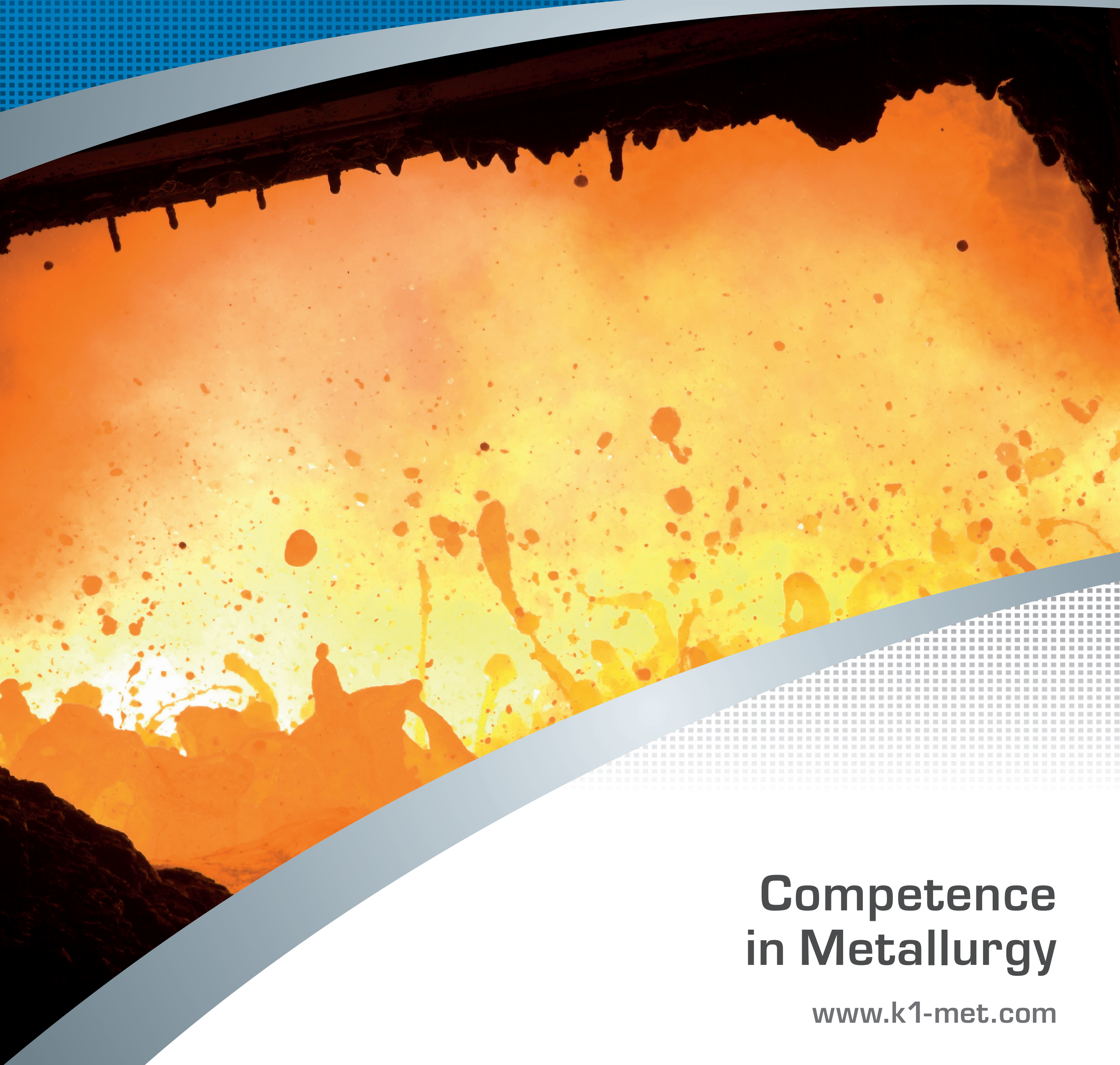
K1 MET
metallurgical competence center



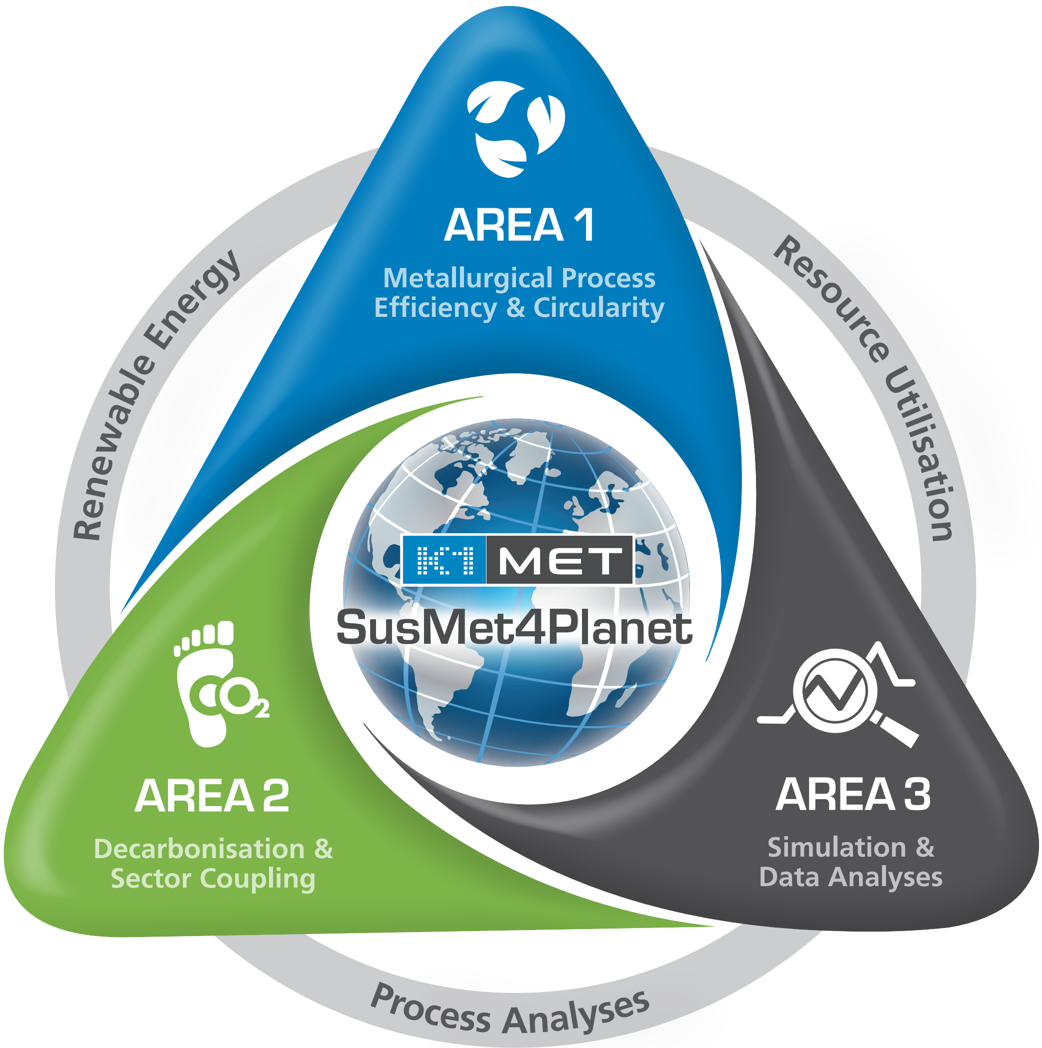
Competence in Metallurgy

www.k1-met.com

K1-MET

SUSMET4PLANET

K1-MET is an international competence center for excellent metallurgical and environmental process development supported by the Austrian Research Promotion Agency within the framework of the COMET (Competence Center for Excellent Technologies) programme. The current K1-MET Competence Center of Sustainable Digitalized Metallurgy for a Climate Neutral and Resource Efficient Planet (K1-MET SusMet4Planet) is executing a research programme with different thematic fields. This comprises three research areas within the funding period from July 2023 to June 2027.



