Workshop "Carbon Capture Integration"

Online, September 12th, 2024

On Thursday, September 12th, 2024, an international webinar on the topic of “Carbon Capture in Industry” was organized by partner Montanuniversität Leoben (MUL) as part of the IETS Task XXI Subtask 2 "Widening the perspective on Circular Carbon: from potentials to practical experience”. The online video conference via Zoom covered seven presentations by representatives from the industry as well as research institutions. The webinar lasted for three hours (14:00 – 17:00 CET) and was attended by more than 50 international experts on the topic of carbon capture with an even distribution of industry and research. The target of the webinar was to get the latest insight into the state-of-the-art in carbon capture technologies in terms of their Technology Readiness Level (TRL), energy and cost demand as well as to get a view on the current limitations for the realization of upcoming projects. In addition, the presentation covered the aspects of utilization and/or storage of the captured CO2 as well as regulatory issues. Overall, the following three topics were addressed in this networking event:

Topic I: Carbon capture in the industry sector
- best practice examples
- long-term experiences
- case studies and comparison of technologies
- differences for various industry sectors (e.g. cement, iron & steel, waste incineration)
- synergetic integration of carbon capture in existing industrial infrastructure

Topic II: Future concepts
- new emerging technologies
- development projects in the pipeline
- energy demand and CAPEX/OPEX -- actual figures and their future development

Topic III: Carbon capture in different perspectives
- views of plant manufacturer vs. operator
- CO2 quality for transport and utilization
- requirements for regulations (certificates, trading, monitoring, legal responsibility)

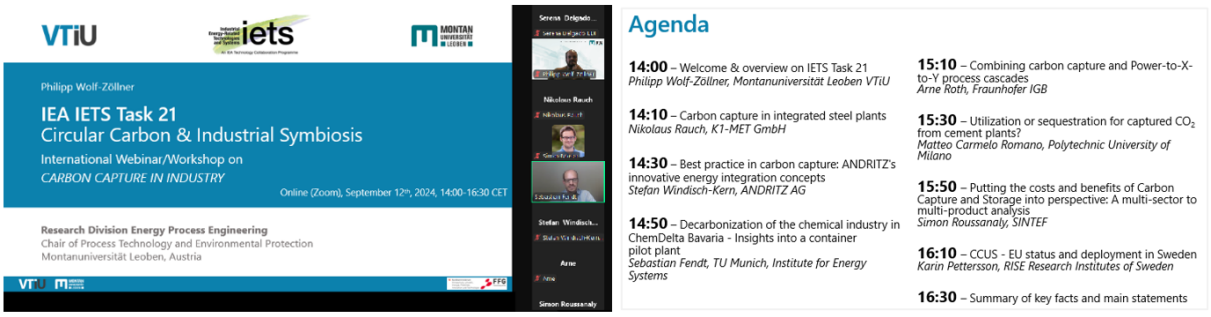

Figure 1: Online webinar on ‘Carbon Capture in Industry’ via Zoom

The webinar was opened by **Philipp Wolf-Zöllner** (MUL), who organized the event, by giving an introduction and overview on the IETS Task XXI as well as on the objectives of this workshop. After a short welcome by subtask leader **Simon Moser** from Energieinstitut an der JKU, the first technical presentation was given by **Nikolaus Rauch**, Project Manager with K1-MET GmbH. K1-MET is a competence center for ferrous and nonferrous metallurgy situated in Linz, Austria. During his presentation with the title ‘Carbon capture in integrated steel plants’ Nikolaus gave an insight into the project ZEUS (Zero Emissions through Sector coupling) which aims on a cross-sectoral demonstration of a climate-neutral process chain at TRL 7. This shall be established by stabilizing the electric energy system through grid balancing and cost optimized green hydrogen production, as well as the demonstration of CCU technologies under dynamic and real operating conditions in an energy intensive industry with real gases from the steelmaking process. For this process an amine scrubber is used to capture up to 800 kgCO2/day from the power plant off-gas located inside the steelworks. Together with green hydrogen, produced by a dynamically driven 6 MW PEM electrolysis, the CO2 is catalytically

