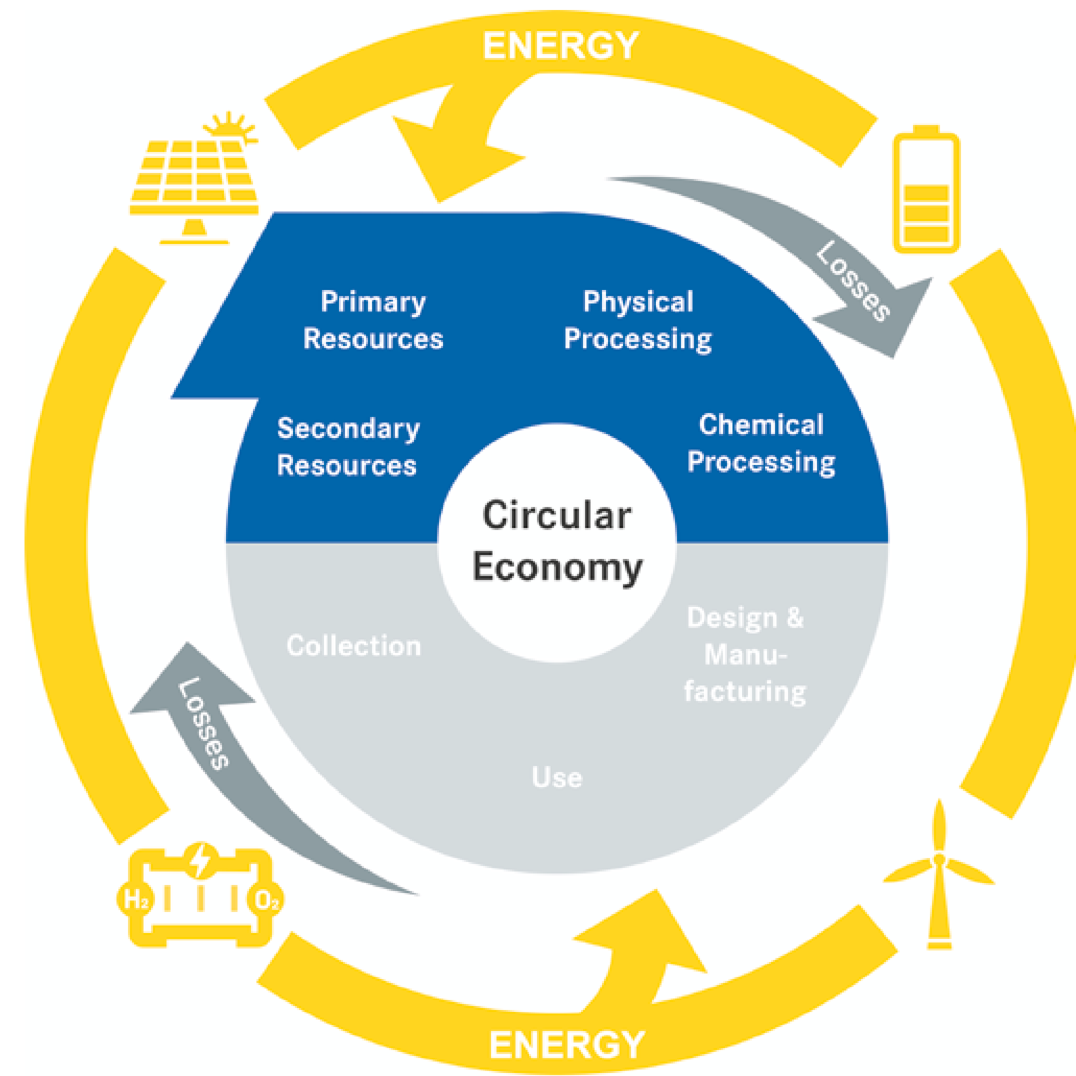
THE FUTURE IS CIRCULAR!

HiF
HELMHOLTZ INSTITUTE FREIBERG
FOR RESOURCE TECHNOLOGY

THE FUTURE IS CIRCULAR!



Contents

"We still have a lot to do!"

Professor Sebastian M. Schmidt (Scientific Director Helmholtz-Zentrum Dresden-Rossendorf) and Professor Klaus-Dieter Barbknecht (Rector TU Bergakademie Freiberg) on the long-lasting cooperation between the founding institutions of the HIF.

Prof. Dr. Sebastian M. Schmidt: Scientific Director of the Helmholtz-Zentrum Dresden-Rossendorf ©HZDR/André Wirsig

With the founding of the Helmholtz Institute Freiberg for Resource Technology (HIF), the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and the TU Bergakademie Freiberg (TU BAF) have not only consolidated their cooperation but also manifested it institutionally. The joint establishment of a extra-university institute for the development of resource technologies at the Freiberg site in 2011 was an important milestone for our institutions. It was driven by the goal of making a significant contribution to the development of a sustainable Circular Economy through collaborative research and innovation. Particular attention was paid to ensuring that the HIF complements the existing strengths of the TU BAF. This approach, which has been consistently pursued since then, is reflected in many successful research collaborations in third-party funded collaborative research projects as well as in joint strategic successes. The foundation was also a gain for the Helmholtz Association because the range of topics of the HIF opened up a new field that fits perfectly with the mission to secure the future through research.

Success through joint research and cooperation

From the onset, the institute and its staff have been developing innovative solutions for the sustainable use of mineral and metalliferous resources. Over 100 EU and federally funded research projects have been initiated and successfully executed with regional, national, and international partners. For example, the AFK project, in which the Institute of Mechanical Process Engineering and Mineral Processing at the TU BAF was involved. In this project, polymetallic complex ores from a skarn deposit in Saxony were investigated using modern analytical methods with the aim of processing the mineral raw materials in an economic, energy-efficient, and environmentally benign way. The large-scale sampling required for this at the Zinnkammern visitor

Towards a sustainable future with a Circular Economy

Raw materials are the starting point of the value creation chain of our strong industry. Without raw materials there would be no production. They are also indispensable for all other links in the value chain.

This is evident in climate-friendly technologies: Without raw materials, we wouldn't be able to build batteries, wind turbines, or photo-voltaic systems. Without raw materials, there would be no magnets – and thus no electric motors and generators. We simply cannot do without copper, aluminum, iron, and rare earth elements. They must be – and remain – available – even if the key technologies for climate protection are driving demand worldwide.

Because Germany is a country of innovation, we want to make "climate protection made in Germany" our new trademark. Our raw materials strategy thus provides for the intelligent and economical use of raw materials in addition to imports. A well thought-out product design, recycling, resource efficiency, and substitution make this possible. The fewer raw materials that must be extracted, the less waste is produced and the fewer greenhouse gases we emit.

For these reasons, we have strengthened our research on resource efficiency: The Helmholtz Institute Freiberg for Resource Technology was launched in 2011. It has quickly become an internationally recognized and highly sought-after partner in the sustainable Circular Economy for metallic raw materials and related industries. Its work flanks our current funding measures for the Circular Economy under the umbrella of our research focus on sustainable development (FONA).

The German Resource Efficiency Program (ProgRess) also helps to protect our natural resources.

As the federal government, we support companies in ensuring a secure and responsible supply of raw materials. We thus strengthen their competitiveness.
This also allows us to minimize the use of primary raw materials. The better we are at it, the more sustainable production will become. This, in turn, strengthens our economy.

Nevertheless, we are among the world's largest consumers of raw materials. That's why we are focusing even more on the Circular Economy. Thanks to this, we have been able to extract raw materials as carefully as possible, use them efficiently, and keep them in the economic cycle for longer. Companies in Germany can thus become less dependent on imports from abroad – especially for metals and minerals.

We have a dual responsibility: for the secure supply of raw materials for our industry and for climate protection for the benefit of future generations. With the Circular Economy, we are living up to this responsibility. Research institutions like the HIF are creating the scientific and technological basis for this. I would like warmly congratulate the HIF on its tenth anniversary and hope for many more groundbreaking impulses for the Circular Economy.

Anja Karliczek
Member of the German Bundestag
Federal Minister for Education and Research

©Laurence Chaperon

mine in Pöhla even necessitated the involvement of the HZDR in an exploration license in Saxony. This was made possible through close coordination with the Saxon Mining Authority. Experience with the AFK project shows that the investigation of local and supraregional raw material potentials as well as the development of innovative processing strategies and technologies can succeed only if the actors involved work well together. This also applies to the recycling of high-tech metals, among other things. The HIF benefits in particular from the resource expertise of the TU BAF as well as from the fundamental and structural research expertise of the HZDR.

> ***The strategic success impressively demonstrates the synergies that have been realized through the institutionally defined cooperation between TU BAF and HZDR in Freiberg.***

The HIF also makes a major contribution to securing a skilled workforce. With its involvement in EIT-certified Master's programs at the TU BAF and the supervision of currently almost 40 doctoral candidates, it is an important partner for students from all over the world. The HIF is also closely linked to the TU BAF through teaching; four scientists are passing on their expertise to students. The HIF has also been approved an institution for the vocational training of chemical laboratory technicians. The institute thus follows a multi-pronged approach to promote young talent in Freiberg.

The successful establishment of EIT RawMaterials by the HIF/HZDR in 2015 was, without a doubt, the most important instrument for effectively networking the work of the HIF with partners from industry and science within the EU. With the establishment of the RawMaterials – Regional Center Freiberg in 2016, the TU BAF and the HZDR have taken regional networking in the raw materials sector to a new level and promoted academic training in the raw materials sector.

Prof. Dr. Klaus-Dieter Barbknecht: Rector of the TU Bergakademie Freiberg ©Detlev Müller/TU BAF

Just one year later, the HIF and TU BAF jointly initiated the regional innovation cluster recomine, which deals with the development of marketable technologies along the interface of environmental technology, resource technology, and digitalization. The recomine alliance now has more than 60 partners, most of them small and medium-sized enterprises in Saxony and the Czech Republic.

The latest success in the strategic cooperation between TU BAF and HIF is the participation in the "Open Innovation Challenge" hosted by the global commodities group BHP. With a modular concept for processing residues from copper mining, the Freiberg team stood out from 153 other applicants in an international innovation competition. The partners from Freiberg are currently implementing the proposed concepts under the leadership of the recomine coordinators.

The strategic successes impressively demonstrate the synergies that have been realized through the institutionally defined cooperation between TU BAF and HZDR in Freiberg. As stipulated in the founding phase by Professor Jürgen Mlynek, the former president of the Helmholtz Association, the whole has become more than the sum of its parts.

Vision and mission – Together we still have a lot to do

The further development of the HIF into a research campus for resource technology and sustainability is not only the logical consequence of successful research but also an infrastructural necessity. The growth of the institute in terms of the number of employees and project acquisitions urgently calls for the expansion and rapid development of the campus. This will also open up new laboratories and facilities for researchers at TU BAF because the proven joint use of infrastructure will be continued.

> ***Our two institutions in Freiberg attract and promote top talent from around the world. That's because pioneering research ensures a promising future.***

With the metallurgical pilot plant, the first major infrastructure on the HIF campus will be completed this year. From the beginning, the scientists from the TU BAF were closely involved in the planning of the scientific and technical equipment. The joint use of the hydro-, biohydro-, and pyrometallurgical facilities is a logical consequence of the scientific issues at stake, the local proximity, and many joint research projects. The so-called FlexiPlant will be the second important infrastructure to be realized on the campus of the HIF in Freiberg. Although the concept of FlexiPlant has initially been developed by researchers at the HIF, it is now taken forward in cooperation with the TU BAF. Once realized, FlexiPlant will provide quantitative answers for opportunities to establish a sustainable Circular Economy in Germany and abroad.

It is also important to transfer research results into the raw materials industry. The HIF will therefore set up an incubator as part of its campus development. In order to create a more direct link to spin-off activities and support programs at the TU BAF, the cooperation with Dresden Concept and SAXEED, the start-up network of TU BAF, will be further expanded. This creates additional synergies and offers the potential for regional value creation and economic development.

