Ref. Ares(2018)4131269 - 06/08/2018

VERAM

Vision and roadmap for European raw materials

Vision for Raw Materials in Europe and for Europe Part II

D4.2 – Report on raw material research and innovation vision for 2050

WP4 – Creating a vision 2030 and 2050 for raw materials

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 690388

Document description

Project	Vision and Roadmap for European Raw Materials
Acronym	VERAM
Grant Agreement	690388
Funding Scheme	Horizon 2020
Webpage	http://www.veram2050.eu
Project Coordinator	ETP SMR
Work Package	WP4
Work Package Leader	ETP SMR
Deliverable Title	Report on raw material research and innovation vision for 2050
Deliverable Number	D4.2
Deliverable Leader	ETP SMR
Version	4
Status	Final
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Due date of deliverable	30/05/2017
Actual submission date	23/10/2017 (advanced draft); final version re-submitted 06/08/2018
Acknowledgements	

Dissemination level:

X	PU	Public
	PP	Restricted to other programme participants (including the Commission Services
	RE	Restricted to a group specified by the consortium (including the Commission Services)
	CO	Confidential, only for members of the consortium (including the Commission Services)

Document history:

Version	Date	Authors	Description
1	03/07/2017	Corina Hebestreit (ETP SMR)	Revision of input and compilation of draft document
2	30/05/2018	Corina Hebestreit (ETP SMR)	Update based on final WP3 conclusions and WP5 roadmap
3	31/05/2018	Boris Vashev (FNR)	Revision
4	05/06/2018	Holger Grünewald (JULICH)	Revision
5	08/06/2018	Corina Hebestreit & Patrick Wall	Final version

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The EU Raw Materials sectors will achieve and underpin greater

- **Sustainability**
- **by providing and improving the sustainable supply and use of primary, secondary and renewable RMs throughout the values chains.**
- **by developing and implementing improved and better adapted measurable scientifically based values/indicators/standards associated with sustainability through the whole value chain where needs have been identified using newly developed data management systems.**

- **Economic resilience**
- **by increasing the resilience of the EU economy by decreasing import dependencies and ensuring base load supply through diversification of primary, secondary and renewable raw materials.**
- **by developing new business models.**

- **Technological leadership**
- **by developing and adapting new technologies such as digitisation, automation, robotics and AI;**
- **by establishing new value chains. Current processes will change radically through big data management;**
- **by improving scientific and technical dialogue along and across business lines, exchange experiences, advance and leverage good practices;**
- **through cross-disciplinary integration between academia and business for identification and development of new, cross-sectorial value chain opportunities.**

INTRODUCTION

Currently the EU is partially self-sufficient in raw material supply, but partly also highly dependent on imports of raw materials that are crucial for a strong European industrial base, an essential building block of the EU's growth and competitiveness.
Raw material production in Europe is under threat from lack of knowledge on raw materials, competing land use and urbanisation as well as the NIMBY attitude and a hypocritical attitude to the sustainability of raw materials used in imported products.
The economic and geo-political changes addressed in the first part of the vision paper and their impacts on raw material supply need to be considered when creating a long-term vision.

The long term vision is to tap the full potential of primary and secondary raw materials to increase the EU's economic resilience, secure growth, jobs and long-term sustainability.

Therefore the innovation capacity of the EU raw materials sector needs to be leveraged, turning it into an even stronger sustainable pillar of the EU economy and a more attractive industry, addressing societal challenges and increasing benefits for society.

Knowledge, innovative creativity, development and capacity building
This can only be done by gaining relevant knowledge about raw materials in Europe and if all the stakeholders, including the relevant authorities, raw materials and downstream industries, research communities and society work towards the same objectives.

In order to secure a sustainable supply, Europe is therefore confronted with a number of challenges along the entire raw materials value chain composed of exploration, extraction, harvesting processing/refining, recycling as well as substitution:

- reduction of import dependency, diversification of resource base,
- optimised resource use and higher resource productivity,
- achieving international competitivity,
- further municipal and regional development and regeneration,
- clean-up of mining and other industrial legacies,
- improved national, regional, and local environmental competence and expertise,
- more and higher paying jobs,
- workforce redeployment and retraining, increased technical training,
- clean water, air, soil and other essential elements including dust abatement, noise abatement, and occupational health and safety,
- application and continued development of advanced technologies.

The metals and minerals value chain

The European mineral raw material sector is facing critical challenges in terms of supporting the transition to a low-carbon, fossil-free sustainable Europe and the green economy.

The metals mined are critical to build electric infrastructure as well as energy storage systems, renewable energy power plants and vehicles for both personal and commercial use.

The sustainable supply of metals and minerals will also be critical to build a future sustainable society that will rely heavily on new transport infrastructure as well as new green buildings.

