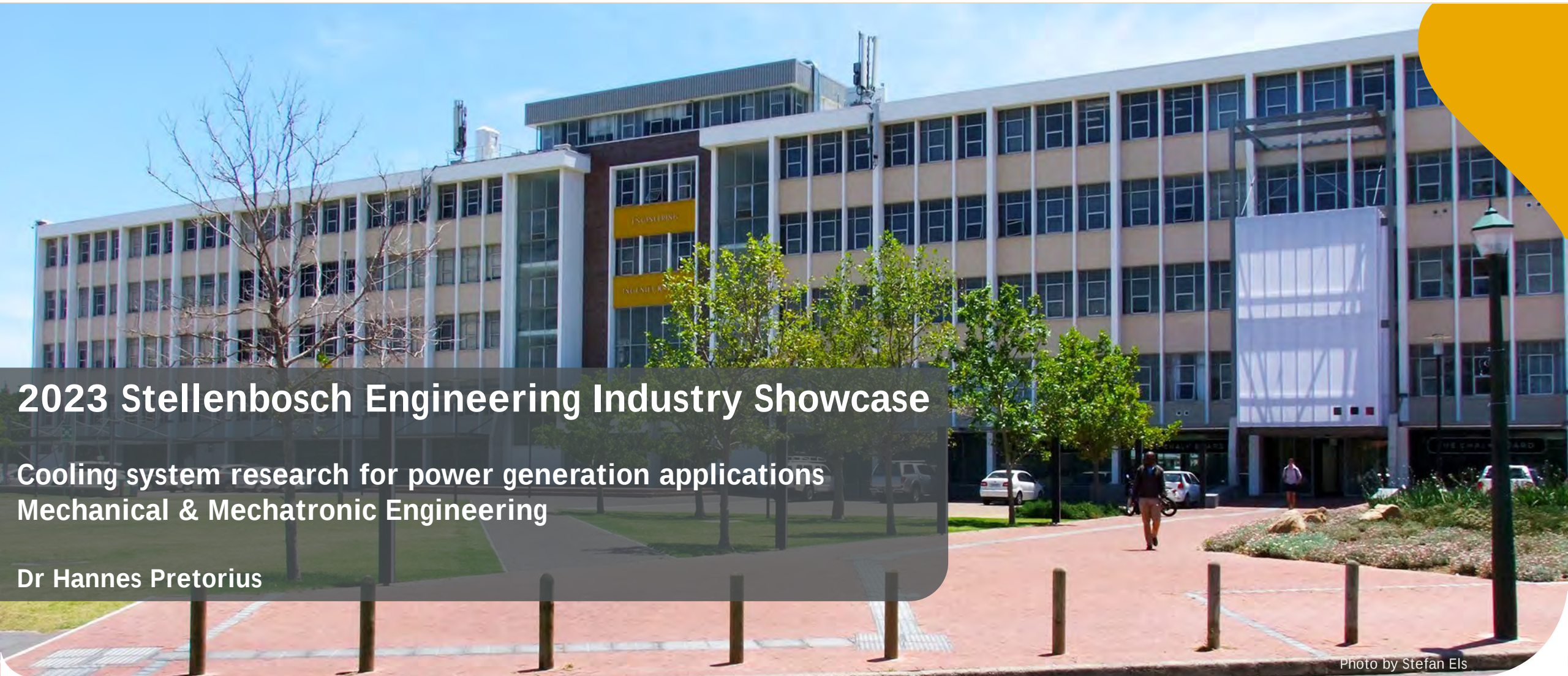


THERMO-COOLING IN ENERGY GENERATION



2023 Stellenbosch Engineering Industry Showcase

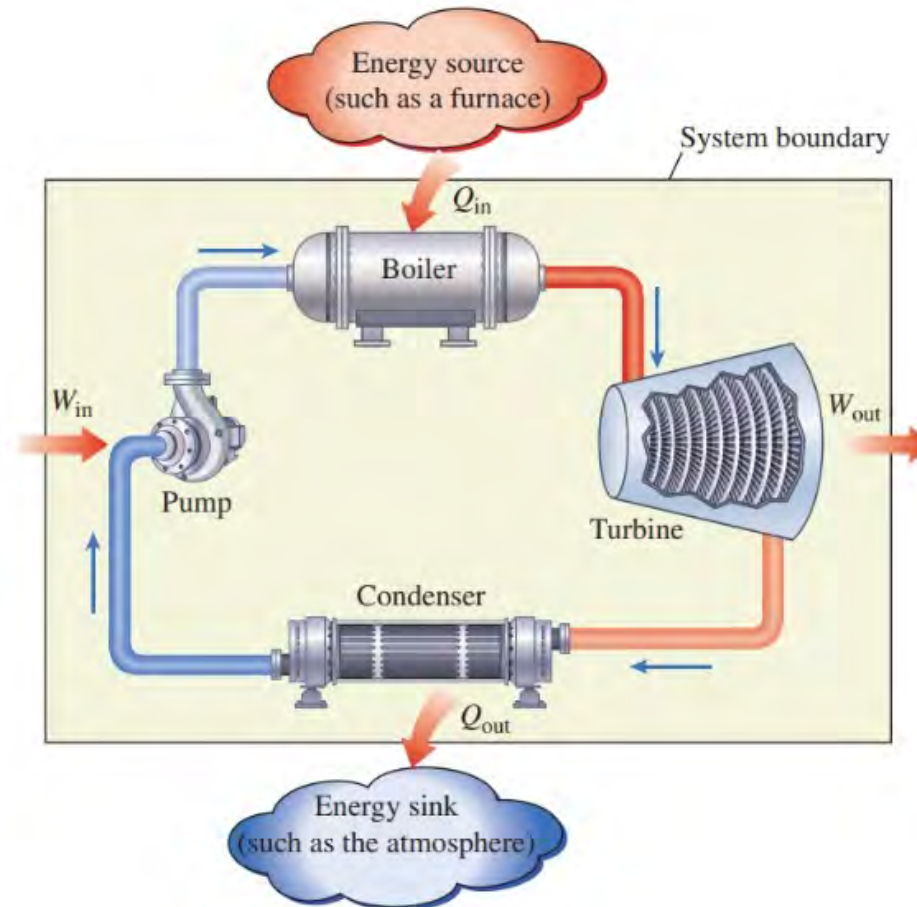
Cooling system research for power generation applications
Mechanical & Mechatronic Engineering

Dr Hannes Pretorius

Photo by Stefan Els

What is thermo-cooling?

