Valuing power cycle options for CSP at the 100MWe scale

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Concentrated solar thermal power uses mirrors to focus sunlight and create heat, which can be stored and converted into usable electricity using a myriad of different power cycles. The variability in the operation and geometry of these cycles makes identification of the optimum solution a non-trivial problem. In this work, an evaluation criteria has been developed allowing power cycles to be ranked according to their ability to decrease the overall LCOE of a CSP system, taking into account the operating temperature, efficiency and capital cost of the infrastructure associated with different thermodynamic cycles.

1. Effect of power cycle efficiency

- Changes in the power block efficiency of a CSP plant result in changes in the required thermal output power of the field, receiver and storage system for constant nameplate electrical power output.
- Typically the power block accounts for only a small fraction (≈20%) of plant capital [1]. Thus, financial investment in an expensive and efficient advanced power block may be justified by the savings of decreased field, tower and storage size. For optimisation this needs to be numerically quantified.
- A sensitivity analysis has been carried out in NREL's SAM package to determine how changing the efficiency of a power block affects the size and operation of key system parameters, as well as the overall system LCOE.

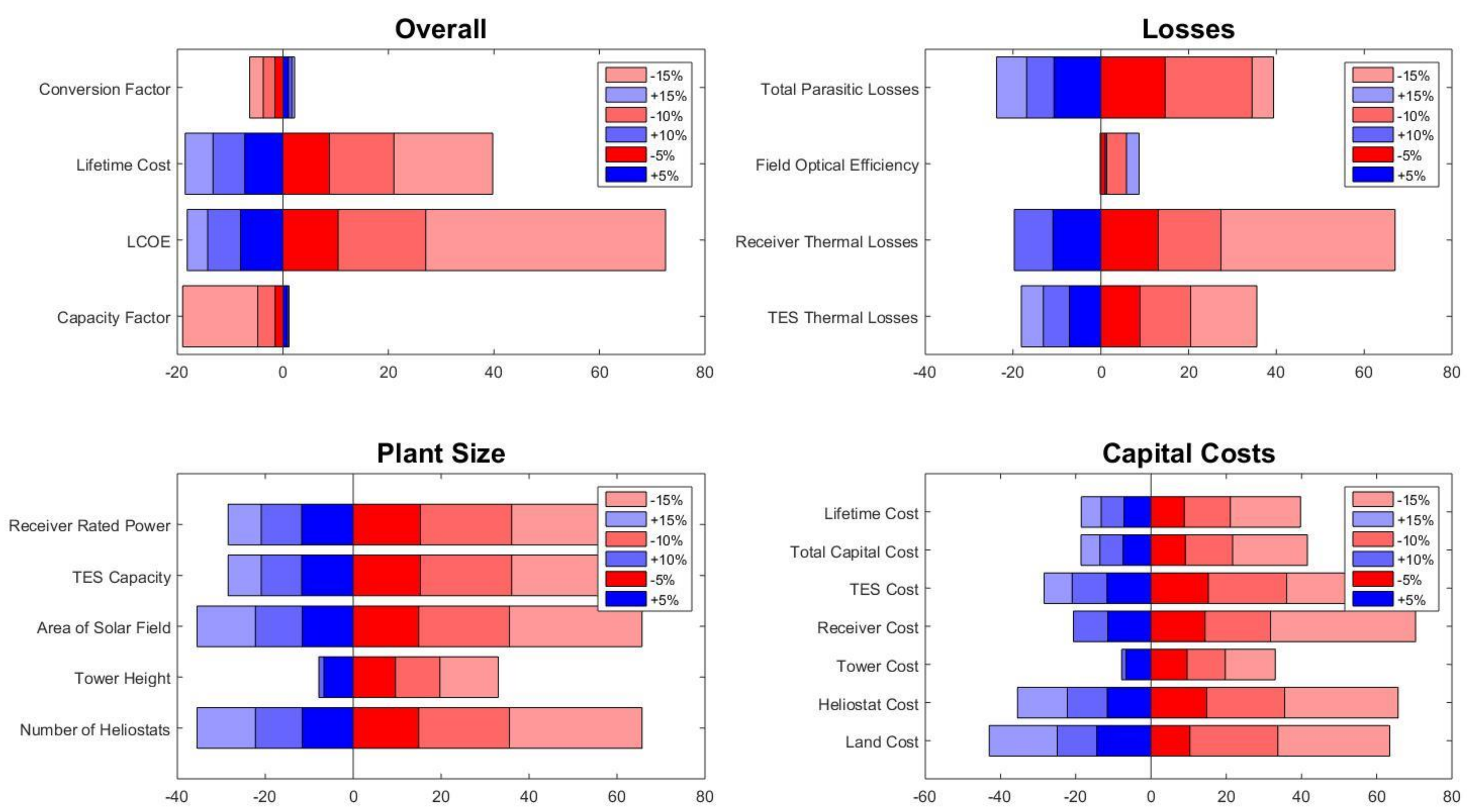

Figure 1: Sensitivity of key plant variables with respect to power block thermal efficiency

2. Effect of power cycle inlet temperature

- The effect of increasing the power block inlet temperature has been examined in the same manner. In this case plant sizing was kept constant, but material costs of plant components exposed to the high temperature heat transfer fluid have been adjusted to reflect the higher cost of more specialised high service temperature materials.

