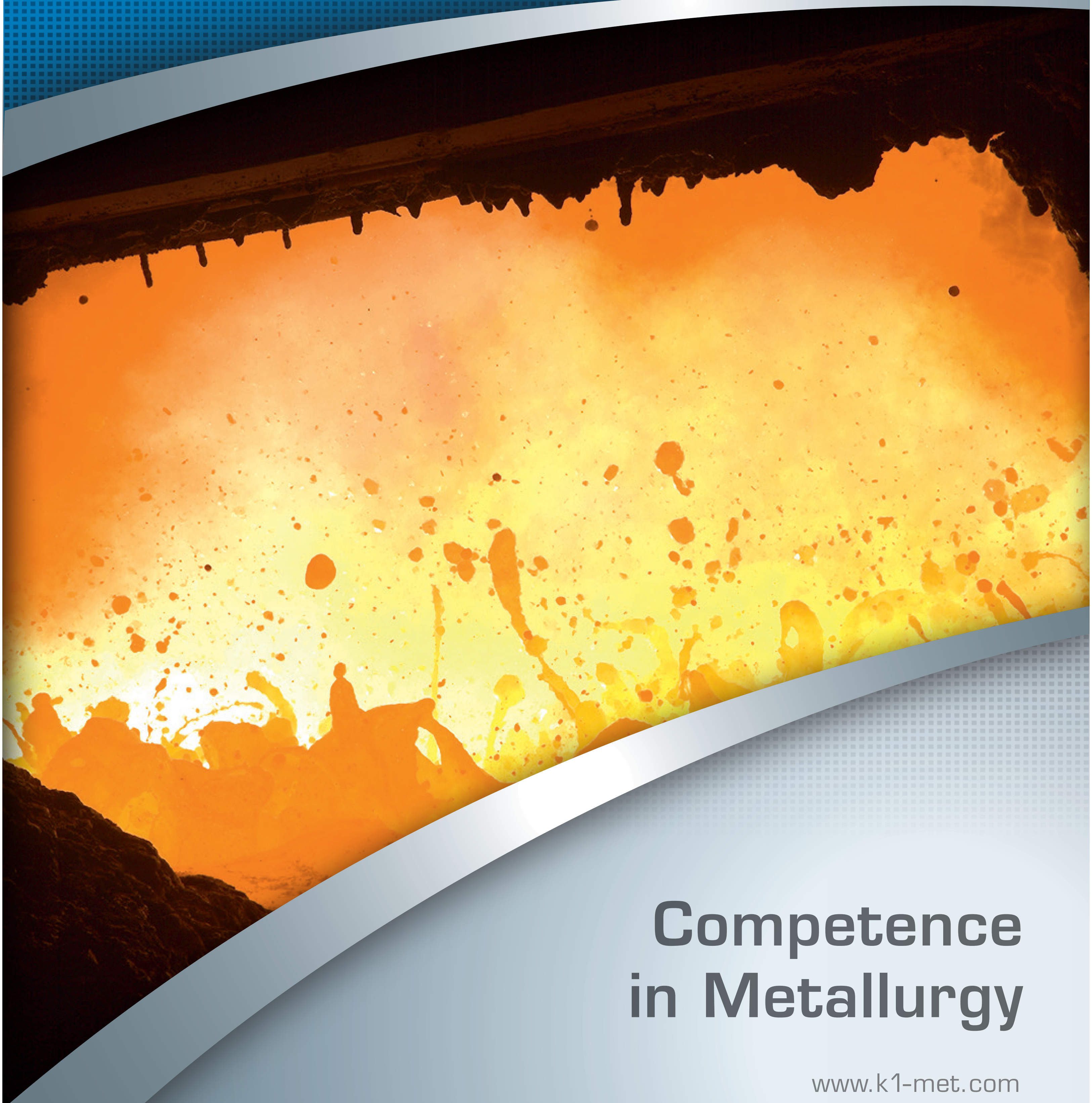