- The heat rejection process at cold end of a power cycle



(Cengel et al., 2019)

Typical methods: wet

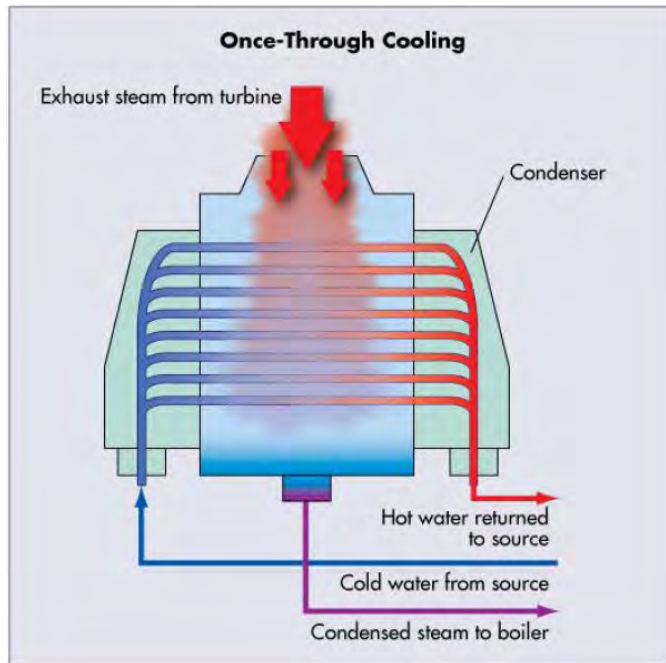
- Wet cooling
 - Once-through cooling
 - Natural draft
 - Mechanical draft



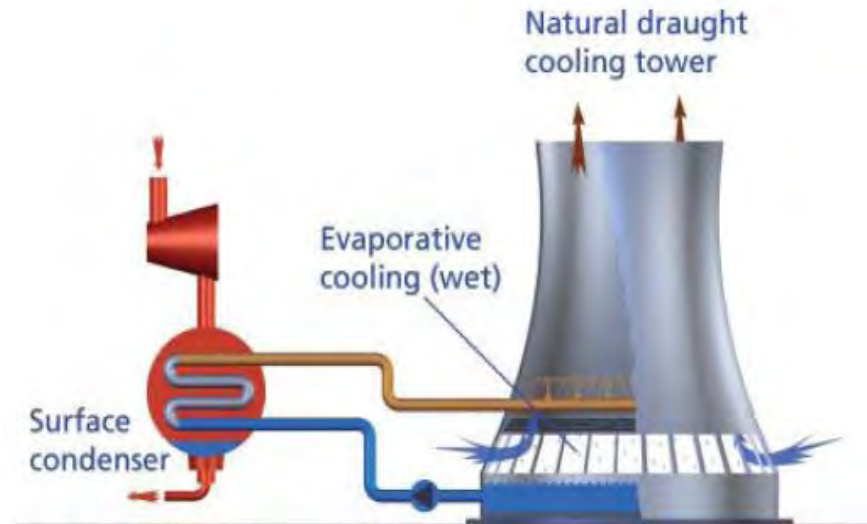
(volksrust.blogspot.com)



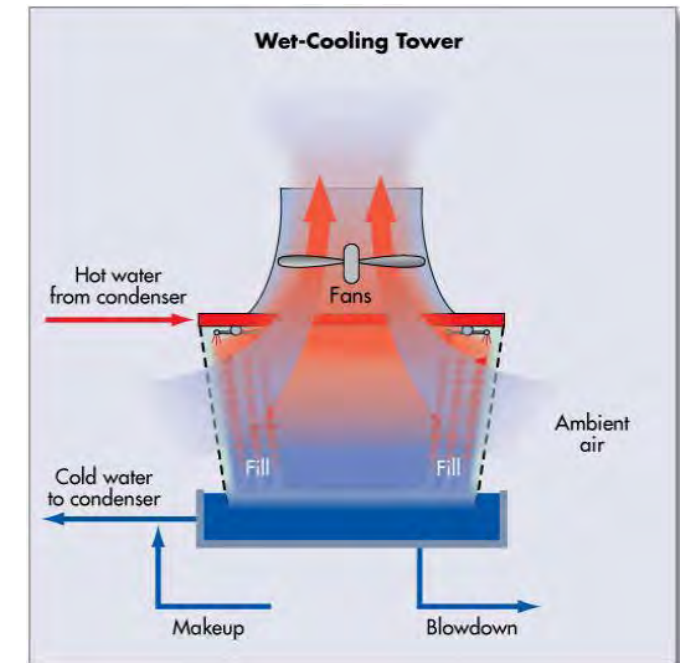
(fansct.com)



(EPRI, 2013)



(Guan & Gurgenci, 2009)



(EPRI, 2013)

Typical methods: dry

- Dry cooling
 - Mechanical draft
 - Natural draft
 - Indirect or direct



(www.polity.org.za)



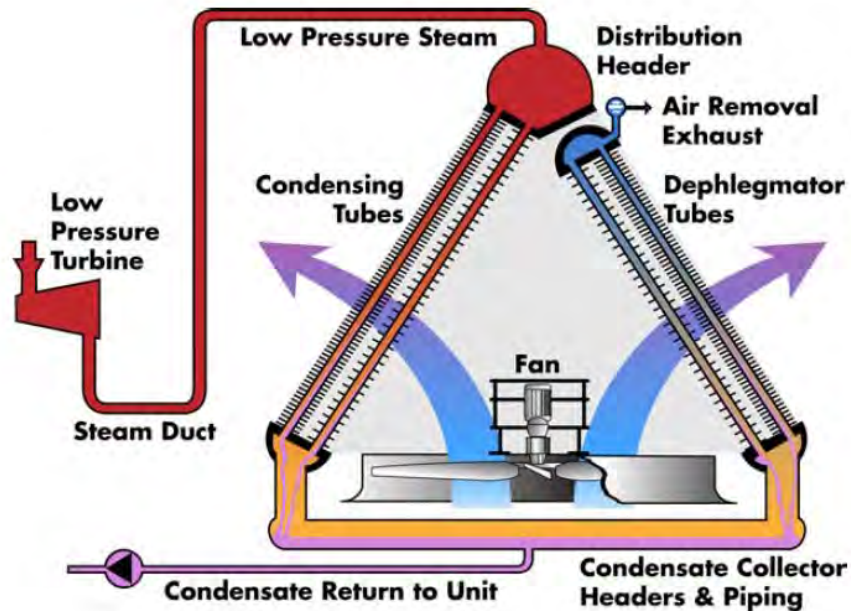
(Lennon, 2011)



