Newsletter VI, October 2021

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.

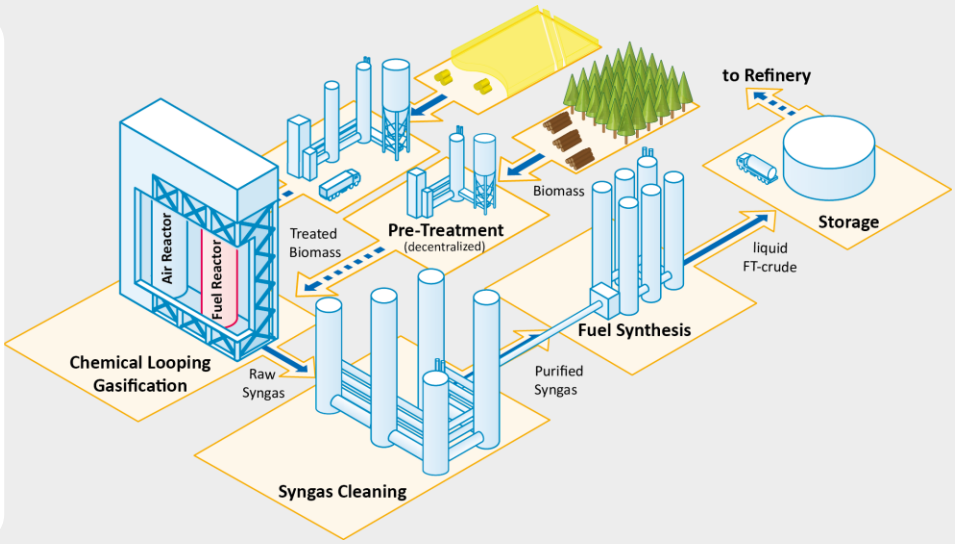
H2020 Research and Innovation action
Grant Agreement n° 817841

https://clara-h2020.eu/
jochen.stroehle@est.tu-darmstadt.de

About the Project

The **de-carbonization of the transport sector** is a key factor to achieve **significant reductions** in greenhouse gas emissions that are required to **prevent a surge in global average temperatures**, exceeding the 1.5 °C Paris Agreement threshold. 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 affecting 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.

On the Inside



Project Highlights

- A first layout for a full-scale 200 MW_{th} chemical looping gasifier has been designed by Aichernig Engineering
- Heat and mass balances for the full-scale design of the developed pre-treatment concept were calculated by CENER
- The 100 kW_{th} pilot unit at Chalmers is being prepared for chemical-looping gasification tests using pine forest residue and straw pellets
- Ilmenite exhibited stable operation and no agglomeration during chemical-looping gasification in a 50 kWth CLG unit at CSIC, where wheat straw pellets prepared with the pre-treatment concept developed in the CLARA project were used as a fuel.
- First test runs with an alternate solvent to H_2O_2 as sulfur oxidizing agent have been carried out in a stirred glass reactor module. Significant conversion rates have been detected and can be used for upcoming modelling of such technology.
- Preparations for the 1 MW_{th} full-chain experiments in Q1 2022 are underway. The pilot-scale gasifier at Darmstadt has been altered to a two-reactor setup allowing for chemical looping gasification and further plant adjustments are within the last stages of realization.

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.

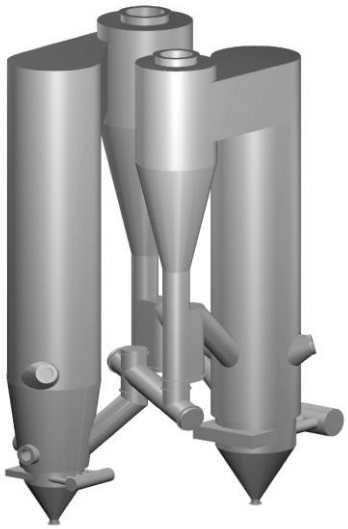
Project Progress

Within the last six project months (April 2020 – October 2021), progress was made in terms of *Full-Chain Process Development*, *Technology Development* (*Concept for Pre-Treatment of Straw*, *Chemical Looping Gasification*, & *Novel Gas Cleaning Concept)*, and the *Demonstration of the Full Process Chain*. Moreover, first advances in the field of *Risk Assessment* and *Techno- & Socio-Economic and Environmental Assessment* were made. The progress is briefly summarized in the following.

