Solar Driven Gasification of Algae Biomass

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ASTRI
AUSTRALIAN SOLAR THERMAL RESEARCH INITIATIVE

Introduction

- Supercritical water gasification (SCWG) is a proposed approach for carbon-neutral fuel from biomass with flexibility in feedstock, much lower char/tar formation, higher yield, and no need for drying the feedstock.
- We integrate SCWG with CSP for the process heat aiming for driving the endothermic gasification reaction which can potentially offer much higher process efficiency and less loss of feedstock carbon.
- Algae as a carbon-rich feedstock have high growth rate and can be cultivated even in brackish water.

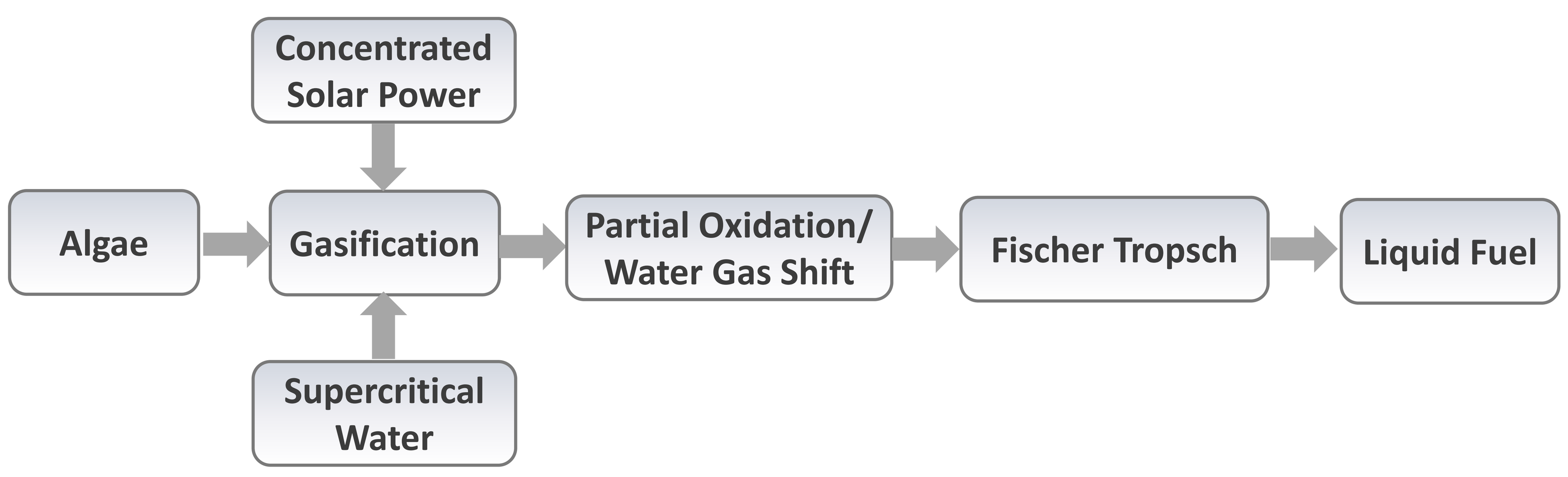


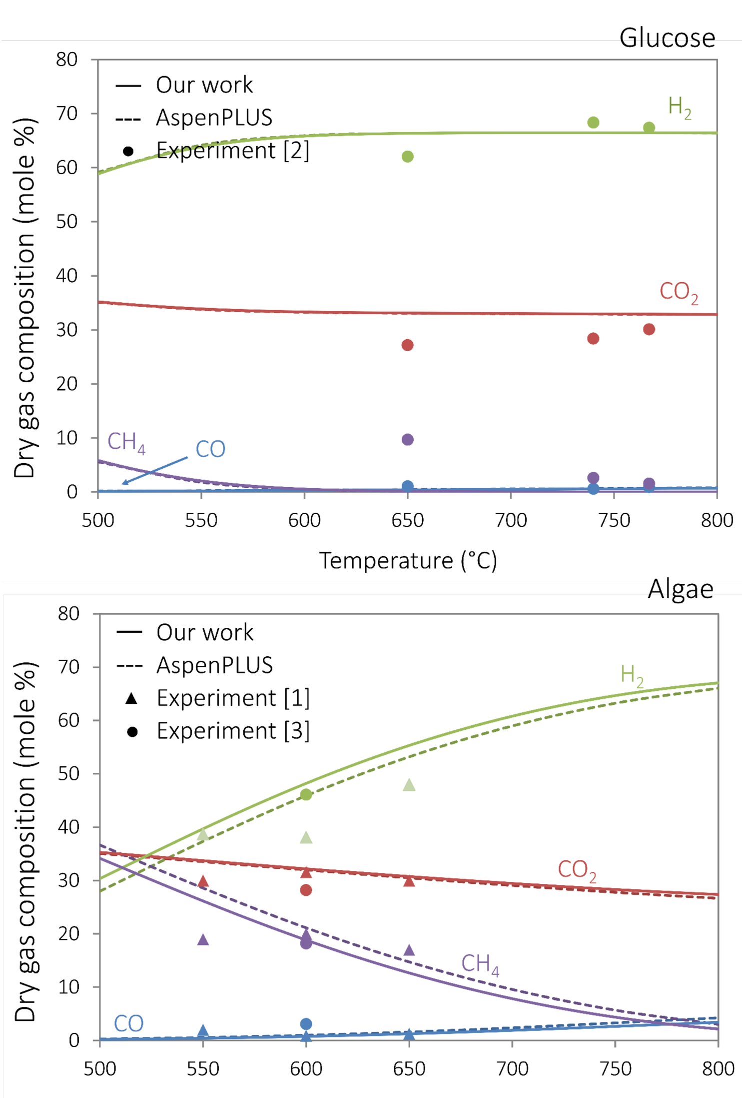
Figure 1: Schematic of a process design for converting algae to liquid fuel using solar driven SCWG

Experimental setup

We demonstrate the proof-of-concept for SCWG of algal biomass through the continuous-flow SCWG apparatus designed at ANU (Fig. 2). The key features include the ability to pump much higher concentrations of algae (up to 30 wt.%), high feedstock heating rate, gas analysis using mass spectrometry. A parametric study for obtaining the effect of temperature, reaction time, algae concentration and catalysts on the gasification process will be performed.

Figure 2: Lab scale continuous-flow tubular apparatus for supercritical water gasification of algae

Thermodynamic modelling



A thermodynamic model has been developed for equilibrium prediction in SCWG, based on Gibbs free energy minimisation and real mixture properties. The model has been validated against reported data for glucose and algae, as well as, reactor model in AspenPLUS (Fig. 3). The model has been further developed in to a full scale solar reactor design with materials constraints incorporated.

Figure 3: Validation of the equilibrium model with experimental data and AspenPLUS for Glucose and Algae.

Solar driven algae-to-syngas process

A 50 MW_{th} CSP for converting algae-to-syngas has been simulated in AspenPLUS. The gasification plant (Fig. 4) is coupled with steam methane reforming (SMR) and photovoltaic (PV)-electrolyzer for achieving suitable H_2:CO ratio in syngas. Key focus areas for our process optimization were:

- Realistic design and sizing of solar reactor, while accounting for allowable stress limits in currently available materials
- Maximizing heat recuperation and minimizing exergy destruction, especially from the large amounts of excess water
- Increasing overall carbon conversion efficiency to achieve the desired ASTRI target of AUD 2.50 per liter of diesel equivalent