The primary objective for the upcoming period from 2023 to 2027 is to enhance the standing and prominence of K1-MET as a preeminent research institution. K1-MET has excellent competences in the fields of metallurgical and environmental process development, circularity, resource efficiency, decarbonization and digitalization of steelmaking.

The realization and implementation of trendsetting innovations will be one of the major challenges. A modern society in the 21st century is unimaginable without metals such as steel, aluminum and copper. The production of metals is intensive in raw materials and energy consumption as well as on environmental impact. For instance, global steel production is about 1.9 billion tons per year and is responsible for 8% of the worldwide CO_2 emissions.

Therefore, three main goals have been identified:

- Increase process efficiency and strengthen circularity in metallurgy
- Push forward the decarbonization of the metallurgical industry and sector coupling
- Generate and use of metallurgical process knowledge through digital technologies

Efficient processing is a key topic for resource intensive industries. Reduction in raw material and energy consumption needs to be reached and must be coupled with increased product output and enhanced material recycling. Landfilling is no longer a viable option for by-products and waste materials. To be in line with the concept of circular economy, waste streams become valuable sources for raw materials after comprehensive treatment processes replacing primary raw materials from nature.

Furthermore, a central point in K1-MET's strategy is related to the development of low carbon (decarbonized) digitalized process solutions. Decarbonization is about demonstrating industrial processes in ferrous and non-ferrous metallurgy by using hydrogen. With regards to sector coupling, the recycling of CO_2 represents an important aspect. By capturing CO_2 from industrial processes and converting it with hydrogen, hydrocarbons, such as methane (main component of natural gas) are produced and can in turn be used in various industrial sectors. CO_2 therefore becomes a valuable material. Process diagnostics and advanced data analytics coupled with single- and multiphase flow simulation are the cornerstones of another research area aiming at a real-time monitoring of metallurgical processes. Machine learning methods will also be applied in this context. Our targets are a nearly waste-free production of metals and the definition of solutions for high quality products.

The basis for a fruitful development of K1-MET is the close cooperation with industries and universities with a mix of fundamental research, computer modelling and experimental trials in laboratory scale up to industrial applications. K1-MET has currently 28 industrial and 13 scientific partners in Austria, Germany, Luxembourg, The Netherlands, Finland, Sweden and Brazil. To fulfil our high aims, the number and diversity of partners is an ongoing process of growth.

Area 1 focuses on making primary and secondary metallurgical processes more efficient (product output and quality) and sustainable (circularity).

This includes ways to reuse raw materials for saving energy and resources. Area 1 will improve the efficiency of ferrous and nonferrous metal processes by innovative solutions and tools. In this way, the resource consumption will be minimized, and the output increased.

The separation of valuable materials from waste streams for a direct recycling is performed. Area 1 will also work on solutions to recover metals and minerals from residues. Refining and casting processes are investigated to improve the product quality. Area 1 therefore enhances process efficiency to create a sustainable metallurgy.

Metallurgical Process Efficiency & Circularity

AREA 1

MAIN FOCUS

- **Strengthen sustainability and circularity in metallurgy**
- **Increasing product output and quality during steel refining and casting**
- **Closing material loops by returning used or waste materials to production**
- **Saving energy by enhanced use of primary and secondary raw materials**

In Area 1, K1-MET focuses on two main topics. These are increased efficiency for more product output in metallurgical processes, and circularity for closing material cycles. A closed material loop is a circular process in which an output can be used and then converted into a new product again.