Full-Chain Process Development

- Last model adjustments for the determination of the heat & mass balances for the entire process chain have been implemented, using the latest input from the CLARA partners working on technology development. Calculations for the final heat and mass balances, laying the foundation for further up-scaling, are in the final stages.
- Production cost for stand-alone biomass pre-treatment plants based on energy and mass balances and operational expenditures (OPEX) and capital expenditure (CAPEX) costs have been calculated, showing that the lion's share of the production costs stem from biomass sourcing. The levelized production costs of the final feedstock amount to 50 €/t for wheat straw and 108 €/t for pine forest residue pellets.
- Aichernig Engineering designed a first layout for the full-scale 200 MW_{th} chemical looping gasifier, consisting of two circulating fluidized bed reactors, with diameters of 4-5 m and a height of approx. 26 m (see right).

repotec



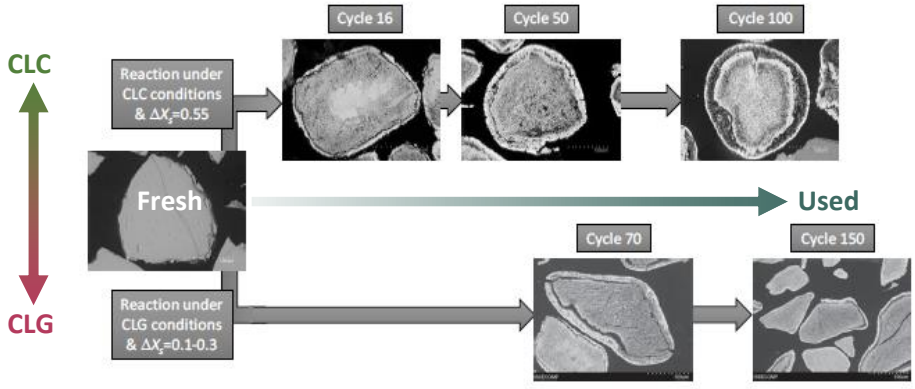
Development of a Concept for Pre-Treatment of Straw

- The final pre-treatment chain for wheat straw has been defined based on pelleting and additivation. Here, focus was not only placed on technical, but also economic criteria, to obtain a competitive product. Ultimately, it was established that a combination of pelleting and additivation is sufficient to guarantee pellet characteristics allowing for application in CLG plants, such as high ash melting temperature and good mechanical stability.

Development of Chemical Looping Gasification

- To further develop and verify the main chemical-looping gasification (CLG) process, the performance of several promising oxygen carrier (OC) materials at CLG conditions have been evaluated at different scales up to 100 kW_{th}. Here, ilmenite and LD slag, a by-product from the steel industry, were found to have the most promising characteristics.
- During the last six months, efforts at CSIS were focused on characterization of ilmenite after the tests in the 50 kW_{th} CLG pilot unit using pretreated wheat straw pellets. The characterization showed no interaction of ilmenite with potassium; therefore, agglomeration of ilmenite is not expected during CLG operation.
- Currently, the 100 kW_{th} unit at CTH is being prepared for CLG operation using ilmenite as an OC and pine forest residue and straw pellets as fuel. The data from this test will be used by TU Darmstadt for demonstration of the full process-chain.
- In addition, gasification kinetics of char obtained from different biomass pellets have been determined at CSIC and CTH during last six months. Moreover, the redox kinetic parameters have been determined for activated ilmenite under relevant CLG conditions. Within the scope of these experiments, it was shown that ilmenite behaves similarly during CLC and CLG operation, which induce comparable changes in particle structure with increased operation time, which can be detected using SEM (see figure below).

