Deutsche Rohstoffagentur

58 DERA Rohstoffinformationen

Final report – executive summary
Platform for dialogue on secondary raw materials

Courses of action for strengthening the contribution of secondary raw materials in ensuring the security of metal and industrial mineral supply

Dialogplattform Recyclingrohstoffe

acatech
DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

Federal Institute
for Geosciences and
Natural Resources

www.deutsche-rohstoffagentur.de
www.bgr.bund.de

Imprint

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Cover images: © Petair/stock.Adobe.com
Layout: deckermedia GbR, Rostock

Reference: DERA – German Mineral Resources Agency at the Federal Institute for Geosciences and Natural Resources (2023): Final report – executive summary Platform for dialogue on secondary raw materials. – DERA Rohstoffinformationen 58: 26 S., Berlin.

Data state: August 2023

ISBN PDF: 978-3-948532-84-0
ISSN: 2193-5319
https://doi.org/10.25928/mc6x-zv40

Federal Ministry
for Economic Affairs
and Climate Action

The Federal Institute for Geosciences and Natural Resources is the central geoscientific authority providing advice to the German Federal Government in all geo-relevant questions. It is subordinate to the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Executive summary

Final report Platform for dialogue on secondary raw materials

Courses of action for strengthening the contribution of secondary raw materials in ensuring the security of metal and industrial mineral supply

Commissioned by the Federal Ministry for Economic Affairs and Climate Action (BMWK)

Federal Ministry for Economic Cooperation and Development

Project coordination

German Mineral Resources Agency (DERA) at the Federal Institute for Geosciences and Natural Resources (BGR)

acatech – National Academy of Science and Engineering

Deutsche Rohstoffagentur

acatech DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

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Project duration

June 2021 – September 2023

The platform for dialogue on secondary raw materials was initiated by the Federal Ministry for Economic Affairs and Climate Action (BMWK) and funded by the German Mineral Resources Agency (DERA) at BGR.

The content of this publication was prepared by the chairs of the working groups and sub-working groups in coordination with the platform participants. Technical responsibility for this final report rests with the project office.

[1] Prof. Dr. Hermann Wotruba (Department of Mineral Processing, RWTH Aachen) was the scientific co-chair of this sub-working group until his death in February 2023. Prof. Schebek, who chairs the Industrial minerals working group, has been the acting chair since.

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Notice:
This document is an abridged version of the final report of the Dialogue Platform on Recycling Raw Materials. Results are therefore presented in condensed form.

The full final report can be accessed here.

The complete profiles of the material flow-specific sub-working groups are also available as a separate document and can be accessed here (only available in German):

Profile aluminium
Profile iron and steel
Profile copper
Profile technology metals
Profile building raw materials
Profile gypsum
Profile ceramic raw materials
Profile industrial residues and by-products

Summary

As a manufacturing country, Germany is dependent on a secure and sustainable mineral resources supply. In addition to domestic production and imports, the recycling of raw materials will be playing an increasingly important role as a further mainstay of supply. In this context, the BMWK (Federal Ministry for Economics Affairs and Climate Action) published its key issues paper “Paths towards a sustainable and resilient raw material supply” in January 2023 (BMWK 2023), emphasising the strategic importance of closely integrating the circular economy and raw materials strategies.

The platform for dialogue on secondary raw materials was commissioned as part of Germany’s 2020 Raw Materials Strategy, with the aim of developing measures that would strengthen the contribution of secondary raw materials in ensuring the security of metal and industrial mineral supply. In a dialogue between more than 380 representatives from industry, science, the public administration and civil society and lasting two years, eight sub-working groups developed specific courses of action. The scope of the different sub-working groups focused on individual material flows that are particularly relevant, for instance, because of their volume, criticality or contribution to greenhouse gas emissions, and which have specific recycling requirements. In each sub-working group, the participants’ expert knowledge also had an impact on the final scope of topics.

The findings from the sub-working groups, which provide the central content of the completed dialogue, are reported in individual profiles. In the Metals working group, material flow profiles were compiled for aluminium, iron and steel, copper, and technology metals. The Industrial minerals working group prepared detailed material flow profiles for building raw materials, gypsum, ceramic raw materials (refractory ceramics), and industrial residues and by-products.

Over the course of the project, the different sub-working groups developed a total of 94 material flow-specific courses of action, based on a systematic analysis of existing barriers. All courses of action for a specific material flow can be found in the relevant profile. Nine additional overarching fields of action for the material flows were aggregated at working group level. The report also transparently presents other issues that could be beneficial in improving recycling, but which were contentious in discussions between the participants. It should be noted, moreover, that all overarching fields of action are directly related to recycling. The dialogue did not address in depth broad economic instruments, e.g. from climate policy, that could also have a beneficial effect on recycling, such as carbon pricing or emissions trading. A brief summary of the overarching fields of action addressed by the two working groups on metals and industrial minerals is given below. Not all topics listed were equally relevant to all sub-working groups.

The detailed profiles compiled by the eight material flow-specific sub-working groups include additional courses of action. These are placed in the context of the initial status quo and the resulting barriers to recycling. Also included in the profiles are a detailed feasibility assessment and potential conflicts between objectives arising from the implementation of a course of action. This reflection on the proposed courses of action represents a key benefit of the dialogue work, as it provides the reader with a more comprehensive understanding of the advantages and, where applicable, disadvantages.

Metals
Overarching fields of action

Product design for recycling
Reduce the use of composite materials and the diversity of materials, and adapt joining methods based on an ecodesign regulation; support cooperation along the supply chains and establish design for recycling in training.

More consideration for recycling in legislation
Consider recycling when classing substances; eliminate inconsistencies and conflicting objectives between waste, substance and product legislation while at the same time strengthening enforcement (e. g. of the EU waste shipment regulation by customs authorities).

Transparency of material flows
Improve data availability regarding current and future volumes and alloy compositions of metals in anthropogenic deposits and during the useful life of products, e. g. with product passports within the framework of an ecodesign regulation.

Mandatory uniform standards for collection, separation and sorting
Improve the separation and collection of end-of-life products, the non-destructive removability of components, and the registration and separation of alloy-specific material flows; advance sorting and analysis technologies, e. g. by intensifying research and development efforts.