In primary iron and steel metallurgy, the sintering process is the first treatment step of iron ore, which should be further used in a low-carbon direct reduction process. A sinter plant heats and agglomerates fine iron ore particles at high temperature. Direct reduction uses natural gas or hydrogen to produce iron without releasing massive carbon dioxide (CO_2) into the atmosphere, making it more environmentally friendly.

Another part of Area 1 deals with alternative reducing agents in the blast furnace and during treatment of copper recycling materials. A blast furnace is a large industrial plant that produces liquid iron (hot metal) during a reduction and smelting process. Reducing agents are used in the blast furnace to remove the oxygen from the iron oxides. The main state-of-the-art reducing agent in the blast furnace is carbon (in the form of coke). K1-MET GmbH is looking for more sustainable alternatives.

In secondary metallurgy, methods such as ladle furnace and Ruhrstahl-Heraeus vacuum degassing are investigated regarding increased steel cleanness. A ladle furnace ensures quality and consistency of the molten steel before it is casted into semi-finished products. Vacuum degassing removes unwanted gases from molten steel by placing the steel melt in a sealed chamber with no surrounding air (vacuum). Additionally, process efficiency and product quality are to be improved in the field of continuous casting. This is a method to produce solid metal semi-products. A molten metal is poured into a mould and is then cooled and solidified continuously. In the field of circularity, Area 1 addresses the treatment of waste materials and by-products to recover valuable materials for recycling in the processes. By-products, such as slags or dusts, are secondary materials produced during the steel making process.

Finally, a fundamental research project investigates methods to define properties of metallurgical slags from iron and steelmaking. One project from the nonferrous sector explores the treatment of copper-containing waste materials in terms of product output and sustainability.

Area 2 is fully committed to the goals of the European Union Green Deal in climate-neutral metallurgical technologies. Processes for reducing CO_2 in energy-intensive industries will be developed to pilot plant scale.

The focus is on the use of renewable energy, which allows a 100 % CO_2 reduction in the long-term perspective. The goal is to achieve climate neutrality for the metallurgical and energy intensive industry in 2050.

The processes to be developed aim to decrease the total energy demand to achieve economically and ecologically sound decarbonised processes. In this way, K1-MET GmbH improves the innovative capacity of their company partners. Area 2 also helps to develop solutions for the key issue of climate protection while remaining competitive. This contributes to a long-term oriented research cooperation between science and industry.

Decarbonisation & Sector Coupling

AREA 2

MAIN FOCUS

- **Increasing decarbonization processes of the metallurgical sector**
- **Developing hydrogen-based plasma smelting, direct reduction and burner concepts**
- **Carbon capture and utilization in the energy industry to transform CO_2 into valuable products**
- **Promoting sector coupling for creating stable renewable energy systems and chemical storage for the demand in winter**

In Area 2, solutions for climate-neutral steelmaking and the development of carbon dioxide (CO_2) as a resource for a carbon cycle are investigated. The use of fossil fuels leads to too much CO_2 in the atmosphere. This promotes global warming due to the artificial greenhouse effect caused by humans. By using CO_2 as a resource in the carbon cycle, K1-MET can reduce greenhouse gas emissions and contribute to a more balanced and sustainable planet.

Several strategies are developed to reduce CO_2 emissions in industries that need a lot of energy. K1-MET is focused on the steel, refractory, cement and chemical industry.

