VERAM

Vision and roadmap for European raw materials

Analysis of European research & funding landscape on raw materials

D3.2 – Report on the RM research & innovation funding and projects: relevant R&I topics in the EU and abroad, strengths and weaknesses of current EU and MS funding landscape

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WP3 – Defining and exploring the playing field

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Disclaimer

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BBR	Federal Office for Building and Regional Planning (Bundesamt für Bauwesen und Raumordnung)
bbs	German Building Materials Association (Bundesverband Baustoffe - Steine und Erden)
BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung)
BDA	Confederation of German Employers' Associations (Bundesvereinigung der Deutschen Arbeitgeberverbände)
BDI	Federal Association of German Industry (Bundesverband der Deutschen Industrie e.V.)
BGR	Federal Institute for Geo-Sciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMWi	Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Energie)
CAPEX	Capital Expenditures
CEMI	Centre for Excellence in Mining Innovation
CMIC	Canadian Mining Innovation Council
CNRS	Centre national de la recherche scientifique
CRM	Critical Raw Material
CSA	Coordination and Support Actions
CSIR	Council for scientific and Industrial Research
CSRIO	Commonwealth Scientific and Industrial Research Organisation
DERA	German Raw Material Agency (Deutsche Rohstoffagentur)
DIHK	German Chamber of Commerce and Industry (Deutscher Industrie- und Handelskammertag)
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DoW	Description of Work
DWPI	Derwent World Patent Index
EIT initiative	European Institute of Innovation & Technology
EP	European Parliament
ER	Economic Relevance
ERA	European Research Area
ERA-MIN	Network on the industrial handling of Raw Materials for European Industries
ERA-Nets	European Research Area Networks
ETP	European Technology Platform
EU	European Union
FNR	Agency for Renewable Resources
FONA	Research for sustainable development (Forschung für nachhaltige Entwicklung)
FTP	Forrest based technology platform
GDP	Gross Domestic Product
GHG	Greenhouse Gas

GPS	Global Positioning System
H2020	Horizon 2020
HSD	High Strength Deformed
ICP	integral cost price
ICT	Information and Communication Technologies
InnoNet	Innovation Network
INTRAW	International Cooperation on Raw Materials
IPC	International Patent Classification
IPR	Intellectual Property Rights
IZT	Institute for Future Studies and Technology Assessment (Institut für Zukunftsstudien und Technologiebewertung)
JSPS	Japan Society for the Promotion of Science
JST	Japan Science and Technology Agency
KET	key-enabling Technology
KIC	Knowledge and Innovation Community
KMU	Small and Medium sized Enterprise
LCA	Life-Cycle-Assessment
LEITs	Leadership in enabling and industrial Technologies
METI	Ministry of Economy, Trade and Industry
METS	Mining Equipment, Technology and Services
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MINECO	Ministerio de Economía, Industria y Competitividad
MINTEK	South Africa’s national mineral research organization
NACE	Nomenclature Générale des Activités Économiques dans les Communautés Européennes
NEDO	New Energy and Industrial Technology Development Organization
NIH	National Institute of Health
NIMS	National Institute for Materials Science
OECD	Organization for Economic Cooperation and Development
OPEX	Operating Expenditures
PCT	Patent Cooperation Treaty
PtJ	Project Management Juelich
R&D	Research and Development
R&I	Research and Innovation
REE	Rare Earth Elements
RM	Raw Material
SME	Small and Medium sized Enterprise
SMETCH	SMEs match in Italy with EIT Raw Materials
SPIRE	Sustainable Process Industry – European Industry Competitiveness through Resource and Energy Efficiency
SR	Supply Risk
TRL	Technology Readiness Level
UDMN	Ultra-Deep Mining Network
UNFC	United Nations Framework Classification
UNIVPM	Università Politecnica delle Marche
US	United States
USA	United States of America
VDI	Association of German Engineers (Verein Deutscher Ingenieure)
VERAM	Vision and Roadmap for European Raw Materials

VITO	Flemish Institute for Technological Research (Vlaamse Instelling voor Technologisch Onderzoek)
WoodWisdomNet	Continuation of ERA Net on wood material science and engineering
ZRE	Centre for Resource Efficiency (Kompetenzzentrum Ressourceneffizienz)
ZVEI	Central Electrical Engineering and Electrical Industry Association Germany (Zentralverband Elektrotechnik- und Elektronikindustrie e.V.)

Executive summary

Deliverable 3.2 “Report on the RM research & innovation funding and projects: relevant R&I topics in the EU and abroad, strengths and weaknesses of current EU and MS funding landscape” was elaborated within task 3.2 in order to explore the current situation of RM R&I funding in the EU and abroad. Together with the report on future societal challenges and the corresponding needs of global markets and EU industries from task 3.3 it provides evidence for the estimation of the gap between future EU industrial needs and current research and innovation funding as the challenge ahead. Deliverable 3.2 is therefore a major input to the development of the RM vision and roadmap taking place in the following work packages 4 and 5.

In the frame of VERAM deliverable 3.2 funding activities and opportunities at international, EU and member state level have been analysed for both abiotic and biotic raw materials. Existing reports and/or studies that assess the effectivity and efficiency of EU and national funding programs (Germany as an example) have been analysed regarding the impact of funding programmes on raw material security of supply and the factors of success. Within the Industrial sector, the consortium has mapped current trends, needs, and evolution and development aspects at international, European and national level (case study: Germany). The raw materials research & innovation landscape has been analysed with regard to strength and weaknesses considering the coverage of sectors, raw materials and value chains.

As a major outcome a comprehensive overview covering many aspects of the current situation in RM funding is provided. In addition to the publication within this report selected information on funded projects, funding programmes and key players is continuously uploaded to a web portal on RM research programs/topics which was developed within task 3.5. The main results of deliverable 3.2 are the following ones:

- Trends in value of EU raw material demand (2001-2011): Differences for RM from mining & quarrying versus RM from forestry & logging:
    - Mining & quarrying: sharp increase of absolute values and imported values
    - 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)
    - 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 raw materials from mining and quarrying
    - 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%.
- Relevant stakeholders and funding programmes in the raw material sector are identified to be considered for the development of the vision and roadmap on European raw materials,

- Current R&I programmes cover most relevant raw materials, industry sectors and value chain sections at European (EU and member states; one dedicated outlook as sample is issued for Italy) as well as at international level for the countries considered,
- The materials addressed by funding programmes vary between countries and reveal differences in terms of understanding and classification of raw materials,
- Funding programmes with new approaches where identified on member state level which could be of interest for a wider community (e.g. widening the raw material basis through the use of CO_2),
- A methodology for the evaluation of effectivity and efficiency of funding initiatives based on four criteria (economic and social, criticality, environmental, innovation) is presented, providing details for running evaluations in concrete terms,
- Through segmentation of the raw materials-intensive sectors, the research initiatives taken from 27 large enterprises in EU, as representatives of 13 sectors, are mapped. Indicators identified to assess the intensity and directions taken span from patent analysis, evidence of product development and scientific papers publication,
- A slight shift from sectoral technology-oriented research on mining and recycling to more holistic topics including non-technological issues seems to take place. This could be a consequence of the implementation of the circular economy policy since 2015,
- Although there is a focus on the reduction of waste in the public discussion as primary resources will still be needed, mining will remain of equal importance as compared to other strategies for the supply of raw materials,
- Transnational cooperation (e.g. within ERA-Nets) fosters a common understanding among funding organizations,
- R&D in business enterprise sector in Europe: Very heterogeneous picture in different Member States: 68.1% of the total R&D in 3 Member States, distributed over country specific sectors,
- Long-term industrial raw materials strategies: Strategies concerning resource efficiency, innovation and industrial needs lead to spontaneous generation of synergies between industrial strategies and the research roadmaps:
  - Complementary industry strategies: need for coherent policies and actions regarding international trade, infrastructure development, standardization and market research,
  - Complementary strategies for companies: risk mitigation, integration with strategic sourcing partners through mergers, acquisitions and joint ventures,
  - Ongoing 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. Europe is not far away from bringing to fruition the true vision of a connected enterprise.
- Some hotspot industrial sectors developments:

- Conductive polymers: high growth markets China, Japan, South Korea, US, Singapore, India. EU opportunities mainly Germany and UK
- Biotechnology: development of European bio-based product markets are needed for bioeconomy expansion
- Electric vehicle batteries: low participation of EU based manufacturers
- Electronics manufacturing: EU growth opportunities in response to global development of higher value, lower volume professional end of the electronics manufacturing spectrum.

- The topics addressed in Europe and oversea (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,
- R&D in business enterprise sector oversea: There is an important and sustained gap of business R&D expenditure as % of GDP in the EU as compared to US, China, Japan, and Korea.
- The German example (r^2 initiative) shows how efficient R&D funding could be in the case further funding for market access is provided.
- Differentiating between raw materials supply risk management strategies
  - Specific business strategies are required when purchasing products or raw materials with high supply risks,
  - Specific barriers exist to the goal of increasing the sustainable sourcing of raw materials for industries.

1. Introduction & Description of the deliverable

The deliverable 3.2 is a result of the activities in work-package 3 in VERAM project and especially from Task 3.2: Exploring the playing field.

Task 3.2 follows Task 3.1: Defining the playing field: current state, aiming to "delineate the current raw materials playing field, identifying the players and their teams and making explicit the setting of the game. It involves desktop research and relies on the deep understanding of the playing field available at the consortium partners" (DoW).

The objective of Task 3.2 was to collect as comprehensively as possible, information on current and planned RM research & innovation funding and projects, taking into account following points:

- "The identification and classification of currently running research programs/topics at the internationally most relevant research centres aims to uncover both needs and opportunities for coordination, innovation and funding and investment. Within this task VERAM will cooperate CRM InnoNet (specifically on material substitution) and the CSA INTRAW - International cooperation on raw materials in order to learn from the world's leading countries in raw materials research and innovation in terms of relevant topics as well as best practice for coordination, innovation and funding.
- Within Europe, the outcomes and findings of the actions considered under SC5-19b [2015] Mapping Member State research and innovation in climate change, environment, resource efficiency and raw materials' will facilitate the exploration of the European research and innovation playing field. Complementary evidence will be obtained from the current project partners and their associates, assuring a broad coverage of the raw materials sector.
- An inventory of currently ongoing funding activities and (possibly planned) opportunities at EU and member state level for initiatives that (i) explicitly aim to enhance the availability of raw materials and (ii) are likely to affect such availability, either by supporting R&D activities or by facilitating upscaling and implementation, will be set up. Existing reports and/or studies that assess the effectivity and efficiency of EU and national funding programs will be analysed regarding their impact on raw material security of supply and the factors of success.
- Within the Industrial sector, the consortium will map the current trends, needs, evolution and development aspects, oriented to granting the availability of raw materials at high level. This action will be performed in particular in close relation with the participants from the industrial segments of interest of the EIT initiative. Strategic aspects will be delivered in order to sum up in synergistic way to the research roadmaps and to highlight the congruence and differentiations.
- The raw materials research & innovation landscape will be analysed with regard to strength and weaknesses considering the coverage of sectors, raw materials and value chains. This includes assessment of innovation success rates and identification of issues of failure" (excerpts from project Dow).

D3.2 presents the results of both collection and analysis and is a contribution to the next activities in VERAM.

2. RM research programs/topics & Identification and classification of currently running research programs/topics

Partners involved: JUELICH, FNR, UNIVPM

2.1. International

2.1.1. Abiotic Raw Materials: CSA Intraw-country reports for US, Japan, Canada, Australia, South Africa

As mentioned in the DoW this part of the work relies on the results of the EU-funded project **INTRAW International Raw Materials Observatory (for abiotic raw materials only)**.

INTRAW "has been set up to map and develop new cooperation opportunities related to raw materials between the EU and other technologically advanced countries, such as Australia, Canada, Japan, South Africa and the United States, addressing following aspects:

- Research and innovation,
- Raw materials policies and strategies,
- Joint educational and skills programmes,
- Licensing and permitting procedures, royalties and tax policies,
- Data reporting systems,
- Exploration, extraction, processing and recycling practices,
- Management and substitution of critical raw materials."

Following INTRAW Reports have been analysed from the point of view of VERAM:

➢ "Contextual Analysis of the reference countries", all from December 2015
  - Australia,
  - Canada,
  - Japan,
  - Republic of South Africa,
  - United States of America,

➢ As well as "ANALYSIS OF RESEARCH AND INNOVATION", INTRAW Deliverable D 1.3, from June 2016, kindly provided by the INTRAW Team.

Informations on R&D are more detailed in D 1.3. The five reference countries offer a broad spectrum for competences as shown in the tables below. Information on industry strategies will be given in part 4.3

In **Australia**, a country rich in minerals where recycling is not so relevant, many innovations using ICT (automation) have been developed in the mining sector (exploration, extraction and ore processing) (Table 2.1).

Table 2.1. Australia

RM wealth	One of the richest RM countries in the world (e.g. bauxite)
Efficiency in RM	Have explored, discovered and made efficient use of its mineral resources
Leader in	Lead, iron, gold, lithium and mostly export in producing countries (especially Asia), low domestic consumption
Ore processing	Most RM exported but iron ore processed in Australia
Recycling	As Australia is rich in minerals, recycling is not a big topic
Present situation	Losing competitiveness (export goods too expensive, companies in mining sector cut investments in exploration)

Innovation in the Australian mining sector

Innovation in mining	36 % of innovation investment for new technology, 27 % Mine development & construction, 19 % Exploration, 8 % R&D etc.
Research intensity	2,11 % (2013, in % gross expenditure on R&D compared to GDP)
Research intensity in mining sector	22,4 % (2011, business expenditure on R&D from the mining industry in relation to overall business expenditure on R&D in the regions)
Drivers for mining R&I	Environmental standards and safety regulations extremely high, have to use and invent good technology to stay competitive
Future trends	Automation
Challenges	Australia needs to prepare for a number of challenges: mineral resources (deeper deposits, mining far from industry and harbours, complex mining processes & lower mineral grade), human resources (aging workforce, hazardous workplaces, lack of skilled workers, decreasing ore grade,), environmental resources (water scarcity, rising energy costs, fragile ecosystems, waste management), social & corporate resources (lowering production costs, accountability, community development and others), which force them to re-think the current mining policies and, among others, to reinforce research and innovation. Lack of coordination between the states, lack of collaboration between miners, METS and other relevant R&I Organizations and between universities and industry, high administrative requirements because of decentralization.
METS (mining equipment, technology and services)	Important actors in mining sectors: almost 75 % invested in R&D, 15 % of METS invested more than 1 Million Dollars. Majority: between 100.000 and 1 M $ overall, METS sector spent 986 M $ in R&D (2008-2009); technology application sector: 530 M $; equipment and machinery: 240 M $, consulting companies: 200 M $ and 16 M $ in contract services
Minerals Council of Australia	Responsible for most mineral and processing companies in Australia and works together with universities in Australia - invested more than 40 M $ for the graduates and university research
Key technologies	Airborne geomagnetic survey sensors and analytical software, flotation separation technique of zinc from ore, recovery techniques to mine low grade gold deposit, CSRIO (Commonwealth Scientific and Industrial Research Organisation): leading player in technology development.

As a global leader in mining questions **Canada** has developed a high quantity of innovative solutions in this field (Table 2.2).

Table 2.2. Canada

Mining industry	Global leader in exploration, environment, mineral processing, mine development and operation, financing, mineral extraction, and site remediation
Efficiency in RM	Innovation as a key element for differentiation from low-cost raw material producers from emerging countries
Leader in	Zinc, produces also much gold, nickel, aluminum, lead and uranium + one of the largest mining supply sectors globally

Innovation in the Canadian mining sector

CMIC (Canadian Mining Innovation Council)	Goals: location of high reserves (seismic mapping) without harming environment. Technology fields such as GPS surveying, 3D data maps, airborne technologies or down--hole seismic imaging, mining methods that reduce costs through automation, smelting and refining improvements.
CEMI (Centre for Excellence in Mining Innovation)	Goals: mineral exploration techniques in geology, geophysics and geochemistry, deep mining, integrated mine engineering, underground mine construction and environmental & sustainability
UDMN (Ultra-Deep Mining Network)	46 million $ initiative: championed by Ontario's Centre of Excellence in Mining Innovation industry, work together with academia
R&D programmes	Numerous and more than 4000 sources of funding. Approx. 40 different R&I organisations
R&D spending	In mining, quarrying and oil and gas Extraction in 2012: 1,6 Bio. $, in 2015 maybe 1,5 bio. $. 2013, Canadian mining companies invested 522 Million $ in R&D (but was reduced significantly in the last years; 2011: 632 Million $). Invest a lot in automation technologies, Ministry of raw materials: funds scientific activities
Research intensity	(2014, in % gross expenditure on R&D compared to GDP): 1,61 %
Research intensity in mining sector	(2013, business expenditure on R&D coming from the mining industry in relation to the overall business expenditure on R&D in the regions): 6,4 %
Challenges	Collaboration industry and state / federal states etc., but Canada aims to improve partnerships between private and public sector. Canada needs to prepare for a number of challenges (lowering production costs, lack of skilled workers, decreasing ore grade, to name a few), which force them to re-think the current mining policies and, among others, to reinforce research and innovation.
Key technologies	Exploration, environment (eco-innovations), mineral extraction, deep mining innovation and ultra-Deep Mining Network, safety and productivity, transportation, processing, extensive science and technology network, broad expertise in geoscience.

In **Japan** mining industry is small and the secondary RM sector very performing. In both domains intensive innovation has been developed (Table 2.3).

Table 2.3. Japan

Domestic mining industry	Very small in raw materials extraction, but RM play a very important role in the Japanese economy, so there are many efforts to guarantee a reliable supply of RM and not to be dependent of foreign markets. Invest and invested worldwide and import that RM for refinement and smelting. (Asia, Australia, Africa and North and South America)
Processing	Large industry
Recycling	To be more independent, also invest into substitution, reuse and recycling of metals

Innovation in the Japanese mining sector

METI (ministry of economy, trade and industry)	Strategy on securing RM: seabed exploration, promoting recycling of scrap and end-of-life products
Recycling	Many laws for recycling – recycle-orientated society in Japan, also recycling of rare earths, promote use and development of alternative materials, so they strengthen industry-university-government linkages
Funding agencies and research:	NEDO, JST, JSPS: Funding. METI: Applied research and industrial related projects, MEXT: Basic research at universities. NIMS + Riken research organization: Strategic research
Strengths	Good cooperation between policy and economy, Japan is on rank 2 in the subject “companies spending on R&D”
R&D in private sector	Get tax credits for R&D, research programmes are developed by the ministries for the private sector, support also R&D in SMEs
Research intensity	2014, in % gross expenditure on R&D compared to GDP): 3,58. Especially in the mining sector: (2013, business expenditure on R&D coming from the mining industry in relation to the overall business expenditure on R&D in the regions): <0,1%
Key technologies	Geophysical exploration, remote sensing technology, development of support device, energy saving refining processes and rare metal recovery technologies, recycling raw materials: waste small appliances, processing, refining by-products (e.g. recovering the tantalum and cobalt contained in capacitors and lithium-ion batteries), exploration of marine mineral resources and technological development

In **South Africa**, a very RM rich country, innovation is needed for different reasons and has been developed for both primary and secondary raw materials (Table 2.4).

Table 2.4. South Africa

Mining industry	5. largest in the world, large access to natural resources, but not especially rich in mineral resources, so mining sector depends on innovation, has deepest mines of the world. Mining industry depends on export (mostly China)

Innovation in the South African mining sector

Strengths	Skilled workforce, are able to do deep level mining, in new programmes there can be seen more potential in collaboration between industry and research organisations
Challenges	Good people are also leaving country (e.g. Canada or Australia for better salaries), state of research institutes, limited R&D funding, shortage of skills, reluctance of the industry to adopt innovation, lack of R&D collaboration amongst industrial companies, decline of mining research programmes, lack of finance power
R&D strategy in mining sector	Efficient, safe and competitive production, environmental and health management, minerals upgrading and value addition, establishing an innovation culture
Education institutes	Perform mining R&D, but still lack of collaboration and percentage of R&D personnel is relatively low
Recycling	Promote new recycling strategies
Key players in mining industry	Suppliers of mining equipment and Services, most of the key mining companies are foreign, especially the large ones drove innovation in the past. Besides, the organisations MINTEK and CSIR are key players in doing R&I
Key technologies	Advanced technological position, cyanide-based extraction technology, large and increasing export of mining equipment, mining explosives, drilling equipment and abrasives, processing and metallurgical processes and plants, and delivering knowledge-based services
Global Innovation Index 2015	ZA worsened its position in comparison to 2014, but overall the South African score is among the best ranks of all innovation indicators considered
Expenditure on R&D	12/13: 0,76 % of GDP, 23.871 million R (considerably below that of other emerging economies). Half of it comes from the private sector. Government funding: 45,4 % and the business sector 38,3 % of R&D activities There is little industry engagement with research and a significant decline of personnel and (publicly funded) mining research programs.

The **United States** are rich in RM and at the same time a big RM consumer (Table 2.5).

Table 2.5. United States

RM wealth	Have a lot of RM, but also need a lot of RM and resources, especially metals and minerals for manufacturing, e.g. cars, airplanes, computers, mobile phones…
Domestic production	Monopoly-like (for metallic minerals), mining companies, smelters and manufacturers work close together, increased domestic production (and employment) within the last years due to rising demand
Processing	Strong industry
Recycling	Improvement of reuse and recycling by developing appropriate technologies

Innovation in the US-American mining sector

Problems	Reputation of mature and environmentally damaging industry, so the industry requires strict regulations to prevent pollution etc.
Major priorities	Provision of critical or strategical minerals. Strategy: Diversify supply (new sources), develop substitutes to replace critical material
Innovation topics	Promote automated mining, establish a procedure for the development of hard mineral resources in the deep seabed
R&D funding	Governmental agencies (USA is a leading innovator in many ways), but mining industry is conservative with new technologies. Still made significant advances, even if there are no particular R&I programmes especially for the mining sector. NIH (national institute of health): leading funder of mining research (because of health and safety aspects). R&D funds by the federal government are pretty small, federal states have only small research programmes. Industry driven R&D: big mining companies can have in-house R&D units or they find researchers for projects. SME usually don't do R&D by themselves.
Research intensity	2013, in % gross expenditure on R&D compared to GDP: 2,37. Especially in the mining sector: 2012, business expenditure on R&D coming from the mining industry in relation to the overall business expenditure on R&D in the regions: 0,9%
Key technologies	Increasing work productivity in individual mines and driving down costs imposed by external factors, solvent extraction/electrowinning process. The major agencies involved in minerals and materials (DOI, DOE, DOD) sponsor. R&D projects, but there are no comprehensive research & innovation programs especially designed for the mining sectors. Much of the R&I in minerals is driven by industry.

Comparison “INTRAW Countries” and results of VERAM survey (2.3.1)

Comparing the important topics and trends in the INTRAW countries for abiotic raw materials with the results of the VERAM survey on funding program topics shows a good overall correlation (Table 2.6).

Topic (1) **“Innovative extraction and harvesting of raw materials”** with the themes automated mining / automation as well as deep-sea mining and Topic (2) **“Resource efficient processing and refining of raw materials”** as well as Topic (3) **“Recycling of raw materials from products, buildings and infrastructure”** are in both cases the most represented. Further recycling themes are also present in Topics (4) and (5).

Table 2.6. Comparison “INTRAW Countries” and results of VERAM survey

Topics* / Country	Australia	Canada	Japan	RSA	USA	VERAM Survey**
(1)	X *Automation*	X *Automation* *New exploration technology*	X *Deep-sea mining*	X *Deep mining*	X *Automation* *Deep-sea mining*	61 of all *31 of (1)* *37 of (1)* *26 of (1)*
(2)	X (Iron)	X	X	X *(transfer to other countries)*	X	71 of all
(3)		X	X *End-of-life products*	X	X	68 of all *76 of (3)*
(4)			X			64 of all
(5)				X	X	63 of all
(6)			X *Circular Economy*	X		52 of all *53 of (3)*
(7)		X *automated loading and transportation systems*				45 of all
(8)	*Lack of coordination*			*Improving research & innovation coordination*		*45 of all* *50 of (8)*

** In the VERAM Survey on funding programmes on RM following topics have been defined:*

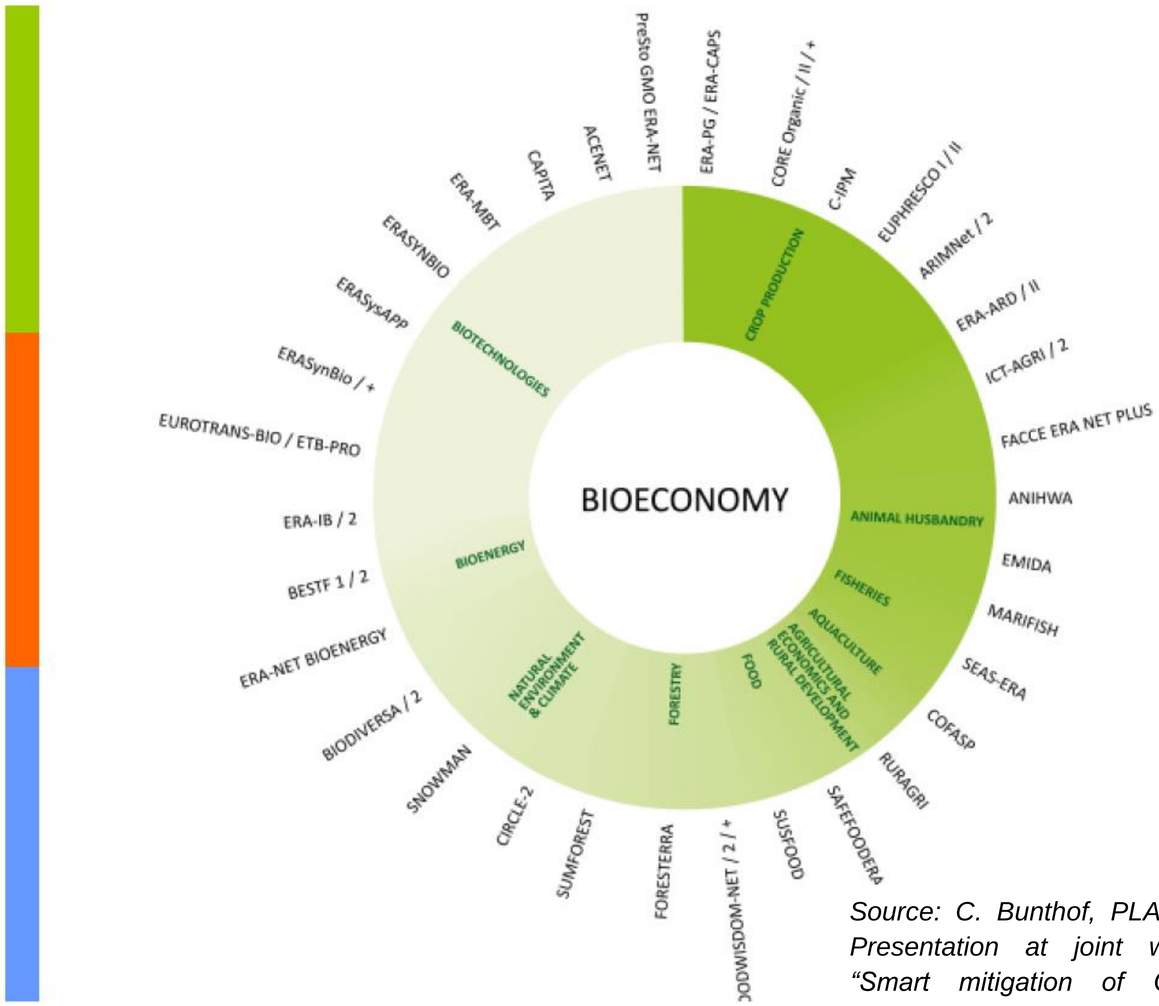
1. *Innovative extraction and harvesting of raw materials*
2. *Resource efficient processing and refining of raw materials*
3. *Recycling of raw materials from products, buildings and infrastructure*
4. *Advanced use and substitution*
5. *Product design optimising use of raw materials & increasing quality recycling*
6. *Circular economy and recycling policies*
7. *Logistics, transport and optimised raw material flows along the value chain*
8. *Non-technological topics*

*** Percent of coverage (e.g. 21 from all answers at topic level (31) = 68 % of all; Inside a topic: theme like automation)*

2.1.2. Biotic Raw Materials

ERA-NETs are the main instrument for alignment of national funding programmes and joint funding activities for research development and innovation in European context. As shown in the figure 2.1. three ERA-NETs are focusing on funding of research activities in forestry domain:

- “Enhancing FOrest RESearch in the MediTERRAnean through improved coordination and integration” - FORESTERRA. FORESTERRA was funded by the EC under FP7 and run from 01. 2012- 12.2015
- Sustainable forests for the society of the future - Sumforest is funded under FP7, with a running time from 01. 2014 -12.2017
- ERA-Net on transnational cooperation for innovative products in the forest-based value chains - WoodWisdomNet/2/+. WoodWisdomNet has three funding phases: 1) WoodWisdomNet was funded by the EC under FP6 from 01. 2004 - 12. 2008; 2) WoodWisdomNet2 was funded under FP7 from 03.2009 – 02.2012 and 3) WoodWisdomNet is funded under the plus-scheme (FP7) from Nov. 2012 - Nov. 2017.