The mining sector and the mineral processing sector are vital to securing the supply of metals extracted in a sustainable manner. The traditional value chain spans from geological exploration, mining and processing to the recycling of metals. However, in order to meet future challenges a cross-sectoral approach has to be applied which takes into consideration the complete material's circle including product design, production and remanufacturing, (re-)use and repair in order to avoid dissipation wherever it occurs. The aggregate sector is spread throughout Europe providing

aggregates for the building and infrastructure industries. Embedded in the value chain is a strong environmental commitment both during operation, as well as for the reclamation of land used for mining.

The biotic value chain

The biotic value chain provides means to tackle global challenges by replacing fossil-based raw materials with sustainable, renewable raw materials sourced in Europe. Forests cover 42% of the EU's land area. The forest-based sector is a key enabler for a low-carbon, bio-based society.

The value chains produce a wide range of products ranging from wood construction products, packaging, furniture, paper and pulp products, and hygiene articles to bio-plastics, bio-composites, carbon fibres, textile fibres and bio-chemicals. Furthermore, forests provide biodiversity and many ecosystem services that are of importance for human well-being and health, including clean air and water and recreational activities. In addition, forest and forest products are a renewable resource, and therefore there is a need to include long-term sustainable measures in forest management. Forests are also fundamental to the mitigation of the effects of climate change.

Natural rubber is a strategic raw material, on which European industry has a complete import dependency. Natural rubber is mainly produced in Asia (93%). Hevea, however, a native tree from South America, is currently the only commercial source of natural rubber. Guayule (Parthenium argentatum) is one of the alternative sources, growing on marginal lands in semi-arid regions of European Mediterranean countries.

I. Assessing the gaps in today's situation

Different scenarios for the future development of our society and their potential impact on the raw materials consumption were assessed leading to the conclusion that whatever the societal development will look in detail, the overriding driver for raw materials consumption will be the growth in population and its demand for increasing living standards.
Relevant megatrends were briefly analysed. The following developments were included:

- demographic shifts;
- changes in income distribution;
- consumer behaviour and preferences;
- economic globalization, et cetera.

Current funding programmes available for the raw materials sector were assessed and it was found that there are many different ways of assessing the merits of funding programs in general, it can be stated that funding programs have to satisfy certain criteria in order to drive innovation, through environmentally and socially sound and economically feasible solutions. The main criteria used to assess the merits of funding programs and initiatives were built along four-dimensional impacts:

- Economic and social: overall affordability of the funding program while considering investment efforts and other economic parameters as well as impact on job creation and skills;
- Criticality: contribution of a funding program to the reduction of the criticality of a given raw material;
- Environmental: based on quantitative and generally acknowledged databases to establish ecological footprints of funded initiatives;
- Innovation: the innovation criteria are dealing with factors that determine whether innovation reaches (or has the potential to reach) the market place.

Existing roadmaps on minerals, metals, aggregates, wood and natural rubber were scrutinized to support the identification of the market needs that might arise from the responses of the different sectors to the societal challenges, as listed for defining the policy priorities of the Europe 2020 strategy:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bio-economy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Europe in a changing world - inclusive, innovative and reflective societies;
- Secure societies - protecting freedom and security of Europe and its citizens.

What have other ETPs identified as raw material related issues

An assessment of the trends in the value of the EU's raw material demand (2001-2011) have shown differences for RM from mining & quarrying versus RM from forestry & logging:

- Mining & quarrying: sharp increase of absolute values and imported values.
- Direct inputs of raw materials from mining and quarrying constitute 0.5% of the total final EU output value, while imported raw materials account for 0.17%.
- Forestry: modest increase of absolute values of forestry & logging products but sharp decrease of imported value.
- Main import dependent sectors: manufacture of furniture & public administration (Forestry); manufacture of basic metals (Mining & quarrying).

Hence raw material policies designed for the sectors dependent on forestry products will face different challenges and hold other opportunities compared to the sectors dependent on abiotic raw materials, from mining and quarrying for example.

An assessment of the Strategic Research and Innovation Agendas of the following European Technology Platforms (ETPs) was carried out and resulted in the following issues being identified as recurring across the different sectors and areas of expertise:

Individual ETPs

Bio-based economy	Energy	Environment	ICT	Production and processes	Transport
EATIP	Biofuels	WssTP	ARTEMIS	ECTP	ACARE
ETPGAH	EU PV TP		ENIAC	ESTEP	ALICE
FABRE TP	TP OCEAN		EPoSS	EuMaT	ERRAC
Food for Life	RHC		ETP4HPC	FTC	ERTRAC
Forest-based	SmartGrids		euRobotics [AISBL]	Manufuture	Waterborne
Plants	SNETP		NEM	Nanomedicine	
TP Organics	TPWind		NESSI	SMR	
	ZEP		Networld 2020	SusChem	
			Photonics 21		