SEM images of ilmenite particles



Development of a Novel Gas Cleaning Concept

- Test runs with stirred glass reactors and column have been performed to get basic performance data for an alternative solvent as sulfur oxidizing reactant. Concentration of the reactant in the liquid solution and H_2S in the feed gas have been varied to get basic data for upcoming modelling of the new concept and design of the large-scale gas cleaning plant.

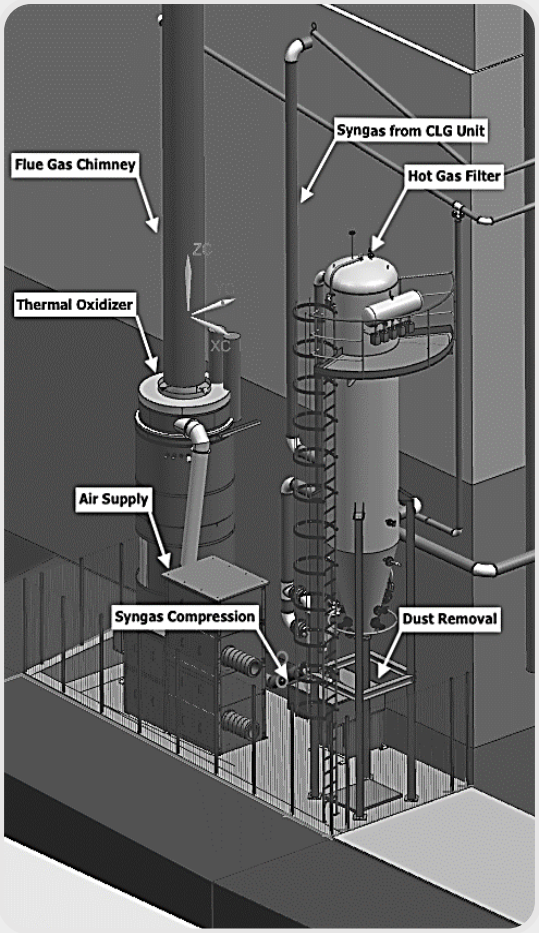
Demonstration of the Full Process Chain

- The modification of the 1 MW_{th} pilot plant to the CLG configuration is in full swing. Coupling of the fuel and air reactor has been completed, preparing the pilot plant for dual fluidized gasification operation.
- Manufacturing of the main components for the syngas removal unit is underway. A 3D-view of the final layout of this plant adaption, allowing for a safe conversion of the excess syngas produced in the chemical looping gasifier, is shown in the bottom right corner.
- The HAZOP analysis for the pilot CLG plant has been finalized. Drafting of the resulting safety shut-down matrix, allowing for fail-safe operation of the pilot, has been completed.
- The gas cleaning test rig of RWE will be transported to Darmstadt in Nov. 2021, before being integrated into the gas treatment pilot plant.
- Production of the first batch of biomass pellets for the 1 MW_{th} pilot tests at the Torkapparater facilities in Sweden has commenced (see pictures below).

Techno- & Socio-Economic and Environmental Assessment

- The assessment of the technology has been kicked off with an initial discussion and brainstorming on the degree of detail of the parameters to be collected and the needed inputs for the overall technical, economic and environmental assessment of the investigated generic biomass-to-end-use chains for the gasification of biogenic residuals in question.

AB TORKAPPARATER
THERMAL PROCESSING EQUIPMENT



AICHERNIG Engineering GmbH, also known by its brand name REPOTEC, is an Austrian SME, engineering and construction company, which is highly specialized in the erection of small and medium sized biomass – combined heat and power plants. Together with the Vienna University of Technology and the Austrian research centre BEST, a CHP-process based on the steam gasification of biomass has been developed and successfully realized in Güssing. This process has been commercialized over Europe within the last years and is recently also being realized in Japan. The Biomass Gasification CHP Plant in Senden (D) set a new levelling for process efficiency and in Gothenburg the first Biomass to SNG plant has been built.