Source: C. Bunthof, PLATFORM: Presentation at joint workshop “Smart mitigation of GHG in livestock production. Potsdam, 29-30.11.2016

Figure 2.1. Overview on bioeconomy ERA-Nets

Comprehensive information on member countries number of calls, call topics, funded projects and spent budgets during the life time of the three above mentioned ERA-Nets can be found in the table 2.7.

Table 2.7. Overview on funding activities of FORESTERRA, Sumforest and WoodWisdomNet+

	FORESTERRA	Sumforest	WoodWisdomNet/2/+
Number of partners	17	23	21
number of calls	1	1	4
budget spent	n.a.	8.363.709 €	82 000 000 €
number funded projects	n.a.	7	62
call topics	• Understanding global change drivers, impacts & indicators on forest ecosystems: a Mediterranean-scale approach • Fostering forest system resilience through managing biodiversity, from genes to communities	"Sustainable forests for the society of the future" • Comparative assessment of the sustainability performance of forest-based, other renewable and non-renewable raw material-based value chains • Risk resilient forest management - Adapting forest management regimes which incorporate risk assessment related to potential climate change impacts • Investigation, appraisal and evaluation of trade-offs related to the provision of forest ecosystem services	• wood material science and engineering • new innovative products in the forest-based value chains • total transformation of the European forest-based industry • sustainable forest management • resource efficiency increment and development of totally new products • adapting to and mitigating the impacts of climate change

Building on the success of three previous ERA-NETs: FORESTERRA, SUMFOREST and WoodWisdom-Net a new Pan-European consortium consisting of 32 partners from 20 countries (Finland, Austria, Czech Republic, France, Germany, Ireland, Latvia, Poland, Slovenia, Spain, Sweden, United Kingdom, Norway, Switzerland, Tunisia, Turkey, Argentina, Egypt, Jordan and Russia is preparing a proposal for new ERA-Net ForestValue - Innovating the forest-based bioeconomy under the Cofund scheme within the H2020 Programme of the European commission.

Presumed a positive evaluation and funding due to the EC within the new ERA-Net with duration of 5 years joint call for research proposals in two anticipated topics areas:

- Sustainable management of forests
- Innovative production technologies, industrial processing and services

and additional calls are planned.

A continuously innovative and forward looking European forest-based industry is essential if the European industry is to be transformed from a resource-intensive to a knowledge-intensive industry. The efficient use of wood as a renewable resource, substituting for limited non-renewable resources, will reduce the resource-intensity of wider European industry. But it requires intensive knowledge to develop new wood-based applications with high added value. This knowledge needs to be created in a common European Research Area in those fields which will be strengthened by this proposed Cofund action.

In order to achieve all this, there is a need to take advantage of process and product developments through alliances with other sectors and to exploit emerging technologies, (as also indicated in the Strategic Research Agenda (SRA) of the Forest-Based Sector Technology Platform (FTP) and in the FTP Vision 2030). FTP has National Support Groups in the following EU countries:

- Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Portugal (observer), Romania, Slovakia, Slovenia, Spain, Sweden and the UK (observer).

FTP also has National Support Groups in Norway, Switzerland and Russia.

The Strategic Research Agenda 2020 elaborated within FTP is a comprehensive document including four areas and subdivided in 19 specific research and innovation areas. To meet major challenges facing European society [1]

A survey on national funding programmes in the domain of forest-based resources was conducted and send to the consortium partners of Sumforest and WoodWisdomNet+ and other relevant stakeholders, however only 8 responses were received. The results on the national funding activities are shown in table 2.8.

[1] http://www.forestplatform.org/files/SRA_revision/Renewed_SRA_for_2020.pdf

Table 2.8. Overview of national funding programs

Funding Organisation	Country	Name of funding programme	total budget	No. of running projects
Austrian ministry of agriculture, forestry environment and water management, BMLFUW	Austria	PFEIL16 /20	1 M€*	10
Agence de l'environnement et de la maîtrise de l'énergie, ADEME	France	ADEME's RDI program	30 M€	400
Agency for Renewable Resources, FNR	Germany	Renewable Resources	61 M€	675
Comisión Nacional de Investigación Científica y Tecnológica	Chile	Programa de cooperacion internacional	n.a.	n.a.
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria	Spain	PROYECTOS DE INVESTIGACIÓN FUNDAMENTAL ORIENTADA y ACCIONES COMPLEMENTARIAS DENTRO DEL PROGRAMA ESTATAL DE I+D+I ORIENTADA A LOS RETOS DE LA SOCIEDAD Y ESPECÍFICAMENTE DENTRO DEL RETO DE SEGURIDAD Y CALIDAD ALIMENTARIA, ACTIVIDAD AGRARIA PRODUCTIVA Y SOSTENIBLE, SOSTENIBILIDAD DE LOS RECURSOS NATURALES E INVESTIGACIÓN MARINA Y MARÍTIMA	14 M€	200
Innovaatiorahoituskeskus, Tekes	Finnland	Smart & Green Growth – clean transition to the bioeconomy	300 M€	46
Research Council of Norway, RCN	Norway	BIONÆR	1,5 M€	130
Swedish Research Council, Formas	Sweden	Forest raw material and biomass	45 M€	70
Verket för innovationssystem, VINNOVA	Sweden	BioInnovation	12 M€	16

*indicative budget of BMLFUW for ForestValue

Private-Public Partnerships (PPP) are another effective mechanism for driving research and innovation, supporting the industry for emerging of innovative technologies and bio-based solutions. Bio-based Industries (BBI) is a PPP in the area of bioeconomy supported by the EU. BBI launched 4 calls for transnational projects and achieved Public-Private Partnerships between private partners on Bio-based Industries with the EU for about € 3.7 billion[2]. Coordination and Support Action (CSA), Research & Innovation Actions (RIA), Demo and Flagship projects in the area bio economy were supported.

13 Projects (1 CSA, 1 flagship, 3 DEMO, and 8 RIA) for ca. 50 M€ in three topic areas (compare table 2.8) were funded[3].

[2] http://www.bbi-europe.eu/
[3] http://www.bbi-europe.eu/projects

Table 2.9. Projects funded by BBI in the area of forest-based bioeconomy

Project Name	Project type	BBI commitment	topic
BIOCANNDO	CSA	€ 998,345.00	improving the integration of energy, pulp & chemicals in biorefineries
BIOFOREVER	DEMO	€ 9,937,998.02	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials
ENZOX2	RIA	€3.000.000,00	improving the integration of energy, pulp & chemicals in biorefineries
EXILVA	flagship	€27.433.610,50	next generation forest-based value chains
GreenLigh	RIA	€1.299.164	next generation forest-based value chains
GREENSOLRES	DEMO	€ 7,451,945.63	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials
LIBRE	RIA	€ 4,919,060.00	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials
NEOCEL	RIA	€ 2,441,612.00	next generation forest-based value chains
SMARTLI	RIA	€ 1.481.258	next generation forest-based value chains
TECH4EFFECT	RIA	€ 4,999,902.50	next generation forest-based value chains
US4GREENCHEM	RIA	€ 3.457.602,5	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials
VALCHEM	DEMO	€13.125.941	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials
ZELCOR	RIA	€ 5,256,993.00	from lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials

Forest-based raw materials bioeconomy strategies around the world

Bioeconomy has gain an importance in the last decades and currently about 45 industrial and developing countries developed strategies for fostering innovation sustainable development and green growth (fig. 2.2)

The most important global players possessing together ca. 67 % of the world forest areas according to the Global Forest Resources Assessment 2015[4] are shown in the table 2.10.

From the top 10 countries by forest area only Democratic Republic of Congo and Peru do not have developed a strategy in the area of bioeconomy and biotic respectively forest-based materials.

[4] http://www.fao.org/3/a-i4808e.pdf

Top 10 countries like Russia, India, Australia and also other countries e.g. Mali, Ireland, Lithuania, Norway, Belgium, Argentina, Paraguay, Finland, New Zealand, Malaysia have defined in their bioeconomy forestry as a one of the major strategic topics for innovation[5].

Figure 2.2. Bioeconomy Policies around the World

Source: German Bioeconomy Council: http://biooekonomierat.de/en/international0/

Other countries with dedicated bioeconomy strategy (Canada, Germany UK, Japan USA and the EU) are considering forestry and forest-based raw materials as essential for a sustainable bioeconomy and also additionally defined comprehensive research and development strategies. These include research support programmes and upgrading of national R&D infrastructure, promotion of interdisciplinary networks, promotions of new business models, training and education measures, building of pilot and demonstration plants for biorefinering and stringing international collaborations.

The web page of the German Bioeconomy Council provides a repository of all currently existing bioeconomy policies in addition two papers summarizing the strategic papers are also available[6].

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[5] http://biooekonomierat.de/fileadmin/international/Bioeconomy-Policy_Part-II.pdf
[6] *http://biooekonomierat.de/en/international0/*

Table 2.10. Top 10 countries by reported forest area in 2015

No.	Country	forest area (M ha)	% of land area	% of global forest area
1	Russia	814.9	50	20
2	Brazil	493.5	59	12
3	Canada	347.1	38	9
4	USA	310.1	34	8
5	China	208.3	22	5
6	Democratic Republic of Congo	152.6	67	4
7	Australia	124.8	16	3
8	Indonesia	91.0	53	2
9	Peru	74.0	58	2
10	India	70.7	24	2
	total	2,687.0		67

2.2. European Union

2.2.1. R&D in EU business enterprise sector

The European Innovation Scoreboard – previously Innovation Union Scoreboard – provides a comparative analysis of innovation performance in EU Member States, other European countries, and regional neighbours. It assesses relative strengths and weaknesses of national innovation systems and helps countries identify areas they need to address. It includes figures on business R&D expenditure as % of GDP per EU Member State.

Detailled business enterprise R&D expenditure statistics by industry and per OECD country are available from OECD. Also the Institute for Prospective Technological Studies (IPTS) publishes yearly an Industrial R&D Scoreboard. Veugelers & Cincera (2010) 7 found, based on IPTS scoreboard data, quite striking differences in Europe's sectoral R&D specialisation, as compared with the US. The EU outperforms the US to a large degree in automobiles, electricals, telecommunications, industrial machinery and various others, but the US was shown to have a quite dramatic comparative advantage in several 'emerging' sectors, like biotech, software and the Internet, areas where the world has seen very much stronger rates of growth in the recent past, when compared with several 'older' sectors like automobiles and industrial machinery. The Industrial R&D Scoreboard shows that the list of US top R&D performers is dominated by companies created after 1975, while the EU scoreboard is dominated by businesses founded before 1975. In the US, these "young" innovators account for 35% of total BERD, while in the EU the equivalent figure is just 7%.8

Huge differences can also be observed between both the absolute and relative performance of different EU Member States. According IPTS 2015 Industrial R&D scoreboard, 898 companies based in the top 10 Member States account for 97.4 % of the total R&D of the 1000 EU sample. The overall performance of the EU group is largely driven by the performance of companies based in Germany, France and the UK, accounting for 68.1% of the total R&D and 68.5% of total net sales. The next seven countries only add another 29% of the total R&D.

2.2.2. Raw Materials in the Horizon 2020 Work Programme for 2014-2015

Research on raw materials is present in different parts of Horizon 2020[9]. For example in the 2014-2015 calls there were funding opportunities in the **societal challenge 5** in the Calls "Towards a near-zero waste society", "Growing a Low Carbon, Resource Efficient Economy with a Sustainable.

Supply of Raw Materials", "Innovative and sustainable solutions leading to substitution of raw materials", and in the pillar **Industrial leadership** in the calls "Nanotechnologies, Advanced Materials and Production" and "SPIRE – Sustainable Process Industries".
The main topics are:

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[7] Europe's missing Yollies (Young Leading Innovators), Bruegel Policy Brief Issue 2010/06 by Reinhilde Veugelers and Michele Cincera (2010). See http://www.bruegel.org/publications/publicationdetail/publication/437-young-leading-innovators-and-eus-r-and-d-intensity-gap/.

[8] European Commission (2014). Performance of SMEs within FP7. An Interim Evaluation of FP7 components. Volume I Main Report.

[9] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/search/search_topics.html#c,topics=topicFileName,callIdentifier,callTitle,identifier,title,description,tags,flags/s/Raw%20materials/1/1/0&+title/desc

- Innovative mining and metallurgical technologies,
- Recycling and inventory of raw materials,
- Substitution of critical materials,
- Industrial symbiosis,
- (International) Cooperation on raw materials research.

Societal Challenge 5

Climate action, environment, resource efficiency and raw materials

Table 2.11. Call - Waste

Call – Waste: A Resource to Recycle, Reuse and Recover Raw Materials – Towards a near-zero waste society H2020-WASTE-2014/2015			
WASTE-1-2014	**Moving towards a circular economy through industrial symbiosis**		
Projects:	Title	Ref.:	Timeframe
	RESYNTEX	641942	2015-06-01 to 2018-12-01
	CABRISS	641972	2015-06-01 to 2018-06-01
	FISSAC	642154	2015-09-01 to 2020-03-01
	BAMB	642384	2015-09-01 to 2018-09-01
WASTE-3-2014:	**Recycling of raw materials from products and buildings**		
	CloseWEEE	641747	2014-12-01 to 2018-11-30
	HISER	642085	2015-02-02 to 2019-02-01
WASTE-4-2014/2015:	**Towards near-zero waste at European and global level c) [2014] Secondary raw materials inventory**		
	SMART GROUND	641988	2015-10-01 to 2018-03-31
	ProSUM	641999	2015-01-01 to 2017-12-31
	d) [2015] Raw materials partnerships		
	MSP-REFRAM	688993	2015-12-01 to 2017-06-30
	IMPACT PapeRec	690182	2016-02-01 to 2018-01-31

Table 2.12. Call – Growing a Low Carbon, Resource Efficient Economy with a Sustainable Supply of Raw Materials

Call – Growing a Low Carbon, Resource Efficient Economy with a Sustainable Supply of Raw Materials - H2020-SC5-2014/2015			
ENSURING THE SUSTAINABLE SUPPLY OF NON-ENERGY AND NON-AGRICULTURAL RAW MATERIALS			
SC5-11-2014/2015:	**New solutions for sustainable production of raw materials a) [2014] Mining of small and complex deposits and alternative mining**		
Projects:	Title	Ref.:	Timeframe
	Real-Time-Mining	641989	2015-04-01 to 2019-03-31
	BioMOre	642456	2015-02-01 to 2018-01-31
	VAMOS	642477	2015-02-01 to 2018-07-31
	b) [2014] Flexible processing technologies		
	FAME	641650	2015-01-01 to 2018-12-31
	OptimOre	642201	2014-12-01 to 2017-11-30
	c) [2015] Deep mining on continent and/or in sea-bed		
	Blue Nodules	688975	2016-02-01 to 2020-01-31
	d) [2015] New sustainable exploration technologies and geomodels		
	SOLSA	689868	2016-02-01 to 2020-01-31

	HiTech AlkCarb	689909	2016-02-01 to 2020-01-31
	UNEXMIN	690008	2016-02-01 to 2019-10-31
	ROBUST	690416	2015-12-01 to 2020-01-31
	e) [2015] New metallurgical systems		
	INTMET	689515	2016-02-01 to 2019-01-31
	METGROW PLUS	690088	2016-02-01 to 2020-01-31
SC5-12-2014/2015:	**Innovative and sustainable solutions leading to substitution of raw materials a) [2014] Materials for electronic devices**		
	INREP	641864	2015-02-01 to 2018-01-31
	INFINITY	641927	2014-12-01 to 2018-01-31
	b) [2015] Materials under extreme conditions		
	Flintstone2020	689279	2016-02-01 to 2020-01-31
	EQUINOX	689510	2016-02-01 to 2019-01-31
SC5-13-2014/2015:	**Coordinating and supporting raw materials research and innovation a) [2014] Mineral deposits of public importance**		
	MINATURA 2020	642139	2015-02-01 to 2018-01-31
	b) [2014] Strategic international dialogues and cooperation on raw materials with technologically advanced countries		
	INTRAW	642130	2015-02-01 to 2018-01-31
	c) [2015] Innovation friendly minerals policy framework		
	MIN-GUIDE	689527	2016-02-01 to 2019-01-31
	d) [2015] Raw materials research and innovation coordination		
	VERAM	690388	2015-12-01 to 2018-05-31
	e) [2015] Raw materials intelligence capacity		
	MICA	689648	2015-12-01 to 2018-01-31
	f) [2015] Strategic international dialogues and cooperation with raw materials producing countries and industry		
	STRADE	689364	2015-12-01 to 2018-11-30

Industrial leadership, *Leadership in enabling and industrial technologies (LEITs)*
ii. Nanotechnologies, Advanced Materials, Advanced manufacturing and processing, Biotechnology

Table 2.13. Call for Nanotechnologies, Advanced Materials and Production

Call for Nanotechnologies, Advanced Materials and Production- H2020-NMP-2014/2015 EXPLOITING THE CROSS-SECTOR POTENTIAL OF NANOTECHNOLOGIES AND ADVANCED MATERIALS TO DRIVE COMPETITIVENESS AND SUSTAINABILITY			
NMP-23-2015:	**Novel materials by design for substituting critical materials**		
Projects:	Title	Ref.:	Timeframe
	CritCat	686053	2016-06-01 to 2019-05-31
	NOVAMAG	686056	2016-04-01 to 2019-09-30
	PARTIAL-PGMs	686086	2016-04-01 to 2019-09-30
all for SPIRE – Sustainable Process Industries - H2020-SPIRE-2014/2015			
SPIRE-7-2015:	**Recovery technologies for metals and other minerals**		
	ADIR	680449	2015-09-01 to 2019-09-01
	REE4EU	680507	2015-10-01 to 2019-10-01
	REMAGHIC	680629	2015-09-01 to 2018-09-01

2.2.3. KIC Raw Materials

The research was carried out also including ongoing projects about raw materials in general funded by the KIC Raw Materials[10].

Table 2.14. KIC Raw Materials

Title	EU Contribution	Total cost (k €)	Start	End
CRM Extreme - Substitution of CRMs in components and coatings used under extreme conditions	-	180	-	-
NANOGREAT - Graphene NANOcomposites REActors at preindustrial Technology readiness	-	130	-	-
OPTNEWOPT - Materials substitution in optoelectronic devices	-	272	-	-
LIGHTWEIGHTMATERIALS - Metal-based lightweight materials	-	228	-	-
PCRec - Product Centric Recycling	-	358	-	-
SSIC - Sustainability Support and Information Centre	-	226	-	-
ERMAT - Efficient use of Residual MATerials	-	229	-	-
ECOCOMBAT - ECOlogical COMposites for High-Efficient Li-Ion BATteries	-	2,320	-	-
AVAR - Added Value Alumina Refining	-	1,560	-	-
STORM - Industrial Symbiosis for the Sustainable Management of Raw Materials	-	237	-	-
RefresCO - Professional Refresher COurses	-	260	-	-
RMProSchool - RMProSchool	-	1,100	-	-
RAMSES - Advanced School on Critical Raw Materials Substitution for Energetics and Photonics	-	67	-	-

[10] https://eitrawmaterials.eu/activities/projects/

The main topics are:

- Innovative materials;
- Recycling and reuse of waste materials;
- Sustainability, low carbon footprint and innovation of materials;
- Use of lightweight materials;
- Establishment of school programs in the field of raw materials.

2.2.4. Raw materials for construction sector

The research was carried out analysing the situation of raw materials for construction sector. At European level, the ongoing projects have been reported in the following table and divided in FP7 and H2020 programs.

Table 2.15. FP7 Program

Number	Title	EU Contribution in k€	Total cost in k€	Start	End
609067	OSIRYS - Forest based composites for façades and interior partitions to improve indoor air quality in new builds and restoration	6,320	9,112	01/06/2013	31/05/2017
605371	WELDAPRIME - Self-repairable Zinc-free Weldable Anti-corrosion Primer for the Steel protection	2,106	2,716	01/02/2014	31/01/2017
335928	GeopolyConc - Durability of geopolymers as 21st century concretes	1,495	1,495	01/09/2013	31/08/2018
608893	H-House - Healthier Life with Eco-innovative Components for Housing Constructions	4,750	6,551	01/09/2013	31/08/2017
607851	endure - European Network for Durable Reinforcement and Rehabilitation Solutions	3,871	3,871	01/10/2013	30/09/2017
324478	EiroCrete - Development of sustainable, lower carbon, pre-cast concrete infrastructure	1,085	1,085	01/05/2013	30/04/2017
605404	DURABROADS - Cost-effective DURABle ROADS by green optimized construction and maintenance	2,511	3,463	01/10/2013	31/03/2017
603862	APSE - Use of eco-friendly materials for a new concept of Asphalt Pavements for a Sustainable Environment	2,448	3,842	01/01/2014	30/06/2017
603722	ANAGENNISI - Innovative Reuse of All Tyre Components in Concrete	3,120	4,499	01/01/2014	30/06/2017
608808	ADAPTIWALL - Multi-functional light-weight WALL panel based on ADAPTive Insulation and nanomaterials for energy efficient buildings	3,348	5,046	01/09/2013	31/08/2017
310645	STOICISM - Sustainable Technologies for Calcined Industrial Minerals in Europe	5,828	8,633	01/01/2013	31/12/2016

Table 2.16. H2020 Program

Number	Title	EU Contribution in k€	Total cost in k€	Start	End
645696	REMINE - Reuse of mining waste into innovative geopolymeric-based structural panels, precast, ready mixes and in situ applications	567	621	01/01/2015	31/12/2018
689857	PRIGEoC - Partnership for Research in Geopolymer Concretes	518	518	01/06/2016	30/05/2020
658884	Eco-LWG - Eco-lightweight granules for energy efficient applications	183	183	01/08/2015	31/07/2017
645704	SUPERCONCRETE - Sustainability-driven interna-tional/intersectoral Partnership for Education and Research on modelling next generation CONCRETE	468	504	01/07/2015	30/06/2019
701531	GEOCRETE - Long-term performance simulation of geopolymer concrete under coupled carbonation and chloride transport	166	166	15/06/2016	14/06/2018

636164	WRIST - Innovative Welding Processes for New Rail Infrastructures	4,188	4,188	01/05/2015	30/04/2018
728652	Ugypsum - Up-cycling manufacturing waste from the composite industry	50	71	01/05/2016	31/10/2016
637138	ECO-Binder - Development of insulating concrete systems based on novel low CO2 binders for a new family of eco-innovative, durable and standardized energy efficient envelope components	5,846	7,616	01/01/2015	31/12/2018
642067	RESLAG - Turning waste from steel industry into a valuable low cost feedstock for energy intensive industry	8,022	9,669	01/09/2015	28/02/2019
636835	ISOBIO - Development and Demonstration of Highly Insulating, Construction Materials from Bio-derived Aggregates	5,470	6,318	01/02/2015	31/01/2019
701932	By-BM - By-products for Building Materials	195	195	25/04/2016	24/04/2018
636709	HOMESKIN - HOMES Key INsulating material	4,518	6,292	01/02/2015	31/01/2018
637186	BRESAER - Breakthrough solutions for adaptable envelopes for building refurbishment	5,849	5,849	01/02/2015	31/07/2019

The main topics are:

- innovative materials for construction sector;
- recycling and reuse of waste materials in the construction sector;
- sustainability, low carbon footprint and innovation of concrete materials;
- use of lightweight materials in the construction sector;
- use of geopolymeric materials in the construction sector;
- use of bio materials in the construction sector;
- increasing the durability and the strength of construction materials.

2.3. Member States

European Member states are involved in National funding programmes as well as in ERA-Nets (e.g. FNR in WoodWisdomNet, CNRS and PtJ in ERA-MIN).

As no proposal has been selected for the CSA “SC5-19b-2015-Mapping MS R&I activities” an online survey has been developed. The classification used for funding programmes is based on the 2x8 matrix of web-portal and roadmaps.

2.3.1. Results of survey (See Annex 3 for details)

A consultation on raw material related funding programmes in European countries has been launched on September 8 and the inputs analysed until January 2017.

Out of 28 EU countries, 13 have replied to the survey, representing more than 75 % of the inhabitants and more than 80% of the GDP of the EU.

Additionally 4 non-EU countries have answered: Brazil, Chile, Norway and Serbia.

A detailed presentation of the results is to bound in annex 3.

Main results

- The results regarding to the **maturity of the projects** show that most of the projects are on a proof of concept level quickly followed by laboratory scale, pilot trail and Fundamental Research. The least of the projects are on a pre-Competitive demonstration reference level.
- For most of the projects SMEs are **eligible beneficiaries**, closely followed by research institutes, universities and large companies. Public authorities are clearly on the last rank and therefore at least of all possible eligible beneficiaries.
- It can be seen that the majority of the projects are organised by organisations which are **programme owner and programme manager** at the same time, closely followed by organisations which are only programme manager. Only a small amount of organisations are programme owners (slightly more than 10 %)
- The majority of projects are only about **abiotic materials**, followed by both abiotic and biotic materials, which means that all in all almost 75 % of the projects are about abiotic materials. This is followed by projects dealing only with biotic materials (about 23 %), which means that all in all approximately 55 % of the projects deal with biotic materials
- Most of the programmes do research with **metals and critical raw materials**, which is followed by forest based materials. On rank three, we can see both construction minerals and industrial minerals and on the last rank plastic. The survey shows that three/31 funding programmes do research with none of those materials.

The survey shows that the majority of the funding programmes address the topic “resource efficient processing and refining of raw materials”, followed by the topics “recycling of raw materials from products, buildings and infrastructure”, “advanced use and substitution” and “innovative extraction and harvesting of raw materials” together with “product design optimising use of raw materials and increasing quality recycling”.

Slightly more than 50 % of the funding programmes address the topics “Circular economy and recycling policies“. About 45 % deal with the topics “Logistics, transport and optimised raw material flows along the value chain” and “Non-technological topics” and on the last rank can be seen “any other raw material related topic”, where interviewees could add additional topics as for example “CO2-utilisation and CO2-separation”, “aggregates and building materials” and “genetics and tree breeding” to name just some of them.