Supply issues

- Ensure sustainable production of large amounts of primary and secondary raw material
- Low impact extraction, non-explosive based
- Robotics: the only extractive technology that may be the way of extracting significant marine mineral resources
- Define and develop the urban-mining concept in the European regions in concordance with the environmental policies
- Development of new prospection for mining
- Developing local supply "use what I have", addressing the EU's "NIMBY" philosophy, e.g. in the case of rare earths
- Increase of sustainable materials at cost competitive prices
- Coping with higher cost/lower availability of energy and raw materials

Resource efficiency issues

- Better utilisation of natural raw materials to eliminate feedstock shortages and increase self-sufficiency
- More efficient use of non-renewable resources and better use of renewables
- Improving efficiency in processing
- Reduction of the specific raw materials to avoid scarcity and to reduce costs by improving design and materials science
- Sustainability parameters of raw materials, use/care aspects of end products and prediction/simulation of performance

Processing technology

- Flexible and mobile processing plants for industrial minerals and aggregates, with energy and transport savings
- Implementation of more continuous and interconnected processes, a route to leaner energy and raw materials use through higher yields
- New methods for treatment of raw materials
- For the Conception and design phase quantifying quality

Data handling and digitisation

- a harmonised way to assess the content of raw materials in products and to collect this information in databases that are then accessible to all actors
- EU Raw Materials Knowledge Base
- New technology developments as robotic mining will map and monitor new large spaces, thereby contributing to "big data" resources

II. Assessment of the needs for a strong European industry

"As it concerns the structure of the EU economy, it is unquestionable that manufacturing remains vitally important for the EU economy. Before the present economic crisis, it contributed some 17.1 % of GDP and accounted for some 22 million jobs (2007). However, the industrial base in Europe stretches far beyond the industrial core of manufacturing and represents a far greater share of the economy than these basic statistics imply. When the wider productive sector is factored in (power generation, construction) along with associated business services the share of GDP is about 37 %.
Indeed, the statistical dichotomy between industry and services does not reflect the reality of the modern
business world. Many industrial companies also derive substantial shares of their revenues from service provision, but there is little quantitative information in this field. Overall, services (including business services and many others) now account for 55.5 % of value added and 60.8 % of employment in the non-financial business economy.
Manufacturing productivity is the motor driving EU wealth creation. There has been a massive increase in manufacturing labour productivity by some 46 % over 1995-2007 compared with economy-wide productivity of less than 20 % over the same period. This productivity performance has been achieved through process and product innovation, and outsourcing of non-core manufacturing business activities (e.g. logistics, facility management, ICT) and an increasing use of a better qualified industrial workforce. In the same period 1995-2007 employment in manufacturing has declined by 0.5 % per year compared with an annual growth rate of 4.5 % in business services (including renting and real estate). As there is no indication that this trend is likely to go into reverse, EU industry will continue to generate economic growth, but it will largely contribute indirectly to employment creation through generation of increased demand for business related services."

In its report "Global Europe 2050"[1] the Commission clearly identified the industry and in particular the manufacturing industry as one of the key drivers of growth for the coming decades. In order to address the key drivers, but also the societal pressure points the raw materials sector will have major challenges till 2030 and 2050.

➢ A still vital European industry[2] and a rising consumption of raw materials

Essential component to the EU's growth and competitiveness:

The raw materials sector is underpinning this economic sect and at the same time is benefiting from its development.
While the EU is close to being self-sufficient for non-metallic minerals, it is highly dependent on the imports of metallic ores, importing roughly 60% of total demand annually.

Many of these metallic ores are crucial for a strong European industrial base, an essential component of EU's growth and competitiveness (Table 1). Furthermore, metal imports are expected to increase for the mid- and long-term future in light of the enabling technologies required to combat climate change and maintain living standards in Europe. Across the continent, more than 12 million people are employed directly in the industry or in down-stream sectors that depend on access to metals such as construction, chemicals, automotive, aerospace, machinery and equipment sectors. Together, these sectors provide a total added value of €700 billion.

It is worthwhile looking at the various industrial sectors to get an idea of the potential demand for the future and to assess other factors, such as energy and resources efficiency and general sustainability aspects.

[1] European Commission: Global Europe 2050, Brussels 2012
[2] European Commission : Global Europe 2050, Brussels 2012, page 68

2.1 Infrastructure and raw materials

The world needs to close its $1 trillion annual infrastructure investment gap. The importance of infrastructure as a key driver of economic growth, competitiveness and social well-being is well established. Yet, a significant number of economically viable infrastructure investments are not moving forward, not in the EU and not worldwide. The EU should address its own gaps and can use the leverage of know-how to improve the world's sustainability goals by know-how transfer and engagement.

Whilst considerable investments have been made in the past decades to develop the infrastructure in particular in Eastern Europe, South-East Europe has fallen behind due to the economic crisis. Equally many older Member States have identified needs for renovating or rebuilding their infrastructure because he has come of age. At the same time climate change rising water levels might require additional infrastructure and protection measures.