All of this shows that: The HIF has closed an important gap in non-university research in Germany and established itself as a pioneer for a sustainable Circular Economy for mineral and metalliferous raw materials. This is a result of the strategic partnership between HZDR and TU BAF. Our two institutions at the Freiberg site attract and promote top talent from around the world. And thus secure the future by engaging in research.

TU BERGAKADEMIE FREIBERG (TU BAF)

Whether innovation, Industry 4.0, the Internet of Things, or e-mobility – all modern developments require resources, energy, and materials as well as a sustainable approach to these. That is why the TU BAF engages in excellent research and teaching on the fundamentals and processes surrounding raw materials, energy, and materials.

Founded in 1765 to drive transformation processes and future technologies and provide a boost with new knowledge, TU BAF aspires to train economists, natural scientists, and engineers who want to take the future into their own hands. 4,000 students in 73 degree programs study in Freiberg in a scientifically sound and practice-oriented manner.

©Crispin-Iven Mokry/TU BAF

HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF (HZDR)

The HZDR conducts research in the fields of energy, health, and matter. The focus is on the following questions:

- How can energy and resources be used efficiently, safely, and sustainably?
- How can malignant tumors be more precisely visualized, characterized, and more effectively treated?
- How do matter and materials behave under the influence of strong fields and in smallest dimensions?

The HZDR develops and operates large infrastructures that are also used by external scientists: The Ion Beam Center, the High-Magnetic Field Laboratory Dresden, and the ELBE Center for High-Power Radiation Sources.

©HZDR/Jürgen-M. Schulter

It is a member of the Helmholtz Association, has six locations (Dresden, Freiberg, Görlitz, Grenoble, Leipzig, Schenefeld near Hamburg) and employs almost 1,400 people – around 500 of whom are scientists (including 170 doctoral candidates).

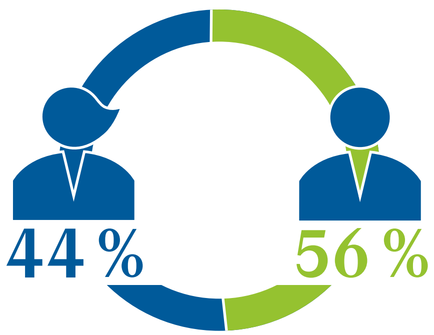
The HIF in figures

Under one roof, the researchers deal with raw materials-related research ranging from exploration, processing, and metallurgy to recycling in an interdisciplinary manner.

Last revised: July 2021

Proportion of men and women at the HIF

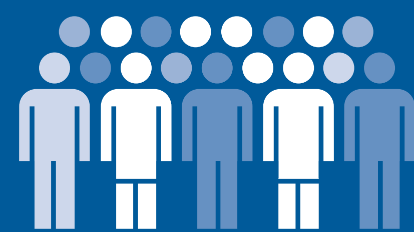
The HIF has an almost equal ratio of female and male staff members.



Team

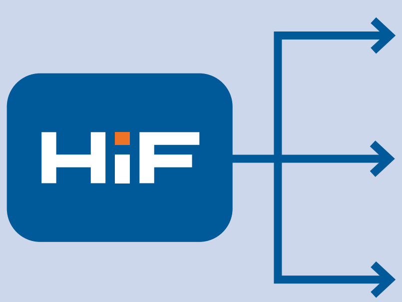
153

Our employees are our most important resource.



3 Spin-offs

In order for ideas to be transferred into industry, researchers must become entrepreneurs.



35 nationalities

Diversity promotes our sense of togetherness.

Scientific staff

44 Support staff

36 Doctoral candidates

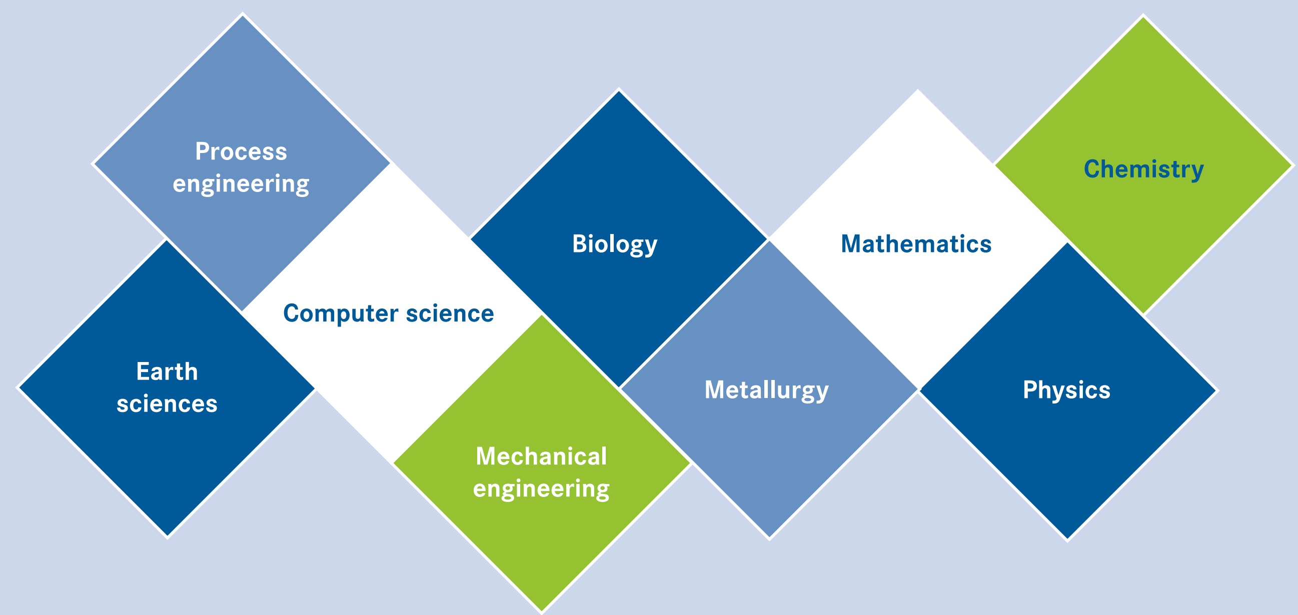
36 Students

Student assistants, Master's and diploma students, and interns

22 Senior research staff

An interdisciplinary approach

The key to our success is that we think and research across disciplines.



Foundation of the institute

MARCH 28, 2011

The cooperation agreement for a joint research institute between HZDR and TU BAF was signed in the presence of Professor Sabine von Schorlemer (former Saxon Minister of Science).
©HZDR

AUGUST 29, 2011

This was followed by the symbolic transfer of keys from, at the time, Federal Research Minister, Dr. h.c. Annette Schavan to the newly founded HIF in Freiberg as part of the HZDR. The founding director is Dr. Jens Gutzmer (PhD ZA).
©HZDR/Lutz Weidler

SITE

While the planned main site is being renovated, the HIF employees are based on the premises of SAXONIA Standortentwicklungs- und -verwaltungsgesellschaft.
©HZDR

TEMPORARY USE

In the first few months, the researchers of the new institute use the laboratories of their founding institutions HZDR and TU Bergakademie Freiberg.
©HZDR/Frank Bierstedt

GO-AHEAD

Old mine tailings as a possible source of raw materials? The HIF wants to know more and is launching its first research activities on the topic of re-mining.
©HZDR/Mario Köhler

Mine tailings – a global challenge with great potential

During the processing of mineral raw materials from primary (geogenic) deposits, ore minerals are separated from so-called gangue, i.e. minerals of no economic value. The latter then end up as fine-grained residues on tailings dams. As a result of the continued global increase in raw material production from ore deposits with ever decreasing grade requires the production and deposition of increasing volumes of tailings. However, many of the resulting tailings storage facilities cause long-term problems. Tailings dams may become unstable; their collapse having catastrophic consequences to the environment. But even if the tailings dams are stable, acidic drainage water loaded with heavy metals may escape and harm the environment in the long term.

In addition to the obvious dangers, many mine tailings also harbor great potential. In the past, technologies were not suited to concentrate all valuable minerals. But modern technologies can usually do this more efficiently. Furthermore, tailings also contain significant concentrations of raw materials that were previously regarded to be of little or no economic interest. Current examples include indium or lithium. Such raw materials can still occur in the tailing material in high concentrations.

> *“As a result of the continued global increase in raw material production from ore deposits with ever decreasing grade requires the production and deposition of increasing volumes of tailings.”*

Towards a realistic resource potential assesment

Since its foundation, the HIF has investigated the recovery of strategic metals and minerals from historic tailings dams in Saxony. In one of the first research projects, the still young institute and its partners created a tailings register starting in 2012. This register includes tangible data for the 20 historic tailings dams deemed to have the highest resource potential. This laid the foundation for research into various technologies related to the topic of re-mining existing tailings dams. These include the use of drones, which are used in remote sensing for the precise and rapid measurement of the surface geometry of the

The tailings dams No. 1 in Ehrenfriedersdorf is a development site of the re-comine alliance on which technologies are to be further developed into marketable solutions under real conditions. ©HZDR/HIF

The researchers use micro-organisms to extract metals. However, in order for the latter to be able to grow and work, optimal conditions must be found. Bioreactors offer such an environment of well-being. They regulate the oxygen supply, the temperature, and the pH value, thereby ensuring that the microorganisms can flourish. ©HZDR/Frank Bierstedt

tailings dams, or the modern mineralogical characterization of tailing material using scanning electron microscopy. By cleverly combining mineralogical and chemical data with particle information, it became possible to estimate the behavior of the tailing material during processing. It was thus possible to create spatial models that visualize not only the material content and distribution but also the fraction of this remaining mineral and/or metal content that can be recovered with state-of-the-art technologies.

The researchers are currently contributing the knowledge they have gained to various international research projects. Together with partner institutions from industry, the HIF is developing technologies that can precisely record the mineralogical and geochemical data of tailing materials with drones or by sensors that are inserted directly into bore holes. The collaboration with two successful HIF spin-offs also plays an important role. For example, TheiaX offers drone- or drill-core-based methods for characterizing tailings, while Erzlabor Advanced Solutions provides methods for characterizing fine-grained tailing materials.

> *Biotechnology – an approach that is widely regarded as an environmentally friendly technology alternative – plays an important role in the development of re-mining concepts.*

Research with experienced partners under real conditions

The work on regional tailings (e.g., the Tiefenbachhalde in Altenberg) helped HIF researchers to combine raw material extraction with concepts for sustainable remediation at an early stage. The HIF has therefore strategically expanded various re-mining topics. The institute currently heads a regional network funded by the BMBF – the recomine alliance – which is an innovation partnership specializing in upscaling and developing holistic strategies for the remediation and use of mine tailings. This alliance of over 60 regional players from industry, research, and social institutions operates at the interface of environmental science, resource technology and Industry 4.0. Innovative solutions are currently being developed at four regional development sites under real-life conditions before being further developed into services and concepts for the global raw materials sector. In this

BHP TAILINGS CHALLENGE – PROOF-OF-CONCEPT-PHASE REACHED

Led by the HIF, a consortium from the recomine alliance was able to successfully compete in the BHP Tailings Challenge. In the competition, BHP, one of the world's largest mining groups, is looking for sustainable solutions to reduce tailing materials at a copper mine in South America. The recomine team was able to reach the top 10 out of 153 teams worldwide in the application phase. With the proposed modular concept, the scientists are now entering the proof-of-concept phase with colleagues from industry. If this is successfully completed, the developed technology could be used at several BHP locations.

particular context, the HIF is strongly committed to scientific cooperation and technology transfer in the border region of Germany, Poland, and the Czech Republic.