The survey clearly shows that amongst all that have answered their programmes deal with the topic “recycling of raw materials from products, buildings and infrastructure”, address the field of “end-of-life products recycling”. On rank two and three are the topics “packaging recycling and Innovative sorting and detection systems” and on the last rank “construction and demolition waste recycling”.

2.3.2. Italy (as an example for a Member state)

The situation of ongoing funded projects about raw materials in general was carried out at regional level. Unfortunately, the information is available only for few regions (6 on a total of 20) and most of the time there is a lack of details which include project duration, public funding, total cost and project abstract. Moreover, funded projects for the 2014-2020 period are still not available.
However, for those regions where the analysis was possible, funded projects on raw materials involve the following main topics:

- increasing the energy efficiency of production processes;
- use of nanotechnologies and innovative nano-based materials;
- recycling, sustainability and innovation in the construction sector;
- new plastic materials and new production processes for thermoplastic materials;
- new metallic materials and new production processes for metallic materials;
- development of innovative composites and polymeric materials in several industrial sectors;
- development of environmentally friendly materials with low carbon footprint for several industrial sectors.

The 4th and 5th of October 2016, UNIVPM participated at the conference “SMETCH: SMEs match in Italy with EIT RawMaterials” held at the central office of the Co-Location Centre South of the KIC EIT Raw Materials located at Centro Ricerche ENEA Casaccia (Italy). The scope of the conference was to inform all those who are interested in the current European initiatives on raw materials and to involve Italian SMEs in the activities and funding opportunities promoted by EIT RawMaterials.
The main activities of the KIC EIT RawMaterials are:

- matchmaking and networking between academia, research centers and business;
- learning and education;
- business creation and support for innovative projects and ideas;
- up-scaling technologies for raw materials.

The feedbacks received by Italian SMEs were focused on the spreading of their priorities, to find the best way to get funding opportunities by EIT RawMaterials and to inform on their needs.

2.4. Programs and projects upload to web-portal

During the project information has been collected in the frame of “RM research programs/topics & Identification and classification of currently running research programs/topics” and uploaded on the web-portal:

http://www.veram.eu/#!/research-projects/index

For the web-portal the VERAM team has chosen following **classification** in order to address research areas on raw materials:

- A. Technologies for primary and secondary RM production
  - A1. Innovative extraction and harvesting of raw materials
  - A2. Resource efficient processing and refining of raw materials
  - A3. Recycling of raw materials from products, buildings and infrastructure
- B. Advanced use and substitution of raw materials
  - B4. Materials for use in large quantities, including energy technologies
  - B5. Materials for consumer products and advanced applications
  - B6. Product design optimising use of raw materials and increasing quality recycling
- C. Improving Logistics and Europe’s waste management framework
  - C7. Optimised waste flows for increased recycling
  - C8. Logistics, transport and optimised raw material flows along the value chain

This work will be continued and the database on the web-portal completed until the end of the project by all project partners.

3. Effectivity and efficiency of funding initiatives: evaluation criteria

Partners involved: D'Appolonia, JUELICH

In this chapter, the criteria for the assessment of the effectivity and efficiency of EU and national funding programs and initiatives on Raw Materials technologies are presented and discussed. These criteria has been individuated starting from the analysis carried out in the report "Raw Materials: Study on Innovative Technologies and Possible Pilot Plants – Second Interim Report" published in the framework of the Ramintech study (Tender No. 112/PP/ENT/CIP/11/C/N0 6S001) and other sources.

3.1 Main evaluation criteria

There are many different ways of assessing the merits of funding programs, none of them being perfect, because of the difficulty of quantifying indicators, and mainly due to the unpredictable outcomes of the research activity itself.

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. This is in particular true, when dealing with the Raw Material correlated research, finalised to deliver sustainable innovation and ultimately assuring Raw Materials supply security.

Therefore, the main criteria to be used to assess the merits of funding programs and initiatives have been built along four dimension 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.

In the following sections a detailed description of these criteria is presented.

3.1.1. The economic and social dimension

Under the economic dimension, the following criteria would apply for **the micro-economics:**

i) **Impact on integral cost price (ICP) of a product (a raw, processed or recycled material, a product in which substitution took place)**: a successful funding initiative may lead to a reduction of the integral cost price (determined by the capital expenditures (CAPEX) and operating expenditures (OPEX) of a given industrial activity, leading to a cost price in €/t, or €/product in the case of substitution) of a given product. In order to assess the (effect on) cost price, a **sectorial approach** is recommended. Such a sectorial approach should reveal benchmark figures concerning production, related manpower (quality and quantity), added value, consumables and emissions (and about learning curves of innovations in parallel fields) from existing and related industrial activities.

ii) **Unlocked volumetric potential (Mt):** what is the projected resource volume becoming accessible as a result of the funding program? This criterion also counts for exploration funded projects (for the complete range of raw materials in scope, on land as well as from the sea since they enable higher resource volumes to become available. This criterion also holds for substitution technologies, only in this case it presents a figure for the avoided use of a given material. Furthermore, additional unlocked volumetric potential may result from meeting current or future environmental and/or legal constraints that prevent such volumes from being developed. In principle there may be Raw Material resource volumes that cannot be developed into reserves because of environmental constraints ("contingent resources"). If such constraints can be overcome using new technologies, then these contingent resources may be matured into "reserves". [11, 12]

iii) **Proportion of unlocked volumetric potential within the EU-27:** as above under ii), but now focused on the potential within the EU-27.

The following criteria would apply for the **macro-economics**.

i) Temporary jobs created in the EU;
ii) Permanent jobs created in the EU;
iii) Impact on skills and knowledge;
iv) Improvement in the balance of payments of the EU: this can be measured by estimating the size of the EU-market (M€/year) for the technology to be developed (related to the unlocked volumetric potential in the EU-27), and estimating how much imports from non-EU countries could be avoided (M€/year).

These criteria should of course be based on the outcome of the micro-economic indicators addressed before. These criteria may be estimated on the basis of sectorial analysis and subsequent sectorial comparison and by using trade statistics. Initiatives in the field of substitution require separate attention. In these cases, it is not only the economy of the innovative technology itself that counts, the assessment needs to take into account the extent to which the innovative technology may influence the current market situation; new technologies may have a positive impact on EU competitiveness or a detrimental impact on the existing market.

3.1.2. Criticality dimension

Worldwide, several risk matrices have been developed to assess the impact of shortage of supply on a given field. At the EU-level, criticality is judged by assessing both the supply risk and the economic relevance to the EU[13]. In a thorough publication by IZT Berlin, (Germany),[14] the vulnerability of the German economy was 'plotted' against supply risk issues. For the purpose of this study, combining supply risks with economic relevance for main industrial sectors in Europe seems a valid starting point for assessing the impact of

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[11] *The UNFC defines the following: contingent resources are discovered mineral/raw material resources that under the current economic (cost price, market price, technical and market risk) and/or legal conditions (licensing, legal, environmental etc.) cannot be developed commercially; reserves are discovered mineral/raw material resources that under the current economic (cost price, market price, technical and market risk) and legal conditions (licensing, legal, environmental etc.) can be developed commercially.*

[12] *The EU seems to be rich in contingent mineral resources that are not developed for environmental/licensing reasons. Overcoming such hurdles should be an important consideration when proposing a project.*

[13] *Critical raw materials for the EU, a report of the Ad-hoc Working Group on defining critical raw materials, published in June 2010; this report defined a group of 14 raw material groups to be of critical importance for Europe.*

[14] *Kritische Rohstoffe für Deutschland - „Identifikation aus Sicht deutscher Unternehmen wirtschaftlich bedeutsamer mineralischer Rohstoffe, deren Versorgungslage sich mittel- bis langfristig als kritisch erweisen könnte",, Lorenz Erdmann, Siegfried Behrendt, Institut für Zukunftsstudien und Technologiebewertung (IZT), Berlin; Moira Feil, Adelphi, Berlin, September 2011, tasked by the KFW Bankengruppe*

funding initiatives on criticality. For reasons of completeness, a possible methodology used by the ad-hoc group on Raw materials is explained and given below.
Criticality C of (raw) materials can be seen as a risk analysis depending on the Supply Risk (SR) and the Economic Relevance (ER) in the form of:

$$C = SR^a \times ER^b$$

a and b representing integers (> 0) to be chosen in order to influence the weighting of SR and ER. A successful funded project will not influence the economic relevance of the material in question, but it will influence the Supply Risk, as perceived from the perspective of the European Union. Therefore, a representation of the effect of a funding program on the criticality (ΔC) is:

$$\Delta C = ER^b \times (SR_0^a - SR_p^a)$$

For reasons of simplicity, we choose a=1.
The Supply Risk used in the Report of the Ad-hoc Working Group on defining critical raw materials[15] is defined as follows:

$$SR_i = \sigma_i (1 - \rho_i) HHI_{WGI}$$

In which: SR_i is the supply risk for raw material i, σ_i is a measure for the substitutability for raw material i, ρ_i is the degree of recycling implemented for raw material I, and HHI_{WGI} is a measure for the stability/instability and level of concentration of producing countries, using the Worldwide Governance Indicators[16] . This indicator is denoted here by WGI_c for the country *c*.
The WGI_c was aggregated using a Herfindahl-Hirschmann-Index based on the share of the country *c* in the world production data (in %), denoted $S_{i,c}$ according to:

$$HHI_{WGI} = \sum (S_{i,c})^2 \, WGI_c$$

Using this methodology for this study it implies that the supply risk is reduced by a funding program when:

- The substitutability for a given material increases because new innovative options appear (the impact is of course related and limited to the economic importance of the affected market)
- The rate of recycling of a given material within Europe increases;
- The HHI 'improves' because more material is (quantifiably) produced within the EU-27 (being stable countries), thereby also improving the balance of supply.

Furthermore, the long-term supply risk may also be a result of dealing with a market with a poor transparency and therefore knowing a risk for high price volatility. This again has a negative impact on the investment climate, especially where profit margins are low and risks are high. Securing a supply of raw materials that suffer under these non-transparent market conditions within the EU-27, may give the opportunity to play (as EU-27) a strategic role in the market forces that influence the long term investment climate.
Under Criticality, the following criteria would apply:

i) **Impact on criticality**: What potential impact could the (total theoretical) unlocked volumetric potential, as a result of implementing the new funding program throughout the EU, have on the criticality of the Raw Material in question? The criticality assessment applied by the Ad-hoc working group on Raw Materials is outlined above, and the various aspects that may be assessed are explained.

[15] See Annex 1 Methodology for qualitative assessment, Ad-hoc working group on defining critical raw materials - 2010 - Critical raw materials for the EU - European Commission , DG Enterprise (Brussels, Belgium), p. 55
[16] provided by the World Bank (http://info.worldbank.org/governance/wgi/sc_country.asp).

ii) **Impact on market transparency**: Could the funding initiative result in contributing to commodity market transparency, better functioning markets and (in the long run) a better investment climate? This criterion will require input from specific experts to be consulted.

3.1.3. Environmental dimension

The environmental performance of the funding program has to be assessed in relation with the impact of funded projects and will be compared to the environmental performance of the state-of-the-art practice or technology within a branch or sector. This will be assessed on the basis of statistical data from Eurostat but also with the experts' experience in performing LCA-studies.

The environmental profile can be evaluated in terms of energy use, water use, Green House Gas emissions and toxic emissions. These profiles concern both direct and indirect emissions and uses. Hence, these can be regarded as footprints. Profiles can be assessed for each environmental impact category proposed.

The actions will be evaluated by asking for specific but readily available data about the projects (e.g. in terms of changes compared to state-of-the-art-technology) which would allow, via a small energy, material and emission chain model, an assessment of the sustainability impact of the action with respect to the state-of-the-art profile.

For further evaluation, a set of prices will be made available for each environmental impact category proposed in order to weigh the different categories and evaluate the total environmental impact. This approach is also used in cost-benefit analysis and concerns both market prices (energy, water and waste) and external costs (greenhouse gas and toxic emissions). The latter are calculated using the avoidance costs method.

The environmental evaluation criteria for assessing funded actions are composed of:

i) Δ (= delta = Modification caused by the funding program) of Energy use, MWh/(unit product);
ii) Δ of water use, million m^3/(unit product);
iii) Δ of GHG (Green House Gas) emissions, Mt CO_2-equivalent;
iv) Δ of toxic emissions, describe + quantify if possible;
v) Δ of waste generated (may include the useful use of waste);

The 'delta'- data asked under this dimension are based on the assumption that an innovative funded projects may lead to activities that are to be compared to existing installed base, or to best practices in the relevant domain. For completely new routes, it is the quantity of consumables as such that counts.

3.1.4. The Innovation dimension

After having treated the economic, criticality and environmental dimensions, the innovation dimension deals with the intrinsic merits of a funding program.

3.1.4.1. Technology assessment: Immediacy of benefits

The funded initiatives and, in particular, pilot plants in the Raw Materials value chain have to be characterised through a Technology readiness Level in order to assess its effective role in the value chain and the expected time to deliver. For this reason the Technology Readiness Level (TRL) of funded technologies will be used as a relevant criterion for assessment. This leads to the following criteria:

i) What is the overall **stage of innovation** of the funding program? (explicitly, Best Available Technologies may be included here); preferably a TRL (Technology

Readiness Level) should be established.[17] The definitions of the various phases of TRL are as follows

Table 3.1. Technology Readiness Level Definitions

	Technology Readiness Level Definition
TRL 1	**Basic Research:** Initial scientific research has been conducted. Principles are qualitatively postulated and observed. Focus is on new discovery rather than applications.
TRL 2	**Applied Research:** Initial practical applications are identified. Potential of material or process to solve a problem, satisfy a need, or find application is confirmed.
TRL 3	**Critical Function or Proof of Concept Established:** Applied research advances and early stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology.
TRL 4	**Lab Testing/Validation of Alpha Prototype Component/Process:** Design, development and lab testing of components/processes. Results provide evidence that performance targets may be attainable based on projected or modelled systems.
TRL 5	**Laboratory Testing of Integrated/Semi-Integrated System:** System Component and/or process validation is achieved in a relevant environment.
TRL 6	**Prototype System Verified:** System/process prototype demonstration in an operational environment (beta prototype system level).
TRL 7	**Integrated Pilot System Demonstrated:** System/process prototype demonstration in an operational environment (integrated pilot system level).
TRL 8	**System Incorporated in Commercial Design:** Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration).
TRL 9	**System Proven and Ready for Full Commercial Deployment:** Actual system proven through successful operations in operating environment, and ready for full commercial deployment.

ii) **Reason of planning of current proposal**. An estimate of the timeline until commercial development is required as is evidence from analogues for how realistic this is. A picture about the economic and/or political drivers, or expected enabling technology breakthroughs that coincide with the proposed action needs to be established.

iii) **Hurdles / threats foreseen until commercial development**; for example:

a. Degree and nature of anticipated competition for the product resulting from the project;
b. Regulations regarding product safety to users, workers industries, environment;
c. Regulations regarding disposability or recyclability.
d. Up scaling from pilot plant to full commercial scale: which hurdles can be anticipated?
e. Market acceptance: which hurdles can be anticipated? Degree and nature of anticipated competition for the product resulting from the project.

3.1.4.2. Technology assessment: Market size

Research on innovation has established that the second most common specific cause of commercial failure of an innovation was an overestimate of the number of potential users. In any case, market size should be sufficient that if the project is commercially successful, R&D costs can be recovered. In the matrix analysis, this may be assessed by (e.g.) an

[17] Many references can be found, e.g. in www.bnl.gov/tcp/.../TRL%20Explanations.doc

estimate of the potential EU market for products related to the proposed project and the market share that might result.

3.1.4.3. *Considerations coming from the Oslo Manual*

The Oslo manual provides a helpful background for assessing innovative solutions[18]. From the factors contained in the Oslo manual a list of indicators (both factors indicating innovation and factors hampering innovation) that were considered relevant and were not yet covered by criteria described in the previous paragraphs have been extracted. These criteria are presented in the following table.

Table 3.2. Innovation indicators from Oslo Manual

Innovation/ Hampering	First Level Factor	Second Level Factor (Objective)
Innovation Factor	Competition, Demand and Market	Replace products being phased out
		Reduced time to respond to customer needs
		Reduce time to market and exploitation expenses
		Adapt current products / processes to new markets
	Production and Delivery	Improve quality / performances of goods and services
		Improve flexibility of production or service provision
		Increase capacity of production or service provision
		Reduce product design costs
		Reduce production lead times
		Achieve industry technical standards
		Increase efficiency or speed of supplying &/or delivering goods or services
	Workplace Organization	Increase the level of automation/ Improve working conditions/Reduce risks for operators/ Increase operator attention and stimulate the awareness/ Improve ergonomics/ Avoid repeated, mechanical operations
		Optimize the internal logistics
Hampering Factor	Cost factors	Excessive perceived risks
		Additional research costs
	Knowledge Factors	Difficulty in finding co-operation partners for Product or process development or marketing
	Market Factors	Uncertain demand for innovative goods or services
		Potential market dominated by established enterprises
		Difficulty of accessing the market due to entrance thresholds
	Institutional factors	Lack of infrastructure
		Weakness of property rights
		non- technical barriers related to access to knowledge, (geo)political barriers
	Other reasons for not innovating	No need to innovate due to earlier innovations
		No need because of lack of demand for innovations
		Competing solution with higher effectiveness, superior funding and market potential, faster roll-out, higher reliability or stronger IPR

3.1.5. A note on substitution

It is important to recognise the distinctions between raw material provision approaches and substitution approaches.

Substitution activities will be on a spectrum between two extremes:

1) *Application-led substitution* where the activity is focused on replacing the use of a specific material in a specific market application; and
2) *Material-led substitution* where a novel material has properties that enable replacement of various materials in various end-applications.

[18] Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data

An example of type 1) is hexachrome in aerospace and at the other extreme type 2) are technologies such as graphene with multiple potential applications. Some cases will lie in the middle. Clearly the former of these is easier to quantify in terms on benefits and impact (since it focuses on a known and given application) but may also be more limited in scale of these. The latter is necessarily more difficult to quantify and is more likely to be early stage TRL levels but may enable a far greater impact across all categories of interest: economic, environmental, innovation and criticality.

Substitution related technologies will be taken into account only in the case where they have an impact on reducing the dependence on critical raw materials. Therefore criteria that are comparative with existing solutions may be most useful. These should include:

- Scale of use of the material being substituted and future forecast use (e.g. fuel cell catalysts will be more important in the future) and scale of availability of the substitute.
- Relative criticality of the material being replaced and the intended substitute (e.g. replacing indium with graphene produced from graphite swaps one critical material for another) – this includes a measure for high EU reliance on the material in its industries.
- Recyclability (a corollary to substitutability for other materials) of the material being replaced i.e. those not currently viable for recycling are of greater importance (e.g. fluorspar, gallium, graphite, beryllium).
- Cost of validation for the accepted use of a new material.
- Technical performance – must be equivalent or better to succeed as an innovation.
- Market Dynamics may be useful to add for substitution– is the intended application(s) a growing or shrinking market. Is the application a critical future technology on current trends (e.g. fuel cells)?

Lastly the potential economic benefit of the innovative technology itself must be balanced against the extent to which the innovative technology may influence the current market situation; new technologies may have a positive impact on EU competitiveness or a detrimental impact on the existing market. The following table looks at the proposed criteria and assesses the suitability for substitution technologies.

Table 3.3. Suitability for substitution technologies

Dimension	Criterion	Notes on applicability for substitution
Economic	Integral Cost price effect	CAPEX is a critical factor for substitution especially when developing a new material – effect on cost price not always as relevant for a substitute; the criterion will depend on the cost of the material and the material proportion of the product price
Economic	Unlocked volumetric potential	Represents volume of materials being replaced. A wide-application technology may displace more than one material in more than one application.
Economic	Temporary jobs created in the EU; Permanent jobs created in the EU ; Improvement in the balance of payments	An important additional factor for substitution is the effect on existing markets – what is the economic importance to the EU27 of the displaced technology/material.
Criticality	Impact on criticality	Substitution has high impact on criticality when activity leads to decrease in use of one or more of the 14 critical materials. Note this measure should take account of the relative criticality of the material being substituted and its replacement. A high critical material being displaced by a low/none critical material rates highest.
Criticality	Impact on market transparency	Depends on the new materials involved; generally substitution will lead to use of products marketed in transparent markets
Sustainability	All aspects mentioned	important metric but unclear what comparison needs to be made; LCA-type judgments at product level can be estimated when either materials or functionalities are substituted
Innovation	Meeting challenges	Applicable to substitution
Innovation	Immediacy of benefits (TRL), reason of planning current proposal, hurdles for commercial development	Time to market is a very important criterion given the aim to have substitutes available by 2020. Thus, activities which have a delivery time of approximately 2-3 years are considered very important (grade 5), while those that exceed the limit of 2020 are not important (grade 0).

The overall conclusion is that generally the criteria are well applicable for the case of substitution with some minor adjustments. The environmental dimension should be treated with care since substitution pilots do not deal with improvements of environmental footprints.

3.2 Germany (as an example for a Member state)

The BMBF (Federal Ministry of Education and Research) supports R&D for resource efficiency within the Funding Programm FONA (Research for sustainability).

In the National sustainability strategy (2002) the objectives of doubling of the raw material productivity between 1994 and 2020 and decoupling raw material consumption from economic growth were set.

Five strategical approaches were followed by the BMBF in launching specific funding initiatives: R², R³, r4, CO2Plus, SME innovative, R+Impuls as well as international cooperation.

The funding initiative R²: Innovative Technologies for Resource Efficiency run from 2009 until 2013, with a public budget of 38 million € by BMBF and a private contribution of 17 million € by the industry.

R² focused on resource-dependent industries with a large use of RM (steel, metal, chemical and construction industry). 22 collaborative projects were funded.

As the evaluation[19] showed the project results are very promising. Their potential in a theoretical case of nation-wide implementation would be:

- Increase of RM productivity of 5-6 %,
- Reduction of energy consumption of app. 75 TWh/a (16%) (equals the average yearly output of roughly 6 large power plants),
- Reduction of material consumption of app. 80 million t/a (25 %),
- Reduction of greenhouse gas emissions of app. 60 million t CO2-eq./a (33%) (equals app. 7.5 % of the total german GHG emissions in 2011 of 800 million t),
- Production cost could sink about 3,4 billion € per year
- Slightly positive influence on the employment rate,

Two other positive research results in line with the r² programme:

- Development of a strip casting method for the production of high-strength, low-weight HSD steels with a high potential for application,
- Development of a dezincification process for steel scrap saving 88 % energy and reducing 90 % greenhouse gas emissions.

[19] Innovative Technologien für Ressourceneffizienz in rohstoffintensiven Produktionsprozessen, Fraunhofer Verlag, 2013

4. Description of industry strategies and the way these affect EU RM supply or demand

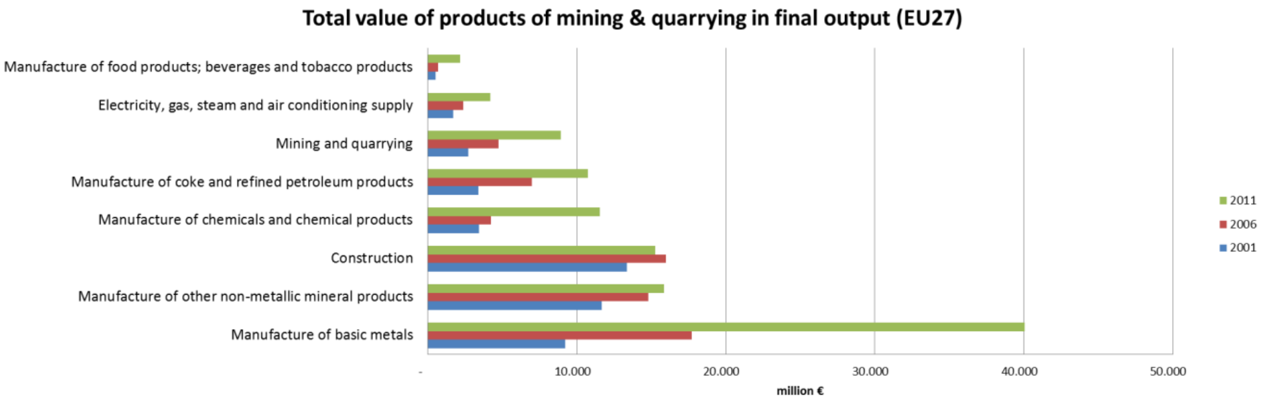
Partners involved: D'Appolonia, JUELICH, VITO

4.1. Absolute values of raw materials in EU final output

For the current analysis, only non-food and non-energy materials were considered. A distinction was made between material inputs obtained from forestry, logging and related services on the one hand, and metal ores and other mining and quarrying products on the other hand. The value of the output from these sectors can almost entirely be attributed to the value of the primary resources they produce. For this reason it is assumed that the aggregated value of raw material inputs of all 60 EU sectors equals the output of the sectors forestry, logging and related services, and metal ores and other mining and quarrying products. These two sectors themselves also require primary resources as an input, obtained from both domestic and non-EU forestry and mining activities.

The figure below represents the value of products from mining & quarrying embedded in the final output of the top-8 (out of 60) industrial sectors aggregated at EU level, for the years 2001, 2006 and 2011.20 Over all sectors, the total value of products from mining and quarrying in the EU industrial output has more than doubled in the period from 2001 to 2011, totalling approximately 123 billion euro in 2011. The manufacturing of basic metals is the single most relevant sector, with the highest absolute value of materials (about 40 billion €) in the final output. Although for some material intensive sectors, such as construction and the manufacture of other non-metallic mineral products, growth has been more moderated, for others, namely manufacture of basic metals, of chemicals and chemical products, and of coke and refined petroleum products, the increase of the mining and quarrying product value in the total output of the sector has been close to or higher than average.

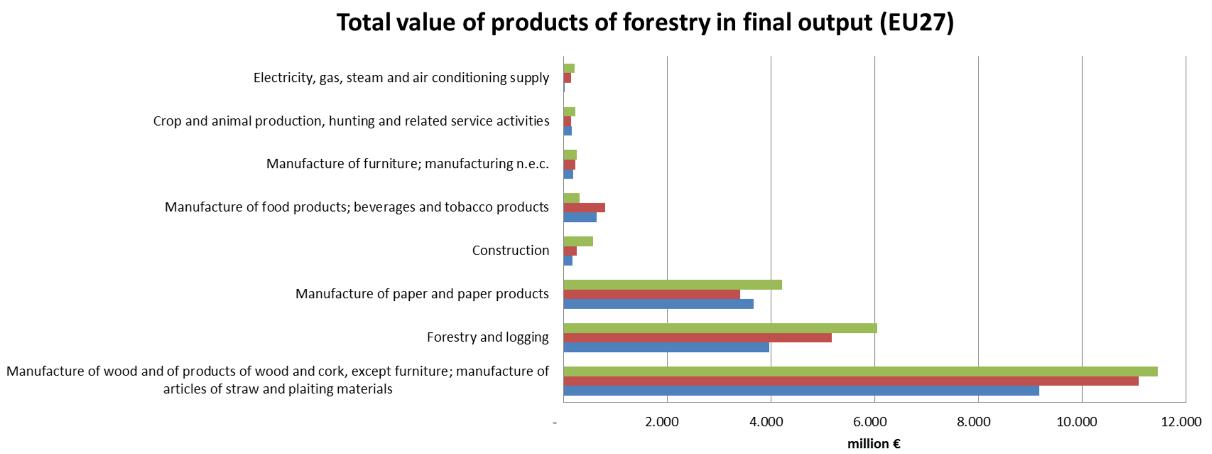
Figure 4.1. Total value of products of mining & quarrying in final output (EU27)



[20] Calculations based on the direct input value of primary resources (non-energy and non-food) to EU sectors. Use tables at current prices, 60 branches - EU aggregates [naio_16_agg_60i]

When performing the same analysis for products of forestry, logging and related services, a different picture emerges. Unsurprisingly, the top-3 of industrial sectors includes the manufacture of wood and wood products, the forestry and logging sector itself, and the manufacture of paper and paper products. The total value of products of forestry in the final EU output, aggregated over all sectors, has increased with 27% approximately in the 2001-2011 period. Only the value of products of forestry in the final output of manufacture of food, beverages and tobacco products sharply decreased over the same period.

