Newsletter II, November 2019

# CLara

Chemical Looping Gasification for Sustainable Production of Biofuels

## WHAT IS CLARA?

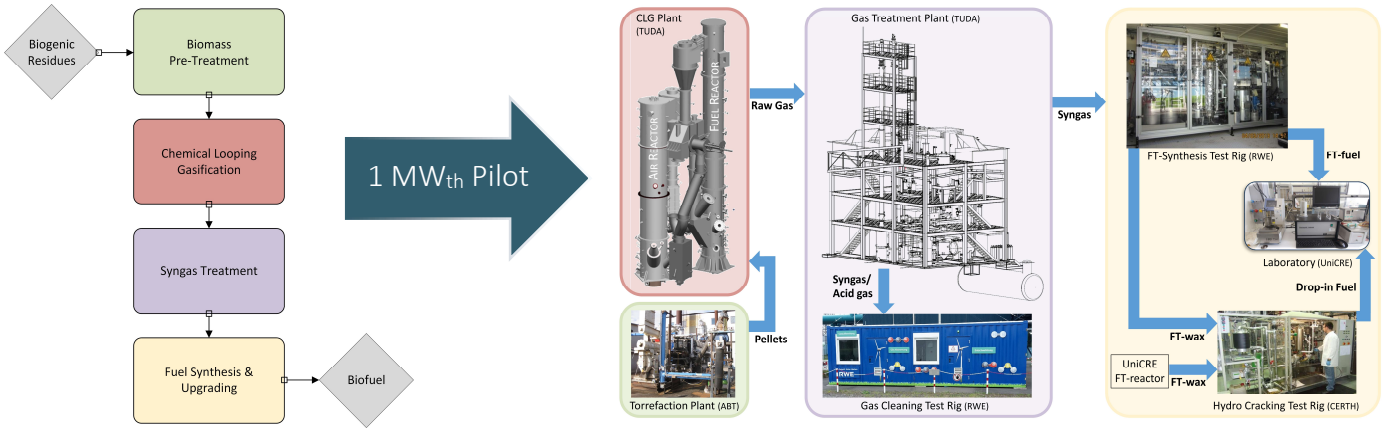
CLARA is a Horizon 2020 project, funded by the EU, involving 13 partners from across Europe, which aims at developing an efficient technology for the production of 2nd generation liquid biofuels based on chemical looping gasification (CLG) of biogenic residues.

H2020 Research and Innovation action
Grant Agreement n° 817841

https://clara-h2020.eu/

jochen.stroehle@est.tu-darmstadt.de

## BIOMASS-TO-BIOFUEL PROCESS CHAIN




**Significant reductions** in greenhouse gas emissions are required to **prevent a surge in global average temperatures**, exceeding the 1.5 °C Paris Agreement threshold. Here, the **de-carbonization of the transport sector**, which represents over one third of the global energy consumption, is a key factor on the route to achieve this goal. Particularly, the **substitution of fossil fuels in those branches of the transport sector** for which electrification is presently not viable (e.g. road transport and aviation), remains a major challenge.
To tackle this issue, the **large-scale deployment of biofuels**, in addition to electrification and the increased deployment of rail transport, is necessary. Therefore**, substantial advances in renewable fuel generation**, not impacting food availability and prices, are required. One route to achieve these objectives is **the synthesis of advanced biofuels through thermochemical conversion** of biomass-based residues. Within the scope of CLARA, an efficient technology for the **production of liquid fuels based on chemical looping gasification (CLG) of biogenic residues** is being developed. The major objective is to further investigate and test CLG up to 1 $MW_{th}$ scale in an industrially relevant environment, elevating the process to market maturity. Furthermore, the project aims at devising and optimizing innovative, cost-efficient technologies for biomass pre-treatment and syngas cleaning. These novel process steps will be supplemented by established fuel synthesis technologies (e.g. Fischer-Tropsch process), yielding the full biomass-to-biofuel process chain.

### Chemical Looping Gasification

CLG is an oxygen-assisted gasification technology through which solid feedstocks are converted into a $N_2$-free synthesis gas, without requiring and energy intensive air separation unit. Moreover, the combination of deploying biomass residues as the feedstock and utilizing an oxygen carrier for oxygen provision facilitates net-negative $CO_2$ emissions of the process, through efficient capturing of the $CO_2$ contained in the $N_2$-free product gas. Last but not least, an efficient alleviation of the tar formation problem through in-situ thermal and catalytic tar cracking is predicted for the CLG technology.

