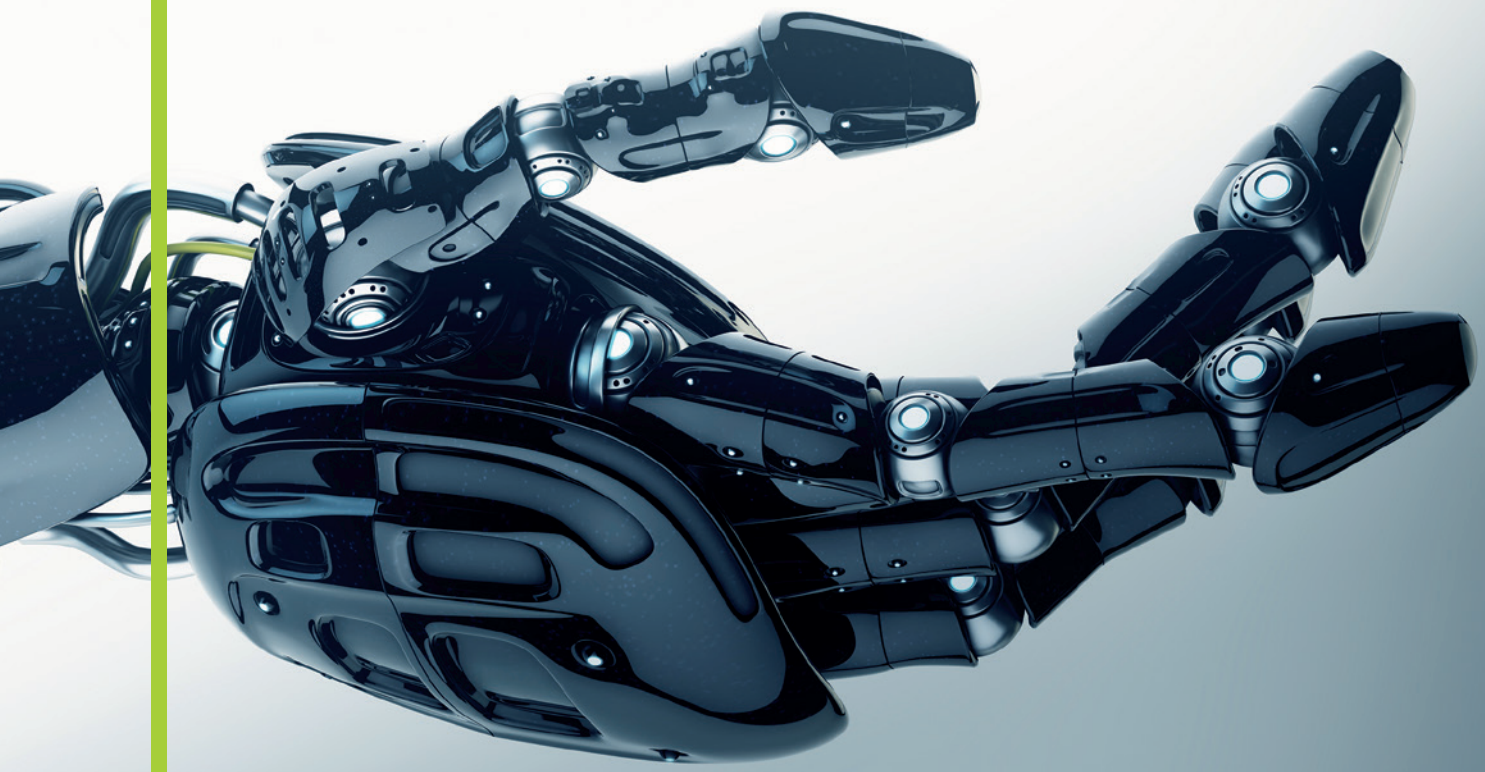
THE FUTURE OF STEEL SCRAP



TECHNICAL, ECONOMIC, ECOLOGICAL AND SOCIAL CHARACTERISTICS OF STEEL RECYCLING

RESULTS OF THE FRAUNHOFER INSTITUTE'S UMSICHT STUDY ON THE FUTURE OF STEEL SCRAP
AN INVESTIGATION FOR THE BDSV

SCHROTT MUSS MAN KÖNNEN.
Die BDSV. DER Stahlschrott-Verband.

BDSV

The Federal Association of German Steel Recycling and Disposal Companies (BDSV)

The BDSV represents the interests of German companies – or companies operating in Germany – that are active in the steel recycling sector and provide other disposal services. It is the largest steel recycling association in Europe. At the focus of the association's objectives are the commercial and ecological framework conditions of the recycling industry. Its aims are to preserve the environment and protect raw material reserves. The ecological objectives must, however, be compatible with a commercially realistic and pro-competitive environment.

Fraunhofer UMSICHT

The Fraunhofer Institute for Environmental, Safety, and Energy Technology (UMSICHT) is a pioneer in the fields of sustainable energy and the raw materials industry through its activities which include the provision and transfer of scientific findings to companies, society and politicians. Together with its partners, the dedicated UMSICHT team researches and develops sustainable products, processes and services that are inspiring.

Achieving a balance between commercially successful, socially just and environmentally compatible developments is the focus of the Institute's work. The Institute has sites at Oberhausen, Willich und Sulzbach-Rosenberg. Fraunhofer UMSICHT generated a turnover of EUR 39.1 million during 2015 with a workforce of 489. One of 67 institutes and research establishments of the Fraunhofer Society, Europe's leading organisation in the field of applied research, the Institute maintains a global network and promotes international collaboration.

Foreword and background to the study

As an independent applied research institute, Fraunhofer UMSICHT supports industry in the development and evaluation of sustainable management methods and environmentally friendly technologies. This strengthens the innovative capability of the German economy. On the way to achieving a circular economy, the steel recycling sector is among the most important players in the value chain. Together with the BDSV, Fraunhofer UMSICHT is therefore pleased to have been involved in mapping out the key role played by the steel recycling industry in this scientifically substantiated study. During the course of our study we carried out interviews with experts in the field.

On behalf of the BDSV too, we would like to thank the interviewees for participating and for their valuable input.



Markus Hiebel, Dr. Eng.
Head of the Department of Sustainability and Resource Management, sustainability officer

Fraunhofer UMSICHT

What is your objective with the "Future of Steel Scrap" study

This is the first comprehensive scientific study into the role of steel recycling in Germany. It deals in detail with the technical, economic, ecological and social factors involved in steel and stainless steel scrap.

What do you consider to be the core message of the study?

The steel scrap sector is the central service provider in the value chain of the steel industry and will in future play an even more important role in the development of the circular economy.

How is your industry perceived by the public and politicians?

The term "scrap" often carries negative connotations. Rusty steel unfortunately conveys a false impression of the actual value of the product. Stainless steel, which does not rust, is not quite as badly affected by this image. Steel is one of the few secondary raw materials that already has a very specific monetary value and can also be recycled as many times as desired, without any loss in quality. At our company, steel products that have come to the end of their lifecycles are processed for further use in steelworks. Although we are an essential element in the value chain, our image is unfortunately somewhat poorer than that of the steel industry as a whole. As the study shows, this is a completely unfair picture.

How would the steel recycling sector like to be perceived?

The steel recycling sector provides benefits! We are preserving the future – and have been doing so for more than 100 years. This is the key message we want to convey to the public and politicians. It is the companies in the steel recycling sector that collect the secondary raw materials and process them to a quality that even allows the steel producers to re-use the material and transform it into new, high quality products. This saves resources and simultaneously reduces CO_2 emissions.

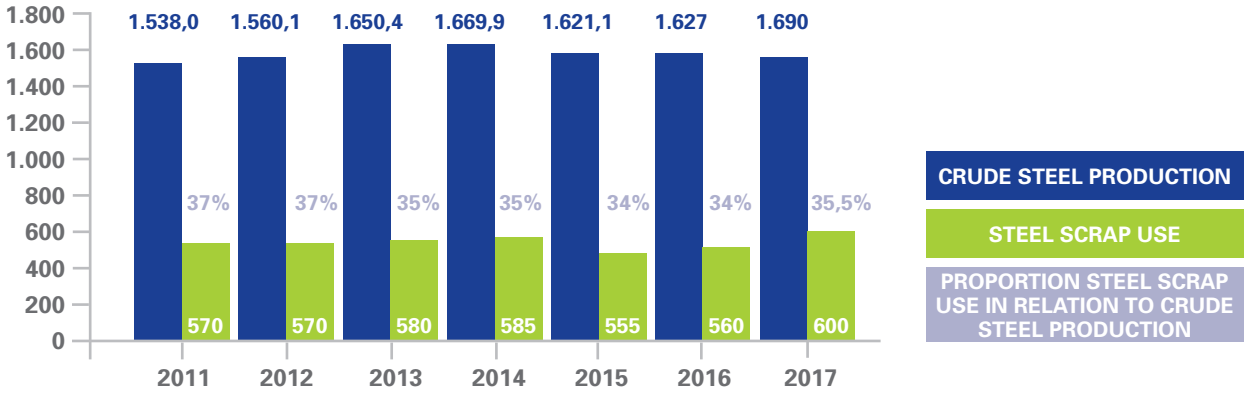
What specific demands do you have on politicians?

