Demonstrating the CCU-Chain and Sector Coupling as Part of ALIGN-CCUS - Dimethyl Ether from CO_2 as chemical Energy Storage, Fuel and Feedstock for Industries

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Abstract

The European and national funded ALIGN-CCUS project unites 31 research institutes und industrial companies in the shared goal to achieve the cost-effective deployment of carbon capture, utilisation and storage, enabling Europe's industrial and power sectors to contribute to a low-carbon future while remaining economically viable. As part of the ALIGN-CCUS project, a full CCU-chain will be demonstrated as an element for large-scale energy storage by CO_2 conversion into a CCU fuel as a promising blue print for sector coupling. The demonstration comprises: CO_2 post-combustion capture and liquefaction processes at a lignite fired power plant, a water electrolysis process unit to split water into hydrogen and oxygen and a methanol/dimethyl ether (DME) synthesis process unit, all located at Niederaussem (Germany). Additionally, the engine of a stationary power generator will be adapted to the use of DME and a passenger car will be fueled with oxymethylen ether (OME), that can be produced out of methanol and DME.

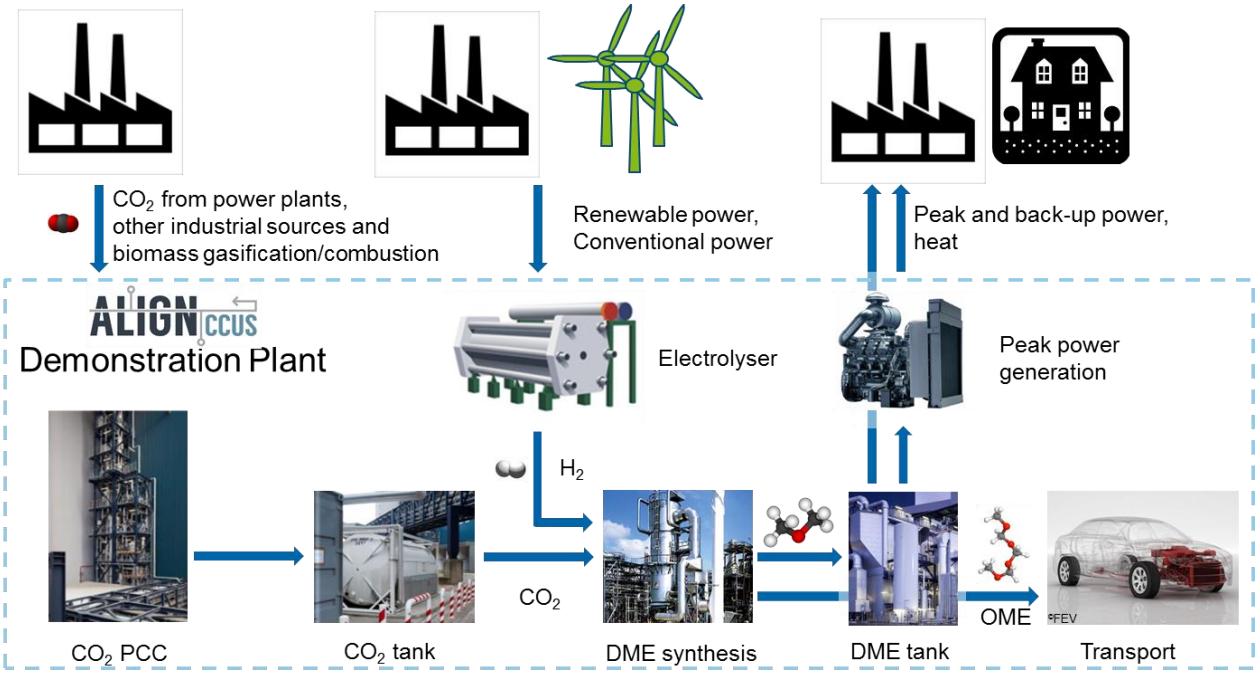
The energy systems are currently transforming into configurations with a significant share of renewable energies, while the security of supply and an intelligent balancing of the power supply and consumption remain important priorities. In general, renewable energy is limited in their temporal availability and with an increasing share of renewable power from wind and photovoltaics, their fluctuating nature demands reliable, efficient energy storage systems and back-up power. To reduce the CO_2 emissions according to the Paris climate protection goals up to 95%, however, it would not be sufficient at all to replace conventional fossil-fired power generation by renewable energies. An analysis of CO_2 emission shares of economic sectors shows ~31% are due to power generation, 20-22% linked with transportation and storage, 22% tied with small consumers and households, and 21-22% due to manufacturing (12.5% processing and trade, 8.5% industry) for Europe and Germany. Without a strong contribution from all economic sectors the CO_2 reduction goals cannot be achieved. Future energy systems require integrated power generation (conventional, renewable and nuclear), heavily interconnected with consumption (industry, transport and households) via exchange of power, heat and materials. In particular, this offers an opportunity for coupling of the energy and the mobility sector and is unlocking the potential for CCU. The proof of feasibility and viability of the demonstrated full CCU-chain and the utilisation of the CCU-products DME/OME in the power and transport sector is also needed to increase public awareness and acceptance of CCU as a climate protection measure.