converted to synthetic natural gas (SNG) which can be injected into the gas grid of the steel plant for further internal usage. Nikolaus gave a detailed overview on the results K1-MET achieved during the first years in operating the amine scrubber in terms of energy consumption, heat demand and the trade-off between separation efficiency versus specific regeneration energy. As main challenges for carbon capture in the steelmaking industry Nikolaus identified that CCU products are only shifting the CO2 emissions and that a CO2-neutral process chain is challenging due to unavoidable CO2-emission. As requirements for future implementations, he sees the need to establish a CO2 and green H2 infrastructure, a stronger demand/communication for synthetic hydrocarbon products (methanol, SNG), and a dedicated use of precious renewable gases. Furthermore, Nikolaus showed that it is necessary to reduce the energy demand for the regeneration of the amine solution by adding new and innovative absorbents such as combinations of MDEA and piperazine.

The second presentation was given by **Stefan Windisch-Kern** from ANDRITZ AG, Austria, on their innovative energy integration concepts when it comes to best practice examples in carbon capture. Stefan is Project Manager for Proposal & Sales, Carbon Capture in Clean Air Technologies and was able to report from a plant manufacturer's perspective. ANDRITZ, as a global leading large-scale supplier of plants, equipment, system and services for industrial applications, is providing carbon capture solutions via chemical absorption using amines, or hot potassium carbonate, as well as through membrane technology. For each technology Stefan could give actual figures for CO2 removal efficiency rates, energy consumption, CO2 purity, CAPEX/OPEX as well as TRL. A dedicated part of Stefan's presentation was on the heat integration for carbon capture solutions and an evaluation of possible heat sources for each technology with the integration of heat pumps for an example of a 500 t/day plant. In summary, several heat sources are available exceeding the regeneration demand, and different qualities of heat require tailored integration concepts. Stefan pointed out that a CAPEX/OPEX comparison is industry and location sensitive, especially when it comes to different evaluations on steam and electricity demand. Heat integration is a major challenge but also an opportunity in carbon capture operations but there is no "one fits all" solution for each individual CO2 source. Client- and site-specific requirements always ask for individual considerations.

Sebastian Fendt, Group Leader at the Chair of Energy Systems of Technical University of Munich, Germany, gave the next presentation with the title 'Decarbonization of the Chemical Industry in the ChemDelta Bavaria - Insights into a Container Pilot Plant'. The information provided is gathered as part of the project H2-Reallabor Burghausen, where the question on how a sustainable chemical industry can be implemented in the future. The anticipated pilot plant solution targets a sustainable production of essential basic chemicals, such as methanol using unavoidable or hard-to-abate CO2 sources. It consists of two containers demonstrating the complete CCU process chain from the carbon capture unit (~100 Nm^3/h) to the Power-to-Methanol container producing ~40 l of crude methanol per day. For capturing the CO2-rich process off-gas also an absorption-based solution with amines is anticipated. The targets for the capture unit are dealing with dynamic parameters such as varying CO2-concentrations and volume flows of the flue-gas, as well as to minimize the required energy demand for the regeneration. Research questions for the magnitude of fluctuations, optimal operating conditions, required purity levels and trace elements, innovative reactor design and dynamic operation control are to be answered during the project.

Arne Roth is Head of Department Sustainable Catalytic Processes at Fraunhofer Institute for Interfacial Engineering and Biotechnology, Germany, and continued the series of presentations with an overview on Power-to-X-to-Y process cascades where chemicals and fuels are catalytically converted from CO2, water, nitrogen and renewable electric energy. Arne provided the audience with technical information on these TRL 3-5 processes where platform chemicals such as renewable ethylene oxide and glycol can be produced. The laboratory-scaled test unit with its individual components was presented for the thermocatalysis in the project EcoFuel, funded through the European Union's Horizon 2020 program. There was also a development plan presented for the upscaling of the small-scale R&D unit in the lab towards a pilot plant to be commissioned in 2026. Arne continued with R&D approaches for CCU such as the synthesis of green methanol or formic acid/format via electrocatalysis within the Celbicon project. As a main challenge for the highly sensitive thermocatalytic processes the impurities in the CO2 feed from point sources was identified. R&D work is often carried out under laboratory conditions with pure CO2, but certain components based on sulfur, chloride or ammonia can already poison the catalysts in the ppm or even ppb range. Consequently, it is necessary that research utilizes real CO2 feed streams for the process development of CCU technologies and defines what kind of pre-treatment is required down to which concentration.