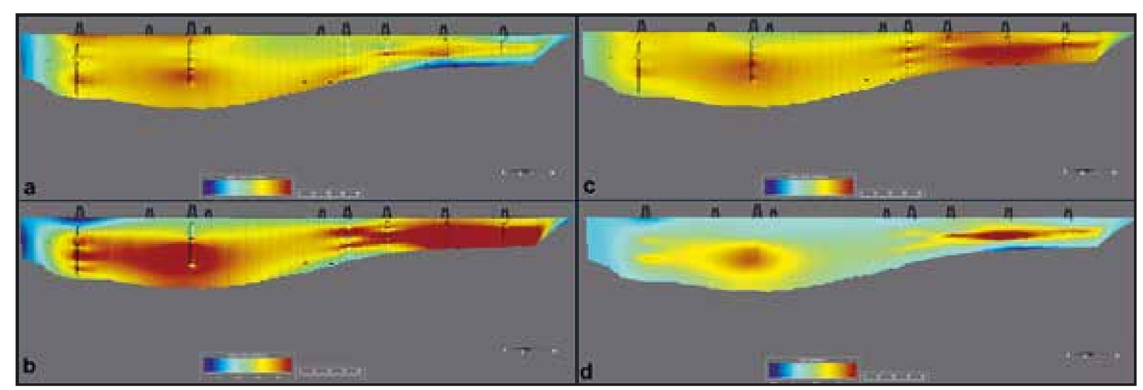
New technologies for re-mining of tailings

The HIF is specifically pushing ahead with further developments in various fields of technology for the processing of tailing materials. Biotechnology – an approach that is increasingly being recognized as an environmentally friendly technology alternative – plays a particularly important role here. It is superior to conventional methods in several respects: On the one hand, it does not require the use of harmful chemicals, on the other hand, it offers the possibility of separating metals very selectively. Above all, it harnesses the potential of raw material sources with low metal contents where the limits of conventional processing methods are exhausted.

"Bioleaching" is particularly suitable for extracting raw materials from mine tailings. In the process, micro-organisms mobilize metals from ore minerals through their metabolic processes or products. Currently, bioleaching is used mainly for the industrial extraction of copper. The application of bioleaching to low grade tailings of complex composition is, in contrast, rather novel. Here, the HIF conducts both basic research and the development of innovative bioleaching processes. Together with regional partners, the Institute has recently designed a semi-mobile bioleaching plant on a pilot scale. Three functional modules located in overseas containers mobilize and separate pollutants and valuable metals from the tailing material. With the help of recomine, this system is now to be set up at a development site for the first time, tested, and ultimately developed into a marketable product.

In further projects, metals such as copper are to be extracted from tailings material. The remaining mineral residues of the tailings materials are to be tested for their use for the production of cement, among other things. In this way, historical mine tailings will be used holistically, and the affected landscape can be rehabilitated.

QR code to link to the recomine alliance website:



Combining the (a) concentration of the tin mineral cassiterite, the (b) liberation (exposure) of the cassiterite particles and the (c) cassiterite grain size distribution, the weighting and combination of the material parameters results in a (d) resource potential model of the Tiefenbachhalde in Altenberg. Red means that the material can be processed quite well and that more than 50% of the cassiterite contained can be separated by flotation. ©HZDR/HIF

First in-house laboratory

INSTITUTE GROWTH

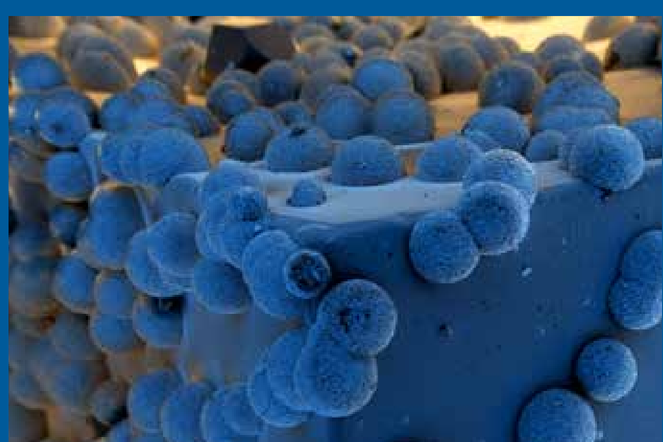
From 2012, the building in Halsbrücker Straße is filled with office furniture, new employees, and the first in-house laboratory for resource characterization.
©HZDR/Detlev Müller

HIGHLY SENSITIVE

For the non-destructive analysis of the chemical composition of small amounts of solid materials, the HIF uses an electron beam microprobe.
©HZDR/Detlev Müller

AUTOMATED MINERALOGY

The first scanning electron microscopes (SEM) are used to magnify rock samples up to 1,000,000 times. Image analysis is used to yield the mineralogical composition and the microstructure both rapidly and automatically.
©HZDR/Detlev Müller



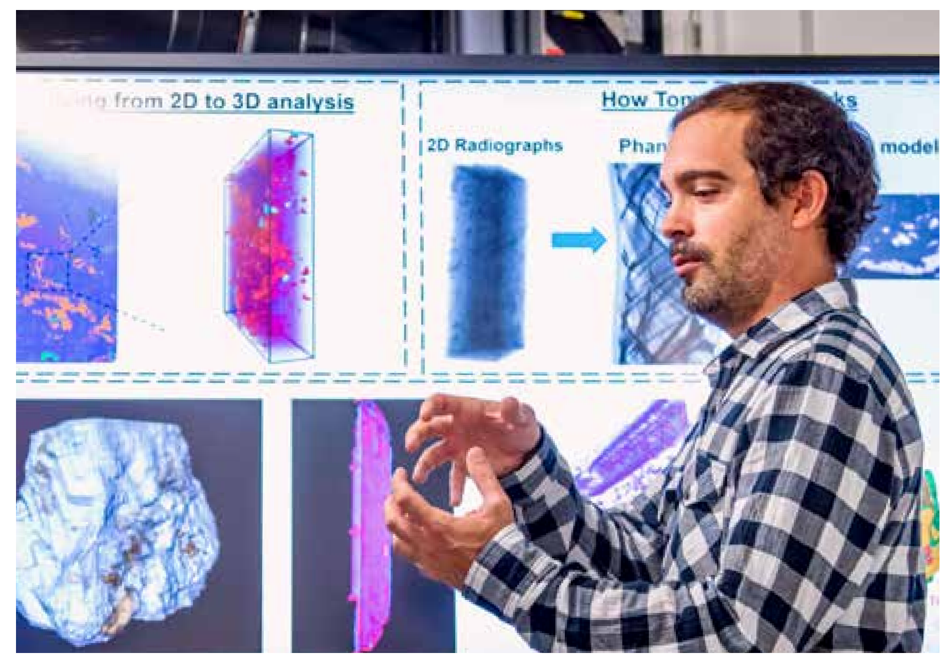
MINERAL MICROCOSM

Roundish aggregates of a copper arsenate on a fluorite cube. The SEM image shows: If you want to process ores efficiently, you have to know their composition and microfabric exactly. The HIF uses its knowledge of analytical methods and becomes a global leader in geometallurgy.
@HZDR/HIF

Why engineering scientists and geoscientists should talk to each other

How can we significantly increase raw material and energy efficiency in the extraction and processing of mineral resources? And at the same time reduce environmental impact and minimize the technical risk of a capital-intensive project in the raw materials industry? Or to put it another way: How can the global raw materials industry – as part of the Circular Economy – be made more sustainable and efficient? These are the essential questions that HIF geoscientists, process engineers and mathematicians address when they speak of geometallurgy. This research is based on a precise understanding of the composition and microstructure of the raw materials as well as their impact on resource efficiency, energy input, and the performance of the processing technologies and metallurgical process routes used. In geometallurgy, the HIF connects relevant knowledge about raw materials and associated technologies in an interdisciplinary manner. The researchers can thus make accurate predictions about the economic extraction of metals from complex raw material sources as well as about the efficiency of innovative technologies.

> *The HIF uses geometallurgy to bring together relevant knowledge about raw materials and associated technologies across disciplines.*



Even though the world is 3D, material characterization data is generally not. At least not yet. The use of 3D instead of the usual 2D data would be a major breakthrough for efficient raw material extraction. The HIF is working on this problem.
©HZDR/Detlev Müller

QR code to link to the 2D3DScopy project video:

Leading in raw materials characterization

The processability of raw material is determined by its mineralogical composition and microstructure. For example, coarse-grained ores, which consist of only a few minerals, are usually easy to process. On the other hand, complex ores (i.e., many different minerals finely distributed in the rock) represent a major challenge for processing.

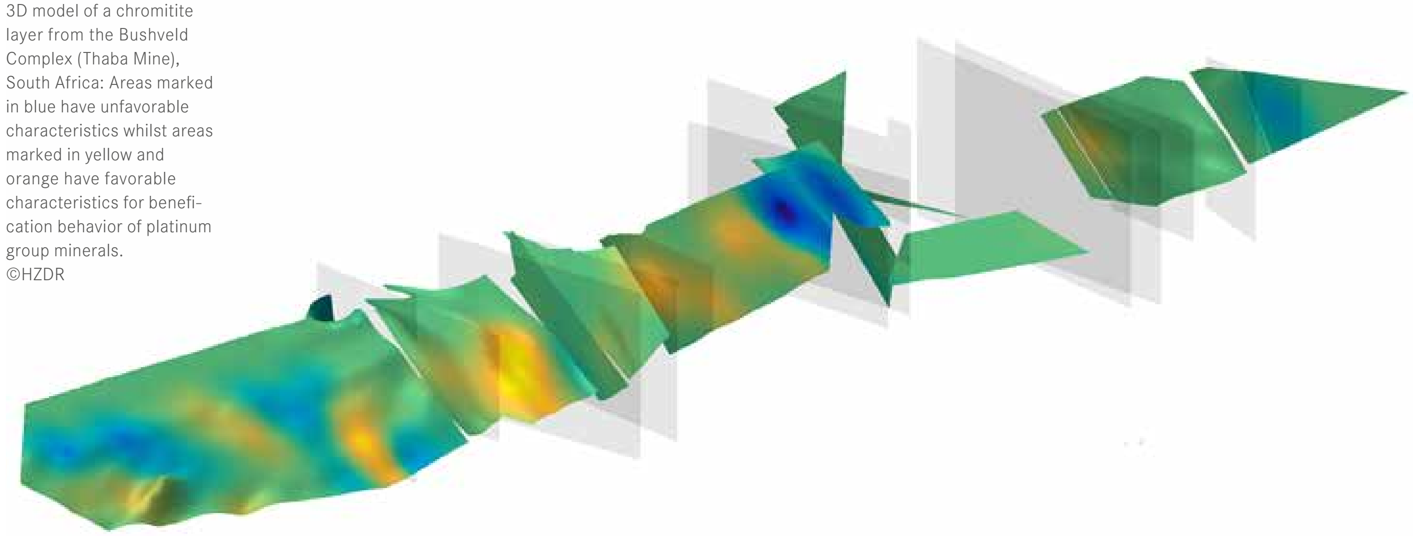
In only 10 years, the HIF has built up an impressive range of methods and expertise for raw materials characterization. Scanning electron microscopy, X-ray computed tomography, and micro X-ray fluorescence spectroscopy record the mineralogy and microstructure in 2D and 3D. Electron beam microprobe or laser ablation-inductively coupled plasma-mass spectrometry help scientists to determine the chemical composition of individual minerals. A particular focus is on the further development of raw materials characterization in order to detect even the smallest contents of important high-tech metals such as platinum group elements. For example, the 2D3DScopy project (funded by EIT RawMaterials) develops a prototypical analytical sensor for X-ray computed tomography that will allow the 3D chemical characterization of various materials. This is currently only one of two devices of its kind in the world.

