1^{st} International Conference on
Sustainable Energy and Resource Use in Food Chains

ICSEF 2017

Techno-economic Survey and Design of a Pilot Test Rig for a Trilateral Flash Cycle System in a Steel Production Plant

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Beaumont Estate Hotel in Windsor, Thursday 20th April,

RCUK Centre for Sustainable Energy Use in Food Chains

CSEF Centre for Sustainable Energy use in Food chains

MANUFACTURING THE FUTURE

Research Councils UK Energy For a Low Carbon Future

Agenda

Opportunity

Technology

Application

Development

Results

The Opportunity

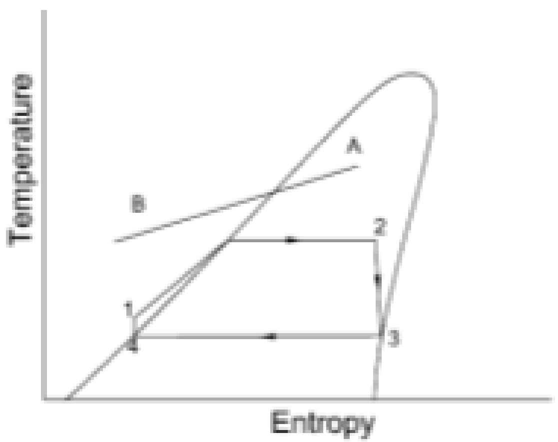
Potential Theoretical Global Waste Heat estimated to be **68.2 TWh**

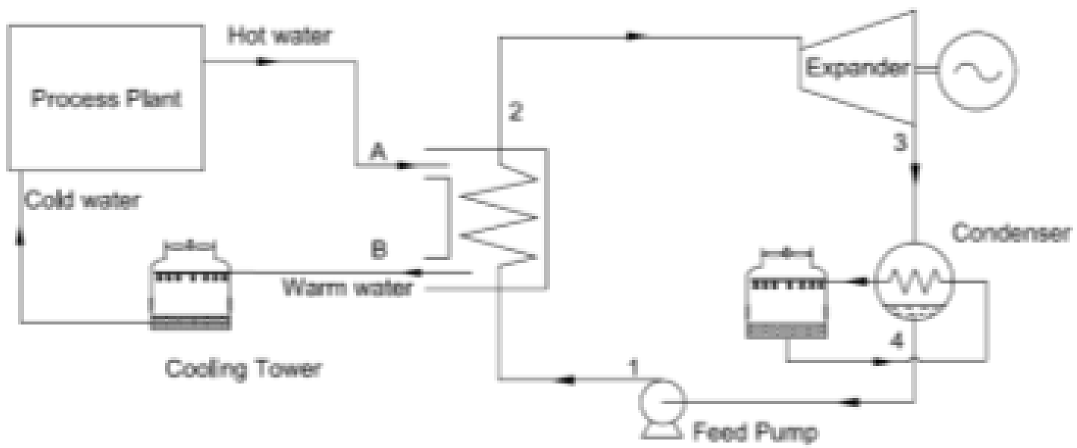
63% occurs below 100℃

Estimated heat recovery potential for industrial sector lies in the region **10-20TWh** (36-71PJ)

Largest heat recovery potential in **Iron and Steel**

Existing Technology - ORC





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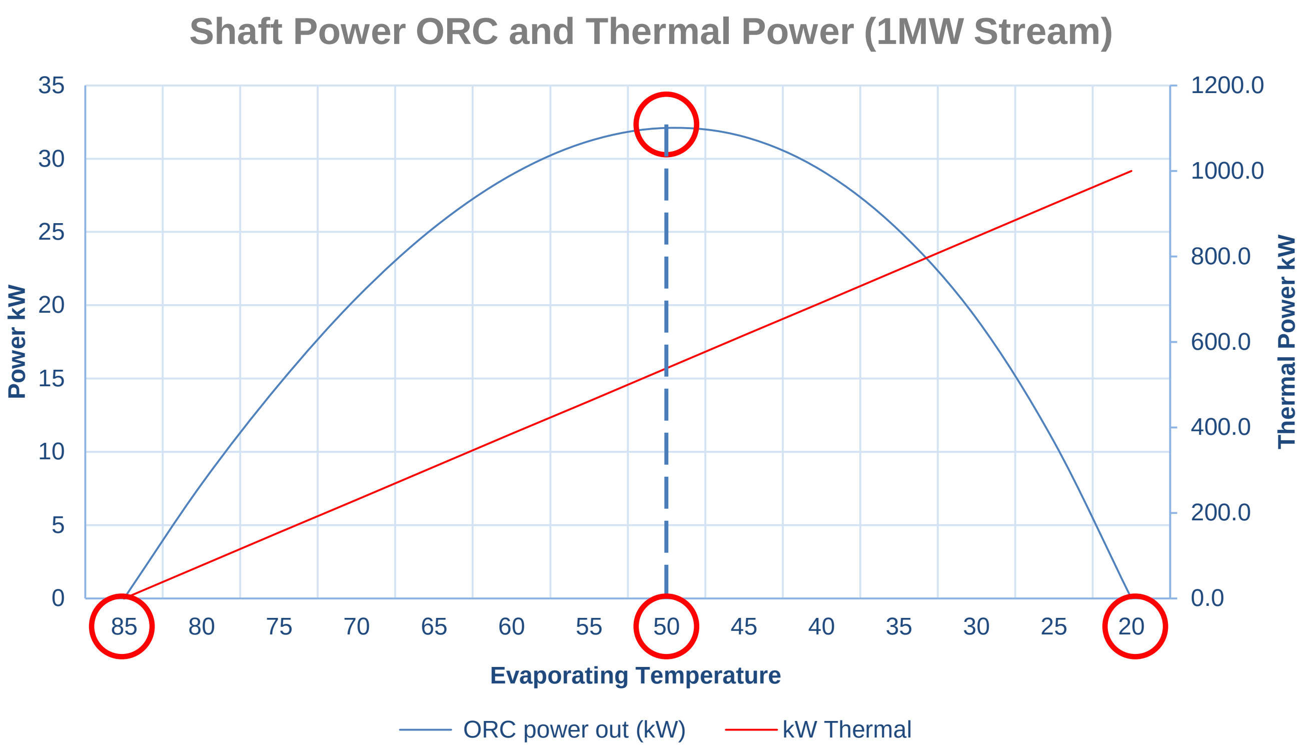