We need a better legal and commercial framework environment. Due to the fact, that we are not financed by the state, we must be able to successfully carry out our work in the private sector. This is the only way in which the steel recycling industry will be able to maintain jobs, develop innovative future-oriented technologies and continue making its extremely important contribution to environmental, social and economic policy.

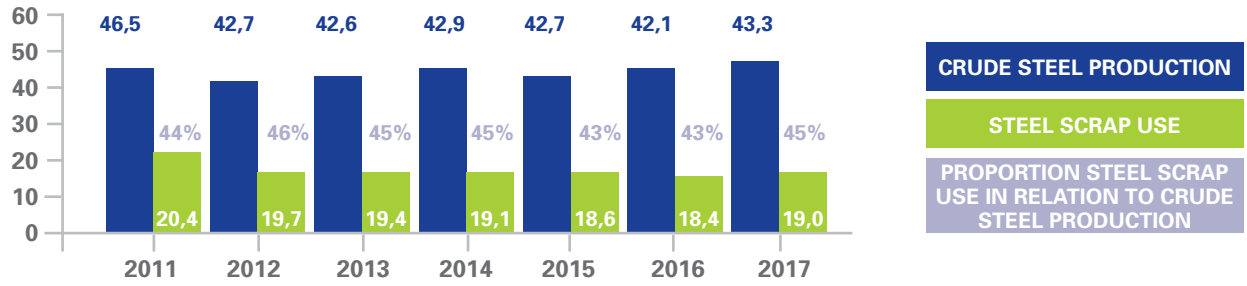


STEEL SCRAP VOLUME

Graphic 1: **Global crude steel production and steel scrap use in millions of tonnes**



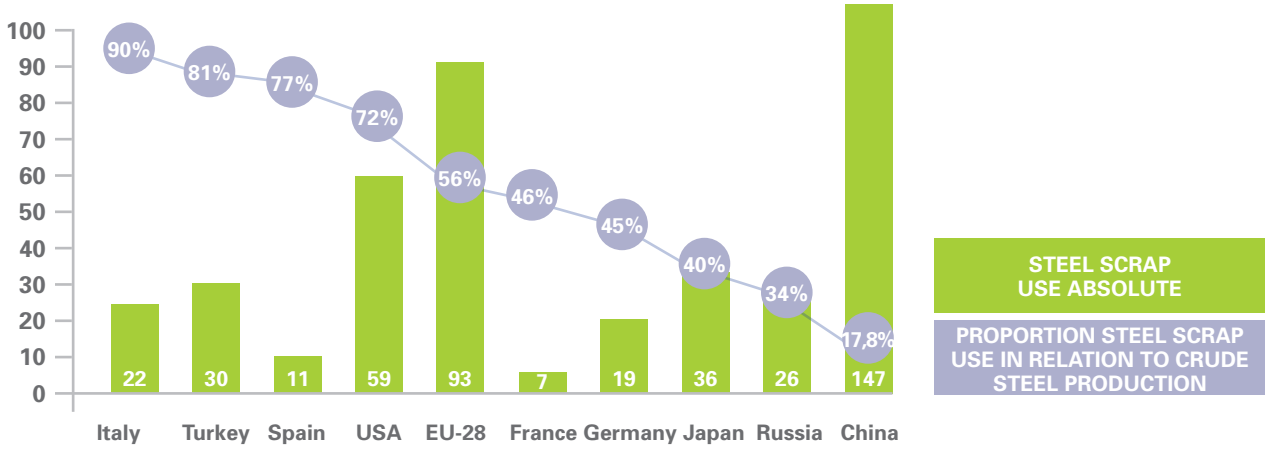
Graphic 2: **German crude steel production and steel scrap use in millions of tonnes**





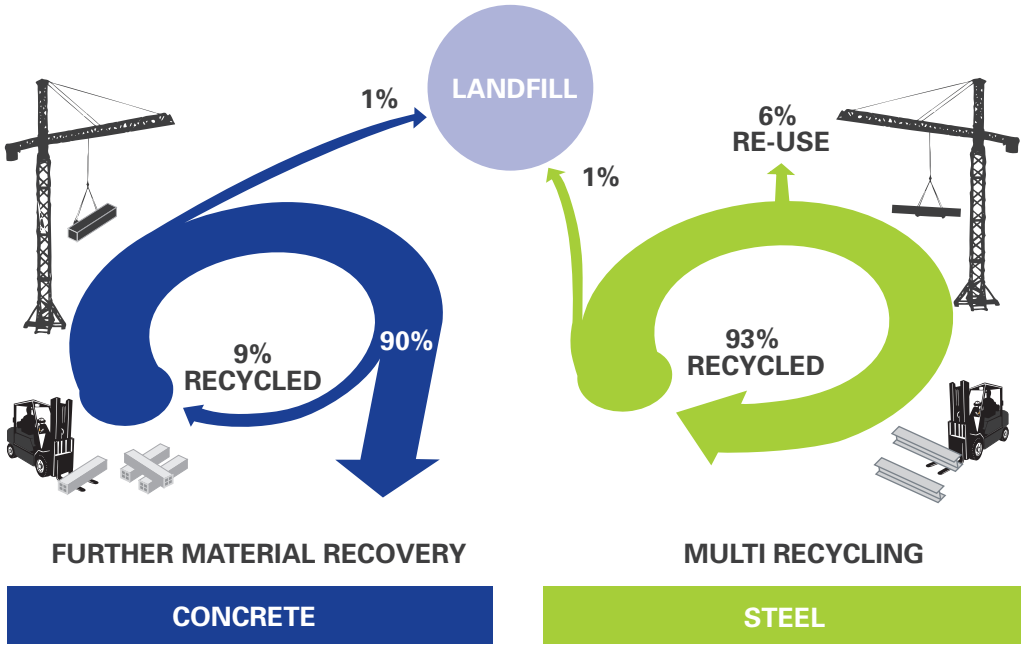
Graphic 3: **Country comparison of steel scrap use for crude steel production 2017 in millions of tonnes**

Steel scrap volume - absolute and as a percentage per tonne of crude steel produced. High steel recycling rates (> 80%) of the steel recycling sector in Italy, Turkey and Spain.

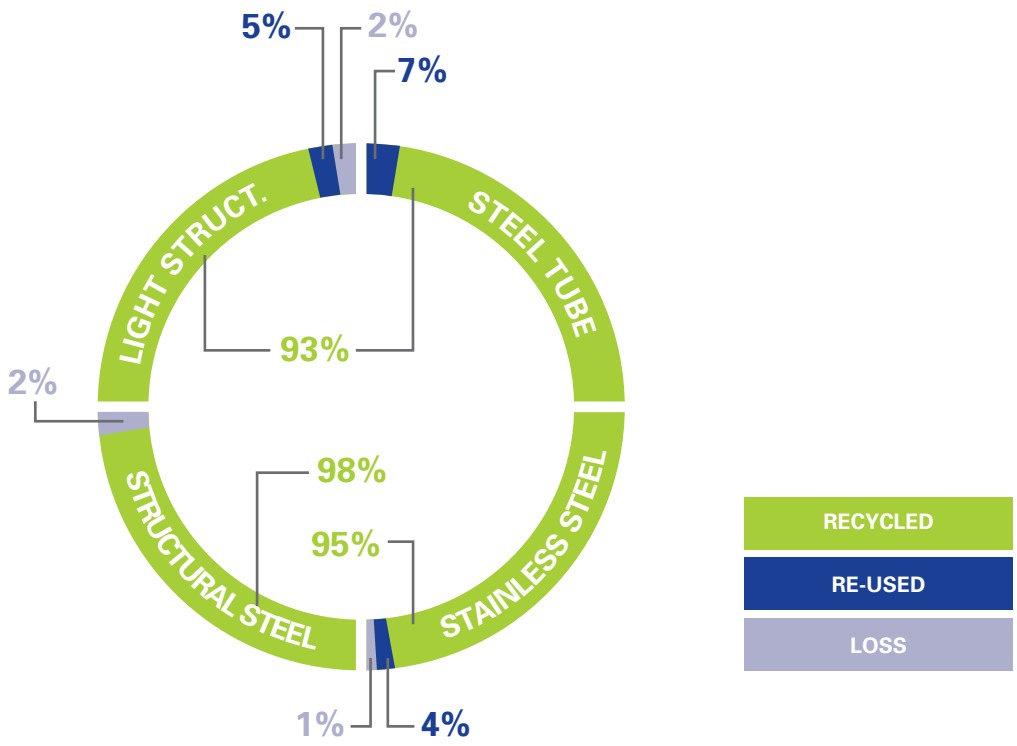


LIFECYCLE SCENARIOS OF CONCRETE AND STEEL

Graphic 4: **What happens to the structure of a building once it has been demolished?**



Graphic 5: **Summary of the re-use and recycling rates of steel**
Eurofer-Study of 2012 (excerpt)





„The provision of quality assured raw materials is a highly significant issue for the purchasing steelworks."