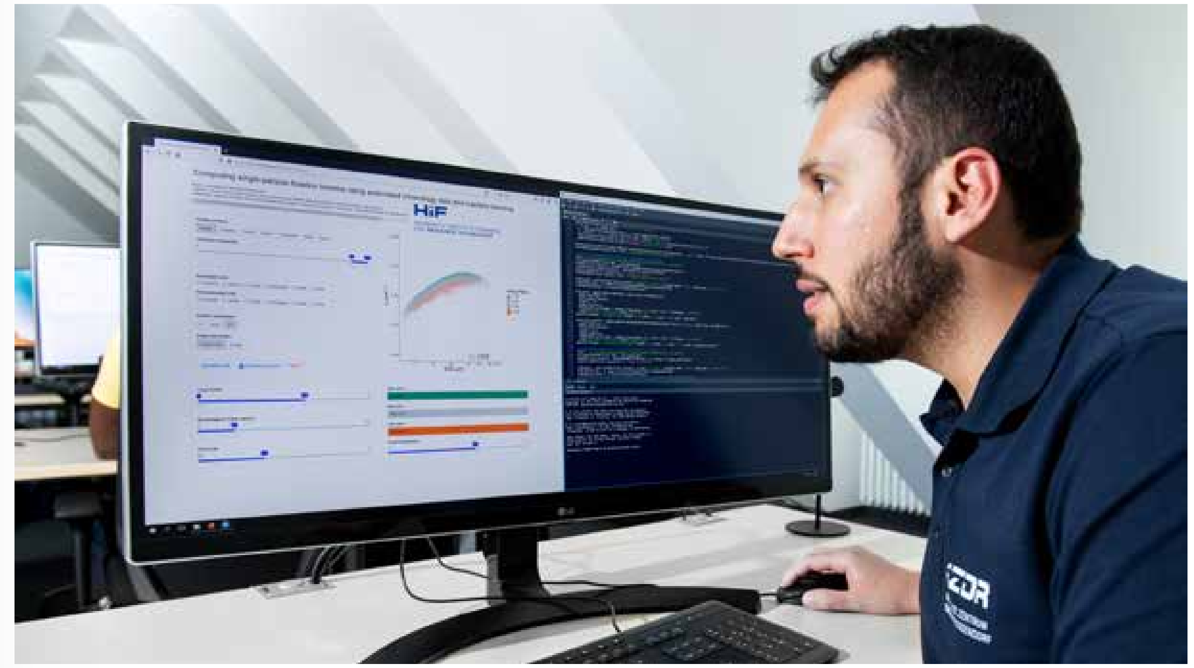
> *“In only 10 years, the HIF has built up an impressive range of methods and expertise for raw materials characterization.”*

The big picture

An ore deposit is sampled only selectively. Sampling is based mostly on available drill cores. These drill cores are needed to explore an ore body from the land surface. Special methods from the fields of statistics and machine learning (ML) are used in order to visualize how ore and ore properties are distributed across the ore body. They combine the results of the detailed characterization data with further information in order to determine a dense data network of easily measured properties. Such information include hyperspectral image data and chemical analyses for the cores as well as training data sets. The result is a geometallurgical block model that integrates all processing-relevant parameters for individual ore blocks or mining units. This determines which ores are suitable for mining, processing, and metal extraction. The AMREP project (funded by the CLIENT program of the BMBF) showed how the geometallurgical approach works. Here, HIF and its partners studied the Thaba mine in South Africa and visualized the processability of chromite ores containing platinum group minerals in a 3D model.

3D model of a chromitite layer from the Bushveld Complex (Thaba Mine), South Africa: Areas marked in blue have unfavorable characteristics whilst areas marked in yellow and orange have favorable characteristics for beneficiation behavior of platinum group minerals.
©HZDR





In order to make beneficiation processes more energy and raw material efficient, HIF is developing particle-based prediction models.
©HZDR/Detlev Müller

Digital raw material processing

Comminution and mineral separation processes are highly energy-intensive; some also require a high input of process chemicals. Hence, the data from the geometallurgical deposit model are also used to simulate and optimize the behavior of the ores during processing. A process model is used to calculate operating parameters such as consumption of energy and chemicals as well as how much of the metal-containing minerals can actually be extracted from the ore. Together with partners, HIF researchers have focused on developing particle-based prediction models – both for crushing and for separation processes such as magnetic separation and flotation. Here, different particles are identified from raw material analysis data sets and tracked through the technical process chain. The aim is to simulate particle behavior in not only a single processing machine but rather in an entire chain of separation processes. In other words, to lay the foundation for a more efficient processing that is precisely adapted to the ore block.

Once deposit and process models have been developed, decision theories and techniques from mathematics can be used to simulate various scenarios that yields the combined geological, economic, and ecological optimum for raw material extraction and beneficiation. The optimal scenario is then continuously adjusted and improved based on data collected from mining and mineral processing operations.

THE BREAKTHROUGH IN RESOURCE EFFICIENCY

Often in science, an innovation is pushed forward only when it is visually understandable. Therefore, following the development of state-of-the-art particle-based separation models, the HIF has set up an active platform in order to better understand how millions of particles behave in the process in relation to their physical properties.

The advantage of this platform: It allows users from different parts of the raw material value chain to extract the information that is important to them.

QR code to link to the Shiny app:

The HIF grows

NOVEMBER 19, 2013

A symbolic act in the presence of numerous representatives from science, business, and administration marked the beginning of the interior renovation at the future site of the institute. ©HZDR/Detlev Müller

MOVING INTO HISTORIC WALLS

The institute, which is only a few years old, is soon to be given its final location at a highly suitable location: The building is located on the campus of the former Research Institute of Mineral Processing (Academy of Sciences of the GDR, Chemnitzer Straße 40). ©UVR-FIA

THE TEAM

From 0 to 50: That's about how many employees the institute has after just two years. Top scientists from all over the world make their way to Freiberg in order to research raw materials. @HZDR/HIF

NETWORKING

Still young but already successful: Under the leadership of the HIF and with the support of the HZDR, the largest raw materials network in Europe, EIT RawMaterials is established; a short time later, the German raw materials network GERRI is founded under the coordination of the HIF.

AIM HIGH

Research is also picking up speed: Together with the TU Bergakademie Freiberg and the Federal Institute for Geosciences and Natural Resources (BGR), the institute launched the first research exploration campaign in the Ore Mountains (Erzgebirge) since the German Re-unification. This marked the start of a successful development of sustainable and modern exploration methods at the HIF. ©HZDR/Detlev Müller

Sustainable exploration

A trained pilot steers a drone over the terrain to be surveyed so that optimal measurements of the subsurface can be made. ©HZDR/HIF

When the HIF exploration team enters a field site, it hardly resembles the cliché of the geologist's profession. Imagine: a group of women and men from diverse backgrounds with reflective protective clothing, tablets, and walkie-talkies. High-tech specialists who fly drones with sensors and control automated cameras. Certainly not typical geologists. Nevertheless, these HIF researchers are revolutionizing the exploration of raw materials with their technological innovations.

Since its foundation, the institute has pursued its mission of exploring new raw material deposits in Germany, Europe, and worldwide. But how can a small group of researchers from Saxony revolutionize a field in which numerous industries and universities have long been active? The core team decided to focus on key challenges that would affect the efficiency of resource exploration and, more importantly, acceptance by civil society. The poor environmental and social reputation of the mining industry suggests the need for technologies that have a much lower impact on nature and society. At HIF, this gave rise to the idea for the development of an all-in-one solution: non-invasive yet highly efficient exploration technologies that increase the acceptance of raw material exploration and reduce the environmental impact.

How does it work? The idea is to map deposits with imaging technologies. The scientists do not recognize the ores directly but rather identify their characteristic influence on various parameters, which can be recorded remotely. Of course, these technologies are not meant to replace geologists. But with their help, local specialists can optimize their work processes and minimize their environmental footprint.

Against this background, the HIF began to develop a technological strategy. One of its main cornerstones is hyperspectral imaging. Just like water drops split light into all visible colors, the rainbow, the sensors measure incident light with a particularly high spectral resolution. Because each material interacts differently with light, the reflected signal can be used like a fingerprint – in this case, to identify specific minerals. So far, hyperspectral sensors have been used on aircrafts and satellites. The HIF is now using them on drones and in the field, and combining the data collected in an integrated 3D environment. However, the technique has one drawback: It can only image the surface. To address this shortcoming, hyperspectral imaging is combined with geophysical methods to explore the subsurface. Using the same principles of non-invasiveness, the team measures anomalies in geophysical signals (e.g., the Earth's magnetic field) in order to infer the presence of potential mineralization. The ultimate goal is to locate targets of interest in the Earth's crust for the exploration of raw materials. There, geologists can then take exactly the samples they need through targeted drilling.

To provide relevant information rapidely and objectively, the HIF is developing machine learning methods with which data can be quickly evaluated and visualized. Then the ground team can optimize and adapt its activities in often inhospitable terrain. The team now includes specialists in artificial intelligence, augmented reality, and automation. Ideally, this will allow users to recreate a three-dimensional representa-

Geologists can view and evaluate the images taken by the hyperspectral cameras directly in the field. ©HZDR/HIF

tion of the surface and subsurface in real time. These "digital twins" of the earth's crust project the mining sector directly into the digital age on the way to Industry 4.0.

The employees of the HIF test their technologies in many regions of the world, especially those areas in which the raw materials needed for the energy revolution and for achieving the goals of the Paris Climate Agreement can be found. Lithium, rare earth metals, copper, and nickel are just a few of these high-tech raw materials that can now be identified in a wide range of climatic and geographical environments with the newly developed technology.

The HIF was able to demonstrate the relevance of this approach by leading the large European project INFACT (part of the Horizon 2020 program). Together with 16 European partners from industry, research and non-governmental organizations (NGOs), several reference sites were developed.

CAN MINING BE SUSTAINABLE?

The mining of mineral raw materials is crucial to the expansion of environmentally-friendly technologies such as solar panels, wind turbines, and electric cars. Precious and rare metals are needed for our cell phones and laptops. How does that fit with the sustainable, green future? Are there sufficient quantities of natural raw materials? An international panel of experts discussed this. The event, "Can mining make the world a greener place?" was organized by the Natural History Museum and the EU-funded INFACT project. BBC science presenter Professor Iain Stewart moderated a debate on mining and its role in our society.

The recording of the English-language event is available at the following link:

At these sites, exploration technologies can be evaluated with regard to both their technical efficiency and social acceptance. In this research project, the HIF was able to bring together NGOs, policy makers, and industry partners to discuss the future of resource exploration in Europe. Because sustainable solutions can be found only if everyone is involved in the decision-making process.

The need for innovative, rapid and non-invasive technologies is shown by the high industrial demand. To meet this need, HIF employees and graduates founded a successfull startup company TheiaX.

What's next? The HIF has already been able to transfer some of its expertise. It is now possible to monitor the development of a mine over time, its tailings, and associated environmental impacts. The techniques used thus help to find, characterize and optimize the extraction of the natural resources required by Society´s changing needs. The sensors and techniques developed by the HIF will allow the automation, intelligent extraction and precision processing needed to make future mines safer while simultaneously reducing their environmental impact.

While still in the field, models of the terrain can be created using the data collected from hyperspectral cameras. The different colors provide information about different mineral contents. @HZDR/HIF

The move

■ JUNE 17, 2016

Finally finished – Dr. Eva-Maria Stange (center), Minister for Science and the Arts for the Free State of Saxony and many others inaugurate the new offices and laboratories. ©HZDR/Detlev Müller

■ CHEMNITZER STRASSE 40

On an area of almost 3,000 m², the HIF scientists now have excellent conditions to conduct top-level research. ©HZDR/Frank Schinski

■ JUBILEE

The 100 employees have barely moved in and are already celebrating the 5th anniversary of the institute. @HZDR/HIF

■ PILOT PROJECT

With the possibilities at the new location, the HIF ventures to advance research into the beneficiation of complex ores from the Ore Mountains. This is the kick-off to the most elaborate research project in this field to date: AFK. ©Knitterfisch (left, center), Detlev Müller (right)

Complex raw materials require holistic solutions

The extraction and beneficiation of natural resources is one of the fundamental pillars to a sustainable Circular Economy. The energy transition in particular is causing demand for copper and similar resources to skyrocket. Despite intensive efforts, this demand cannot be met by recycling alone. But the mining industry is facing major challenges. At the beginning of the last century, the ore bodies were often still so coarse-grained and rich that it was possible to concentrate the valuable minerals by hand. This is very different today, where ores often consist of a complex and fine-grained association of many different ore and gangue minerals that is difficult to beneficiate. Such ore deposits are well known to exist in the Ore Mountains. The development of resource- and energy-efficient technologies for the processing of such complex ores may thus also spur the reconnaissance of domestic mineral and metal production, with a particular focus on high technology metals such as tin and indium.