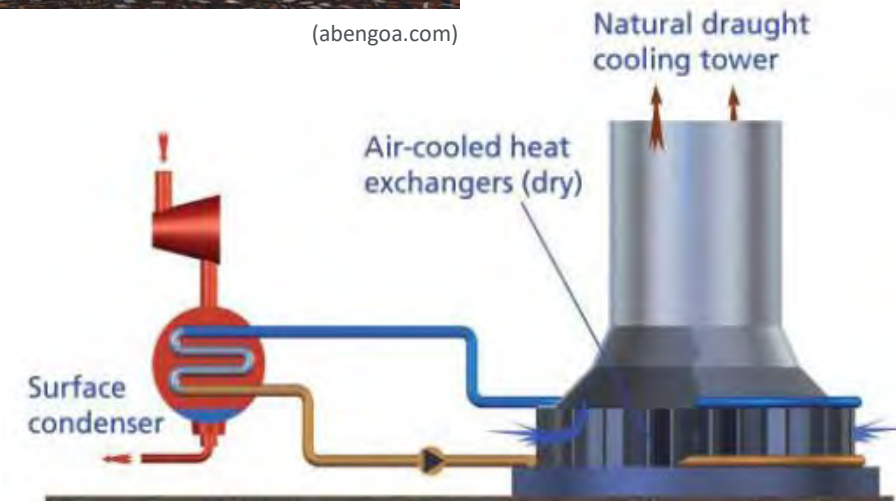
(EGI, 2005)



(abengoa.com)



(EPRI, 2009)



(Guan & Gurgenci, 2009)

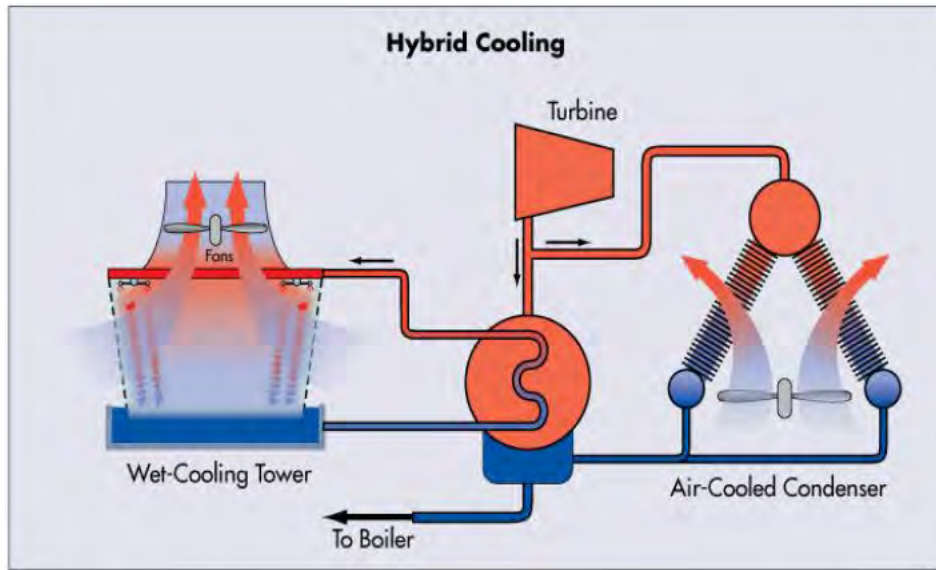


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Typical methods: hybrid

- Hybrid dry/wet



(EPRI, 2013)



(Ortega, ACCUG 2010)

Applications

- Heat rejection for steam power generation cycles
 - Coal-fired
 - Concentrated solar power
 - Combined cycle gas (traditional fuel or H₂-fired gas cycle)
 - Geothermal
 - Nuclear
 - Waste-to-heat
 - Biomass



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(energynews.us)



(heliocsp.com)



(enka.com)



(fujielectric.com)



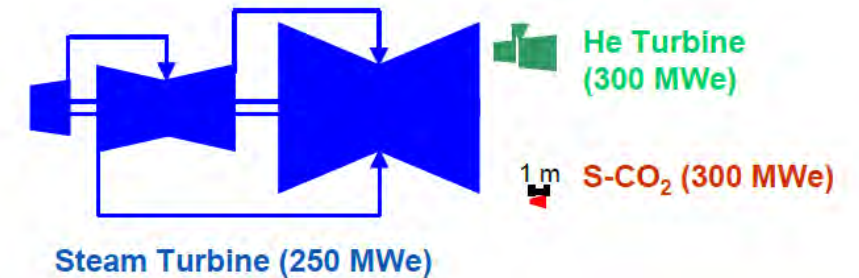
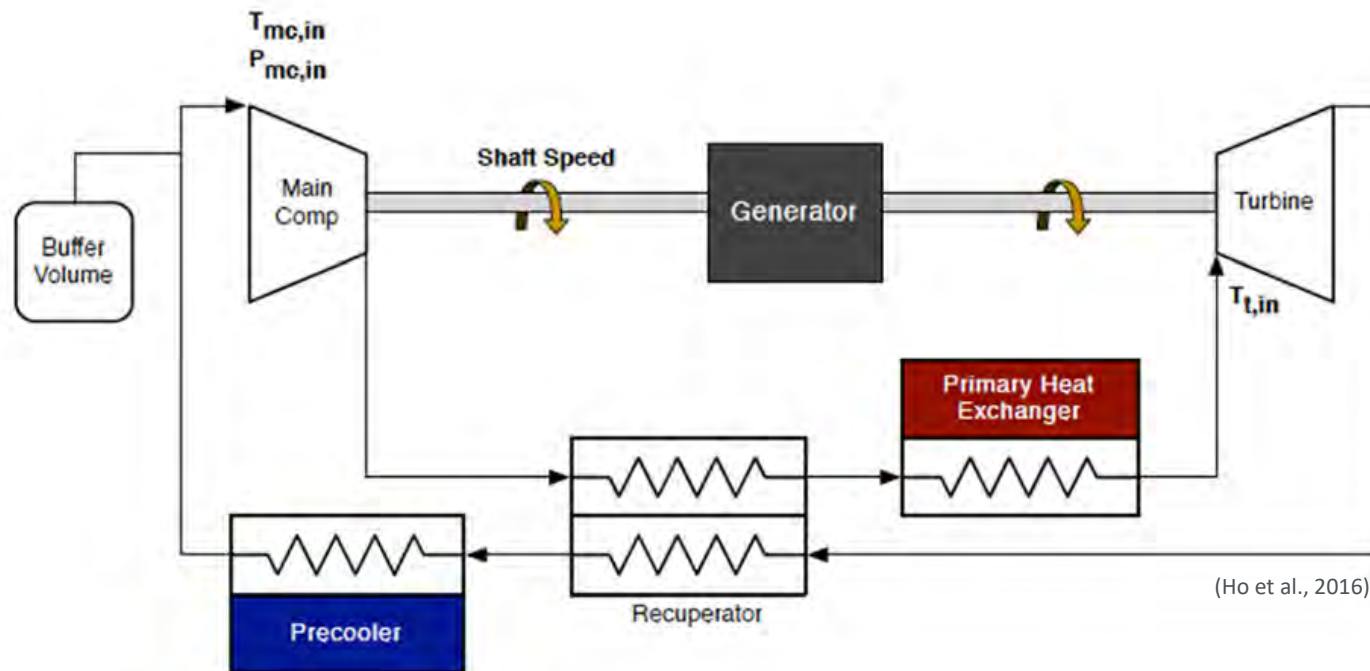
(eskom.co.za)



