The climate change challenge increases the interest in CCUS

From residual steel gases to methanol

New PhD in process metallurgy
Climate change – for the carbon-intensive industry

The steel industry and other carbon-intensive industries are facing a major challenge to reduce CO\textsubscript{2} emissions to mitigate climate change. Swerea MEFOS is actively engaged with industry to identify and develop technologies to meet this global challenge.

Carbon Capture, Use and Storage (CCUS)

In recent years, the drive to reduce CO\textsubscript{2} emissions from integrated steelmaking, that is steel made from iron ore and coal, has increased the interest in the development of gas conversion technologies to transform industrial syngases containing CO\textsubscript{2}/CO/H\textsubscript{2} into products (such as pure streams of H\textsubscript{2} & CO\textsubscript{2} and further processing to chemicals and products such as methanol and polymers). Converting the carbon in gases to products will both reduce CO\textsubscript{2} emissions and replace the use of oil or other natural resources currently used to make these chemicals. It is expected that multiple products will be made, or be combined with CO\textsubscript{2} storage, in order to significantly reduce CO\textsubscript{2} from steelmaking.

One example of this is conversion of blast furnace gas which contains about 2/3 of all CO\textsubscript{2} generated in integrated steelmaking. Basic oxygen furnace gas is another, higher value gas usually recovered from integrated steelmaking. Both these gases are typically combusted in lower-efficiency steam cycle power plants. With the implementation of CCU technologies, these gases will be converted to higher-value products that significantly improve carbon efficiency and reduce emissions.

Pilot plants in industrial environment

Swerea MEFOS offers specialist expertise in building and operating large pyrometallurgical pilot plants, including handling and cleaning
Climate change challenge – for the carbon-intensive industry of process and flue gases. Developing and proving gas separation and conversion processes requires testing with real industrial gases. To facilitate this, a gas line transporting up to 2500 m³/n/h blast furnace gas from the neighbouring SSAB steelplant has been installed to supply our pilot plant facilities. Infrastructure for adding coke oven gas and basic oxygen furnace gas lines has also been installed. The access to gas presents possibilities for testing CCU/CCS systems using real industrial gas from smaller scale, e.g., 100 m³/n/h, to large pilot-scale depending on the needs of the project.

Careful integration
To achieve maximum-efficiency systems CCUS should be carefully integrated into industrial systems. Process integration is a methodology developed to optimize systems over a wide range of processes, including combining CCUS technologies into existing or new industrial processes. Swerea MEFOS hosts The Center for Process Integration in Metallurgy, which is engaged in studies for potential integration of CCUS with goals to minimize costs and energy use and maximize impact on overall CO₂ emissions.

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International study understands the costs of carbon dioxide capture
Commissioned by the International Energy Agency Greenhouse Gas R&D Programme (IEAGHG), Swerea MEFOS has studied the costs of incorporating carbon dioxide capture in integrated steelmaking.

The steel industry is looking for ways to dramatically reduce CO₂ emissions. Carbon dioxide capture and sequestration are one alternative. IEA Greenhouse Gas (IEAGHG) is an international research programme whose aims are to assess technologies for reducing Greenhouse Gas (GHG) emissions caused by use of fossil fuels and to provide programme members with independently reviewed technical assessments.

IEAGHG contacted Swerea MEFOS for assistance in understanding the costs and problems associated with carbon capture and storage in integrated steelmaking. Together with Tata Steel Consulting UK and SINTEF, Norway, detailed technical models were made and integrated with cost models to obtain independent cost calculations.

Scenarios include various alternatives for carbon dioxide capture, after combustion from conventional integrated steelmaking and for capture from an oxygen-fired blast furnace off-gas.

The report has been published as part of a series of studies and is used as a reference by IEA, UK BERR, Eurofer and ZEP.

“Reporting CO₂ avoidance cost alone in assessing the GHG mitigation cost of a complex industrial site such as an integrated steelmill is not enough and could be misleading. This report has demonstrated the different factors that could affect this value. This report has more than achieved its objective by providing a transparent methodology for understanding the cost of incorporating CO₂ capture in an integrated steelmill,” says Stanley Santos, project manager of Capture & Integrated Systems at IEAGHG.