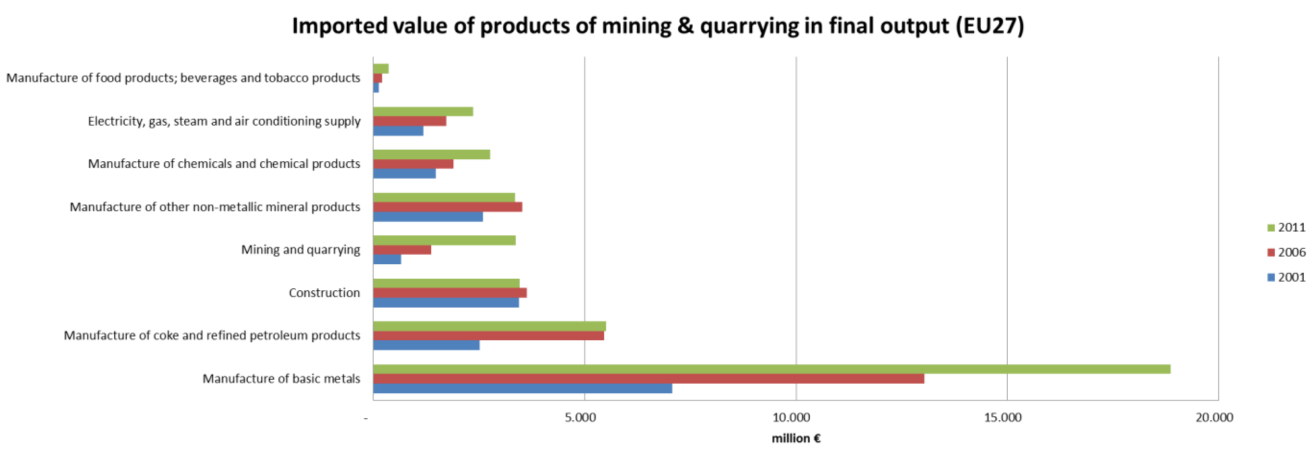
Figure 4.2. Total value of products of forestry in final output (EU27)



4.1.1. Absolute values of imported raw materials in EU final output

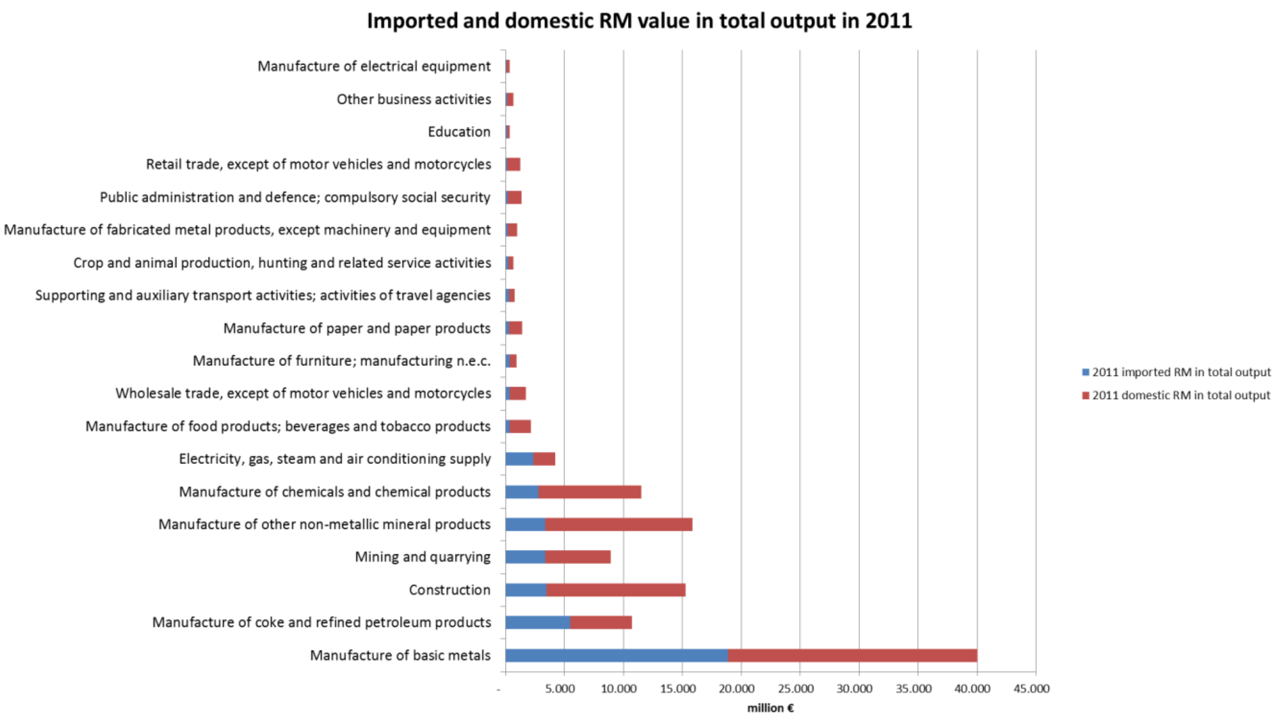
When it comes to securing the raw materials supply for EU industries, it is relevant to look at the value represented by imported raw materials. The figures on imports of raw materials only reflect the value of direct imports, and do not include the value of the materials embedded in imported intermediate and finished products. This way, double-counting of raw material values is avoided.

Figure 4.3. Imported value of products of mining & quarrying in final output (EU27)



The same industrial sectors that were present in the top-8 of raw materials value in final sector output, are found in the top-8 materials importing sectors, although in a different order, except for the first place. In 2011, the manufacture of basic metals alone represents roughly 44% of the aggregated imported raw material value of the EU, and this value has almost tripled between 2001 and 2011. A considerable growth of imported raw materials value in the final output also can be observed for the mining and quarrying sector. For the construction sector and the manufacture of coke and refined petroleum products and of other non-metallic mineral products, the value of imported materials in the final output of the respective sectors has grown at a slower pace since 2006, or even declined. Overall, at an EU aggregated level for all sectors, the imported value of products of mining and quarrying has doubled between 2001 and 2011. More than half of this increase can be attributed to the rise of the value of imports for the manufacturing of basic metals.

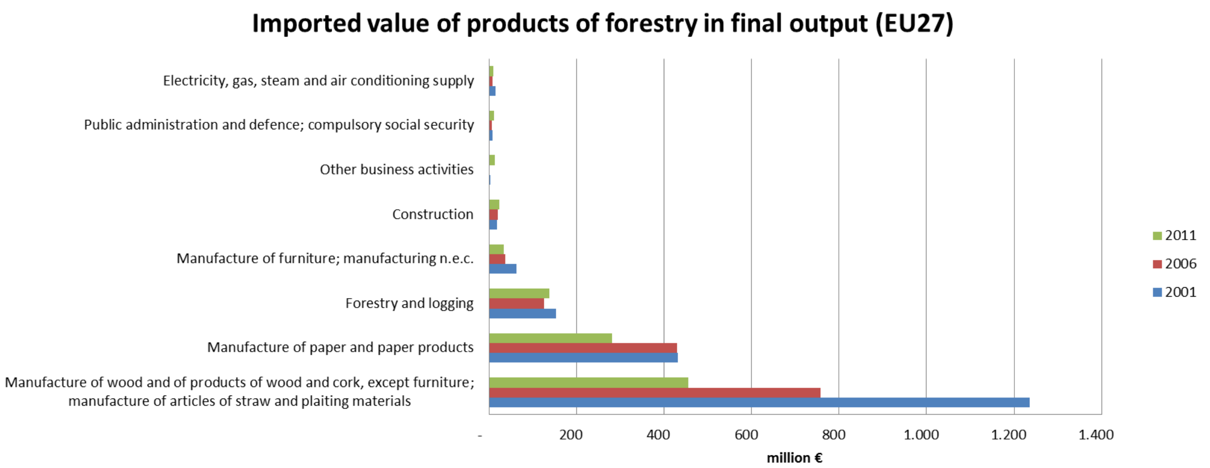
Figure 4.4. Imported and domestic RM value total output (EU27)



The graph above illustrates the relation between the value of domestic versus imported products from mining and quarrying in the final output of EU businesses in 2011. For both parameters, the picture is dominated by the manufacture of base metals.

Again, a different picture is obtained from the analysis of the value of imported products of forestry. In 2011, the absolute value of imported products of forestry in the final output of the aggregated industrial sectors, about one billion euro, has been halved compared to 2001. Since the total value of forestry products in the EU final output has grown by 27% between 2001 and 2011, import dependency for the generation of added value has declined for most sectors that are forestry product intensive, notably for the manufacture of wood and products of wood, for the forestry and logging sector itself, and for the paper and paper products industries.

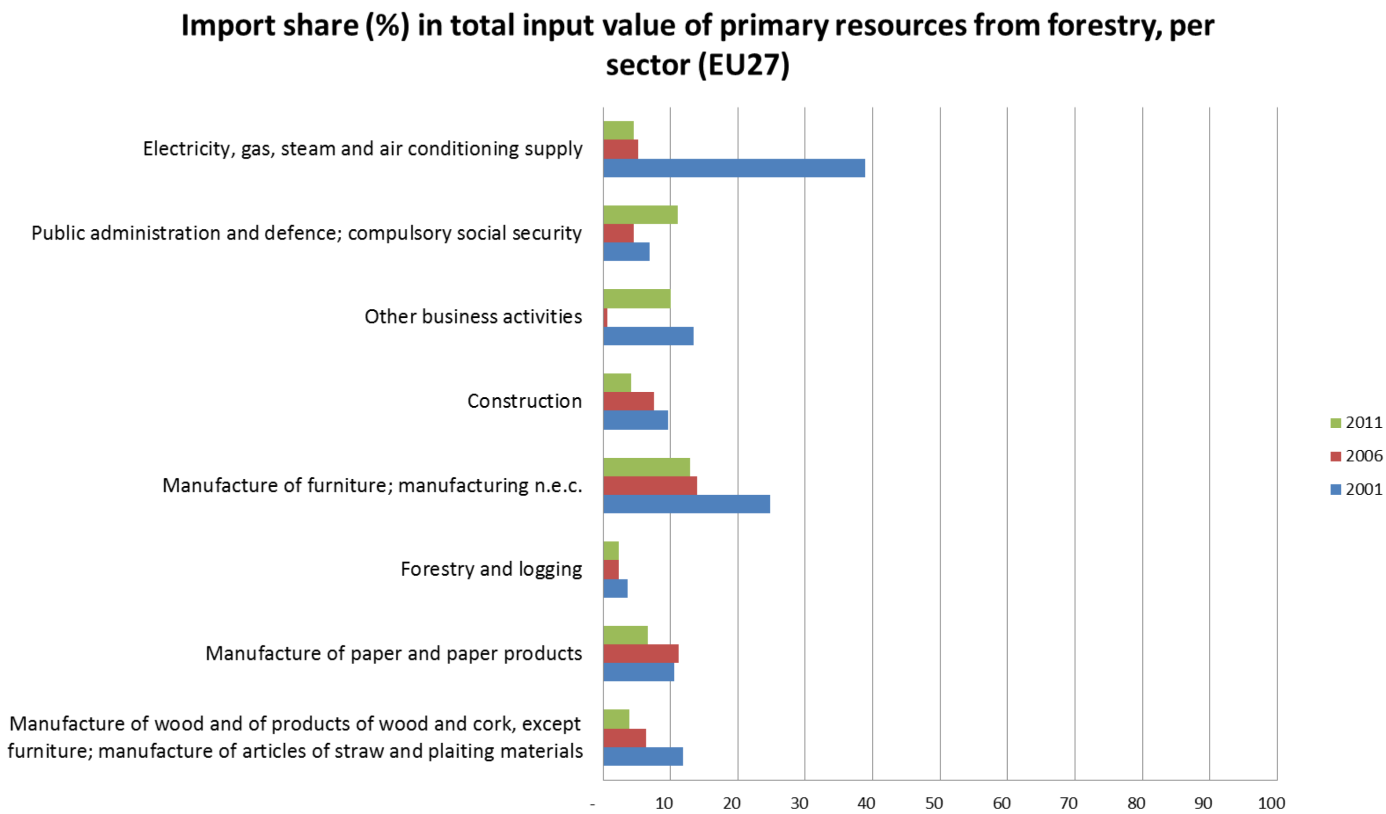
Figure 4.5. Imported value of products of forestry in final output (EU27)



4.1.2. Values of imported versus domestic raw materials

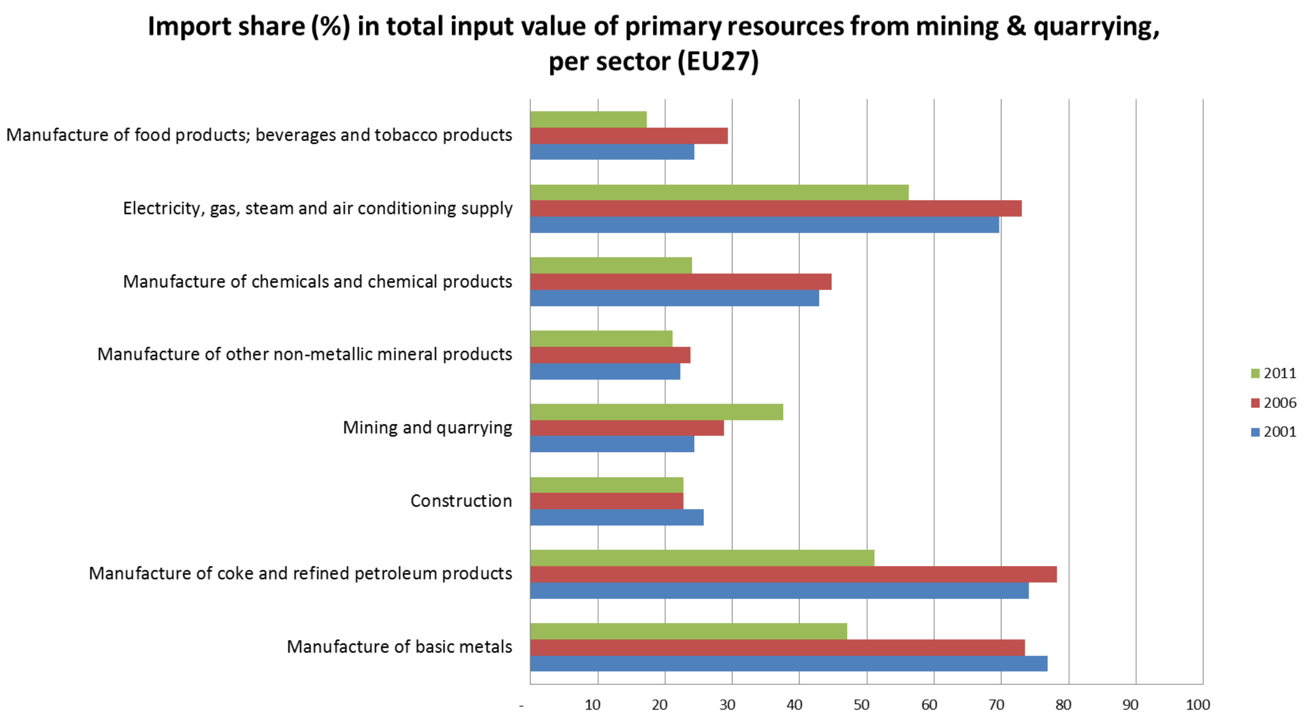
In order to give an idea not only of the absolute values related to (imported) raw materials in the final output of the most relevant material intensive EU sectors, an analysis was performed on the relative importance of imported raw materials as well.

Figure 4.6. Imported share (%) in total input value of primary resources from forestry, per sector (EU27)



Regarding the share of the value of imported products of forestry, relative to the value of domestic raw materials in the final output of sectors that present high imports of forestry products, a considerable decrease is observed in all but one sector (public administration and defense). In 2011, more than 87% of the value of products of forestry used by those sectors that import important absolute values in forestry products, is obtained from domestic forestry and logging products.

Figure 4.7. Imported share (%) in total input value of primary resources from mining & quarrying, per sector (EU27)



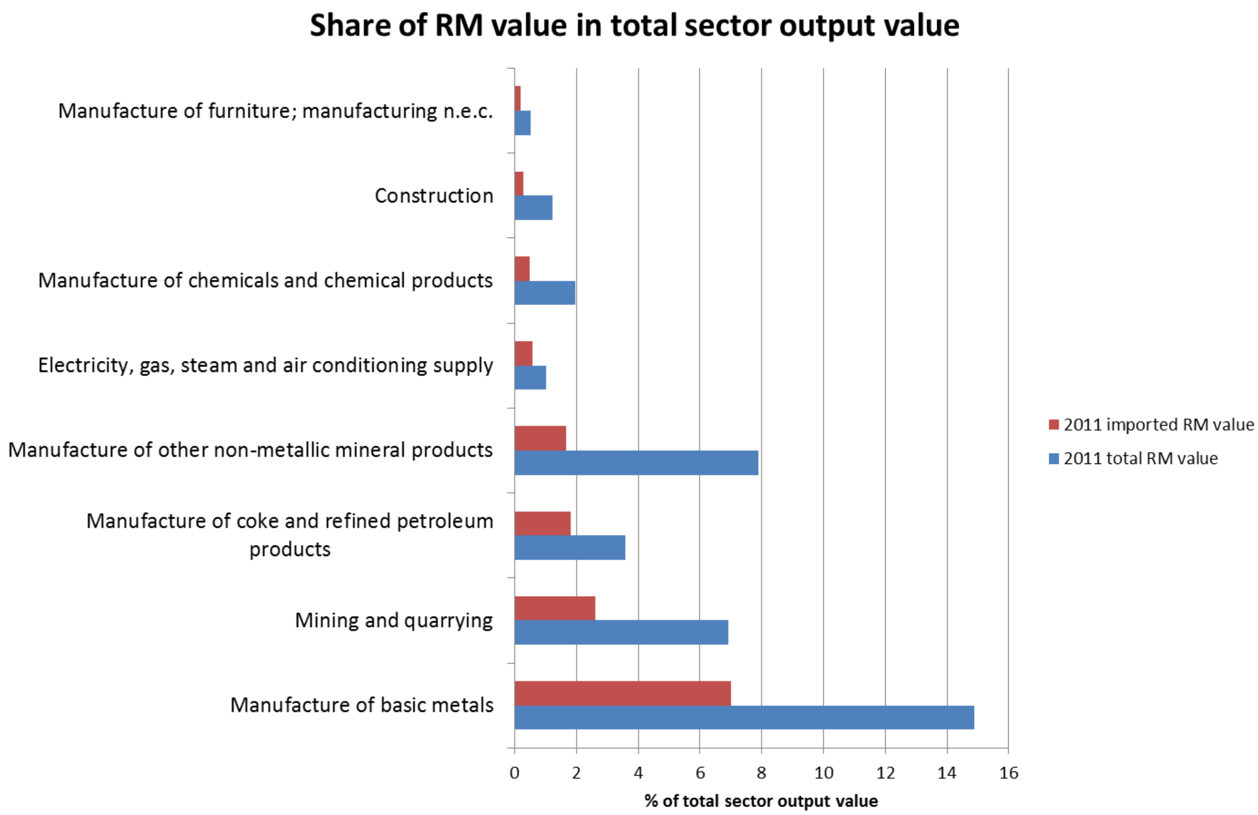
Also for those sectors that import high values of products from mining and quarrying, between 2001 and 2011 a decrease is observed of the relative share of the imported raw material value in all but one sector (mining and quarrying). In 2011, between 17 and 56% of the value of raw materials used by those sectors that import important absolute value of raw materials is not obtained from domestic but from imported raw materials, where for forestry products, this share is below 13% for all relevant sectors.

From the latter observation, it can be concluded that 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 raw materials from mining and quarrying. The EU forestry product dependent sectors can rely considerably more on domestic resources for the building up of product value chains than those sectors that import a relevant share of their raw materials required to realize their final output.

4.1.3. Share of raw materials relative in the total final output value

Finally, the share of the raw material value in the total final output of the EU sectors completes the picture. Since 2001, the relative share of imported materials in the final sectoral output has increased for all material intensive sectors. In 2011, only 8 out of 60 sectors show imported raw material value shares that account for more than 0,19% of the total sectoral final output. Only in 4 sectors, the total raw material value constitutes more than 2% of the final output value. For all 60 sectors, 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%. Even for the manufacture of base metals, less than 16% of the output value can be attributed to the raw materials.

Figure 4.8. Share of RM value in total sector output value (EU27)



4.2. Long-term industrial raw materials strategies

4.2.1. Resource efficiency, recycling and complementary strategies at sector level

4.2.1.1. Non-biotic raw materials sector strategies

A selection of raw materials industry roadmaps towards 2050 has been scrutinized in order to identify the corresponding industry’s strategic objectives and concrete measures proposed by the different sectors for achieving these objectives.

Table 4.1. Strategic objectives, examples of proposed measures per sector

Strategic objective	Example of proposed measure	Sector
Increased energy efficiency	Energy efficiency improvements for lime products of 16% are projected for 2050.	Lime industry
	Breakthrough technologies are developed and deployed to reduce heat demand in papermaking, by reducing water use and improving drying processes. Paper drying accounts for up to 70% of fossil fuel energy consumption in the pulp and paper sector alone.	Forest fibre industry
	Development of a system for producing hot water and electricity from the latent heat in post-production gases	Ferro-alloys and silicon producers
	Grinding efficiency techniques and thermal processes, energy recovery and closed circuits	Industrial minerals
Fossil fuel substitution	Replacement of the current 51% energy use in the form of solid fossil by gas would reduce the average emission factor of the fuel mix with 28%.	Lime industry
	Lime production in pulp mills and replacing the natural gas or fuel oil with biomass-based fuels in lime kilns. This could deliver savings in Kraft pulp production in the order of 3-4 Mt of fossil-based CO2.	Forest fibre industry
	60% of kiln energy could potentially be provided by alternative fuels of which 40% could be biomass. This fuel mix would lead to an overall decrease of 27% in fuel CO2 emissions.	Cement industry
	Half of all kilns are converted to electric kilns in the period 2030-2050, and the remainder to syngas or biogas co-fired with natural gas.	Ceramics industry
CCSU	The retrofit of existing blast furnaces with top gas recycling technology involves full deployment of CCS, leading to a reduction of absolute CO2 emissions of ca. 60% in 2050 compared to 1990.	Steel industry
Increased recycling	Development of processes for the recycling of rhenium, nickel and cobalt contained in the waste from the manufacture of superalloys	Ferro-alloys and silicon producers
	Recovery of manganese and generation of a valuable residue from ferromanganese slags	Ferro-alloys and silicon producers
	Surface chemistry applied to minerals can make polymers compatible with one another and therefore increase their recyclability.	Industrial minerals
	Recycling a wider range of glass types, e.g. glass from solar panels, from the hospitality sector or from construction/ demolition/ refurbishment projects	Glass industry
Increased material efficiency	Limestone needed to make clinker can be partially substituted by a range of alternative calcium containing materials, including waste and industrial by-products	Lime industry
	Raw materials pelletisation, with each pellet containing the correct proportion of mixed, powdered raw materials in close contact, improving efficiency.	Glass industry
Process technology innovation	Burning fuels in oxygen instead of air to improve the efficiency of the furnace	Glass industry
	Development of a camera-baked Soderberg electrode slip measurement device	Ferro-alloys and silicon producers
	Fractionation technologies offer the potential to modify the properties of fibre to develop new added-value products.	Forest fibre industry
Product design and new products	Developments of glues, paints, coatings and further treatment for increasing the durability of wood material and surfaces.	Forest fibre industry
	New combinations of aggregates for high-strength cements	Cement industry
Partnerships and integration	The formation of industrial clusters and industrial integration, to allow waste from one process to become a valuable raw material for another, resulting in new market opportunities and utilisation of unused minerals in post-mining rehabilitation programmes	Industrial minerals
	Integrated bio-refinery complexes and combinations with other sectors (waste management, steel, cement, refineries, and energy)	Forest fibre industry

Increased resource efficiency, innovation and industrial integration usually improve the competiveness at company level. This fact obviously favours the spontaneous generation of synergies between industrial strategies and the research roadmaps established at sectoral, national and EU level.

At the same time, sectoral industry roadmaps and raw material related position papers stress the limitations of proposed and imposed raw materials policies and strategies, including the technical, economic and environmental limitations of resource-efficiency targets, as well as the need to complement and support efficiency and recycling strategies with coherent policies and actions regarding international trade, infrastructure development, standardization and market research. Furthermore, industry calls not to forget that raw material demand precedes raw material supply. Therefore, it is posited to be essential to also consider those strategies and policies that aim to sustain a European industrial base. The following statements illustrate these concerns of industries:

- Under the flagship of its resource efficiency policy Europe has the chance to strive for: stimulating the secondary materials market, however, without imposing or prescribing recycling technologies: market forces should remain the driver for innovation; the setting of quality standards for secondary raw materials. (European Engineering Industries Association[21])
- New cement types have neither been shown to be economically viable, nor tested on a large scale for long-term suitability and durability. Nor have these products been accepted by the construction industry, where strong materials and strict building standards reign supreme. (CEM Bureau[22])
- The possibility to use recycled materials largely depends on the individual application. Using recycled content in a product is not always technically feasible nor beneficial from an environmental or economic perspective. Ultimately, recycled materials need to fulfil exactly the same technical specifications as primary materials. (European Automobile Manufacturers' Association[23])
- The cost to capture CO2 would more than double the production costs of lime, to around €60/ton lime. This would create a serious impact on the sector's competitiveness (local production compared to imports). (European Lime Association[24])
- Ensure consistent raw materials provisions in multilateral as well as in bilateral trade agreements; Prevent countries applying restrictive measures to benefit from preferential treatment (GSP) when assessing the EU market; Use existing mechanisms to identify and address restrictive measures in third countries i.e. Market Access Partnership; Market surveillance is also needed to ensure that instability and price fluctuations are kept under control and they are not the pure result of speculation and the growing intervention of financial operators in this market. (European Apparel and Textile Confederation[25])

[21] http://www.orgalime.org/sites/default/files/position-papers/PP_Circular_Economy_and_Waste_Policy_6%20May%202014.pdf
[22] CEMBureau (2013).The role of cement in the 2050 low carbon economy.
[23] ACEA Position Paper on Circular Economy – September 2015
[24] http://eula.eu/documents/eula-position-paper-carbon-capture-and-storage-ccs
[25] Euratex Raw Materials Position Paper (2011)

- The move from academic research to market-driven research will greatly benefit the Industrial Minerals industry and the entire value chain making sure that innovative products get to market more quickly (Industrial Minerals Association Europe[26])
- When tackling the issue of securing a sustainable supply of raw materials from international markets, Europe must first of all ensure that it has an industrial base that processes the raw materials. If it does not, Europe will have to live with the policies imposed by other jurisdictions as its buyer purchasing power and bargaining strength will decline because of its reduced demand for raw materials on the one hand and the rise of emerging economic giants on the other hand. (The Nickel Institute[27])
- Better quality of secondary raw materials available on markets can be achieved by mandatory compliance with EN standards for proper collection, logistics and treatment of WEEE and the development of quality standards for secondary raw materials. This could be complemented with further investment in EU recycling and treatment infrastructure. (European Committee of Domestic Equipment Manufacturers[28])
- Any new methodology that is developed by the EU to address dumping by Chinese producers must be sufficiently defined and include a clear link with the EU's five long-established market economy criteria. Without these criteria acting as the bedrock of European trade defense there will be an increased danger of legal uncertainty and consequently a greater risk for investments and manufacturing jobs in Europe (Aegis Europe).