Prof. Daniel Goldmann, Dr. Eng.
Institute of Mineral and Waste Processing, Waste Disposal and Geomechanics (IFAD) – Chair of Raw Material Processing and Recycling at the Technical University of Clausthal.

The steel industry already started to recycle steel scrap in the 19th century. Due to the increase in production of steel, combined with the use of steel for manufacturing of a wide range of goods, meant that an increasing amount of steel scrap became available at cost-effective prices. Secondary raw materials were born and soon caught the attention of the steel producers of the time, well before the current debates about resource efficiency came to the fore.

The success story of steel recycling, and the use of the secondary raw material as an economical alternative to iron ore, was facilitated by the development of the Siemens-Martin process, which emerged as the first large-scale technical process for using steel scrap in the production of steel. Depending on the type, stainless steel already contains the alloying elements that are otherwise very expensive to procure and which define the characteristics of the final steel product and its field of application. This ranges from the steel girders used for bridge construction to the steel sheets used for manufacturing cars.



In modern steel production a distinction is made between the manufacture of steel using the electric arc and basic oxygen processes via the blast furnace route. Electric arc steel plants are almost completely dependent on supplies from the steel recycling sector. The current production ratio of electric arc steel to basic oxygen steel is approx. 30:70. For stainless steel the ratio is 100:0 outside China in Germany. The raw materials used here for producing the various steel products are the defined and quality-assured secondary raw materials, steel and stainless steel scrap.

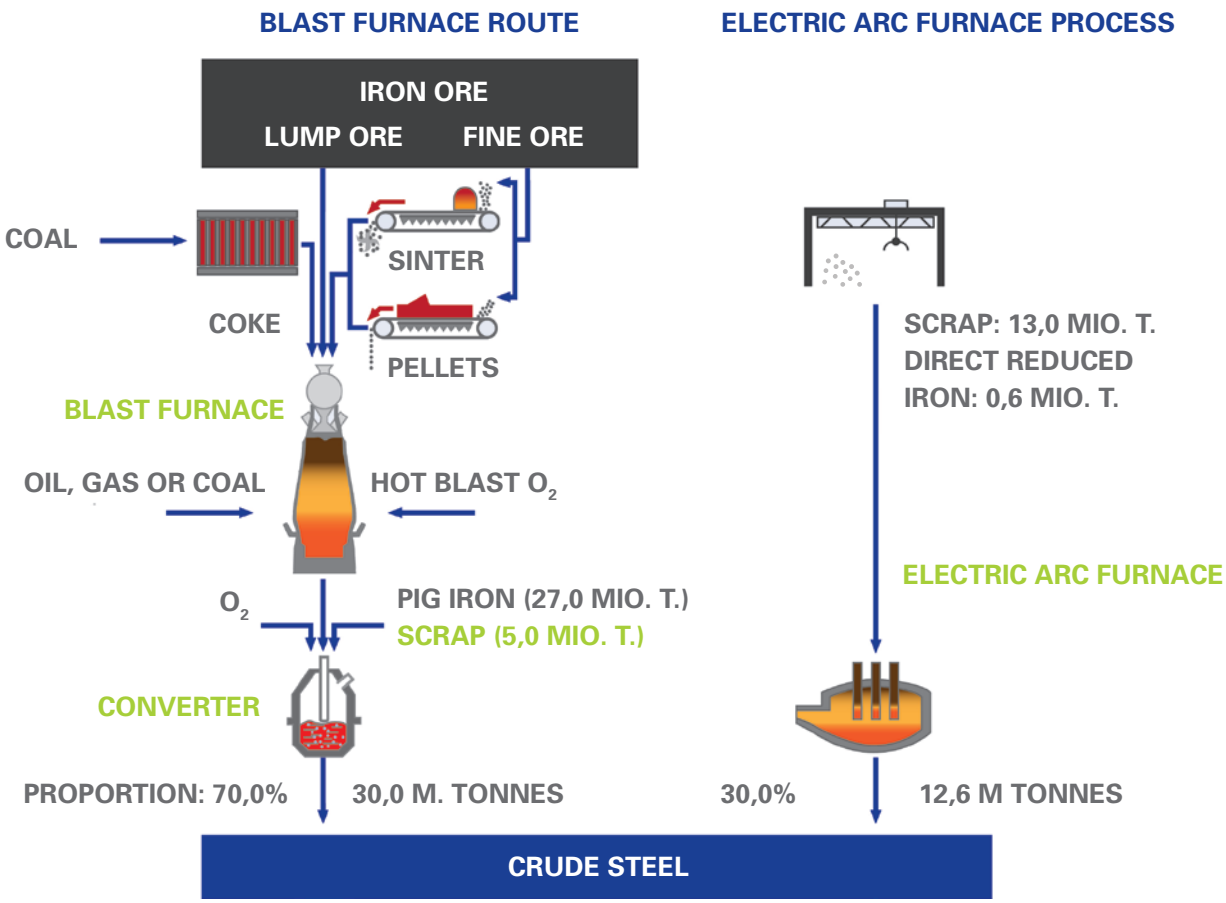
However, basic oxygen steelworks, which primarily produce steel from pig iron, and therefore on the basis of iron ore, also use up to 20% steel scrap.

This means that steel scrap represents an essential pillar in delivering the raw material requirements for the steel industry. This, in turn, is an important mainstay of the German economy, for instance in infrastructure projects. Steel – and therefore a proportion of what was once scrap – is found in every car (including every electric car), almost every building, every bridge, every machine and every wind turbine. In the case of standard steel alloys, the ratios of scrap content are actually even higher. One could even say that the stainless steel sink in your kitchen contains between 70% and 80% recycled materials.

In order to assure the quality, utilise production capacities to the optimum extent and produce steel under the optimum technological and commercial conditions, the two manufacturing routes form a symbiotic relationship – which therefore encompasses steel production and steel recycling. Steel can theoretically be recycled infinitely. This makes steel recycling a key foundation stone of the circular economy.