The progressing electrification of the road transport system will also require additional infrastructure measures that will consume materials.

2.2 Raw materials required for new technologies

The portfolio of emerging technologies analysed by a study by ITS and Fraunhofer identified a list of required sectors and technologies which is far from complete and would deserve an expansion to even more emerging technologies. [3]

[3] IZT and Fraunhofer : Final report abridged. Raw materials for emerging technologies. Karlsruhe/Berlin 2009, page 6

Automotive engineering,	1. Light-gauge steel
	2. Electric traction motors for vehicles
	3. Fuel cells electric vehicles
Aerospace industry	4. Super capacitators
	5.Scandium alloys for constructing lightweight airframes
Information and communication technology, optical technologies, micro-technologies	6. Lead-free solders
	7. RFID
	8. Indium-Tin-Oxid
	9. Infrared detectors
	10.White LED
	11. Fiber optic cable
	12. Microelectronic
	13. High performance micro
Energy, electrical and drive engineering	15. Thermoelectric generato
	16. Dye-sensitized solar cells
	17. Thin layer photovolatics
	18. Solarthermal power stations
	19. Stationary fuel cells -SOFC
	20. CCS – Carbon Capture Storage
	21. High performance lithium-ion batteries
	22. Redox flow batteries for electricity storage
	23. Vacuum insulation
Chemical, process, production and environmental technology, mechanical engineering	24. Synthetic fuels
	25. Seawater desalination
	26. Solid state lasers for industry
	27. Nano-silver
Medical engineering	28. Orthopaedic implants
	29. Medical tomography Materials technology
Materials technology	30. Super-alloys
	31. High-temperature superconductors
	32. High performance permanent magnets

Based on these technologies the global demand has been estimated and clearly indicates the increases in demand expected.

Global demand of the Emerging technologies analysed for raw materials in 2006 and 2030 related to today's world production of the specific raw materials[4]

Raw material	2006	2030	Emerging technologies (selected)
Gallium	0.28	6.09	Thin layer photovoltaics
Neodymium	0.55	3.82	Permanent magnets, laser technology
Indium	0.40	3.29	Displays, thin layer photovoltaics
Germanium	0.31	3.29	Fibre optic cable, IR optical technologies
Scandium	low	2.28	SOFC, aluminium alloying element
Platinum	low	1.56	Fuel cells, catalysts
Tantalum	0.39	1.01	Micro capacitors, medical technology
Silver	0.26	0.78	RFID, lead-free soft solder
Tin	0.62	0.77	Lead-free soft solder, transparent electrodes
Cobalt	0.19	0.40	Lithium-ion batteries, synthetic fuels
Palladium	0.10	0.34	Catalysts, seawater desalination
Titanium	0.08	0.29	Seawater desalination, implants
Copper	0.09	0.24	Efficient electric motors, RFID
Selenium	low	0.11	Thin layer photovoltaics, alloying element
Niobium	0.01	0.03	Micro capacitors, ferroalloys
Ruthenium	0	0.03	Dye-sensitized solar cells, Ti-alloy
Yttrium	low	0.01	Super conduction, laser technology
Antimony	low	low	ATO, micro capacitors
Chromium	low	low	Seawater desalination, marine technologies

[4] IZT and Fraunhofer: Final report abridged. Raw materials for emerging technologies. Karlsruhe/Berlin 2009, page 10

2.3 A challenging transition to digital Europe[5]

"Nowadays, in Europe, the ICT sector is directly responsible for 5 % of European GDP, with a market value of € 660 billion annually, but it contributes far more to overall productivity growth (20 % directly from the ICT sector and 30 % from ICT investments).
… This will present interesting challenges as business come to terms with a world in which collaboration, open innovation and crowd sourcing may make the traditional corporate structure seem very out-dated. Over the next decades, we should expect that fast, efficient connectivity will facilitate the growing trend towards virtual companies as knowledge workers increasingly become free agents.
It will be challenging for business and other organizations to find new ways of work-life integration. The increasingly free production and access to information content will challenge the traditional business model in many sectors too….."

The raw materials sector provides vital raw materials for the hardware and at the same time is and will be a beneficiary in particular of the software and data management (be it for exploration, process management and controls, quality controls), but also the automation and robotics for extraction, processing and logistics) enabled by digitisation.
The 5G developments and their implementation in industrial contexts are highly desirable.
For the raw materials sectors this means two things:

- On the one hand the sector will embrace in the coming years the digital revolution and already by 2030 new raw material extraction sites will be fully automated. Older ones might need longer to adapt- due to the large investments required or sometimes the infeasibility of adaptation due to existing structures. It will provide autonomous transportation and zero-exposure to emissions and occupational risks.