(margamgreenenergy.co.uk)

Applications

- Heat rejection for sCO₂ power cycle



(Conboy et al., 2014)

South African context

- Coal-fired

Power station name	Cooling system
Arnot	Wet cooling towers
Camden	Wet cooling towers
Duvha	Wet cooling towers
Grootvlei	Wet & dry cooling towers
Hendrina	Wet cooling towers
Kendal	Indirect dry cooling towers
Komati	Wet cooling towers
Kriel	Wet cooling towers
Kusile	Air cooled condenser
Lethabo	Wet cooling towers
Majuba	Wet cooling towers and Air cooled condenser
Matimba	Air cooled condenser
Matla	Wet cooling towers
Medupi	Air cooled condenser
Tutuka	Wet cooling towers

South African context

- Nuclear

Power station name	Cooling system
Koeberg	Once-through cooling (wet)

South African context

- Concentrated Solar Power

Power station name	Cooling system
Khi Solar One	Natural draft air cooled condenser
KaXu Solar One	Air cooled condenser
Bokpoort CSP	Mechanical draft wet cooling
Xina CSP	Air cooled condenser
Karoshhoek Solar One	Air cooled condenser
Kathu solar park	Air cooled condenser
Ilanga	Air cooled condenser
Redstone CSP	Induced draft air cooled condenser

International trends: mechanical draft

- Most generating capacity is once-through or wet cooled
- Move towards dry cooling selection for water conservation



(cpv.com)



(Howell, ACCUG 2014)

- Forced draft ACCs
- Induced draft ACCs



(spgdrycooling.com)



(iwc.co.za)

International trends: natural draft

- Indirect natural draft
- Natural draft ACCs



(mvmegi.mvm.hu)



(news.gtn.com)

Stellenbosch University: history

- Our department has been actively involved in cooling system research for over 5 decades.
- Prof. Detlev Kröger
 - Initiated cooling system research at SUN in the 1970s
 - South Africa's large ACC design and features are greatly influenced by his research
 - Established a strong relationship with industry
- Why are we still interested?
 - Majority of global power generation applications still use steam / gas power cycles
 - Efficient operation of heat rejection system has a major influence on cycle efficiency
 - Latest trends towards $s\text{CO}_2$ / H_2 power cycles require heat rejection systems
 - Water conservation expected to be major future focus



(Pretorius, 2012)



(Lennon, 2011)



(Lennon, 2011)



(Augustyn, 2017)



(power-technology.com)

Stellenbosch University: current research

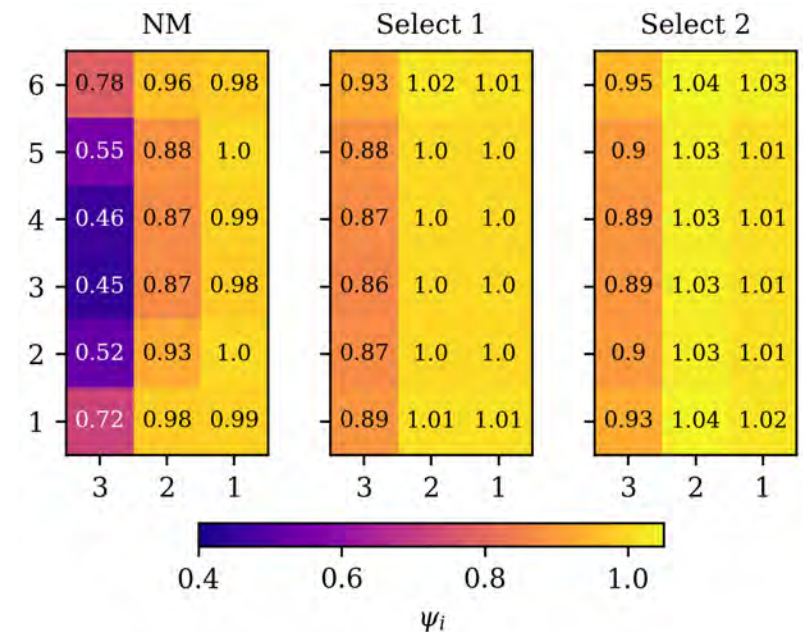
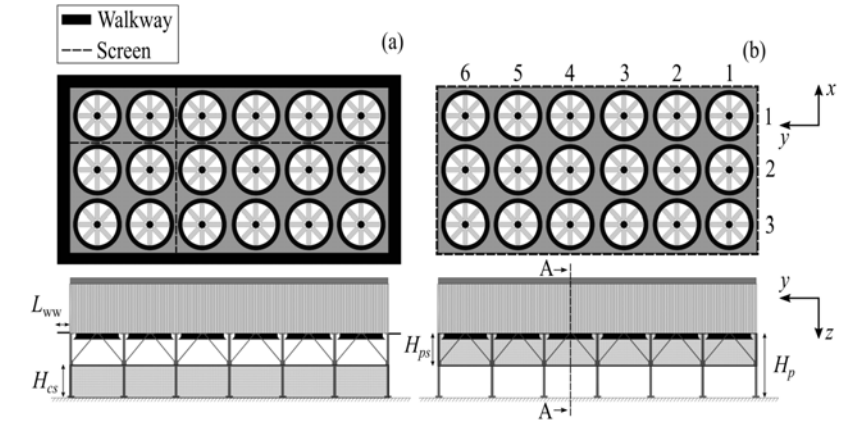
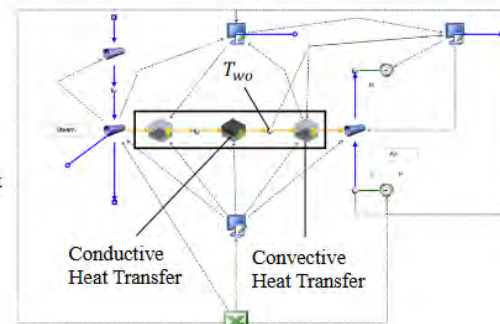
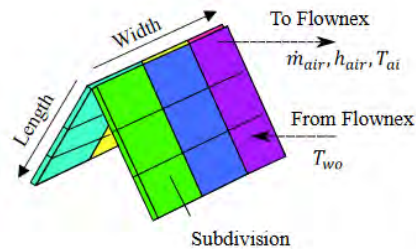
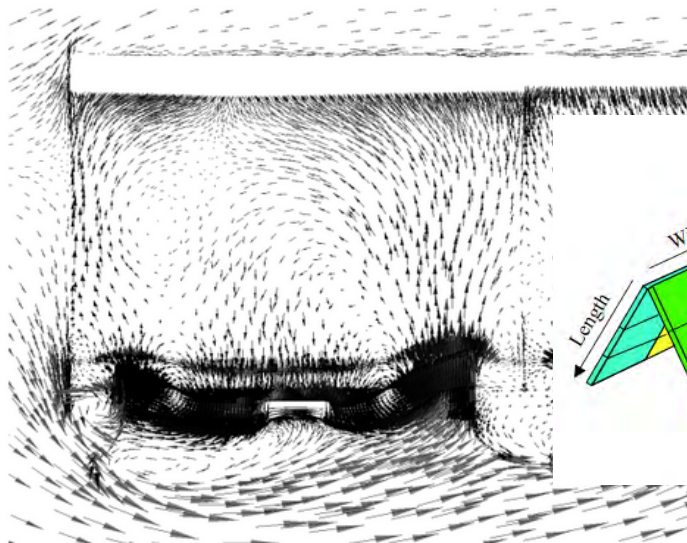