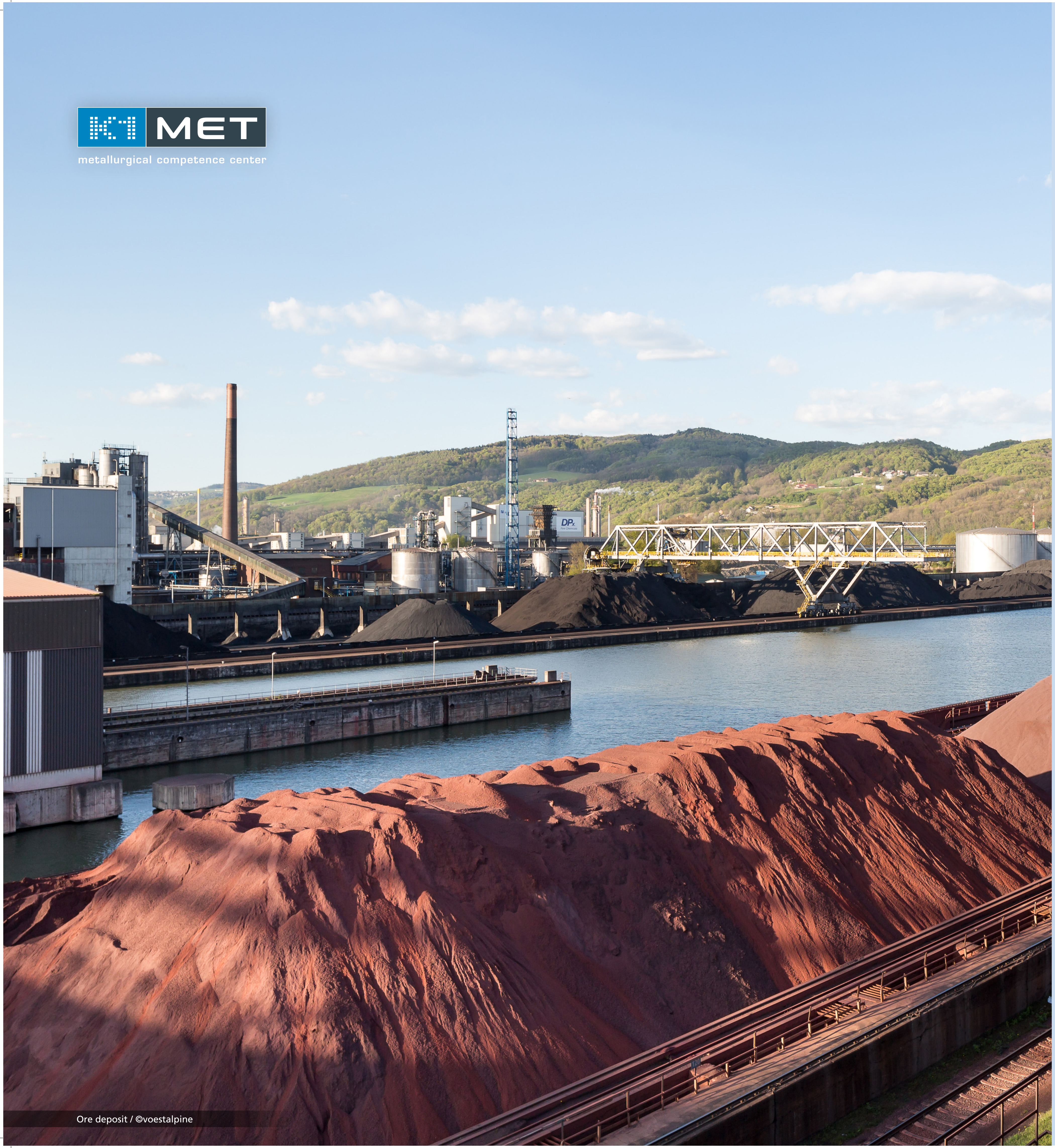
K1 MET