Getting to Know the Partners – Aichernig Engineering

Producing a high quality syngas from various feedstocks is a challenging task. Here, chemical looping gasification (CLG), being employed within the scope of CLARA, is an auspicious technology. AICHERNIG ENGINEERING is an Austrian SME, engineering and construction company, which is highly specialized in the erection of small and medium sized bioenergy plants. We had the chance to talk to ***Christian Aichernig*** *from AICHERNIG ENGINEERING, to learn about the industry view on the CLARA project and promises invested industry stakeholders associate with the novel CLG technology*

What appealed to you in the CLARA project, sparking the interest to get involved in it?

We have been working in the field of biomass gasification for over 20 years. Many of the members of the consortium we had known before, some even as partners in previous research projects. When we were approached by TU Darmstadt we were sure, that the CLARA consortium will guarantee the project to become a success.

What is your role in the project and what expertise do you bring to the consortium?

As an industrial partner within the consortium, we have to ensure the feasibility and practicability of all results and solutions proposed by the partners. We will propose the design for the commercial scale CL-gasifier, will support the HAZOP for the pilot plant as well as the risk assessments with our industrial experience. Additionally, we will also support the estimation of CAPEX and OPEX of an industrial scale plant to get a realistic view on the economic feasibility of the project.

Furthermore, we will lead the exploitation task, coordinating the elaboration of an exploitation plan. ⇘

Which gasification concept, air-blown, oxygen blown or steam-driven, do you consider most beneficial for biomass gasification?

That is an easy question for me: steam blown double fluidized bed. This concept has been the basis for our successful plants in the past. With some minor changes to the geometry of the reactors, it will as well be successful for chemical looping gasification.

What, advantages do you see in the novel CLG concept, when compared to the "standard" dual fluidized bed gasification (DFBG) setup? Do you also see advantages of the DFBG concept? If so, which?

The major advantage of the CLG concept is the possibility to realize CO_2 negative energy conversion technologies. By capturing CO2 from the producer gas stream, you can realize a process without any CO_2 emissions. If the feedstock is renewable, you create negative CO_2 emissions.

What are the biggest technical, regulatory or economic obstacles for investors and companies standing in the way towards a widespread rollout of large-scale biomass gasification plants?

Today most of the energy is taken from oil and natural gas, which can be extracted from the ground at very low costs. CO2 emissions, which lead into a global climate catastrophe, can be emitted without any costs in most parts of the world. Anyhow, general public has to bear the enormous costs that arise from floods, wildfires, drought and other catastrophes caused by CO2 emissions.

To enable bioenergy plants as well as other forms of renewable energy CO2 emissions must have a price, equivalent to the cost of the effort to avoid such emissions

With the Renewable Energy Directive (RED II), the European Union set a target of a share of 14% renewable energy in the transport sector by 2030. Which political incentives do you deem to be most beneficial to reach or even surpass this target?

First of all I have to say, that the 14% target is much too low to reach the goal to limit the temperature rise to 1.5 °C.

In addition, it will need a mixture of incentives like subsidies for R&D as well as for investments in production plants for renewable fuels and access to loans for such investments. Finally, it will need also a high CO_2 tax for fossil fuels.

Which role do you see carbon capture utilization & storage (CCUS) technologies play in biomass-to-biofuel process chains in the future?

