Liquid-Flooded Ericsson Power Cycle

Nelson James, James Braun, Eckhard Groll, Travis Horton

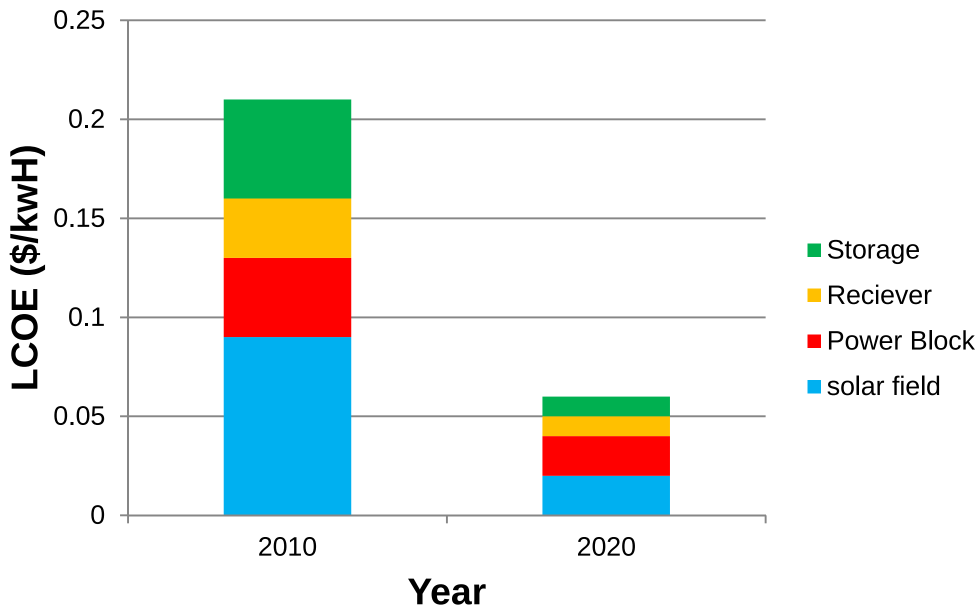
Ray W. Herrick Labs, Purdue University, West Lafayette, IN, USA

Presentation Outline

- Motivation
- Cycle Modelling
- Working Fluid selection
- Comparison to Alternative Cycles
- Summary

