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Modelling of an On-Sun Reactor for SCWG of Algae:

Understanding the Design Constraints

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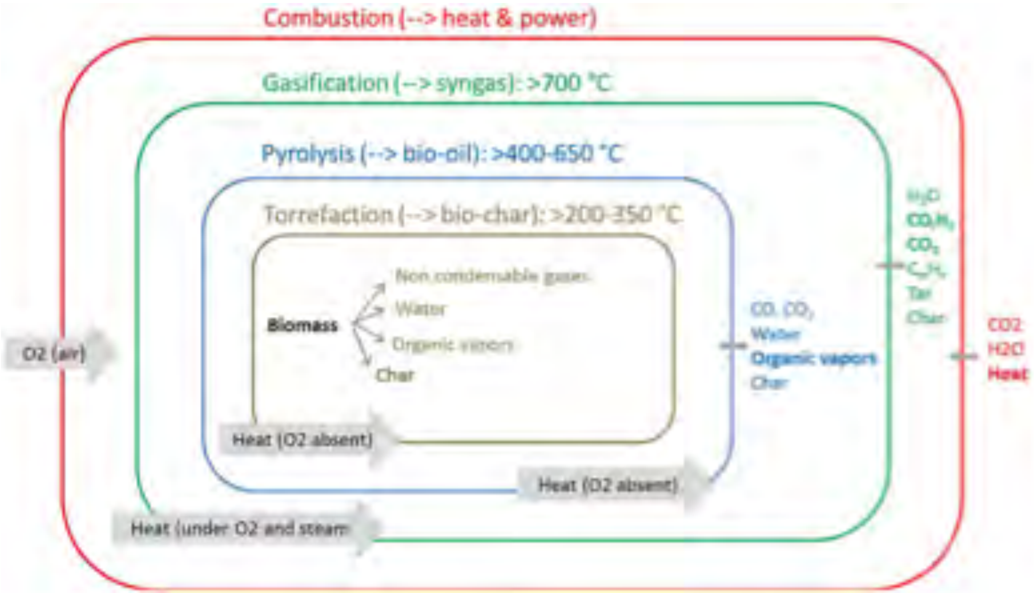


Matsakas et al., Elec. J. Biotechnol., **26**, 2017, 69–83

- One-third of global anthropogenic GHG-emissions is due to liquid fuels
- Farmed-biomass could provide a route for carbon-neutral fuel production
- Solar-driven liquid fuels production

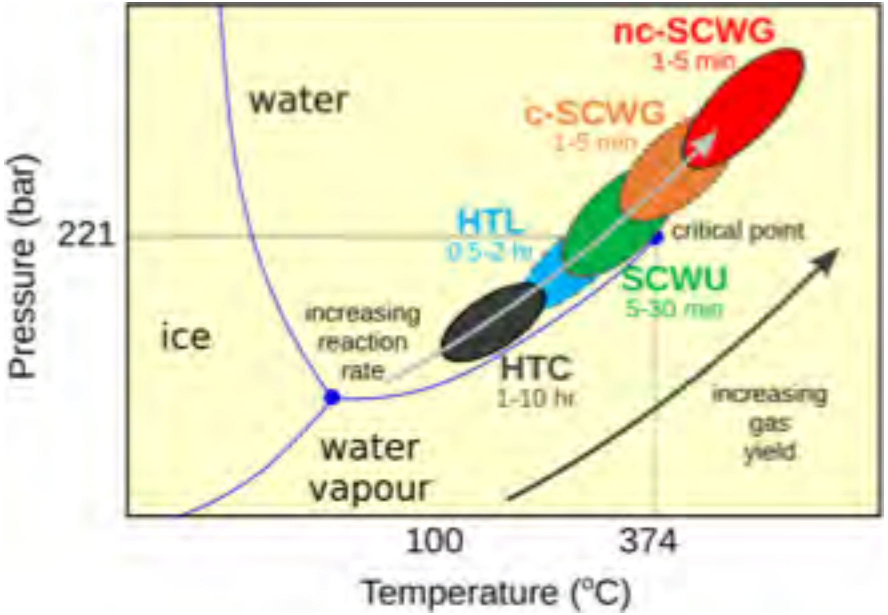
Why do we want to move to SCWG?