4.2.1.2. Biotic raw materials sector strategies

Similar concerns and policy recommendations have been expressed by the biotechnology sector, as analysed by de Besi & McCormick (2015)[29]: They found that industrial biotechnology research agendas of the national and industrial strategies focus on:

- developing conversion technologies;
- expanding bio-refineries;
- exploring novel ways of using biological feedstocks and developing bio-based products through biotechnological research.

The authors further found that often, national strategies are mirrored by industrial strategies by calling for support into technological research, particularly into the advancement of bio-refineries. The industrial approaches in particular state that a successful transition to a bioeconomy will require advancements in industrial biotechnology; this can only come about by focusing research and innovation into these areas. The industrial strategies also call for

[26] Industrial Minerals Association Europe (2014). Imagine the Future with Industrial Minerals 2050 Roadmap.
[27] Nickel Institute (2011). Raw Materials Strategy. Position Paper of the in view of Rapporteur Bütikofer´s Draft Report on “an effective raw materials strategy for Europe”
[28] CECED Position Paper (2016). CECED views on the Proposals amending EU Waste Legislation.
[29] de Besi, M. and McCormick, K. (2015). Towards a bioeconomy in Europe: National, regional and industrial strategies. Sustainability. 2015; 7: 10461

investment in regional infrastructures to ensure the most complete use of biomass, including waste-based raw materials. The national and industrial strategies both state that there is a need for the creation of international standards and certification to ensure that imported biomass is sustainable.

The industrial strategies provide policy advice and recommendations focused at the EU level:

- need for the EC to ensure supportive and regulatory policies that create a level playing field for all actors.
- need for policies that facilitate the collaboration between all actors involved, that support the development and demonstration of bio-based technologies and products and that help stimulate market demand for these bio-based products.
- call for financial support for bio-based activities and coherence among other EU policies, particularly related to the EU 2020 strategy.

These supportive measures identified in the industrial strategies seem to be in agreement with the actions proposed by the EU, national and regional strategies. Five main actions to help develop the necessary framework for the development of the bioeconomy are present within all these strategies. These include:

- creating measures that aim to increase coherence between different policy sectors;
- creating measures for facilitating the cooperation between government, research institutions and industry;
- increasing communication to society on bio-based activities;
- implementing measures that support the creation of new markets and the uptake of bio-based products; and facilitating the development and demonstration of bio-based activities through financial and administrative support.

4.2.2. Complementary strategies at company level

A.T. Kearney (2011) suggested that firms that master raw material price volatility can improve earnings margin by 2 to 5%, increase security of supply, and improve supply chain operations. Thereto, a four-pronged approach to raw materials management is proposed, and some myths and truths about the raw materials are put forward.

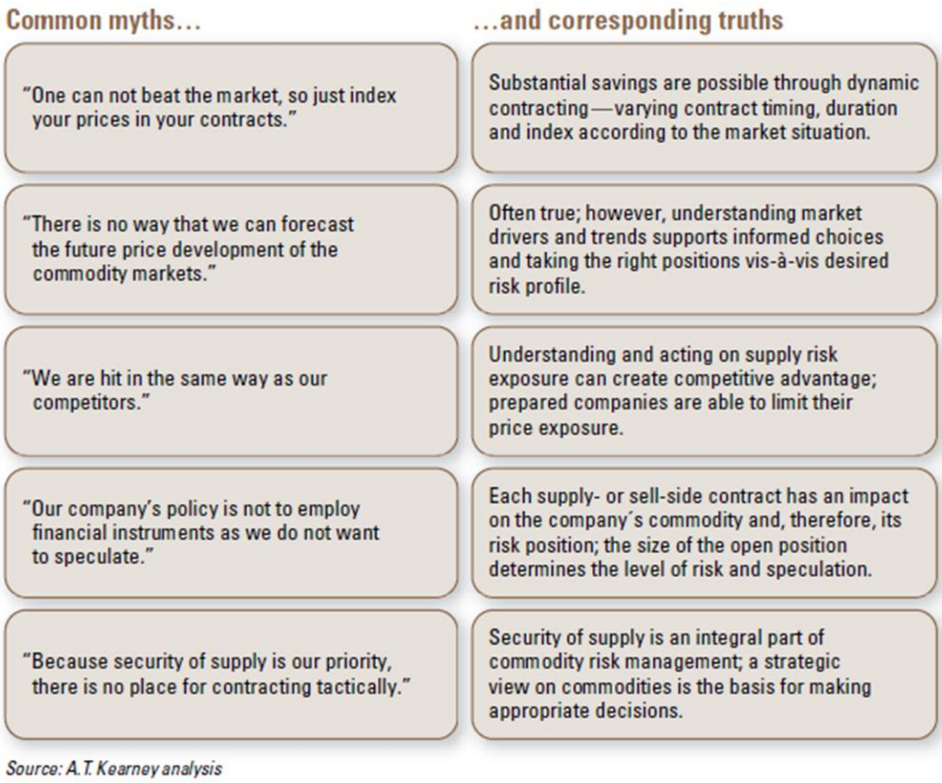


Figure 4.9 Myths & truths on companies raw materials management options

Frost & Sullivan have long emphasised that companies have pursued integration with strategic sourcing partners through mergers, acquisitions and joint ventures30.

DSM's company strategy for instance relies on a business model that aims to capture opportunities arising from global megatrends by combining global production capabilities in active ingredients and formulations with customized local formulations, premix activities and distribution channels. DSM Advanced Surfaces stresses the importance of leveraging collaborations and strategies such as licensing and venturing to expand its product range, while partnerships and acquisitions are expected to remain critical for accelerated growth.31

AkzoNobel reports a 5.5 billion euro spending on raw materials in 2014. Raw materials contribute around 40 percent to the company's cradle-to-grave carbon footprint and 63 percent to the cost of sales. AkzoNobel expanded the existing joint development agreement with Solazyme, in order to provide for funded development and a multi-year supply of renewable algae-based oils, in replacement of petroleum and palm oil-derived products. Risk mitigating actions for raw material sourcing consisted of:

- Periodically review all critical raw materials, with the aim of bundling the purchasing power in both product related and non-product related requirements

[30] Frost & Sullivan (2009). 360 Degree CEO Global and Economic Perspective of the Chemicals & Materials Industry.
[31] DSM (2015). DSM at a glance. Factbook 2015

- Use our purchasing power and long-term supplier relationships to acquire raw materials and safeguard their constant delivery in a sustainable manner
- Implement plans to mitigate dependencies brought about by single sourced raw materials
- Monitor our critical value chains to understand the critical suppliers and markets of our suppliers to detect risks and opportunities at an earlier stage

The AkzoNobel procurement strategy considered moving further beyond availability-price-synergy towards cross-functional sourcing, integration and value chain orientation. Buying on price is believed to move towards total cost of ownership, while selected supplier relationships are moving towards cooperation and partnering. This way, the company expects to leverage the size and scope of their global business, their position with suppliers and to drive competitive advantage. The cross-functional approach with key suppliers was set as the standard in the key supplier management process, in order to enable to structure the cooperation regarding joint sustainability and innovation topics with key suppliers. Company raw material strategies included elements such as material resource planning, capacity and supply cover, supplier selection and sourcing plans per region, “make” versus “buy” and renewable materials.

4.3. EU: Raw Materials Private Investments

Chapter 4 has been developed with the purpose of searching relevant data on public databases (patent, scientific literature, industrial literature) to identify a number comprised in the range between 10 and 15 of industrial sectors playing central role for the investment in Raw Materials mobilized by key players - main industrial stakeholders in the EU.

The question to be answered is: “What are the relevant research efforts carried out privately by the industry for what Raw Materials are concerned?”

Though a wide search and a comprehensive approach is deployed, the present document does have the purpose of highlighting the most relevant sectors, and to drive the attention on those on which the key stakeholders and players (e.g. large companies and multinationals) having at the same time the financial capacity to invest in sound way and to steer the global balance, as well as a long term strategy to secure a prominent position in their segments.

4.3.1. Methodology - Approach

In this chapter the analysis of relevant research efforts on RMs carried out privately by the industry in EU is reported. Starting from the NACE codes (Nomenclature Générale des Activités Économiques dans les Communautés Européennes - French, Statistical classification of economic activities in the European Community), the sectors in which the key players and industrial EU stakeholders have the highest investments for research on RMs have been identified. For each of the main sectors identified, two or three major stakeholders have been selected as representative, for the subsequent in-depth analysis. The relevant research analysis carried out takes in consideration both Scientific

Publications, released from 2011 to 2016, and Patents (2011-2016) related to RMs Research.

4.3.2. Scientific Research Analysis

The analysis of scientific papers has been carried out utilizing the Elsevier's Science Direct online database. Science Direct provides subscription-based access to a large database of scientific research. It hosts over 12 million pieces of content from 3,500 academic journals and 34,000 e-books. The research selected the papers publicized between 2011 and 2016. For each industrial player, the list of scientific researches has been analysed in order to select the papers referring to researches realized exclusively in EU. The number of total papers is reported, together with some examples of relevant publications (3 for each industrial player). The complete list of papers selected is reported in APPENDIX 1.

4.3.3. Patents Analysis

The analysis of Patents has been carried out utilizing the Thomson Innovation, an integrated search service launched by Thomson Reuters that offers cross-content search across patent data, scientific and technical content, and business information. The patent collections covered by Thomson Innovation include the British, Chinese, European, French, German, Japanese, Korean, PCT and US collections as well as bibliographic data from other collections. The Patents analysis has been carried selecting the patents with Publication date from 2011 to 2016, published with European application coverage (EP patent code). For each industrial player, the analysis of IPC (International Patent Classification) codes is reported, together with the corresponding description, permitting to identify the industrial sectors having the highest relevance with respect to the innovation generated.

For each industrial player, the query used in the Thomson database in order to select RM related researches is reported: specific queries have been adapted to each of the single player, in order to match the field of the raw materials of utmost interest, and to ensure a result clean from spurious outcomes.

In order to get an insight in the industrial sectors selected, a map of the topics of the resulting patents database is given, based on a semantic analysis on the title and abstract population (exploiting the Derwent World Patent Index® DWPI: recognized as the world's most comprehensive database of enhanced patent documents, through experts correction, analysis, abstract and manually indexing of individual patent record). The map has been realized utilizing the proprietary Themescape tool of the Thomson suite. The complete list of patents selected is reported in APPENDIX 2.

4.3.4. Selected Sectors

The sectors have been identified on the basis of the current expertise, leadership and industrial heritage in Europe, granting the maximum visibility to those for which European industry has established a worldwide visibility and setting of the scene. The selection has however been made according to arbitrary vision and in order to permit a good share between the different industries represented (from primary to secondary industry), and in the optic of the maximum coverage of all types of raw materials.

To each of the following 13 industrial sectors, the most relevant companies are identified as well in brackets: they have emerged from a first screening, and will be further subject of analysis to better understand their core interests and directions of development, from the information publicly available.

At the same time, the industrial key players identified to each sector have been extracted on the basis of their renowned activity in research and on the basis of the absolute volume of industrial and scientific publications. Also in this case, the selection has been made on the basis of a combination of numeric aspects related to the evaluation of the activity in the field, and the name and visibility owned by such entities. The continuous process of merger and acquisition in such fields makes this decision strongly dynamic (e.g. the Heidelbergcement recently acquired the control of Italcementi: the latter company innovation portfolio has been therefore included into the mother company assets) as well as the events of acquisition from outside of Europe (e.g. AGC glass is owned by Asahi Glass, and therefore is to be excluded from such list due to the non-EU ownership). Being the situation fluid, and in continuous evolution, the current list represents the vision of the VERAM project, on the European industrial research in Raw Materials, as of August 2016.

The following list provides a short classification of the main sectors where the large industry in Europe is active fostering RMs research, further grouped by the fields where they are applied.

- Building Materials:
  1. Glass & Ceramics (Saint-Gobain, Schott)
  2. Cement (Lafarge-Holcim, Heidelbergcement)
- Industrial Metals:
  3. Steel (ThyssenKrupp, ArcelorMittal)
  4. Aluminium & Alloys (Constellium, Rio Tinto)
- Chemistry
  5. Catalysis (Haldor Topsøe, Johnson Matthey)
  6. Fine Chemicals (Basf, Air Liquide)
  7. Bio-Plastics (Arkema, Novamont)
- Forest-Based
  8. Pulp and paper (Stora Enso, UPM-Kymmene Corporation)
- Transport
  9. Automotive (Volkswagen, Daimler)
  10. Aerospace (Airbus, Rolls-Royce)
  11. Tyres (Continental, Michelin, Pirelli)
- Telecommunications
  12. Electronics and Consumers products (Nokia, Philips)
  13. Automation (Siemens, ABB)

In the following sections, the different sectors are briefly described, altogether with dedicated in-depth analyses of the single players. This type of assessment is meant to provide indications and guidelines on the global research directions in the EU, as well as declining each of them towards their practical implementations. The outcoming aspects will serve in bidirectional way: to address the lacking of the R&D, national and EU actions, as well as to identify those overlapping and gaps eventually existing between the institutional research and the public funding priorities.

Roadmaps of developments shall be strongly established on this type of assessment, as the activities performed in the industrial research constitute a core element to the future strategic evolution in the Raw Materials initiatives at European level.

4.3.5. Building Materials

The field of Building Materials is the world's largest consumer of raw materials. It comprises metals, polymers and, over all, glass & ceramics and binders (cement).

The EU strategy for the sustainable competitiveness of the construction sector in general focuses on five main goals: investments, jobs, resource efficiency, regulation and market access. Moreover, the EU policies for Building Materials aim at an integrated approach, covering sustainability, and health and safety issues, in terms of air quality, noise and radiation. In particular, the market comprises both the built of new buildings and the renovation of existing ones.

Sustainable buildings combine improved energy performance, reduced environmental impact and reduced use of resources, by increasing the replacement of non-renewable raw materials with renewable ones and industrial by-products, throughout their entire life cycle. It begins with the extraction and processing of raw materials, moving towards manufacture, distribution and use, and ending with reuse recycling and ultimate disposal. The circular economy provides opportunities for better construction and demolition waste management since wastes can be treated as secondary raw materials in a more general term. It has been estimated that buildings have the potential to reach a 90% reduction of their greenhouse gas emissions by 2050.

The specific objectives are to set environmental performance standards, provide incentives for citizens and public authorities to choose resource efficient products and services and stimulate companies to innovate.

There is a great interest at EU level for actions which improve scientific and technical dialogue with international partners focusing on exchange experiences and good practices, boost cooperation on research and higher education and encourage innovation in construction products and works, energy and resource efficiency[32]. In particular, a cross-disciplinary integration and co-operation for new cross-sector value chains between academia and business within agri-food and biobased, mechanical engineering, green chemistry and building materials fields is encouraged.

32 The European construction sector - European Commission - Europa.eu

In the following the lists of the most relevant player in Europe for Glass[33] & Ceramics[34] and Cement[35] sectors are reported. We extract the first two of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale

Table 4.1. Glass & Ceramics and Cement

GLASS & CERAMICS	
Company	**Country**
Saint-Gobain	France
Schott AG	Germany
Wienerberger	Austria
Lasselsberger	Austria
Gruppo Concorde	Italy
CEMENT	
Company	**Country**
Lafarge-Holcim	France
HeidelbergCement	Germany
CRH	Ireland
Buzzi	Italy
Cimpor	Portugal
Vicat	France
Titan	Greece

4.3.6. Industrial Metals

The field of Industrial Metals comprises the metal industries processing **ferrous metals,** such as iron and its alloys (mainly steel), and **non-ferrous metals** such as aluminium, copper and zinc and their alloys. Both sectors are very important to the EU's economy, competitiveness, and industrial development, in fact they supply a number of downstream industries such as mechanical and electrical engineering, automotive, aerospace and construction, just to report some examples. The steel industry has long held a strategic place in the EU economy, fostering innovation, growth, and employment. To face the downturn of steel demand after the economic crisis and ensure a promising future for the sector, the European Commission is working on boosting the industry. Non-ferrous metals are important for the EU's manufacturing industries, sustainability, and economic growth.

They are irreplaceable for many products. Their thermal, electrical, and isolating characteristics coupled with high recyclability and low weight make them key materials to achieving the EU's energy and resource efficiency goals.

This chapter analyses the two sectors of **Steel** and **Aluminium and Alloys** (other than steel). In the following the lists of the most relevant player in Europe for each sector are

33 http://www.ceramicindustry.com/articles/94979-ci-top-12-leading-worldwide-manufacturers-of-advanced-ceramics-glasses-and-refractories
34 Ceramic World Review, n. 97 (2012).
35 http://www.globalcement.com/magazine/articles/822-top-75-globalcementcompany

reported. We extract the first two of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale.

Table 4.2. Steel

STEEL	
Company	**Country**
ArcelorMittal	Luxembourg
Severstal	Russia
Thyssenkrupp	Germany
Evraz Group	Russia
Gruppo Riva	Italy
Novo Lipetsk Steel (NLMK)	Russia
Magnitogorsk Iron And Steel Works (MMK)	Russia
Techint (Tenaris)	Luxembourg
Voestalpine AG	Austria
Metinvest	Ukraine

Table 4.3. Aluminium & Alloys

ALUMINIUM & ALLOYS	
Company	**Country**
Rio Tinto	United Kingdom
Norsk Hydro ASA	Norway
Reynaers Aluminium	Belgium
Constellium	Netherlands
Alusuisse*	Switzerland
Slovalco	Slovakia
Talum	Slovenia
Tata Steel Europe	United Kingdom
Rusal	Russia

*owned by Alcan Canada

4.3.7. Chemistry

In Europe the field of Chemistry comprises the chemical industries covering a wide range of different products, from organic chemicals to polymers, from consumer chemicals to basic inorganics. An important sector directly related to chemistry is Catalysis, and many European industrial companies active in this field occupy top positions at global level. A relatively new branch of this field is Bio-chemistry that intends to obtain chemical products from bio-based sources. Among others the sector of Bio-plastics appears to be an important field of innovation and research related with Raw Materials and is further analysed.

The European chemical industry is facing major challenges as value chain increasingly move eastward, drawn by economic growth and market opportunities in Asia. The future of the chemistry field is expected to be characterized by innovations in specialty chemicals niches with technological leaps in customer industries, such as biotech and fuel cells. Minor innovations are expected for large chemistry. This chapter analyses the sectors of **Catalysis, Fine Chemicals** and **Bio-Plastics**.

In the following the lists of the most relevant player in Europe for each sector are reported. We extract the first two of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale. Our analysis selected preferably EU companies from different EU countries, to better cover the market sector.

Table 4.4. Catalysts, fine chemicals and bio-plastics

CATALYSIS	
Company	**Country**
Haldor Topsøe	Denmark
Johnson Matthey	United Kingdom
Axens	France
Süd-Chemie	Germany
Evonik Industries	Germany
FINE CHEMICALS	
Company	**Country**
BASF	Germany
Ineos	Switzerland
Bayer	Germany
Royal Dutch Shell	Netherlands
Air Liquide	France
AkzoNobel	Netherlands
The Linde Group	Germany
Evonik Industries	Germany
Yara International	Norway
Solvay	Belgium
BIO-PLASTICS	
Company	**Country**
Arkema	France
Novamont	Italy
Reverdia	Netherlands
Roquette	France
CoSun	Netherlands

4.3.8. Forest-based industry

In Europe the field of Forest-based industry consists of four major sectors: woodworking, furniture, pulp and paper manufacturing and converting, and printing. Raw material used by the forest-based industries is wood from forests. For this reason the correct and sustainable management of forests appear to be a key point to monitor and assure in the Forest-based industry value chain. EU forests are subject to national laws and international commitments to ensure their sustainability. Sustainable forest management is monitored and can be confirmed by certification processes.

The key sector analysed in this Chapter is **Pulp and Paper**.

The Pulp and paper industry in Europe accounts for about a quarter of world production and is a major employer. The leading producing countries are Finland, Sweden and Germany. The industry is a large user of renewable energy and achieved a recycling rate of 71.5% in 2015. Other important topics related to innovation in the pulp and paper sector appear to be the recycling and reuse of paper: improvements in separate collection systems and innovation in sorting and recycling technology can further increase the quality and availability of secondary raw materials.

In the following, the list of the most relevant player in Europe for Pulp and Paper sector are reported. We extract the first two of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale.

Table 4.5. Pulp and Paper

PULP AND PAPER	
Company	**Country**
Stora Enso Oyj	Finland
UPM Kymmene Corporation	Finland
SCA	Sweden
Smurfit Kappa Group	Ireland
Mondi Group	Austria
Metsäliitto	Finland
Sequana Capital	France
DS Smith	United Kingdom
Norske Skog	Norway
Lenzing	Austria

4.3.9. Transport

In Europe the field of Transport represent a very important industrial field, a backbone of EU's economy contributing to a large portion of the continent's export. The sector is very fragmented and includes a number of different industries related with different ways of transport, mainly air, road, rail and water. Each of them collects numerous sub-categories.

This chapter analyses the sectors of **Automotive, Aerospace** and **Tyres**. These sectors have been selected according to their high impact on European economy and to the importance of European industrial players in the global market.

EU automotive industry is a key sector for European Economy. The EU is among the world's biggest producers of motor vehicles and the sector represents the largest private investor in research and development (R&D). The European aerospace industry develops and manufactures civil and military aircrafts, helicopters, drones, aero-engines and other systems and equipment. The sector represents a high-tech sector, strongly characterized by continuous efforts for research, development and innovation. The tyres manufacturing industry is characterized by three major players, further analysed, strongly dominating the EU market. These companies maintain a top position also on the global market, where they have to deal with other players, mainly from US, Japan and China.

In the following the lists of the most relevant player in Europe for each sector are reported. We extract the first two or three of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale. Our analysis selected preferably EU companies from different EU countries, to better cover the market sector

Table 4.6. Automotive, Aerospace and Tyres

AUTOMOTIVE	
Company	**Country**
Volkswagen	Germany
Daimler	Germany
Exor	Italy
BMW	Germany
Groupe PSA	France

AEROSPACE	
Company	**Country**
Airbus	France
Rolls-Royce	United Kingdom
BAE systems	United Kingdom
Thales	France
Dassault Group	France

TYRES	
Company	**Country**
Continental AG	Germany
Michelin	France
Pirelli & C. S.p.A.	Italy
Nokian Tyres P.L.C.	Finland
Belshina Ltd.	Belarus

4.3.10. Telecommunications

In Europe the field of Telecommunications includes radio and telecommunications industries as well as wireless communications industries, encompassing all products that use the radio frequency spectrum, e.g. mobile communications equipment, such as mobile phones and the mobile network infrastructure, citizens-band radio, broadcast transmitters, car door openers, wireless routers, maritime radars, sensors, etc.

The field of Telecommunications is closely linked with Electrical and Electronic Engineering industries. This field appear to be important for EU economy, because it drives innovation and provides key-enabling technologies (KETs). Electronic components and systems are not only essential to digital products and services, they also underpin the innovation and competitiveness of all major economic sectors. Today's cars, planes, and trains improve their safety, energy-efficiency and comfortability thanks to electronic parts. The same holds for large sectors like medical and health equipment, home appliances, energy networks and security systems, just to report some examples.

This chapter analyses the sectors of **Electronics** and **Automation and Consumers products**.

In the following the lists of the most relevant player in Europe for each sector are reported. We extract the first two of which data were available and public, in order to pick the most representative ones, and henceforth be able to infer the sector trends and long term strategies at European scale.