Industrial minerals
Overarching fields of action

Legally codified end of the waste status
Codify the product status for recycled materials by clearly defining the end of the waste status, simplifying practical application and achieving maximum recovery of material flows.

Segregation of waste flows/selective deconstruction
Monitor the duties of segregation more closely and enforce the trade waste regulation more strictly; codify a standard national demolition permit incl. proof of disposal of the waste and a deconstruction concept (selective deconstruction) in the building code.

Strengthening the use of SRMs with rules and incentives
In public sector procurement, give actionable conditional preference to (regional) secondary raw materials; give more weight to the use of secondary raw materials in the sustainability assessment/certification of buildings and products; include SRMs in standardisation activities and develop supporting rules for the quality assurance process.

Regulatory system to ensure legal certainty for handling asbestos issues
Establish a national rating value “asbestos-free”, to be included in a regulation on handling low asbestos content.

Improved classification as a basis for digital records and compliance systems
Introduce more differentiated waste codes for selected material flows and additional waste codes for SRMs leaving a recycling plant; use an improved classification system for the standardisation of quality requirements for standardised areas of application.

Fig. 1: Overarching fields of action (source: own illustration)

1. Introduction

The platform for dialogue on secondary raw materials brought together more than 380 representatives from industry, science, the public administration and civil society. Over a period of two years and in 32 working meetings, they developed courses of action for the two working groups, Metals and Industrial minerals.

This is an executive summary of the final report on this work and therefore a condensed version of the findings. The aim of this executive summary is to give the reader a quick overview of the central contents. Please refer to the full version of the final report for details.

The circular economy comprises measures ranging from waste reduction and product reuse to repair and regeneration, and to the resource-efficient approaches of a sharing economy. It emphasises the innovative potential of new business models along the entire value chain.

Recycling is a key component of the circular economy, because it is a process that permits the recirculation of valuable resources from components and products, reducing the need for new production. In its work, the platform for dialogue on secondary raw materials focused on precisely this key component, in line with its mandate. Other measures for a circular economy were thus not at the centre of discussions.

Figure 2 summarises the organisational structure and implementation of the platform for dialogue on secondary raw materials.

DERA at BGR together with acatech, the National Academy of Science and Engineering, coordinated the project office for the platform for dialogue on secondary raw materials.

The focus of the platform was on metal resources and industrial minerals, and working groups were set up for both of these topics.

Each working group (WG) was supported by four sub-working groups (SWG) that discussed material flow-specific issues and problem areas. In the Metals WG, we set up sub-working groups for the material flows for aluminium, iron and steel, copper, and technology metals. The material flows for building raw materials, gypsum, ceramic raw materials (refractory ceramics), and industrial residues and by-products formed the Industrial minerals WG.

For each working group and sub-working group, the BMWK appointed two experts from science and industry as chairs, to combine both perspectives and give equal weight to each.

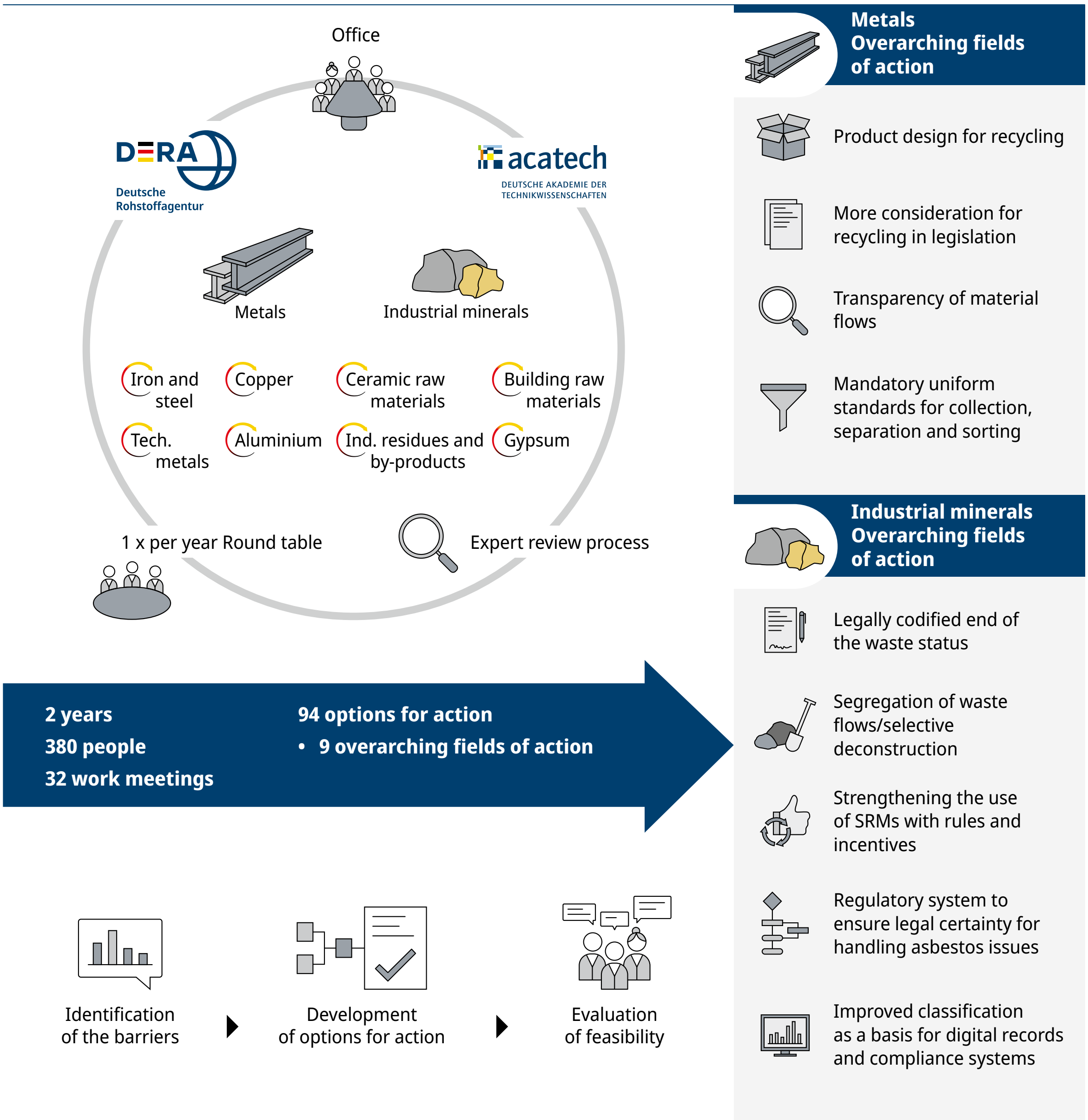


Fig. 2: Concept and implementation of platform for dialogue on secondary raw materials