Supercritical Water Gasification (SCWG):

- a thermochemical conversion technique
- faster kinetics, low char
- ability to process wet feedstocks

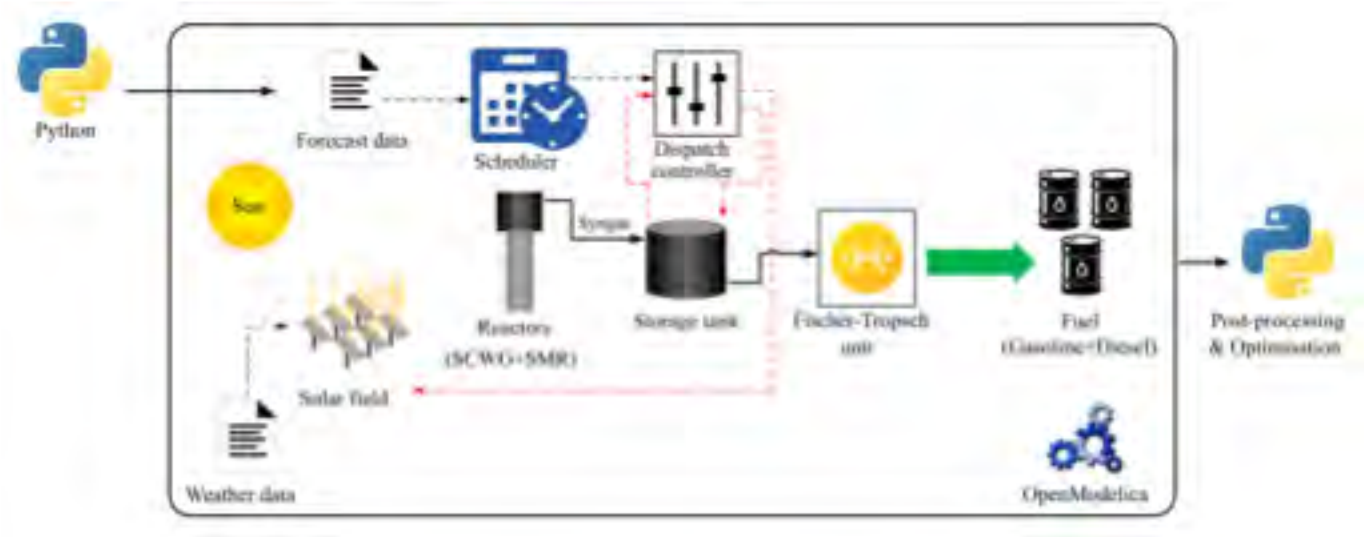
Algae as a feedstock:

- fast growth rates, can grow in sea water and non-arable land
- does not compete with food crops or infrastructure land
- currently very expensive to grow



Timko et al., J. Supercritical Fluids, **96**, 2015, 114–123

Solar driven SCWG-based fuel synthesis



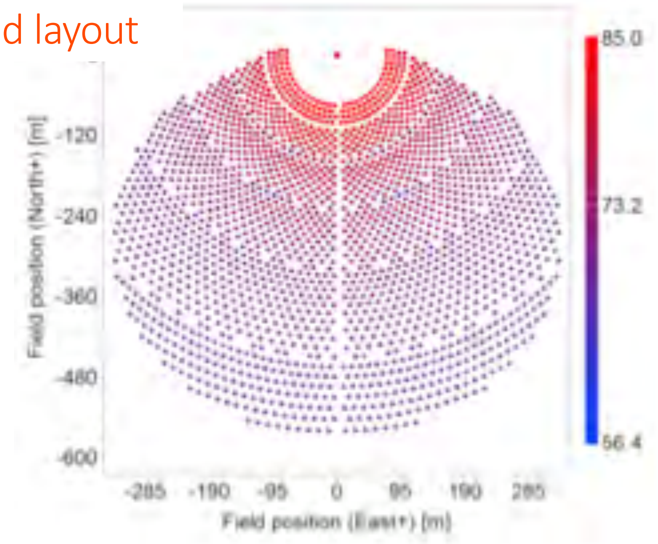
Key issues: Materials compatibility, overall cost, storage, Heat transfer limitations, solar variability and FT integration

ANU activities: Process simulation, lab-scale experiments, dynamic modelling, technoeconomic feasibility, full-scale on-sun reactor modelling