Motivation

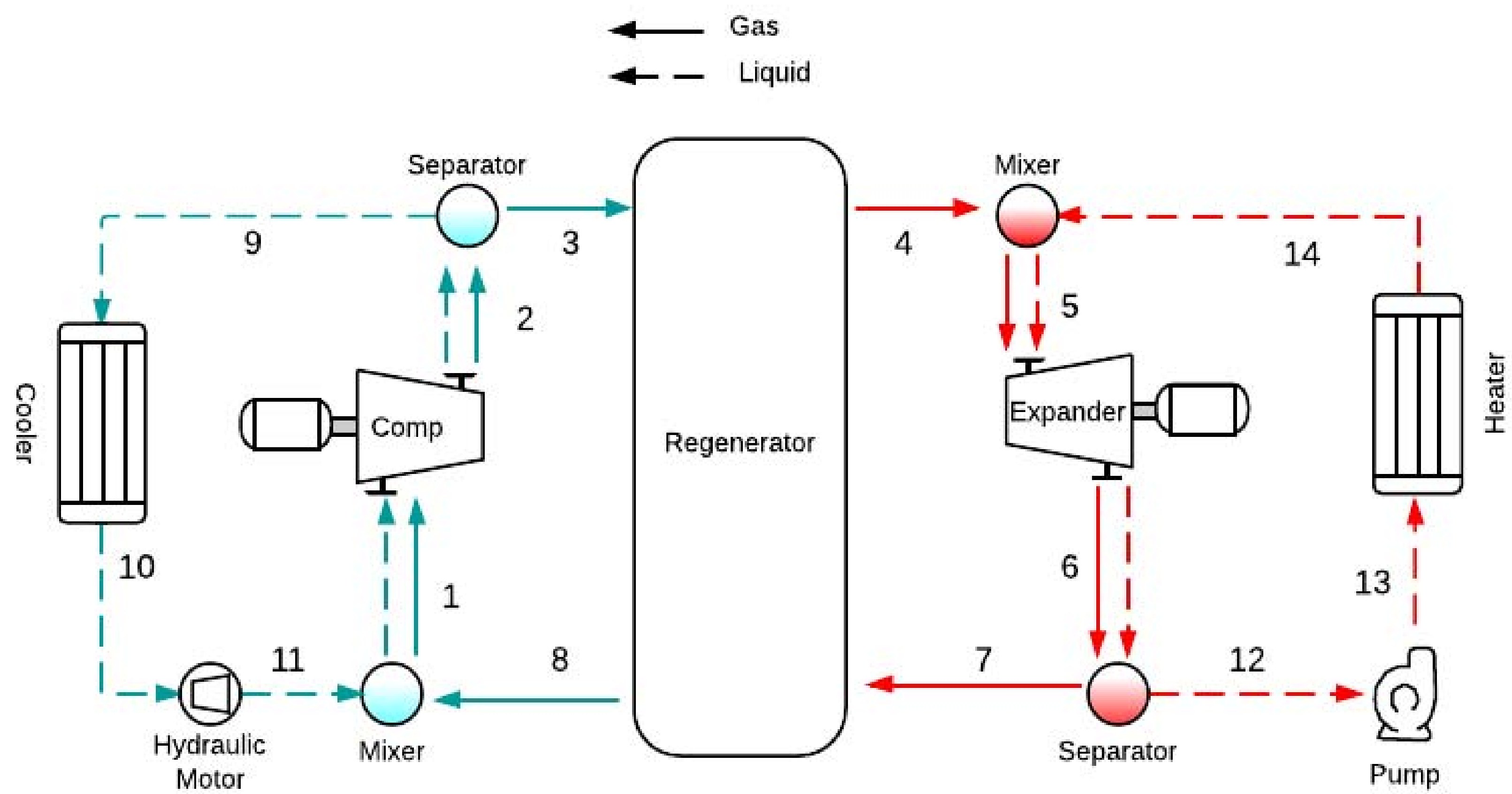
- Department of Energy SunShot Initiative



(U.S. Department of Energy, 2012)

- Liquid-Flooded Ericsson Cycle (Hugenroth, 2006) can serve as new high efficiency power block for CSP