metallurgical competence center



Competence in Metallurgy

www.k1-met.com



Ore deposit / ©voestalpine

K1-MET is a competence center for excellent metallurgical and environmental process development. Founded in 2015, K1-MET is currently executing a research programme with four main research areas within the funding period 2019-2023:

AREA 1
Raw Materials and Recycling

AREA 2
Metallurgical Processes

AREA 3
Low Carbon Energy Systems

AREA 4
Simulation and Analyses

The vision for the current period 2019-2023 is to enhance the reputation and visibility of K1-MET as a leading research institution with excellent competences in the fields of metallurgical and environmental process development. To reach this, realization and implementation of trendsetting innovations will be one of the major challenges. Steel, Aluminium and Copper are the dominant metal construction materials in the 21st century. 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 1.8 billion tons per year and is responsible for 7% of the worldwide CO_2 emissions.

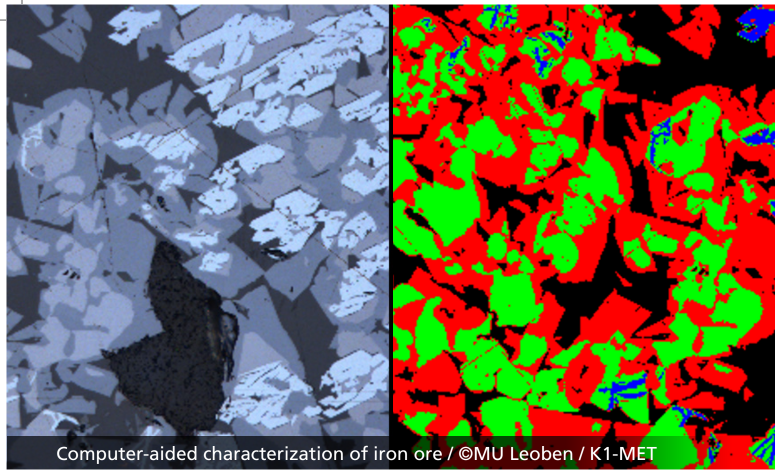
Therefore, four main goals have been identified:

- Development of sustainable processes with low carbon footprint for a decarburization of metallurgical industry
- Process efficiency through recovery of secondary resources and energy
- Measurement of high temperature material properties
- Digitalisation and optimisation of metallurgical processes by numerical simulation and data analyses in order to enhance the process efficiency and to ensure the quality of metal products

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 yield 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 process solutions. Our targets are a nearly waste-free production of metals and the definition of solutions for high quality products.

The used methodology within K1-MET is based on a 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 fifteen industrial and eight scientific partners in Austria, Germany, Belgium and Slovakia. The research topics, however, have not been fully developed and finalized yet. To fulfil our high aims, the number and diversity of partners is an ongoing process of growth.


Computer-aided characterization of iron ore / ©MU Leoben / K1-MET

Raw Materials & Recycling

AREA 1


Steelmaking slag / ©voestalpine


LD dust / ©MU Leoben

Research Area 1 focuses on the further development and up-scaling of processes to treat residues and recycling materials, such as slags and dusts to recover valuable materials and to close material cycles. On the other hand, the characterization and efficient utilization of raw materials for metallurgical production processes is investigated. Furthermore, measurement methods for material properties of metallurgical slag systems will be developed.

MAIN FOCUS:

- **Characterization of raw materials for iron and steel production**
- **Methods to determine physico-chemical and thermodynamic slag properties**
- **Sustainable treatment of dusts and slags from ferrous and nonferrous metallurgy**
- **Concepts to recover valuable materials from residues for a more efficient material cycle closure**

Slags are by-products generated during smelting operations and hot metal treatment. They should fulfill several metallurgical tasks during production of steel and thus, the desired composition of the slag influences efficiency of different process steps during iron and steelmaking up to a great extent. Rapid formation of the reactive slag with adequate viscosity, density and chemistry facilitates the removal of sulfur and phosphorus from the melt. Therefore, the investigation of physico-chemical properties of the slag contributes to a better process control and an enhanced productivity. Accordingly, the development of methods to determine properties of metallurgical slag systems is in the focus of one project.

Residues from ferrous and nonferrous metal production processes, such as slags, dusts and sludges, represent secondary resources with considerable amounts of valuable materials. Increasing stringent legislation makes the utilization of residues more complicated. However, a reuse is necessary to be in line with the concept of circular economy. Therefore, processes to reuse the residues must be developed and operated. The benefits of recycling technologies are a reduced demand of primary resources and landfill volume. Furthermore, economic savings can be generated for plant operators.