It seems that we are much too slow in reducing our CO_2 emissions to reach the 1.5 °C target. Therefore, it will become necessary, to remove some of the CO_2 which we have already emitted, to lower the CO_2 concentration in the atmosphere. A Biomass-to biofuel process with additional carbon capture utilization & storage, as we develop it in the CLARA project, can not only solve the problem of CO_2 emissions in the transport sector, but also can remove CO_2 from the atmosphere in an efficient way at reasonable costs. ♦

DI Christian Aichernig is the managing director of the company, specialized in economic evaluation and process engineering. He has over 25 years of experience in the industrial application of innovative processes for environmental technologies. He was a lecturer for process engineering at the FH Joanneum Kapfenberg and is the Head of the advisory board of Austria's leading bioenergy research centre BEST. He is the author of numerous publications and conference papers.

Selected Publications:

- Aichernig Ch, November 2001: "A Wood Gasification CHP Project in Güssing, Austria", EPRI
- Biomass Interest Group, Washington, USA
- Aichernig Ch., Hofbauer H., Rauch R., Koch R., May 2004: "Biomass CHP Plant Güssing", 2nd World Biomass Conference, Roma, Italy
- Aichernig Ch., Hofbauer H., Rauch R., 2009: " Biomass Gasification CHP Plant Güssing (Austria):
- Research Centre for 2nd Generation Biofuels", 8th World Congress of Chemical Engineering, Montreal, Canada
- Aichernig Ch., 2016: " European Biomass-to-SNG projects – Progress and lessons-learned", 3rd
- Nuremberg Workshop on Methanation and Second Generation Fuels, Nürnberg, Germany
- Aichernig Ch., 2019: " Biomass Gasification – Research and Realization", Mission Innovation Austria Week May 2019, Vienna, Austria

Dissemination Activities

Scientific 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.
- Dieringer, P.; Marx, F.; Alobaid, F.; Ströhle, J.; Epple, B. "*Process Control Strategies in Chemical Looping Gasification—A Novel Process for the Production of Biofuels Allowing for Net Negative CO2 Emissions*", Applied Sciences 2020, 10 (12), 4271.
- Condori, O.; García-Labiano, F.; de Diego, L. F.; Izquierdo, M. T.; Abad, A.; Adánez, J. "*Biomass Chemical Looping Gasification for Syngas Production Using Ilmenite as Oxygen Carrier in a 1.5 KWth Unit*", Chemical Engineering Journal 2021, 405, 126679.
- A. Di Giuliano, I. Funcia, R. Pérez-Vega, J. Gil, K. Gallucci, *"Novel Application of Pretreatment and Diagnostic Method Using Dynamic Pressure Fluctuations to Resolve and Detect Issues Related to Biogenic Residue Ash in Chemical Looping Gasification"*, Processes 2020, 8 (9), 1137
- A. Di Giuliano, S. Lucantonio, K. Gallucci, "*Devolatilization of residual biomasses for chemical looping gasification in fluidized beds made up of oxygen-carriers*", Energies 2021, 14 (2), 311
- A. Hedayati, A. H.Soleimanisalim, C. J. Linderholm, T. Mattisson, A. Lyngfelt, "*Experimental Evaluation of Manganese Ores for Chemical Looping Conversion of Synthetic Biomass Volatiles in a 300 W Reactor System*", Journal of Environm. Chemical Engineering, 2020
- O. Condori, F. García-Labiano, L. F. de Diego, M. T. Izquierdo, A. Abad, and J. Adánez, "Biomass chemical looping gasification for syngas production using LD Slag as oxygen carrier in a 1.5 kWth unit," Fuel Processing Technology, vol. 222, p. 106963, Nov. 2021.
- S. Lucantonio, A. Di Giuliano, and K. Gallucci, "*Influences of the Pretreatments of Residual Biomass on Gasification Processes: Experimental Devolatilizations Study in a Fluidized Bed*," Applied Sciences, vol. 11, no. 12, p. 5722, Jun. 2021.
- F. Marx, P. Dieringer, J. Ströhle, and B. Epple, "*Design of a 1 MWth Pilot Plant for Chemical Looping Gasification of Biogenic Residues*," Energies, vol. 14, no. 9, p. 2581, Apr. 2021.

Consortium

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.