VERAM

Vision and roadmap for European raw materials

Vision for Raw Materials in Europe and for Europe Part III

D4.3 – Report on innovation and capacity building needs across the EU economy till 2050

WP4 – Creating a vision 2030 and 2050 for raw materials

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Part III. Innovation Implementation

1. The framework conditions for a successful Raw Materials Innovation Strategy depend on a comprehensive system including knowledge, people, and financial and policy support

The role of institutions, business environment and entrepreneurship through the regulation and standards is to facilitate EU supply and secure it through dynamic understanding of the demand, availability of services and modernization of infrastructures.

The central factors to future innovation for vision of Raw Materials Supply in and for Europe are:

Leveraging the European dimension – "together we are stronger"

a. Increasing the engagement of all EU Member States through ERA-Nets;
b. "Innovation" Fitness-check of (European and national) patent and standardisation procedures;
c. Creating incentives through economic instruments (e.g. national legislation and tax frameworks);

Leveraging the innovative capacity – "picking the brains"

d. Expanding the cross-sector collaborative approach and knowledge transfer: bringing together various ETPs;

Leveraging EU's innovation leadership – "hitting the ground running"

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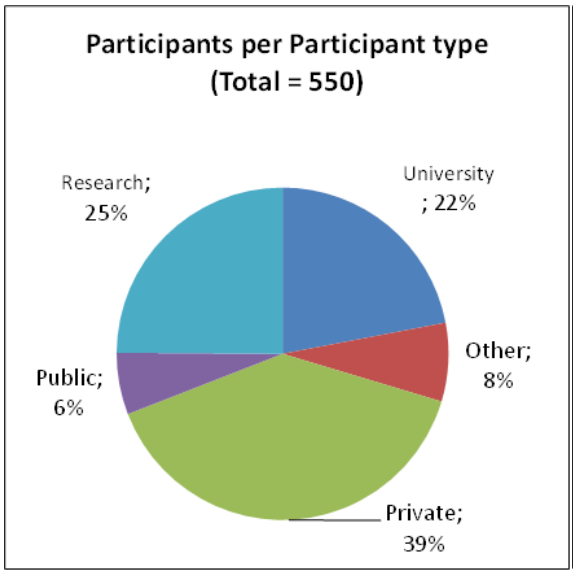
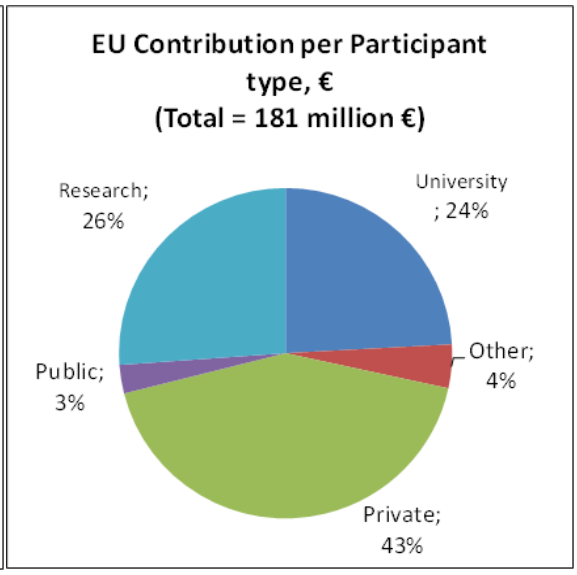
1.1. Leveraging the European dimension – "together we are stronger"

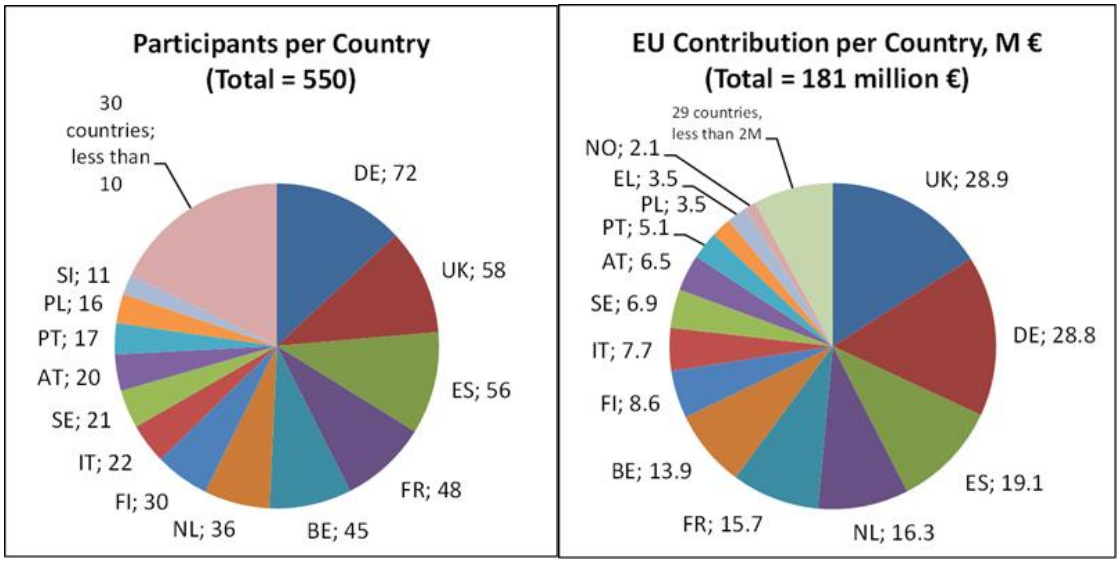
Trans-national cooperation removes barriers and creates a 'common market' for research and innovation, whilst the split by type of participant for Horizon 2020 SC5 projects seems to suggest a relatively balanced representation.