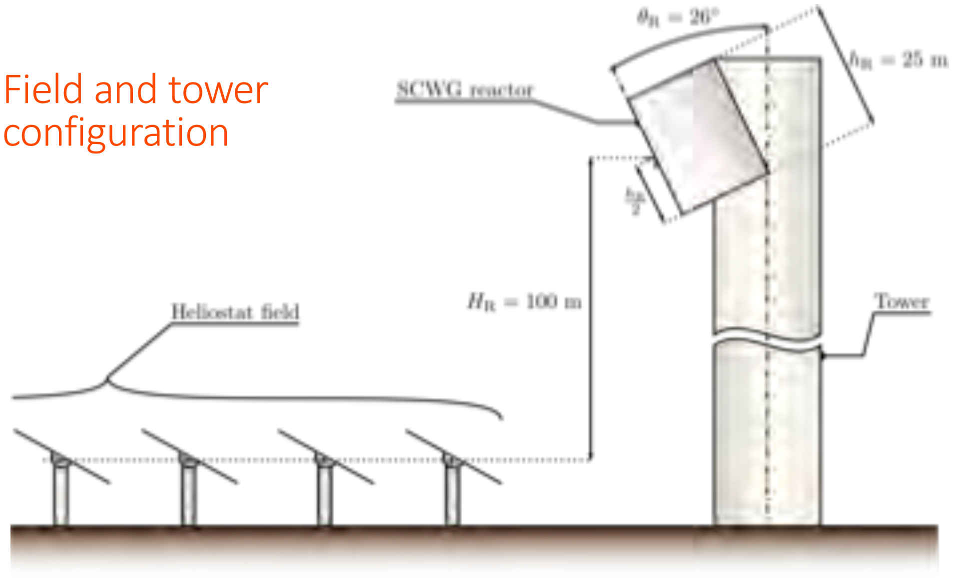
Heliostat field

- Heliostat field layout using SolarPILOT
- SolTRACE used for ray-tracing to get the flux distribution on the aperture of the hemi-cylindrical cavity

Field layout



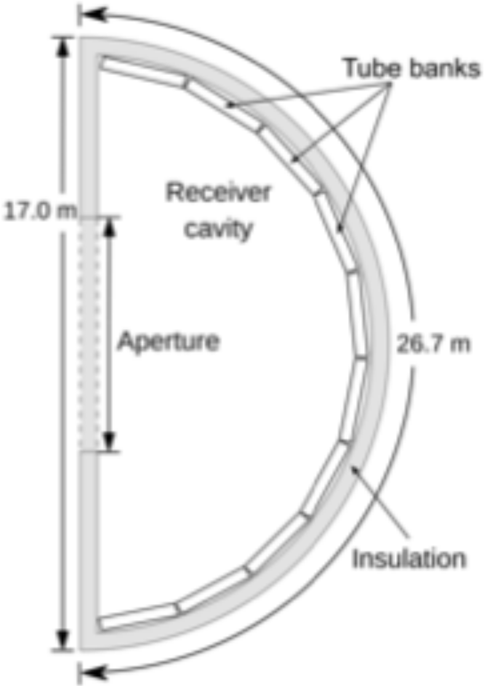
Field and tower configuration



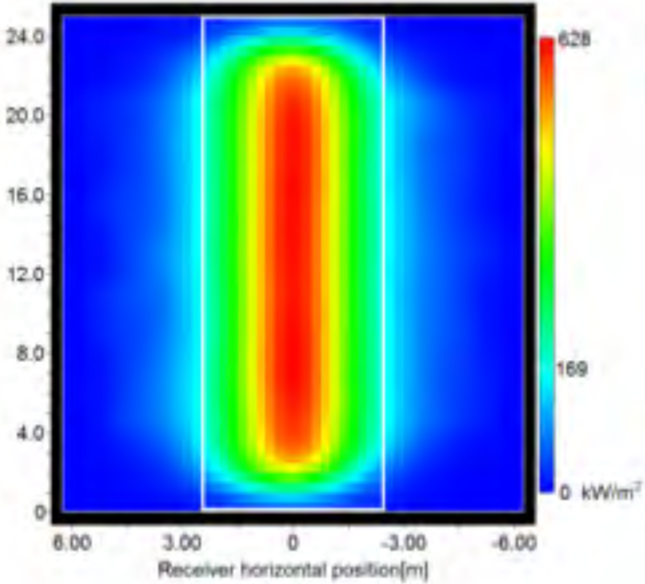
Receiver Model

- An in-house developed code (TRACER) used for Monte-Carlo ray tracing to calculate the flux distribution inside the cavity. View-factors to the aperture also calculated using MCRT.
- PR-EoS with vdW mixing rules used for prediction of gas composition. Zeroth-order kinetics assumed for algae gasification
- Radiosity solved with equilibrium prediction and hydrodynamic model and flow-rate in each bank optimised for fluid outlet temperature
- Equivalent von-Mises stresses — Thermal and pressure stresses