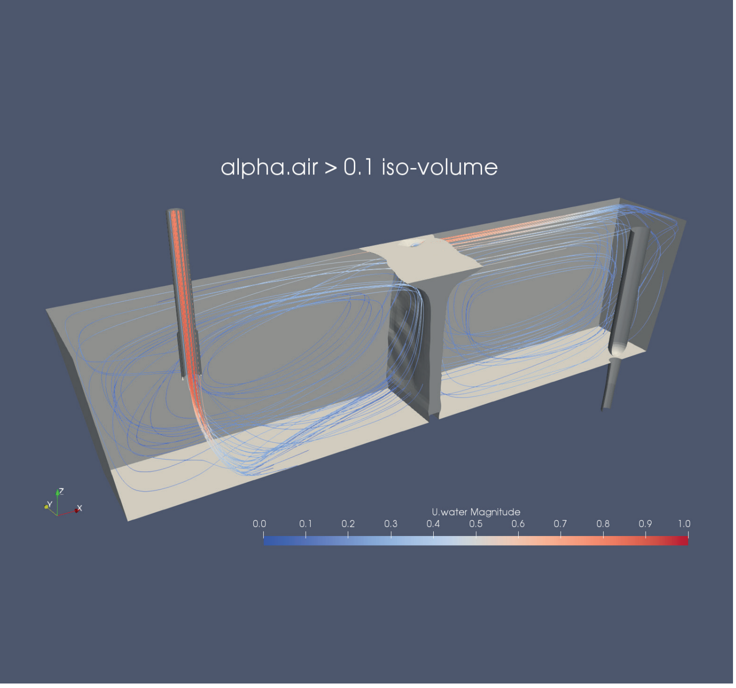
One approach is carbon direct avoidance like the hydrogen plasma smelting reduction (HPSR) and hydrogen-based fine-ore reduction (HYFOR). Carbon Direct Avoidance (CDA) is the European steel industries' low carbon strategy with almost zero CO_2 emissions. Hydrogen plasma smelting reduction is a process with electricity in combination with hydrogen plasma as energy carrier and reducing agent. The main state-of-the-art reducing agent in the blast furnace (BF) is carbon (in the form of coke). K1-MET is looking for more sustainable alternatives such as hydrogen. HPSR produces liquid steel from fine ores in a single step using hydrogen plasma as the reducing agent and electricity as the primary energy source. This is an efficient technology for a sustainable steel industry with low CO_2 emissions. Hydrogen-based fine-ore reduction (HYFOR) is the direct reduction of iron ores with hydrogen and zero CO_2. Direct reduction needs less energy because the process takes place at lower temperatures.

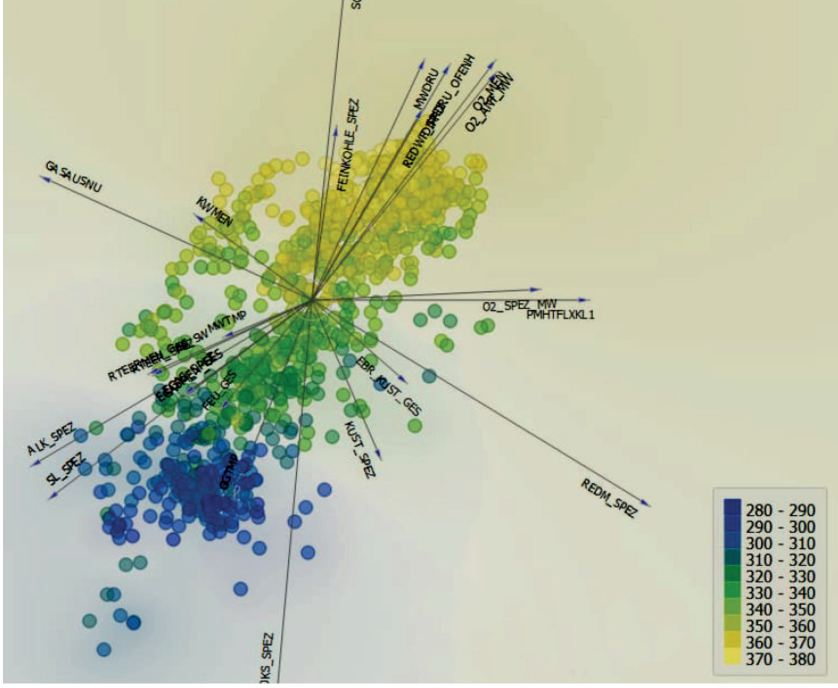
Another strategy to achieve this objective is sector coupling. This means that different industries and sectors are working together to jointly use energy and resources. The aim is to balance surpluses and shortages and increase overall efficiency. The goal is to save resources and reduce greenhouse gases. Sector coupling is a key factor to stabilize the renewable energy system and to offer chemical storage for winter needs.