In the past years, both the number of Eastern European participants in EU-funded projects as well as the total funding for research and innovation earmarked for these countries have been significantly lower than the participation of and funding provided to Western European countries.

The unbalanced representation of EU countries in the EU budget for research and innovation is of concern and needs to be addressed in the future.



Experience has shown that the effective communication and dissemination of opportunities and the engagement of Eastern Europe is hindered by the linguistic barriers, the lack of experience in applications, the lack of Eastern European evaluators and existing networks that are difficult to access for newcomers.

Former Eastern Europe countries still receive and can apply for the European structural and investment funds (ESIF). This is maybe the biggest (and most successful) form of funding from the EU for these countries and companies operating in these countries.

However, with the EU's climate change policies and the related closure of major parts of the Eastern European coal mining industry there is a substantial threat that the relevant research facilities will lack future funding and national policies will not prioritise the extractive industry and its products as an area worth of future funding. At the same time, it is exactly these closures that will require increased research and have the potential of developing a worldwide first-class competence in coal mining and general mine rehabilitation – an expertise and service that would be exportable by 2050 if not before.

Vision: The EU and its MS will provide a range of national training courses for project applications and project management, and not leave this field to consultants or already established companies. Participation from all MS will be levelled and have a higher rate of success than today.

a) Increasing the engagement of all EU Member States through ERA-Nets

The existing network of funding organisations established in the FP7-ERA-Net ERA-MIN (2011-2014) and further developed under Horizon 2020 within the ERA-Net Cofund ERA-MIN 2 (2016-2021) needs continued support since the coordination of calls between Member States will gain increasing importance, in particular in the area of waste management and remediation, recovery of secondary resources and better logistics systems.

The ERA-NET Cofund on Raw Materials **ERA-MIN 2** is a public-public partnership based on the ERA-NET Cofund scheme under Horizon 2020. ERA-MIN 2 aims to implement a European-wide coordination of research and innovation programs on raw materials to strengthen the industry, competitiveness and the shift to a circular economy. The objective of ERA-MIN 2 is to strengthen the coordination of national and regional research programmes in the field of non-energy non-agricultural raw materials by implementing several activities. Among these activities, ERA-MIN 2 publishes 3 joint calls for collaborative transnational R&I projects between 2017 and 2020.

In line with the integrated strategy proposed in the EU Raw Materials Initiative and the Strategic Implementation Plan of the European Innovation Partnership on Raw Materials, ERA-MIN 2 currently covers 21 public research and innovation funding organisations of EU countries and regions and non-EU countries which collaborate and participate with this aim.

Member State / Region	Funding organisation	Website
EU		
Belgium/Flanders	FWO	http://www.fwo.be/en/
Belgium/Flanders	Hermesfonds	http://www.iwt.be/
France	ANR	http://www.agence-nationale-recherche.fr/
France	ADEME	http://www.ademe.fr/
Finland	TEKES	https://www.tekes.fi/en/
Germany	JUELICH	https://www.ptj.de/en/
Ireland	GSI	http://www.gsi.ie
Italy	MIUR	http://www.istruzione.it
Poland	NCBR	http://www.ncbr.gov.pl
Portugal	FCT	http://www.fct.pt/
Romania	UEFISCDI	http://uefiscdi.gov.ro
Slovenia	MIZS	http://www.mizs.gov.si/en
Spain	CDTI	https://www.cdti.es/
Spain	MINECO	http://www.mineco.gob.es
Spain/Castilla y Léon	ADE	http://www.empresas.jcyl.es
Sweden	Vinnova	http://www.vinnova.se/en/

EFTA		
Turkey	TUBITAK	https://www.tubitak.gov.tr/en
LATIN-AMERICA		
Argentina	MINCyT	http://www.mincyt.gob.ar/
Brazil	Finep	http://www.finep.gov.br/
Chile	CONICYT	http://www.conicyt.cl/
AFRICA		
South Africa	DST	http://www.dst.gov.za/

This network of national funding agencies needs to be continued and extended, in particular from the 12 European countries to the 28 EU countries.