The technology chain demonstrated in the ALIGN-CCUS has various co-benefits, beside the substitution of fossil fuels by producing platform chemicals (MeOH, DME) with many applications in different economic sectors. Coupled power generation and production and use of CCU fuels support the renewable energies by stabilising the grid, providing long-term energy storage and peak-load/back-up power generation. The use of DME/OME as fuels additionally lowers emissions (SO_x, NO_x, CO and particulates/soot) in the transport sector.

In ALIGN-CCUS CO_2 will be captured from the flue gas of the power plant by the already existing capture and liquefaction plant at RWE's Coal Innovation Centre in Niederaussem and supplied to the MeOH/DME synthesis unit from Mitsubishi Hitachi Power Systems Europe. H_2 will be produced via a highly-efficient alkaline water electrolyser from Asahi Kasei which is scalable for large-scale applications. The production of MeOH and DME (approx. 50 kg/day) is realized by an innovative one-stage DME process in the synthesis unit. This hybrid reactor technology allows adjustments to the product composition depending on the reaction conditions and catalyst loadings. The hybrid reactor design leads to thermodynamic improvements for the process and the possibility to produce not only valuable products but also yields high productivity. To demonstrate the supply of back-up and peak power, which becomes more and more critical with an increasing share of fluctuating wind and photovoltaic power generation, a stationary DME-fueled peak-power generator (power output 240 kW) will be installed. RWTH Aachen and FEV will modify this engine to run on this CCU fuel. A car which will run on OME, will demonstrate another possible implementation of a CCU fuel. FZ Jülich will perform a techno-economic-ecological assessment based on real data from the demonstrator to evaluate integration costs and environmental benefits of the CCU-chain technology for large-scale units and decentralised smaller facilities. Together with ECN and TNO all partners will jointly work on options for the techno-economical optimization of the demonstrated CCU technology.
The project aims at providing answers to the key questions:

- What size of the demonstrated CCU-chain is commercially most promising and what is its most promising environment (economy of scale, decentralised units, installation at industrial sites or urban areas)?
- How can the developed technology be integrated into the transforming energy world to achieve maximum benefit (CO_2 sources, share of the energy content of MeOH, DME, OME, distances between CO_2 source, CCU-fuel synthesis plant and end-user)?
- CO_2 – usually treated as waste – becomes a product/resource in the ecological investigation. Can a fair and transparent mechanism be defined for the allocation of mitigated emissions of recycled CO_2 and the resulting co-benefits?

The paper will present the actual status of the demonstration project regarding engineering and construction of the demonstrator as well as the first findings of the techno-economical-ecological analysis.



The CCU-demonstration plant in the ALIGN-CCUS project realizes the full process chain and the use of CCU-products in the power and mobility sector.