- On the other hand, the minerals sector will provide the vital raw materials for the devices and machines that enable the digitised world. If Europe does not want to leave this market to the developing world it needs to develop and provide its own resources and foster research into the tools, devices, machines and applications.

For many electric and electronic devices the raw materials are coming nowadays from non-European countries, the potential growth market therefore does not lie in the production of the raw materials, but in their use and its applications in highly sophisticated machinery and devices. For some raw materials, relevant foresight studies have identified growth rates of more than the factor 100.

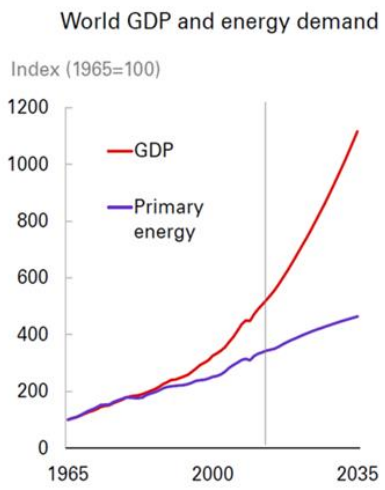
[5] European Commission : Global Europe 2050, Brussels 2012, page 74

"Overall oil and gas demand is growing faster than new reserves are being found, and, in addition, most of the oil is in the Middle East and most of the gas is in the Middle East, Europe and Russia. …
The International Energy Agency (IEA) reference scenario proposes that, over the next twenty years, global energy demand will increase by around 40 % – so an average of 1.5 % a year – with the vast majority of the growth coming from non-OECD countries such as China, India, etc. Oil will remain the largest single fuel, providing 30 % of the total energy mix, with more and more transport accounting for 97 % of the increase in its use. Global gas supply will also increase by around 45 % by 2030 to provide just over a fifth of the world's energy needs.
World electricity demand will grow at an average of 2.5 % a year. In 2009, 13-14 % of the world's electricity came from nuclear power and its use is expected to grow in most regions except Europe. However, its overall share of electricity is expected to fall. In absolute terms, the biggest increases in demand will be met by coal-based power generation. The growing use of renewable energies – wind, wave, solar, hydro and geothermal – will start to make an impact but, in comparison to the other energy sources, their individual shares of the mix will still be in single figures by 2020.
Associated to this type of energy prospect, there is a continued rise in carbon emissions.
By 2020, an additional 5 000 million tonnes will be being emitted annually, and double that by 2030.
So, without a massive and fundamental global shift in energy consumption behaviour, any chance of slowing CO2 emissions is years away."

2.4 Increased energy constraints[6]

Climate change and the minerals-energy nexus
The climate change challenge and the energy demand should be addressed on a global scale.

Raw materials provide a variety of solutions or contribute to the solution of these energy constraints, either by
- providing bio-fuels, or
- providing raw materials that are required for extracting and/or processing energy sources, and
- delivering this energy to the customer.