The development of the EU-LA platform MNDP can assist in extending the network in LA.

The potential development of an EU-Canada investment facility could extend the cooperation to Canada.

The ERA-NET mechanism has also proved to be an appropriate one to accommodate the research priorities of the biotic raw materials sector. The **WoodWisdom-NET** is a very successful ERA-NET dedicated to wood material science, engineering and forestry. It has launched 4 Joint Calls and mobilised around € 85 Million to 62 transnational forest-based research and innovation projects since the start of its activities in 2004. WoodWisdom-Net aims at supporting the total transformation of the European forest-based industry and sustainable forest management by enabling increased resource efficiency and developing a totally new products scope, while adapting to and mitigating the impacts of climate change. In 2017 the national research funding organisations in the WoodWisdom-NET consortium have been granted an ERA-Net Cofund project by the EC and the funding programme of WoodWisdom-NET project will continue under the ForestValue ERA-NET Cofund scheme.

Vision: ERA-NETS or equivalents will be EU wide and complement the EU and the nationally oriented RTD funding with additional complementary funding mechanisms. Where appropriate these ERA-NETs will reach out to other important global governments in the resource sector.

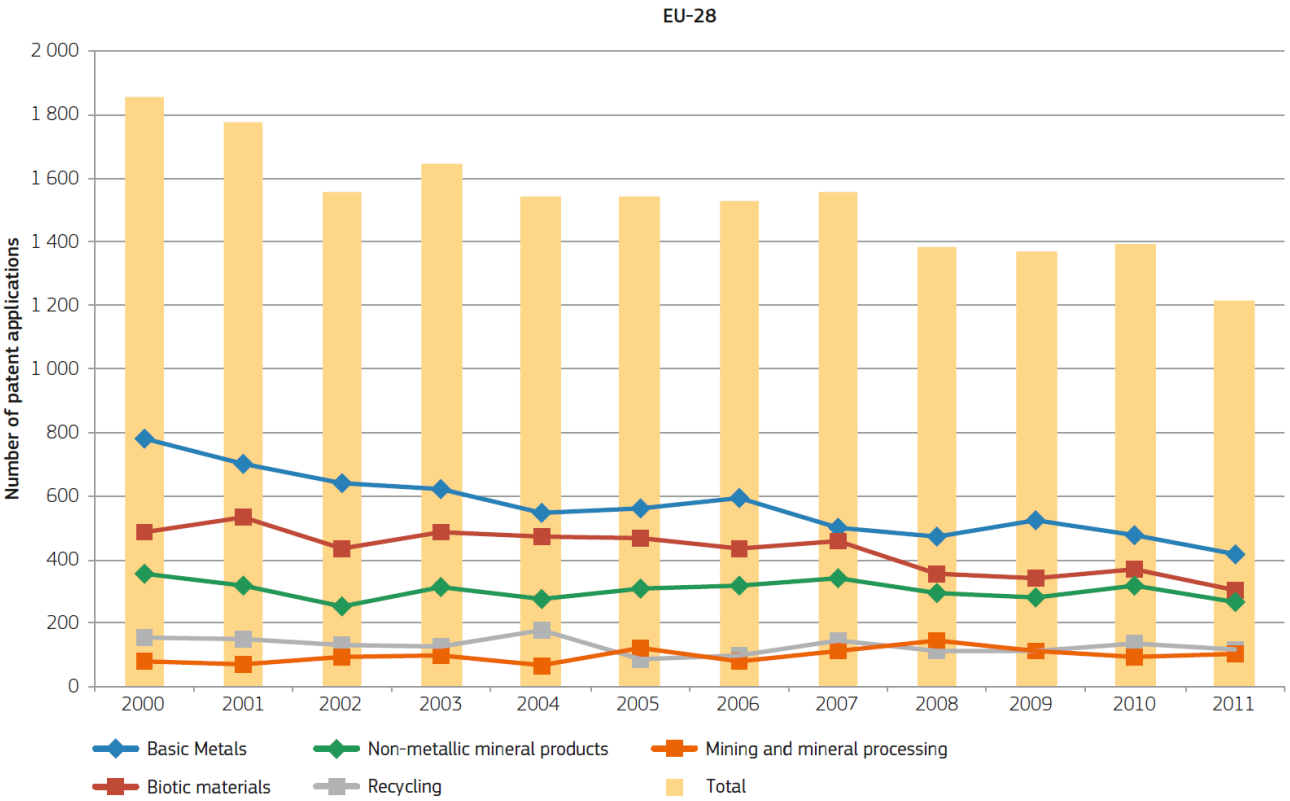
b) "Innovation" Fitness-check of (European and national) patent and standardisation procedures