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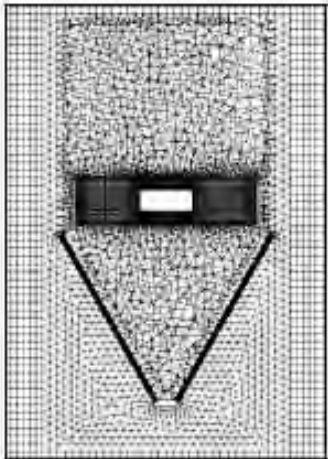
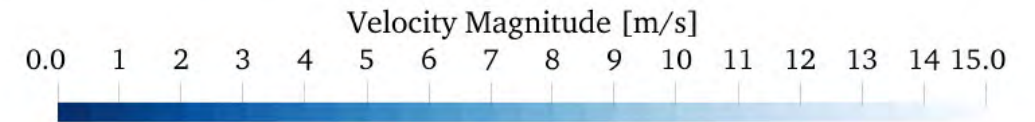
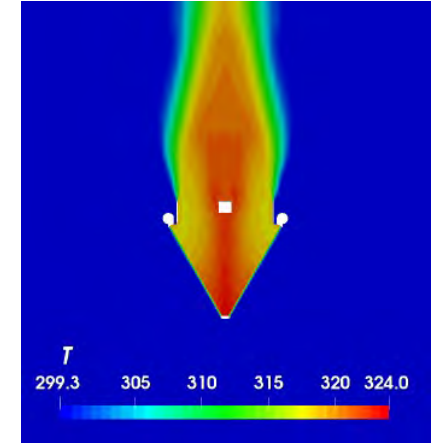
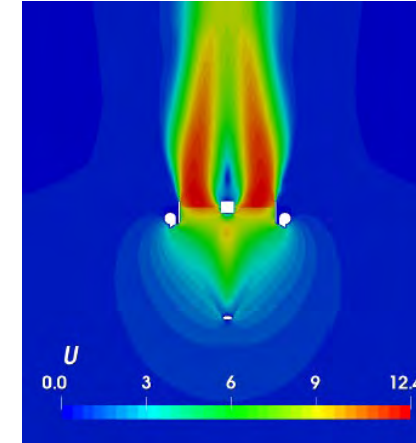
- Forced draft ACC performance
 - Simulation of air side performance
 - Wind effect mitigation
 - Co-simulation of steam-side (1D) and air-side (3D)



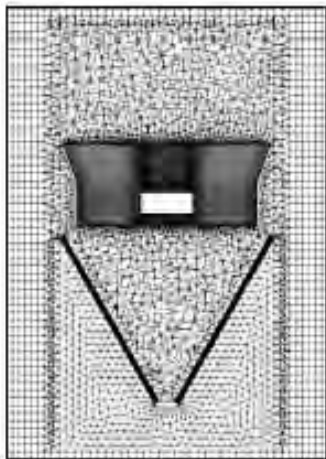
Stellenbosch University: current research



- Induced draft ACCs
 - Simulation of wind effects on ID ACCs
 - Development of exhaust diffuser for ID ACCs