Beneficiation of complex ores is so difficult because they first require energy-intensive milling to very fine particle sizes in order to liberate valuable (ore) minerals from closely associated gangue minerals, followed by selective separation of the ore minerals by technologies suitable for such fine particle sizes. This is where the limits of conventional separation methods are reached. The mineralogical diversity in complex ores also means that not just one but rather a whole range of particle properties such as density, magnetizability, or surface properties dictate the separation success.

Experiments on a grand scale

In order to harness the potential of raw materials extraction and beneficiation while reducing the environmental footprint of mining, the HIF is pursuing several technological approaches simultaneously. These got their first big boost through the project "Processing of fine-grained complex ores" (Aufbereitung feinkörniger Komplexerze; AFK). In this collaborative research project results from modern raw materials characterization were incorporated into mathematical models that allow many different process sequences to be simulated and the optimum combination of separation steps to be determined. It is essential that the individual processes not be considered in isolation from each other but rather always as an entire process chain. This is groundbreaking because conventional process flowsheet development based its processes largely on experience and time-consuming test work.

Together with researchers from across Europe, the AFK team processed an approximately 140-ton ore sample of a

More than 100 tons of complex ore from the Tellerhäuser deposit in the Ore Mountains are being processed in a pilot project using modern analytical methods and computer models. ©HZDR/Detlev Müller

In order to understand the separation processes at the particle level, HIF researchers are experimenting with flotation cells at both the laboratory and pilot scale. ©HZDR/Frank Schinski

skarn – rich in tin, zinc, and indium – from the Schwarzenberg District in the Ore Mountains in an energy- and resource-efficient manner on a pilot scale. The deposits in the Schwarzenberg District are particularly advantageous for research into new processing strategies. They are well explored and are polymetallic, i.e. have high grades of several high technology metals. Much of the experimental work took place at the UVR-FIA GmbH pilot plant, which is located immediately adjacent to the HIF institute.

In addition to selecting the optimal beneficiation process chain, the potential of efficient ore sorting technologies is being researched at the HIF. The use of artificial intelligence (AI) enables the targeted selection and adjustment of sensors for the optimal use of sorting plants in order to efficiently separate waste rock from ore even before secondary crushing and milling. This means that less material is considered for the energy-intensive comminution and separation steps – and less tailings are produced.

Size does matter

Flotation is a proven process for separating valuable minerals from finely ground ore. It uses the surface properties of particles in order to separate different minerals from each other. The principle is simple: If you guide gas bubbles into a mixture of liquid and ore particles, bubbles adhere to those mineral grains that have water-repellent surface properties. These rise to the top because of the attached air bubbles and form a foam layer that can be skimmed off. Minerals with different surface properties can thus be efficiently separated from each other.

Flotation technology in current use is limited in its technical possibilities. Particles smaller than 20 µm in diameter cannot be efficiently separated. The HIF researchers – together with the Institute of Fluid Dynamics at the HZDR and many international partners – are thus improving the flotation process from basic research to pilot scale. In current research projects such as FineFuture (a research project coordinated by the HZDR in the Horizon 2020 program of the EU), various questions are being investigated for this purpose: How do individual ore particles behave during flotation? How do their surfaces change through the use of chemicals? What interactions occur at the interfaces with other particles?

The answers allow to conclude about the conditions under which valuable minerals can best be separated from ore in the form of a mineral concentrate. The spectrum of results ranges from gaining knowledge and optimizing process chemicals to successfully simulating turbulent processes in the flotation cell and pilot-scale flotation trials.

Innovation inspired by nature

Because they can modify the properties of particle surfaces and thus separate different particles from each other, micro-organisms or biomolecules may also used in flotation. By exploring this approach, which is referred to as bioflotation, the HIF entered into a novel field of research in recent years. This is done using Bioflotation tests with the ability of the small biological helpers to attach themselves to mineral surfaces and interact with them. Here, the institute is researching the use of microbial metabolites (i.e., substances formed as products of the metabolism of micro-organisms) and natural substances as flotation reagents. These are produced using biotechnological methods, characterized, and tested together with "the" flotation specialists. The advantage of this approach is that the number of chemical reagents can be reduced. The reagents can also be recovered and reused. In the next few years, the HIF will use bioflotation for not only ore processing but also the recycling of end-of-life products of particularly complex composition.

THE "AFK" PROJECT

BENEFICIATION OF FINE-GRAINED AND POLYMETALLIC ORES FROM DOMESTIC SOURCES

From May 2015 to December 2018, the "AFK" project was supported by the Federal Ministry of Education and Research with almost € 2 million. The project was part of the funding program "r4 - Innovative Technologies for Resource Efficiency Research for the Provision of Economically Strategic Raw Materials" in the "Research for Sustainable Development" (FONA) framework program.

QR code to link to the AFK project video:

Biotechnology opens up completely new possibilities – including those for the further development of classic separation processes. ©HZDR

The HIF expands

METALLURGICAL PILOT PLANT

Saxony is financing the new pilot-scale research infrastructure with a total of € 10.2 million. Different metallurgical processes are to be combined and interconnected. ©Baubüro Freiberg

OCTOBER 17, 2018

The HIF celebrates the start of construction of its new pilot plant with a groundbreaking ceremony. The institute is thus expanding its research infrastructure, especially for the recycling of strategic raw materials.
©HZDR/Detlev Müller

BASEMENT EXPANSION

Construction is also continuing in the main building, and the basement wing is being developed. Additional space, including a laboratory for the drill core scanner and a conveyor test facility for the real-time characterization of raw materials, is being built.
©HZDR/Detlev Müller

FIRST RESEARCH FACILITY

A vacuum induction furnace, which inductively melts metallic scrap and alloys, is the first test facility in the pilot plant. @HZDR/HIF

PROGRESS

After the groundbreaking ceremony, things are progressing rapidly. After just over a year, the blue sky is already reflected in the new glass facade of the pilot facility, which measures around 400 m². @HZDR/HIF

MODELING

With the topics of sustainability and Circular Economy, the HIF is increasingly specializing in researching the entire raw materials value cycle. By simulating and optimizing such cycles, the HIF is providing new impetus in systemic assessments.
©HZDR/Detlev Müller

Innovation platform for the Circular Economy of the future

Building a sustainable Circular Economy is an integral part of the "European Green Deal". This recognizes the supply of mineral and metalliferous raw materials as a strategic element of the economic development of the EU. These current political developments and the global geopolitical situation with steadily increasing raw material consumption and conflicts, climate change, and the energy revolution illustrate the great social relevance of research at the HIF, which will continue to grow in importance over the next 10 years.

Building a sustainable Circular Economy provides a possible answer to one of the most pressing issues that our modern society has to deal with: How can we sustainably manage our natural resource base? Resource use, emissions, and energy consumption are minimized by intelligently and sustainably closing raw material loops. This seemingly simple principle of the Circular Economy is actually highly complex and requires innovative technologies, among other things.

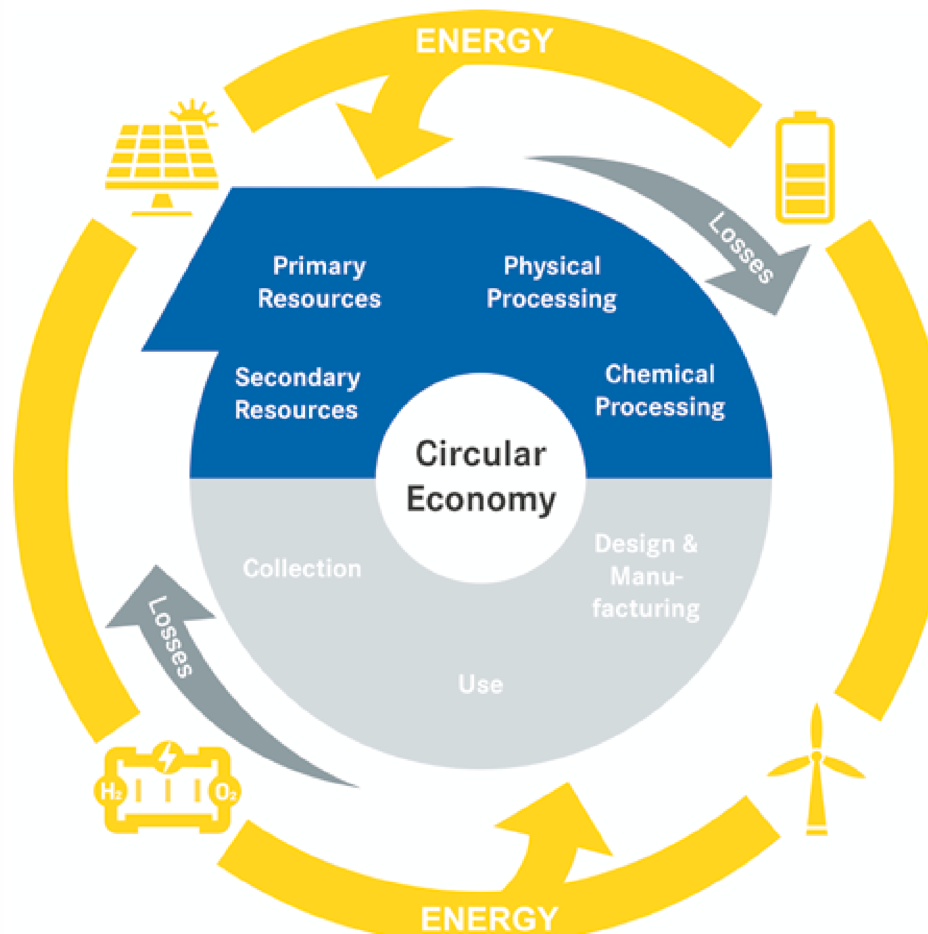


Illustration of the research portfolio of the HIF (blue) in the context of the Circular Economy of mineral and metalliferous raw materials. Special attention is given to the interplay between the changing energy system and the material flows of the Circular Economy. ©HZDR/HIF

> ***This is because the raw materials needed for a sustainable Circular Economy will continue to come from both primary and secondary sources.***

The focus of research at the HIF is therefore on mapping the entire value chain of mineral raw materials and metals. This is because the raw materials needed for a sustainable Circular Economy will continue to come from both primary (geogenic; formed in the earth) and secondary (anthropogenic; modified by humans) sources. The HIF follows the approach of viewing both sources as complementary and of equal value and to always considering raw materials and energy demands together.