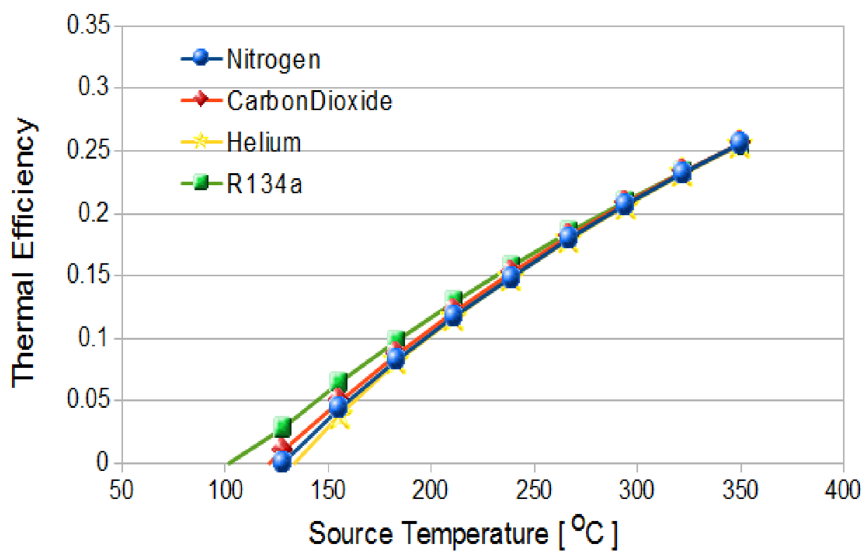
The Liquid-Flooded Ericsson Cycle



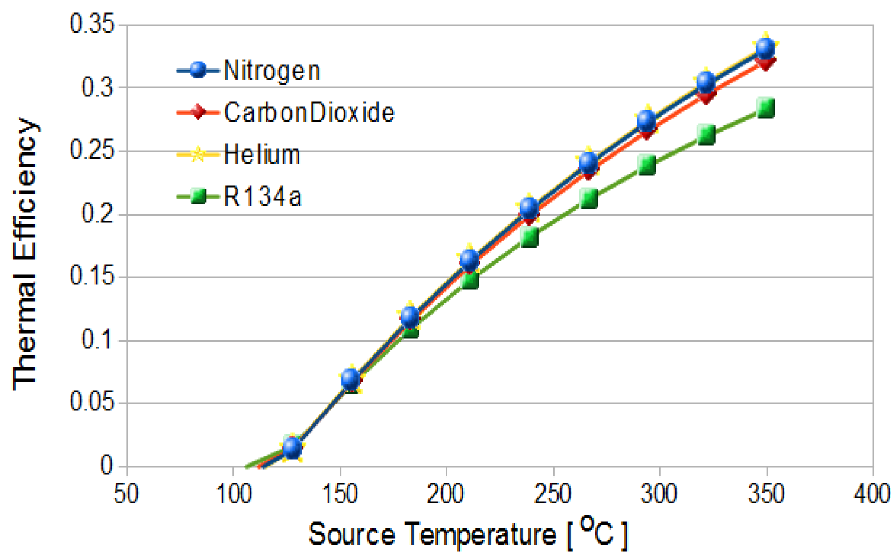
Cycle Modelling

- Assumptions
  - Heat rejection temperature of 43^{O}C
  - Regenerator effectiveness of 95%
  - Component adiabatic efficiencies of 90%
  - Pressure drops in lines and heat exchangers are neglected
  - All components are adiabatic
  - Gas is non-condensable in liquid and separation is complete
  - Gas and liquid are in thermomechanical equilibrium
- Thermodynamic equations of state found in EES
- When property data not available in EES, property formulas derived from thermophysical property data provided by manufacturers.