The work in the eight sub-working groups always formed the starting point for discussions. In a first step, the sub-working groups would develop findings for specific material flows. These would then be presented to the higher-level working group and summarised (see Fig. 2), with the aim of identifying specific barriers and developing possible enablers for the material flow level.

For the purpose of harmonising discussions across the different sub-working groups, structuring elements were specified. These served as a framework for the content and were included in the profiles for each material flow.

Thematic dimensions

The discussions about barriers and possible enablers/solutions were structured based on the dimensions regulatory system, technology and processes, infrastructure & logistics, incentives & funding and data & digitalisation.

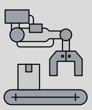
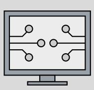
Common reference framework for material flows

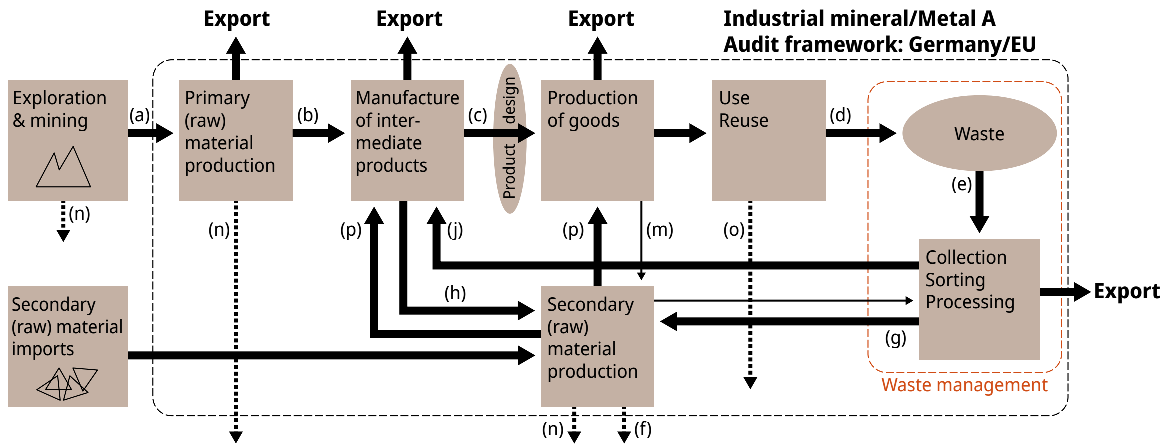
A common reference framework for dialogue was set up (see Fig. 4), in order to structure discussions regarding technical processes, material flows and stakeholders, and to permit a systematic analysis of the recycling potential along the value chain. The scope of investigation was Germany, and the reference framework was created based on the material flow analysis developed by UNEP 2011. This clearly structures material flows, terminology and, where applicable, recycling indicators. Although this simplified representation does not apply to every material flow in detail, it is useful as a general overview. The reference framework for structuring discussions in the sub-working groups could therefore be adjusted as required.

General strategy map

Together with the working group chairs, a strategy map as a conceptual framework for discussions on the platform was developed . The map also helps define specific courses for action that, at the same time, take into account the many diverse objectives in recycling. It served as a framework in which each sub-working group was able to set focus areas for its specific material flow.

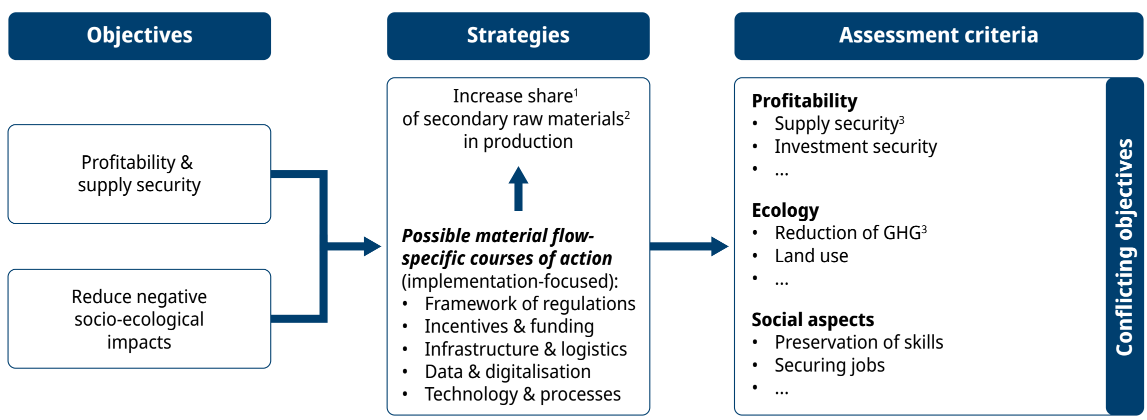
Thematic dimensions

	**Regulatory system** comprises all issues concerning legislation and the legal framework. For instance, approval processes, standardisation, laws and regulations, and regulations at the European and national levels such as the Circular Economy Act (KrWG 2012), the Waste Shipment Act (VVA 2006) or the Law on Waste Electrical and Electronic Equipment (ElektroG 2015). Reference can be made both to existing regulations and ongoing legislative processes or political initiatives (e. g. under the European Green Deal).
	**Technology and processes** refers to all process-related and technological aspects such as sorting, separation and processing techniques or recycling processes.
	**Infrastructure and logistics** comprises all issues that concern the collection and transport of material flows. For instance, options for collection (household waste recycling centres, retailers, dispatch by post etc.) and transport (rail, road etc.), as well as their coordination and implementation.
	**Incentives and funding** includes financial and other incentives for the individual stakeholder groups, and funding for education, training, start-up financing and similar schemes.
	**Data and digitalisation** comprises issues concerning the collection, distribution, management and processing of data. Digitalisation refers to all methods and related processes that are concerned with the digitalisation of analogue processes and the creation of data-based impact models for measures.