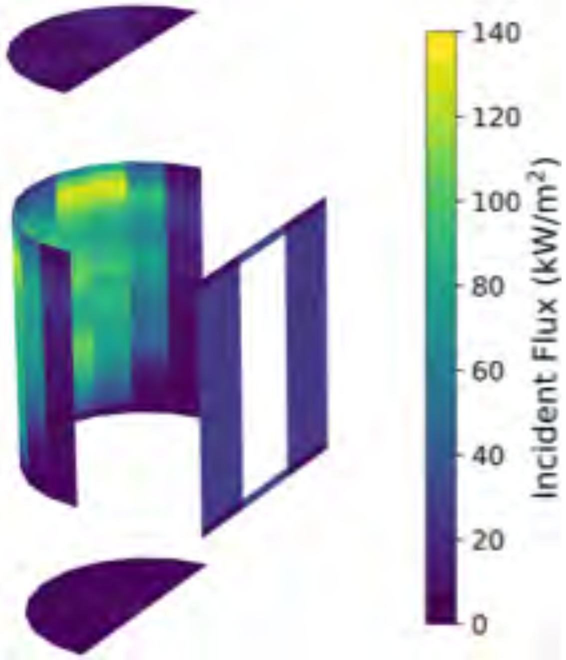
Results – flux distribution



Receiver schematic



Aperture plane flux distribution

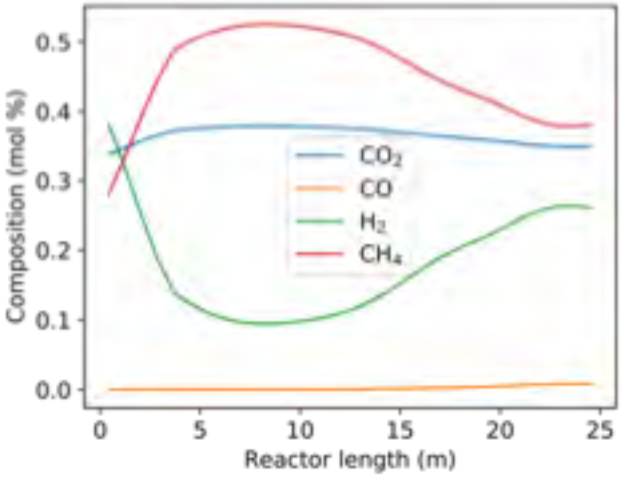


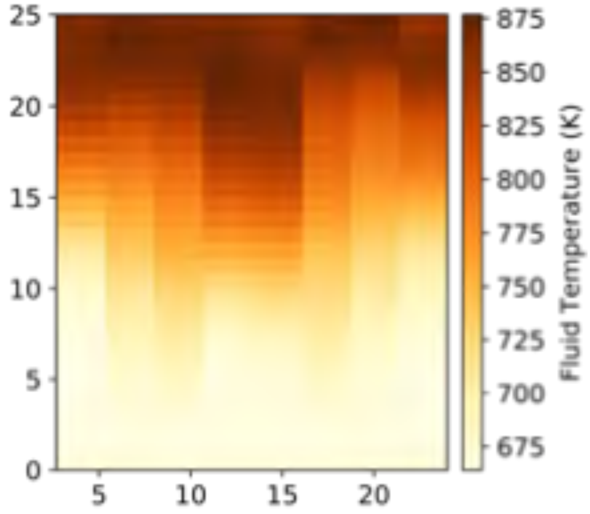
Cavity flux distribution

Results – temperature and composition

Gas evolution along the flow path

(one representative tube shown)