Table 4.7. Electronics

ELECTRONICS	
Company	**Country**
Nokia	Finland
Philips	Netherlands
Ericsson	Sweden
Seagate Technology	Ireland
Alcatel-Lucent	France

Table 4.8. Automation and Consumer Products

AUTOMATION AND CONSUMER PRODUCTS	
Company	**Country**
Siemens	Germany
ABB	Switzerland
Haraeus Holding	Germany
Schneider Electric	France
Alstom	France

4.4. Trends and results of synergies between industry strategies and EU research agendas

The cross-sectorial and holistic SPIRE research and innovation roadmap provides an excellent example of cooperation and coordination of innovation and business strategies, in combination with an extensive process of exchange with and input from a wide range of the SPIRE research and technology organisations (RTOs) and academia across disciplines. In this process, business sector involvement was not limited to the eight SPIRE industry sectors along and across their value chains, but included consultations with other sectors like glass, paper and pulp. The final roadmap represents a coordinated and integrated framework from research to business following a staged approach with short-term, medium-term and long-term objectives and benefits.36

In several specific domains, analysts believe that ongoing 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. Examples of such expected potential are summarized in the sections below, that were elaborated departing from the analysis provided by Sarwant Singh, in 'The Future Of Manufacturing In Europe: 7 Transformative Forces That Will Boost Industrial Growth'37

4.4.1. Factories of the Future, Industrial 4.0:

- The term Industry 4.0 refers to the combination of several major innovations in digital technology, all coming to maturity right now, all poised to transform the energy and manufacturing sectors. These technologies include advanced robotics and artificial intelligence; sophisticated sensors; cloud computing; the Internet of Things; data

[36] https://www.spire2030.eu/what/walking-the-spire-roadmap/spire-Roadmap
[37] http://www.forbes.com/sites/sarwantsingh/2016/03/29/future-of-manufacturing-in-europe-seven-transformative-forces-that-will-boost-industrial-growth/#7f14c20f24cc

capture and analytics; digital fabrication (including 3D printing); software-as-a-service and other new marketing models; smartphones and other mobile devices; platforms that use algorithms to direct motor vehicles (including navigation tools, ride-sharing apps, delivery and ride services, and autonomous vehicles); and the embedding of all these elements in an interoperable global value chain, shared by many companies from many countries.38

- ‘Factories of the Future’ is the European Union's €1.15 billion public-private partnership for advanced manufacturing research and innovation. With the Horizon 2020 R&D funding program allocating an approximate €17 billion budget (2014-2020) for the “Industrial Leadership” category, the manufacturing sector will see a lot of activity in the areas of advanced computing, sensor technologies and robotics. Singh concludes that if the growing information and communication technology (ICT) infrastructure spend and strategic initiatives, such as the 5G rollout plan, are factored into the equation, Europe is not far away from bringing to fruition the true vision of a connected enterprise.39

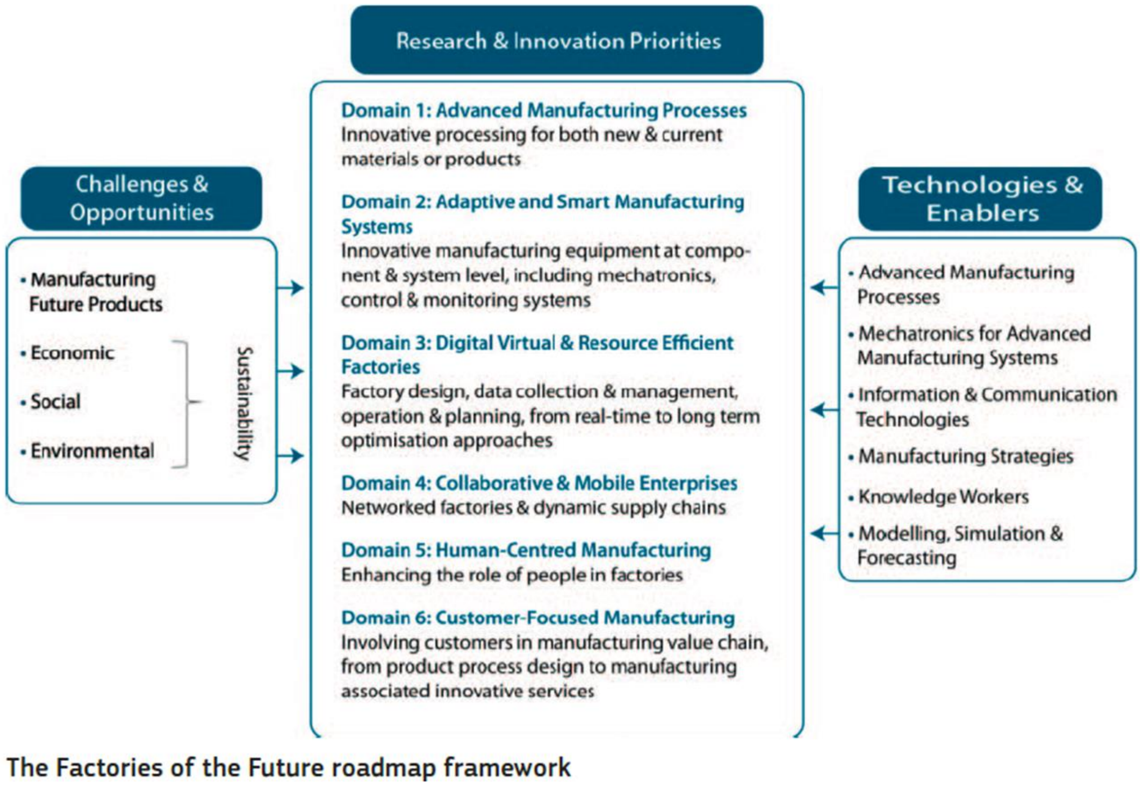


Figure 4.10 The Factories of the Future roadmap framework

- In the race for automation in manufacturing, the European Union is currently one of the global frontrunners: 65 percent of countries with an above-average number of industrial robots per 10,000 employees, are located in the EU. The strongest growth figures in Europe are being posted by the Central and Eastern European states – the

38 From: A Strategist’s Guide to Industry 4.0, by Reinhard Geissbauer, Jesper Vedsø, and Stefan Schrauf, 2016

39 http://www.forbes.com/sites/sarwantsingh/2016/03/29/future-of-manufacturing-in-europe-seven-transformative-forces-that-will-boost-industrial-growth/#310d528f24cc

rise in sales was about 25% in 2015. The positive trend is expected to continue. The average growth will remain steady at around 14% per year (2017-2019). The biggest climbers in sales of industrial robots are the Czech Republic and Poland. The robot density in the big Western European economies is still currently ahead of up-and-coming China. The largest gap in this respect is with Germany (301 vs. 49 units) – the smallest being with the United Kingdom (71 vs. 49 units).40

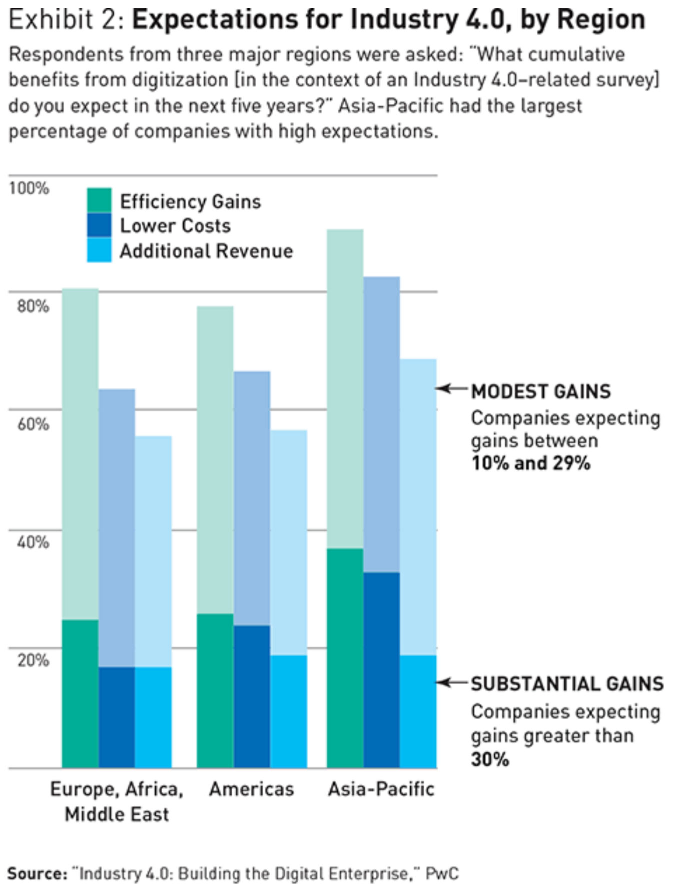


Figure 4.11 Expectations for Industry 4.0, by region

4.4.2. Nearshoring in the East:

- Central and Eastern European countries, such as Poland, Czech Republic, Hungary, Romania and Turkey, might become a major hub for manufacturing innovation due to the easy availability of cash grants and tax incentives, and the accessibility of skilled researchers. Poland is among the largest and strongest growing economies in the region, with its advanced manufacturing market growing two times faster than the EU-15 region. According to A.T. Kearney, also Bulgaria has become an interesting location for high level activities such as computer-aided design and manufacturing. Bulgaria's education system produces a wealth of engineering and

[40] http://ein.iconnect007.com/index.php/article/100210/european-union-occupies-top-position-in-the-global-automation-race/100213/?skin=ein

technical skills, which makes it a particularly suitable place to look for specialised technology and programming skills.41

- Cost advantages, geographical proximity, rising education standards, as well as comparatively minor cultural differences are just a few reasons in favour of growing interest in offshoring in Eastern European countries from companies in Europe.42
- The European Parliamentary Research Service (2014)43 concludes that the range of products that are more likely to be reshored includes: Products that are expensive to transport to the end market; Goods subject to frequent changes in consumer demand, to be closer to the end market; Products where safety concerns are important. The relative importance of individual criteria to decide where to produce varies by industry. Factors like scalability, time to market and the speed of ramping up capacity tend to be more important in dynamic industries with short product life-cycles and high levels of demand variability, e.g. consumer electronics. Less dynamic but highly price sensitive industries such as furniture manufacturing place importance on total landed cost44, which is where China has scored highly.

4.4.3. Carbon Neutral Manufacturing:

- Both industry roadmaps and EU R&D research agendas have put forward climate change as a core topic and main driver of research and innovation.
- The COP21 in Paris was a major event to curb the growing challenge of climate change. From a manufacturing standpoint, the two key takeaways were optimizing current energy consumption in the plant and focusing on electricity from renewable sources. Plus, the EU's plan to reduce 40% of its carbon and greenhouse gas emissions by 2025 and 2030 has resulted in solution providers embracing the concept of carbon neutral manufacturing.
- The United Nations Sustainable Development Goals (SDG) also offer business opportunities. The World Business Council for Sustainable Development (WBCSD) is a global, CEO-led organization of over 200 leading businesses and partners working together to accelerate the transition to a sustainable world. The WBCSD created a SDG Business Hub45, arguing that 'Companies can use the SDGs as an overarching framework to shape, steer, communicate and report their strategies, goals and activities, allowing them to capitalize on a range of benefits. Those companies that embrace the transformative power of the goals will be able to open up exciting and lucrative new markets while also contributing to the realization of stable societies and markets – the pillars upon which business success is built.'
- The United States Mid-Century Strategy for Deep Decarbonisation (Nov 2016)46 outlines a strategy to reduce U.S. carbon emissions by the year 2050 by 80 percent or more below their 2005 levels, and estimates that the US can meet the growing demands on its energy system and lands while achieving a low-emissions pathway,

[41] http://raconteur.net/business/the-most-attractive-european-countries-for-outsourcing
[42] http://www.interventure.info/blog/nearshoring-eastern-europe/
[43] http://www.europarl.europa.eu/EPRS/140791REV1-Reshoring-of-EU-manufacturing-FINAL.pdf
[44] The total cost of a landed shipment including purchase price, freight, insurance, and other costs up to the port of destination. In some instances, it may also include the customs duties and other taxes levied on the shipment. (http://www.businessdictionary.com/)
[45] http://www.wbcsd.org
[46] https://www.whitehouse.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf

maintaining a thriving economy, and ensuring a just transition for Americans whose livelihoods are connected to fossil fuel production and use.

- In 2016, Research and Markets announced the addition of the "Carbon-neutral Manufacturing - The Need for New Business Models" report to their offering47. The study indicates that investments made towards de-carbonization initiatives can be accepted as a business case to attain ROI. Some of the strategies embraced by production companies to achieve carbon neutrality are identified.
- Relevant progress on carbon neutral manufacturing has been claimed by an increasing number of global companies, including Microsoft48, Volvo49, Siemens50, Harbec51, Faber-Castell52, and many others.

4.4.4. Nano-disruptions:

- Nanotechnologies have the potential to improve material properties while simultaneously reducing raw materials use. Applications are not limited to electronics, but cover a wide range of products. Concrete structures for instance can be made more durable and resistant to deterioration either by direct use of nano raw materials in the concrete or by treating concrete structures with nanocoatings53. This way, the use of nanotechnology also offers new opportunities for very diverse industrial sectors, including the concrete industry.
- Nanotechnology is one of the key enabling technologies in Europe's Horizon 2020 plan. It is foreseen that tremendous opportunities will be seen in the recession-proof food and beverage sector, where nano-scale polymers can prevent oxygen from spoiling the food. Furthermore, Currently, Europe is acutely focused on taking a safe and integrated approach to nanotechnology, with approximately 10.0% of the Horizon 2020 funding allocated for nano-safety.38

4.4.5. Some hotspot industrial sectors developments

- The global conductive polymers market is expected to reach USD 6.5 billion by 2024, according to a new report by Grand View Research, Inc. Rising awareness towards antistatic packaging as a protection medium for electronic devices and appliances is projected to fuel the demand for conductive polymers. Favorable outlook towards the electronics industry in China, Japan, South Korea and Singapore as a result of new product launches including smartphones by market players such as Samsung and LG is expected to have a significant impact on growth over the forecast period. In July 2015, the government of India launched the "Digital India Campaign" aimed at ensuring internet connectivity along with upscaling the production output in digital electronics on a domestic level. Asia Pacific is expected to drive the global conductive polymers market on account of growth of the automotive and electronics industries.

[47] http://www.researchandmarkets.com/research/53nplb/carbonneutral
[48] http://www.microsoft.com/about/csr/transparencyhub/citizenship-reporting/
[49] http://www.sustainablebrands.com/news_and_views/cleantech/stephen_kennett/volvo_production_plant_achieves_carbon_neutrality
[50] http://www.siemens.com/press/en/feature/2015/corporate/2015-09-co2-neutral.php?content[]=Corp
[51] http://www.harbec.com/sustainability-3/sustainable-manufacturing/
[52] http://www.faber-castell.com/company/our-global-commitment/faber-castell-carbon-neutral
[53] http://www.nanops.eu/wp-content/uploads/2013/09/1304_nanops_en.pdf

North America held a 44.9% of the global volume market share in 2015. The high adoption rate of electroactive polymers in electronics, solar energy, healthcare and automotive industries in light of the immense potential of R&D infrastructure in the U.S. and Canada is expected to have a positive impact. Europe is expected to witness revenue growth at a CAGR of 8.9% from 2016 to 2024. The increasing application of biomimetics in healthcare applications, particularly in Germany and UK, is likely to play a significant role in increasing the demand for conductive materials over the forecast period. Key industry participants include 3M (US), Heraeus Group (Germany), Solvay SA (Belgium), SABIC (Saudi Arabia), KEMET (US), Covestro (Germany), Celanese (US), Enthone (US), Premix (US), and Hyperion Catalysis International (US). 54

- The industrial biotechnology (IB) sector outlook to 2030 shows that employment in the IB value chain may increase to well above one million FTEs. Two different growth scenarios for the IB sector have been considered. The first is the extrapolation of the historical growth rate of IB production observed in the Key Enabling Technologies (KETs) Observatory time series. The second is the market forecast made for the IB sector in the context of the BIO-TIC market roadmap. It was found that by 2030, total employment for IB will lie between 900.000 FTEs (BIO-TIC scenario) and 1.500.000 FTEs (KETs Observatory scenario). The IB sector is becoming an increasingly important source of employment in the chemical and pharmaceutical sector. As of 2013, the share of IB related employment in total chemicals and pharmaceutical amounted to about 5%. The share of IB based employment in these two sectors is anticipated to increase to between 10% and 15% by 2030, highlighting the importance of IB for maintaining employment in these key strategic EU sectors. The IB market in the EU is expected to contribute between €57,5 billion and €99,5 billion to the European Economy by 2030.55
- The analysis ‘Transition to a bio-economy’, made for the f3 project by de Besi & McCormick (2015)29, shows that a common direction for the bioeconomy, based on research and technological innovation in the various applications of biotechnology, is developing in Europe. It highlights the important role that the regional level will play in facilitating collaborations between industries and research institutions needed to foster innovation and optimize the use of biomass. The analysis also identifies that the development of European bio-based product markets are needed for bioeconomy expansion.
- Europe plays a minor role in the global production of electric vehicle batteries, which is dominated by Panasonic. The reason for Panasonic’s market dominance is largely down to the company’s partnership with Tesla Motors, and the relatively large battery-pack sizes used in the Tesla Model S and Model X.56 Musk confirmed that Tesla plans to choose a location for ‘Gigafactory 2’ in Europe next year and he added that the factory will combine both the production of batteries and complete cars57.

[54] http://www.grandviewresearch.com/industry-analysis/global-conductive-polymers-market
[55] EuropaBio (2016). Jobs and growth generated by industrial biotechnology in Europe.
[56] https://cleantechnica.com/2016/03/26/top-ev-battery-producers-2015-vs-2014-top-10-list/
[57] https://electrek.co/guides/tesla-gigafactory/

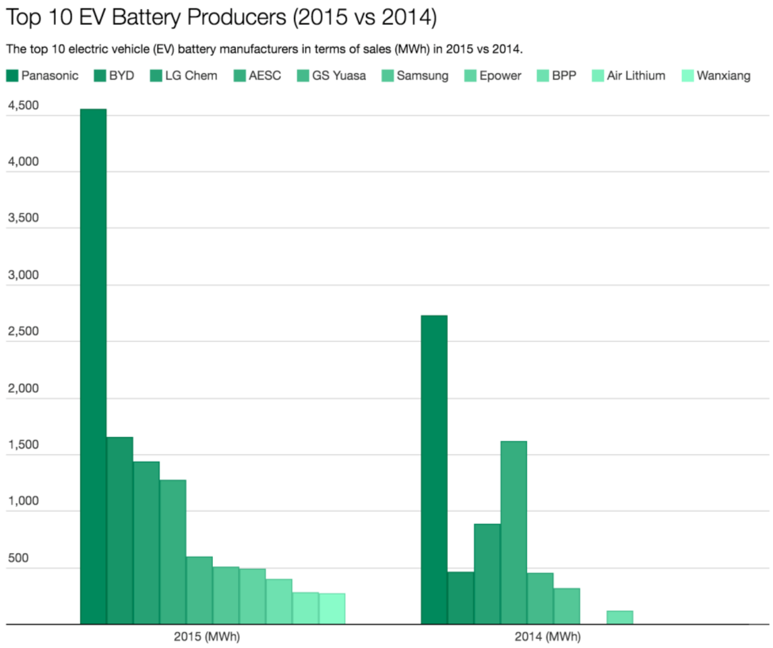
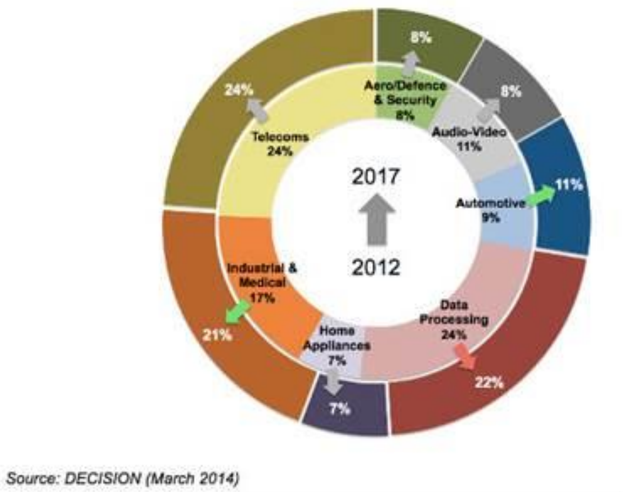


Figure 4.12 EV Battery Producers (2015 vs 2014)

- The share of Europa in the global production of consumer electronics has been declining over the past decade. Although experts believe this trend is likely to continue, the future of Europe as an electronic device manufacturer looks bright, since it is expected that 'Europe and North American can not only retain manufacturing at the higher value, lower volume professional end of the manufacturing spectrum but can also benefit from rising export demand for these industrial, automotive and medical products as spending power increases in the emerging economies of the world'.58

Figure 4.13 Global electronic equipment production by application sector in 2012 (center) and 2017 (outer). Source: Decision Etudes Conseil.



58 http://www.electronics-eetimes.com/news/report-europe-can-shine-global-electronic-production/page/0/3

4.5. Differentiating between raw materials supply risk management strategies on megasector level and on company level

From the examples in section 3.4.1 on iridium and indium for the OLED panels manufacturing and purchasing industries, it is clear that individual companies or industrial sector organizations will apply specific strategies when purchasing products or raw materials with high supply risks.

The Kraljic matrix allows a distinction of products or raw materials that have to be purchased into four categories, based on the criteria of supply risk and the financial impact on the profit of the company. This approach is analogue to the methodology used for determining EU critical raw materials, with quadrant given by the supply risk and the economic importance for 8 megasectors.

Kraljic's observed clear distinctions between alternative purchasing strategies, attributable to differences in power and dependence between buyers and suppliers, which are reflected in the different matrix quadrants.

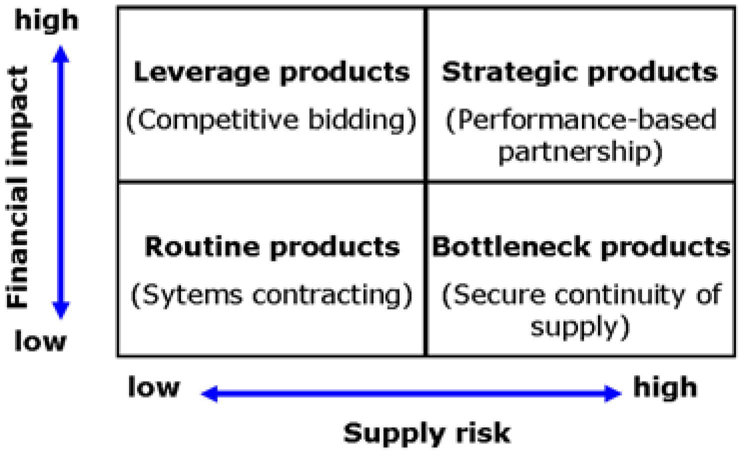


Figure 4.14 Kraljic's Matrix

Caniëls& Gelderman (2005) describe different scenarios corresponding to the purchasing strategies that are useful in the Kraljic matrix quadrants (table 4.9).

Table 4.9. Scenarios corresponding to the purchasing strategies that are useful in the Kraljic matrix quadrants

Quadrant in the Kraljic matrix	Purchasing strategy/ scenario	Scenario description
Strategic	1. Maintain a strategic partnership	Consider a product with a high supply risk and a high financial value. You **consider the supplier as an important partner** with whom a satisfactory, cooperative strategic relationship exists. The performance of the supplier is excellent. Both parties have an interest in continuing the relationship and the parties have a good mutual understanding.
	2. Accept a locked-in partnership	Consider a product with a high supply risk and a high financial value. The relationship with the supplier leaves much to be desired. Earlier your company was to a large extent forced to do business with that supplier. Now, your company has to put up with the supplier and **tries to make the best of the involuntary relationship with the supplier**.
	3. Terminate a partnership, find a new supplier	Consider a product with a high supply risk and a high financial value. It is expected that the supplier behaves as a strategic partner. However, the relationship leaves much to be desired. Your company feels that the behavior of the supplier cannot be controlled. It is decided **to search for another supplier with whom the company has to build up a new relationship**. It is clear that this will be a difficult and challenging task
Bottleneck	4. Accept dependence, reduce the negative consequences	Consider a product with a low financial value, but a high supply risk. Your company is vulnerable regarding the supply of the (single) supplier. Assurance of supply is pursued by **keeping high safety stocks**.
	5. Reduce dependence and risk, find other solutions	Consider a product with a low financial value, but a high supply risk. Your company is vulnerable regarding the supply of the (single) supplier. In response to this situation, it is decided to search for other solutions, especially by **working with more generic specifications**, if necessary finding another supplier

According to these strategies, In the OLED panel case, industries might be interested in keeping safety stocks, or in finding other suppliers or more generic specification. The latter could be done, although only theoretically in this case, by looking to suppliers of recycled materials.

A 2015 study on EU needs with regard to co-operation with Greenland, European downstream industries were consulted regarding their interest in raw material mining projects in Greenland:

- Several stakeholders pointed out that their downstream industries pursue the strategy of focusing on their core business, i.e. the manufacturing at the higher end of the value chain. This implies that they are not interested in financial investment in mining projects, since mining and ore processing is very different to their business activities.

- Even if European downstream companies would invest in mining, they might not to be able to establish a successful mining and refining business due to lack of know-how.
- Several stakeholders confirmed that shortages of minerals would not have any influence on their strategy of remaining with the core business.

Instead, several companies indeed preferred alternative raw material strategies such as recycling, substitution, material efficiency and international businesses offering access to raw materials.

In the Greenland study, generic strategies that already were examined by the EU, namely greater recycling, substitution and stockpiling of materials, were discounted, either because they had been rejected as inefficient (e.g. stockpiling), or because of the limited and uncertain impact for the foreseeable future (e.g. recycling of many critical raw material) and/or because they are already being examined within EU policies (e.g. projects to promote substitution of critical materials via EU innovation policy and funding). The study conclusions found the following barriers to the goal of increasing the sustainable sourcing of raw materials:

- From an economic point of view, the current market slump – coupled with the long-lead times required for opening mines – are factors which act as a deterrent to investing in the development of long-term raw material supply chains with more stable supply countries.
- Very long and fragmented supply chain which characterises the metal industry. The fact that downstream manufacturers do not engage in mining and generally buy their materials on the market does not facilitate the establishment of sustainable raw materials supply chains.
- The lack of awareness and knowledge on the part of customers of what raw materials are used in environmental and high-tech goods, and where they may be sourced from, may also prevent the development of sustainable sourcing.

4.6. Critics, incongruences and differentiations

4.6.1. Dimensioning the impact of raw materials supply to EU industries

The observation that 'In 2011, only 8 out of 60 sectors show imported raw material value shares that account for more than 0,19% of the total sectoral final output. Only in 4 sectors, the total raw material value constitutes more than 2% of the final output value.', seems to be in contradiction with other sources. Degamo et al. (2011)59 for instance, sustain that the largest part of manufacturing costs, usually 50%, for a product (like a car) is materials. Manufacturing costs are estimated to represent about 40% of the selling price. The material costs are including storing and handling materials within the plant. The European Commission stated that 'reportedly, European manufacturing firms spend, on average, 40% of their costs on raw materials, with energy and water pushing this to 50% of total manufacturing costs, to be compared to a share of 20% for labour costs'60.

[59] Degarmo, J. T. Black, Ronald A. Kohser (2011). Degarmo Materials and Processes in Manufacturing. John Wiley & Sons, 1184 pp.

[60] EC (2014). Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. Green Action Plan for Smes. Enabling SMEs to turn environmental challenges into business opportunities. COM(2014) 440 final.

The apparent contradiction can be explained by differentiating 'materials' as is referred to in the EC Communication and by Degarmo et al. (2011) and 'raw materials' as used in the present document. 'Materials' includes besides actual raw materials also subassemblies, components, parts and the corresponding storage and handling costs, while 'raw materials' here refers to metal ores and other mining and quarrying products only. The difference can be illustrated by the use of indium for the production of OLED panels. OLED panels will have a high cost share in the LED TV manufacturing industry, although there is less than 0.008 grams of iridium and 0.56 grams of indium required per square meter of panel. For the manufacturer, the value of the ITO layer is not determined by the indium content, but by the layer production process: ITO coatings in 2009 had a production cost of more than $30 per square meter, including a material cost of indium of 17 cents. The value of iridium contained in the phosphorescent emitters amounted to 1 cent per square meter of panel in 2009.61

•Typical emitter thickness: 3 x 10nm	•Typical ITO thickness: 100nm
•Density of hosts: 1700 kg/m3	•Density of ITO: 7150 kg/m3
•Mass of emitter layers: 0.05 g/m2	•Mass of ITO layer: 0.72 g/m2
•Mass of phophorescents @ 6% doping: 0.003 g/m2	
•Iridium content: 0.0008 g/m2	•Indium content: 0.56 g/m2
•Cost of iridium: $15/g	•Cost of indium: $0.31/g
•Value of Ir in emissive layer: $0.01/m2	**•Value of In in ITO layer: $0.17/m2**

Manufacturers of OLED panels or of devices that use such panels will thus not particularly be looking for material resource efficiency strategies aiming to save critical raw materials such as indium or iridium. From a manufacturers point of view, it is the sensitivity of the industry regarding to a supply risk within the industry's value chain that will be key for deciding which raw materials strategies need to be considered. In order to take into account such 'sensitivity' of industry, Erdmann et al. (2011), in a study on critical raw materials for the German industry on behalf of the German KfW Bank, proposed a criticality matrix divided in 6 different sections, with each section containing a particular combination of different levels of supply risk and vulnerability. The vulnerability factor is composed of indicators that include the 'sensitivity of affected value chains in Germany' and, additionally 'substitutability', both on mid to long term.

The methodology currently used for determining EU critical raw materials calculates the economic importance of a raw material by adding the value–added of 8 individual megasectors weighted by their relative share in the overall use of the raw material. This quantity seeks to characterize the economic impact of a sudden supply stop, assuming this leads to a complete stop of production in the affected megasectors, which would reduce the megasector added value to zero. The Working Group While acknowledges that this is an overestimation, but deemed this to be the most pragmatic way of assessing economic impact in face of the data limitations.62 Several authors have made suggestions to improve the EU methodology, such as the incorporation of substitutability as a factor of economic importance, and the introduction of curved thresholds (instead of the current rectangular threshold) for distinguishing more and less critical raw materials. The latter suggestion would

[61] Bardsley Consulting: DOE SSL Manufacturing Workshop, April 2009

[62] DG Enterprise and industry (2013). Study on Critical Raw Materials at EU Level, Final Report

bring the current criticality assessment closer to classical risk assessment, deemed to be more suitable for defining company raw materials strategies.

4.6.2. Industrial development strategies in emerging economies

Already the 2010 Report of the Ad-hoc Working Group on defining critical raw materials stated that 'many emerging economies are pursuing industrial development strategies by means of trade, taxation and investment instruments aimed at preserving their resource base for their exclusive use. This trend has become apparent through an increasing number of government measures such as export taxes, quotas, subsidies etc.'