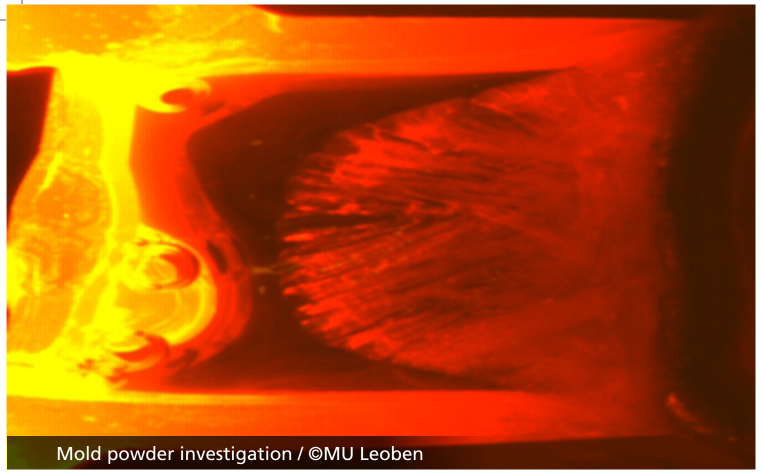
Area 1 investigates and develops concepts for the treatment and utilization of residues from ferrous and nonferrous industry with the final goal to recover valuable materials and to recycle


Steel mill by-products / ©voestalpine

the metallurgical by-products within existing processes respectively. A process for the pyrometallurgical treatment of LD dust will be brought from pilot plant scale to semi-industrial scale. Beside process developments, bulk characteristics of other fine-grained metallurgical residues as well as their behaviour during agglomeration represent further aspects within Area 1.

For a recycling of slag coming from the oxygen blowing process (LD process), mineral processing represents one utilization concept, in which the metals remain in their oxidic state. The generally known disadvantage of mineral LD slag processing routes lies in an incomplete separation of the metal fraction due to fine-grained intercrystal growths. On the contrary, LD slag treatment under reducing conditions possesses a higher potential regarding a more complete metal recovery and separation of the mineral fraction respectively. Within the frame of an Area 1 project, LD slag is the starting point for the development of a metal product for steel mill internal reuse and a mineral product with latent hydraulic properties. A process requiring a minimum input of additives should be established to recover secondary resources. Beside LD slag, recycling possibilities for secondary metallurgical slags as well as for slag from copper refining are explored.