(a)	Primary raw material input		(h)	By-products and waste from manufacturing
(b)	Refined primary (raw) material		(j)	Processed waste used in manufacturing
(c)	Intermediate products		(m)	Waste used in production
(d)	End-of-life (EOL) products and materials		(n)	Tailings and slag
(e)	Waste collected for recycling		(o)	In-use dissipation
(f)	Waste separated for non-functional recycling		(p)	Secondary raw materials (SRMs) in manufacturing and production

Fig. 3: Basic reference chart based on UNEP (2011)



[1] Implies an increase in the substitution rate as the ratio of secondary raw materials used to the total materials used (UBA, 2019c).
[2] Produced in a closed cycle at the national/European level.
[3] Specified as particularly important target criteria and used to synthesise/prioritise the solutions developed.

Fig. 4: Strategy map for the platform for dialogue on secondary raw materials

2. Recycling of metals

The findings from the sub-working groups of the Metals working group form the core content of the dialogue process. They can be found in the detailed profiles of all material flows. This executive summary briefly outlines key points for the individual material flows and gives an overview of the relevant volumes for each material flow. The executive summary does not include the contentious issues on which no consensus was reached.

The detailed profiles provide a description of the respective status quo and the resulting barriers to recycling. Furthermore, the profiles include a description of all options for action (enablers) and a differentiated assessment of the feasibility as well as possible conflicts of objectives in the in the implementation. A final conclusion summarizes the next steps for the actors from industry, science and administration. Import and export volumes are specified according to the trade classification of the Harmonized System (HS); they refer to materials with a metal content that is not clearly defined. Mining output is only considered in the context of metal production.

The DOI at the end of each overview page links to the relevant complete profile (German only). This comprises all information and source references.

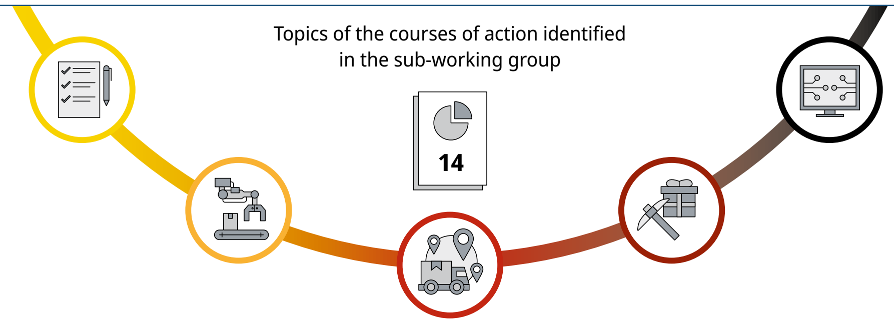
2.1 Profile – aluminium

Aluminium. Raw aluminium can be alloyed with elements such as magnesium (Mg), silicon (Si), manganese (Mn), copper (Cu) or zinc (Zn) to achieve specific properties, so aluminium has a wide range of applications: in the automotive and aircraft industries, packaging industry, and machine and building construction. A distinction is generally made between cast alloys and wrought alloys, and these should preferably be collected separately for recycling.

Tab. 1: Overview of aluminium material flow

Material flows	Volume [t]	Source
SWG Aluminium (reference year: 2021)		
Primary raw materials		
Mining output[1]	0	(BGR 2022)
Imports (HS 2606; ores and concentrates)[2]	2,020,000	(DESTATIS 2023)
Exports (HS 2606; ores and concentrates)[2]	34,700	(DESTATIS 2023)
Refinery output[1]	509,000	(AD 2023)
Secondary raw materials		
Imports (HS 7602; waste and scrap)[2]	1,040,000	(DESTATIS 2023)
Exports (HS 7602; waste and scrap)[2]	1,250,000	(DESTATIS 2023)
Refinery output[1] (refiner only)	565,000	(AD 2023)

[1] In tons of aluminium metal content
[2] Aluminium content of material not clearly defined



#1	Material flow inventory	#8	Legislation with a recycling focus
#2	Understanding of terminology	#9	Product design
#3	Sorting and reprocessing processes	#10	Household waste recycling centres and collection points
#4	Furnace and burner technologies	#11	Automation and digitalisation
#5	Carbon footprint	#12	Investment in independent raw material supply
#6	Scrap availability	#13	Supply chain partnerships
#7	Recycling goal	#14	Legislation, standards and processes

Profile aluminium

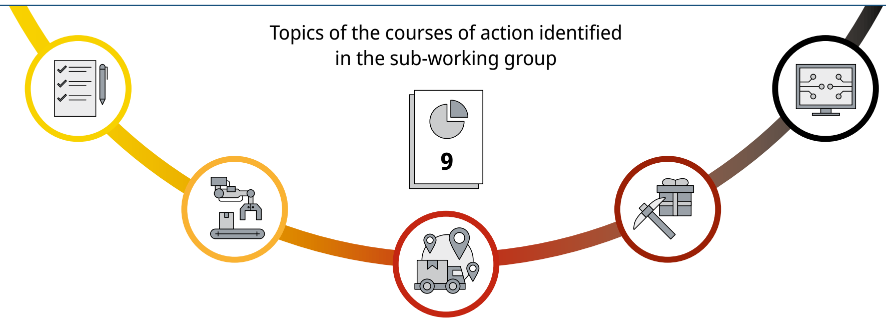
2.2 Profile – iron and steel

Iron and steel. In Germany, scrap iron and steel are largely used in the iron and steel industry, in iron foundries, and in the production of alloyed steel. Beside own, old and new scrap, relevant material flows for this SWG are in particular filings and turnings, grinding sludge and soft scrap, as well as filter dust containing metal. The switch from blast furnace technology (BOF) to hydrogen, the switch to electric arc furnaces, the direct induction process, and iron foundries will determine the future of scrap handling.