Patent procedures

There is a high spread in performance in patent application under the Patent Cooperation Treaty. For the EU, on average 3.7% patents per billion GDP have been applied for. There are large differences with 8 or more patent applications per billion GDP in Israel, Sweden, and Finland, and less than 1 application per billion GDP in 13 countries.

From the EU Raw Materials Scoreboard:

> *EU patent applications in the raw materials sector on the other hand show a decreasing trend. Nevertheless, in 2011, the EU still accounted for 36 % of patent applications filed by the EU, Australia, Canada, Japan, Russia and the USA together (Indicator 9).*
>
> *In the EU, the overall number of patent applications in the raw materials sector fell by about 35 % from 2000 to 2011, while the selected international group of reference countries registered a fall of 15 % over the same period. For both groups, a marked drop in patent applications is evident after 2008, which is most likely a consequence of the global economic downturn. The biggest contribution to the total number of patent applications in the raw materials sector comes from the 'basic metals' category. In the EU, this is followed by 'biotic materials', 'non-metallic mineral products', 'recycling' and 'mining and mineral processing'. Between 2000 and 2011, the number of patent applications varied significantly across the individual categories. In the EU, for example, the 'basic metals' and 'biotic materials' categories saw a significant reduction in the number of patent applications, while 'non-metallic mineral products' and 'recycling' registered relatively moderate declines. In contrast, the number of patent applications in 'mining and mineral processing' increased by 35% over the same period. It has been observed that patent filing in this category follows the cyclical nature of mineral exploration investments, which are mainly driven by the commodity prices index.*



Number of raw materials patent applications from EU-28 Member States, European Raw Materials Scoreboard 2016.

Trademark registrations:

From the EU's Innovation Scoreboard:

Trademarks are an important innovation indicator, especially for the service sector. The Community trademark gives its proprietor a uniform right applicable in all Member States of the European Union through a single procedure, which simplifies trademark policies at European level. It fulfils the three essential functions of a trademark: it identifies the origin of goods and services, it guarantees consistent quality through evidence of the company's commitment vis-à-vis the consumer, and it is a form of communication, i.e. a basis for publicity and advertising.

There is a high spread in performance in trademark applications per billion GDP. High numbers of trademark applications above 35 per billion GDP are observed in Cyprus, Malta, and Luxembourg. Trademark applications per billion GDP are lowest in Turkey, Ukraine, the Former Yugoslav Republic of Macedonia, and Romania, all less than 2.5 per billion GDP.

Vision:

A more detailed patent analysis will be developed and will enable the policy makers and the business sector to address issues such as bureaucratic hindrances in a better way. At the same time the rate of patents will be increased considerably, in particular in the machinery and tooling sector, but also in applications of raw materials.

The raw materials industry will increase by two categories of trademarks, the one for machinery and the one for mineral products. Both will be considered when assessing the innovation rate in the sector. By 2050 the rate of innovation in the sector will have increased the patents and the trademarks granted.

Standardisation

Standardisation is a voluntary cooperation among industry, consumers, public authorities and other interested parties for the development of technical specifications based on consensus. Standardisation complements market-based competition, typically in order to achieve objectives such as the interoperability of complementary products/services, and to agree on test methods and on requirements for safety, health, organisational and environmental performance. Standardisation also has a dimension of public interest, in particular whenever issues of safety, health, security and of the environment are at stake. However, it can inhibit innovation and it is important to ensure that standardisation procedures are fit for purpose and sufficiently fast in order to allow for market uptake.

The impacts of standardisation on the Raw Materials innovation strategy are related to the following aspects:

- Standards for use in the materials composition: granting access to the actual presence of critical raw materials into products;
- Standards for the transparency of the raw materials provenience and traceability;
- Standards regulating the evidence of impacts (e.g. LCA) associated to the whole life cycle of products and their components, permitting EU citizens to make environment conscious choices.

Dynamic standardisation is an important enabler of innovation. This occurs in different ways:

- Standards that express the state of the art give innovators a level playing field facilitating interoperability and competition between new and already existing products, services and processes and solutions. Standards provide customers with trust in the safety and performance of new products and allow differentiation of products and services through reference to standardised methods;
- The development of new standards and evolution of existing standards is also necessary to accompany the emergence of new markets new products, and the introduction of complex systems;
- The use of standards contributes to diffusing knowledge and facilitating the application of technology; this may then trigger innovation, in particular non-technological innovation in the service sector.