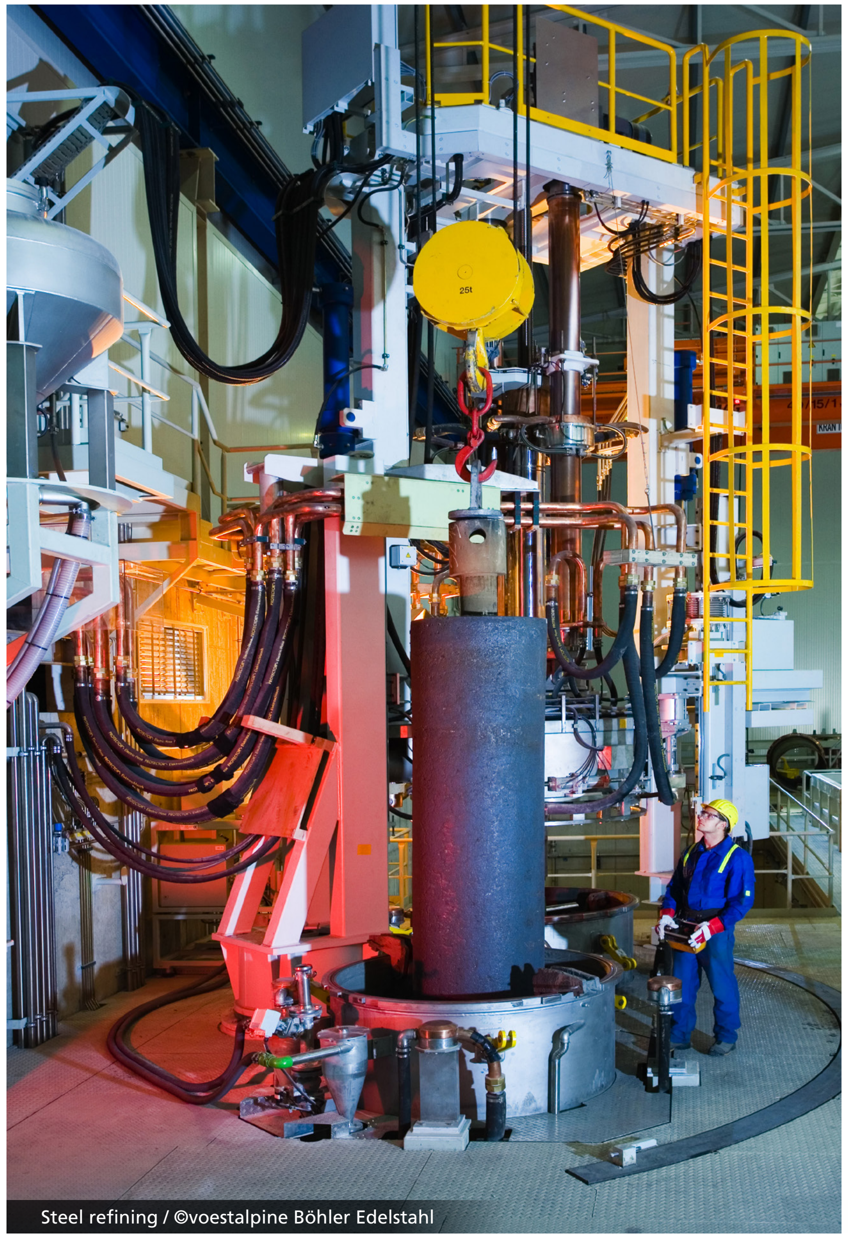
Metallurgical Processes



Mold powder investigation / ©MU Leoben

Continuous casting / ©Primetals

Copper refining / ©Montanwerke Brixlegg



Steel refining / ©voestalpine Böhler Edelstahl

BOF converter / ©Primetals

K1-MET Research Area 2 unites the core topics of metallurgical process development and represents a combination of the former Area 2 (High-Temperature Metallurgy) and Area 3 (Processing and Energy Performance) from the 1st funding period (2015-2019) accompanied by innovative aspects. Ferrous and nonferrous applications and processes are explored here.

AREA 2

MAIN FOCUS:

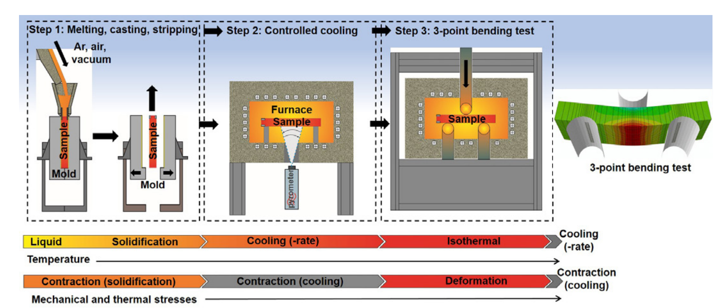
- BOF converter process modelling and link to secondary metallurgy (steel cleanness)
- Development of casting mould powders and crack formation during continuous casting and hot rolling
- Guidelines for the design of refractory linings in metallurgical plants
- Influence of slag properties on the energy demand during Electro Slag Remelting
- Alternative reducing agents and increased productivity during copper refining

Deeper understanding regarding the impact of process conditions on the final quality during steelmaking in the BOF converter should be generated by investigating the interaction of thermodynamic and kinetics to increase the steel cleanness and to reduce the necessary downstream steel refining efforts. In addition, the evolution of non-metallic inclusions during ladle refining will be investigated by employing an equilibrium zone model under usage of FactSage® databases.

Further downstream the metallurgical process chain, surface defect formation during the continuous casting process and the ductility behaviour of different steel grades will be investigated. During this, the IMC-B test (In situ Material Characterization-Bending) will be further developed as benchmark experiment to quantify the thermal history on the crack susceptibility of steel. In the submerged entry nozzle of a continuous caster, the nozzle wall is equipped with carbon-bound zirconia refractory material between steel and slag (called slag band). In some cases, the refractory corrosion process is enhanced by infiltration of mould slag components into the refractory material due to an oxidation of the carbon. Therefore, alternative mould fluxes with certain compositions will be investigated within the frame of a further project regarding an implementation in the casting process.