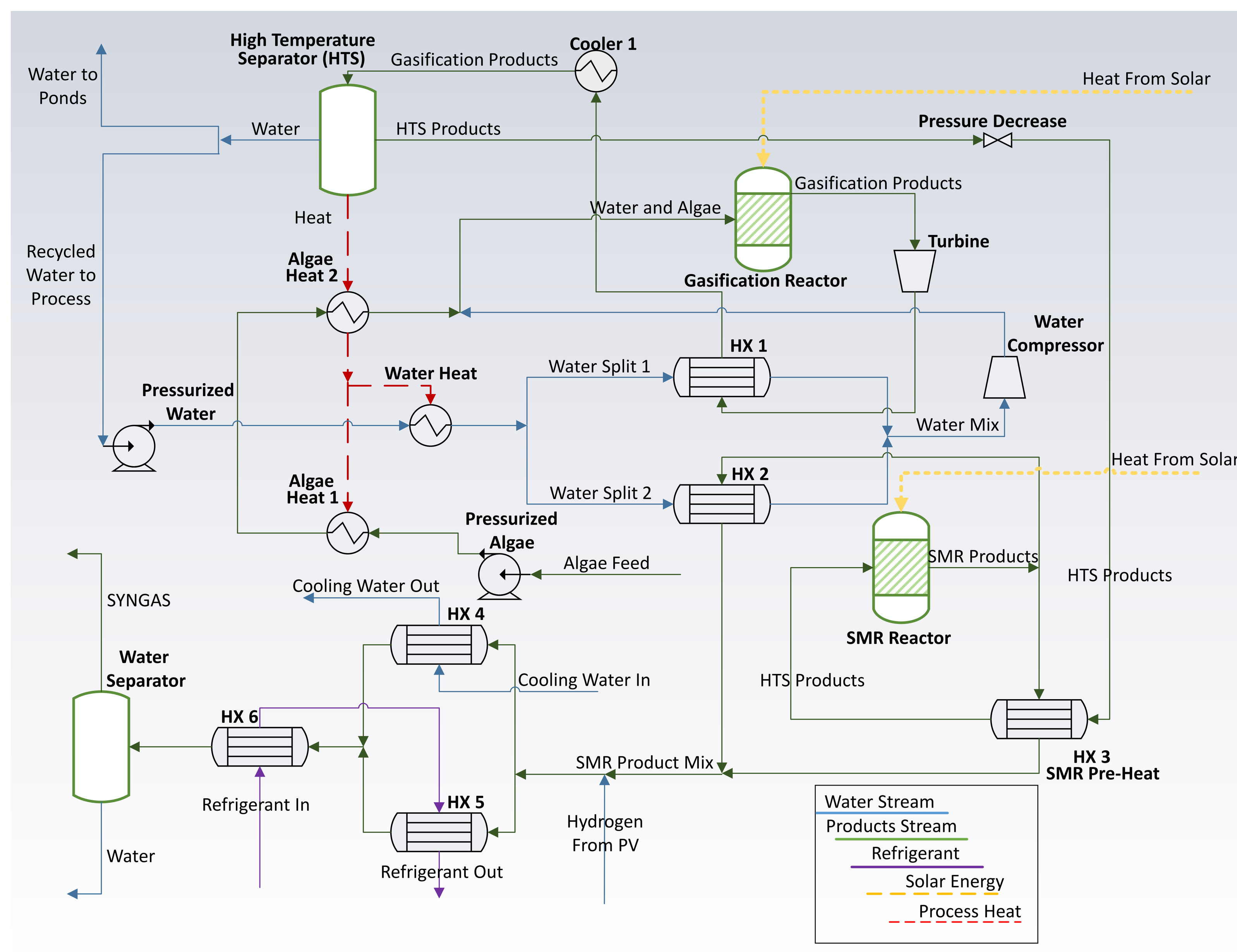


Figure 4: Schematic showing the process plant for conversion of algae into syngas using solar driven SCWG

Challenges, Benefits and Future Work

Challenges
- Materials for high press and temp
- Pumping high algae concentration
- High-cost feedstock
- Heat transfer limitations
- CO_2 separation from syngas

Benefits
- High carbon yield to syngas
- No cost for drying
- Renewable energy resource
- On-track for ASTRI cost target

SCWG

Future Work
- Optimizing the reaction conditions
- Exergy analysis
- Integrating with downstream Fischer–Tropsch process
- Techno-economic analysis
- Data on gasification kinetics

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