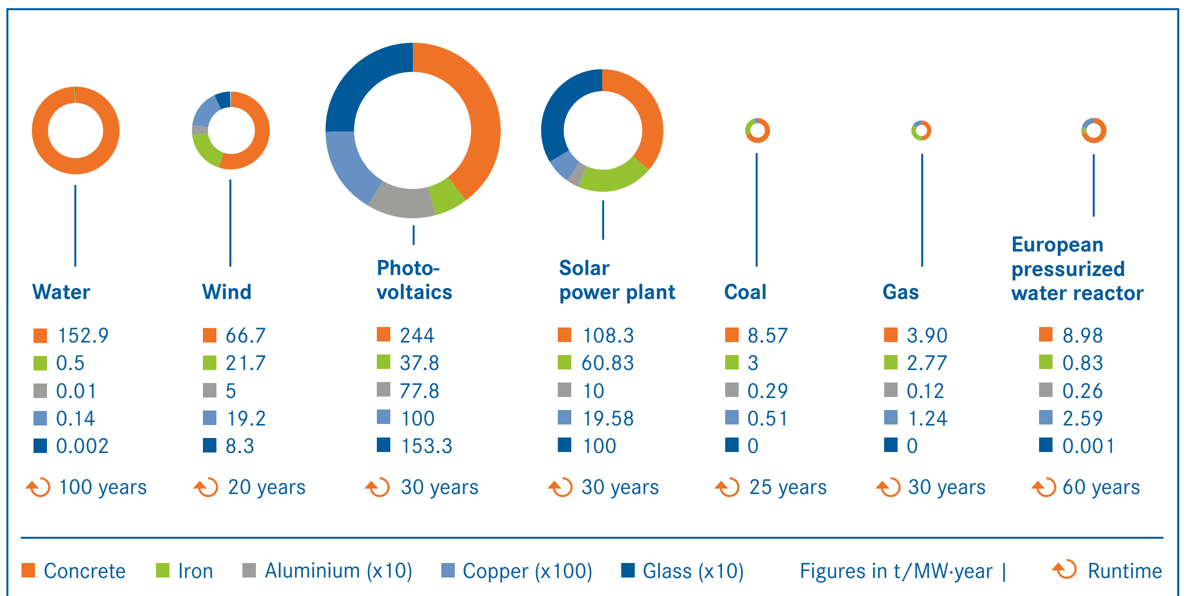
The finite nature of raw materials

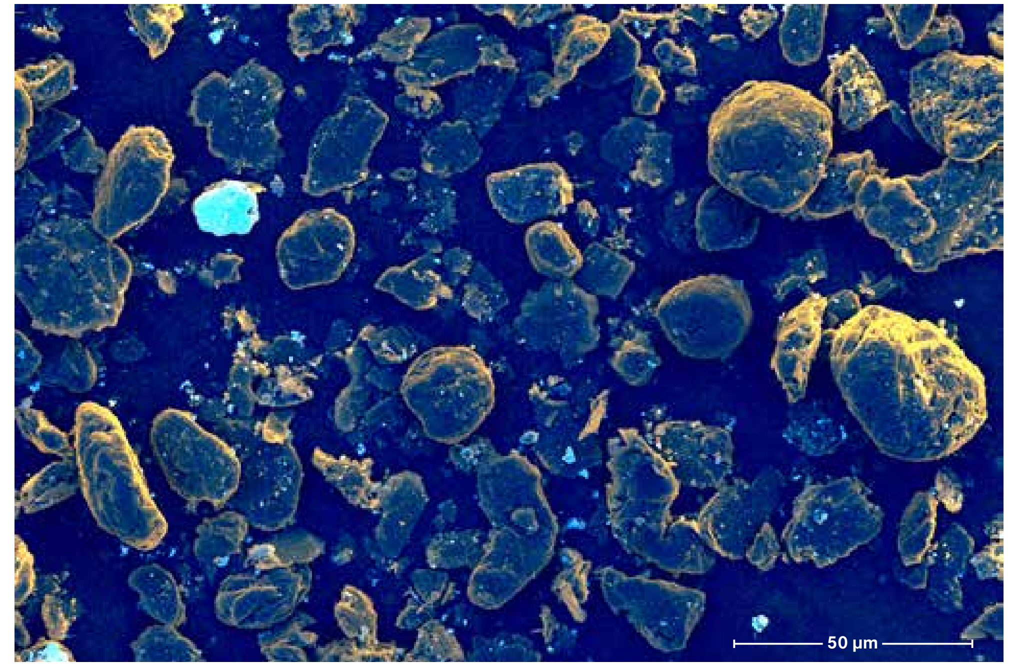
Mineral raw materials – and especially metals – are indispensable for technological and industrial development. According to a UN report, resource consumption was projected to double between 2015 and 2050. Wealthy countries use up to 10 times more resources than poorer countries.[1] For example, the consumption of metals such as copper is increasing dramatically because of their use in renewable energy systems such as wind turbines or photovoltaics. However, the expansion of the renewable energy system is necessary in order to reduce the use of non-renewable fossil energy resources such as coal, oil, and natural gas. The availability of sustainably extracted mineral raw materials is therefore a prerequisite for dealing with societal challenges such as the energy transition. Assessing supply potentials and risks is thus a necessity to adjust future changes and technologies to the availability of raw materials.

Of particular importance are those raw materials that can be obtained only as by-products. A study[2] carried out at the HIF in 2016 investigated the geotechnological availability of the high-tech metals indium, gallium, and germanium. The results suggest that the availability of germanium and gallium is – at least in principle – far higher than the quantities currently extracted. The situation is different for indium for which a considerable supply risk could soon arise if the demand for electronic products continues to increase. The availability of further high-tech raw materials is currently being examined in various cooperations. This is also the case in the BatMix project, part of BMBF Recycling and Green Battery (greenBatt) competence cluster in which statistically robust scenarios are being modeled for the availability of the critical battery raw materials lithium, cobalt, nickel, manganese, and graphite up to 2050. This includes the CO_2 emissions and energy consumed for the production of these raw materials. In addition, it is calculated how much of the respective raw materials can be obtained from secondary sources in a functioning Circular Economy and how much must be supplemented from primary sources.

1 www.resourcepanel.org/reports/assessing-global-resource-use
2 www.sciencedirect.com/science/article/pii/S0301420716303269

The need for industrial raw materials for the expansion of wind and solar plants, energy storage, and electricity grids is increasing. The demand per unit of energy produced is shown for various energy technologies.
©HZDR/Gudrun Wegener





The HIF participates in five projects in the BMBF research cluster greenBatt. The mission of the cluster is to develop innovative technologies and tools for an energy- and material-efficient battery life cycle as well as closed material cycles.

Among other things, the HIF is concerned with the recycling of anode graphite (microscopic image).
©HZDR/HIF

QR code to link to the greenBatt cluster:

Technological developments for the Circular Economy

Under the premise of sustainability, energy and resource efficiency must always be considered together. This requires expertise along the entire value chain of raw materials as well as transdisciplinary cooperation. Together with its partners, the HIF researches the development of recycling processes, including the the simulation, evaluation, and optimization of such technologies. For example, for the recycling of refrigerators or smart phones or for the value chain of rare earth elements. Completely new technological processes – such as the use of aluminum scrap as a reducing agent in the production of silicon – are also being evaluated.

The findings from these activities can also be translated into design-for-recycling concepts. This is because in order to minimize the complexity of the material flows in the recycling process, it is necessary to start at the product design stage. This means, for example, that parts of a product should be plugged into place rather than glued. Lightweight materials, in particular, pose a major recycling challenge because it has so far not been possible to recycle them. Using the example of refrigerators and freezers, a collaborative research project is currently simulating a circular product design that is both energy and resource efficient. To this end, various scenarios

The Highspeed Images Demonstrator is used to characterize complex composite recycling materials. @HZDR/Detlev Müller

with a focus on repair and reuse as well as recycling paths are being developed. Merging the resource efficiency analysis with the technology-oriented design-for-recycling model should allow the prediction of a product design suitable for full recycling.

The increasing variability and material complexity of recycling material flows makes the rapid development of raw material characterization essential. To this end, technologies are being developed in combination with digital platforms. Imaging techniques in particular are used to characterize recycling materials. Modern multi-sensor systems can use artificial intelligence (AI) to make predictions that enable more efficient recovery of complex raw materials. For example, from waste electrical and electronic equipment and scrap. In order to structure, analyze, and evaluate the volumes of data generated by the measurements, the approaches of the HIF benefit from the application of AI and machine learning (ML). A prototype combining these technologies was developed and built at the HIF. The Highspeed Images Demonstrator now enables the considerably improved identification of complex recycling material flows.

> ***"The increasing variability and compositional complexity of recycling material flows makes the rapid development of raw material characterization essential."***

A functioning Circular Economy also includes converting old mine tailings into important sources of raw materials. The re-mining of tailings storage facilities de-pollutes the environment and thus enables renaturation. The re-mining process includes the extraction of remaining ore minerals and thus financing remediation. For this purpose, the recomine alliance, which brings together partners from science and industry, was founded at the HIF. recomine has the vision of developing regional expertise in resource and environmental technologies needed to unlock the value residues from the raw materials industry. Test and demonstration sites in the Ore Mountains are exemplary of similar sites worldwide.

From pilot scale to application

Computer chips are shrinking, and the mountains of high-tech scrap are growing. The advance of digitalization makes better recycling all the more necessary. Consistent digitalization is also the key to a better understanding of recycling and the Circular Economy. Sensor-based raw materials characterization is used to assemble extensive data sets. This data must be collected, suitably corrected and overlaid, and then fused and interpreted. With AI and ML, it is possible to systemically illuminate the path of raw materials, visualize losses, and improve raw materials production and recycling rates in a targeted manner. Similarly, geometallurgical and systemic models can be created – whether for carrying out efficient exploration, mining, and processing of complex ore bodies, deciding on the best recycling process for scrap material, or determining the optimal design of a sustainable Circular Economy. To this end, HIF and its partners are developing a fully digitalized and automated processing research infrastructure on site in Freiberg. This will be operated on a pilot scale in order to advance the simulation, evaluation, and optimization of mechanical processing technologies. With the establishment of the FlexiPlant – a unique research infrastructure for the flexible processing of complex raw material flows – the multidisciplinary expertise of the HIF will be combined. Large-scale trials will show how recyclables can be intelligently and efficiently processed from a wide variety of raw material sources and using flexibly interconnectable agile technologies. In the newly established metallurgy pilot plant, metallurgical process technology will be piloted and then linked to adaptive processing technologies. The Circular Economy will thus be exemplified at the HIF with the final goal to contribute meaningfully to a sustainable Circular Economy for minerals and metals.

In the newly established metallurgy pilot plant, innovative technologies can be tested on a semi-industrial scale, and associated simulation models can be verified. ©HZDR/Detlev Müller

The future Research Campus

LOOKING TO THE FUTURE

In order to meet future challenges, the expansion of the overall site into a research campus for resource technology and sustainability is required.
©Baubüro Freiberg

CAMPUS CONCEPT

Renovation and construction will take place in several stages – in addition to new laboratory space and an extensively renovated pilot plant for mineral processing (FlexiPlant), office capacity will be expanded. Up to 300 people will be involved in resource technology research on the campus.
©Baubüro Freiberg

Prepared for the future

The development of the HIF is already a success story. Who would have thought 10 years ago that the idea of founding an institute for resource technology research would come to fruition so quickly? The fact that it has become a Helmholtz Institute plays an essential role. That's because Helmholtz Institutes intensify strategic partnerships between the centers of the Helmholtz Association and universities. In this case, it is the spatial proximity and close cooperation between the HZDR and the TU Bergakademie Freiberg. Hermann von Helmholtz, the man who gave the Helmholtz Association its name, advocated a natural science that built bridges between medicine, physics, and chemistry. His pioneering research and developments linked theory, experiment, and practical application. The HIF would like to continue this proven approach with its Campus for Resource Technology and Sustainability and establish a nationally and internationally renown competence center for the research, development, and evaluation of innovative resource technologies in the context of a sustainable Circular Economy.

The research campus will enable researchers of the HIF and their partners to advance innovations for the sustainable utilization of complex raw materials, to take them from laboratory to pilot scale, and to ultimately transfer them into industry. This increases the attractiveness of Freiberg as a location not only as a research partner but also with regard to cooperation with regional, national, and international partners from both academia and industry.

> *“The research campus will enable researchers of the HIF to advance innovations for the sustainable utilization of complex raw materials.”*

The pilot plant consists of a 12-meter-high experimental hall and a 15-meter-high front building with various functional rooms.
In the 950 m² experimental hall, systems and equipment for the entire range of metallurgical research – from pyrometallurgy (heat-guided processes) to hydrometallurgy (water-based processes) – will be set up.
A further 110 m² are earmarked for storage.
The researchers can experiment with raw material batches of between 1 and 500 kg – which roughly corresponds to the gap between the laboratory and industrial scale.
©HZDR/Detlev Müller

From laboratory to pilot scale

A first milestone on the way to the campus has been reached with the commissioning of the metallurgy pilot plant. The new pilot facility will be used to transfer research results on the pyrometallurgical or hydrometallurgical recovery of economically critical raw materials for (re)use in modern key technologies from the laboratory to the pilot scale and thus prepare them for transfer to industry. Innovative processes are combined and digitally networked. The pilot plant thus creates excellent conditions for the testing, optimization, and automation of new technologies and processes.