### Biomass Pre-Treatment

Efficient gasifier operation requires proper pre-treatment of the feedstock to prevent ash melting and excessive corrosion. Moreover, pre-treatment facilitates the de-centralized provision of the feedstock through measures such as pelletization or torrefaction, allowing for an easier handling, storage, and transportation of the biomass. Due to these reasons, tailored pre-treatment concepts are being devised for the biogenic feedstocks *wheat straw* and *pine forest residue* within the CLARA project.

### Syngas Treatment

Downstream treatment of the raw syngas formed during gasification is a relatively mature technology, being currently deployed in IGCC plants. Yet, it is related to high CAPEX and OPEX. Especially the state-of-the-art Rectisol® process, which is being deployed for acid gas removal, brings about significant costs, as it relies on solvent refrigeration. To tackle this problem, a novel acid gas concept, operating at moderate temperature levels, is being investigated within the scope of CLARA.

# PROGRESS

## Conception of the Biomass-to-Biofuel Process Chain

Within the last twelve months, a process concept for the entire process chain, allowing for an efficient production of biofuels while at the same time limiting process bottlenecks and reducing associated costs and risks, has been developed. Especially, a tailored alignment of the gasifier, syngas treatment, and fuel synthesis unit, facilitating an efficient limitation, avoidance, and conversion of side products formed during the CLG process was achieved. This means that through the suggested process chain excellent material and energetic utilization of the feedstock is accomplished.

## Process Modelling

To estimate heat and mass balances of the process, a process model for the entire process chain, stretching from gasification to fuel synthesis and upgrading, was devised. Simulation results show that chemical looping gasification facilitates a close to complete conversion of the utilized feedstock in the fuel reactor, while at the same time retaining the majority of the input energy in the gaseous product stream. Moreover, the process scheme not only allows for an efficient conversion of carbon to the final transport fuel, but also promises major $CO_2$ capture rates, allowing for net-negative $CO_2$ emissions. A summary of the most important key performance indicators (KPI) is given below.

| KPI | Definition | Range | Target |
|---|---|---|---|
| Carbon utilization | Fraction of carbon in initial feedstock that is converted to the fuel. | **31-35 %** | **> 33 %** |
| Carbon conversion | Fraction of carbon in feedstock that is converted to gas in the gasifier. | **96-98 %** | **> 98 %** |
| Cold gas efficiency | Fraction of chemical energy in feedstock that is transferred to syngas in the gasifier. | **75-77 %** | **> 82 %** |

## Investigation of CLG in Lab and Bench Scale Units

Chemical looping gasification (CLG) is a novel technology requiring in-depth analyses of multiple phenomena to attain a stable and efficient process allowing for continuous conversion of solid biomass-based feedstocks to a high quality syngas. Initially, the research focused on the preselection of oxygen carriers suitable for CLG of biomass. Here, raw materials of low cost, available at industrial scale were characterized and analyzed. Moreover, some of the preselected materials were tested in continuous CLG units, using different biomass feedstocks. Within the scope of these considerations, the effect of different boundary conditions (e.g. temperature, air-to-fuel equivalence ratio) on the process performance was assessed. On top of that, the oxygen carrier stability and reactivity was investigated during continuous operation. Last but not least, an experimental procedure for investigating the fate of tar surrogates has been developed at Chalmers University, to assess the potency of different strategies to prevent tar formation.

## Development of a Novel Pre-Treatment Concept for Wheat Straw

Due to the unfavorable properties of wheat straw (e.g. high chlorine content), pre-treatment is essential to prepare the feedstock for CLG. To attain suitable feedstock characteristics, CENER has developed a pre-treatment concept for wheat straw consisting of the following steps:

- *Pelletization* to enhance transport and feeding characteristics.
- *Torrefaction* to minimize contaminant concentrations and increase the net calorific value of the feedstock.
- *Washing/leaching* to further remove undesired components
- *Additivation* to improve ash melting behavior and fluidized bed characteristics

A more detailed description of the project progress can be found in the first public report of the CLARA project.

# ACTIVITIES

## Publications

- K. Atsonios, A. Nesiadis, N. Detsios, K. Koutita, N. Nikolopoulos, and P. Grammelis, "Review on dynamic process modeling of gasification based biorefineries and bio-based heat & power plants," Fuel Processing Technology, vol. 197, p. 106188, Jan. 2020.

## Presentations & Posters

- CLARA - Chemical Looping Gasification for Sustainable Production of Biofuels, *Paving the Way Towards Clean Energy and Fuels in Europe*, EUBCE Lisbon, 29.05.19
- Chemical Looping Gasification for Sustainable Production of Biofuels, *2. German Doctoral Colloquium Bioenergy*, Nuremberg, 30.9-1.10.19

For more information on the project progress visit: https://clara-h2020.eu/. In case you want to receive regular updates on the project, you can subscribe to the biannual newsletter.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 817841.