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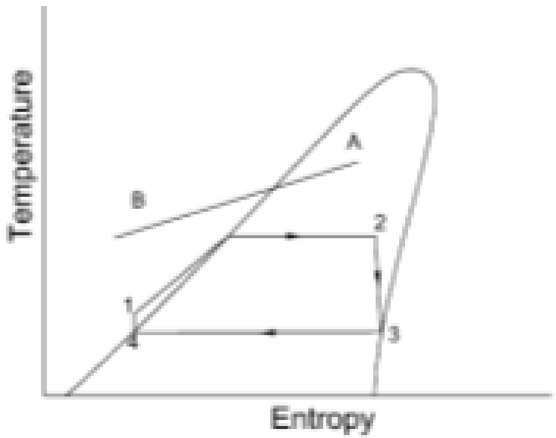
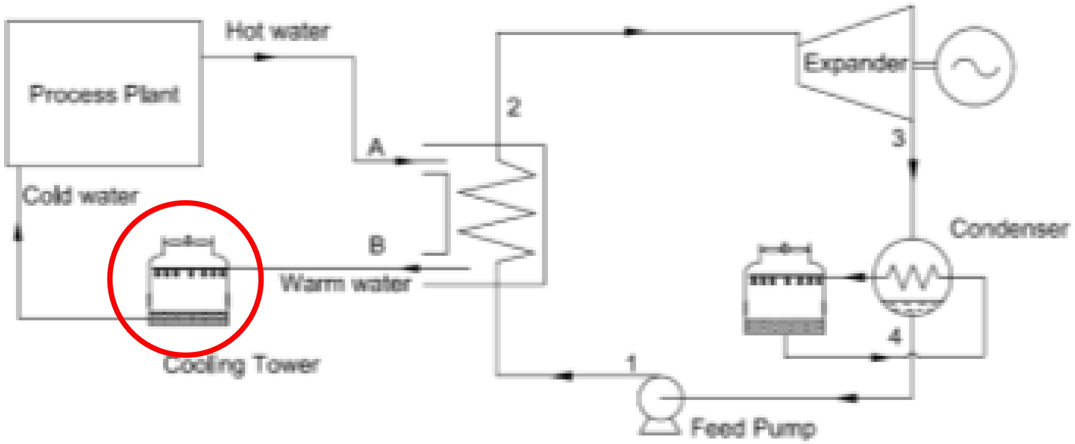
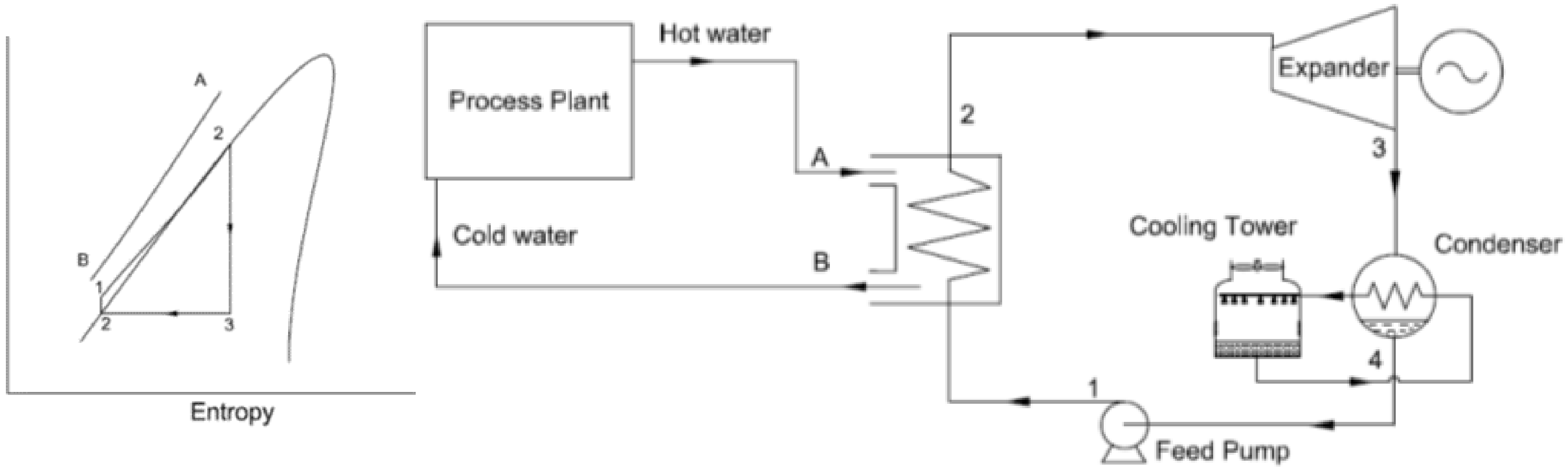
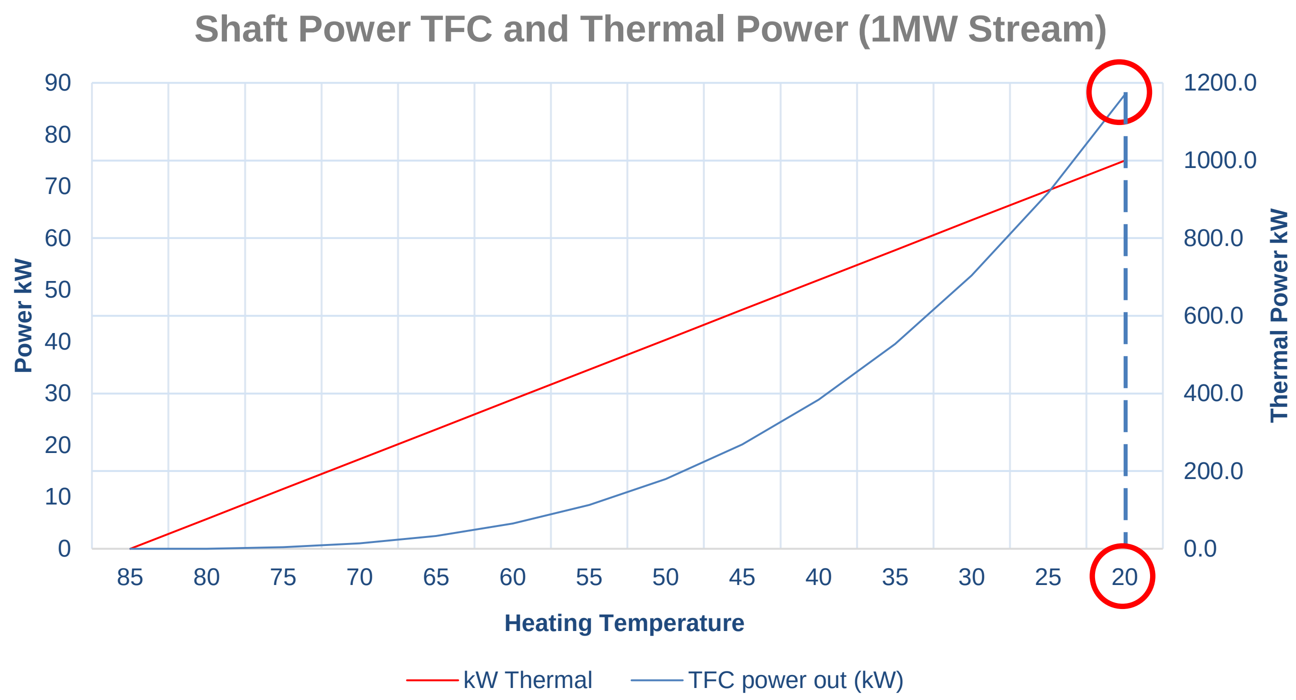




