Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

ENGINEERING
EYOBUNJINELI
INGENIEURSWESE

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- **Research Field**
  Solar thermal energy, green hydrogen

- **General Description of Research Field**
  Solar thermal Energy and Green Hydrogen research, focusing on:

  * techno-economic analysis * systems engineering and optimization * heliostat design and mechatronics * thermofluid design of solar receivers and thermal energy storage systems * industrial application of solar thermal heat * power cycle design for CSP and high temperature heat pumps

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
A review of recent CSP cost reductions through a technical and economic assessment of recent tariff price bids Concentrating solar power (CSP) has seen considerable cost reductions over the past decade, with installed costs having halved according to IRENA (2021). Given our excellent solar resources in South Africa, CSP offers an excellent opportunity to address our current electricity supply constraints whilst establishing a significant manufacturing industry in the country. This project will study the landscape of recent international CSP projects to model and review the causes of the cost trends over the past 5 years and to assess the implications for CSP technology deployment in South Africa. Technical and economic models of each of the recent CSP plants will be built in NREL's System Ad- visory Model and compared with published performance data on the plants. The economic model will be used to calculate the lev- elised cost of electricity and bid tariffs. The cost model must finally be fine-tuned to accurately predict the bid tariffs of the modelled projects. This cost model can then be used to forecast future cost trends for CSP in South Africa. **Requirements:** none	✓	✓		

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Fuel-fired augmentation of CSP plants in South Africa as back-up for poor solar days Given our excellent solar resources in South Africa, concentrating solar power (CSP) offers an excellent opportunity to address our current electricity supply constraints whilst establishing a significant manufacturing industry in the country. Because a CSP plant includes a significant amount of thermal energy storage it can dispatch power throughout the night. Even in the desert locations such as the Karoo of the Northern Cape where CSP plants are lo- cated, there are periods of overcast or cloudy weather that would interrupt generation. A CSP plant that includes a fuel-fired sys- tem that would be able to continue generating electricity during periods of low solar resource, making CSP a firm and depend- able power source. This project will study the technical and eco- nomic aspects of such a fuel-fired augmentation of CSP. The project should consider biomass and fossil fuel sources and investigate the best power cycle configuration (direct integration through the ad- dition of a fuel-fired boiler, or an integrated solar combined cycle mode obtained by adding an open cycle gas turbine to the existing steam Rankine cycle of the CSP plant). **Requirements:** thermodynamics	✓	✓		
Design and configuration of solar thermal multi-tower field layout Central receiver CSP plants, also known as power towers, are built at very large scale (typically 50 to 100 MW or more). They re- quire significant capital, and the 150- to 250-metre-tall tower can take up to two years to build. Conversely, utility photovoltaic (PV) plants can potentially be constructed within six months and re- quire much less upfront capital. The intent of this project is to design and optimise a CSP plant composed of an array of heliostat field/tower modules (multi-tower system) that can be constructed quickly and sequentially, and that all supply a single power plant. Such a system has the potential to start generating electricity (and hence revenue) after completion of the first module of the array. The study will develop a simulation of the multi-tower includ- ing optical and thermal components, together with a cost model, will be used to optimise the configuration of the system. See e.g. https://doi.org/10.1063/5.0028916 **Requirements:** none		✓	✓	✓