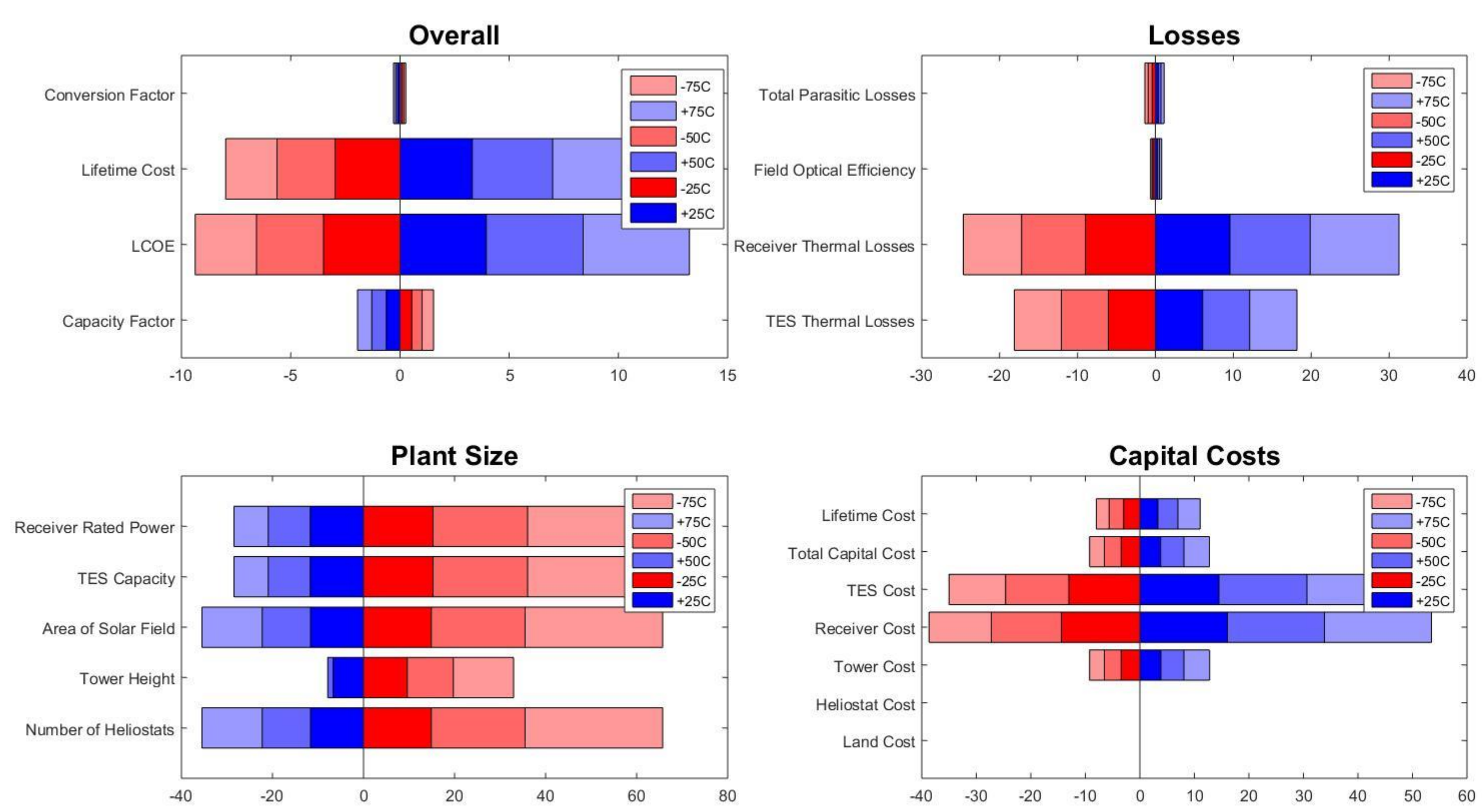

Figure 2: Sensitivity of key plant variables with respect to power block inlet temperature

3. Compound effects

- A result of Carnot's theorem is that power cycles operating at higher inlet temperatures are capable of higher thermal efficiencies than those closer to ambient. This causes a trade-off in power block selection between operating temperature and efficiency, with capital cost often depending on both.
- Because of the complexity of this relation, a more robust approach is to examine the effect of power block efficiency, temperature and capital cost simultaneously on the total system LCOE. Figure 3 displays the combined effect of power cycle efficiency and operating temperature (horizontal axes) on total system LCOE on the vertical axis.