Trilateral Flash Cycle



Trilateral Flash Cycle



Tata Steel Application

Application	Flowrate (m^3/h)	Inlet Temperature (°C)	Outlet Temperature (°C)	Thermal Power of Waste Stream (kW)	Number of Hours Running	MWh per year generated
Tata Steel Heat Source A	33,820 (gas)	250	95	1478	7000	833
Tata Steel Heat Source B	63,000 (gas)	200	85	2415	7000	1001
Tata Steel Heat Source C	37.4 (liquid)	70	24	2000	8600	782

✓ Typical Heat Recovery Opportunity
833+ MWh Potential Generation

✗ Large modifications required
Undesirable payback

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✓
- Local cooling water available
- Commercially attractive location
- Opportunity for low-temp application

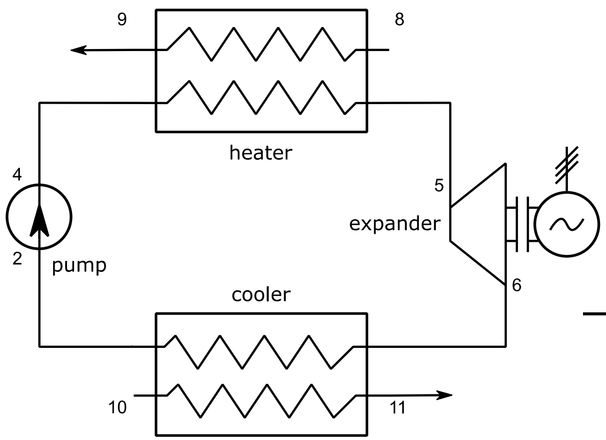
✗
- Diversion of streams required
- Currently unmetered

Tata Steel Design Specifics

Stream	Flowrate (kg/s)	Inlet Pressure (bara)	Outlet Pressure (bara)	Inlet Temperature (ºC)	Outlet Temperature (ºC)
Waste heat stream	10.39	4	3.5	70	24
Refrigerant stream	31.4	5.47	1.18	66	19
Condensing water stream	90.85	4	3.5	12	17