Working Gas Selection

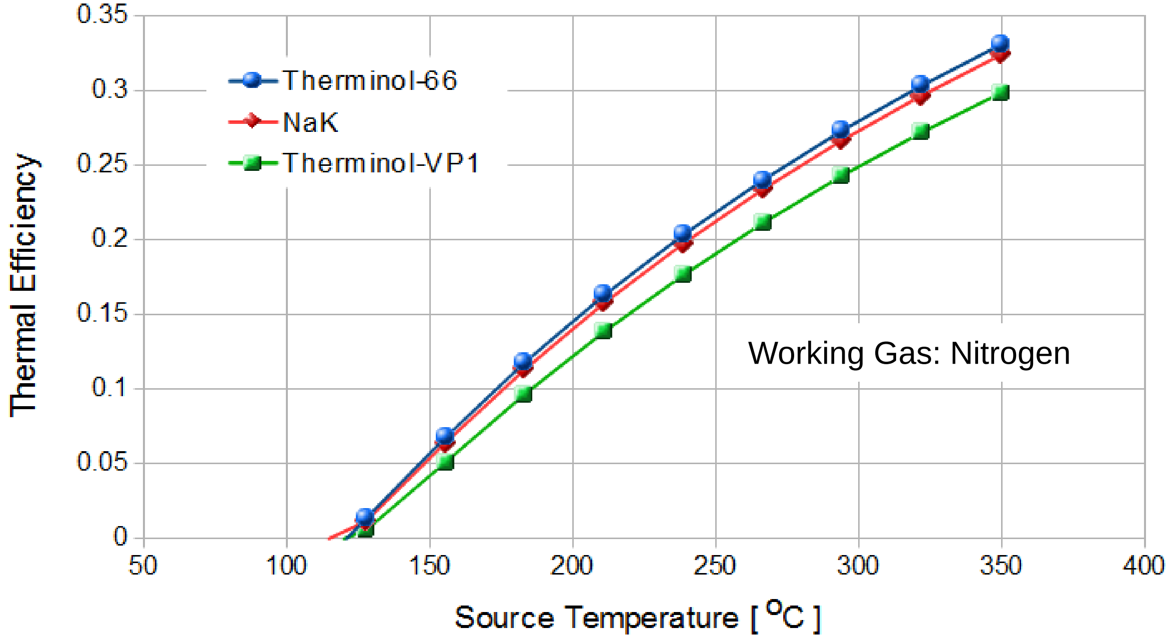


Thermal efficiency of regenerative Brayton cycle



Thermal efficiency of LFEC utilizing thermal oil

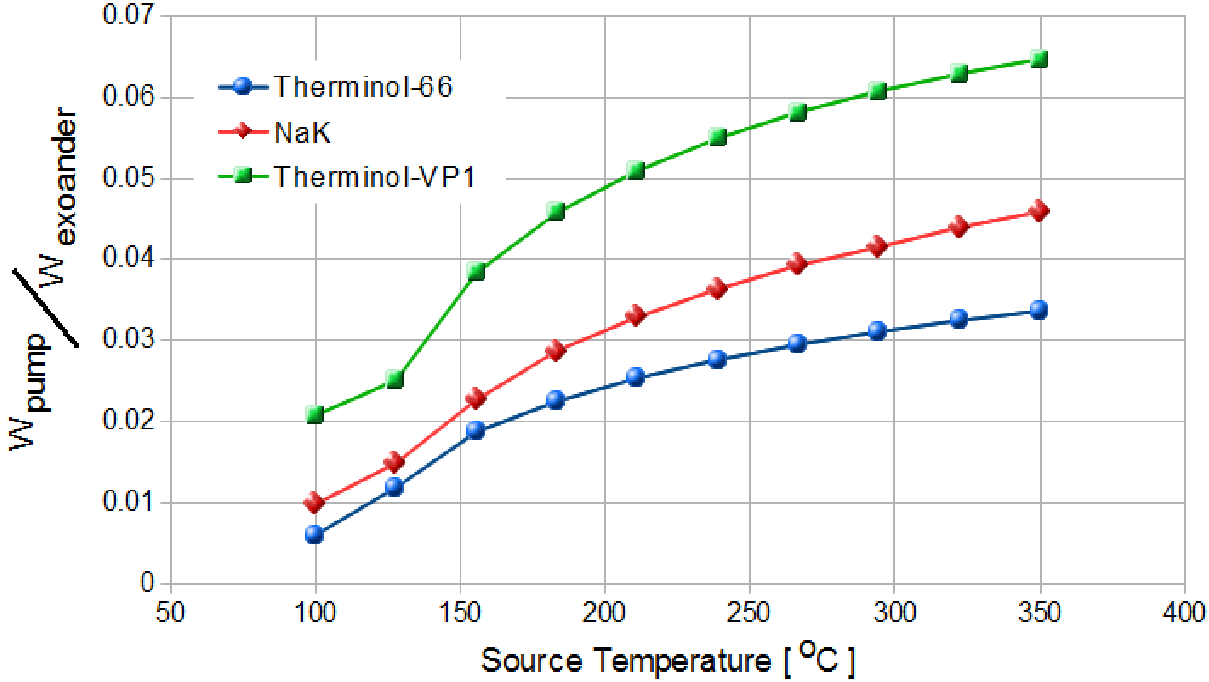
Flooding Liquid Selection



Liquid	T_{max} (^{o}C)	*Specific Heat (kJ/kg-K)	*Vapor Pressure (kPa)
Therminol VP1	400	2.33	1320
Therminol 66	370	2.01	130
$Na_{22}K_{78}$	785	0.88	0.13