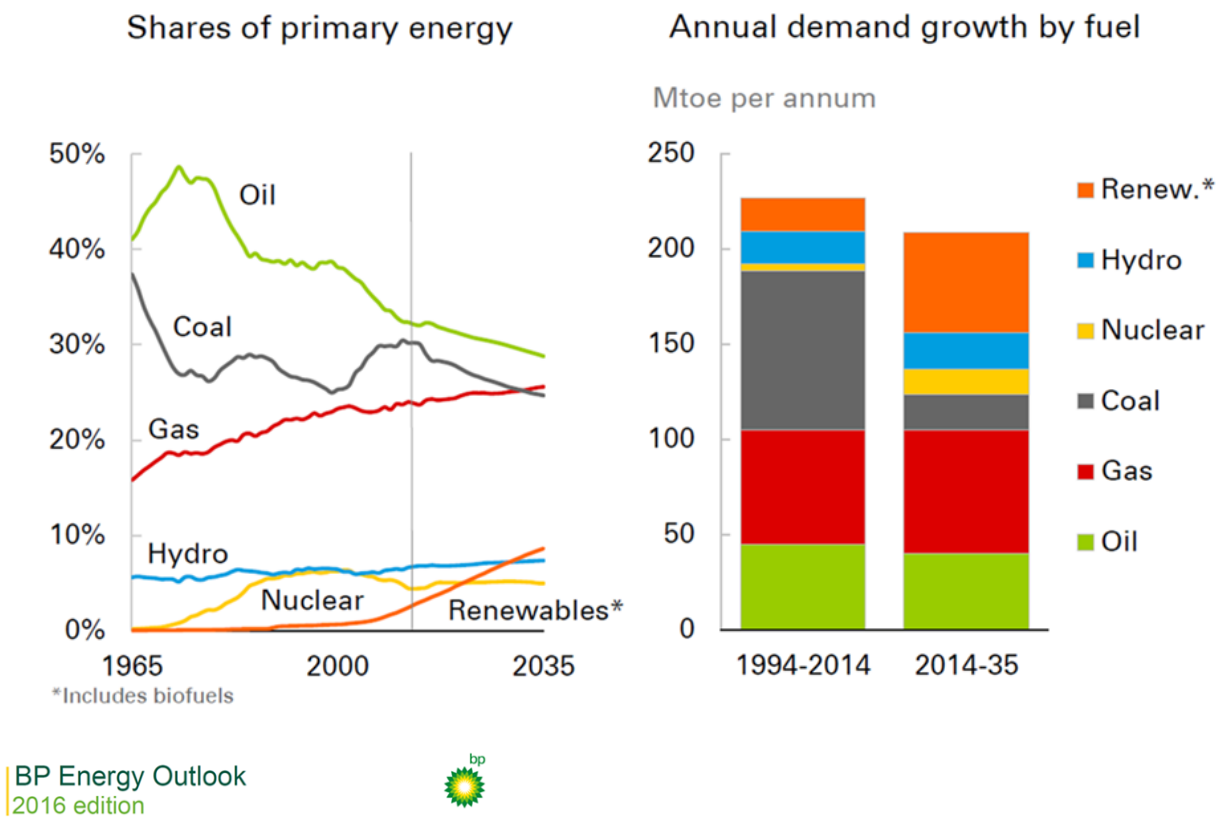
At the same time alternative energy production will require considerable amounts of raw materials.
Raw materials provide 97% of our current energy through fossil fuels, uranium and biomass (IEA 2010) (10). Global energy demand will also continue to rise (IEA, 2014)
The infrastructure of the energy sector requires the massive use of metals and minerals, in particular
(1) steel for ships, pipelines, mining equipment, power plants, refineries and exploration activities,
(2) copper for the electricity grid, generators and electric motors, and
(3) aluminium, primarily for the electricity grid, and
(4) a host of other metals and minerals including phosphorous, potassium and nitrogen for biomass production.

[6] European Commission: Global Europe 2050, Brussels 2012, page 66

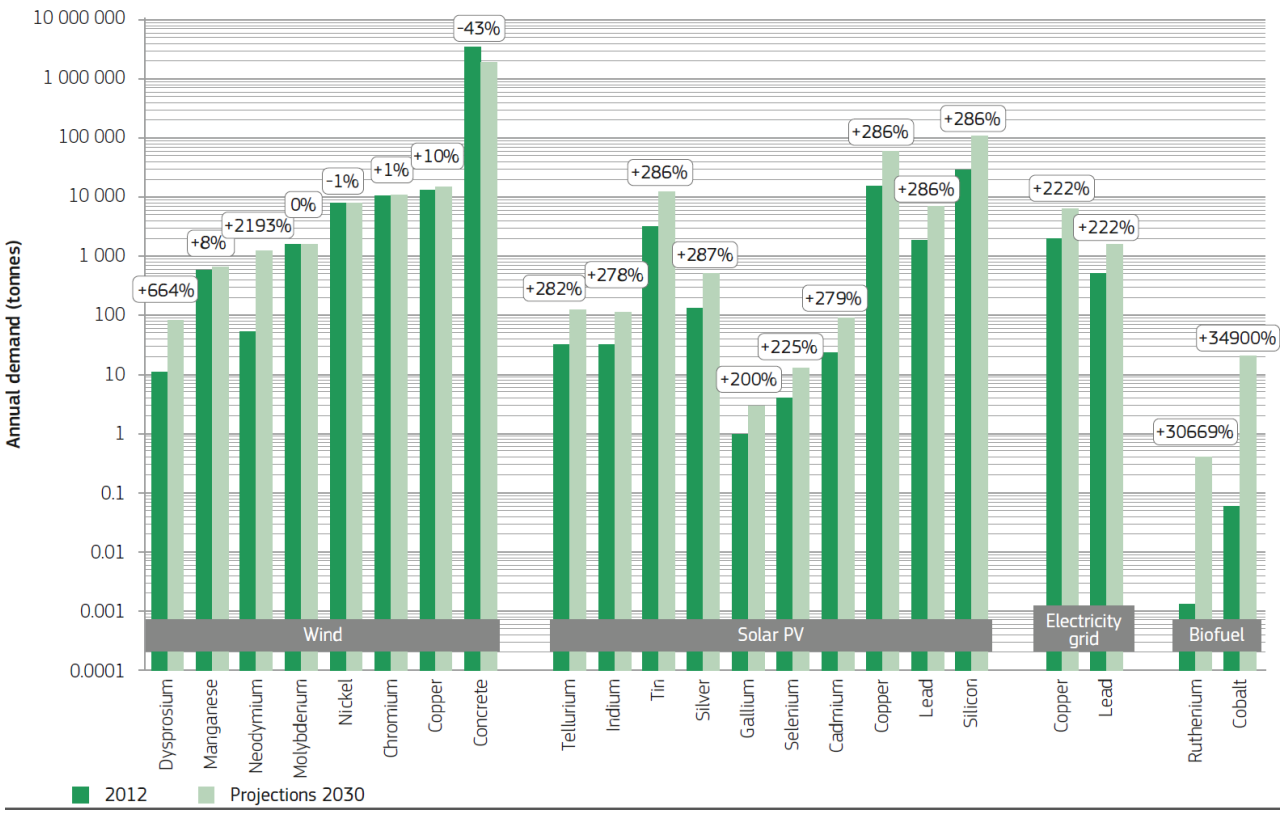
The remainder of the energy is produced through hydropower, wind and sunlight – which need huge amounts of concrete, steel and specialty metals (Hertwich et al. 2015).
It is this low carbon energy supply that global leaders will seek to expand in order to transition to a low carbon society within the coming decades to counterbalance climate change.

