The iron and steel industry is responsible for 7-9% of global greenhouse gas emissions. According to the International Energy Agency (IEA), the sector is currently off-track to reach net-zero emissions by 2050. This means it needs to accelerate efforts to reduce its carbon footprint and scale up both proven and developing decarbonisation technologies.

As one of these key technologies, recognised by both the Intergovernmental Panel on Climate Change and the IEA, CCUS is essential for achieving the Paris Agreement ambitions, particularly in curtailing CO2 emissions from the main energy intensive industries such as iron and steel production. Policymakers and investors have become increasingly confident about the prospects of CCUS with project developers announcing ambitions for over 200 new CCUS facilities worldwide by 2030 according to the IEA and the technology is improving.

The EU-funded research and innovation project called C4U (Advanced Carbon Capture for steel industries integrated in CCUS Clusters) tackles some of the key challenges of deploying the technologies in the iron and steel industry at commercial scale. This is done by advancing processes to make them more cost and energy efficient, and identifying optimal industrial integration solutions while analysing the economic, environmental and business impacts.

The combined use of the C4U technologies can tackle up to 94% of the sources of CO2 in a steel mill, resulting in an overall CO2 emission reduction of 89%. The project is also developing and testing approaches with stakeholders and businesses to assess and advance societal readiness for CCUS. A team led by Professor Haroun Mahgerefteh of University College London’s Department of Chemical Engineering coordinates the project.

There is no one-size-fits-all solution for decarbonising the iron and steel sector and a mixture of technologies are likely to be needed in the future. CCUS offers certain advantages – it can be retrofitted to existing industrial plants and offers new ways of integrating iron and steel production with other industries by using co-products of the CO2 capture process.

Recent research has shown that in the absence of large amounts of renewable electricity being made available to the iron and steel sector, CCUS offers the most energy efficient way to reduce the CO2 emissions. CCUS therefore offers the opportunity of drastic emissions reduction in the near-term.

Alternatives to advance carbon-neutral steelmaking in Europe, particularly hydrogen based methods, have also been in the spotlight. Recently, major European steel companies have announced initiatives to push forward hydrogen-based steel production technologies. The first sites for these are being built for example in Sweden and Germany. Nevertheless, the commercial competitiveness of these technologies in relation to CCUS is still unclear, especially when considering the current and future availability of green hydrogen, produced by water electrolysis using renewable electricity.
In a transitional period while awaiting for green hydrogen infrastructure to come on line, blue hydrogen produced via the steam methane reforming route using fossil natural gas may fill the shortfall, but this also necessitates CCS as a means of mitigating the co-produced CO2 through geological storage. These issues are compounded by the associated fuel and energy costs, which are significant. Both CCUS and hydrogen based technologies are needed to accelerate the net-zero transition in the iron and steel industry.

Still, there are key challenges for CCUS deployment in the industry that must be overcome - costs remain high and the technology still has not yet been implemented at large-scale. Nevertheless, the greatest barriers to CCUS deployment are considered to be commercial, regulatory, and societal rather than technological issues. To overcome these, novel business models must be developed to promote take-up of the technology within industrial CCUS clusters. This includes building a sustainable business case by working with key stakeholders and identifying best case scenarios to reduce financial risks.

Bringing down the costs and creating infrastructure to boost adoption

Given the urgency of emission reductions in the steel sector, a portfolio of promising CO2 capture technologies must be developed and practically tested to a high Technology Readiness Level (TRL) while identifying optimal integration solutions that deliver minimum cost and energy consumption. The C4U research project develops carbon capture processes that address this challenge.

Central to the C4U project’s value proposition to businesses are two key chemical carbon capture processes – DISPLACE (high-temperature sorption-displacement process for CO2 recovery) and CASOH (Calcium Assisted Steel mill Off-gas Hydrogen production). While capturing CO2, they can recover heat at very high temperatures and produce decarbonised fuels which can be used to reheat furnaces or generate clean energy, as well as be used in a variety of other steel plant operations or industries.

C4U is elevating the DISPLACE and CASOH capture technologies from TRL5 to TRL7 through pilot testing at inspiring scales in real world operational environments and then designing them for full-scale optimal integration in the iron and steel industry.

The integration of CCUS in existing industrial clusters is also key to optimising adoption across the value chain. The North Sea Port industrial cluster, a 60-kilometre-long cross-border port area that stretches from Vlissingen on the North Sea coast in the Netherlands, to Ghent in Belgium, for example, is pushing forward with building an integrated CO2 transport network and is home to a steel mill using carbon capture and utilisation technology. The “Ghent Carbon Hub” aims to build a CO2 pipeline network and liquefaction terminal for shipping liquefied CO2 to permanent storage sites under the North Sea.

The hub is expected to be able to process around 6 million tonnes of CO2 each year, representing about 15% of Belgium’s emissions. In the C4U project, detailed modelling approaches are developed and applied to investigate the operation and safety of CO2 pipeline transport and storage infrastructure whilst exploring opportunities to integrate CCUS technologies into the North Sea Port industrial cluster. This involves developing a pipeline network flow model that predicts CO2 flow conditions and chemical composition at any time and point along the network, including for delivery to a geological storage site.

A rapidly evolving policy and business environment

Societal readiness and political acceptance for CCUS will also be critical for achieving industrial decarbonisation. An urgent mix of policy instruments, environmentally-sound and transparent narratives and approaches, and innovative business models can deliver effective incentives that are in-line with business and stakeholder needs.

While researchers help prepare CCUS for large-scale adoption, policymakers play their part in creating an enabling environment for the sector; for instance, by championing clear narratives on the role of CCUS in achieving national decarbonisation targets, encouraging innovation and recognising the need for ongoing operational support for industry. Globally, policy support for CCUS is growing. The last few months saw the announcement of a number key policy packages to drive the scale up of CCUS.

In the USA, the Inflation Reduction Act provides significant tax benefits to CCUS developers to encourage investment. It is estimated that the incentives could see the CCUS industry grow in the USA 13-fold by 2035;

Similarly, the EU has bolstered its financial support for CCUS and identified it as a strategic net-zero technology that will benefit from new measures under the proposed Net-Zero Industry Act. The Act aims to scale net-zero industry technology manufacturing in the EU to meet at least 40% of its demand by 2030;

Additionally, the UK has announced to earmark £20 billion to boost CCUS projects across the country.

With advances in research and increasing policy support and investments, CCUS has the potential to play a leading role in decarbonising the iron and steel industry. In combination with hydrogen and other technologies, CCUS offers the sector the opportunity to meet its climate targets, helping to build a cleaner future.

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More information
c4u-project.eu