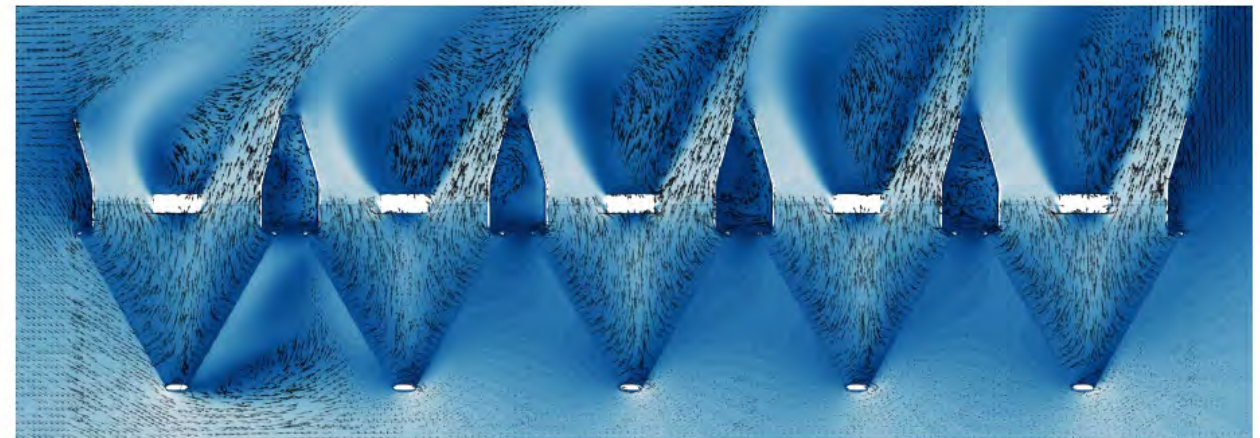
(a) Fan only



(b) $l_{\text{dif}} = 0.2d_F$ diffuser



(c) $l_{\text{dif}} = 0.4d_F$ diffuser



Stellenbosch University: current research



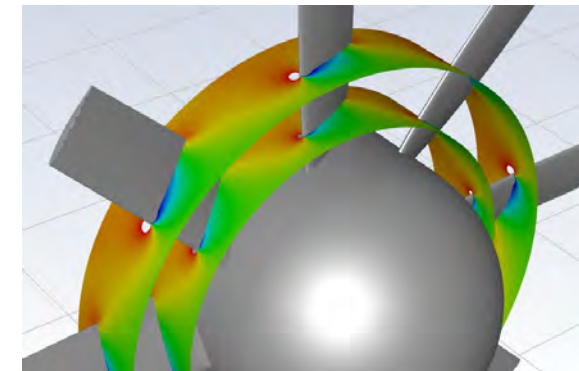
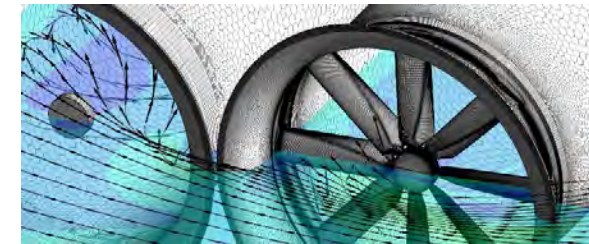
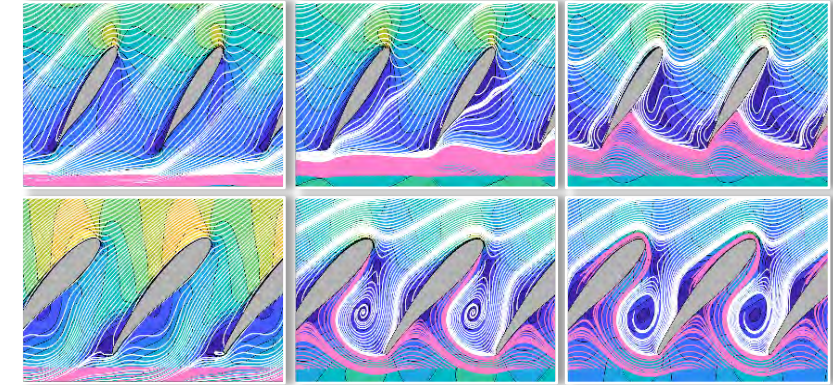
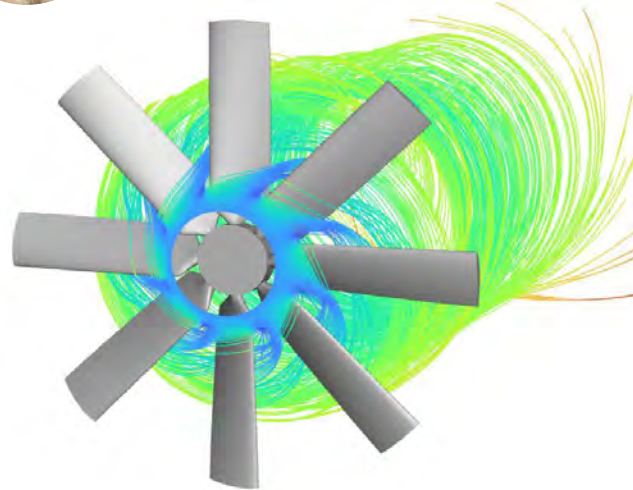
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- Fans

- Axial fan design and analysis
- ACC wind mitigation
- Fan performance improvement with tip appendages
- Measurement of scale and large fan performance
- Fan noise analysis
- Fan drive analysis



Stellenbosch University: current research

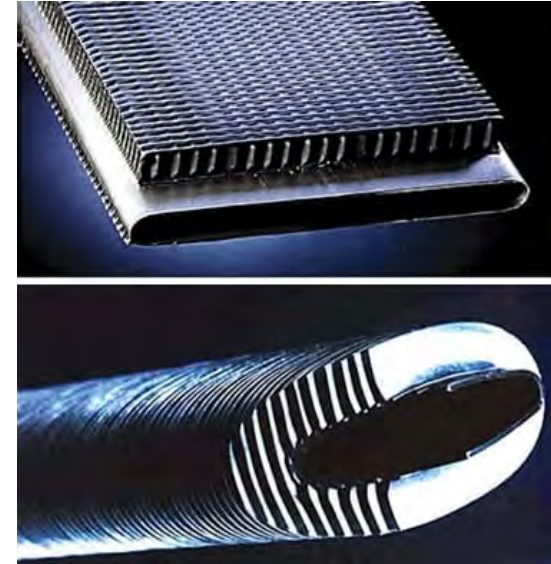
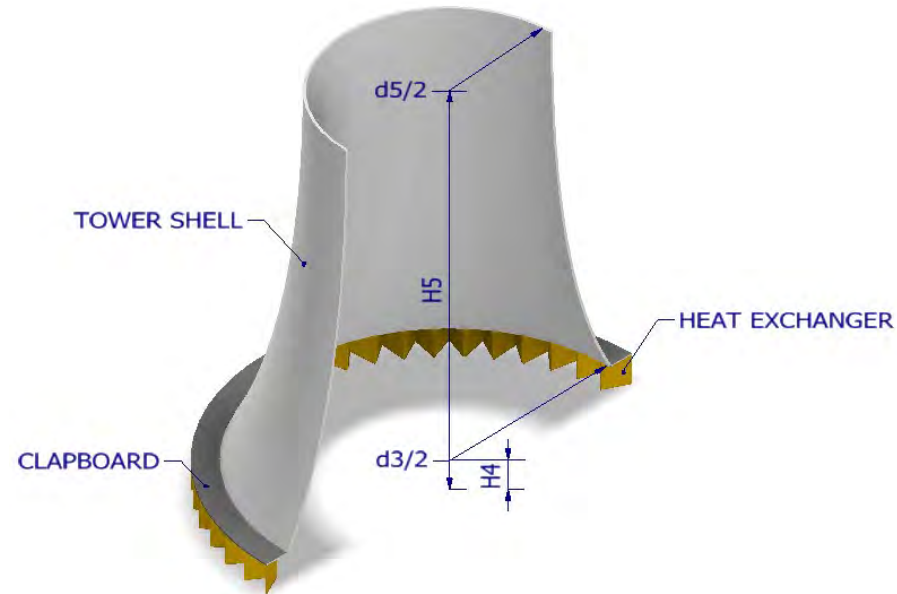


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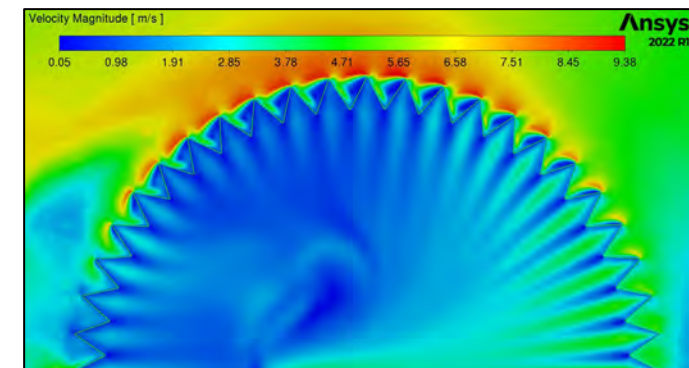
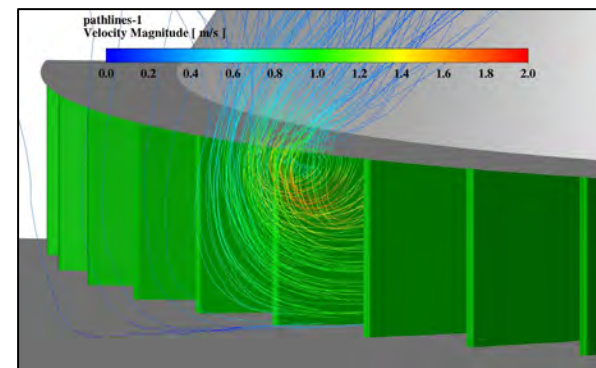
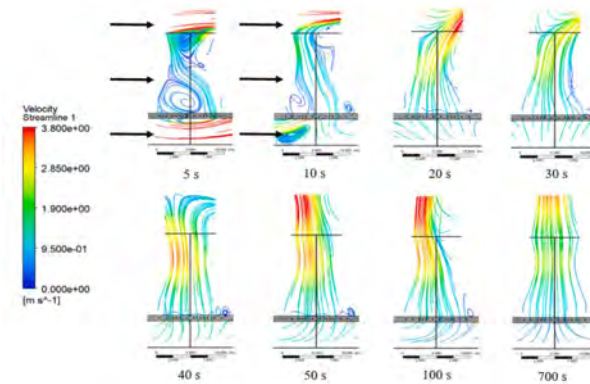
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- Natural draft ACC
 - Air and steam side performance simulation
 - Effect of wind on performance
 - Different application scales
 - HX-optimization for NDACC
 - Transient effects