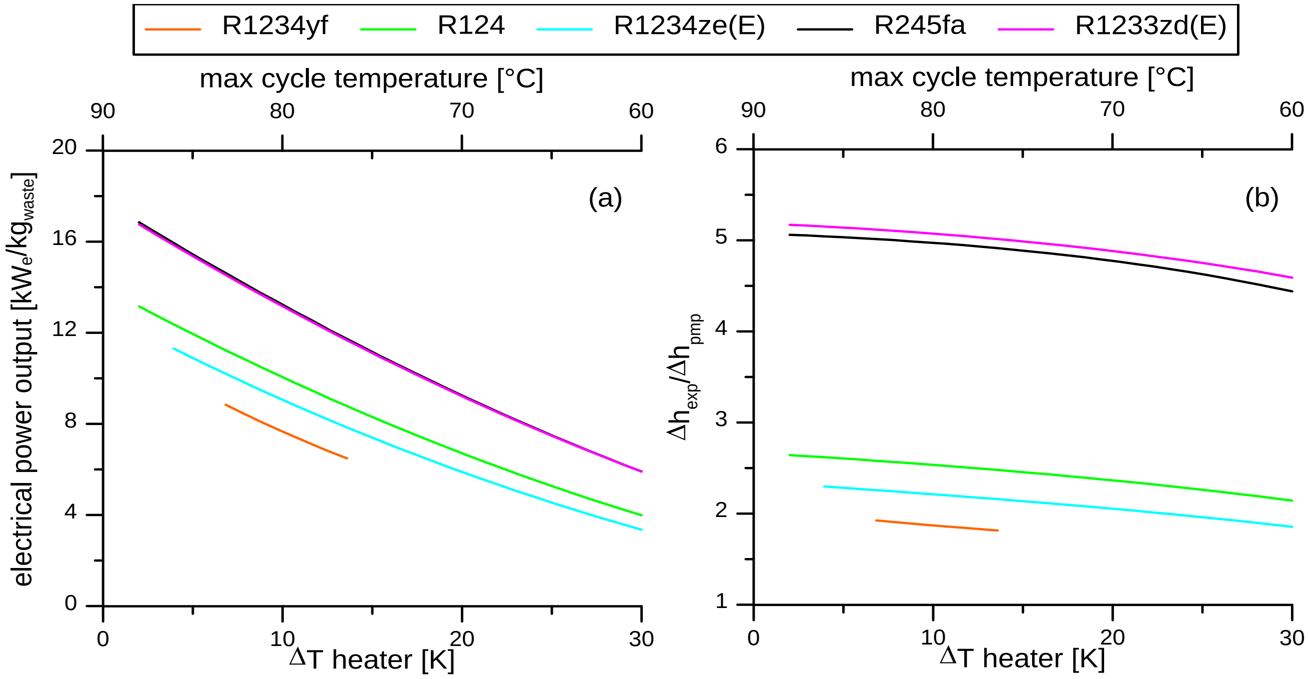
100kW Electrical Power Generation

Thermodynamic Modelling

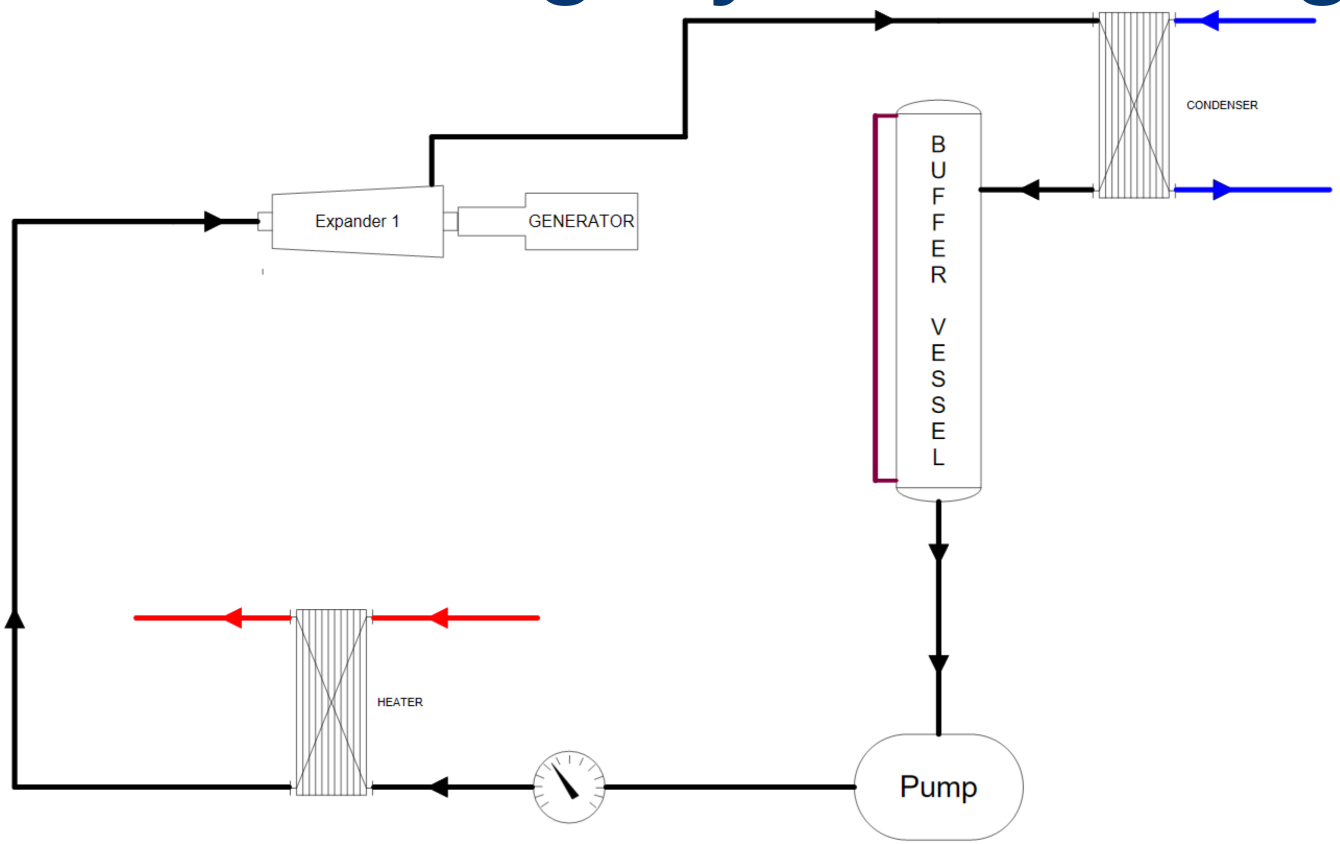


Heater	$\dot{m}_{hot} c_{p,hot} (T_8 - T_9) = \dot{m}_{wf} (h_B - h_A)$
Cooler	$\dot{m}_{cold} c_{p,cold} (T_{11} - T_{10}) = \dot{m}_{wf} (h_D - h_C)$
Pump	$\eta_{pmp} = (h_3 - h_2)/(h_4 - h_2)$
Expander	$\eta_{\exp} = (h_5 - h_6)/(h_5 - h_7)$