Therefore sustainable and competitive energy supply and use requires

- diversification,
- competitively priced alternative/renewable energy,
- development of infrastructure,
- reduction of emissions.



The demand for many of these raw materials is predicted to grow by varying factors from doubling to hundred times. Exact predictions are not possible since the market will decide on the technologies to go forward and the rate of market uptake till 2050. However, it is probably fair to assume that 2030 and 2050 will still see an energy mix and hence the use of a variety of raw materials to provide for the ever-growing demand, at least on a global scale since predictions of population growth also suggest an overall increase in energy demand.



Current (2012) and projected (2030) annual **demand of raw materials** used for selected low-carbon energy technologies. EC Scoreboard 2017

2.5 The societal challenge linked with the EU's climate change policy

Not only Europe's coal mines will be gradually closed and increased knowledge and capacity is required to do so. This process will require not only special know-how in terms of closure of such sites, but also in terms of land and water as well as biodiversity management.

The whole area of social and economic restructuring is an area where some EU Member States have acquired expertise in the past years, but good and bad experiences and lessons to be learned have not been collected across the EU and an EU competence centre in this area should be fostered.

Cooperation between the two technology platforms in this area would be very valuable.

"Water is clearly a key resource, without substitutes of any sort. As GDP per capita rises, so does water demand and by 2025 two-thirds of the world's population are expected to be living in water-stressed regions.
The problem is not new, as over one billion people currently experience water scarcity, having less than the minimum 50 litres a day recommended by the UN. In Europe, we use around 300 litres per day and the average US citizen consumes twice that. With 20 % of the population but only 7 % of global water supplies, China is particularly vulnerable. The World Bank reports that half of China's 660 cities suffer from water shortages, affecting 160 million people. Worse, it seems that about 90 % of cities' groundwater and 75 % of the rivers and lakes are also polluted. Despite all the bad news, water is still however a renewable resource: we are not running out of it. A significant part of the problem is the huge and often deeply inefficient use of water. In addition, throughout many parts of the world, rainfall and river flows are strongly seasonal, with too much water arriving during monsoon periods followed by maybe seven or eight months of water scarcity. Climate change will exacerbate this and we will increasingly get the wrong water in the wrong places at the wrong times of the year."

2.6 Rising pressure on water[7]

Water management is a key issue in the raw materials sector and needs to be handled together with land management whether in and around currently operating businesses or in the context of closure and legacy projects. At the same time the raw materials sector provides products, solutions and services for water management.

Solving water management issues in around newly established raw material operations should no longer be an issue in 2030.
For existing operations and legacy sites water quality management issues should be addressed and possibly resolved by 2030, the latest by 2050.

In many cases water quality issues are resolved via use of minerals or other technological means that again depend on use of raw materials in one way or another.

For both sectors this area entails cooperation possibilities, but also with the Water Technology platform.

[7] European Commission : Global Europe 2050, Brussels 2012, page 68

"Another key natural resource is land and the global food supplies. While growing and supplying food to feed ever more people is in itself a major challenge that has already led to riots and government changes, namely in Africa, the bigger immediate challenge concerns bio-fuels and associated regulations that have been passed in recent years. Bio-fuels support programs have contributed already to raise global food prices and consequently increased malnutrition among the world's poorest. … Loss of biodiversity takes places mostly because of the destruction or substantial alteration of natural habitats. Agricultural land is now the largest category of completely transformed, much less biodiverse land. In 2005 its extent, including permanent tree crops, was about 15 million km2, and the three largest grain crops – cultivars of wheat, rice and corn – are now grown on every continent and occupy a combined area of about 5 million km2, more than all remaining tropical forests in Africa. …. A very conservative estimate of the global extent of degraded forests is at least 5 million km2, and the real extent may be twice as large. The consumption of ecosystem services, which is unsustainable in many cases, will continue to grow as a consequence of a likely three- to sixfold increase in global GDP by 2050 even while global population growth is expected to slow and level off in mid-century."