Most of the benefits of standards for innovation only materialise when standards are effectively implemented and market-relevant. The actual use of standards remains voluntary, depending on the perception of different market players of their interests and their capacity to use them. Standards may fail to achieve relevance because of the inappropriate timing of their development or their lack of visibility, or due to the existence of competing standards which introduce uncertainty.

Vision: CEN and CENELEC will have improved their assessment of market implications before and during the development of the standards. Standards will be closer to the market on the one hand, protect consumers from low quality products and foster quality products of European origin in the other hand which are in competition from lower quality products from non-European countries and bear environmental and health and safety risks.
Standardisation will also have addressed the needs of the Circular Economy agenda and integrate these considerations.

c) Creating incentives through economic instruments (e.g. national legislation and tax frameworks)

Overall, the aggregated R&D investment of the stock-exchange listed companies has grown by 86% from roughly EUR 1.6 billion in 2003 to EUR 2.9 billion in 2013, at a compound annual growth rate of 6.4%. This is twice as much as the increase in public R&D expenditure, whose rate increased by 2.92%. The biggest growth rates in R&D investments were in the 'Construction & Materials' and 'Mining' categories, which experienced, respectively, 2 and 3.5-fold R&D expenditure increases from 2003 to 2013. The growth rate in 'Industrial Metals & Mining' (73%) roughly corresponds to the overall average, while the growth rate of R&D expenditures was significantly lower in 'Forestry & Paper' — about 11%.

In some mining countries around the world exploration costs are treated as investment in RTD and are either tax free or at least covered by reduced tax rates.

Vision: EU Member States will have reviewed their respective tax regimes with regard to exploration for resources and provide a tax break for exploration as an RTD activity.

1.2. Leveraging the innovative capacity – "picking the brains"

d) Expanding the cross-sector collaborative approach and knowledge transfer: bringing together various ETPs

Cross-sector collaboration is an opportunity for the metals and minerals and the biotic raw materials to gain knowledge and to create mutual benefits and added value through integrated production, processing and recycling concepts.

Therefore substantial progress can be achieved from cross-sectorial themes addressed by other EU funding programs. Such programs can comprise a broad variety of financial support in structural funds and action programs. Funds like Interreg V-A, B, C; ELER, EFRE as well as action programs like LIFE have proven to be complementary to Horizon 2020 raw material R&D funds.

European Technology Platform (ETPs) are crucial to unlock opportunities for cross-sectoral research cooperation. Bringing together key stakeholders from industry, national and European public authorities, the scientific and financial communities, as well as consumers and users, ETPs are unique fora to drive innovation, knowledge transfer and boost sustainability and competitiveness in Europe. However, ETPs need financial and political support to extend and engage.

The support given to ETP Sustainable Mineral Resources (ETP SMR) and the Forest-based Sector Technology Platform (FTP) to develop the VERAM project was effective in identifying potential synergies between two raw materials sectors since and making evident a number of common research and innovation issues.

At the same time, it shed light on the fact that technical innovation has always to be embedded in a broader context of innovation approaches and has to involve other stakeholders and disciplines to ensure successful implementation.

This is specifically true for innovation in recycling because here the whole product lifecycle and various interactors need to be considered. Innovation is a strongly interlinked process:

- Innovations in product design includes design for disassembly, design for recycling, design for tracking & tracing, eco-design since product development;

Early communication and innovation partnerships between developers at multiple ends and an interactive innovation process are crucial;

- Innovations in material sciences and materials substitution impact both demand patterns for primary and secondary production of raw Materials as well as product recyclability;
- Innovative technologies and models for tracking and tracing product and material flows and for predicting product life times in order to build up an inventory of the potential urban mine and create transparency about real flows. The volumes of data impose links with "big data" initiatives; Innovation in sales strategies, economic incentives and business models to close the loop and incentivise the collection of end-of-life (EoL) products;
- Innovation in consumer/user focussed approaches to raise awareness and trigger handling in of EoL products. For consumers, the focus will shift from using products and returning for re-use/re-cycle stead of owning a product. This might require completely different and new business models with potential impact on raw material cycles.

Vision:

Raw materials provide the basis for most societal development and "Megatrends" and therefore conduct research in cooperation with value chains.