The Electro Slag Remelting (ESR) process is a secondary metallurgical treatment to reach highest quality steel grades in terms of toughness and corrosion resistance. A suitable composition of ESR slags is necessary for an efficient removal of non-metallic inclusions, and furthermore, ESR slag influences the energy consumption during the re-melting process. In this context, correlations with viscosity and the solidification behaviour of ESR slags and their interrelation with energy consumption should be quantified in Area 2.

The current processes in copper pyrometallurgy are partially operated with fuels and reducing agents based on fossil sources producing climate-relevant emissions, such as CO_2. Nut coke represents the main energy carrier and reducing agent within the classical shaft furnace process. The injection of low carbon reducing gases via lances is in the focus of one project. Beside this, the injection of complex fine-grained materials is still challenging, since not all kinds of fine-grained materials can be agglomerated efficiently for a subsequent use in the shaft furnace inducing high agglomeration costs. The use of complex secondary copper materials as an alternative is therefore attractive. However, process adaptions are necessary, on the one hand to guarantee certain product qualities and on the other hand, to reach a certain output of valuable materials. Recycling materials often contain Nickel, Zinc, Lead, Tin, Copper, Bismuth and other elements which cause problems in the standard shaft furnace process or cannot be recovered completely.



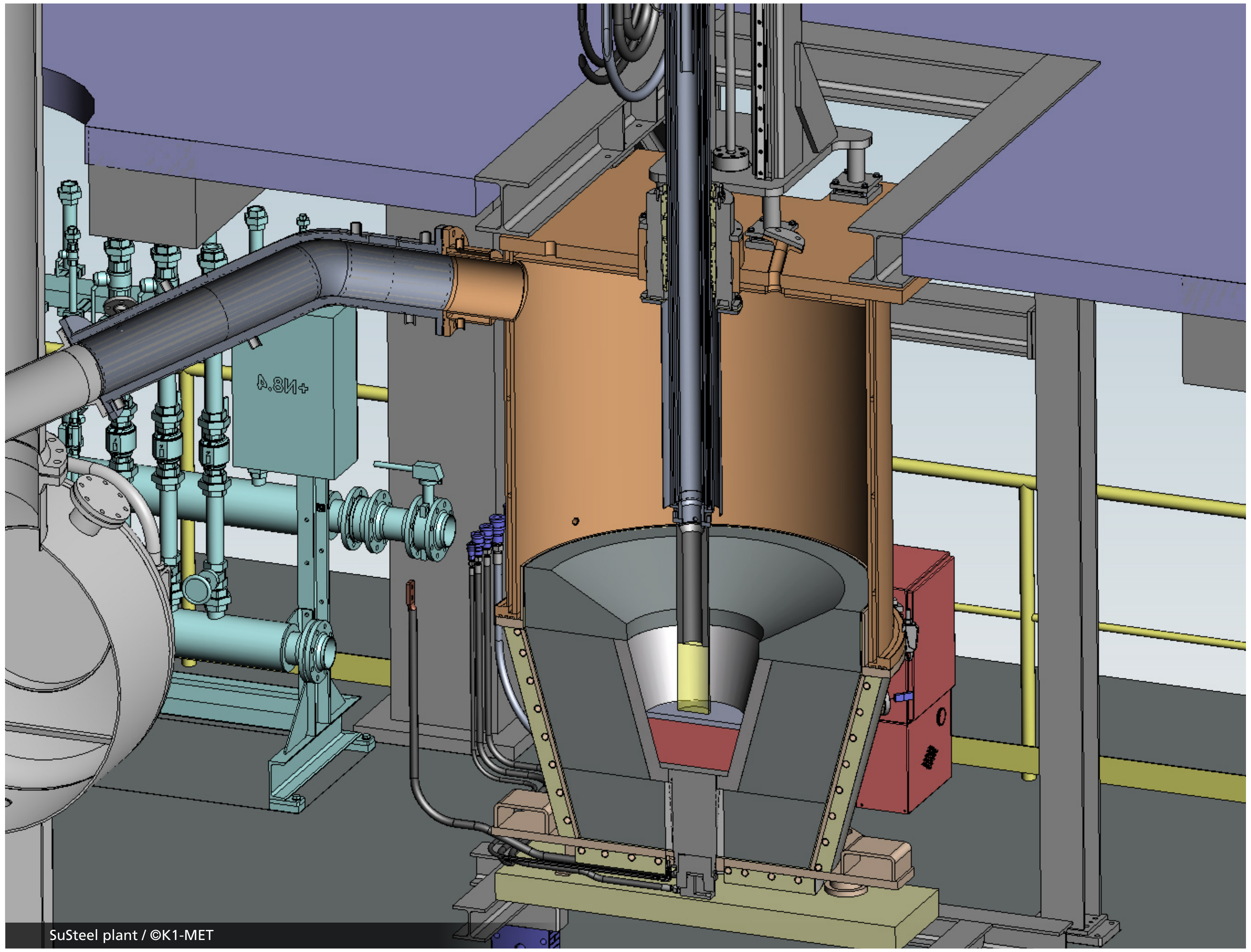
IMC-B Test / ©MU Leoben

Beside the processes itself, investigations regarding refractory materials are in the focus of Area 2. The goal of one project is to define expansion allowances in refractory linings. For that purpose, Finite Element simulations are planned to analyse thermally loaded refractory linings and to quantify possible damages due to thermomechanical stresses.

Power plant / ©voestalpine

Low Carbon Energy Systems

AREA 3



SuSteel plant / ©K1-MET

Hydrogen pilot facility / ©voestalpine

The urgent need for reducing CO_2 from anthropogenic sources creates the necessity of developing new systems and/or readjusting current ones. Only with breakthrough technologies a success will be achieved. Current investigations aim on the three pathways Carbon Direct Avoidance (CDA), Process Integration (PI) and Carbon Capture, Storage and Usage (CCU).