PRODUCTIONS ROUTES FOR STEEL IN GERMANY DURING 2017

Graphic 6: **Facts on steel production during 2017**



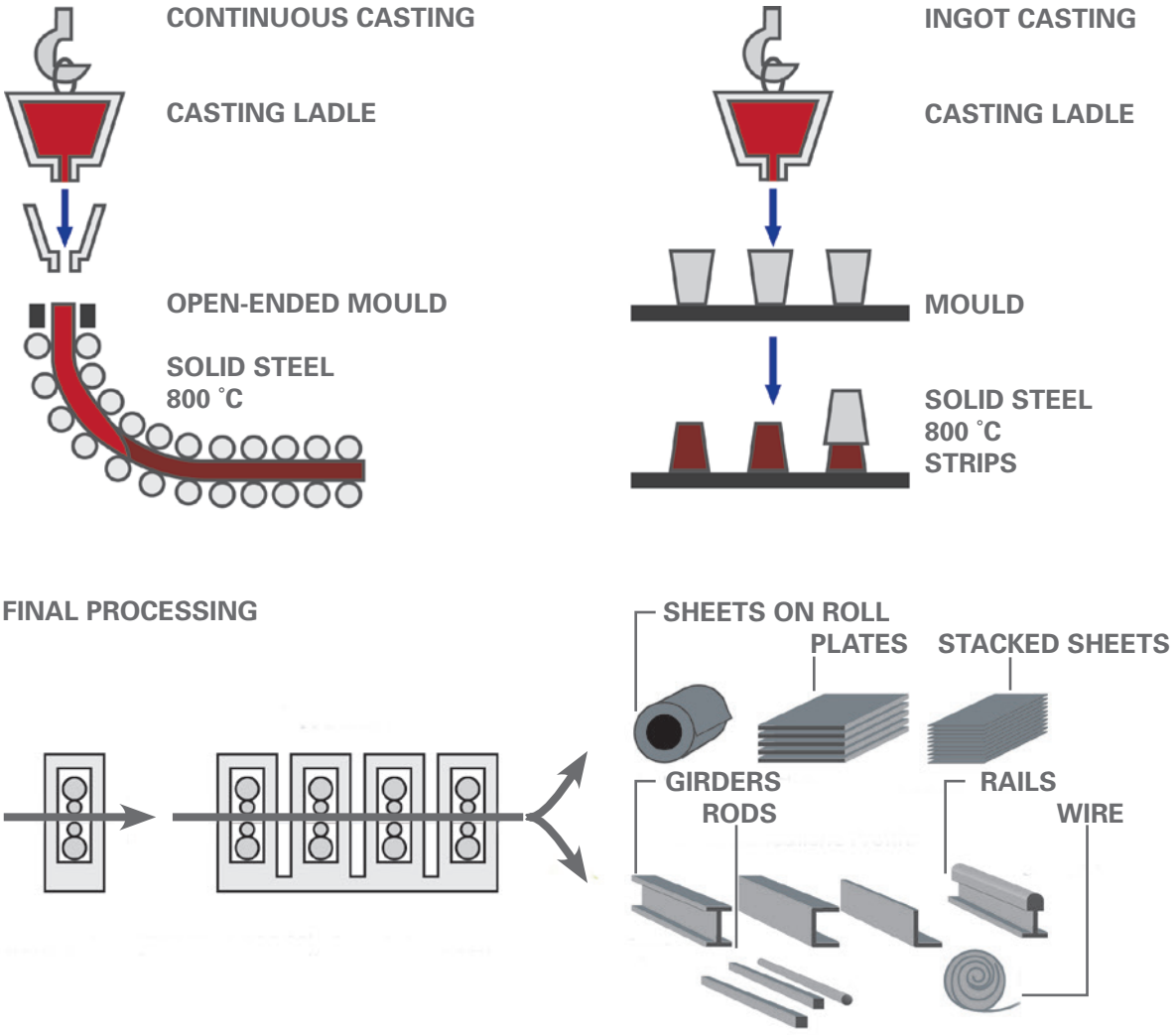


→ **Continuous casting:** The steel is poured into an open-ended mould with a square, rectangular or round cross section. This creates a solid square, rectangular or round rod that is subsequently cut to the desired length.

→ **Ingot Casting:** The steel is poured into casting moulds where it is allowed to solidify. Once solidified, the metal blocks are stripped from the moulds. In both of these processes the final result is known as semi-finished steel.

→ **Final processing:** This semi-finished steel is heated in furnaces to 1,200°C so that it can be rolled, i.e. drawn between rollers, and flattened. The rolling process results in two product categories: long products (e.g. girders, rods or wire) and flat products (e.g. steel plates and sheets in stacks or on rolls).

Graphic 7: **Comparison continuous casting to ingot casting**



WITHOUT STEEL SCRAP THERE WOULD BE NO STEEL INDUSTRY

If it were not for the German steel recycling industry there would be no German steel industry. The steel scrap sector is the central service provider in the value chain of the steel industry and will also play a decisive role in the future development of the circular economy. The companies of the steel recycling industry are the facilitators which collect the secondary raw materials and process them to a quality that allows the material to be re-processed at the steelworks. This, in turn, is the prerequisite for the creation of new steel products. Steel scrap ensures that the raw material requirements of the German steel industry are – and will also in future – be secured by providing quality assured secondary raw materials.

RECYCLING WITHOUT QUALITY LOSS

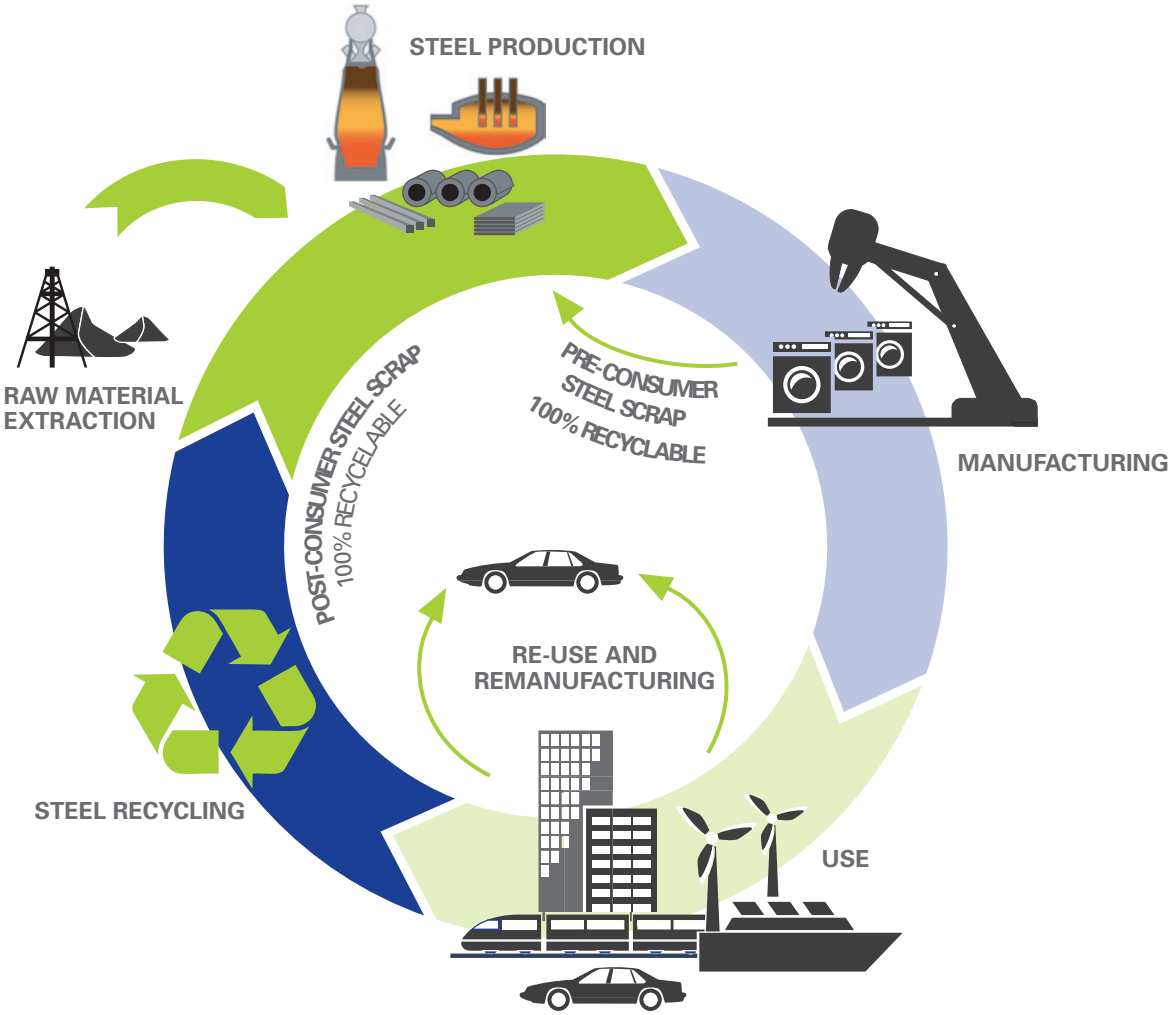
Primarily – but not only – for the stainless steel sector, the steel recycling industry has developed sophisticated analytics and innovative technologies in order to satisfy the increasing quality standards demanded by the steelwork.

Through good processing and intelligent material flow management, the secondary raw materials can be repeatedly used in the production of steel and stainless steel, among others in the construction, automotive, energy technology and aerospace sectors. By leveraging modern material flow management techniques, the steel recycling industry delivers both alloyed and non alloy steel scrap for the right fields of application, thereby providing the steelworks with a quality assured secondary raw material of the highest quality and purity. This also ensures that the valuable alloying elements enter the right production paths and that their functionality, in terms of determining the characteristics of the steel products, is maintained.

This service, in the form of continuous monitoring using chemical analysis and intelligent sorting processes, has allowed alloyed steel scrap in particular, to find a use as a raw material for high-tech product.



Graphic 8: **Steel´s life circle**



„There is effectively no downcycling in the (stainless) steel recycling sector. However, upcycling tends to be more prevalent, because material developments over the years now mean that increasingly better materials can be manufactured from scrap."

Prof. Rüdiger Deike, Dr.-Eng.
Chair of Iron and Steelmaking Metallurgy at the University of Duisburg-Essen

INNOVATIONS IN THE STEEL RECYCLING INDUSTRY

Over recent decades, a large number of innovations have contributed not only to optimising the processes used in the steel recycling sector – they are also playing an increasing role in environmental protection and the conservation of resources. The foundation stone for innovation in the steel recycling sector was laid as far back as the start of the industrial revolution. As already discussed on page 7 (The steel production process), steel scrap was used as a main raw material for the first time in 1864 in the so-called Siemens-Martin process.

However, a lot has happened since those pioneering years of industrialisation: Today, significant developments in terms of process optimisation are mostly driven by plant engineering firms in cooperation with experts from recycling companies – and not only with the aim of satisfying the increasingly stringent legal requirements in the area of environmental protection and emission control.