Tab. 2: Overview of iron and steel material flow

Material flows	Volume [t]	Source
SWG Iron and steel (reference year: 2021)		
Primary raw materials		
Mining output[1]	0	(BGR 2022)
Imports (HS 2601; ores and concentrates)[2]	39,500,000	(DESTATIS 2023)
Exports (HS 2601; ores and concentrates)[2]	1,480,000	(DESTATIS 2023)
Refinery output[1,3]	22,840,000	(WV STAHL 2022a)
Secondary raw materials		
Imports (HS 7204; waste and scrap)[2]	5,030,000	(DESTATIS 2023)
Exports (HS 7204; waste and scrap)[2]	8,790,000	(DESTATIS 2023)
Refinery output crude steel[1,4]	17,400,000	(WV STAHL 2022b)

[1] In tons of metal content
[2] Metal content of material not clearly defined
[3] Calculated from 40m t total output minus use of scrap steel
[4] Use of scrap steel in crude steel production



#1	European Raw Materials Strategy	#6	Rail freight transport
#2	Exports of scrap	#7	Ecodesign
#3	Legal interpretations	#8	Sorting of scrap
#4	More goal-focused regulations	#9	Research & development
#5	Approval processes		

Profile iron and steel

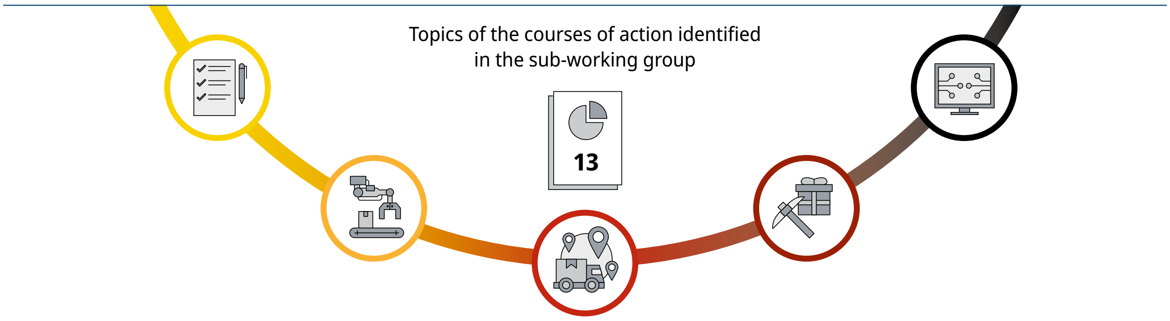
2.3 Profile – copper

Copper. With its high electrical and thermal conductivity and because of electromagnetic induction, the most important applications of copper are the generation, transformation and transport of energy in generators, transformers, heat exchangers and cables. Copper is a key material for the implementation of the energy and mobility transition and it is found in a large number of products. As many of these as possible must be registered and enter recycling at the end of their useful life.

Fig. 3: Overview of copper material flow

Material flows	Volume [t]	Source
SWG Copper (reference year: 2021)		
Primary raw materials		
Mining output[1,2]	37	(BGR 2022)
Imports (HS 2603; ores and concentrates)[3]	1,150,000	(DESTATIS 2023)
Exports (HS 2603; ores and concentrates)[3]	44,500	(DESTATIS 2023)
Refinery output[1]	384,000	(ICSG 2022)
Secondary raw materials		
Imports (HS 7404; waste and scrap)[3]	589,000	(DESTATIS 2023)
Exports (HS 7404; waste and scrap)[3]	464,000	(DESTATIS 2023)
Refinery output[1]	231,000	(ICSG 2022)

[1] In tons of copper content
[2] As a by-product of baryte and fluorite production
[3] Copper content of material not clearly defined



#1	Limits and requirements	#8	Copper losses to the steel cycle
#2	Recycling standards	#9	Incentives for EOL product collection
#3	Enforcement	#10	Recycling capacities and technologies
#4	Design for recycling	#11	Data collection
#5	Export regulations for scrap	#12	Product passport
#6	Sorting and separation technologies	#13	Sorting
#7	Recycling technologies		

Profile copper

2.4 Profile – technology metals

Technology metals. The term "technology metals" is not clearly defined, so the SWG selected the magnesium, zinc and tungsten material flows to be considered as examples. Characteristics of technology metals are complex mass flows with a low metal content and use in alloys, coatings and special applications.

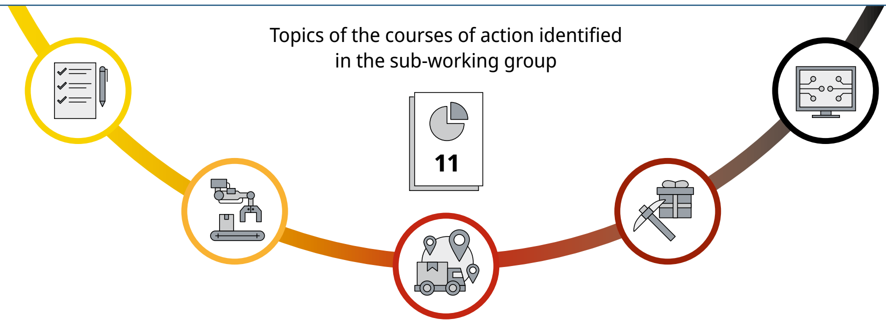
Fig. 4: Overview of material flow for technology metals