Cycle efficiency	$\eta_{cy} = \dfrac{\dot{m}_{wf} \left((h_5 - h_6) - (h_4 - h_2)\right)}{\dot{m}_{hot} c_{p,hot} (T_8 - T_9)}$
Overall efficiency	$\eta_{tot} = \eta_{cy} \eta_{mech} \eta_{el}$

Thermodynamic Modelling



Pilot Test Rig System Design



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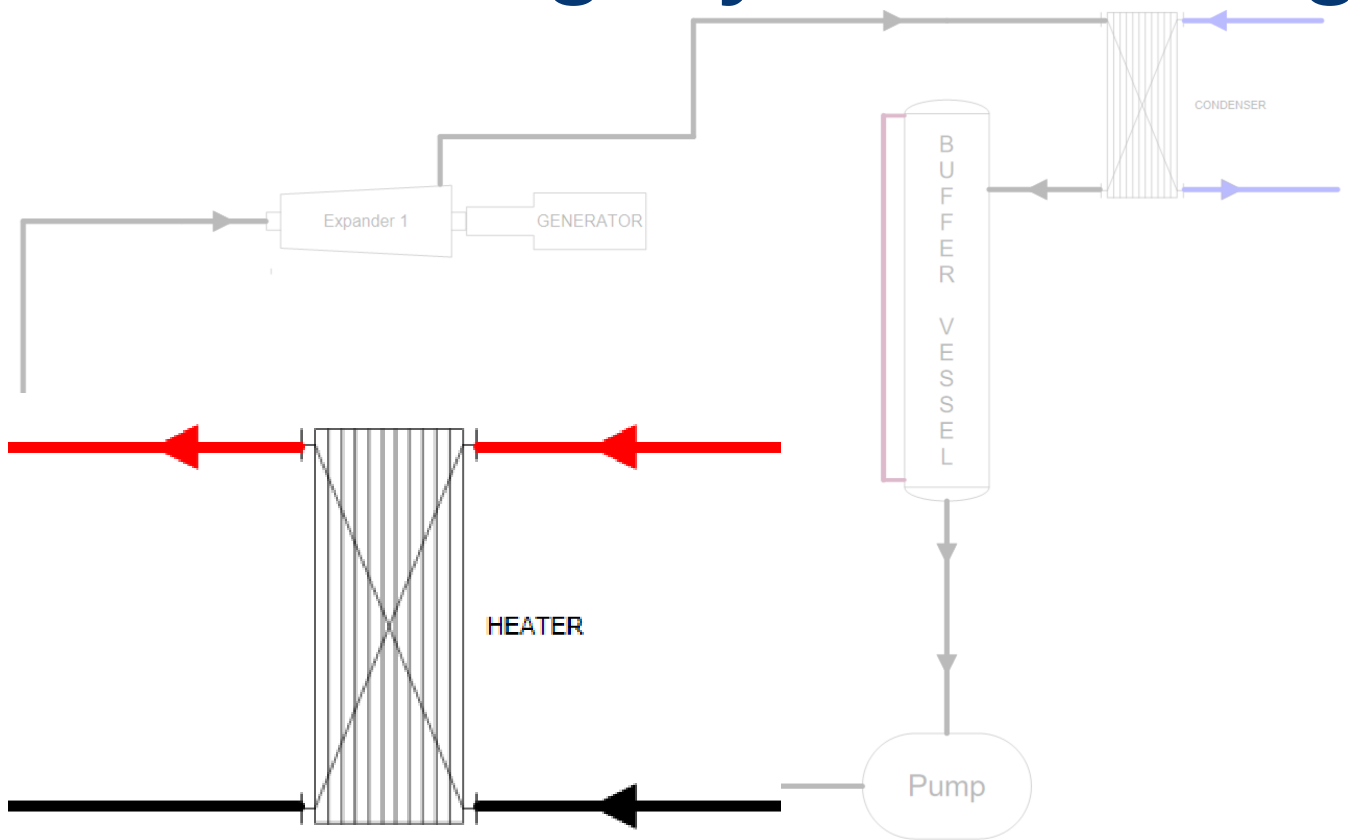