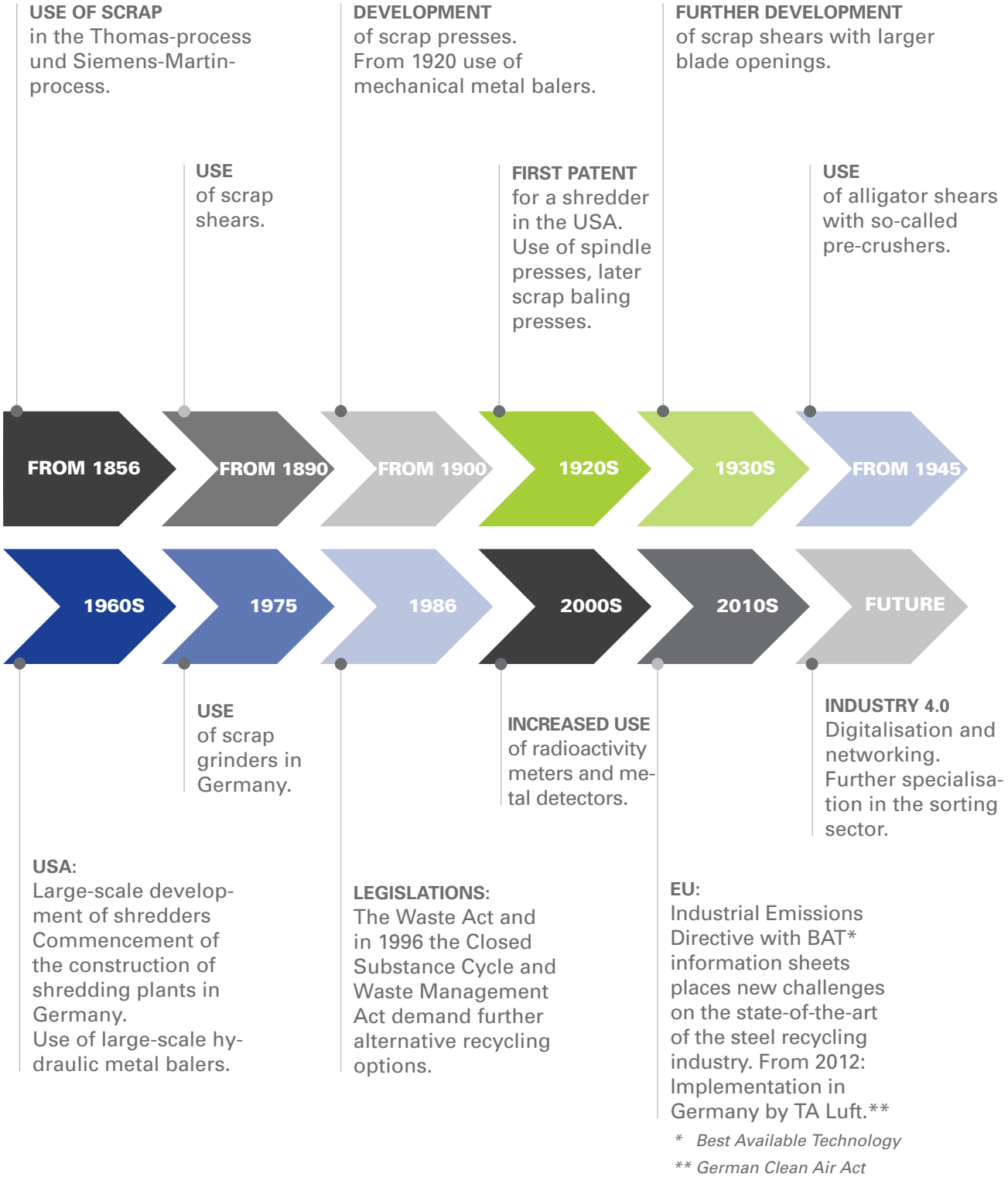
The same is true for the steel recycling industry: Significant innovations took place, among others, with the development of low-emission shredding, sorting and treatment processes in order to make pure raw materials that could be produced in batches. Other key innovations occurred in the areas of logistics, infrastructure and quality assurance. Automation of the workflows and their networking and digitalisation have emerged as the key components of intelligent material flow management.

The bundling of the experiences and services of individual companies allows the continuous provision of premium quality materials.

However, the willingness of the industry to innovate is also subject to limits imposed from the outside: Unfavourable commercial and environmental policy framework conditions can limit the willingness to innovate. This is particularly true of smaller businesses which, as a result of their lower profit margins, are less frequently able to finance innovations. In this connection, medium-sized firms definitely consider innovations as a competitive advantage.

First and foremost are the development of analytical methods and the separation of old and new scrap into pure grades, in particular when seen against the backdrop of increasingly complex materials. The automotive industry has made a significant contribution to promoting innovation – also in the area of steel recycling – through its demand for high-functionality steel products and their manufacture. The issue of improving the separation of high-tensile steels into pure grades of steel scrap still offers particular potential for innovation. The challenges of a circular economy apply to the whole value chain. In this connection, all parties involved should endeavour to expand their continuous dialogue.

Graphic 9: **Innovation milestones (a selection)**



STEEL SCRAP OFFERS THE POSSIBILTY OF A CIRCULAR ECONOMY

In Europe, optimising the collection, sorting and processing of steel scrap is becoming an in-creasingly important issue in the development of the circular economy. As a result of the high standards required of steel products and their functionality, the complexity of the composi-tion of these is increasing. The combination of steel with other materials, such as plastic (so-called composites) is growing in order to meet the requirements of our industrialised society. This in turn brings new challenges in terms of pyrometallurgy at electric arc and basic oxygen steelworks. The steel recycling industry must correspondingly deal with these challenges as a service provider and secondary raw material supplier.

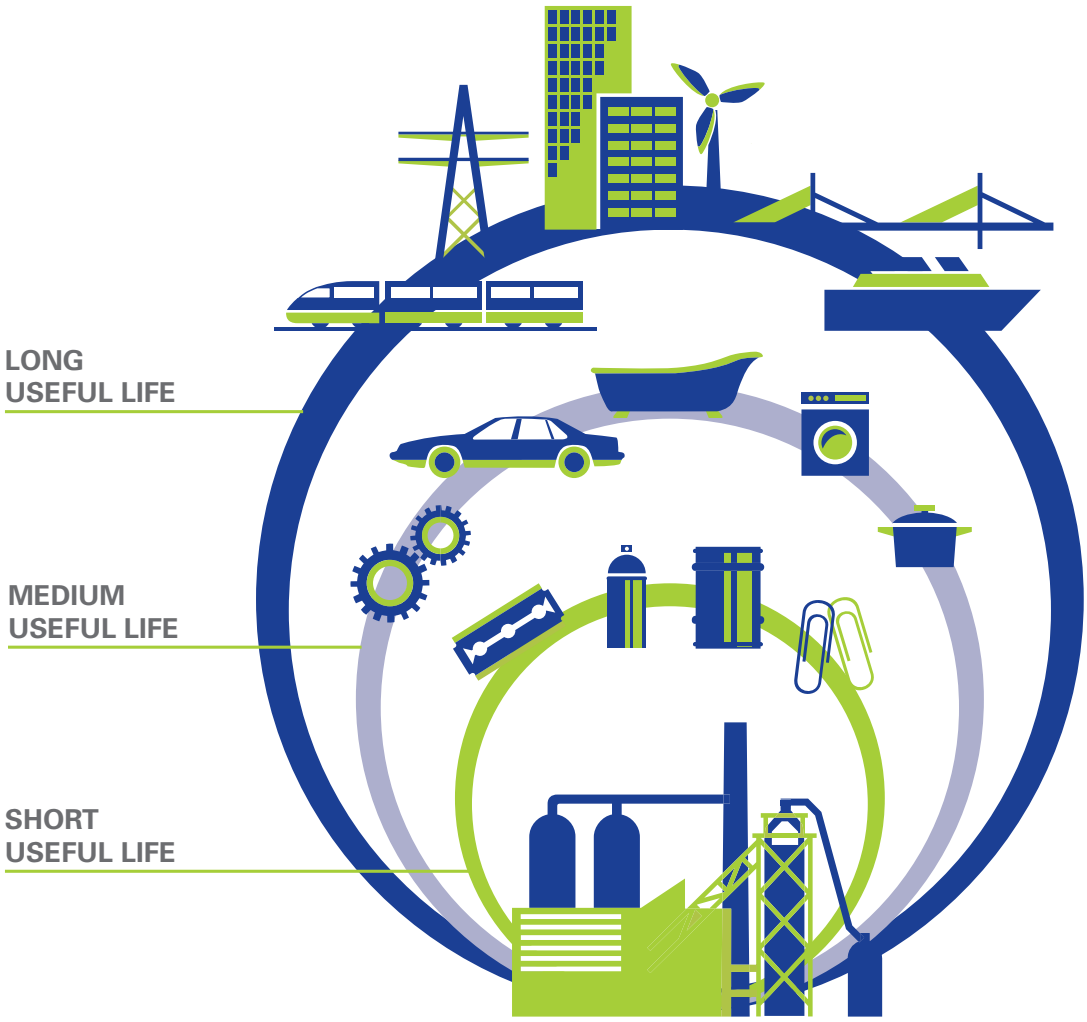
The process of separating end-of-life steel products is already subject to stringent quality requirements. The available analysis and sorting technology makes it possible to meet the demanding specifications of the steelworks in respect of the proportions of chromium, nickel, molybdenum, copper and a wide range of alloying elements contained in the steel scrap.