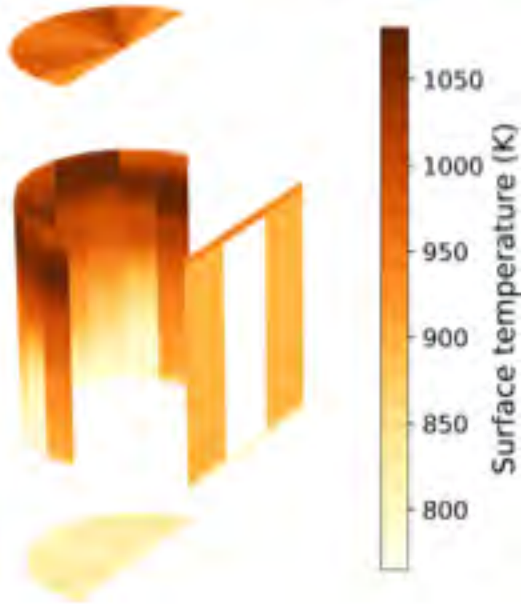


Fluid temperature in the reactor

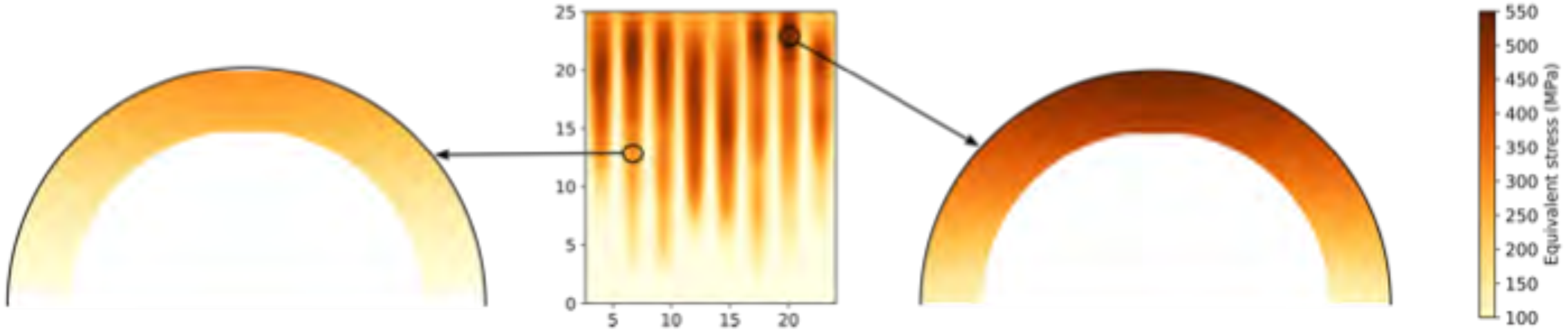
(one tube per bank shown)

Tube outside wall temperatures

(one tube per bank shown)



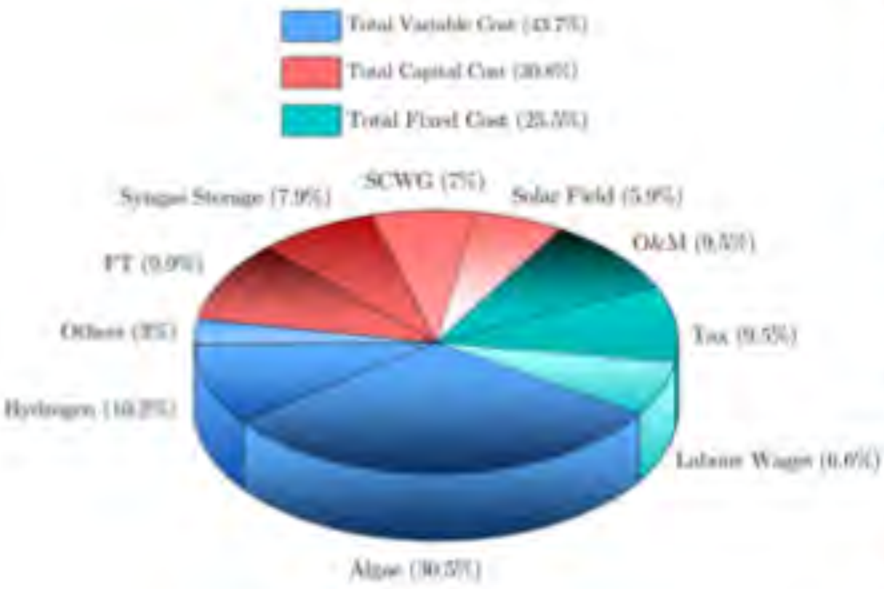
Results – stresses and overall performance