Support for coordinated actions between value chain operators as well as horizontal activities such as robotics, digitisation, e-mobility, water and energy is granted as an important support for knowledge transfer and adaptation leveraging major changes in Europe's raw materials supply.

e) Extending Strategic Research Partnerships (existing and future) along global value chains and with preferred "lead" countries

Strategic Partnerships

Strategic Partnerships within Europe, based on the societal challenges and enabling technologies identified need to be supported, be it in the form of the European Innovation Partnership (EIP) on Raw Materials, EIP on Sustainable Agriculture, EIP on Water Efficiency, or Public-Private Partnerships (PPPs) on Energy Efficient Buildings (EeB), Bio-based Industries Joint Undertaking (BBI JU) and Factories of the Future (FoF). These concepts y will be increasingly important and should be fostered.

The Public-to-Public Partnerships supported by Horizon 2020 co-funding are building lasting collaborations, but appear not to have been too influential on Member States' policies and strategies which could be a communication issue and needs to be addressed in the future by either continuing them with a stronger communication chapter or by feeding them into/or linking them to existing other organisations whose remit is to regional foster cooperation amongst Member States.

Partnerships (public-private and public-public) with industry, foundations and public authorities should be taken forward in as far as they mobilise joint investment in established missions, through a simple and flexible co-fund mechanism.

Equally, strategic partnerships with researchers from non-European leading institutions around the world should be fostered to tackle global issues identified by the UN Sustainability Goals, such as climate change and energy related issues in particular. Involving raw materials issues will become key in levering these sustainability goals.

Several key institutions/activities come to mind:

- The EIT outreach
- The EU-Canada investment facility
- The EU-Latin America Platform MNDP
- The Intraw international observatory

Others might be added.

Vision: The results of Climate change policies will have lead to a series of closures of the energy extractive industry and Europe has become the leader in closure and rehabilitation of coal and lignite mine sites. The technologies and practices developed will give the EU a major, exportable know-how that will contribute to effective climate change around the world.

1.3. Leveraging EU's innovation leadership – "hitting the ground running".

f) Supporting innovation in SMEs: the innovation brokers/hubs/incubators

From the EU Innovation scoreboard:

> *About 31% of EU SMEs have innovated by introducing at least one new or significantly improved product or process. In Belgium, Switzerland, and Ireland, more than 45% of SMEs have introduced a product or process innovation. In Romania, this share is only 5%, and in Ukraine, Latvia, Poland, and Bulgaria, it is below 15% (figures for 2014, European innovation scoreboard 2017).*
> *On average 28.8% of SMEs innovate in-house in the EU. Much higher shares are observed in Switzerland and Ireland, where more than 40% of SMEs innovate in-house. In Romania, Poland, Latvia, Bulgaria, the Former Yugoslav Republic of Macedonia, and Hungary, less than 12% of SMEs innovate in-house (figures for 2014, European innovation scoreboard 2017).*
> *About 11% of EU SMEs collaborate with others in their innovation activities. In Belgium, the United Kingdom, Iceland, and Austria, this share is more than 20%, whilst in Ukraine, Romania, Latvia, Bulgaria, Poland, and Malta, this share is less than 5% (figures for 2014, European innovation scoreboard 2017).*

Biotic

More than 365,000 SMEs in the **forest-based sector** in Europe employ over 2.5 million people. These SMEs in the forest and woodworking industries are key drivers of innovation, thanks to their ability to quickly and efficiently transform new ideas into successful businesses. They cover a wide range of traditional and innovative industrial activities: **timber** harvesting; stand management and transport; sawmilling and pressure treatment; veneer, panel and board production; joinery and carpentry; the manufacture of construction products, pallets, packaging and furniture; printing, wood-related biotechnology and specialist communication and information services. Recycling of paper, board and other wood-based products corresponds to a significant part of the raw material streams.

Cork, a non-timber forest product, is another important biotic Raw Material. Portugal and Spain together produces more than 4/5 of all cork produced world-wide. Cork is mainly used for wine stoppers (more than 70%). If not counting farmers of cork, the industry is rather consolidated into a few large companies.

Natural Rubber is mainly used for tyres and imported to Europe by companies such as Bridgestone and Michelin. The value-chain supports some 4000 companies in Europe, most of them SMEs.

Often located in rural areas, these companies make an important contribution to the local economy, labour markets and the demographic structure, also helping to reduce migration to cities. This strength should help overcome the European dilemma of huge research funding budgets resulting in relatively little private-sector exploitation and commercialization.

SMEs are particularly important in laying the ground for new value chains to emerge. In future value chains, existing biorefinery units (e.g. pulp and sawmills) play an essential role as they can supply the downstream value chain actors with renewable, non-food raw material. The range of raw materials processed by integrated biorefineries operated by the forest-based industries will be broadened to include agro-materials and various recycled materials (‘urban biorefinery’). This will strengthen the competitiveness of the forest-based industries in their current markets.

