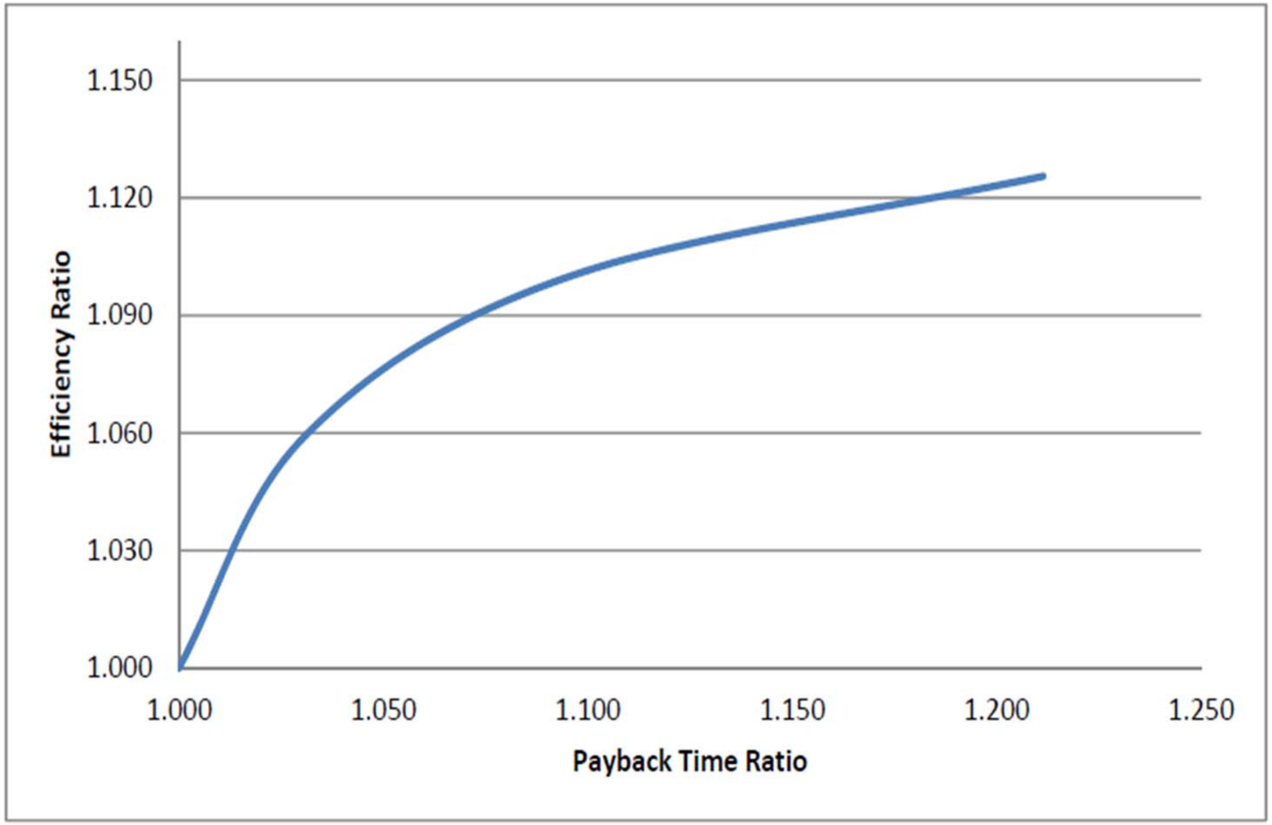
Economic feasibility



Material design stress vs temperature change



Economic feasibility



» Payback Time ratio increases faster than Efficiency ratio

Economy of scale

- Economy of analysis basis:
  - Plant size from 5MWth to 500MWth;
  - All PCHE design parameters fixed except for flow rate