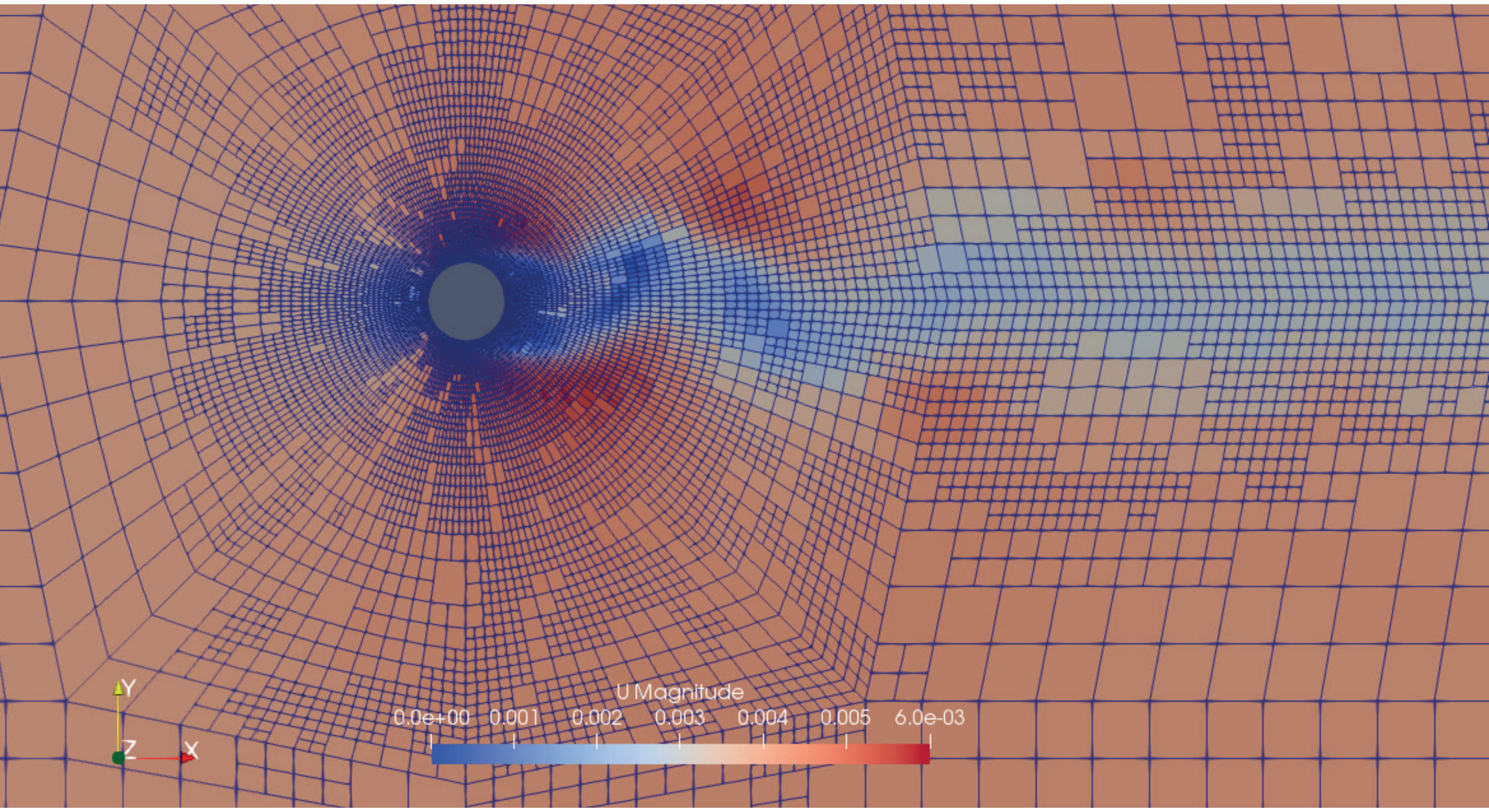
Further innovative technologies for short-term carbon reduction are smelting technologies and green and smart furnaces. As direct reduction works without any liquid phase, a pre-smelter is demanded as a link between the direct reduction plant and the basic oxygen furnace to convert low-quality Direct Reduced Iron (DRI) into hot metal before being refined. The development of such a smelter is the focus of a project.