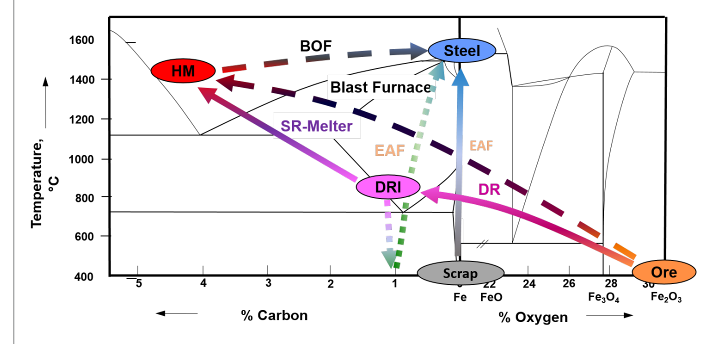
MAIN FOCUS:

- **Fully replacement of carbon with hydrogen for iron and steelmaking processes and its CO_2 emission**
- **Evaluation and feasibility of different reforming technologies and its process integration**
- **Increase of energy efficiency in burners and kilns to reduce emissions**
- **Catalyst development to convert CO in CO_2**
- **Concept of CO_2 transformation from energy intensive processes to valuable products**

The CDA part covers the development of new processes that use renewable electricity and/or hydrogen produced from renewable electricity to massively replace the current fossil fuels (coal and/or natural gas).

The different routes for steel production are shown using the binary systems Fe-C and Fe-O. Starting from the iron ore, the conventional route runs via blast furnace (product is hot metal with a carbon content of more than 4 %) to the basic oxygen furnace (product is crude steel with very low carbon contents). Both process steps are linked with high CO_2 emissions. Another possibility is the way via direct reduction in the solid state (product is DRI or HBI) and then melting to produce hot metal (COREX, FINEX) or to use the DRI/HBI in the EAF to produce crude steel. If hydrogen is used as reducing agent for the DRI/HBI production and the EAF as melting equipment a large decrease of the CO_2 emissions could be realized. Consequently, the only possibility to produce liquid steel from iron ore in one step, is the use of hydrogen in the HPSR (Hydrogen Plasma Smelting Reduction) process. If the electricity for the hydrogen production is generated by water, wind, solar or renewables, nearly no CO_2 emissions can be awaited. The interconnection of the FluidRed and the HPSR exhibits energy saving potential and a possibility to develop a hydrogen-based process route to produce steel.

Regarding CCU (i.e. CO_2 usage and valorisation) all the options for utilising CO and CO_2 captured as raw material for production of / integration into valuable products are considered (chemical conversion of CO/CO_2). A reduction of the CO_2 emissions from energy intensive sectors like the steel, cement and refractory industry is projected, through the establishment of reforming processes where CO_2 containing gases constitute a feedstock for the process itself.