*evaluated at 300^{o}C

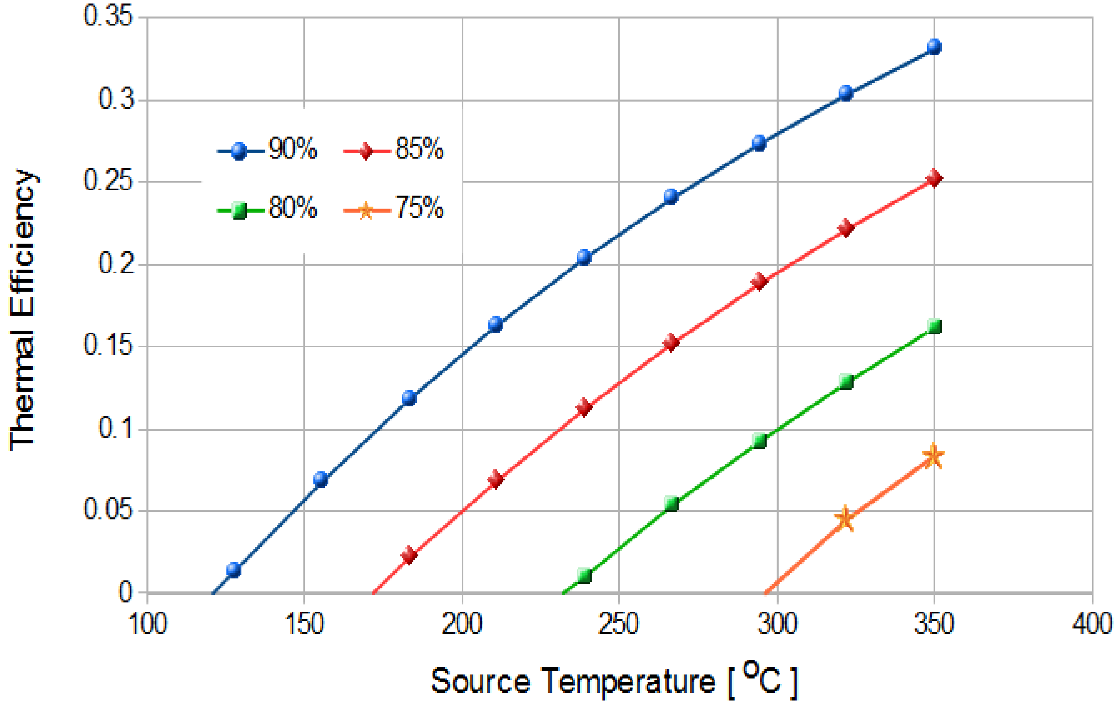
Relative Pumping Losses



$$W = \dot{m}v(P_2 - P_1) \qquad P_2 = P_r(P_1)$$

$$W = \dot{m}vP_1(P_r - 1)$$

Component Efficiency

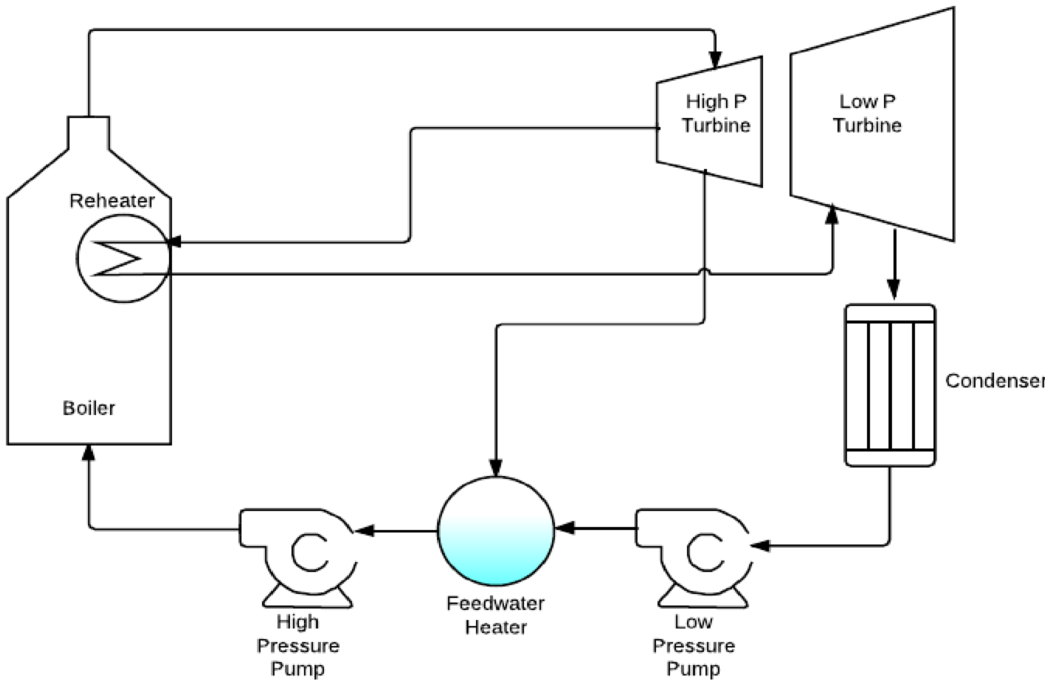


Working Gas: Nitrogen

Flooding Liquid: Therminol-66

- The LFEC's performance is highly sensitive to component efficiency.