Metals and Minerals Sector

The extractive sector has a large number of SMEs in the aggregates and the ornamental stone segment whereas in the industrial minerals, metals and coal and lignite segment the enterprises are usually larger. In the technology supply segment there are both.
This creates two challenges for the sector: active involvement of SMEs in research and development and innovation and secondly the dissemination of results into the sector.

Vision: In 2030 already the sector will not only continue to use its professional organisations to mobilise more SMEs and tap into their innovative abilities, but active European and national brokering and support networks will be available in every MS.
The minerals sector will have a specific Mining Competence Centre to provide active training and coaching for professionals of SMEs on the ground and on site to facilitate transfer of knowledge.

g) Supporting the "genius"

The EIT CHANGE Award celebrates graduates of EIT-labelled education programmes who spur innovation and entrepreneurship and bring about a change in the areas of climate change, digitalisation, energy, health, food and raw materials addressed by the EIT and its innovation communities.
The EIT Innovators Award recognises innovation teams composed of individuals from our innovation communities that have developed a product, service or process with a high potential for societal and economic impact.

Vision:
The EIT award is well recognised worldwide and brings international recognition to the winners.

h) Extend awareness raising, education, skills and capacity building: the EIT Raw Materials

Training, capacity building and education are an essential part to foster innovations in the raw materials sector. The value chain of today's raw material management in the form of closed product life-cycles from exploration-mining-processing-refining–recycling and back to new products offers ample opportunities for jobs, many of them advanced and highly sophisticated. Besides innovations in technology, we also need social innovations to develop skills and transfer knowledge and understanding within and beyond current practice. It is essential that training and education includes a strong interdisciplinary approach to address the complex interdependencies in the RM field and to facilitate a true value chain approach. It further requires collaborative work between research institutions in the EU 27 Member States.

Stronger ties between industry and universities in general through public and private sector partnerships should be developed as well as increased mobility in between sectors to nurture innovations. Well-funded academic institutions that foster research and education of future researchers will be required to further develop and maintain technological leadership.

A secure access to raw materials also requires capable human resources. We need to raise awareness among young people for the significance of the sector as a corner stone in the sustainable development of Europe and to attract more students to engage in related fields.

The EIT Raw Materials

The EIT Raw Materials, initiated by the EIT (European Institute of Innovation and Technology) and funded by the European Commission, is the largest and strongest consortium in the raw materials sector worldwide. Its vision is a European Union in which raw materials are a strategic strength. Its mission is to boost competitiveness, growth and attractiveness of the European raw materials sector via radical innovation and guided entrepreneurship.

EIT RawMaterials unites more than 100 partners – academic and research institutions as well as businesses – from more than 20 EU countries. They collaborate on finding new, innovative solutions to secure the supplies and improve the raw materials sector all along its value chain – from extraction to processing, from recycling to reuse. It supports entrepreneurs, Start-ups and SMEs receive funding and support through our partner network and collaboration activities, fostering innovation and empowering students, entrepreneurs and education partners.

It will play a key role in bridging the valley of death and bringing the research developed under EU and national funding programmes to the market.

Awareness raising and education

The concept of sustainability with respect to the use of natural resources must become an accepted and integral part of the educational system, in order to promote a wider understanding of the importance of raw materials and their geological context, alongside other teaching in the natural sciences. This is important not only to the general educational curriculum but also to economics and commercial studies in particular. RM sector training programmes must be further promoted over the medium and long term, with efforts to strengthen international connections. These objectives are aligned with those of the “young people on the move” flagship projects of the Europe 2020 plan, which aims to improve education system results and facilitate young people’s access to the job market. We should accordingly actively promote the inclusion of RM sector education objectives within the EU’s training programmes.

From the EU Raw Materials Scoreboard

At global level, more than 90 % of mineral processing graduates are reported to be educated in Asia, Africa, and South and Central America. The figure for Western Europe is less than 1 %. Data also indicate that the number of educational programmes in the EU relevant to raw materials is in decline. The mining and minerals sector in particular is already reported to be suffering from a significant talent shortage (Indicator 10).
The mining and minerals processing sector in many parts of the world, but also in Europe is reported to be characterised by a talent shortage.

- *At global level, more than 90 % of mineral processing graduates are reported to be educated in Asia, Africa, South and Central America; the figure for Western Europe is less than 1 %.*
- *Within the EU, countries with a strong mining industry and/or a long-standing mining history have in general more educational programmes related to raw materials.*
- *There are indications that the number of educational programmes relevant to raw materials is in decline. The dismantling of the coal extraction sector will lead to a further drain in funds, university courses, research institutions and students.*
- *The average level of workforce qualification increased between 2009 and 2013. With the increasing uptake of new technologies in the area of automation and digitisation the need for additional training and further qualifications will rise.*

Vision:

The work started under the European Skills, Competences, Qualifications and Occupations (ESCO) with the identification of professional profiles will have been completed with an EU wide standardisation of qualifications in the sector.