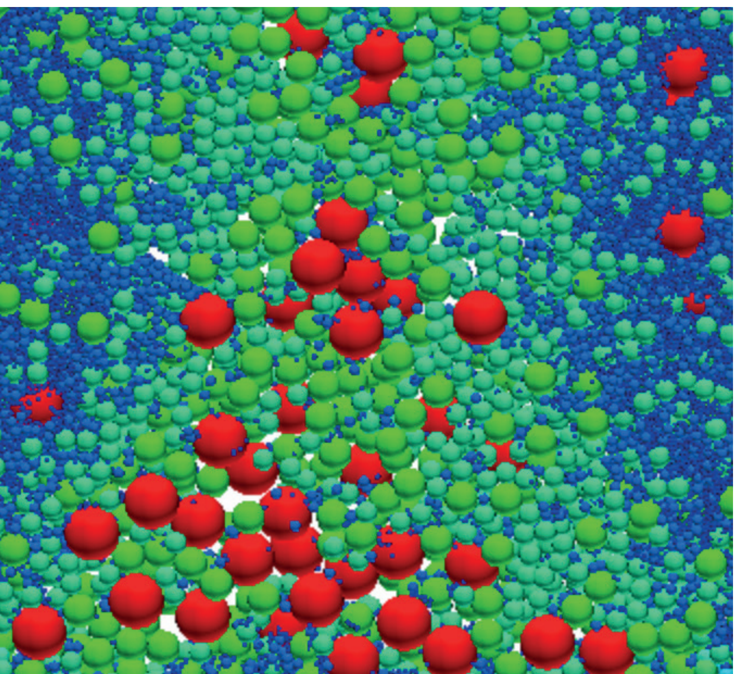
Heating furnaces powered by renewable energy or alternative fuels are researched to reduce the carbon footprint. Alternative energy sources include hydrogen, electric energy and biological or renewed gases such as methane. Smart furnaces are equipped with advanced technology to improve operation and minimize energy consumption. Data analytics and artificial intelligence help to monitor and control furnace operation. Several methods to adapt existing furnaces with electric heating will be investigated. Mathematical methods, e. g., Computational Fluid Dynamics (CFD) and "FastCalc" methods are used for this. Moreover, hydrogen-based burners concepts are being developed. These technologies use hydrogen as a fuel in steel production. Additional methods for Carbon Direct Avoidance can support sustainable steel production. Carbon Capture and Utilization (CCU) enables to capture CO_2 and use its pure form for further processes. One example is methanation, where methane is produced from hydrogen and CO_2. This gas can be further used in the steelworks. Another process is methanol synthesis, where the end product is methanol, which can be used in other industries.

Another approach to meet the climate agreement is the carbonisation, where by-products from steelmaking such as ashes or slags are used to bound CO_2 in a solid form. The produced so-called carbonates are deposited. Since these side products have to be deposited anyway, this method acts as an alternative to common Carbon Capture and Storage (CCS) methods.









Area 3 is focused on the application of modelling approaches to new and existing metallurgical processes.

Data analysis is carried out to increase the process efficiency of steelmaking. Modelling helps to understand and predict the behaviour of complex systems or processes. It allows researchers to study and analyze different scenarios, make predictions, and test hypotheses without the need for costly or time-consuming real-world experiments. Models or prototypes can range from simple mathematical calculations to challenging computer simulations.