(powermag.com)



Stellenbosch University: current research

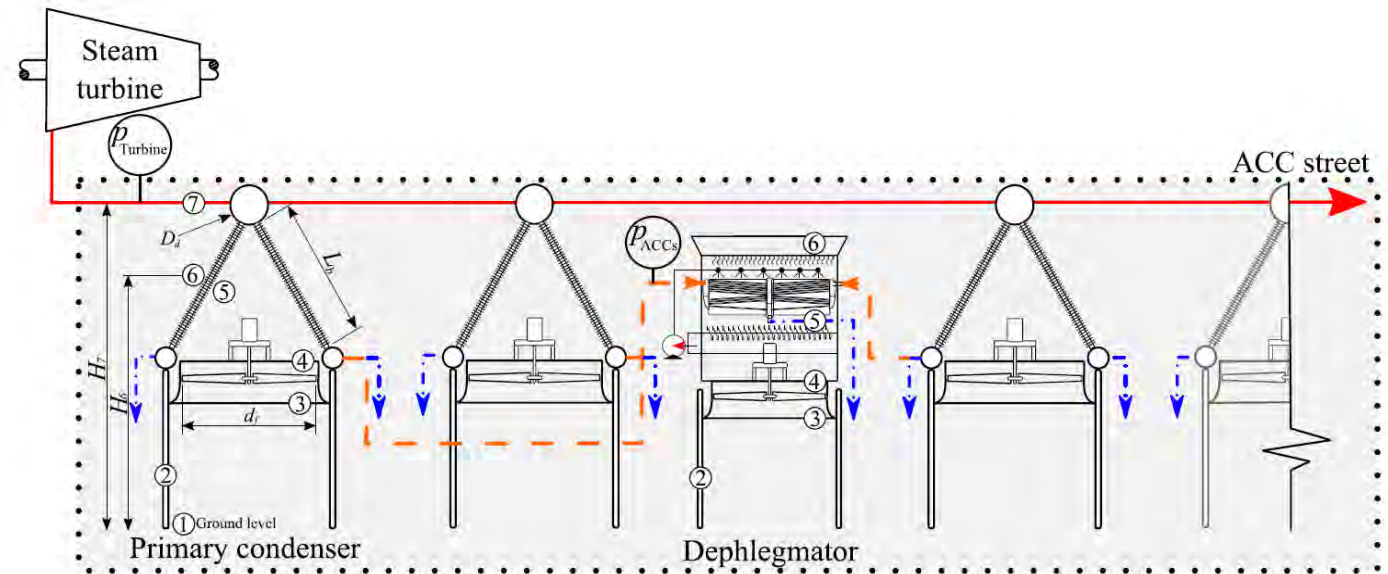
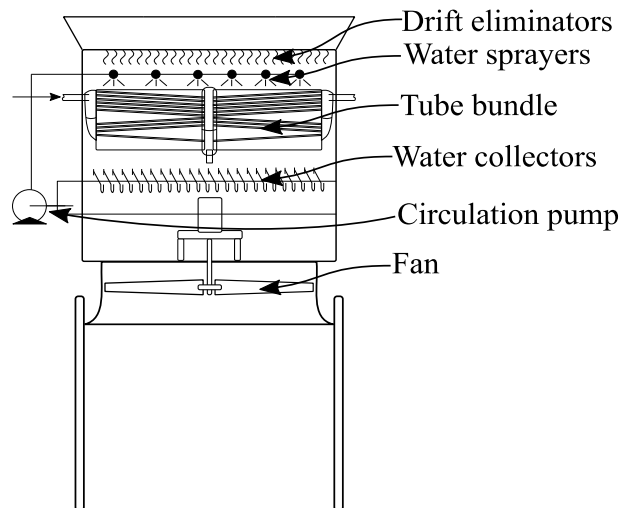


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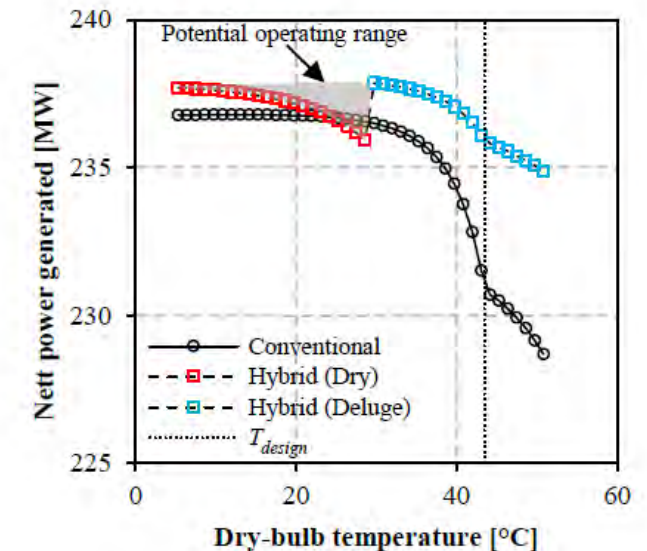
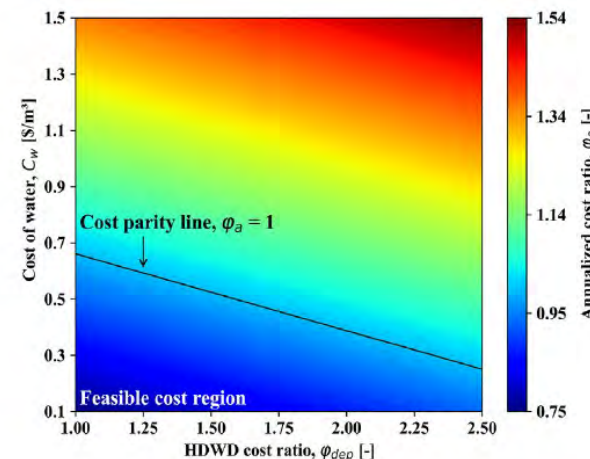
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- Hybrid dry-wet dephlegmator (HDWD)
 - Simulation and testing of novel hybrid heat exchanger module
 - Techno-economic feasibility