Further education and life-long-learning in particular with regard to health and safety, automation and robotics, as well as digitisation will have developed into a harmonised European-wide multi-lingual training programme.

2. Assessing progress and success

The **EU's Innovation Scoreboard 2017** states that the indicator measures **the technological competitiveness** of the EU, i.e. the ability to commercialise the results of research and development (R&D) and innovation in international markets. It also reflects product specialisation by country. Creating, exploiting, and commercialising new technologies are vital for the competitiveness of a country in the modern economy. Medium and high technology products are key drivers for economic growth, productivity and welfare, and are generally a source of high value added and well-paid employment. Exports of medium and high-tech products account for 56% of total product exports in the EU. For Hungary, Germany, Slovakia, and the Czech Republic, shares are above 60%. For Iceland, Norway, and Greece, exports of medium and high-tech products are below 25%.

The indicator: R&D expenditure in the public sector as percentage of GDP

R&D expenditure represents one of the major drivers of economic growth in a knowledge-based economy. As such, trends in the R&D expenditure indicator provide key indications of the future competitiveness and wealth of the EU. Research and development spending is essential for making the transition to a knowledge-based economy as well as for improving production technologies and stimulating growth. The average R&D intensity in the public sector is 0.71% for the EU. R&D expenditure in the public sector is close to or above 1% of GDP in Denmark, Sweden, and Finland. In the Former Yugoslav Republic of Macedonia, Bulgaria, and Romania, R&D intensities in the public sector are below 0.30% of GDP.

The indicator: R&D expenditure in the business sector as percentage of GDP

The indicator captures the formal creation of new knowledge within firms. It is particularly important in the science-based sectors (pharmaceuticals, chemicals and some areas of electronics), where most new knowledge is created in or near R&D laboratories. The R&D intensity in the business sector is above 2.00% of GDP in only four countries: Israel, Sweden, Austria, and Switzerland. The average R&D intensity in the business sector for the EU is 1.30%. For 12 countries, the intensity is below 0.50%, and it is particularly low in the Former Yugoslav Republic of Macedonia, Cyprus, and Latvia.

Overall, the aggregated R&D investment of the listed raw materials companies has grown by 86 % from roughly EUR 1.6 billion in 2003 to EUR 2.9 billion in 2013, at a compound annual growth rate of 6.4 %. This is twice as much as the increase in public R&D expenditure, whose rate increased by 2.92 %. The biggest growth rates in R&D investments were in the 'Construction & Materials' and 'Mining' categories, which experienced, respectively, 2 and 3.5-fold R&D expenditure increases from 2003 to 2013. The growth rate in 'Industrial Metals & Mining' (73 %) roughly corresponds to

the overall average, while the growth rate of R&D expenditures was significantly lower in 'Forestry & Paper' — about 11 %.

The indicator: Non-R&D innovation expenditure as percentage of total turnover

This indicator measures non-R&D innovation expenditure as a percentage of total turnovers. Several of the components of innovation expenditure, such as investment in equipment and machinery, and the acquisition of patents and licenses, measure the diffusion of new production technology and ideas. On average, 0.76% of enterprises' total turnover is spent on non-R&D innovation activities in the EU. In Turkey, Switzerland, and Lithuania, this share is at or above 2%. In Luxembourg and the Netherlands, less than 0.2% of enterprises' total turnover is spent on innovation activities not involving R&D.

The indicator: for knowledge-intensive services exports as percentage of total services exports

This indicator measures the competitiveness of the knowledge-intensive services sector. Competitiveness-enhancing measures and innovation strategies can be mutually reinforcing for the growth of employment, export shares, and turnover at the firm level. The indicator reflects the ability of an economy, notably resulting from innovation, to export services with high levels of value added, and successfully take part in knowledge-intensive global value chains. At EU level, 69% of total services exports are knowledge-intensive. Export shares are more than 75% in Ireland, Luxembourg, the United Kingdom, the Netherlands, Norway, and Sweden. Export shares of knowledge-intensive services are very low, below 25%, in Croatia and Lithuania.

Innovation is essential for the EU to remain competitive internationally. Despite being an industry of low R&D intensity, top R&D investor companies in the raw materials sector have almost doubled their annual R&D expenditure since 2003. Between 2003 and 2013, it grew more than twice as fast as public R&D investments (Indicator 8).