The 2010 article titled 'The New Resource Grab: How EU Trade Policy on Raw Materials is Undermining Development'63, observed that the 'EU is promoting the Raw Materials Initiative despite recognising that export restrictions are part of some countries' development strategies. Among several other dangers of the initiative, a major concern is that it could increase the unfolding global competition for resources and contribute to resource conflicts. The Initiative is also likely to hinder developing countries' economic prospects by reinforcing their dependence on unprocessed raw material exports'. And further: 'The Raw Materials Initiative is likely to reinforce Europe's own dependence on raw materials. Although the initiative addresses recycling, pushing for ever-greater access to the world's raw materials is a distraction from reducing Europe's existing consumption of them.'

In order to better align the EU Raw Materials Initiative with the needs of developing economies, Küblbock (2013)64 makes several suggestions, departing from the observation that in many developing countries, the mining sector has not made any substantial contribution to inclusive development, especially in Africa. She argues that 'the primary focus of the initiative on securing „undistorted" access to raw materials which the EU is resolutely pursuing via its trade and investment policies is clearly in contradiction with the demand for increased policy coherence for development. On the contrary, policy measures undertaken by the EU in the context of its trade and investment policies risk to further reduce necessary policy space.' The author concludes that 'In addition to efforts to increase public revenue from resource extraction, there is an intensifying discussion about a greater contribution of the mining sector to broader to economic transformation and diversification. To live up to these ambitions, wide ranging and pro-active policy measures would be needed to ensure extractive industries become a foundation for local economic development. This requires on the one side the strengthening of policy capabilities in resource-rich countries as well as a shift in international policies related to natural resources.'

[63] Curtis, Mark (2010): The New Resource Grab: How EU Trade Policy on Raw Materials is Undermining Development, London.

[64] Küblböck, Karin (2013) : The EU Raw Materials Initiative: Scope and critical assessment, Briefing Paper, Austrian Foundation for Development Research (ÖFSE), No. 8

4.7. Germany (as an example of member state)

Overview on industrial trends in Germany concerning abiotic raw materials.
In general

- The extraction of raw materials in Germany is on the decline, especially for metal ores mining and energetic raw materials (1).
- The recycling quota of building materials is very high: construction and demolition waste (78%), road demolition (96 %) (1, 2).
- A major part of the metal production is based on secondary materials aluminum (54 %), steel (44 %) and copper (43 %) (1, 3).
- Decoupling of raw material extraction and growth in the Nonmetallic Minerals Industry to be continued (2, 14).
- Resource efficiency more and more considered as a part of business strategy and/or business model. Large enterprises are more aware of the necessity of pushing resource efficiency. Most of them consider product development as the most promising phase for new measures aiming at increasing resource efficiency (3, 4, 14).
- New role for raw materials processing industry through additive manufacturing / 3D-printing (5).
- Fracking technology can be used in Germany without risk for the environment (6).
- In order for the secondary commodity markets can develop better and companies and government agencies are relieved, the process for the end of waste must be clearly defined and unbureaucratic permits. The planned interface between chemicals, waste and products should take this into consideration and the transition from the waste regime in products and secondary raw materials should occur on a pragmatic way (8).
- The industry associations support the concerns of the European Union to break through connection between conflicts in crisis countries and trading of raw materials. Many companies have already been working for a long time in order to enforce ecological and social standards even in far actors in their supply chain and got involved at European and at international level within the framework of existing voluntary initiatives to implement due diligence in the supply chain and the certification of suppliers (12).
- The industry supports nondiscriminatory access to raw materials and reliable trading rules. (13, 14) At the same time the industry should consider access to raw materials as a strategic issue and think about alternatives (16, 17).
- The industry supports the implementation of a circular economy, more resource efficiency and the development of products based renewable raw materials (14).

On R&D topics

- Unlike many other OECD countries was Germany able to defend its market share of world industrial production in recent years, especially by focusing on research-intensive productions in the basic materials and capital goods industry (2).
- The companies of the electrical industry amplify the research and development work in the field of recycling (3).
- Research projects in the field of additive manufacturing or materials research should place emphasis on the development of new materials for industrial 3D printing. Research is also needed on the question of the recycling capability of combinations of materials and on efficient processes for powder production (5).
- Research on fracking technology has clearly proven that there is no environmental concern for the industrial development of fracking in Germany (6).
- Research in the building materials sector begin with the development of each construction material and the required technology. They have a very long tradition. In contrast, the research for the specific product and process development in the sector of construction material recycling is still in its infancy. Thus, there is considerable research and development requirements, if the contribution of construction material recycling to resource efficiency should be increased both quantitatively and qualitatively (7).
- There are research projects that aim to produce cement and concrete more environmentally friendly. They are based on reduced fuel use, new secondary fuel sources and raw material substitution. Further optimizations have the potential to reduce the amount of raw material needed, such as textile / Carbon concrete, ultra-high strength concrete or specific macroscopic cavities. The material substitution is an issue in the construction industry, here are mainly fiber composites in focus, which are usually joined by adhesive bonding. Their material recycling at the end of life still needs to be developed. There are first approaches to research, segregated to separate and fiber composites. The so-called "Molecular Sorting" has already been shown in laboratory scale, that the removal of foreign substances in glass or the separation of wood fractions is possible, and also applicable to composite fiber materials (9).
- Further R&D activities on assessment methods of resource efficiency in the building sector are needed in order to consider the all value chain (10).
- An overview of reserves, resources and availability of energy raw materials in the world and in Germany is given by (11). In Germany renewable energy sources are still increasing while fossile energy raw materials (most of them have to be imported) are slowly decreasing: they were contributing to 78% of primary energy consumption in 2010.
- An environmentally sound extraction of shale gas is possible. The domestic oil and gas industry has significant research budgets, to further develop the process - can be used - for example, in a common, accompanied by the public key project of industry and science. So profound knowledge for a reliable basis for decision can be obtained (14).

- The German industry supports the research on recycling of small amounts of technology metals and rare earths as well as on new use of renewable raw materials and for deep seabed mining (14). For deep seabed mining R&D on metallurgy as well as effective networking and cooperation between the fields of Marine engineering, mining and robotics is needed (19).
- The chemical industry invests a lot in R&D for resource efficiency. The use of raw materials has been consequently reduced and the use of renewable raw materials developed. Further efforts are necessary for example in order to implement circular economy in SME, e.g. through better networking and clustering and in core technologies “Biotechnology,
  Nanotechnology and new catalytic processes” (15).
- Because of the dependency on imports of the metal raw materials was and is the German economy continues to support research on new material properties and new applications for individual raw materials (17).
- The German industry supports fast and coordinated transfer of commodity research results. Through strong orientation towards SMEs, may in addition to the benefits for the company itself, the acceptance of raw materials management to improve the general public.
  Research should focus on the use of domestic raw materials and recycling of raw materials, environmental protection and prevention of risks in raw materials extraction and sustainable rehabilitation of areas used, raw material efficiency and recycling and substitution of raw materials industries (20).

4.8. International level

4.8.1. Abiotic raw materials

The analysis of INTRAW reports mentioned in 2.1.1. gives information on industry strategies and trends in Australia, Canada, Japan, the USA and South-Africa and on the way these affect EU RM supply or demand.

In **Australia**, the RM sector is losing competitiveness: environmental standards and safety regulations extremely high, export goods are too expensive, companies in mining sector cut investments in exploration. The Research intensity in mining sector is still high: 22,4 % (2011, business expenditure on R&D from the mining industry in relation to overall business expenditure on R&D in the regions).

Canada considers innovation and efficiency as a key element for differentiation from low-cost raw material producers from emerging countries. For this reason lot of public and private money is invested in automation technologies.

According to the authors: “**Australia** and **Canada** need to prepare for a number of challenges (lowering production costs, lack of skilled workers, decreasing ore grade), which force them to re-think the current mining policies and, among others, to reinforce research and innovation”.

In **Japan** the RM industry, mostly composed of processing and recycling industry, is spending a lot in R&D. Many efforts are done to guarantee a reliable supply of RM and to stay independent from foreign markets: Japan invests worldwide in RM and imports RM for refinement and smelting.

In **South Africa** mining sector especially depends on innovation (because of deep level mining) and on export. The industry has to manage several negative trends at the same time: shortage of skills, as people are leaving the country (e.g. to Canada or Australia for better salaries), own reluctance to adopt innovation, lack of R&D collaboration amongst industrial companies, decline of mining research (public funded) programmes, lack of finance power.

The RM Industry in the **United States** is very strong in both primary and secondary RM sectors. Mining companies, smelters and manufacturers work close together. Big industry is the first funding partner for innovation development, but mining industry is still conservative with the implementation of new technologies.

For Europe the example of **Japan** maybe the most interesting one in the five INTRAW countries as the RM situation quite similar is. Both produce little primary RM and consume huge amounts of RM.

RM rich countries like Australia, Canada and South Africa may also be good partners for European industry as they have (at still the two first ones) both large RM reserves and high developed R&D and experienced industry in fields like automated mining or deep mining.

The USA have a unique situation as they are rich in RM and producing them mostly for domestic use.

Europe can benefit from reinforced cooperation with all these countries on different ways, ensuring direct supply with primary RM, develop investments in RM rich countries, exchange of experience in strategic fields like deep mining, deep sea mining (Japan, USA), recycling (Japan).

4.8.2. Biotic raw materials

Wood, a special raw material, is a natural resource used by humans over thousands of years. Forests, as the producing ecosystems, have to face increasing industrial, social and ecological demands. Sustainable forestry has the requirement of preserving the essential characteristics, stability and natural regeneration ability of this ecosystem. Numerous countries have identified with these principles in the last decades, but still the concepts of realizing these standards are different. This is reflected in the different strategies the forest sectors pursue worldwide.

The production of all leading forest products (industrial roundwood, sawnwood, wood-based panels, pulp and paper) has increased since the economic downturn of 2008-2009 and is now at a pre-crisis level[65].

China has a high significance as a producer and consumer of forest products. 11% of the global consumption of industrial roundwood and 23% of sawnwood appears in this country. The same applies for the worldwide consumption of recovered paper (37%) and paper and paperboard (27%), but China is also the biggest producer of these products. Over 75% of the export volume to the European Union goes to 5 EU-member states only: United Kingdom, Germany, France, Belgium and the Netherlands[66].

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[65] FAO, 2015 Global Forest Products and Figures, http://www.fao.org/3/a-i6669e.pdf
[66] http://forest-trends.org/documents/files/doc_4908.pdf

To maintain the performance of Chinese forests and to recapture areas for forest establishment, after 50 years of exploitation and monoculture, China established their National Forest Programme (NFCP) in 1998. The NFCP is one of the largest conservation programmes in the world. The implementation is a success story for Chinese legislation. Forests are recovering: since 1998 about 1,6% of the Chinese territory sees a significant gain in tree cover and China is the leading country in annual net gain in forest area. However the demand for timber remains high and China has to import 40% of its wood supply[67]. As the exporting timber countries reduce or restrict their logs, China faces problems in satisfy their needs for the industry and maintain a sustainable management for their forests. Most imports come from Russia, United States, Canada, EU and New Zealand[68]. Also the surrounding countries like Indonesia and Vietnam export wood to China. The question is whether the problem of forest destruction is shifted into other regions, as these countries, especially Indonesia is facing massive problems with deforestation.

As in China, the forest area also increases continually in **Australia**. Reason for this is the 2020 Vision launched in 1997. The aim is trebling the plantation estate by 2020. The plantations should provide a sustainable and profitable supply of wood. The outcomes of the developing plantation industry are products which are internationally competitive, commercially orientated and market focused. Private investment is the key factor for achieving the goal of a flowering plantation industry which will enhance growth in other forest industry sectors and rural development. Until now the plantations have moved from 1M hectare to 2 M hectare. Institutional investors and managed investment schemes (MIS) own more than 50 % of the plantations, governments have around 23%. Challenges for the future are the change in the ownership structure of the plantations as many MIS have broken down. The loss of hardwood plantations in marginal areas and the change of the markets are just some of the questions Australia has to answer.

Although both countries, China and Australia, made a big step towards establishing new forest areas, the question remains what ecological value these new forests have. The settings on biodiversity, ecosystem services and the appropriate location have not yet been sufficiently clarified. The European Union could provide information exchange and knowledge transfer about these problems. In Europe sustainable forestry is practiced over decades and much practical and scientific expertise exists here.

A different situation can be found **Canada**. This country has a stable forest area, but tries to re-arrange their vision of the future forestry. One element for this new vision is the Program on International Forestry[69] set up by the CCFM's (Canadian Council of Forest Ministers). Goal of this programme is to help prevent forest policy–based trade and non-tariff barriers from being established in export markets and to promote Canadian forest policies and programs internationally.

Canada's Innovation Action Plan 2016-2020, set up by the Canadian Council of Forest Ministers Innovation Committee, aims at advancing the forest sector innovation. Thereby Canada wants to support climate change mitigation, long-term environmental sustainability, economic competitiveness and green jobs. To capture a bigger share of global markets, forest product producers are encouraged to work cooperatively. Additionally other actors

[67] http://www.un.org/esa/forests/wp-content/uploads/2014/12/China_case_study.pdf
[68]http://forest-trends.org/documents/files/doc_4908.pdf
[69] http://www.ccmf.org/pdf/CCFMCanForStratBklt.pdf

like academic and industrial partners should comply with the forestry sector to establish bioproducts to a wide range of consumers. Furthermore the CCFM in collaboration with different stakeholders wants to develop a Forest Bioeconomy Framework for Canada[70]. The European Union can guide Canada in establishing such a framework, as the European commission has developed a programme for research and innovation for itself (Horizon 2020).

Russia is the country that accounts 20% of global forests, but its share in the global trade of forest products is not higher than 4%. The forests are underused und probably underestimated by the government[71]. According to the authors of the FAO study “The Russian Federation Forest Sector Outlook Study to 2030”, “the twenty-year delay in the development of the Russian forest sector has opened up a unique historical possibility to radically renovate and reconstruct its key branches on a fundamentally new technological basis for the twenty-first century. This must be achieved through the introduction of breakthrough technologies and innovations in the leading branches of the forest sector. This conclusion relates to techniques, technologies, policy, institutions, science and education. With the help of breakthrough technologies and innovations, the Russian forest sector should bypass the twenty-year gap and integrate into the global economy as a renovated, competitive and innovative segment.”

The European industry could provide such technologies and techniques. Forest research institutions from Europe are able to provide their knowledge and experience to Russian partners.

The forest products statistic collected by the FAO[72] shows some interesting developments. Namely the **wood pellet production** has increased drastically in the recent years. In 2015, 28 million tonnes were produced. 16 million tonnes were traded internationally. Europe and Northern America have a leading role here. They are responsible for almost all global production (92%) and consumption (90%).

The global production of panels reached an unprecedented climax: 399 million m^3. Sawnwood achieved the highest production since 1990: 452 million m^3.

[70] Canadian Council of Forest Ministers, Innovation Action Plan 2016-2020, http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/37112.pdf
[71] FAO 2012, The Russian Federation Forest Sector Outlook Study to 2030, http://www.fao.org/docrep/016/i3020e/i3020e00.pdf
[72] http://www.fao.org/3/a-i6669e.pdf

5. Description of strengths and weaknesses of EU R&I landscape regarding coverage of relevant sectors, raw materials and value chain sections

Partners involved: JUELICH

According to the results of this analysis, including survey, current EU R&I programmes cover most relevant raw materials, industry sectors and value chain sections.

5.1.1. Coverage of raw materials

In terms of the coverage of abiotic and biotic raw materials there is a focus on abiotic raw materials since almost 75 % of the funding programmes responding to the online consultation address abiotic raw materials (see Figure A.4. Biotic / abiotic materials, annex 3). Nevertheless, biotic raw materials play also an important role being addressed by more than the half of the funding programmes responding to the consultation. The funding organizations don't expect that the importance of both groups of raw materials will change substantially in the future. According to the assessment of the funding organization, funding of biotic and non-biotic raw materials will remain on the same level as compared to the current situation.

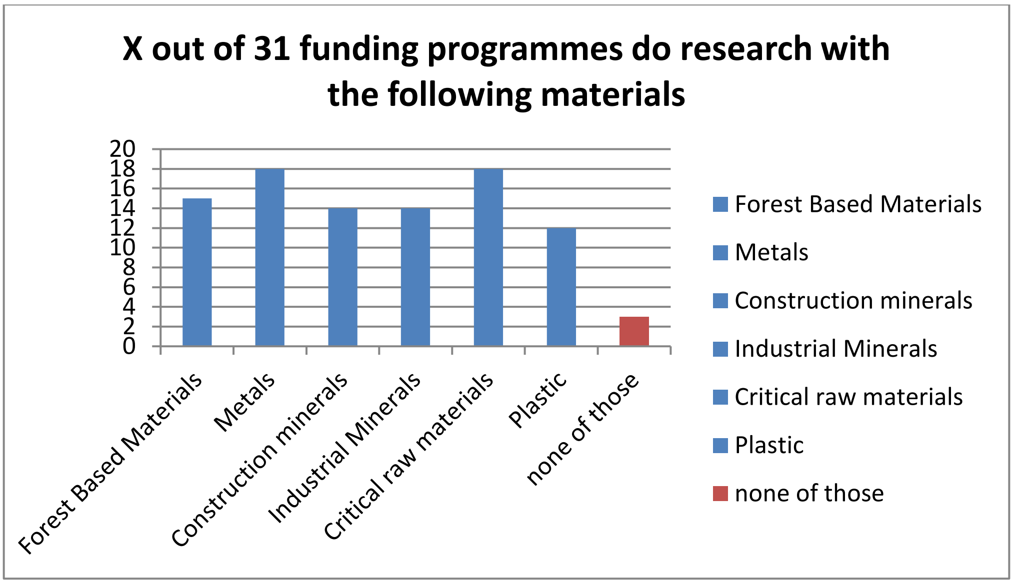
At the same time the results show that the majority of funding programmes is either restricted to non-biotic or to biotic raw materials. However, a substantial number of funding programmes is open to fund topics related to biotic and non-biotic raw materials. Whether the conventional approach with separate funding strategies for biotic and non-biotic raw materials will be appropriate to respond to future challenges has to be taken into account for the development of a long-term vision and roadmap for raw materials.

The publication of raw materials considered as critical provides a guideline for many funding organizations. Consequently many funding programmes address critical raw materials and metals (considering that most of the critical raw materials are metals). Nevertheless, other raw materials are addressed by a substantial number of funding programmes.

Though not considered as a raw material, plastic is addressed by 12 out of 31 funding programmes and is therefore integrated in research programs related to raw materials (Fig. 5.1.). Only 3 funding programmes address none of the specific raw materials which were given as possible answers: metals, construction minerals, industrial minerals, plastics and forest based materials.

It would be worth to check whether these programmes address completely new raw materials which could be of interest for the future. For example, there is a German funding programme where CO_2 is considered as a raw material which widens the sources of raw materials. Since the use if CO_2 for the productions of new materials responds both to the supply of raw materials and climate protection it could be a promising approach which may become more important in the future and beyond national funding programmes in Germany.

Figure 4.14. Distribution of the raw materials adressed by the R&I funding programmes (Survey)



5.1.2. Coverage of relevant sectors, value chain sections

As shown in the figure below the majority of funding programs addresses all parts of the production cycle: supply of raw materials (1), product design (5), production (2), use (4) and recycling (3). Other topics are clearly less represented in funding programs. However, in terms of their importance for the future especially Circular economy and recycling policies (6) and Non-technological topics (8) are expected to become much more important.

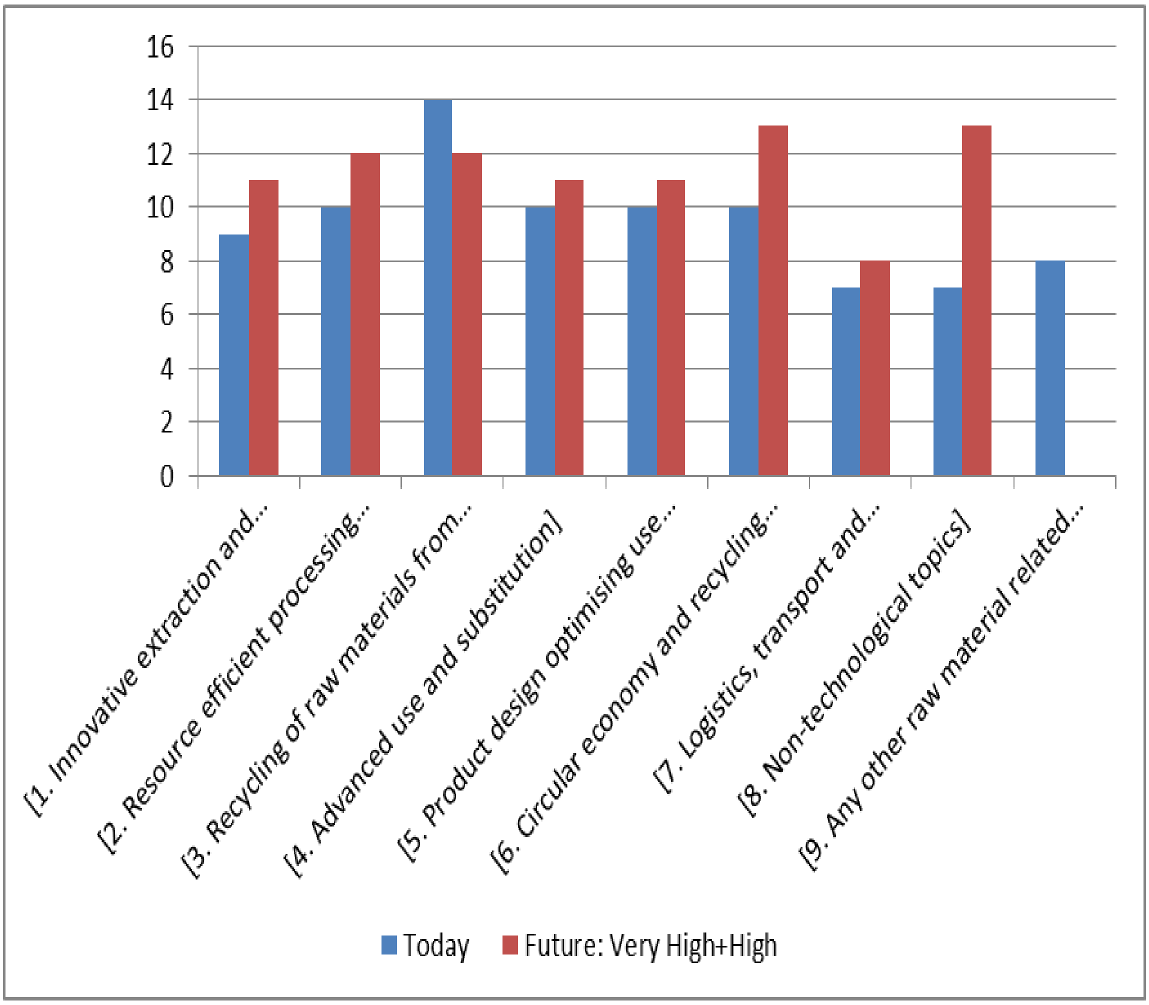
Hence, the differences in terms of the coverage of different topics would disappear to a great extent. As consequence the focus would shift from technological innovation with an emphasis on recycling to an approach taking into account the whole system including cross-cutting issues.

Only topics related to logistics, transport and material flows are not expected to get increasing attention in the future within national funding programs. Please see annex 3 for detailed information on sub-topics. Generally, differences between sub-topics are not substantial. However, results show that within topic 6 (Circular economy and recycling policies) the focus is clearly on sub-topic 6.4 (Innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products) since other sub-topics are not well represented.

Within topic 8 (non-technological topics) the focus is on international cooperation. In Annex 3 sub-topics are listed which were assigned to topic 9 (any other raw material related topics).

Although not mentioned explicitly within the topics 1 to 8 many of the aspects of topic 9 have close links to the topics mentioned before. Nevertheless, there are also some aspects which could add something completely new to raw materials research and innovation activities and which are at the moment not wide spread. Among these aspects are for example CO_2-utilisation and –separation.

Figure 4.15. Distribution of the research topics adressed by the R&I funding programmes (Survey)



5.1.3. Comparison between VERAM survey and the topics of the first call of ERA-MIN2

During the preparation of this report on 1st February 2017 a transnational call on raw materials was published in the frame of the Horizon 2020 funded ERA-Net ERA-MIN 2 (https://www.era-min.eu/call). The topics of this call were compared to the answers given to the VERAM consultation. For many countries the topics funded in the transnational call confirm the answers given for the VERAM consultation.

However, there is already an obvious shift of the focus from certain parts of the production cycle (e.g. mining, recycling, and substitution) to a more holistic view taking into account the whole production cycle. It is pointed out that despite all efforts to reduce waste and to increase recycling mining will not disappear and still play an important role within a circular economy.

6. Conclusions

As planned, this report analyses, for both abiotic and biotic raw materials, the ongoing funding activities and (possibly planned) opportunities at international, EU and member state level (Chapter 2) for initiatives that:

(i) explicitly aim to enhance the availability of raw materials
(ii) are likely to affect such availability, either by supporting R&D activities or by facilitating upscaling and implementation.

Existing reports and/or studies that assess the effectivity and efficiency of EU and national funding programs (Germany as an example) have been analysed regarding their impact on raw material security of supply and the factors of success (Chapter 3).

Within the Industrial sector, the consortium has mapped the current situation, trends, needs, long-term strategies and evolution and development aspects, oriented to granting the availability of raw materials at high level. Strategic aspects are delivered in order to sum up in synergistic way to the research roadmaps and to highlight the congruence and differentiations (Chapter 4).

The raw materials research & innovation landscape has been analysed with regard to strength and weaknesses considering the coverage of sectors, raw materials and value chains (Chapter 5).

6.1. Main outcomes from current and planned RM research & innovation funding

The main conclusions that were drawn from the present situation of the R&I landscape in the raw materials sector are the following:

- relevant stakeholders and funding programmes in the raw material sector are identified to be considered for the development of the vision and roadmap on European raw materials,
- current R&I programmes cover most relevant raw materials, industry sectors and value chain sections at European (EU and member states; one dedicated outlook as sample is issued for Italy) as well as at international level for the countries considered,
- the materials addressed by funding programmes vary between countries and reveal differences in terms of understanding and classification of raw materials,
- funding programmes with new approaches where identified on member state level which could be of interest for a wider community (e.g. widening the raw material basis through the use of CO_2),
- a methodology for the evaluation of effectivity and efficiency of funding initiatives based on four criteria (economic and social, criticality, environmental, innovation) is presented, providing details for running evaluations in concrete terms,
- through segmentation of the raw materials-intensive sectors, the research initiatives taken from 27 large enterprises in EU, as representatives of 13 sectors, are mapped.

Indicators identified to assess the intensity and directions taken span from patent analysis, evidence of product development and scientific papers publication,
- a slight shift from sectoral technology-oriented research on mining and recycling to more holistic topics including non-technological issues seems to take place. This could be a consequence of the implementation of the circular economy policy since 2015,
- although there is a focus on the reduction of waste in the public discussion as primary resources will still be needed, mining will remain of equal importance as compared to other strategies for the supply of raw materials,
- transnational cooperation (e.g. within ERA-Nets) fosters a common understanding among funding organizations,
- 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,
- the topics addressed in Europe and oversea (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,
- There is an important and sustained gap of business R&D expenditure as % of GDP between the EU and the US, China, Japan, and Korea.
- the German example (r^2 initiative) shows how efficient R&D funding could be in the case further funding for market access is provided.

6.2. Trends in value of EU raw material demand

- 2001-2011: Differences for RM from mining & quarrying versus RM from forestry & logging
    - Mining & quarrying: sharp increase of absolute values and in imported values
    - 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)
- 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 raw materials from mining and quarrying.
- 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%.