Material flows	Volume [t]	Source
SWG Technology metals (reference year: 2021)		
Magnesium		
Primary raw materials		
Mining output[1]	0	(BGR 2022)
Imports (HS 810411; unwrought with Mg ≥ 99.8 %)[2,3]	24,000	(DESTATIS 2023)
Exports (HS 810411; unwrought with Mg ≥ 99.8 %)[2,3]	1,350	(DESTATIS 2023)
Refinery output	not recorded	
Secondary raw materials		
Imports (HS 810420; waste and scrap)[2]	1,500	(DESTATIS 2023)
Exports (HS 810420; waste and scrap)[2]	2,760	(DESTATIS 2023)
Refinery output[1]	not recorded	
Zinc		
Primary raw materials		
Mining output[1]	0	(BGR 2022)
Imports (HS 2608; ores and concentrates)[2]	353,000	(DESTATIS 2023)
Exports (HS 2608; ores and concentrates)[2]	0	(DESTATIS 2023)
Refinery output[1]	135,000	(ILZSG 2023)
Secondary raw materials		
Imports (HS 7902; waste and scrap)[2]	7,690	(DESTATIS 2023)
Exports (HS 7902; waste and scrap)[2]	46,500	(DESTATIS 2023)
Refinery output[1]	29,800	(ILZSG 2023)
Tungsten		
Primary raw materials		
Mining output[1]	0	(BGR 2022)
Imports (HS 2611; ores and concentrates)[2]	0	(DESTATIS 2023)
Exports (HS 2611; ores and concentrates)[2]	609	(DESTATIS 2023)
Refinery output[1]	not recorded	

Fig. 4: Overview of material flow for technology metals

Material flows	Volume [t]	Source
Secondary raw materials		
Imports (HS 810197; waste and scrap)[2]	5,300	(DESTATIS 2023)
Exports (HS 810197; waste and scrap)[2]	7,260	(DESTATIS 2023)
Refinery output[1]	not recorded	

[1] In tons of metal content
[2] Metal content of material not clearly defined
[3] HS code does not differentiate between unwrought metal from primary sources and secondary raw materials



#1	Export and enforcement	#7	Classifications
#2	Returns options	#8	Review of legal requirements and standards
#3	Recycling capacities	#9	Industrial policy
#4	Producer responsibility and/or product stewardship	#10	Competitiveness
#5	Separation and recycling requirements	#11	Substance bans
#6	Research & development		

Profile technology metals

2.5 Recycling of metals – conclusions

Metals are essential for Germany as an innovative location for business and manufacturing. Primary metal ore mining is virtually non-existent in Germany today and the two pillars of raw material supply are therefore imports and metal recycling.

Although demand is rising, output of the base metals iron, steel, copper and aluminium already contains around 50 % of secondary raw materials (new and old scrap, recycling input rate). The recycled content of the selected technology metals is still low by comparison. For other technology metals, it is either in single digit percentages or they are not recovered at all. These shares of secondary raw materials in production and output could doubtless be higher, and certainly have to be.

Many metals in use have already passed through several recycling cycles, because, except for a few alloys, their properties are such that they have theoretically almost fully closed material cycles without any detriment to quality. In reality, recycling is limited by economic and ecological factors, as well as real losses in the value chain (for instance, in collection, sorting, processing, and remelting). Further losses can arise due to dissipation or because metals are bound in slag, (underground) landfills etc. It is therefore important to ensure that no metals are lost after use, that they are available for recycling, and that they can be used in the circular economy with minimum losses.

Although we opted for an approach that looks at individual material flows, many of the barriers and fields of action identified and listed apply to metals in general. We identified the following overarching fields of action (see Fig. 1 for details):

- recycling-friendly product design
- more consideration for recycling in legislation
- transparency of material flows
- mandatory uniform standards for collection, separation and sorting

The metal recycling sectors in Germany and Europe need scrap metal. Global value chains in production lead to global value chains in the recycling sector. Both exports of scrap and substance and product bans remained contentious topics on the platform for dialogue until the end. Metal recycling makes a significant contribution to climate protection that is not yet adequately reflected in current legislation for climate change mitigation. The energy transition requires large and rising quantities of metals that, in the long term, will increasingly come from recycling. But recycling alone cannot cover the metal demand, which is why primary and secondary metal processing should be considered together.

A sustainable transformation of the economy requires both an energy transition and a raw materials transition. The courses of action developed here can help create the necessary framework for this.

3. Recycling of industrial minerals

The platform for dialogue on secondary raw materials opted for the generic term “industrial minerals” as a title to collectively refer to the material flows of industrial minerals, building raw materials, industrial residues and by-products, and ceramic raw materials (refractory ceramics). It covers non-metallic raw materials and thus also the commonly used “construction and industrial minerals”.

The findings from the sub-working groups of the Industrial minerals working group form the core content of the dialogue process. They are included in the detailed profiles of the material flows. This executive summary briefly outlines key points for the individual material flows and gives an overview of the relevant volumes for each material flow. The executive summary does not include the contentious issues on which no consensus was reached.

The detailed profiles provide a description of the respective status quo and the resulting barriers to recycling. Furthermore, the profiles include a description of all options for action (enablers) and a differentiated assessment of the “feasibility” as well as possible conflicts of objectives in the in the implementation. A final conclusion summarizes the next steps for the actors from industry, science and administration.

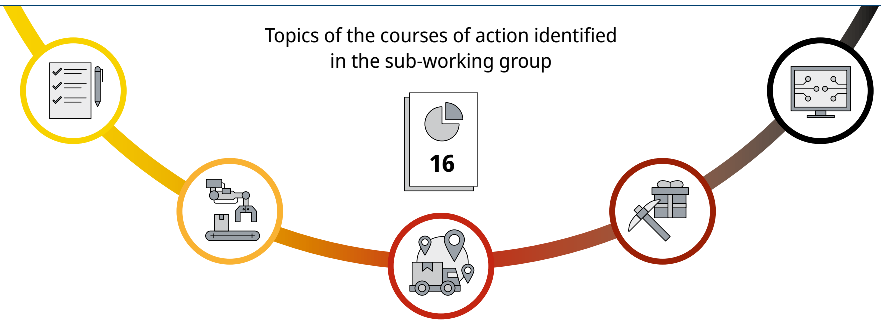
The DOI at the end of each overview page links to the relevant complete profile. This comprises all information and source references.

3.1 Profile – building raw materials

Building raw materials. In the division of content between the sub-working groups of the Industrial minerals working group, the SWG Building raw materials only concerns itself with non-hazardous mineral-based construction and demolition waste. Its focus is therefore on the material flows for demolition waste (concrete, bricks, tiles, ceramics and mixtures of brickwork, plaster etc.), road construction waste, and soil and rock. It does not consider gypsum-based construction waste, which is addressed by the SWG Gypsum.