Other than steel, there are actually very few raw materials that can be recycled without any fundamental loss of quality. In some cases sheet steel from a car body can be turned into a washing machine, which then becomes raw material for structural steel – and this may eventually end up again as the basis for car body sheet. Or perhaps it will become steel for an offshore wind turbine. Such multiple recycling without any loss of quality is not possible with other, non-metallic, raw materials.

As products become more complex, the proportion of undesired tramp elements in the steel scrap increases. The industry-specific knowledge of the German steel recycling industry is therefore essential for preventing material shrinkage and quality deficits, because the steel scrap industry is the first stage of the intelligent management of these material flows.



Graphic 10: **The availability of steel scrap**



- STEEL AND STAINLESS STEEL SCRAP REMAIN A PERMANENT SOURCE OF RAW MATERIALS FOR SOCIETY.
- SOME 70% OF THE STEEL PRODUCED TO-DATE IS STILL IN USE.
- 600 MILLION TONNES OF STEEL SCRAP WORLD-WIDE WERE USED IN 2017 FOR PRODUCING STEEL.
- 35,5% OF GLOBAL CRUDE STEEL WAS PRODUCED FROM SECONDARY RAW MATERIALS IN 2017.
- SINCE THE BEGINNING OF STEELMAKING, MORE THAN 23 BILLION TONNES OF STEEL SCRAP HAVE BEEN RECYCLED.

STEEL RECYCLING IS A PRIME EXAMPLE OF RESOURCE EFFICIENCY

The steel recycling industry, together with the steel industry itself, embodies the principles of the circular economy. They have actively been commercially and ecologically implementing these principles – which still exist only as a vision in many sectors – for a long time.

By providing secondary raw materials, the steel recycling industry is making a significant contribution, not only in Germany, to environmental protection and the conservation of resources – is also conserving primary resources at their source.

CLIMATE- & ENERGY-FRIENDLY

The volume of steel scrap used makes German steel products more climate-friendly than steel produced in China or India, for example. The proportion of steel scrap used in Germany amounts to some 45% while in China, where almost half of the world's crude steel is made, this figure is only around 18%.

It's not only in the production of alloyed steels where "urban mining" in Europe represents a significant source of raw materials, thereby contributing to a reduction in the amount of raw materials that need to be imported.

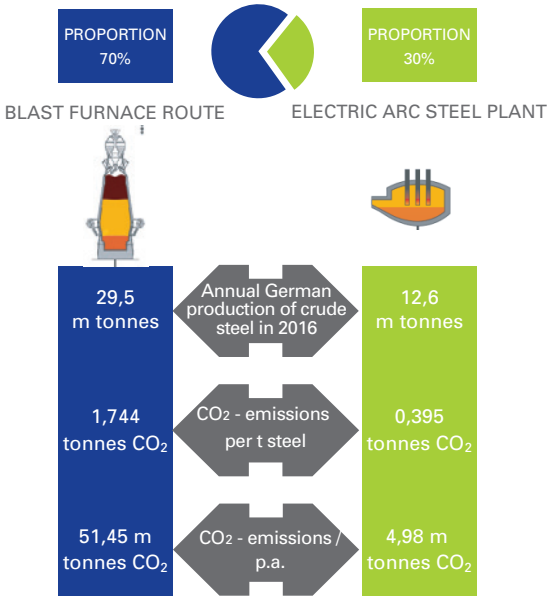
Steel recycling contrasts with raw material extraction in conflict regions or from large-scale projects which also affect the environmental and working conditions of people. In terms of technology, economics, ecology and society, steel scrap and stainless steel offer significant benefits – especially in direct comparison with steel products that are produced purely on the basis of primary raw materials. Taking the overall balance into consideration, manufacturing steel from scrap is therefore more environmentally friendly than producing steel from iron ore and coal. Of course, this does not recognise the fact that it has been possible to make huge advances over recent years, especially in reducing emissions caused by the blast furnace production route.

FIVE BENEFITS OF STEEL SCRAP

→ BENEFIT 1:

By producing 12.6 m tonnes of crude steel from a secondary raw material, using steel scrap via the electric arc furnace route, the steel recycling industry helps achieve savings of 17 m tonnes of CO_2 emissions per annum* in Germany.

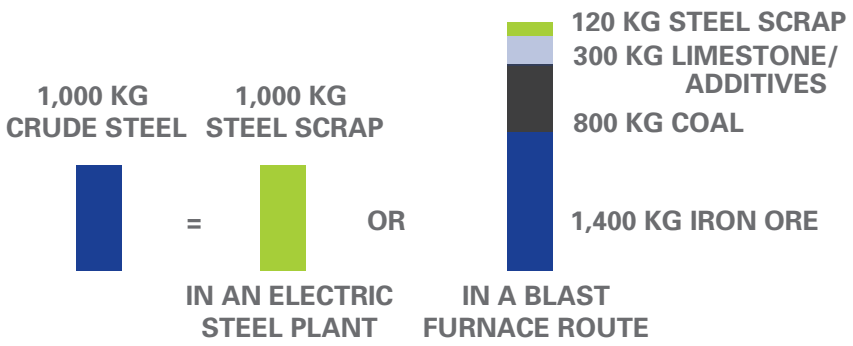
Graphic 11



Calculated in comparison with the assumed production of steel using a method other than the electric arc furnace process.

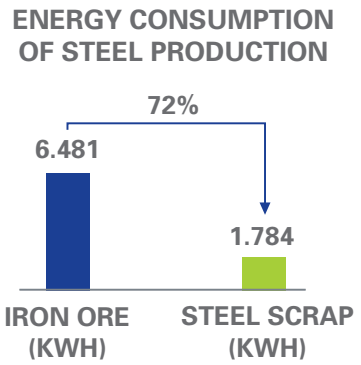
BENEFIT 2: A significante saving in resources

Graphic 12



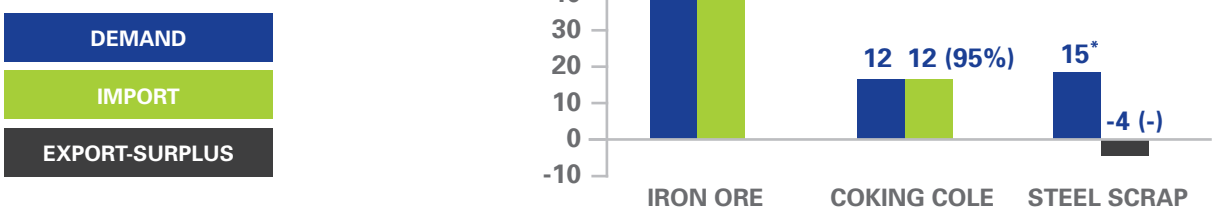
BENEFIT 3: The use of steel scrap reduces energy consumption by 72% per tonne crude steel in comparison with making steel from primary resources.

Graphic 13



BENEFIT 4: No dependence on imports as with primary raw materials (e.g. iron ore, coal). On the contrary, there is an export surplus of steel scrap.

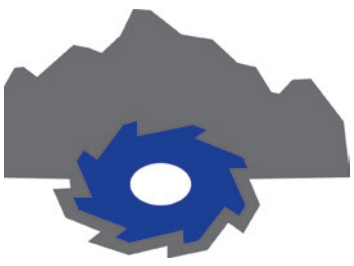
Graphic 14



*Without own arisings (circulating scrap), import ratio on demand in percent in brackets

BENEFIT 5: Fewer negative effects caused by raw material extraction in countries where mines are located:

- No concerns about lower standards of occupational safety
- Less land use
- Lower environmental risk
- No need for relocations
- Shorter transportation distances



Graphic 15



„The structure shows that the market is functioning in the area of secondary raw materials. This contrasts with the primary raw material markets which sometimes have oligopolistic characteristics, and is a key benefit of secondary raw materials."

Prof. Rüdiger Deike, Dr. Eng.
Chair of Iron and Steelmaking Metallurgy at the University of Duisburg-Essen

THE STEEL RECYCLING INDUSTRY SECURES AND CREATES JOBS AT ALL QUALIFICATION LEVELS

German industry supports over 4 million so-called "steel-intensive" jobs. These include the steel industry itself as well as the upstream and downstream sectors. The steel recycling industry, upstream of the steel industry, supports approx. 37,000 jobs (in 2017). In the employee area, in particular, the close cooperation between the steel industry and the upstream steel recycling sector is of great importance.