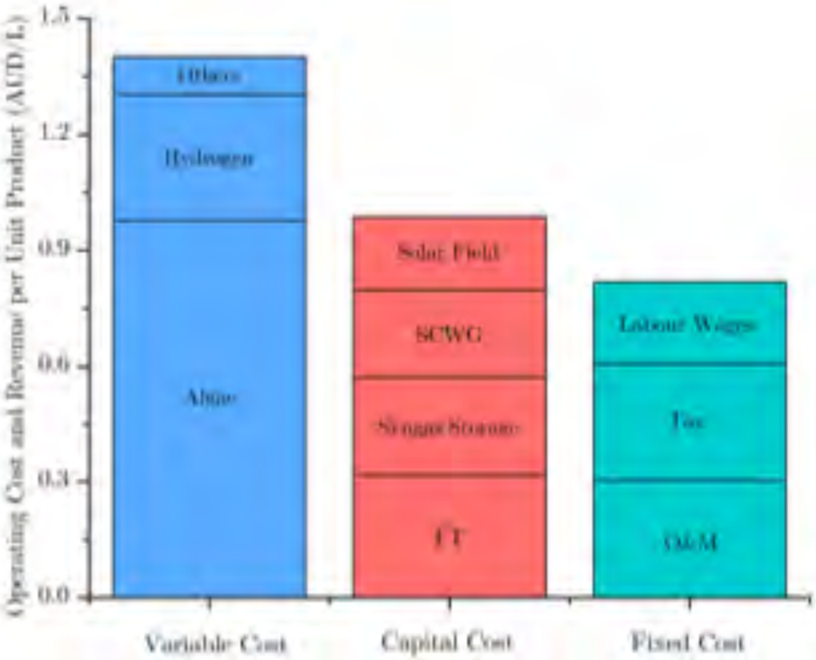


- Thermal stresses were dominant
- Despite the imposed flux limitation, the equivalent stresses were of the order of 530 MPa

Receiver efficiency:	67%
Radiation losses:	13.3%
Convective losses:	16.7%
Cavity reflection:	3%
Spillage:	16.7%

Levelised cost of algae-based liquid fuel





- The LCOF is 3.2 AUD per litre of diesel equivalent. Still 3x expensive
- Main contributors are the cost of algae and hydrogen

Conclusion and Outlook

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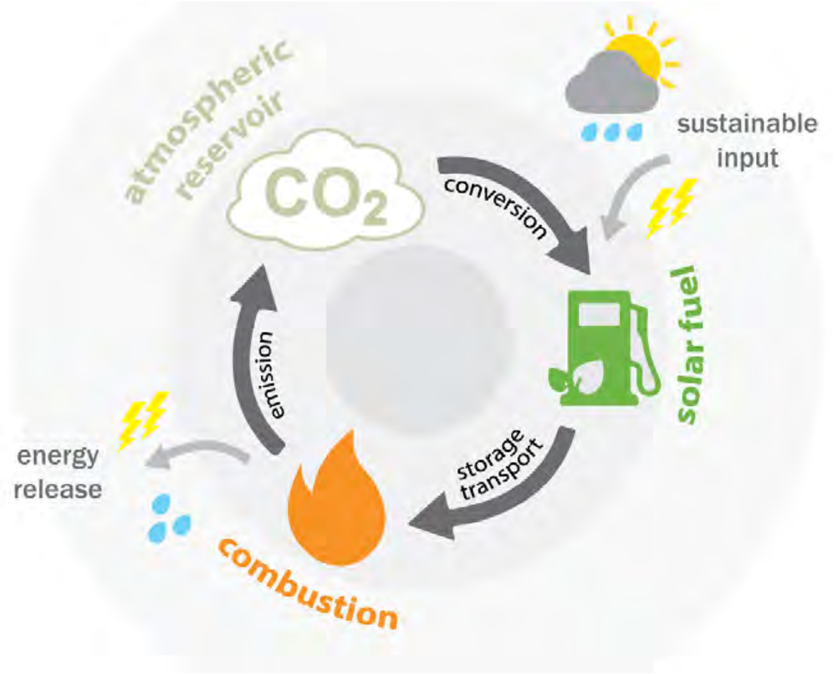
Solar driven SCWG + FT can provide:

- sustainable carbon-neutral fuel production route
- cost competitiveness if algae production becomes cheaper

Future areas of research:

- technological advancement need for microtubular FT process
- scope for improvement in solar integration with appropriate modelling of transients
- off-sun reactor design



https://www.differ.nl/research/solar-fuels

Thank you

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