Tab. 5: Overview of material flow for building raw materials

Material flows	Volume [t]	Source
SWG Building raw materials (reference year: 2020)		
Mineral-based construction and demolition waste, of which	220,600,000	(KWB 2023)
Soil and rock	129,200,000	(KWB 2023)
Demolition debris	60,000,000	(KWB 2023)
Road construction waste	16,900,000	(KWB 2023)
Construction site waste	13,800,000	(KWB 2023)
Gypsum-based construction and demolition waste	741,000	(KWB 2023)



#1	Segregation	#9	Regulations and standards
#2	End of waste status	#10	Rates of recycled content use
#3	Asbestos	#11	Incentives
#4	Umbrella regulation	#12	Tenders
#5	Selective deconstruction	#13	Building construction and product design
#6	Processing technology	#14	Supply chain information
#7	Duties	#15	Climate protection aspects
#8	Statistics	#16	Research and implementation

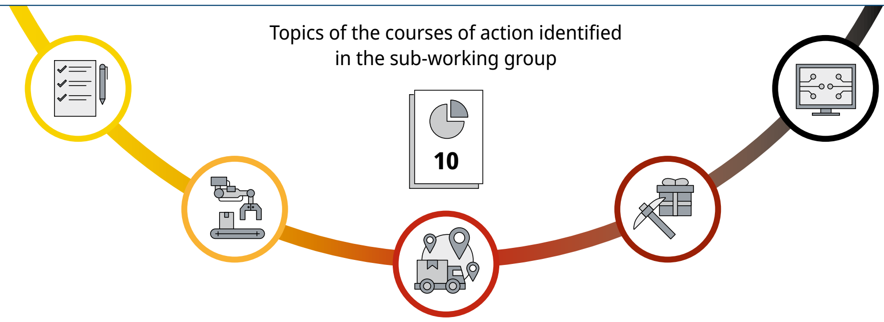
Profile building raw materials

3.2 Profile – gypsum

Gypsum. The SWG Gypsum focuses on recycled gypsum. It only touches on natural, synthetic and "secondary" gypsum (gypsum produced during chemical-industrial processes, such as FGD gypsum, phosphogypsum or "lithium gypsum") and these materials need to be addressed separately. For details of the scope of this sub-working group, please see the full version of this report.

Tab. 6: Overview of gypsum material flow

Material flows	Volume [t]	Source
SWG Gypsum (reference year: 2020)		
Primary raw materials		
Mining/primary raw material output	5,200,000	(BGR 2022)
Imports	197,000	(BGR 2022)
Exports	752,000	(BGR 2022)
Secondary raw materials		
Gypsum-based construction and demolition waste, of which approx. 50 % recyclable	741,000	(DESTATIS 2023)
Imports	not recorded	
Exports	not recorded	
Recycled gypsum (from gypsum-based construction and demolition waste)	63,000	(BGR 2022)
FGD gypsum	3,860,000	(BGR 2022)



#1	Asbestos limit and analysis methods	#6	Training and commitment
#2	Landfill reduction	#7	Information campaigns
#3	Infrastructure for sorting, collection and recycling	#8	Recyclable building constructions
#4	Exports of gypsum waste	#9	Waste code for autoclaved aerated concrete
#5	Technology adaptation & development	#10	End of waste status

Profile gypsum

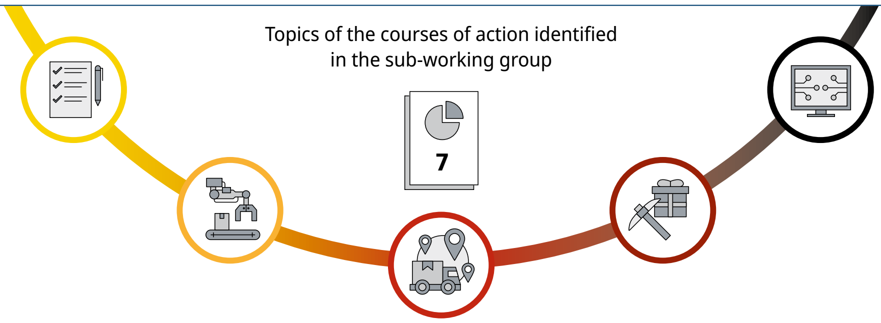
3.3 Profile – ceramic raw materials (refractory ceramics)

Ceramic raw materials. The SWG Ceramic raw materials focuses on refractory ceramics, while construction ceramics etc. are addressed by the SWG Building raw materials. In particular, the focus is on refractory waste from the steel industry, which uses around 60 – 65 % of refractory products. But refractory waste from the steel industry only cannot be considered a single material flow, since the refractory products used are based on different raw materials, depending on the application.

Tab. 7: Overview of material flow for refractory ceramics

Material flows	Volume [t]	Source
SWG Refractory ceramics (reference year: 2020)		
... from carbon-based metallurgical processes (AVV 161101*)	11,700	(DESTATIS 2023)
... from carbon-based metallurgical processes (AVV 161102)	1,900	(DESTATIS 2023)
... from metallurgical processes (AVV 161103*)	60,000	(DESTATIS 2023)
... from metallurgical processes (AVV 161104)	462,900	(DESTATIS 2023)
... from non-metallurgical processes (AVV 161105*)	16,200	(DESTATIS 2023)
... from non-metallurgical processes (AVV 161106)	51,800	(DESTATIS 2023)

* Hazardous waste



#1	Turn waste legislation into recycling legislation	#5	Selective deconstruction
#2	Shipments of waste	#6	Design for recycling
#3	End of waste status	#7	Competitiveness
#4	Approval processes		

Profile ceramic raw materials

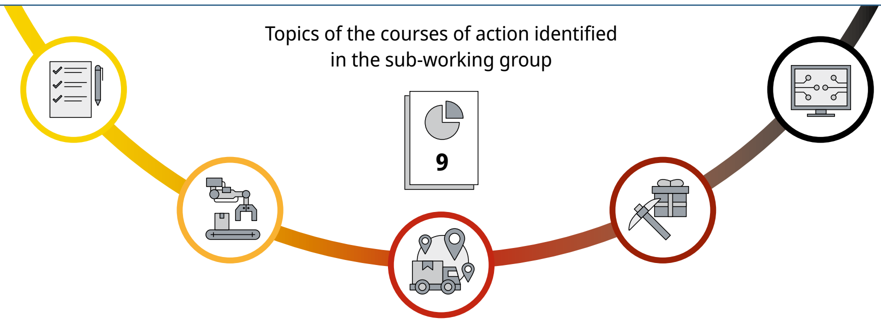
3.4 Profile – industrial residues and by-products

Industrial residues and by-products. This sub-working group is concerned with the residues and by-products from industrial processes. The objectives associated with individual material flows for industrial by-products differ in terms of their intended use. Whereas the aim with the metallic fraction is to produce or recover the largest possible share, with the mineral fraction, it is the fullest possible use. The sub-working group addresses in detail ferrous slag, non-ferrous slag, incinerator bottom ash (IBA) and red mud.