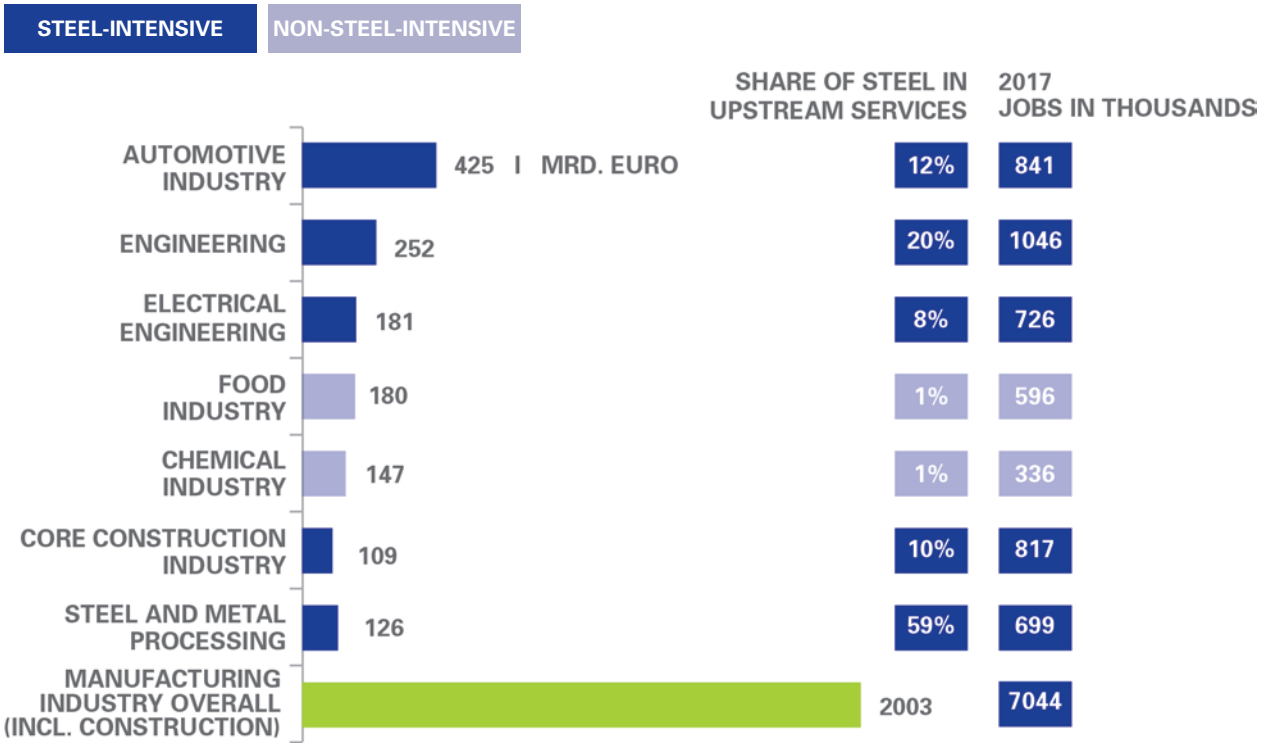
This commonality results in a situation where the domestic steel recycling sector not only secures jobs on all qualification levels, but also remains focused on the further qualification of technicians and engineers. Only in this way can it be ensured that metallurgical know how stays in Germany and is prevented from shifting abroad. This represents a significant competitive advantage for Germany.

Germany also has an excellent reputation as a major global exporter of plants for manufacturing and sorting steel and for recycling technology.

The existing stock of raw materials and the work of the steel recycling sector ensure the supply of secondary raw materials to the steelworks. This supports the supply and downstream processing industries and also offers them a wide range of competitive advantages. In this way, the largely medium-sized structure of steel recycling businesses promotes regional value-added effects. Upstream and downstream service providers to the steel recycling businesses benefit in turn from this proven structure. These include, for instance, the logistics and machinery and plant engineering sectors.

Graphic 17: **Turnover of the largest industrial branches**

Some 4 million jobs are steel-intensive. A large proportion of Germany's export surplus is attributable to steel intensive goods.







OUTLOOK: CLOSING LOOPS WITH STEEL SCRAP IN THE FUTURE TOO

Although crude steel production in Germany has remained at an almost constant level over recent years, the steel scrap market is subject to considerable fluctuations. Steel scrap is a global commodity which means that is also affected by external influences, making development forecasts fundamentally difficult. As before, the current overcapacity in the Chinese market has a strong influence on the global raw material and steel markets. Today, the volume of steel scrap used for producing crude steel in China is relatively small. However, this is expected to increase over the medium term there too, as old scrap from infrastructure projects and end-of-life products is fed back into steel production. In our own economic interests, German know how should be in pole position as the Chinese trading and processing structures undergo development.

While the metal content of the extracted ores is exhibiting a decreasing trend, and it can safely be assumed that the cost of extraction and of the energy used will consequently rise, steel scrap – as a secondary raw material – will become increasingly important from an economic perspective too. The electric arc furnace process, which is currently the most important steel producing process using steel scrap as the secondary raw material, will maintain its dominating position alongside the blast furnace route, and secure sales.

Principally as a result of the technical and commercial ability to create closed loops over the long term through the use of steel scrap, the future now belongs to this secondary raw material.

The steel scrap industry needs to address the following challenges and trends:

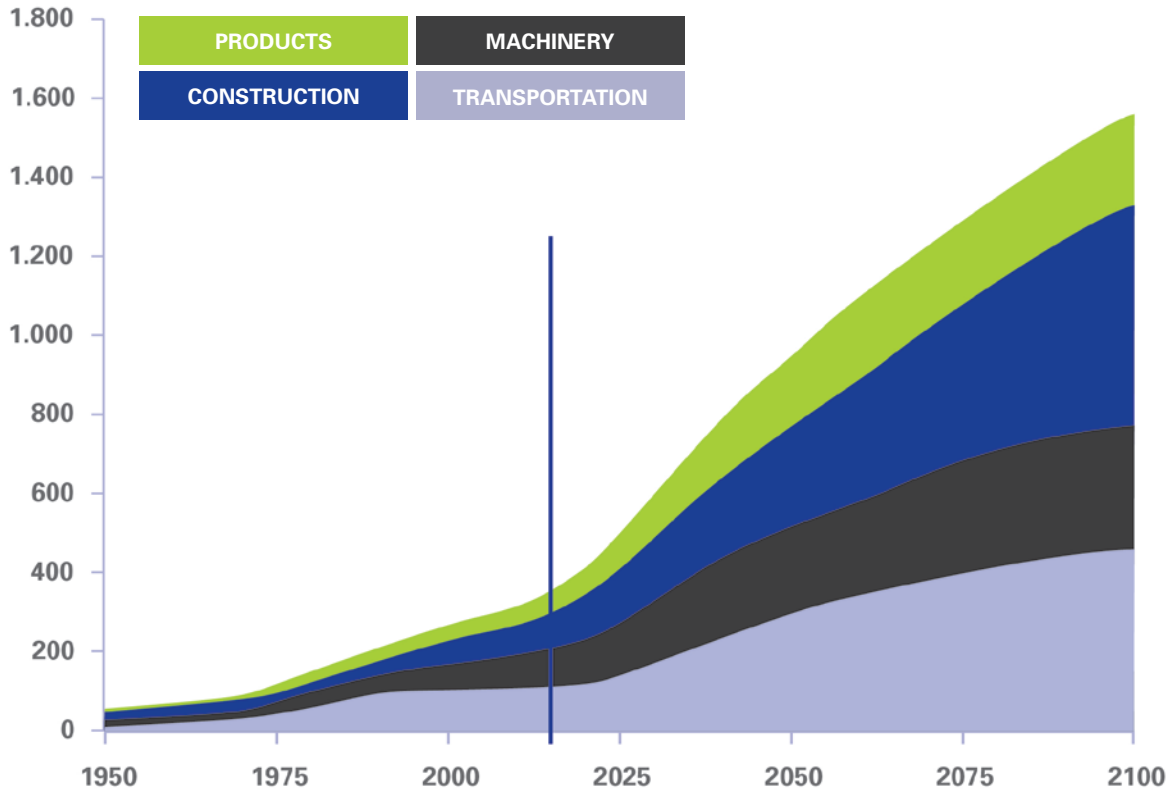
- Ensure a nationwide collection and processing of complex composite materials
- Handling and processing of complex composite materials
- Ensure alloy-specific separation despite the increasing diversity of materials in the input flows in order to minimise quality losses
- Digitalisation of the production processes in the steel recycling industry

The opportunities are huge: As a key supplier of secondary raw materials and service provider to the domestic steel industry, the steel recycling industry represents a key business location factor for the circular economy. Expanding existing know how in the area of collecting and separating processes and leveraging intelligent material flow management techniques – in order to ensure the continued and reliable supply of quality assured secondary raw materials to the steel industry – will deliver a secure foundation for a circular economy.