Simulation & Data Analyses

AREA 3

MAIN FOCUS

- **Investigating industrial production processes and generating process understanding**
- **Digital co-development of prototypes and process exploration**
- **Reducing CO_2 by advancing data science and digitalization in industrial settings and production environments**

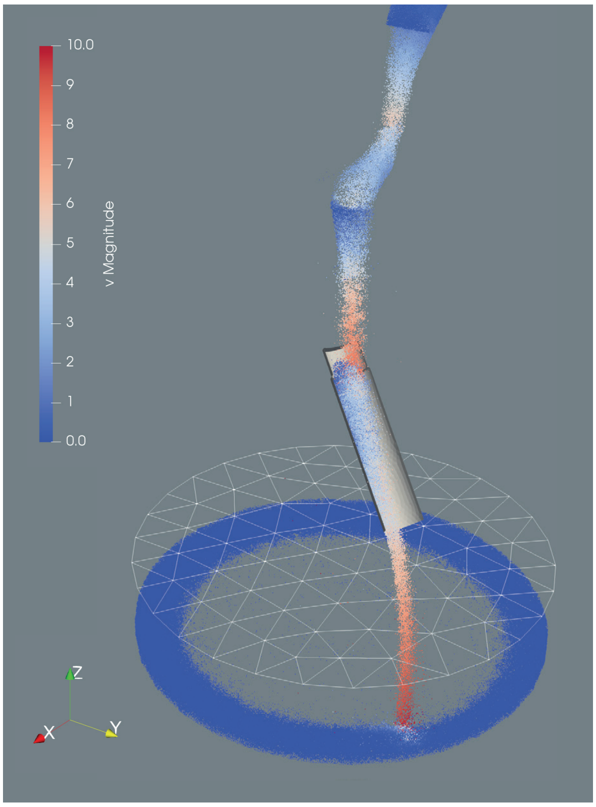
Numerical simulations of fluids and particulate flows are a widely used tool in research and development activities on industrial processes. It means using computer models and calculations to understand how liquids and gases behave in different situations. Area 3 uses both open source and commercial tools and software frameworks for detailed simulations in Computational Fluid Dynamics (CFD), Discrete Element Method (DEM) or Finite Element Method (FEM) modelling. These methods have been applied successfully at K1-MET in the investigation of metallurgical processes along the steelmaking chain. This chain ranges from the blast furnace (BF) to different liquid metal processes in a steel plant, such as Ruhrstahl-Heraeus (RH) degassing, ladle furnace treatments, and continuous casting. Apart from developing process simulations and models, the further development of simulation methodologies and techniques are very important in future activities. Existing simulation models are expanded, and different methods are united and applied to larger projects. Experimental investigations will show how well the models work. Accompanying simulation activities in Area 1 and 2 are planned to support experimental developments there.

The third aspect is digitalization, data analytics and evaluations from a process-oriented point of view. Artificial intelligence tools like machine learning and data analytics tools are used to understand large quantities of diverse data. Solutions to important questions on process understanding and optimal process operation will be obtained.

The overall strategy of Area 3 is to improve knowledge, develop new simulation models and unite existing methods. The cooperation with scientific partners enables to profit from each other's expertise. With their activities in numerical simulations, K1-MET and its partners contribute to open-source software projects with their own developed specific models or calculation packages. Simulation methodologies and results are not only shared with the involved partners, but also with the community and the public. These are great secondary effects.

Numerical simulation activities will be accompanied by laboratory experiments and model plant measurements. This will offer new insights into physical phenomena. Big data approaches will help to understand processes in real life. Fast simulations will contribute to a higher simulation efficiency, and this will increase the gained knowledge.

Another important roadmap is the digital transformation of the steel industry by using artificial intelligence. By doing so, energy and resources will be saved, processes enhanced, and CO_2 reduced. Continuing in this way, our planet is becoming more sustainable.



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