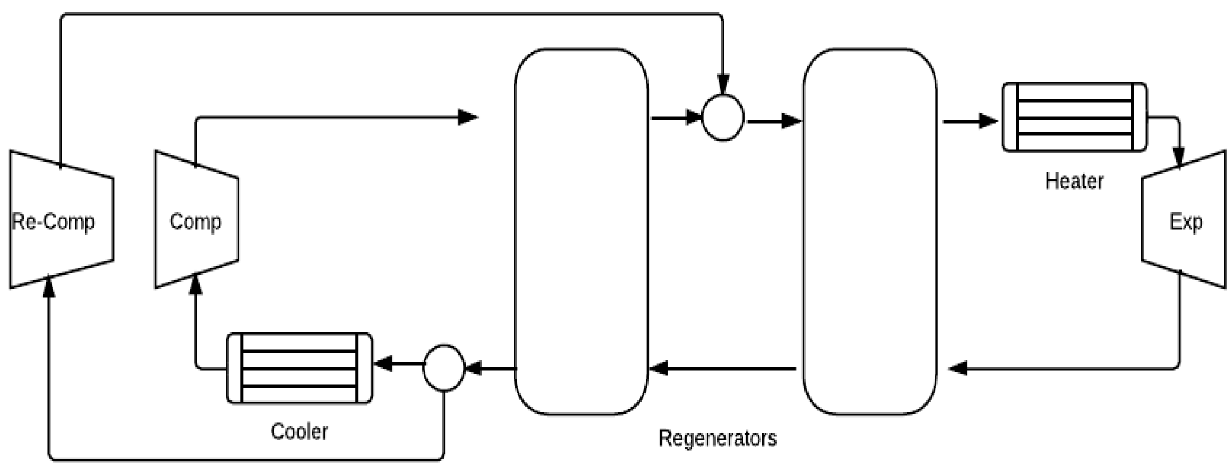
Cycle Comparisons: Rankine



Rankine cycle with Open feedwater heating and reheating

Working Fluid: Water
Sub Cooling: 5^{O}C
Component Efficiency: 90%

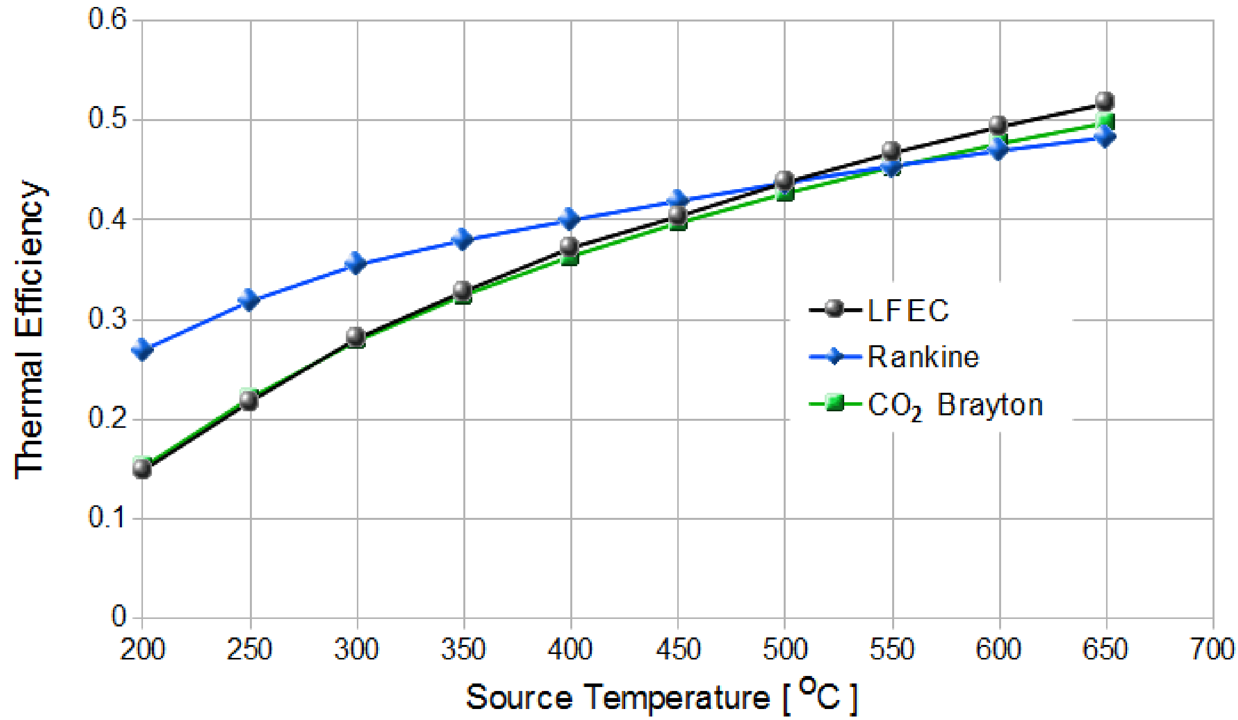
Cycle Comparisons: Brayton



Supercritical Brayton Cycle with recompression

Working Fluid: Carbon Dioxide
Min Regenerator Pinch Point: 5^{O}C
Component Efficiency: 90%

Cycle Comparisons



- The molten alloy NaK used as the LFEC flooding agent
- At elevated temperature LFEC provides higher thermal efficiencies
- LFEC operated at much lower pressures than Rankine and Brayton counterparts

Summary

- The Liquid-Flooded Ericsson Cycle has been investigated as a high efficiency power cycle for solar thermal power generation
- The performance of a number of working fluid combinations have been evaluated
- For high component efficiencies the LFEC becomes an attractive alternative for concentrated solar power generation.
- Future work is needed to develop high efficiency components capable of tolerating liquid flooding at temperatures of interest to CSP

Related Publications

Hugenroth, J. (2006). Liquid Flooded Ericsson Cycle Cooler. Mechanical Engineering. West Lafayette, IN: Purdue University.

U.S. Department of Energy. (2012). SunShot Vision Study

Thank you for your attention