- Steam header from turbine
- - - Steam line to dephlegmator
- . - . - Condensate line drains to the condensate tank



Stellenbosch University: current research

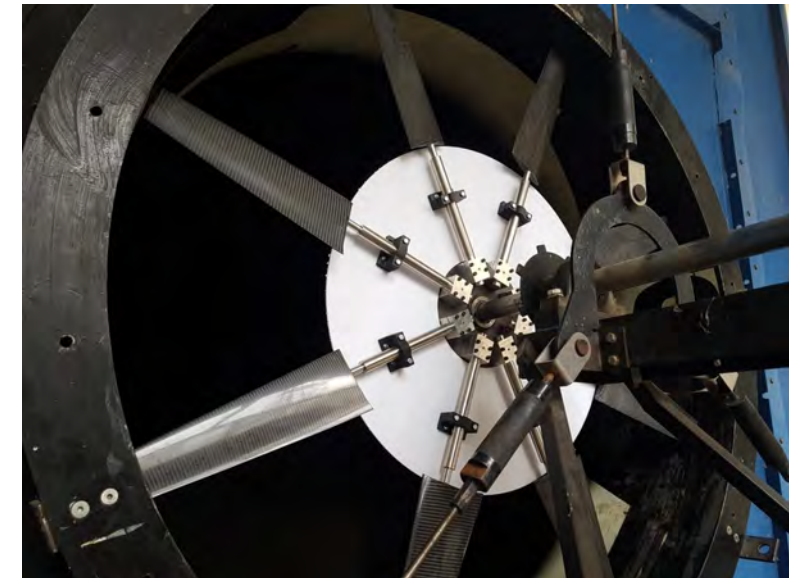
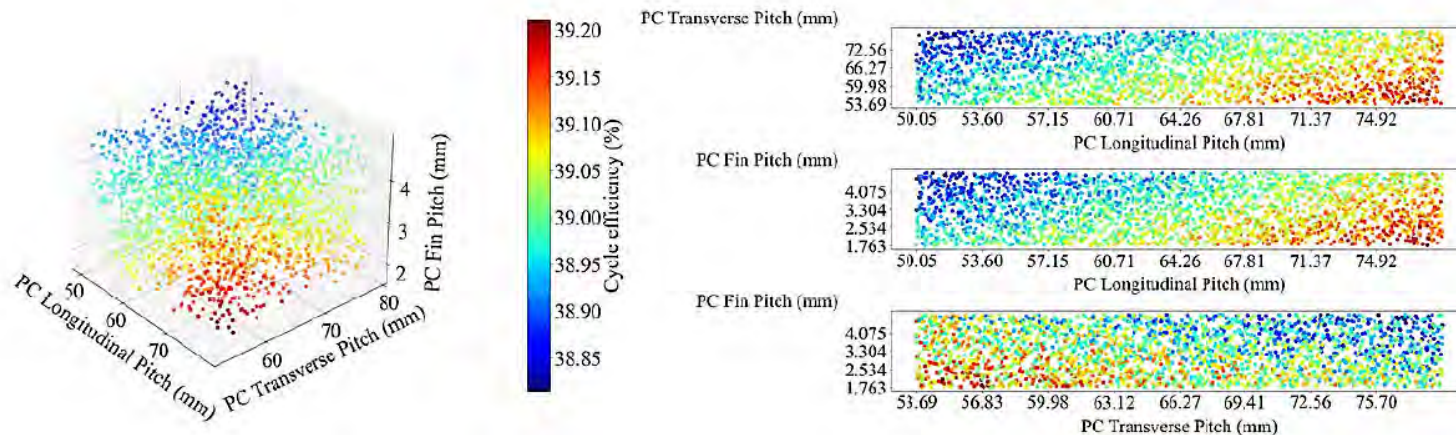
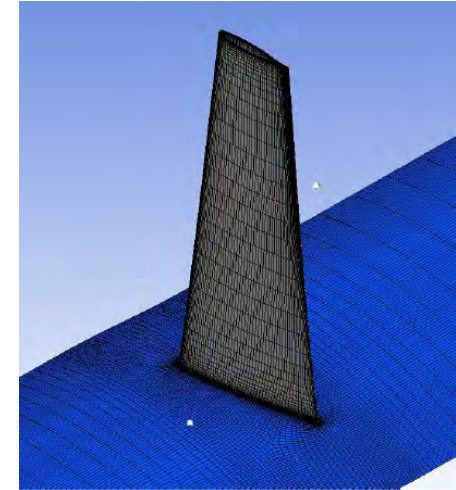


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- Cooling systems for sCO₂ applications
 - Fan design, simulation, build and test for sCO₂ application
 - Simulation of fan and sCO₂ heat exchanger interaction
 - Optimizing finned tube heat exchanger for sCO₂ pre-cooler and intercooler
 - Hybrid cooling of sCO₂ cycles



(Abrahams et al., 2022)

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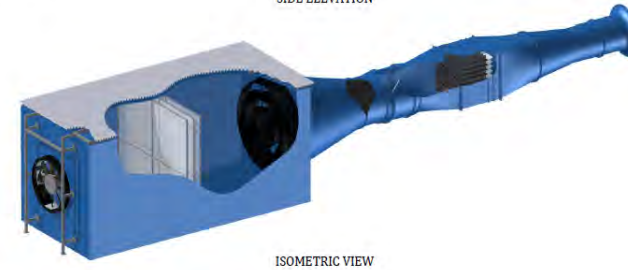
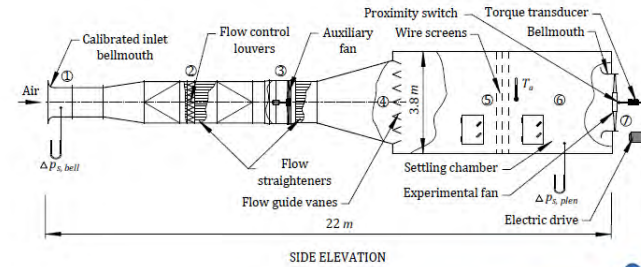
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Thank you
Enkosi
Dankie

Photo by Stefan Els

Stellenbosch University: test facilities

- MinWaterCSP facility
 - 24ft fan
- ACC scale fan test facility (ISO 5801)
 - 1.542 m dia. fan
 - Ability to investigate fan noise
- ACC heat exchanger test facility
- Cross and counterflow wet cooling tower test facility
- Well-equipped heat transfer and wind tunnel laboratories



(Van der Spuy et al., 2021)

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