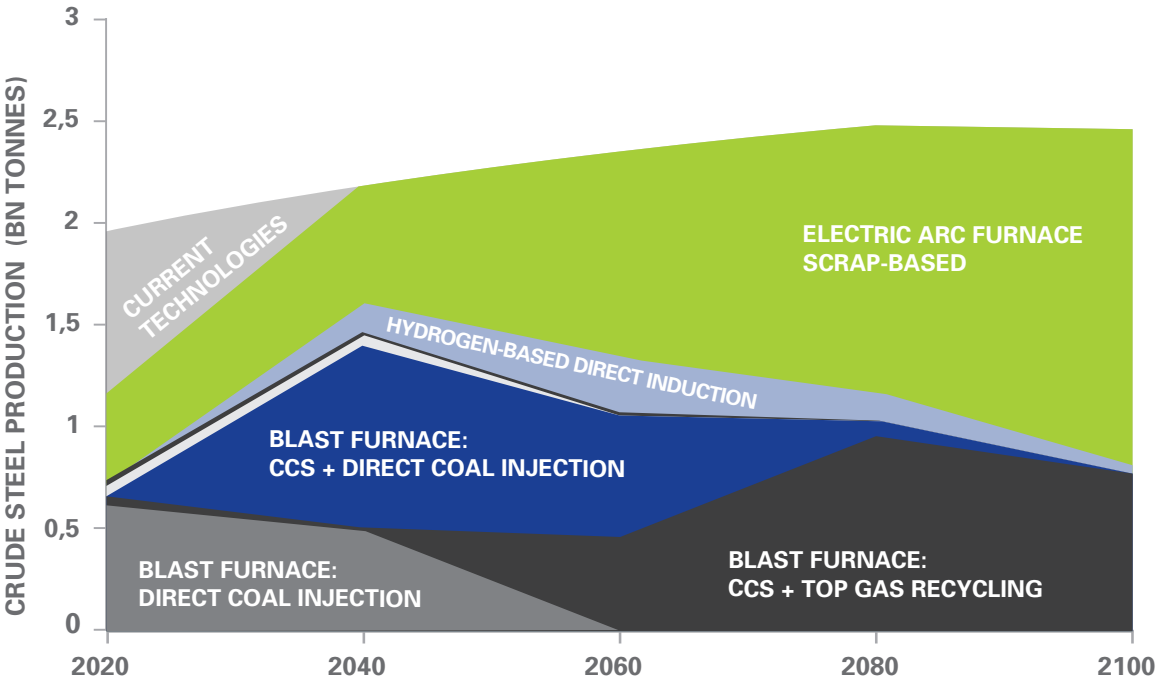
„Scrap is the future, because we are going to see closed cycles develop over the long term. Good examples of this, and ones that are already apparent today, include foundries, electric arc steel plants (where there is only 5 – 10 percent deficit before a completely closed cycle is achieved) and metallurgical companies that recycle non-ferrous metals."

Prof. Rüdiger Deike, Dr.-Eng.
Chair of Iron and Steelmaking Metallurgy at the University of Duisburg-Essen

Graphic 17: **Old scrap by end-use sector**



Graphic 18: **Technology competition in the binding climate target scenario (3.5 F scenario) for Demand Stagnation in 2050**



METHODOLOGY



The methodological approach to the study encompasses an in-depth compilation of the technical, economic, ecological and social characteristics of steel recycling on the basis of a review of scientific literature and analysis.

Existing know how in the area of the raw materials and steel industry, already in the institute's archives, was incorporated into the results. Key questions were then derived from the compiled data and facts on steel recycling.

During interviews with selected well-known experts from industry and the scientific community, the role of the steel recycling industry in the steel and stainless steel manufacturing value chain was subsequently explored in greater detail and the future tasks of the sector derived.

The purpose of the interviews was primarily to fill knowledge gaps identified in existing literature, validate imprecise literature references and to substantiate the statements made by the experts. In this manner, it has been possible to ensure the well-founded documentation of the technical, economic, ecological and social factors relating to steel recycling. The statements made regarding steel scrap are also generally applicable to stainless steel.

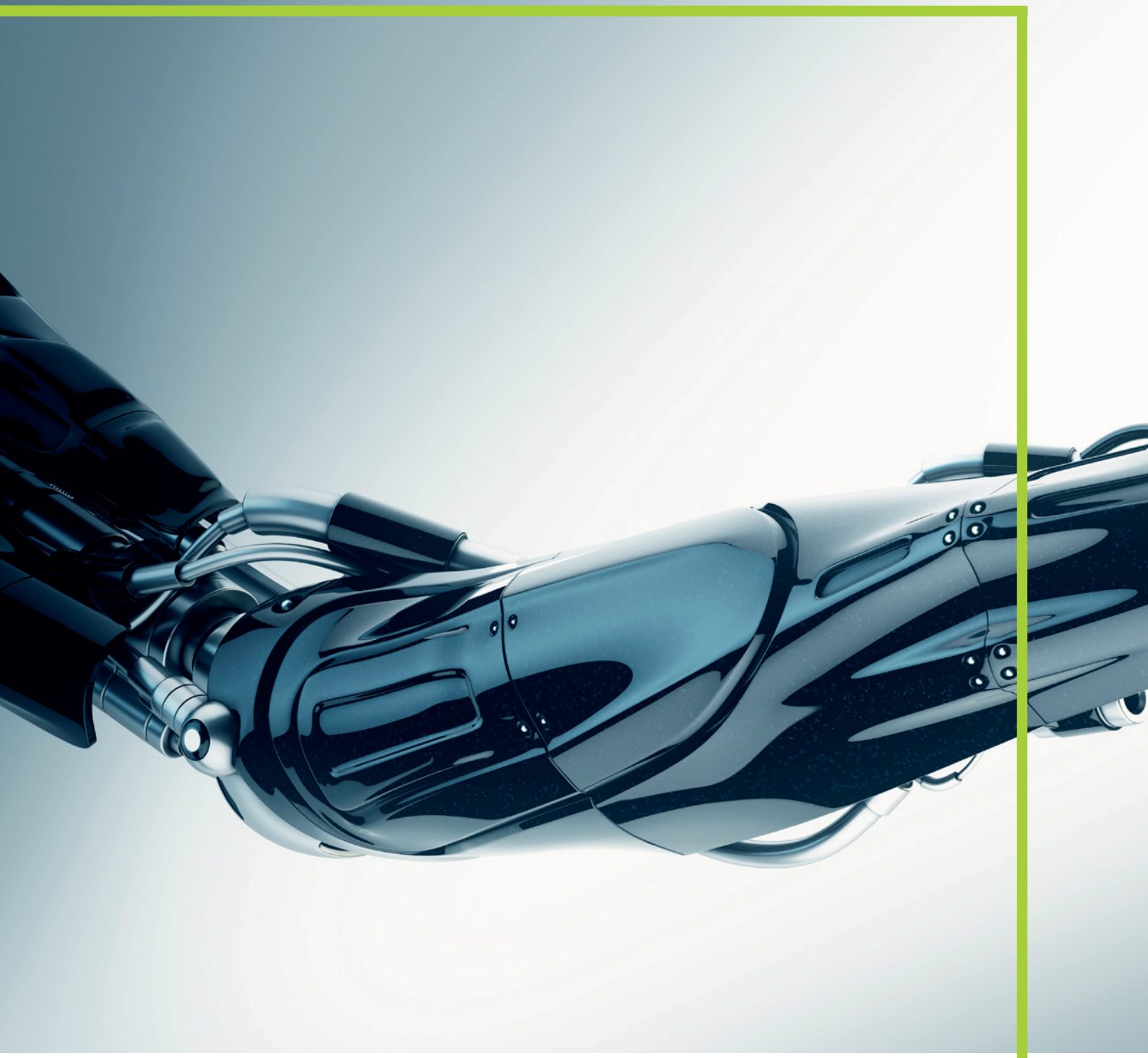
A steering group comprising members of the BDSV Executive Committee and the BDSV branch office supported the work of Fraunhofer UMSICHT on an advisory basis.

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BDSV Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen e. V.

Berliner Allee 57 | 40212 Düsseldorf
T: +49 211 828953-0 | F: +49 211 828953-20

Postal address: Postfach 200151 | 40099 Düsseldorf
Capital office: Hedemannstraße 13 | 10969 Berlin
zentrale@bdsv.de | www.bdsv.org

Person responsible for contents pursuant to §6 MDStV
is BDSV Managing Director Dr. Rainer Cosson

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