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Structural design and testing of advanced polygonal heliostat facets for advanced assembly line manufacturing A heliostat is a mirror assembly with dual-axis tracking that focuses solar irradiation on to the central receiver of a concentrating solar power (CSP) plant. Heliostats are high precision "robotics" systems that are costly to manufacture and constitute roughly 40% of the capital of a CSP plant, and a significant portion of the heliostat cost is the structure that supports and moves the aligned heliostat facets. Significant cost reductions in heliostat manufacture can possibly be achieved by applying a design for manufacturing approach on a novel heliostat facet sandwich structure and high reflectivity anodised aluminium sheeting, configured into a polygonal shape for increased optical and structural performance. The structural design, considering assembly line manufacturing, will be completed in the study followed by the fabrication of a large-scale facet for characterisation and testing. See e.g. http://dx.doi.org/10.1016/j.solener.2017.03.029 and https://doi.org/10.1063/1.5067066. **Requirements:** none		✓	✓	✓
Design and testing of a winch actuated heliostat A heliostat is a mirror assembly with dual-axis tracking that focuses solar irradiation on to the central receiver of a concentrating solar power (CSP) plant. Heliostats are high precision "robotics" systems that are costly to manufacture and constitute roughly 40% of the capital of a CSP plant, and a significant portion of the heliostat cost are the two actuators that perform the dual axis tracking of the sun. Typical commercial heliostats use worm drives for the azimuth drive and linear actuators with lead screws for the elevation drive. This study will design, build, and test a heliostat using a novel winch and cable actuation. See safeTrack H4™ - Trackers - Products - Ideematec safeTrack H4™ - Trackers - Products - Ideematec for a similar winch actuation concept applied to single-axis PV tracking. **Requirements:** good mechatronics topics, but suitable for mechanical stream students as well		✓	✓	✓

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Thermofluid design and modelling of a thermosyphon liquid sodium receiver concept The central receiver is a critical component of a power tower concentrating solar thermal power system, cf. https://www.solarpaces.org/how-csp-works/. Solar energy is concentrated onto heat exchanger tubes in the receiver, where the heat is typically carried away by a heat transfer fluid such as molten nitrate salt or used to raise steam. The design of the receiver is complicated by the high temperatures and very heat fluxes (MW/m2) involved, and the need to make sure that the structural and material properties of the heat exchanger tubes of the receiver do not deteriorate. A novel concept using a loop thermosiphon (https://www.1-act.com/products/loop-thermosyphon/) has been proposed as an alternative to the conventional design. In the loop thermosyphon a working fluid evaporates to carry heat to a heat exchanger sur- face where is condenses, setting up a loop that can transport heat with no active pumping of the working fluid. The objective of this project is to develop a conceptual design and thermofluids model of a loop thermosyphon based solar receiver, using boiling liquid sodium metal as the working fluid. Students with a more practical inclination build and test a working prototype loop thermosyphon receiver that operates at a lower temperature, and that uses a safer working fluid. Co-supervised with Prof Ryno Laubscher. **Requirements:** CFD experience not required, would be an advantage		✓	✓	
Comparison of electrification of the South African Railroad network to the use of hydrogen fueled locomotives Railroad networks around the world have moved to electrification to eliminate greenhouse gas emissions. However, electrification of the networks involves the installation and maintenance of large systems of electric power distribution systems with the associated risk of restrictions on usage from vandalism or natural events. Traditionally, for many areas, the choice has been the usage of diesel fuelled locomotives over some or all the system. The South African rail system has challenges unique to this country. The limits of an economically justifiable electrified system should be investigated, and the economic analysis of hydrogen fuelled locomotives quantified. The use of hydrogen fuelled locomotives will require an entirely new infrastructure for production, storage, and distribution of the fuel. This fuel supply must be considered in the choice to use hydrogen fuel. As the development of this application proceeds, this supply question could determine its economic value to the user and to the transition to a sustainable energy system. Co-supervised with Dr Steve Clark. **Requirements:** none		✓		

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Exploitation of excess renewable generation Solar and wind generation are well known to be variable and dependent on weather rather than demand. Major usage of these resources requires overbuilding of the system to account for times when they do not meet the demand. The focus in designing these systems has been in meeting the times when they fail to meet the demand. Little effort has been expended in finding viable uses for the excess power that will be generated from these systems. Systems around the world are already faced with times where excess generation must be handled, leading to curtailment or negative prices. This situation will grow as the transition continues. Modelling indicates that this excess production could be over 30% of the overall energy generated with a system having generation completely from wind and solar resources, which in South Africa would be over 100 TWh of available energy annually. Any use of this excess energy must have the flexibility to use the energy when it is available with daily and seasonal variation. With little research and development in this area, there is a very large scope for innovation and open thinking in identifying and developing opportunities. Co-supervised with Dr Steve Clark. **Requirements:** none	✓	✓		