# Mechanical Engineering Doctoral Defense

## Design and Evaluation of a Concentrating Solar Power System with Thermochemical Water Splitting Process for the Co-production of Hydrogen and Electricity

School for Engineering of Matter, Transport and Energy

Vishnu Kumar Budama

**Advisor:** Dr. Nathan Johnson

## abstract

Thermodynamic development and balance of plant study is completed for a 30 MW solar thermochemical water splitting process that generates hydrogen gas and electric power. The generalized thermodynamic model includes 23 components and 45 states for quasi-steady state analysis used for system sizing and annual performance studies. Detailed consideration is given to water splitting reaction kinetics with governing equations generalized for use with any redox-active metal oxide material. Specific results for Ceria include reduction occurring in two solar receivers for an oxygen partial pressure of 10 Pa and particle temperature of 1773 K at a design point DNI of 900 W/m2. Sizes of the recuperator, steam generator and hydrogen separator are calculated at the design point DNI to achieve 100,000 kg of hydrogen production per day from the plant. The total system efficiency of 39.50% is comprised of 19.88% hydrogen efficiency and 19.62% electrical efficiency. Hydrogen production cost is $3.378 per kg for a 25-year plant life. Sensitivity analysis explores the effect of environmental parameters and design parameters on system performance and cost. System efficiency is relatively inelastic to recuperator effectiveness because 81% of excess heat is recovered from the system for electricity production. Increasing the water inlet pressure up to 20 bar reduces the size and cost of the super heaters but beyond 20 bar the increasing cost of pumps outweighs cost savings of super heaters. Improving recuperator effectiveness has high value, with a change in effectiveness from 0.7 to 0.8 contributing to a 2.0% increase in plant to achieve a 12.1% decrease in cost for delivered hydrogen.

March 29, 2018; 10 AM; ERC 593