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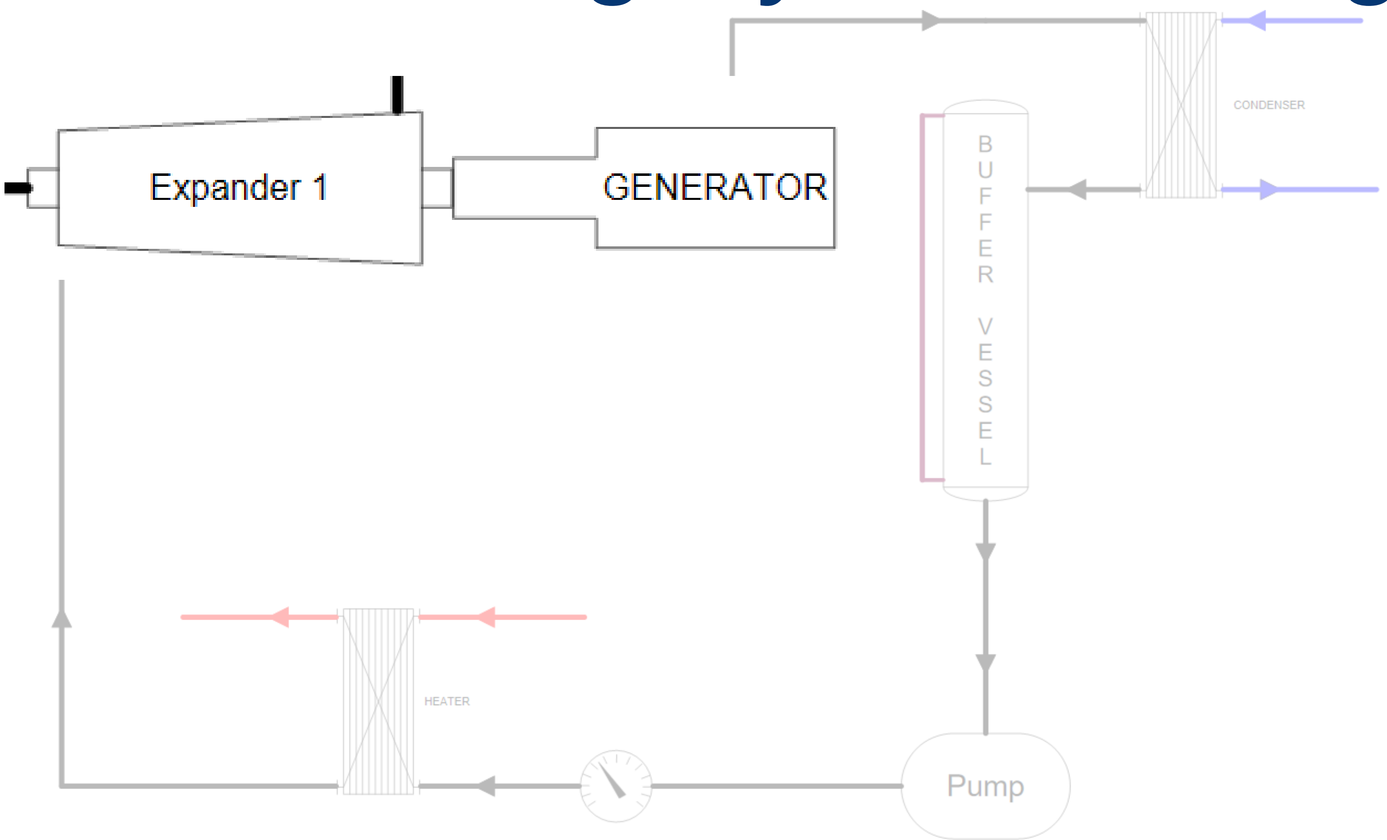

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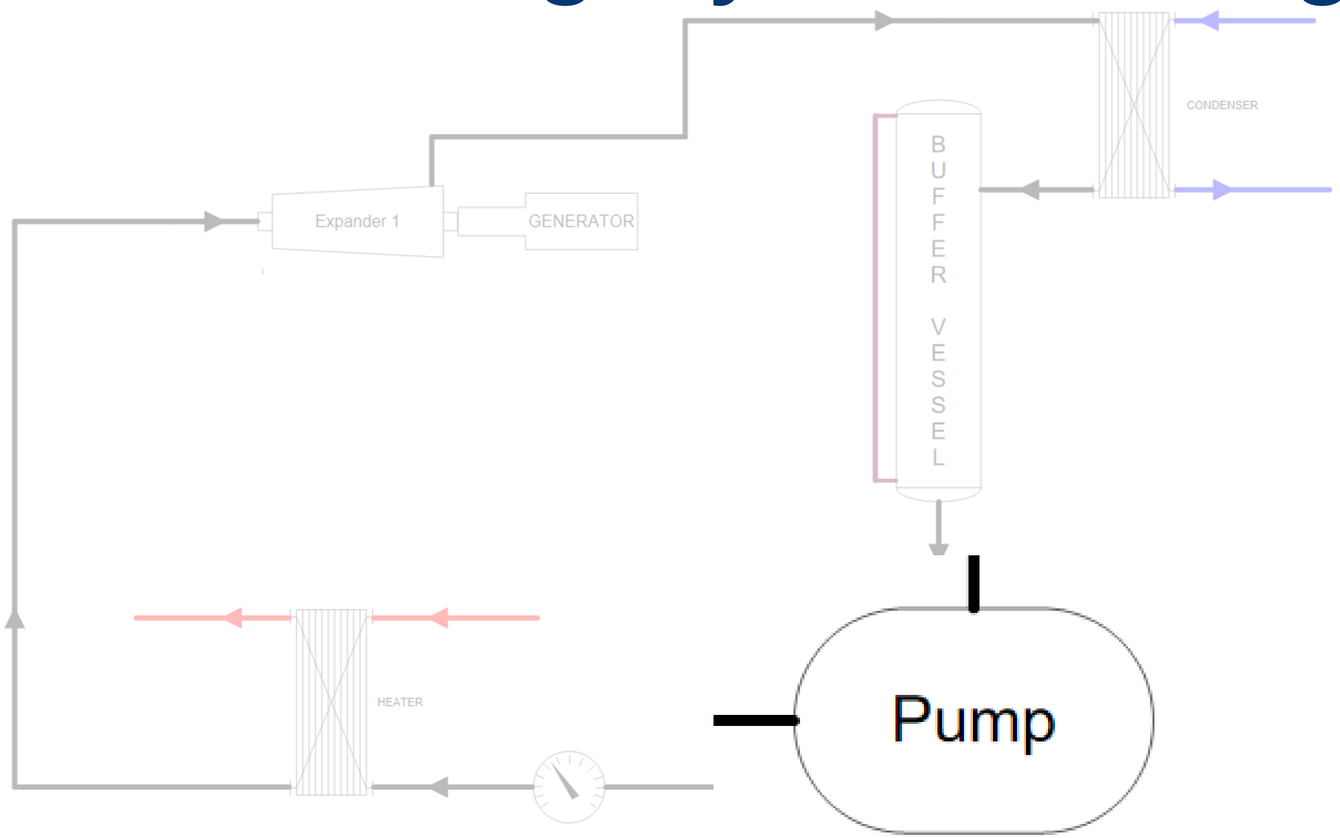