2.7 Rising pressure on land, food production and biodiversity loss[8]

Raw materials are an integral part of our nature and are part of the ecosystem services. They provide vital ingredients for food production, pest control, vital nutritional additives, but also can prevent biodiversity loss when well managed.

With the growing world population, the pressure on land use will increase. Whilst in Europe the population might diminish, this is not the case in other parts of the world. Even in these circumstances, returning land to good prosperous use will be key and in the case of rehabilitation of old extraction sites and former waste disposal sites of the raw materials sector the know-how about the concerned raw materials will be key.

The rehabilitation of Europe's coal mines will be a key challenge till 2050, but it will also provide an opportunity to develop early on an expertise that will be marketable around the world.

Managing biodiversity will be key to returning the land to societal beneficial use and requires considerable knowledge about the interdependencies of some natural elements, biotopes and biodiversity.

[8] European Commission : Global Europe 2050, Brussels 2012, page 68

III. Conclusion

The EU will manage its own natural resources in a sustainable way and for some raw materials needs to secure access in the short to medium term.

In order to ensure the competitiveness and sustainability of the industry and enhance the resilience of the industrial network it will be important to close the sustained gap of business R&D expenditure as % of EU GDP in comparison to the US, China, Japan, and Korea.

A sustained support from public and private funding for RTD and innovation will ensure that the EIP will bring its implementation plan to fruition. On-going and planned initiatives such as the Public Private Partnership (PPP) driven by the European Process Industry and the successfully achieved synergies between industrial strategies and national and regional research agendas have the potential to transform the European manufacturing industry. Programmes such as the ERA-Nets are adding real value to the coordination across MS.

It should be noted that in terms of areas the focus of the current EU and MS funding covers the whole value chain. If this is continued the future RTD and innovation and with it, Europe's sustainability will have to orientate itself on four key pillars which have been identified. These four pillars ideally cover all topics to tap the full potential of the transformation from linear value chains to material cycles where waste occurring in one process becomes the resource needed by another process, and dissipation is avoided as much as possible.

ROADMAP STRUCTURE AND PRIORITIES

PRIORITY 1: Fostering a sustainable supply of raw materials to feed new and existing value chains
- 1.1: Primary supply of EU raw materials for sustainable value chains
- 1.2: Improved utilisation of raw materials from EU sources

PRIORITY 2: Resource-efficient processing for raw materials
- 2.1: Development of resource-efficient, advanced processing for raw materials
- 2.2: Minimisation and valorisation of residues

PRIORITY 3: Raw materials in new products and applications
- 3.1 Development of material applications and markets
- 3.2 Development of new biobased products

PRIORITY 4: Closing material loops by maximising the recycling of products, buildings and infrastructure
- 4.1 Increasing material recovery by efficient detection, sorting and separation
- 4.2 Reuse and recycling technologies adapted to complex, durable or miniaturised products
- 4.3 Developing and integrating methods for assessing and optimising cost and benefit in recycling

These pillars address issues for all raw materials, although sometimes in different ways and to varying degrees. However, in some areas there are interests common to all raw material subsectors. Automation and digitisation in particular will allow the EU to improve its sustainability in many ways. It will increase the resource and energy efficiency along the whole life cycle of raw materials. It will increase industry's competitiveness and it will increase safety.

Stronger cooperation across ETPs will help to address the challenges of tomorrow's industry
As indicated in chapter2 the European ETPs all have identified various raw materials related issues and hence future more structured cooperation across ETPs will be the way to address raw materials issues along the value chain. By 2030 those issues identified today should have been resolved. Arising new ones should be identified and tackled along the longer time lines.

More cohesion and equal participation across Member States
The R&D in the business enterprise sector in Europe shows a very heterogeneous picture in different Member States. Three Member States hold a share of 68 % of the total R&D, distributed over country specific sectors. For 2030 the sector will aim for a wider involvement across the EU and this should be achievable when considering a wider participation across sectors and value chains.
The same applies for R&D in the public sector. Recent efforts of the EU to support the cooperation of member states and to build a European Research Area have proved to be successful to some extent. Nevertheless, this cooperation has to be continued and extended aiming at an increasing level of participation across member states.

More strategic cooperation with countries with similar challenges and issues
Equally, it is true that progress in a number of raw material related issues will not only enhance the EU's economic and sustainability performance, but will also allow to contribute know-how to other parts of the world. At the same time the WP 3.2 report concluded "*The topics addressed in Europe and overseas (Australia, Canada, Japan, South Africa and the United States) are very similar, which means that international cooperation should be pushed in order to join efforts to solve common problems.*

For 2030 a wider cooperation with resource rich countries as well as countries which have particular issues in common with the EU will be invited and included in programmes and activities to increase synergies and technological leverage.