Simulation models developed for the quantitative evaluation of material use and energy consumption can be tested in practice. The industrial feasibility and economic viability of innovative technological approaches (e.g., through the use of alternative raw material sources) as well as sustainability of new product designs can thus be assessed at an early stage.

The view into the future FlexiPlant research infrastructure shows the different levels on which all types of raw materials can be processed in the most energy- and resource efficient manner. ©Baubüro Freiberg

The heart of the campus will be another pilot-scale facility: the FlexiPlant. The building, which is in need of renovation and is the precursor of this unique infrastructure was built in the mid-1950s; it belonged to the former Research Institute of Mineral Processing (Academy of Sciences of the GDR) and is now operated by the privately owned UVR-FIA GmbH. The pilot plant was built as a three-aisled heavy steel structure with a central aisle flanked by strands; the facility is ideally suited for modular pilot-scale test work. After the planned renovation and modernization, this unique research infrastructure consisting of around 1,700 m^2 of floor space will be a pilot-scale demonstrator for an agile next-generation raw material processing system that adapts the Industry 4.0 concept to the needs of the raw materials industry. The aim of the FlexiPlant is to process all types of raw materials in the most energy- and resource-efficient manner. This is achieved in particular through the intelligent coupling of a new generation of mineral processing technologies that are flexible, adaptive, automated and digitally interconnected. A fully automated collection and (pre-)sorting of the recyclable material flows prior to actual processing is intended to minimize losses. Precise, sensor-based raw material characterization should then enable the optimally adapted further processing of each raw material type.

The infrastructure will provide a unique collaboration platform for the benefit of regional, national, and international partners active in Circular Economy research and innovation. It offers the ideal testing ground for innovative technologies, novel machines and sensor systems as well as for the development of appropriate control algorithms and systemic modeling.

Sustainability

The scientific excellence of the institute as well as the topic of sustainability should also be visible in the architectural realization on the campus. Environmental awareness, modernity, and openness as well as the transdisciplinarity of the HIF thus become visible. As a research institute that is committed to sustainability and which receives a considerable amount of its third-party funding from the "Research for Sustainability" program of the BMBF, the working environment must also be as sustainable as possible. The basic principles of sustainability will not only be reflected in the research topics but also explicitly determine the external appearance of the campus. Equal attention will be paid to the sustainable construction and operation of the planned research infrastructures. The HIF thus follows the principle "Reuse – repair – recycle – dispose".

Sustainability is also reflected in the area of mobility. For example, a rail siding is to be reactivated for the delivery and removal of raw materials to the campus. Company bicycles and charging stations for e-cars and e-bikes will be provided for employees. The joint use of laboratories and facilities with the TU BAF at the site also underlines the aspect of sustainability. Finally, the research results are to be brought into application. In order to ensure that technology transfer succeeds, the integration of an incubator for the efficient integration of start-ups and innovative industrial partners at the site is planned. With all these developments the HIF will contribute to Freiberg becoming an attractive destination for nationally and internationally leading experts and young scientists from the various disciplines of natural sciences and engineering as well as automation, digitalization, and computer science. Close collaboration of all these experts on campus will be needed to be able to contribute significantly to a sustainable Circular Economy for minerals and metals.

Efficiency	+ Power consumption + Water consumption + Heat demand
Sustainable construction	+ Durable design + Recycled materials + Regional, natural, and low-pollutant building materials
Indoor quality	+ Lighting concept + Noise reduction + Building materials
Mobility	+ e-Mobility + Public transport + Bicycles
Outdoor design	+ Green spaces + Path system + Lounge areas

Campus development places considerable emphasis on sustainability. The HIF thus follows the principle "Reuse – repair – recycle – dispose". ©HZDR/HIF

THE FLEXIPLANT CONCEPT INCLUDES THE FOLLOWING KEY SYSTEMS:

- Fully automated mineral processing equipment for the various physical and physico-chemical separation steps of raw material processing
- A fully automated routing system for the agile and flexible transport and distribution of raw materials and processing products
- High-resolution, imaging sensor systems that generate information at the particle level
- High rack storage systems
- A data center – as the brain of the pilot plant – that captures all data generated and predicts, adjusts, and evaluates ongoing processes based on learning systems.
- Additional buildings for resource analytics (with physico-chemical laboratories) and for biotechnology will eventually complete the research infrastructure on the campus.

Aerial view of the campus at Chemnitzer Straße 40 (as of: July 2021). ©HZDR/HIF

Scientific visibility

In the past 10 years, the HIF has established many collaborations with partners from science and industry within and beyond the borders of Europe. The result is quite impressive.

Patents until 2020

18

An important instrument for successful technology transfer

151

Projects in total

85
National project funding
e.g. funded by the German Research Foundation, the Federal Ministry of Education and Research, and the Helmholtz Association

32
European project funding
For example, through the EIT RawMaterials as well as the Horizon 2020 and Horizon Europe programs

24
Industry contracts

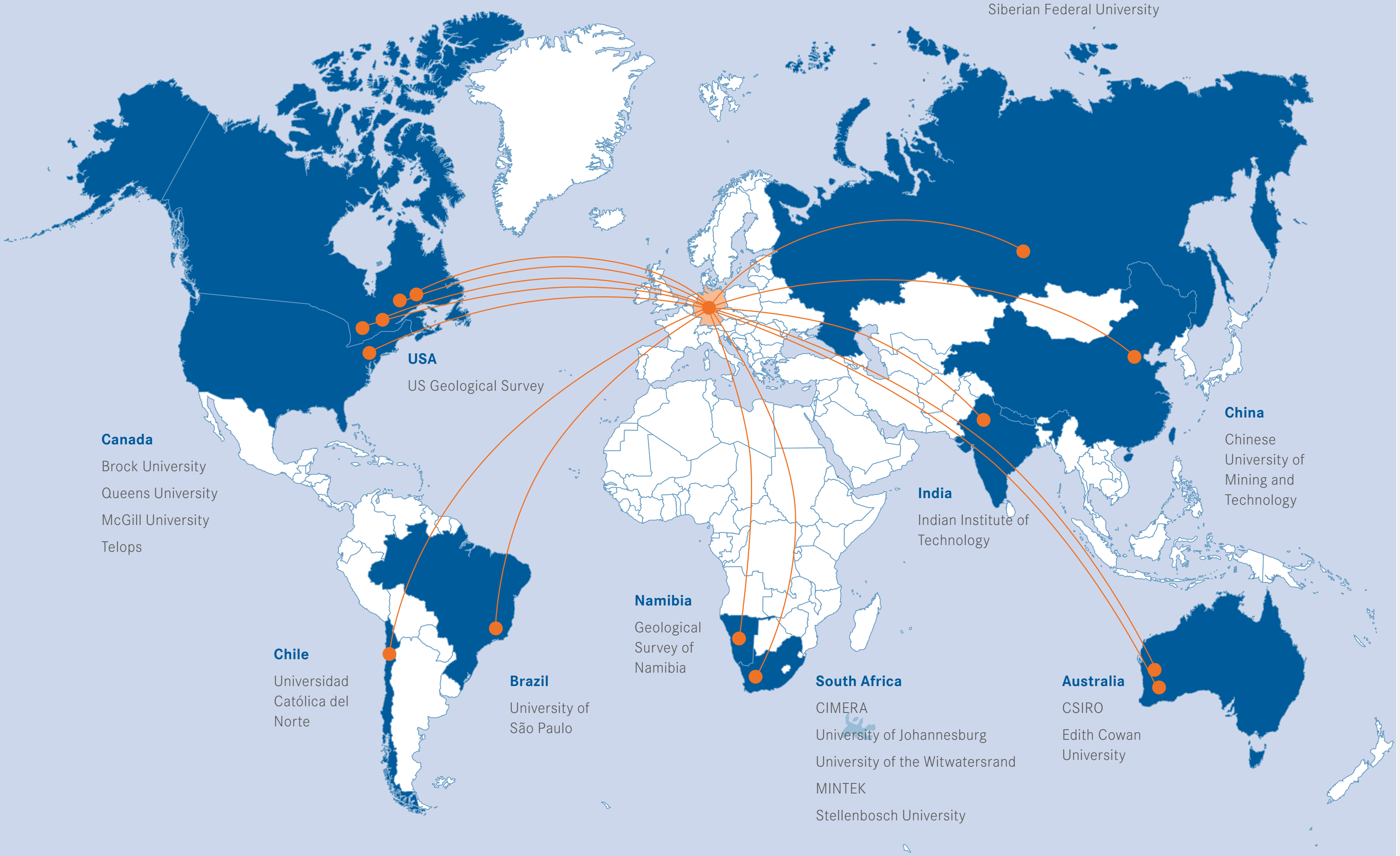
10
Regional project funding
by the Sächsische Aufbau-Bank and the State of Saxony

Publications until 2020

>500

Scientific publications

Selected research partners worldwide



Russia
Siberian Federal University

USA
US Geological Survey

Canada
Brock University
Queens University
McGill University
Telops

China
Chinese University of Mining and Technology

India
Indian Institute of Technology

Chile
Universidad Católica del Norte

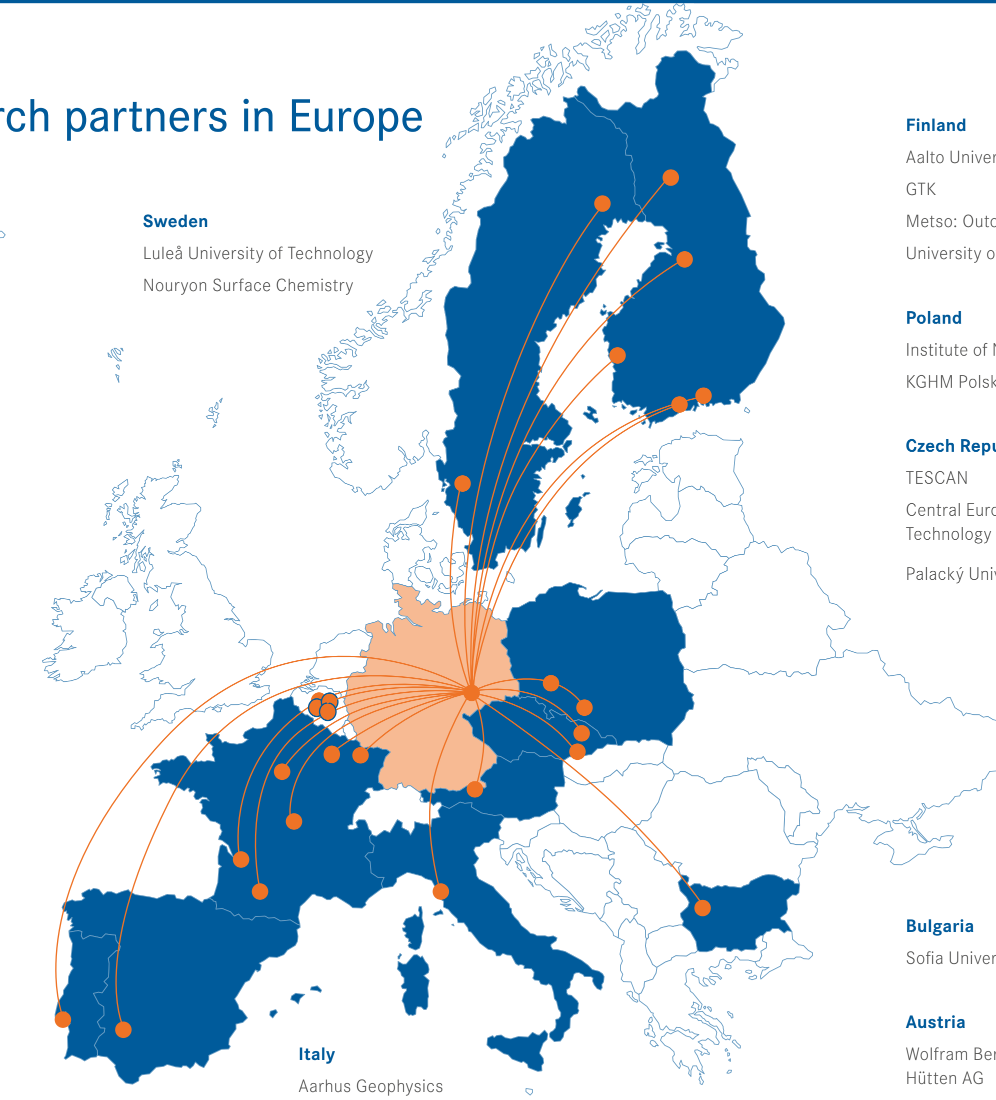
Brazil
University of São Paulo

Namibia
Geological Survey of Namibia

South Africa
CIMERA
University of Johannesburg
University of the Witwatersrand
MINTEK
Stellenbosch University