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Reforming blast furnace off-gas into hydrogen
The Stepwise project aims at the demonstration of advanced pre-combustion CO₂ removal technology within the framework of the iron and steel industry to lower the CO₂ footprint of steel production. The scope is to reform blast furnace off-gas into hydrogen, and in the same process capture CO₂. The process produces a hot H₂-rich stream at pressure that is suitable for power production, and a CO₂-rich stream suitable for CCS or CCU. In the Stepwise project this process is demonstrated at Swerea MEFOS in a scale of 14 t/day CO₂ removal. The project is coordinated by ECN (NL).

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The Stepwise facilities. Photo: Maria Åsén.
Techniques for \(\text{CO}_2\)-utilization discussed in Lyon

The 7th Carbon Dioxide Utilization Summit was held 19-20 October, in Lyons. The purpose of the conference was to highlight and discuss the challenges and benefits associated with capturing and recycling (CCU), which may be viewed as a complement to \(\text{CO}_2\) capture and storage (CCS) in the effort to reduce emissions. CCU concerns the use of \(\text{CO}_2\) as a carbon-based raw material. During the conference several techniques for producing, for example, fuel and plastics, were presented.

Many of the speakers showed examples of small-scale implementation, but pointed out that the the cost of producing a specific product depends a lot on the separation method, possibilities for green-energy production and \(\text{CO}_2\) quality. Therefore, it is important that the technology chosen matches the \(\text{CO}_2\) source.

Delegates we met expressed great interest in Swerea MEFOS’s activities in this area, above all, our participation in the Stepwise and FReSMe pilot projects. Conference delegates mainly included CCU technology developers, but also industry people who are seeking solutions for reducing emissions, as well as lobby organizations that are working to raise the issue of legislation concerning \(\text{CO}_2\)-based products.

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From residual steel gases to methanol

Stena Germanica will run on methanol from the FReSMe project. Photo: Victoria Edström/Stena

The EU’s Horizon 2020 research and innovation programme has granted funding amounting to 110 million kronor for the FReSMe project, “From residual steel gases to methanol”. The aim is to develop a method for producing methanol from residual gases from steelmaking to fuel ships.

New PhD in Process Metallurgy

Extracting iron via direct reduction can enable greater production efficiency while reducing environmental impact, for example, through reduced carbon dioxide emissions.

Mania Kazemi’s doctoral thesis outlines the effects of different reducing gases in the reduction of iron oxide.

Mania Kazemi, Swerea MEFOS, in September defended her doctoral thesis at KTH Royal Institute of Technology. The thesis is entitled “Fundamental studies related to gaseous reduction of iron oxide”.

In conventional ironmaking, iron ore is reduced with coal and coke as reducing agents in blast furnaces. The demand for greater efficiency and reduced environmental impact in iron and steelmaking has attracted increased interest in direct reduced iron, so-called DRI-based production. This means that the iron is reduced in solid phase and no liquid phase occurs. Among other things, Mania Kazemi has studied the effects of different reducing gases in the reduction of iron oxide. The study has shown that a higher hydrogen content in the reducing gas results in higher reaction rates, which is positive from a process point of view. Further studies have shown that the reduction is controlled by both chemical reaction and gaseous diffusion.

“Mania’s work has given us an important understanding of how DR pellets can be developed and
A by-product of steelmaking, residual gases, are currently used to produce electricity and heat. By utilizing the full potential of the gases, environmental impact from industry can be reduced while at the same time making use of an environmentally friendly fuel, in this case, methanol for fueling ships.

The objective of the FReSMe project is to produce methanol for use/demonstration in the vessel Stena Germanica. This green fuel will be produced from carbon dioxide recovered from an industrial blast furnace at SSAB in Luleå, and hydrogen recovered both from the blast furnace gas itself, as well as H₂ produced by electrolysis.

The project will make use of the existing equipment from two pilot plants: the Stepwise plant, which is being built at Swerea MEFOS in Luleå (for energy-efficient separation of carbon dioxide from blast furnace gas) and the MefCO₂ plant, which is being built in Germany (to develop a method for producing methanol from recovered CO₂ and renewable H₂). Trials will be conducted at Swerea MEFOS, where parts of the MefCO₂ plant will be installed during the course of the project. A newly built, 600-metre-long gas pipeline from SSAB’s blast furnace to Swerea MEFOS is an essential component for realizing the project.

