collaboration

by Adelbert Goede

KEROGREEN

The first EU funded R&D project secured by the DIFFER Solar Fuel department.

Hardly a day goes by without being reminded of the dire consequences of climate change and the need to decarbonise the energy system. Electric power generated by wind and PV is making big strides, but is limited by ill-matched supply and demand. In addition, electricity only makes up 20% to 25% of total energy demand. Domestic heating, high temperature Industrial processes (steelworks, chemical industry) and mobility gobble up the rest. Mobility and transportation prove particularly difficult to decarbonise.

The mood was rather different in the eighties when a group of climate modellers, Glomac, raised the alarm on the increasing greenhouse gas emissions by Industry, traffic and agriculture and, as a result, predicted the climate to change. Lack of data to validate these models hampered public acceptance. I had the good fortune to meet the leader of this group, the later Nobel Prize winner Paul Crutzen, and to team up with the Space Research Organisation Netherlands to build a satellite instrument to measure these greenhouse gases from space. The instrument, SCIAMACHY (SCanning Imaging Absorption SpectroMeter for Atmospheric CartographY), a UV-vis-NIR spectrometer, circled the earth every 100 minutes in polar orbit, thereby covering the entire earth atmosphere in a couple of days. After launch on the ESA Envisat in 2002, this instrument produced the first ten year data record of global atmospheric greenhouse gas distributions. To date, this pioneering effort has evolved into an Atmospheric Monitoring Service under the EU Copernicus Earth Observation programme.

One can spend a life time monitoring greenhouse gases, but by now we know that our climate is changing. Better to concentrate on solving the problem of CO_2 emissions. This is where KEROGREEN comes in. By converting renewable electricity into fuel, power to molecules (P2M), two birds are killed with one stone; providing fuel for long haul transportation and enabling long term, large scale energy storage to cover the seasonal mismatch between supply and demand of renewable electricity.

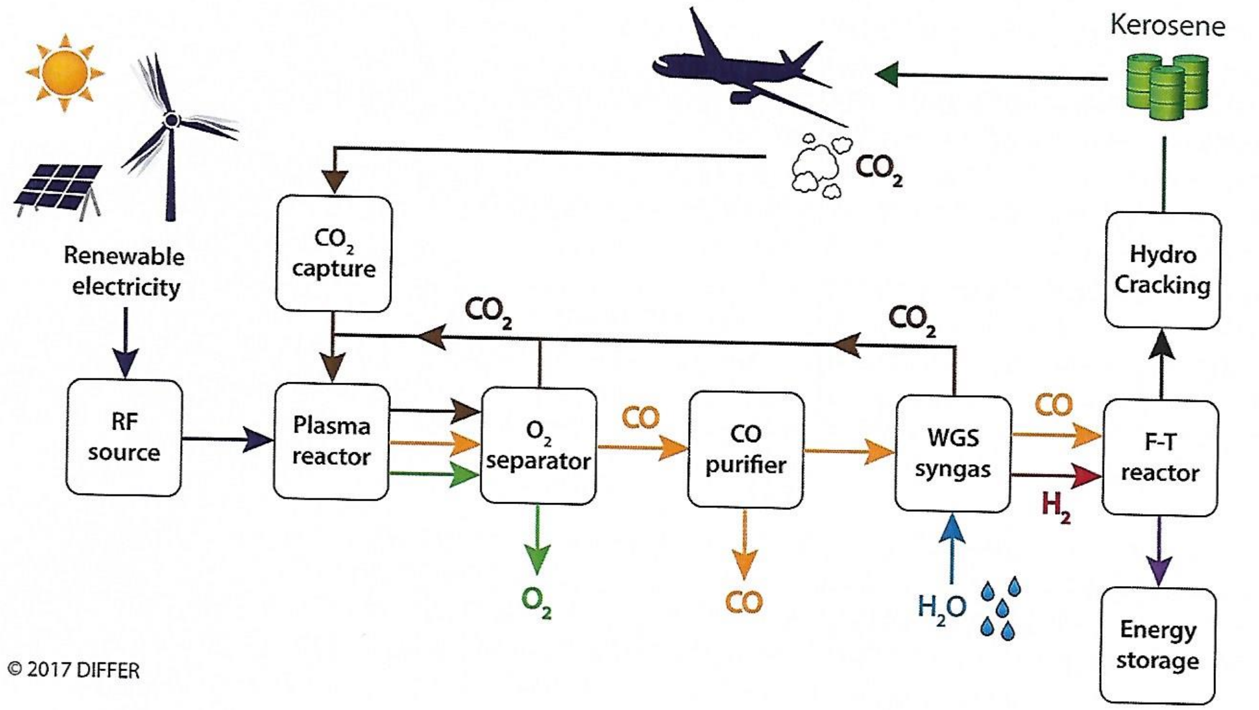
Self-driving electric cars are showing the way in urban mobility, reducing both air pollution and greenhouse gas emission. Necessary electricity and data infrastructure is less prolific in sparsely populated areas, limiting long haul road transportation to be electrified. For shipping and aviation, decarbonised fuel options are particularly hard to find. Hydrogen, even when liquefied, needs a much larger volume to store the same amount of energy contained in hydrocarbon based fuel. For example, an aircraft would need a 5 times larger volume to store liquefied hydrogen with the same energy as contained in kerosene, not taking into account the thermal isolation needed to reduce hydrogen boil-off during flight. The mass of an equivalent battery is prohibitive; an Airbus 380 with a lift off mass of 575 tonnes, including approx. 250 tonnes of kerosene, would need a battery of around 14.000 tonnes to carry the same amount of energy. The plane would never take off.