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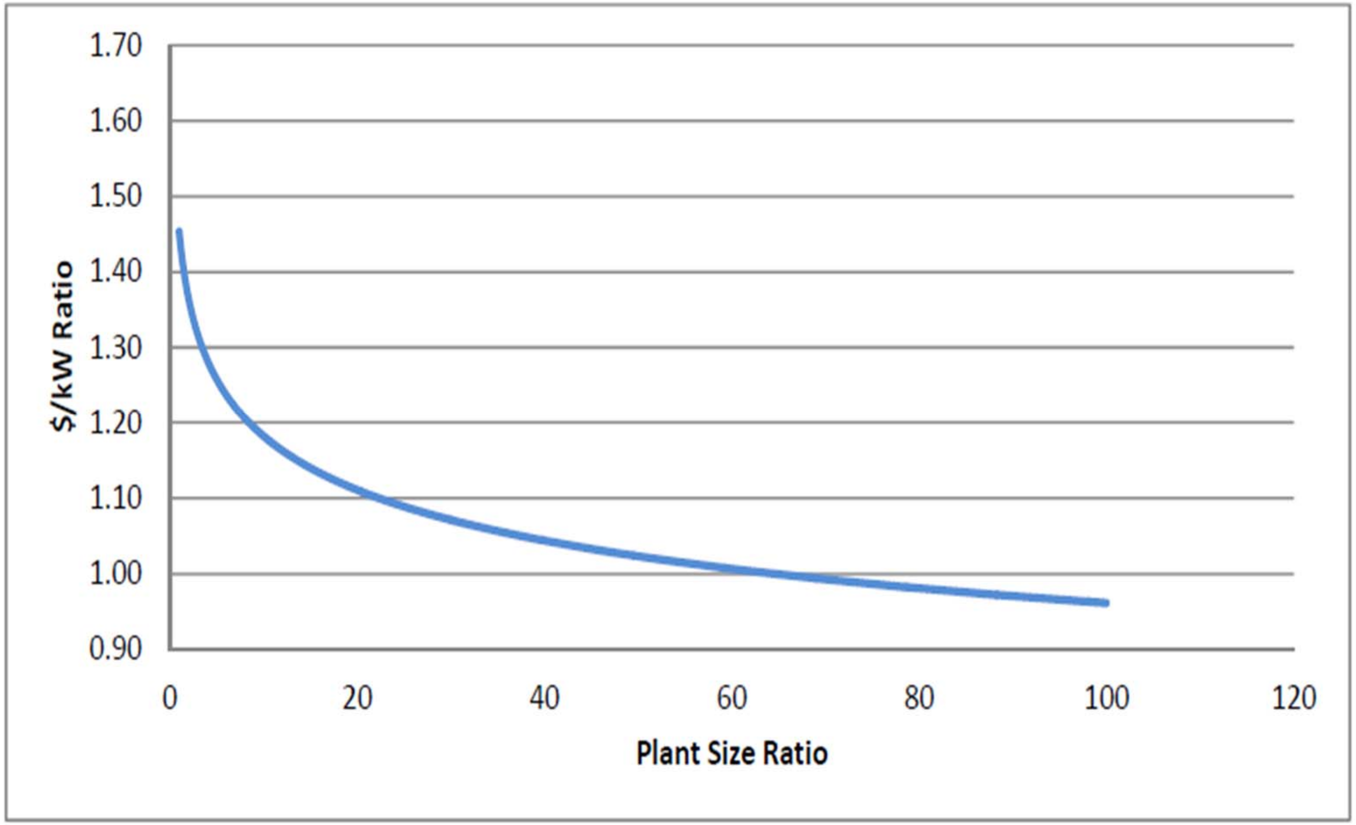
Economy of scale



» Economy of scale is non-linear

Conclusion

- Small variations in heat exchanger design parameters greatly affect their size and cost at high efficiency cycles;
- Performance gain vs cost increase needs to be carefully assessed;
- Return on investment ratio is slower than efficiency gain ratio;
- There is an economy of scale when considering larger plants
- This optimisation needs to be done at the earliest and in collaboration between system designs and component manufacturers

Questions

WWW.HEATRIC.COM

Renaud Le Pierres
Business Development Engineer

HEATRIC
46 Holton Road
Holton Heath
Poole
Dorset BH16 6LT
England
Tel: +44 (0) 1202 627077
Fax: +44 (0) 1202 632299