“One of our focus areas is use of cleaner energy. Here, we have to be creative and try new routes. The FReSMe project demonstrates the possibility of developing fossil-free fuels in new and unforeseen ways and the project is a good example of how we, together, can make both the steel industry and the maritime industry even more environmentally friendly,” says Per Stefenson, project manager, Stena Teknik.

The project period is 2016-2020. Among the eleven companies from six countries participating are SSAB and Stena Rederi AB from Sweden. The project coordinator is Spanish I-Deals.

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As 2016 draws to a close I can sum up the year by saying that it has been a very eventful one. The world around is changing, as are we with it.

A major challenge to society, the climate issue is also a challenge for the iron and steel industry and our customers. Therefore, we at Swerea MEFOS are increasingly involved in research within CCUS (Carbon Capture, Utilization and Storage) and steam reforming. Our business concept is to conduct research geared towards renewal and sustainable growth among our members and other customers.

We are now working with several projects within CCUS and gas reforming. This work deals with several aspects, from the development of specific engineering solutions to systems analyses. Here, we are benefiting from successful collaboration with academia, in among other ways, through an industry-employed doctoral student who is focusing on “Carbon Dioxide Abatement (CCS/CCU) – Possibilities for the Iron and Steel Industry” via Luleå University of Technology (Energy Engineering). Our international leading-edge expertise in pilot-scale and demonstration-scale work is a key component. We have also invested in a gas pipeline which now gives us continuous access to real blast furnace off-gas. Thereby, we are able to provide even better pilot and demo research. Thus far, the projects have mainly been joint research projects, funded mostly via public-sector bodies. Two large projects, Stepwise and FReSMe, are presented in this issue of News.

Backed by our new experiences and new facilities, we look forward to a greater share of commissioned work for industry.

In June we arranged Scanmet V in Luleå. This year’s conference, held in central Luleå, was a success. A large number of topics were presented and discussed, and delegates had the opportunity to meet and network, see some of Luleå and visit Swerea MEFOS and, hopefully, be inspired to continue researching and developing. We are already looking forward to an even more rewarding conference in four years.

My expectation for 2017 is that Swerea MEFOS will become even better at meeting the industry’s challenges in research projects towards renewal and sustainable growth.

Eva Sundin
In mid-June we welcomed delegates to the international SCANMET conference, the fifth since the start in 1999. Some 300 delegates from about thirty countries met to discuss current research in steelmaking.

International steel experts meet in Luleå

The intensive four-day programme featured nearly 150 papers on important topics including recycling and sustainable production, resource and energy efficiency, and reduction and separation of carbon dioxide.

“With SCANMET we wish to create a forum for industry and academia where there is scope for the exchange of ideas and knowledge towards the development of future, sustainable steelmaking processes. This is the fifth time we have arranged SCANMET and interest is great, despite the fact that the industry is facing economic pressure,” says Anna Utsi, business development manager at Swerea MEFOS and project manager for the conference.

This year’s SCANMET also included a “2nd Process Integration Forum” with four sessions. Swerea MEFOS first arranged the latter two years ago. Process integration is a form of systems analysis that considers the entire chain of production, instead of merely looking at single processes.

“Today, a holistic approach is essential for meeting the industry’s sustainability targets,” says Mikael Larsson, department manager at Swerea MEFOS and associate professor at LTU. Process integration is an important tool that can be used by the steel industry to improve both material efficiency and energy efficiency in production systems.

From raw material to furniture
The introductory plenary sessions provided insight into current developments in the steel world, as well as a look into the future. Göran Carlsson, President and CEO, Swerea, kicked off the first plenary session with a look at what might be expected in terms of future trends in the industry, technology and behaviour. A paper by Ernst Lutz, EIT Raw Materials, presented the world’s largest-ever raw-materials consortium, EIT Raw Materials. The aim of collaboration is to secure Europe’s supply of raw materials and the initiative involves over 100 partners from more than 20 countries. The address was given by Professor Pär Weihed, Luleå University of Technology.

Much further along the chain of production we find manufacturers of consumer products. Åsa Lidén, Ikea, gave an informative presentation on how her company works with product development, where there are interesting possibilities for incorporating metal into furniture design.

What’s happening on the international scene?
The European Steel Technology Platform (ESTEP) represents Europe’s steel industry. Participating via video link, Klaus Peters presented ESTEP’s strategic research agenda and the vision for sustainable steel production by 2030. Jianliang Zhang from the University of Science and Technology Beijing followed up with a presentation on the status of the Chinese steel industry.