Binary systems Fe-C and Fe-O / ©K1-MET

Furthermore, existing systems like burners and kilns will be optimised via simulation regarding their energy efficiency and emission reduction potential. Furthermore the optimisation of the calculation time of the simulation methods will be in the focus of Area 3.


Converter tapping / ©K1-MET

Simulation & Analyses

AREA 4


Converter / ©K1-MET


Sinter plant / ©K1-MET

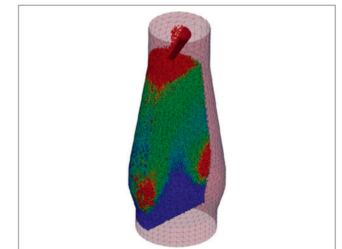
K1-MET Research Area 4 – Simulation and Analyses focuses on model development, numerical simulations and the analyses of complex (big) data sets. It combines the knowledge from a wide range of industrial and academic applications.

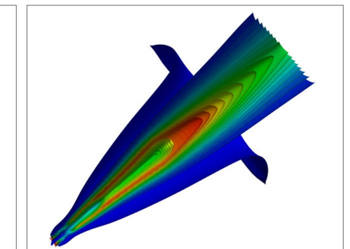
MAIN FOCUS:

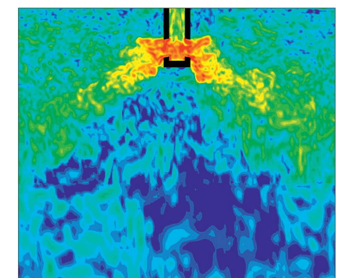
- **Comprehensive modelling tools for metallurgical processes**
- **High quality simulation tools from particle scale to plant scale**
- **Novel methodology development to combine high resolution and high-speed simulations**
- **Continuous, discrete and coupled simulation engines**
- **Fusion of process expert knowledge and data science to provide applicable data analyses tools and prediction schemes**

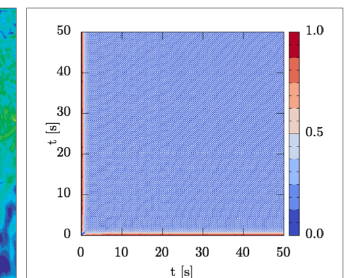
During several years of development K1-MET was able to build up and maintain a substantial library of numerical models, improvements and methodologies to investigate the complex nature of multiphase flow and multi scale processes. These developments enjoy extensive international reputation and rank at the leading edge of research. The Fast simulations project incorporates novel methodologies to reduce the calculation times of complex simulations by the order of >100 and might enable close to real time calculations within a limited parameter space.

Other projects in Area 4 involve multiphase flow modelling on varied temporal and spatial dimensions. Here, the focus lies on comprehensive modelling and simulation of key elements of the iron and steel making processes. Examples include modelling of raceway dynamics in shaft furnaces, particle dynamics in reactive moving beds, chemical coupling in fluidised bed reactors, liquid melt models (in e.g. converters, RH degassers, ladle furnaces) and electromagnetic flow control within the mould flow in the continuous casting process. Several computational tools are further developed or extended to include models for reactive particles, droplets and carrier phases as well as interfacial flows. These computational tools include both, open source codes as well as proprietary packages. The main open source tools are the Discrete Element Model (DEM) code LIGGGHTS® and Computational Fluid Dynamics (CFD) code OpenFOAM®. Moreover, these codes are coupled (CFDEM) to enable the simulation of dense multiphase flows.


CFD-DEM simulation of blast furnace charging / ©JKU Linz


Temperature Distribution in a Flame / ©TU Wien


LES simulation of molten steel flow through a submerged entry nozzle in continuous casting / ©JKU Linz



Recurrence Matrix / ©K1-MET

In addition, Area 4 is dedicated to acquiring, processing and analysing (big) datasets originating from simulations as well as process measurements. Digitalisation and big data aspects are becoming a wide field of interest, but industrial implementation still requires expert knowledge to turn the data streams into interpretable and applicable results. The close cooperation with industrial and academic partners as well as the interdisciplinary approach within Area 4 enables best possible results.

Finally, the united know-how is transformed into algorithms and methods that contain useful information for the process operators and allow for higher process efficiency.

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metallurgical competence center

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