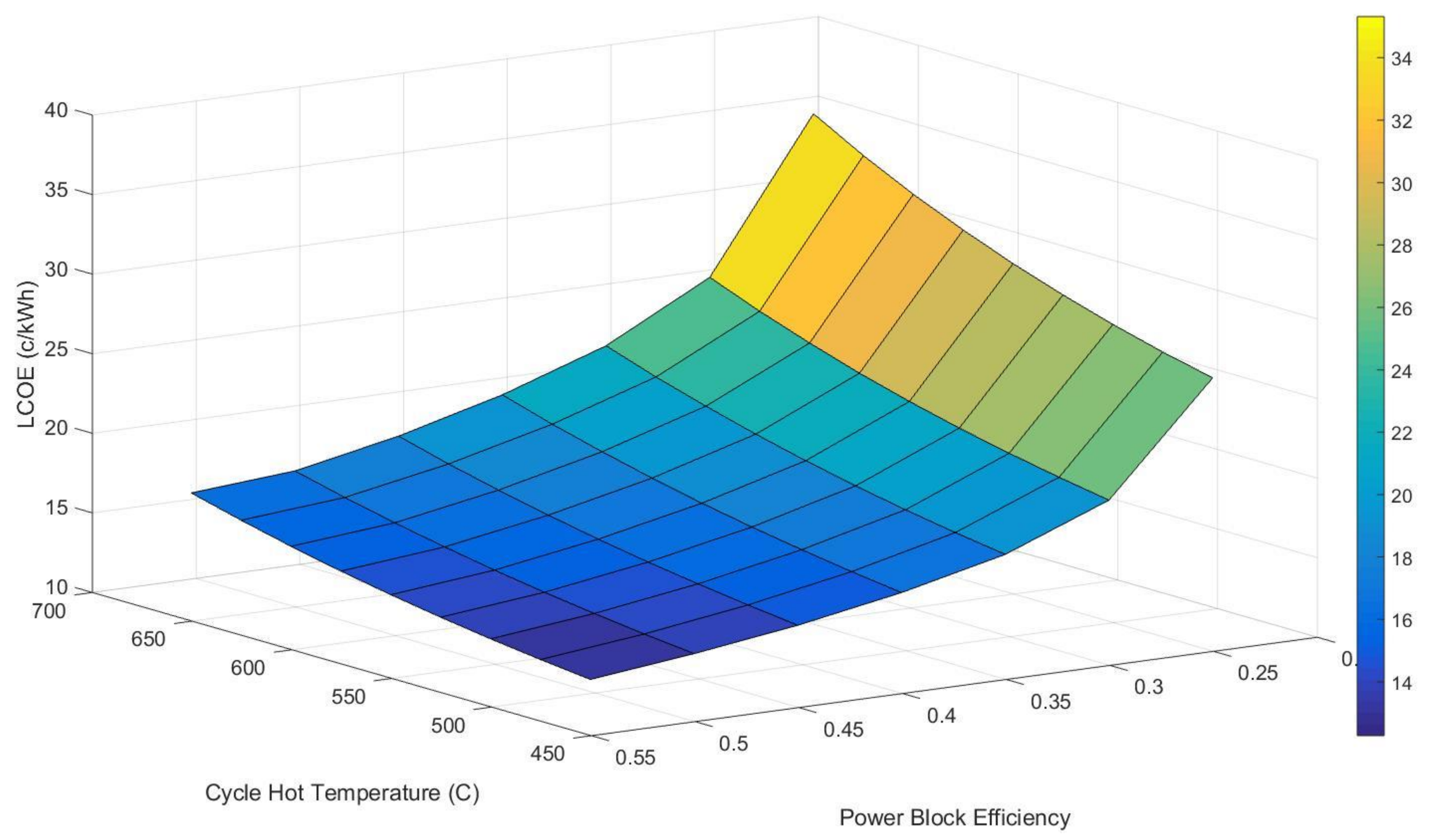

Figure 3: Total system LCOE as a function of Power block efficiency and operating temperature

4. Figure of merit:

- Using the sensitivity data, the system LCOE could be expressed as functions of power block efficiency, operating temperature, and capital cost.
- These sensitivities were used to develop weightings for an overall figure of merit in order to independently rank power block options according to their capacity to decrease the system LCOE.
- The formula for the figure of merit is expressed as:

$$z = \eta z_1 - T z_2 - C z_3$$

- η – power block thermal efficiency as a percentage
- T – power block inlet temperature in Celsius
- C – power block capital cost in million Australian dollars.
- The coefficients z_1, z_2 and z_3 were calculated from sensitivities to be:

$Z_1 = 7.173\times10^{-3}$, $Z_2 = 1.7\times10^{-4}$, $Z_3 = 1.53\times10^{-4}$

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REFERENCES
[1] "An analysis of the costs and opportunities of concentrating solar power in Australia", Hinkley et al., Renewable Energy 57, 2013

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