# Enabling concentrating solar power in Australia: An investigation of the benefits and potential role of concentrating solar power and non-conventional fuel hybrid plants in Australia's transition to a low-carbon energy future

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**STATEMENT OF ORIGINAL AUTHORSHIP**

I certify that the work in this thesis has not previously been submitted for a degree and nor has it been submitted as part of the requirements for a degree.

I also certify that the thesis is an original piece of research written by me, except where noted in the text. Any help that I have received in my research work and in the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of candidate:

Juergen Heinz Martin Peterseim

I dedicate this thesis to love and hope:

love for my wife Anja and my children Lola and Leon, and

hope for a bright future for concentrating solar power in Australia.

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**LIST OF ABBREVIATIONS**

| | |
|---|---|
| AHP | analytical hierarchy process |
| ASTRI | Australian solar thermal research initiative |
| AU$ | Australian dollar |
| b | billion |
| CapEx | capital expenditure |
| $CO_2$ | carbon dioxide |
| CSP | concentrating solar power |
| DNI | direct normal irradiance |
| EfB | energy from biomass |
| EfW | energy from waste |
| EPC | engineering, procurement and construction |
| GIS | geographic information system |
| GWh | gigawatt hour |
| h | hours |
| HRSG | heat recovery steam generator |
| ISCC | integrated solar combined cycle |
| kW | kilowatt |
| kWh | kilowatt hour |
| LCOE | levelised cost of electricity |
| m | million |
| MLP | multi-level perspective |
| MSW | municipal solid waste |
| MW | megawatt |
| MWh | megawatt hour |
| MWth | Megawatt thermal |
| NEM | national electricity market |
| OpEx | operational expenditure |
| PPA | power purchase agreement |
| PV | photovoltaic |
| R&D | research and development |
| RDF | refused derived fuels |
| RECs | renewable energy certificates |
| RET | renewable energy target |
| SEGS | solar energy generation systems |
| SNM | strategic niche management |
| SRF | solid recovered fuels |
| t | tonnes |
| t/h | tonnes per hour |
| TES | thermal energy storage |
| TWh | terrawatt hour |
| US$ | U.S. dollar |

**ABSTRACT**

After decades of stability the Australian electricity market is undergoing changes. Current government targets aim to reduce greenhouse gas emissions by 5% and raise renewable electricity production to 45 TWh by 2020. In addition, increases to natural gas prices, aging generation assets and falling electricity demand have had an impact in recent years.

Uncertainties exist around current policies, including the carbon pricing mechanism and the renewable energy target, but in light of Australian and international ambitions to lower greenhouse gas emissions the deployment of renewable energy technologies is essential. In recent years wind and photovoltaic installations have shown the highest renewable energy growth rates while concentrating solar power has struggled, despite Australia having some of the best natural resources for concentrating solar power in the world and some selected government funding. Reasons for the slow uptake include the comparatively high cost and lack of financial incentives. While technology costs are expected to decrease by up to 40% by 2020 through deployment as well as research and development, other cost reduction options have to be identified to promote short-term implementation in electricity markets such as Australia where the wholesale cost is low. To overcome the cost problem and to address other relevant implementation barriers this research analyses the hybridisation of concentrating solar power with biomass and waste feedstocks.

The results of this research include:

- a recommendation for a categorisation system for CSP hybrid plants based on the degree of interconnection of the plant components
- the availability of combined resources to generate up to 33.5 TWh per year and abate 27 million tonnes $CO_2$ annually
- an analysis of the most suitable CSP technologies for hybridisation
- a technology comparison showing CSP cost reductions through hybridisation of up to 40%
- the identification of cost differences of up to 31% between different hybrid concepts
- an analysis showing that the current economic and policy settings are the most significant implementation barriers
- two case studies with different biomass and waste feedstocks requiring power purchase agreements of AU$ 100-155/MWh.

Based on the various benefits of concentrating solar power hybrid plants, this research analyses the potential role of this technological pairing in Australia's transition to a low carbon energy future. The research concludes that concentrating solar power hybrid plants, not only hybridised with biomass and waste feedstocks, can immediately enable a lower cost deployment of concentrating solar power facilities in Australia. The technology, deployment and operation of the first hybrid installations would provide market participants with valuable lessons and would have the potential to reconfigure the electricity market towards more sustainable generation. This could help promote the development of future low-cost concentrating solar power plants in Australia.

## FOREWORD

When I started considering a PhD candidature in 2010 I already had a few potential topics in mind that derived from observations I had made since entering the energy business in 2003. I worked as an industrial engineer in several areas, including project management and business development, for the German boiler design companies La Mont-Kessel GmbH & Co. KG and ERK Eckrohrkessel GmbH. This allowed me to develop a detailed understanding of current issues with solid, liquid and gaseous fuel fired water tube boiler systems, and of their impact on power plant efficiency, reliability and cost. My early focus was on energy from biomass and from waste systems as well as work on compact boiler and heat exchanger systems. After moving to Australia in 2007 I continued work in these fields but also expanded into heat recovery and natural gas fired boilers.

The good resource for solar energy in Australia, and my interest in Rankine cycle systems, shifted my attention to concentrating solar power. The technology was immediately appealing due to its futuristic appearance, its low carbon intensity, and the availability of mature equipment for most of the plant. In late 2010 I was awarded a UTS scholarship and since commencing this research in March 2011 my interest in concentrating solar power has continued to grow. The work I have done for my PhD has enabled me to expand my knowledge not only through theoretical work, such as a literature review and thermo-economic modelling, but also through the exchange of ideas and cooperation with industry partners, both those I had known previously and others I have met during the last three years.

I sincerely hope that this thesis will contribute to the deployment of concentrating solar power plants in Australia and I am looking forward to further engaging with the technology for the foreseeable future.