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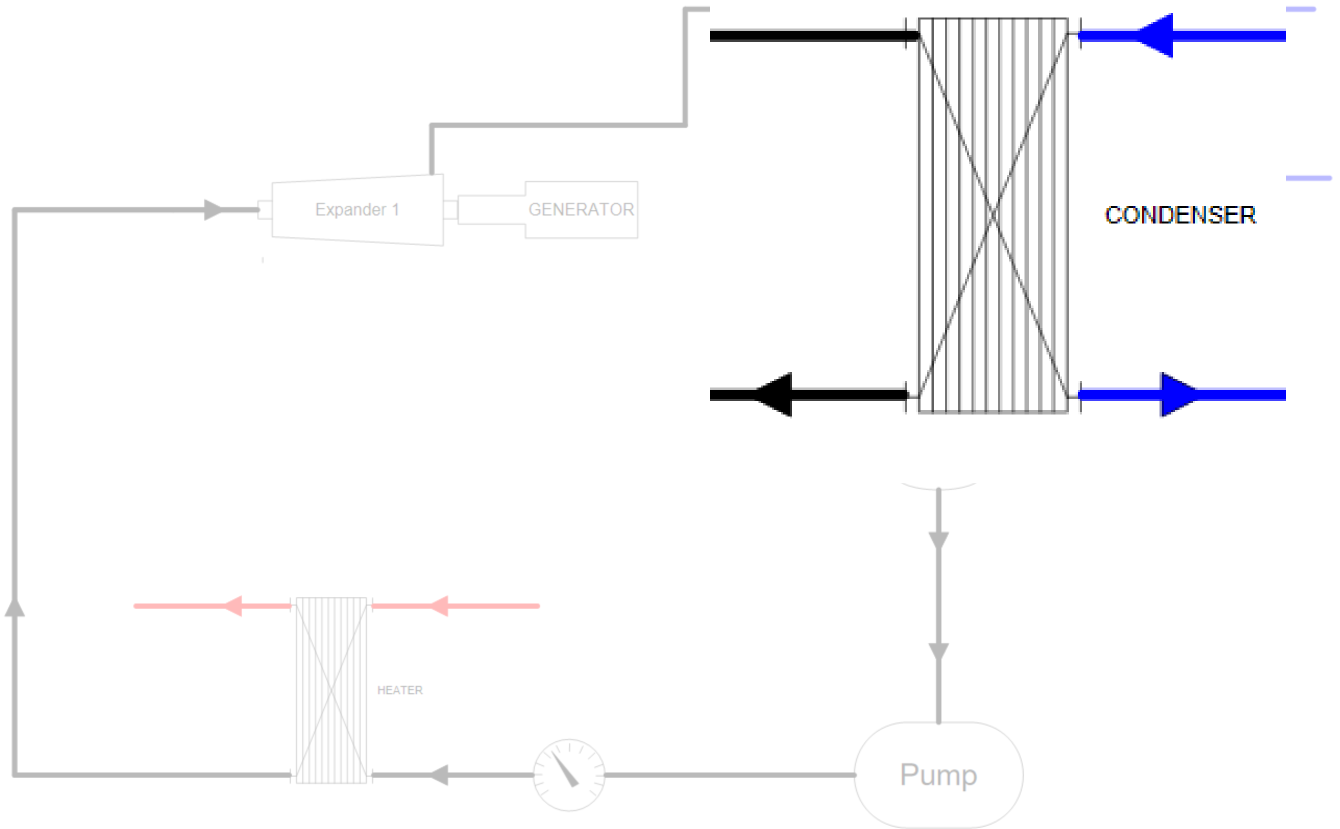
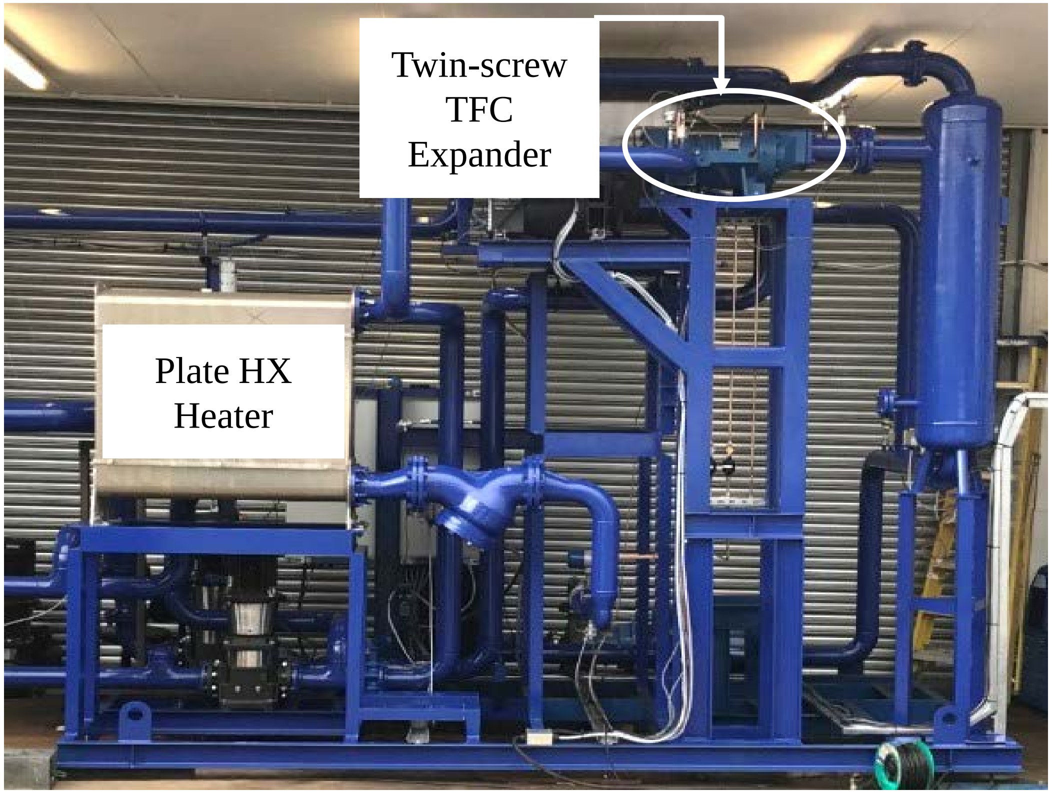
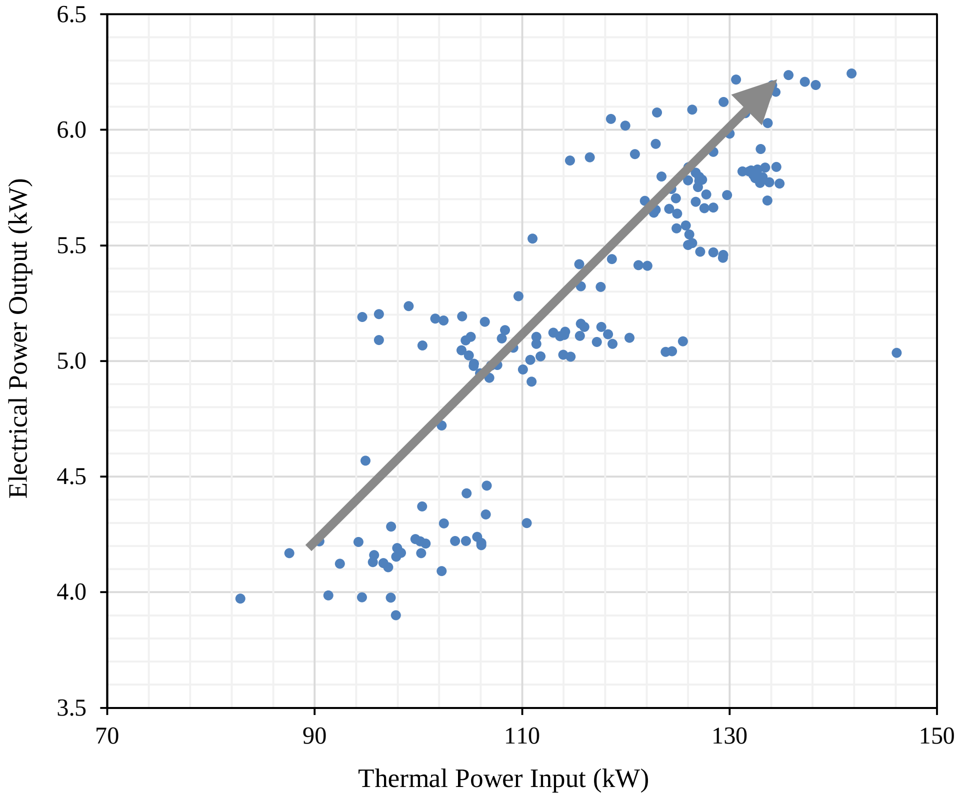


Pilot Test Rig Development



Initial Testing



Conclusion

Thermodynamic model created

Commercial business cases reviewed and Tata Steel demonstration site chosen

TFC system designed, built and run successfully

Preliminary tests demonstrate ability to reach **6.2kW$_e$** from **141.8kW$_t$**

Limitation in the control system

Further development under I-ThERM