Tab. 8: Overview of material flow for industrial residues and by-products

	Volume [t]	Reference (year)	Source
Total industrial by-products	45,000,000	2020	(Merkel & Reiche 2020)
Ferrous slag	12,500,000	2021	(FEhS 2022)
Residues from flue gas cleaning in steel production	1,600,000	2021	Extrapolated[1]
Copper slag	1,000,000	2021	Aurubis AG 2022
Incinerator bottom ash (processed IBA)	4,700,000	2022	(ITAD & IGAM 2022)
Red mud (AOS-Stade)	900,000	2022	(AOS-Stade 2022)
Other by-products (esp. power plant residues)	24,300,000	2020	(Merkel & Reiche 2020)

[1] Extrapolated: 40m t/a of crude steel · 40 kg/t of residues



#1	Standards/regulations on transformation	#6	Public visibility
#2	Tenders	#7	Tax incentives
#3	Environmental impact assessment	#8	Networks and digital platforms
#4	Standards and terminologies	#9	Basic research
#5	Landfill reclamation		

Industrial residues and by-products

3.5 Recycling of industrial minerals – conclusions

Industrial minerals are of considerable importance for the objectives supply security, resource efficiency and sustainability. Industrial mineral material flows are of particular significance, since demand is likely to remain constant or rise because of construction activities in the years ahead. Secure industrial mineral supply will then rely not only on domestic production but also on recycling.

Unlike metals, the domestic output and waste volumes of industrial minerals are such that their material flows have a large impact in these fields:

- Land: Primary raw material production uses/requires land. While open-cast and underground mines and quarries together occupy only 0.4 % of the surface area of Germany (Destatis 2022), land use conflicts are nevertheless possible, especially in metropolitan areas, which have a wide range of land use requirements. These areas also have a high consumption of building materials and primary raw materials may therefore have to be sourced from more distant deposits.
- Biodiversity: Primary raw material deposits are sometimes located in places with precious ecosystems. In order to preserve them and protect biodiversity, the deposits are not available for exploitation, thus reducing the primary raw material supply.
- Landfill capacities: Because of the quantities involved, the disposal of industrial minerals consumes considerable landfill capacity, which is valuable and scarce. Construction and demolition waste is the main type of waste that is disposed of in landfills. More recycling therefore saves landfill capacity.

Regarding the potential for reducing greenhouse gases from industrial minerals, this is found mainly in the material flow for cement or concrete from the demolition of buildings or infrastructure. Because of the enormous impact that cement production has on the climate, this should in future receive particular attention.

Further potential for reducing greenhouse gases could result from shorter transport distances if secondary instead of primary raw materials are used. However, this aspect is very much dependent on the specific conditions of material availability.

Although we opted for an approach that looks at individual material flows, many of the barriers and fields of action identified and listed apply to industrial minerals in general. We identified the following overarching fields of action (see Fig. 1 for details):

- Legally codified end of the waste status
- Segregation of waste flows/selective deconstruction
- Strengthening the use of SRMs with rules and incentives
- Regulatory system to ensure legal certainty in handling asbestos issues
- Improved classification as a basis for digital records and compliance systems

The courses of action developed here can help create the necessary conditions and framework and improve the recycling of industrial minerals in future.

4. Platform for dialogue on secondary raw materials – conclusions

The work carried out in the context of the platform for dialogue on secondary raw materials has shown that considerable barriers have to be overcome in some areas before the cycle for the selected metals (copper, iron and steel, aluminium and technology metals) and industrial minerals (building raw materials, gypsum, ceramic raw materials and industrial residues and by-products) in Germany can be physically closed as fully as possible and with minimum losses. In a first step of the dialogue process, the sub-working groups together identified around 250 barriers to a strengthening of recycling. Beside regulatory barriers, these were mainly technology- and process-related, or they concerned incentives and funding. Based on a systematic analysis of current barriers, the different sub-working groups developed a total of 94 material flow-specific courses of action over the course of the project. They are described in the sub-working groups' profiles and discussed in terms of their feasibility and potential conflicts between objectives. Nine overarching fields of action for the material flows were derived by the working group chairs.

The participants greatly valued the close collaboration with the competent ministries and authorities, which involved direct exchange and round table discussions. Interim findings of the dialogue work have already been included in the BMWK's key issues paper on sustainable and resilient raw material supply (BMWK 2023). This final report also provides important input for the development of the National Circular Economy Strategy (NKWS) under the auspices of the BMUV (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection). Particularly the feasibility assessments of the courses of action developed for the individual material flows including the conflicting objectives provide an important basis for further coordination between the ministries.

In retrospect, the three-tier approach for the dialogue process, of identifying barriers, developing courses of action, and assessing their feasibility, has proved successful. It has helped create a transparent basis for decision-making that has the backing of many of the stakeholders. In future, dialogue formats that bring together the stakeholders along the value chain should therefore be made available. This would permit discussions about possible ways of improving recycling and prompt responses to changing conditions. Care should be taken in particular to include stakeholders from the early stages of the value chain. It would then be possible to consider issues such as design for recycling in the context of broader product stewardship right from the start. An exchange on narrowly defined material flow-specific or product-specific challenges would be a means to develop effective measures to quickly and effectively improve recycling in a specific context. This report makes an important contribution towards that goal.

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