The plenary sessions were concluded by Professor Veena Sahajwalla, who
heads the Centre for Sustainable Materials Research and Technology (SMaRT) at UNSW in Australia. She gave some very interesting insights into work done at the centre and the concept of sustainable manufacturing, exemplified in a paper on industrial collaboration between different sectors. Recycling of plastics in steel-making is an example of a concept for converting waste into a valuable resource. Reduced climate impact and better resource utilization

For the steel industry, today’s challenges have a lot to do with minimizing carbon dioxide emissions, recycling as much as possible and doing it all with the best possible energy efficiency. Through innovative solutions, resource efficiency and optimization of manufacturing processes the steel industry can help to realize the vision of a circular economy while at the same time improving the industry’s competitiveness.

The underlying theme of the SCANMET conference was sustainability in steel-making via development of recycling of residual products, process development enabling greater efficiency in process control, and methods and concepts for reducing CO₂ impact. More than 15 papers dealt with recycling across the entire process chain. In a keynote address, Björn Haase from Höganäs presented possibilities and opportunities for recycling from a Swedish perspective. The presentation featured examples of recycling of residual products in the steel industry, both internally within production systems and in the form of secondary materials that can add value externally.

Several presentations also addressed the important question as to how carbon dioxide emissions can be reduced, for example, by replacing fossil fuels with biofuels. In a keynote address, Hannu Suopajärvi from the University of Oulu outlined the possibilities for substituting coal with biomass in the steel industry. Martin Pei from SSAB presented the Hybrit project, a national joint project concerning carbon-dioxide-free steel-making.

Networking gives new insight

Society’s need to achieve sustainability and the need to remain competitive in industry necessitate a move towards greater resource-efficiency and environmental friendliness. In addition, the reduction of greenhouse gases and access to high-quality raw materials are two issues that unify the steel industry. Forums like SCANMET where researchers can meet, engage in discussion and share knowledge with one another are decisive for industrial development and for finding new routes for the steel industry in these challenging times.
The types of coal used for making high-quality coke are considered critical raw materials for the European steel industry. Limited supply and high costs render the use of alternative coal and carbon-bearing materials all the more important as input for cokemaking.

Swerea MEFOS is project managing and coordinating the Flexcoke project, the aim of which is to find ways of avoiding increased use of coal and coke in the blast furnace as a result of waning supplies of high-grade coking coal.

“In the project we have produced coke in several different stages, in both laboratory scale and pilot scale, and tested it in different ways including evaluation of basket samples charged into LKAB’s experimental blast furnace. Following successful results we have proceeded with production trials at SSAB’s coking plant, where the two coke grades that are now being tested in the experimental blast furnace have been produced. If these trials go as planned, we intend to make coke in large scale at the coking plant and test it in industrial scale in SSAB’s BF No. 3,” says Maria Lundgren, project manager at Swerea MEFOS.

The Swedish contributions to the project are being made in collaboration between Swerea MEFOS, SSAB and LKAB.

Anna Dahlstedt, engineering specialist at LKAB:

“The experimental blast furnace is a unique tool for research and development, and this is an important joint project that gives us an opportunity to assist our customers in their efforts to develop sustainable processes. By verifying the performance of the coke prior to testing in industrial scale the risks associated with full-scale trials can be reduced.

By acquiring new knowledge of the interaction between raw materials in the coal blend, coking properties and coke performance in the blast furnace researchers hope to be able to develop alternative coke with optimal quality for the blast furnace. This has major, positive implications for reduced carbon dioxide emissions and energy use.”

“Test results for the alternative coke are very encouraging. The type that will be selected for production-scale trials depends on the results of trials in the experimental blast furnace. In full-scale trials later in the project, in order to minimize deviations in the process, a successively greater proportion of alternative coke will be used,” says Per Lagervall, process engineer at SSAB’s Luleå blast furnace.

Funded by RFCS (Research Fund for Coal and Steel), the project will continue through 2017. The total budget is 5.1 million euros. Other project partners include TKSE, one of Europe’s biggest steel producers.

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Alternative coke can reduce carbon dioxide emissions

Trials with new types of coke have been carried out at LKAB’s experimental blast furnace in Luleå during November. Within Flexcoke, a research project managed by Swerea MEFOS, alternative coke is being developed and tested in pilot scale.