The next presentation was given by **Matteo C. Romano**, Professor of Systems for Energy and Environment at the Politecnico di Milano, Italy, on the topic of how the captured CO2 from cement plant off gases can be further used in an optimized way. In Matteo's research, he showed that for European cement producers, CCS projects should be prioritized in the short term, because of lower cost of CCS compared to CCU projects. CCU may be considered also in Europe as a long term option, at the condition of a substantial reduction of costs of renewable energy technologies; a significant expansion of the e-methanol market demand, driven by the chemical industry; the persistency of a differential cost of capital with respect to renewable energy (REN)-rich emerging countries, which would otherwise outcompete the European domestic production; as well as the availability of good REN-sites (i.e. with high capacity factors) after the higher merit order local electricity demand is satisfied. The use of renewable carbon (from biomass or air) makes CCU more competitive, by exploiting a premium selling price, which is not the case of e-methanol from cement plant captured CO2.

Simon Roussanaly continued the shift in presentations from carbon capture to CCU/CCS by giving insights on the costs and benefits of CCS projects. Simon is a Research Scientist in the Research Department for Gas Technology at SINTEF Energy, Norway and presented his latest work on a multi-sector to multi-product/service analysis. Motivated by the fact that CCS is behind where it should be to achieve the European net-zero ambitions, he pointed out that there are several elements contributing to this: CCS is often associated with fossil fuel, there are limited policy and regulatory frameworks, and CCS has been criticized for being too expensive. In his work he addresses the point that the costs and benefits of CCS implementations are rarely presented from the end-user perspective. The question is raised if CCS is really too expensive for end-users and notes that costs are only presented at the plant level right now. In his study, he included nine products form potential areas of application for CCS and calculated the potential emission reductions and resulting cost increases. While large emission reductions could be unlocked thanks to CCS implementation (7 with reductions larger than 50%, 4 with reductions larger than 65%), only a marginal increase in costs could be observed (1.2% for 7 cases) which are below the yearly global inflation rates.

The final presentation of the webinar was given by **Karin Pettersson**, Senior Researcher and Project Manager at RISE Research Institutes of Sweden. She gave an overview on the deployment status of (BE)CCUS projects in Sweden. She started with the details on the EU policy when it comes to climate neutrality by 2050. In Sweden the climate neutrality target is set for 2045 with an at least 85% reduction of GHG emissions. For (BE)CCUS the Swedish government presented a dedicated strategy and investigations for suitable locations to permanently store CO2 are ongoing. According to the Swedish climate policy framework, fossil-based CCS is only allowed for hard-to-abate industries such as the production of cement. There are 30 different plants within the heat and power sector as well as pulp and paper industry which have investigated the possibility of implementing BECCUS. Stockholm Exergi for example plans for a facility which captures 800,000 tCO2/year at the combined heat and power plant in Värtan. Business models for the near future are based on the combination of state support as well as selling credits on voluntary carbon markets. The Swedish support scheme for BECCS is planned in the form of reverse auctions, with the first one starting in fall 2024. Around 3 billion Euros have been allocated in the state budget for the years 2026 – 2046, supporting 15-year contracts for the winner(s). For the production of chemicals and plastics recycled and renewable feedstock shall be used. For this, targets for the raw materials shall be introduced within the EU as well as a cut-off year shall be defined for the intake of new fossil raw materials. The incentives shall be designed in a way that most energy- and resource-efficient circulation is rewarded where possible. At the same time, there also needs to be incentives to recycle carbon atoms through CCU when other alternatives are not possible. In general, for the production of sustainable carbon-based products, a broader perspective than pure CCU must be adopted