Australia
CSIRO
Edith Cowan University

Selected research partners in Europe



Sweden
Luleå University of Technology
Nouryon Surface Chemistry

Belgium
Umicore
Ghent University
KU Leuven
VITO

France
BRGM
Eramet Group
University of Bordeaux
University of Lorraine
University of Paris
University of Strasbourg
University of Toulouse

Portugal
University of Lisbon

Spain
Atalaya Mining

Italy
Aarhus Geophysics

Finland
Aalto University
GTK
Metso: Outotec
University of Oulu

Poland
Institute of Non-Ferrous Metals
KGHM Polska Miedz

Czech Republic
TESCAN
Central European Institute of Technology
Palacký University Olomouc

Bulgaria
Sofia University

Austria
Wolfram Bergbau und Hütten AG

"The HIF is a highly sought-after partner"

The Helmholtz Institute Freiberg for Resource Technology has now been in operation for 10 years. And the director of the institute, Dr. Jens Gutzmer (PhD ZA), has been there from the beginning. In the interview, he talks about the success "made in Freiberg" as well as the great challenges in the development of resource technologies that the staff of the institute is eager to address.

Especially in research, a decade isn't a particularly long time. In 2011, did you think it possible that after 10 years the HIF would be able to "secure the future through research" according to the motto of the Helmholtz Association?

JENS GUTZMER Looking back on the founding year, I have to admit that probably no one from the small team entrusted with setting up the HIF was aware of the immense challenges – but also opportunities – associated with the topics of raw material security and sustainability. Just as well, I sometimes think. We thus approached the establishment of the institute in a goal-oriented and committed manner. In the process, we had – and still have – high and sometimes conflicting expectations to fulfill. These include expectations of the federal and state funding agencies, expectations of the Helmholtz Association and the HZDR, and expectations of our research partners and colleagues in Freiberg or Dresden. However, the expectations we placed on ourselves certainly weighed the heaviest. We aimed to establish a globally recognized Helmholtz Institute that is competitive in resource technology research in the shortest possible time.

Now, after only 10 years, we can proudly say that we have succeeded. With its about 150 employees, the HIF is a highly sought-after partner of the national, European, and global raw materials industry as well as the scientific community. We have clearly defined our role as a pioneer of a sustainable Circular Economy for mineral and metalliferous raw materials and occupy leading positions worldwide in our area of expertise.

However, our most important achievement is certainly that our institute, with its research portfolio, has become a magnet for national and international talents. Our employees represent six continents and more than 30 nationalities. From my point of view, this is the highest recognition that the Institute has achieved in its first 10 years.

What do you consider to be the most important success of the HIF?

JENS GUTZMER The positive decision on the application and the establishment of EIT RawMaterials in 2014 and 2015 can certainly be considered the most important success of the HIF in its brief history – an achievement that placed the HIF in a prominent position in the European research landscape at an early stage. With a volume of € 2 billion, EIT RawMaterials is still the largest third-party funded project that has been applied for and coordinated by actors in the new federal states of Germany. For a team that had barely three years to establish itself at the time, that's quite a remarkable achievement.

Securing raw materials supply means securing the future

The discovery and exploitation of ore deposits has a long tradition in Saxony. Saxon expertise in resource technology research dates back to the 12th century and Saxony is still a region rich in raw materials. Saxony has considerable potential for the exploration and discovery of high technology raw material resources. However, an increasingly important and indispensable source of raw materials are also the secondary raw materials obtained from industrial residues and municipal waste streams. Primary and secondary raw materials from local sources can therefore help to reduce dependence on international raw material markets. The use of these sources is also an important building block for regional value creation and job security.

The foundation of the Helmholtz Institute Freiberg for Resource Technology by the Helmholtz-Zentrum Dresden-Rossendorf and the TU Bergakademie Freiberg was a substantial gain for research and innovation in Saxony and throughout Germany. This is because basic and applied research on resource and recycling technologies as well as the transfer of results into industrial practice are becoming increasingly important for our future. For 10 years now, the Helmholtz Institute in Freiberg has been pioneering a sustainable Circular Economy for mineral and metalliferous raw materials. The team of scientists from Freiberg and Dresden-Rossendorf is developing urgently needed technologies and solutions for the efficient use of these limited resources. It thus makes decisive contributions to securing strategic raw materials for the local economy and training the next generation of scientists and highly qualified engineers. The institute has also taken a leading position at the European level. Perhaps the most remarkable evidence of this is the "Knowledge and Innovation Community EIT RawMaterials" of the EU. The HIF played a leading role in the successful application and implementation of this, and the HZDR and TU Bergakademie Freiberg continue to be involved as leading partners.

In accordance with its founding mission, the Freiberg Institute plays a leading role in the implementation of the raw materials strategy of the Federal Government and Saxony. With the “Raw Materials Strategy Saxony”, which was adopted in 2012, the goals of the German Raw Materials Strategy were adapted for Saxony. The focus was deliberately on primary mining-related raw materials and secondary raw materials because Saxony offers great potential for these.

With the targeted use and further development of regional expertise in raw material exploration, extraction, benefication and Circular Economy 4.0 in close cooperation with numerous actors from education and research, the mining administration, and regional and international companies in the industry, we hope to further strengthen Saxony as a location for sustainable raw materials. Above all, we want the innovative technologies developed here to be used right on our doorstep, thereby forming an important basis for regional value creation and job security.

Sebastian Gemkow
Saxon State Minister
for Science

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The heads of the Helmholtz Institute Freiberg for Resource Technology: scientific director Dr. Jens Gutzmer (PhD ZA) and administrative director Dr. Simone Raatz. ©HZDR/HIF

At the scientific level, I would like to highlight the success of the AFK pilot experiment. In 2018, together with our partners, we were able to document that the approaches we are pursuing for the flexible and agile processing of complex raw materials can indeed lead to unexpected breakthroughs, which directly influence industry. In this particular case, we were able to prove that, contrary to earlier expectations, the skarns (mineralized rocks) of the Schwarzenberg district in the Ore Mountains, which are rich in tin, zinc, and indium, can indeed be processed in an economically feasible manner.

Failure is part of success. Especially in science, failed experiments often lead to considerable progress. Can you also give an example of this from HIF research?

JENS GUTZMER We have not really failed in any of our activities so far. But there are initiatives that take much longer to implement than we would have expected or would have liked. For example, the development of a unique analysis device, the Super-SIMS, on which we are collaborating with our colleagues from the Ion Beam Center of the HZDR. This joint development, which we started 10 years ago, is still ongoing despite promising interim results. Another “project” on which we must focus is the development of the research campus for resource technology and sustainability. Here, a timeous success will be essential for the further successful development of our institute.

In order to make Germany less dependent on international raw materials markets, the HIF is particularly committed to harnessing local potential. Where do you see the most suitable starting points for this?

JENS GUTZMER The Ore Mountains live up to their name. Even in a global comparison, there is still enormous geogenic raw material potential in Saxony. The diversity of existing deposit and raw material types – and the high level of knowledge of the subsurface geology, at least locally – make the Ore Mountains an ideal laboratory for developing and testing innovative exploration technologies. Furthermore, the historical extraction and processing of raw materials has left behind numerous secondary raw material potentials – these include in particular waste rock piles, slag heaps and tailings dams. These also offer excellent local research and development potential. We took this inherent potential as an opportunity to deal with local raw materials early on. Here we see excellent starting points for cooperation with local partners – with both our colleagues at the TU Bergakademie Freiberg and the local raw materials industry.

In the Ore Mountains, there is a unique pool of knowledge on the subject of raw materials. How can this be used better?

JENS GUTZMER Perhaps the most important development in the last five years has been the establishment of the recomine alliance coordinated by the HIF. Here, partners from industry and science deal with technological developments at the interface between raw material extraction and environmental protection. After only a short time, the holistic approach to resource and environmental research and innovation has led to a common understanding among the most important regional cooperation partners. This is demonstrated, among other things, by the successful joint participation in the "Global Tailings Challenge", an international open innovation competition organized by BHP, one of the world's largest raw materials groups. Through efficient networking and close cooperation of innovative partners from science and industry, we hope to be able to bundle the creative potential in the region.

What is the importance of knowledge and technology transfer for the HIF when it comes to ensuring that science and business are compatible in both directions?

JENS GUTZMER The research results of the HIF have been repeatedly rated as excellent by high-ranking international panels of experts. However, these results can be effective only if they are translated into innovations and find their way into industrial and societal reality. Both knowledge and technology transfer are essential for this. We have been actively pursuing both for many years. In the area of knowledge transfer, we regularly contribute to training events for teachers in Saxony and participate in open house activities in Freiberg and Dresden. We have introduced a prize for resource efficiency that is regularly awarded as part of the state competition of "Jugend forscht". We have also been successful in technology transfer. Researchers at the HIF have founded no less than three spin-off start-ups that have successfully been established in the market. We want to push these developments further as part of campus development. For example, we would like to establish an incubator for young, innovative resource technology companies and establish services for students on our campus. In this endeavour we are actively supported by the HZDR student laboratory DeltaX and HZDR Innovation.

How can resource efficient technologies be used in industrial applications?

JENS GUTZMER In the last few years, we have developed numerous innovative technological concepts. However, the transfer of these concepts to industry can succeed only if their effectiveness is demonstrated not only on a laboratory scale but also on a pilot scale. For process metallurgy and biohydrometallurgy, this is made possible in the newly-built metallurgy pilot plant. For technologies for the mechanical processing of raw materials, we have developed the FlexiPlant concept. This research infrastructure is currently on the national road map of the Helmholtz Association. We hope this ambitious infrastructure project can be realized in a timely manner. FlexiPlant and the metallurgy pilot plant will form the heart of the Campus for Resource Technology and Sustainability for which we have developed a detailed concept. The HIF – as an institute of the HZDR and part of the Helmholtz Association – will offer unique conditions for transdisciplinary research with global partners. We thus aim to make an important contribution to achieving a sustainable Circular Economy for mineral raw materials and metals not only in Saxony and Germany but also worldwide.

Pioneer of a sustainable Circular Economy for minerals and metals

All electronic objects in our everyday lives contain numerous raw materials. Scientists at the HIF are investigating how these resources can be recovered at the end of the lifecycle so that they can be used once more.

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Helmholtz Institute Freiberg for Resource Technology
Dr. Jens Gutzmer (Director)
Anne-Kristin Jentzsch (Press officer)
Tina Pereira (Project manager)

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p. 3 Illustration of the research portfolio of the
HIF (blue) in the context of the Circular Economy
of mineral and metalliferous raw materials.
Special attention is paid to the interaction
between the changing energy system and the
material flows of the Circular Economy.
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Contact/order
Helmholtz-Zentrum Dresden-Rossendorf
Helmholtz Institute Freiberg for Resource Technology

Public relations
Anne-Kristin Jentzsch
Telephone: +49 351 260 4429
contacthif@hzdr.de

Translated from German by
Kern AG
Christiane Hofmann
Certified translator

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