KEROGREEN, a 4 year, 5M€ European funded H2020 project, is carried out by KIT, VITO, CerPoTech, HyGear, INERATEC and led by DIFFER. It provides a novel conversion route to sustainable aviation fuel synthesised from air and water, powered by renewable electricity. The conversion is based on plasma driven CO_2 dissociation, electrochemical oxygen separation and Fischer-Tropsch (F-T) synthesis of kerosene. The CO_2 emitted upon use is recirculated as feedstock to the process by direct air capture, rendering the fuel cycle CO_2 neutral.

Sustainable kerosene emits less soot and no sulphur, meeting future aviation air pollution standards. The technology is modular, scalable and relies on existing infrastructure for storage, transport and distribution. Jet-engine technology can be kept unchanged as F-T synthesis has been qualified as jet-grade fuel. The technology readiness level is raised from TRL 3 to 4 by novel system integration into a container sized unit to produce 1kg/hr kerosene as an end product of KEROGREEN in the year 2022.

The KEROGREEN process flow is illustrated by the beautiful picture made by Erik Langereis. It represents the individual units specified, designed, developed, tested and integrated into a self-contained system by the KEROGREEN project. There are three main sub-systems: the plasma splitting of CO_2, the separation of

Oxygen out of the exit gas stream and the formation of syngas (CO and H_2) with subsequent synthesis of kerosene. The fourth element, carbon capture, albeit essential, is not part of this EC project, being not part of the EC Call. The plasma part is the responsibility of DIFFER, the oxygen separator is responsibility of VITO with support from DIFFER, CerPoTech and HyGear. The synthesis part is responsibility of KIT and INERATEC.



Production of Sustainable aircraft grade Kerosene from Water and Air powered by Renewable Electricity through the splitting of CO_2, formation of Syngas and Fischer-Tropsch synthesis

Plasma splitting of CO_2 was demonstrated by DIFFER on the Stuttgart facility in 2012 and published shortly afterward[1)]. This work is being reproduced by Waldo Bongers on our DIFFER facilities. Paola Diomede tries to understand the underlying plasma chemistry. Separating O_2 from the CO_2, CO and O_2 exit gas stream proves to be the hard bit. Michalis Tsampas has now turned his attention to plasma membrane interaction where the electro-chemical surface interaction and oxygen transport through the membrane is hoped to be enhanced by energetic plasma species. Suleyman Er provides theoretical support by modelling the quantum mechanics of perovskite plasma particle interaction and oxygen ion transport. The synthesis of kerosene concentrates on creating conditions that are product specific and on system integration of heat to improve the overall energy efficiency.

The KEROGREEN project was recently kicked off on 5 - 6 April 2018 at DIFFER and concentrates on the critical production of high temperature (700 - 800 °C) oxygen transporting membranes. René Schoonen, Ed van Wijk and myself are forming part of the day to day management team for the consortium as a whole. Here, timeline and financial envelope are the other main risk factors of this project.

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1) Goede, A P H., et. al., EPJ Web of Conferences 79, 01005 (2014), DOI: 10.1051/epjconf/20147901005