6.3. Long-term industrial raw materials strategies

- Strategies concerning resource efficiency, innovation and industrial needs lead to spontaneous generation of synergies between industrial strategies and the research roadmaps,
- Complementary industry strategies: need for coherent policies and actions regarding international trade, infrastructure development, standardization and market research,

- Complementary strategies for companies: risk mitigation, integration with strategic sourcing partners through mergers, acquisitions and joint ventures,
- Ongoing 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. Europe is not far away from bringing to fruition the true vision of a connected enterprise.

6.4. Some hotspot industrial sectors developments

- Conductive polymers: high growth markets China, Japan, South Korea, US, Singapore, India. EU opportunities mainly Germany and UK
- Biotechnology: development of European bio-based product markets are needed for bioeconomy expansion
- Electric vehicle batteries: low participation of EU based manufacturers
- Electronics manufacturing: EU growth opportunities in response to global development of higher value, lower volume professional end of the electronics manufacturing spectrum.

6.5. Differentiating between raw materials supply risk management strategies

- Specific business strategies are required when purchasing products or raw materials with high supply risks,
- Specific barriers exist to the goal of increasing the sustainable sourcing of raw materials for industries.

6.6. Critics

- Value of (critical) raw materials in total selling prize not always provides an incentive for manufacturers to apply resource efficiency strategies which provides argument for circular economy so that alternative company supply risk management strategies are needed,
- Suggestions have been made for improving EU criticality methodology, alternative national methodologies are also available,
- Need to improve estimates on both the relevance of critical raw materials supply risks for companies, to better focus corresponding industrial strategies,
- Need to avoid the risk to reduce necessary EU policy space by measures undertaken by the EU in the context of its trade and investment policies as weakening of developing countries industrial development might be counterproductive for EU industries,
- US and China actively preparing for extending raw materials system boundaries into outer space.

The results of this task, both collection and analysis of data, will contribute to the next activities in VERAM, namely developing a roadmap and a vision for European raw material research. In addition to this the web portal on Raw Material research programs/topics & Identification and classification of currently running research programs/topics will help to support this work. Through the survey new stakeholders have been identified who should be involved in the further project activities.

Annexes

Annex 1 Consulted reports and studies

In this section the list of existing reports and studies that assess the effectivity and efficiency of Raw Materials funding programs and Raw materials technologies is presented.

Table A.1. Consulted reports and studies for part 4.4

Title	Author	Affiliation	Year	Contents	Source	Main Topic
Raw Materials: Study on Innovative Technologies and Possible Pilot Plants – Final Report	Emile Elewaut Ton Bastein	TNO	2012	Study on the methodology for assessment of Raw Materials Pilot plants. Identification, ranking and evaluation of the pilot plants in Europe	EC	Raw Materials
Rare Earths – Facts & Figures	Dr. Doris Schüler d.schueler@oeko.de	Öko-Institut e.V.	2011	Rare Earths Reserves and Mine Production Worldwide, Environmental aspects of rare earth mining Exports, Imports, Processing and Applications Development of Prices Strategy for a sustainable rare earth economy	EC	Raw Materials
A New European Regional Competitiveness Index: Theory, Methods and Findings	Lewis Dijkstra Paola Annoni Kornelia Kozovska		2011	EU Regional Competitiveness Index (RCI) Eleven pillars grouped in three groups: basic, efficiency and innovation. It takes into account the level of development of the region by emphasizing basic issues in less developed regions and emphasizing innovative capacity in more developed regions. The pillars measure not only issues relevant for firms but also for residents and their quality of life.	EC	Methodology
Study on Rare Earths and Their Recycling	Dr. Doris Schüler Dr. Matthias Buchert Dipl.-Ing. Ran Liu Dipl.-Geogr. Stefanie Dittrich Dipl.-Ing. Cornelia Merz	Öko-Institut e.V.	Jan 2011	Methodologies for determination of criticality Reserves Mining data Global rare earth processing Rare earth trade Environmental aspects of rare earth mining and processing Applications and demand of rare earths Demand-supply balance Substitution and efficient use of rare earths Recycling of rare earths – current situation Strategy for a sustainable rare earth economy	EC	Raw Materials
Materials critical to the energy industry - An introduction	John Simmons	ON Communication	2011	(Non-energy) Minerals for energy pathways Functionalities, from rock to use, criticality and constraints, sustainability indicators, resources and reserves, materials market. Two-page outline for 19 energy-critical materials.	EC	Raw Materials

Innovation Union Atlas		EC	2011	European maps on: Investments in Research and Innovation Human resources Performance Towards a more efficient Research and innovation system Structural change for a knowledge-intensive economy Research and Innovation responding to societal challenges	EC	Drivers
World Markets for Recovered and Recycled Commodities - Time to Smile Again?	Professor Philippe Chalmin, Dauhpine University / CyclOpe, France	Bureau of International Recycling	May 2010	World Commodity Markets in 2009 and 2010, Ferrous Scrap: Market Revival and Structural Changes in the Iron and Steel Complex, Recycled Cellulose Fibres and the China Syndrome	EC	Raw Materials
DRAFT OPINION of the Consultative Commission on Industrial Change (CCMI) on the Communication ... on Tackling the challenges in commodity markets and on raw materials	Rapporteur: Mr Zboril Co-rapporteur: Mr Gibellieri	Consultative Commission on Industrial Change (CCMI)	May 2011	DRAFT OPINION of the Consultative Commission on Industrial Change (CCMI) on the Communication ... on Tackling the challenges in commodity markets and on raw materials	EC	Raw Materials
The International Cyanide Management Code		International Cyanide Management Institute	October 2009	Safe management of cyanide in gold industry	EC	Raw Materials
Critical Metals in Strategic Energy Technologies - Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies	R.L.Moss 1, E.Tzimas 1, H.Kara 2, P.Willis 2 and J.Kooroshy 3	1 JRC – Institute for Energy and Transport 2 Oakdene Hollins Ltd 3 The Hague Centre for Strategic Studies	2011	Strategic Energy Technology Plan (SET-plan), Metal Requirements of SET-Plan, Bottleneck Screening Technology Scenarios of Bottleneck Metals Mitigation Strategies Metal Composition of SET-Plan Technologies	EC	Raw Materials
Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in the south east of England - Final report	Adrian Chapman	Oakdene Hollins Ltd	March 2011	Applications and Future Supply and Demand Concerns for the Critical Raw Materials Recycling and Recovery Best Practice for Critical Materials Identification of Principal End Use Applications Resource Efficient Use of Critical Raw Materials	EC	
Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in the south east of England - Summary report	Adrian Chapman	Oakdene Hollins Ltd	March 2011	Applications and Future Supply and Demand Concerns for the Critical Raw Materials Recycling and Recovery Best Practice for Critical Materials Identification of Principal End Use Applications Resource Efficient Use of Critical Raw Materials	EC	
Generation and treatment of waste in Europe 2008	Hartmut Schrör	Eurostat	July 2011	Waste generation for mineral and non-mineral waste	EC	Raw Materials

Breakthrough technologies: For the security of supply of critical minerals and metals in the EU - Synthesis Report	Luke Georghiou, Jacques Varet and Philippe Larédo	University of Manchester, BRGM, ENPC, LATTS & IFRIS et al.	January 2011	The raw materials situation: Resource availability, Critical materials, Mineral processing, energy and environment issues, Recycling, re-use, substitutions and new applications, Governance and equity Key drivers The Key Challenges Identifying potential breakthroughs	EC	Drivers
Dynamising innovation policy: Giving innovation a central role in European policy - Synthesis Report	Matthias Weber and Luke Georghiou	University of Manchester, AIT, MCST, et al.	May 2010	Innovation policy in Europe, Issues for action on European innovation policy governance,	EC	
Finland's Minerals Strategy	Ministerial working group on climate and energy polic	Natural Resources Strategy of Finland	2010	The significance of minerals Global challenges Minerals policy in the EU The Finnish minerals sector The minerals sector as an opportunity for Finland Action proposals	EC	
Frascati Definitions Limits to Experimental Development					EC	
Scarcity of Minerals - A strategic security issue	Jaakko Kooroshy, Christa Meindersma, Richard Podkolinski, Michel Rademaker, Tim Sweijs, André Diederen, Martijn Beerthuizen and Sophie de Goede	The Hague Centre for Strategic Studies	2009	Understanding scarcity: a conceptual framework Findings National Mineral Policies Security implications	EC	Raw Materials
Innovation Union Competitiveness report - 2011 edition		EC - DG-RTD	2011	Europe's competitive position in research and innovation - Acting in the new geography of knowledge Investment and performance in R&D - investing for the future A European Research Area open to the world - towards a more efficient research and innovation system Towards an innovative Europe - contributing to the innovation union New perspectives: Smarter policy design – Building on diversity Country Review	EC	Country
Lanthanide Resources and Alternatives	Dr Hüdai Kara, Dr Adrian Chapman, Dr Trevor Crichton, Peter Willis and Nick Morley	Oakdene Hollins Ltd	May 2010	Background on Material Security Rare Earth Resources Supply Rare Earth Applications Demand Demand-Supply Balance Alternative Technologies End-of-Life Recovery of Rare Earths Environmental Impacts	EC	

Material Security ensuring resource availability for the UK economy		Resource Efficiency Knowledge Transfer Network Oakdene Hollins Ltd	March 2008	Case Study 1: RUTHENIUM The economics of resource depletion Case Study 2: LEAD Case Study 3: COPPER Case Study 4: TELLURIUM Materials and industrial impacts Resource Efficiency Strategies Addressing Material Security Case Study 5: COBALT Recommendations	EC	Raw Materials
Recycling Rates of Metals - A status report		UNEP	2011	Metal recycling considerations Recycling rates Statistics	EC	Raw Materials
Offshore Production System Definition and Cost Study		SRK Consulting for Nautilus Minerals	June 2010	This study includes a description of the offshore components for a seafloor production project at Solwara. It includes CAPEX / OPEX estimates for the offshore components but does not include an economic analysis	EC	Drivers
Material Scarcity	Huib Wouters (1) Derk Bol (2)	(1) Chorus Research (2) M2i	November 2011	Material scarcity Scarcity and industry Solution paths Thinking aboutt scarcity Scenarios for transitions	EC	Raw Materials
Benchmarking Industry-Science Relationships		OECD	2002	The Growing and Changing Role of Industry-science relationships in Innovation-led Growth Benchmarking Industry-science Relationships Pilot Study on France and the United Kingdom Industry-science Relationships in France Industry-science Relationships in the United Kingdom Industry-science Relationships in Japan	EC	Country
Proposed Standard Practice for Surveys on Research and Experimental Development - Frascati Manual		OECD	2002	Recommendations and guidelines on the collection and interpretation of established R&D data	EC	Methodology
Oslo Manual - Guidelines for collecting and interpreting innovation data		OECD	2005	Understanding of the structure and characteristics of the innovation process and its implications for policymaking Basic definitions of innovation, innovation activities and the innovative firm Institutional classifications Measuring linkages in the innovation process; types of knowledge and their sources Innovation activities and their measurement Objectives, barriers and impacts of innovation Innovation surveys in developing economies	EC	Methodology
Science, Technology and Innovation Indicators in a Changing World		OECD	2007	Policy Perspectives Measuring Innovation	EC	Methodology

Governance of Innovation Systems Vol. 2 - Case studies in innovation policy		OECD	2005	Adapting Institutions in Innovation Policy Greece, Ireland, South Korea, Austria, Finland Japan Integrating Policies for Innovation The Netherlands, Norway, Sweden, New Zealand, Australia, Flanders	EC	Country
Governance of Innovation Systems Vol. 3 - Case studies in innovation policy		OECD	2005	Governance and the Information Society Austria, Finland, Norway, Ireland, the Netherlands, Greece, Sweden Governance in Sustainable Development Finland, Norway, Flanders, Austria	EC	Country
Towards green growth - A summary for policy makers		OECD	May 2011	Green Growth	EC	
Outotec offers new partial roasting process to purify contaminated copper and gold concentrates		www.mining.com	December 2011	two-stage partial roasting process to remove impurities – such as arsenic, antimony and carbon – from copper and gold concentrates as a pre-treatment to actual extraction processes	EC	Raw Materials
Rare Earth Elements: The Global Supply Chain	Marc Humphries	Congressional Research Service	September 2010	What Are Rare Earth Elements? Major End Uses and Applications Rare Earth Resources and Production Potential Rare Earth Legislation in the 111th Congress Possible Policy Options Rare Earth Elements (Lanthanides): Selected End Uses Rare Earth Elements: World Production and Reserves—2009	EC	Raw Materials
Reinventing the wheel - A circular economy for resource security	Hannah Hislop Julie Hill	Green Alliance	October 2011	Recommendations on metals, water, phosphorus, resource stewardship. Recycling rates	EC	
Rohstoffe für Zukunftstechnologien Einfluss des branchenspezifischen Rohstoffbedarfs in rohstoffintensiven Zukunftstechnologien auf die zukünftige Rohstoffnachfrage	Dr. Gerhard Angerer Dr. Frank Marscheider-Weidemann Arne Lüllmann Lorenz Erdmann Dr. Michael Scharp Volker Handke Max Marwede	Fraunhofer IZT	May 2009		EC	
Research Institutes in the ERA	Erik Arnold Kate Barker Stig Slipersæter	University of Manchester Tecnopolis	July 2010	The Research Institute Sector The Past and Future of Research Institutes in Six Fields Implications for the research institute sector in the ERA Policy Implications	EC	Drivers

Critical Materials Strategy		U.S. D.o.E.	December 2010	Use of key materials in clean energy technologies Historical supply, demand and prices for the key materials Current DoE programs Other U.S. Government programs Materials strategies from other nations Supplt and demand projections Criticality assessment Program and policy directions	EC	Raw Materials
Energy Critical Elements: Securing Materials for Emerging Technologies		APS Physiscs MRS	2010 - 2011	Constraints on Availability of Energy-Critical Elements: Crustal abundance, concentration, and distribution; Geopolitical risks; The risks of joint production; Environmental and social concerns; Response times in production and utilization Responses: Findings and Recommendations: Coordination, Information, Research, development, and workforce issues, The role of material efficiency, Possible market interventions	EC	
Waves of Innovation	Michael Burnam-Fink		May 2011	Waves of Innovation	EC	Methodology

Annex 2: Bibliography for 4.2.

(1) Rohstoffgewinnung in Deutschland – von tiefen Löchern und kleinen Flittern, BGR (Bundesanstalt für Geowissenschaften und Rohstoffe) & DERA (Deutsche Rohstoffagentur), 2016
(2) Die Nachfrage nach Primär- und Sekundärrohstoffen der Steine-und-Erden-Industrie bis 2035 in Deutschland, bbs, Bundesverband Baustoffe – Steine und Erden e.V., 2016
(3) Die Deutsche Elektroindustrie – Innovationen für mehr Ressourceneffizienz, ZVEI (Zentralverband Elektrotechnik- und Elektronikindustrie), 2012
(4) Stand der Ressourceneffizienz in kleinen und mittleren Unternehmen des verarbeitenden Gewerbes sowie fördernde und hemmende Faktoren der Umsetzung 2015, VDI-ZRE, Zentrum Ressourceneffizienz, 2015
(5) Implikationen des 3D-Drucks für die Rohstoffsicherung der deutschen Industrie, BDI (Bundesverband der Deutschen Industrie e.V.), 2016
(6) Schieferöl und Schiefergas in Deutschland, BGR, 2016
(7) Erschließung der Ressourceneffizienzpotenziale im Bereich der Kreislaufwirtschaft Bau, Müller, BBSR/BBR, 2016
(8) Stellungnahme zur Mitteilung der Kommission „Den Kreislauf schließen – Ein Aktionsplan der EU für die Kreislaufwirtschaft“ (sowie zu weiteren Vorschlägen), DIHK, 2016
(9) Systemische Ansätze zur Steigerung der Ressourceneffizienz im Bauwesen, VDI-ZRE, 2015
(10) Wissenschaftliche Unterstützung in Einzelfragen des ressourceneffizienten Bauens, Fritz, BBSR/BBR, 2015
(11) Reserven, Ressourcen und Verfügbarkeit von Energiestoffen, BGR, 2015
(12) Gemeinsame Position zur geplanten EU-Initiative zum verantwortungsvollen Bezug von Rohstoffen aus Konfliktregionen, BDI, DIHK, BDA, 2015
(13) Handels- und Wettbewerbsverzerrungen bei Rohstoffen - Für einen diskriminierungsfreien Zugang und verlässliche Handelsregeln, BDI, 2015
(14) Anforderungen an eine ganzheitliche und nachhaltige Rohstoffpolitik, BDI, 2014
(15) Studie: Analyse von Ressourceneffizienzpotenzialen in KMU der chemischen Industrie, VDI-ZRE, 2014
(16) Angebotskonzentration bei mineralischen Rohstoffen und Zwischenprodukten – potenzielle Preis- und Lieferrisiken, DERA-Rohstoffliste, DERA, 2014
(17) Deutschland – Rohstoffsituation 2014, DERA, 2014
(18) Der Bergbau in der Bundesrepublik Deutschland 2014, BMWi, 2015
(19) Die Chancen des Tiefseebergbaus für Deutschlands Rolle im Wettbewerb um Rohstoffe, BDI, 2014
(20) Wie Forschung und Innovation Deutschland stark machen, DIHK, 2013

Annex 3: Details of the survey results

3.1 Answers (Characteristics)

Basic information

Project title:	ADE grants for international R&D projects in the framework of ERA -NETS	Web Page:	http://www.empresas.jcyl.es/ (Web Page of Organisation)
Funding Organisation	Agencia de Innovación, Financiación e Internacionalizacion Empresarial de Castilla y León (Spain)		
Time frame	2016 - 2020	Budget:	0,35 Mio €
Contact person:	Isabel Gobernado	E-Mail:	gobmitma@jcyl.es
Programme owner and programme manager			
Maturity:	Laboratory scale, proof of concept, pilot trial		
Eligible Beneficiaries:	SME, large company		
Number of Projects:		Average Funding per project:	

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	High
Biotic Material	Yes, forest based materials	High
Innovative extraction and harvesting of raw materials	Yes	High
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	Yes	High
Advanced use and substitution	Yes	High
Product design optimising use of raw materials and increasing quality recycling	Yes	High
Circular economy and recycling policies	No	High
Logistics, transport and optimised raw material flows along the value chain	Yes	High
Non-technological topics	No	High

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	ADEME's RDI program	Web Page:	http://www.ademe.fr/recherche-innovation/programmes-recherche
Funding Organisation	ADEME Agence de l'environnement et de la maîtrise de l'énergie (France)		
Time frame	2014 - 2020	Budget:	30 Mio €
Contact person:	Erwan Autret	E-Mail:	erwan.autret@ademe.fr
Programme Owner and Programme Manager			
Maturity:	Laboratory scale, Proof of concept, Pilot trial		
Eligible Beneficiaries:	University, Research Institute, Public authority, SME, Large Company		
Number of Projects:	400	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	Very high
Biotic Material	Yes, forest based materials, agriculture	Very high
Innovative extraction and harvesting of raw materials	Yes, geomodels resp. resource/wood quantity and quality assessment, environmental-friendly forest operations (harvesting, transport and management)	High
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, innovative sorting and detection systems	High
Advanced use and substitution	Yes, renewable energy solutions, development of new biobased products	High
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, intelligent packaging solutions, improve the re-usability of construction materials	High
Circular economy and recycling policies	Yes, qualitative targets, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	High
Logistics, transport and optimised raw material flows along the value chain	Yes	High
Non-technological topics	Yes, improving Europe's raw material strategy, international cooperation	Very high
Other topics	Yes, LCA methodology, prospective studies, material flow analysis , social science on consumer behavior	-
Which raw Material is especially important for the future considering a time frame until 2050?	biomass, CRM	
Future topics	First, evaluate the environnemental and energetic affordable costs of RM in 2050-2100 ; then, derive the impacts on the consumption society	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Austrian WWN Research	Web Page:	http://www.woodwisdom.net/
Funding Organisation	Austrian ministry of agriculture, forestry environment and water management		
Time frame	2013 - 2017	Budget:	1,635 Mio € (1,6 Mio € public funding)
Contact person:	Martin Greimel	E-Mail:	martin.greimel@bmlfuw.gv.at
Programme Owner & Programme Manager			
Maturity:	Fundamental Research, Laboratory scale, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	University, Research Institute, Public authority, SME, Large Company		
Number of Projects:	10	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance of the topics for the future
Non Biotic material	no	High
Biotic Material	Yes, forest based materials	Very high
Innovative extraction and harvesting of raw materials	Yes, environmental-friendly forest operations (harvesting, transport and management)	Very high
Resource efficient processing and refining of raw materials	yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, packaging recycling, Construction and demolition waste recycling	Very high
Advanced use and substitution	Yes, substitution of non-renewable with renewable raw materials, renewable energy solutions, development of new biobased products	High
Product design optimising use of raw materials and increasing quality recycling	Yes, intelligent packaging solutions	High
Circular economy and recycling policies	Yes, extraction, separation and fractionation of paper and wood components	Very high
Logistics, transport and optimised raw material flows along the value chain	yes	High
Non-technological topics	no	-
Which raw Material is especially important for the future considering a time frame until 2050?	Lignocellulose	
Future topics	Replacing non -renewable with renewable raw material, recycling issues for non-renewable materials	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	BioInnovation	Web Page:	http://www.bioinnovation.se/
Funding Organisation	Verket för innovationssystem (Sweden)		
Time frame	2014 - 2016	Budget:	12 Mio € (6 Mio € public funding)
Contact person:	Anders Holmgren	E-Mail:	anders.holmgren@vinnova.se
Programme manager			
Maturity:	Proof of concept, pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company		
Number of Projects:	16	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	No	Very high
Biotic Material	Yes, forest based materials, agricultural residues	Very high
Innovative extraction and harvesting of raw materials	No	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	No	High
Advanced use and substitution	Yes, substitution of non-renewable with renewable raw materials, renewable energy solutions, development of new biobased products	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes	High
Circular economy and recycling policies	No	High
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	Yes, improving research and innovation coordination	High
Which raw Material is especially important for the future considering a time frame until 2050?	Forest and Agricultural raw materials rich in cellulose, hemicellulose and lignin	
Future topics	Presently needed topics: -Public opinion/consumer trends, -EU and national directives	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	CO2Plus	Web Page:	https://www.fona.de/de/co2plus-stoffliche-nutzung-von-co2-zur-verbreiterung-der-rohstoffbasis-20057.html
Funding Organisation	Forschungszentrum Jülich GmbH (Germany)		
Time frame	2006 - 2009	Budget:	22,5 Mio € (17,5 Mio € public funding)
Contact person:	Stefanie Roth	E-Mail:	s.roth@fz-juelich.de
Programme Manager			
Maturity:	Laboratory scale, Proof of concept, Pilot trial		
Eligible Beneficiaries:	University, Research Institute, Public authority, SME, Large Company		
Number of Projects:	13	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, plastics, CO2	Very high
Biotic Material	Yes, algae; microorganisms	
Innovative extraction and harvesting of raw materials	No	
Resource efficient processing and refining of raw materials	No	
Recycling of raw materials from products, buildings and infrastructure	No	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	No	High
Other topics	Yes, CO2-utilisation and CO2-separation	-
Which raw Material is especially important for the future considering a time frame until 2050?	CO2	

Basic information

Project title:	Cooperation between Germany and France on sustainable technologies for raw		
Web Page:	http://www.fona.de/de/zusammenarbeit-zwischen-deutschland-und-frankreich-zu-nachhaltigen-rohstofftechnologien-17355.html		
Funding Organisation	Forschungszentrum Jülich GmbH (Germany)		
Time frame	2012 - 2017	Budget:	6,6 Mio € (5,7 Mio € public funding)
Contact person:	Holger Gruenewald	E-Mail:	h.gruenewald@fz-juelich.de
Programme Manager			
Maturity:	Laboratory scale, Proof of concept, Pilot trial		
Eligible Beneficiaries:	University, Research Institute, public authority, SME, Large Company		
Number of Projects:	2	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, critical raw materials (according to EU Ad-hoc working group)	Very high
Biotic Material	No	
Innovative extraction and harvesting of raw materials	No	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling	Very high
Advanced use and substitution	No	Low
Product design optimising use of raw materials and increasing quality recycling	No	Low
Circular economy and recycling policies	Yes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products	High
Logistics, transport and optimised raw material flows along the value chain	No	Low
Non-technological topics	No	High
Which raw Material is especially important for the future considering a time frame until 2050?	critical raw materials, metals/industrial minerals/construction minerals with high demand	
Future topics	System innovation including business models, regulation etc.; circular economy	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure

Basic information

Project title:	Defi 1 - Climate Change and Natural	Web Page:	www.agencerecherche.fr
Funding Organisation	Agence nationale de la recherche (France)		
Time frame	Annual - figures for 2014 - 2016	Budget:	0,7 Mio €
Contact person:	Darmendrail Dominique	E-Mail:	dominique.darmendrail@agencerecherche.fr
Programme Owner			
Maturity:	Fundamental research, laboratory scale		
Eligible Beneficiaries:	University, Research Institute, SME		
Number of Projects:	2	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, critical raw materials (according to EU Ad-hoc working group)	
Biotic Material	No	
Innovative extraction and harvesting of raw materials	Yes	
Resource efficient processing and refining of raw materials	No	
Recycling of raw materials from products, buildings and infrastructure	No	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	No	
Which raw Material is especially important for the future considering a time frame until 2050?	-	
Future topics	-	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials

Basic information

Project title:	Efficient resource management and adaptation to climate change AND stimulating industrial renewal	Web Page:	http://www.agence-nationale-recherche.fr (Website of the organisation)
Funding Organisation	Agence nationale de la recherche (France)		
Time frame	2013 - 2016	Budget:	
Contact person:	Spalla Olivier	E-Mail:	olivier.spalla@anr.fr
Programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept		
Eligible Beneficiaries:	University, research institute, public authority, SME		
Number of Projects:	6	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, industrial minerals, critical raw materials (according to EU Ad-hoc working group)	High
Biotic Material	No	Low
Innovative extraction and harvesting of raw materials	Yes, geomodels resp. resource/wood quantity and quality assessment	High
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling	Low
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in catalysts, substitution of CRM in photovoltaic materials, substitution of non-renewable with renewable raw materials, substitution of CRM in super alloys and steels alloyed with scarce elements, Renewable energy solutions, substitution of indium in transparent conductive layers, substitution of CRM in light sources, substitution of CRM in hard materials, development of new biobased products	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products	Very high
Circular economy and recycling policies	Yes, qualitative targets	High
Logistics, transport and optimised raw material flows along the value chain	No	Very low
Non-technological topics	No	Low

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	Cooperation between Germany and France on sustainable technologies for raw		
Web Page:	http://www.fona.de/de/zusammenarbeit-zwischen-deutschland-und-frankreich-zu-nachhaltigen-rohstofftechnologien-17355.html		
Funding Organisation	Forschungszentrum Jülich GmbH (Germany)		
Time frame	2012 - 2017	Budget:	6,6 Mio € (5,7 Mio € public funding)
Contact person:	Holger Gruenewald	E-Mail:	h.gruenewald@fz-juelich.de
Programme Manager			
Maturity:	Laboratory scale, Proof of concept, Pilot trial		
Eligible Beneficiaries:	University, Research Institute, public authority, SME, Large Company		
Number of Projects:	2	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, critical raw materials (according to EU Ad-hoc working group)	Very high
Biotic Material	No	
Innovative extraction and harvesting of raw materials	No	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling	Very high
Advanced use and substitution	No	Low
Product design optimising use of raw materials and increasing quality recycling	No	Low
Circular economy and recycling policies	Yes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products	High
Logistics, transport and optimised raw material flows along the value chain	No	Low
Non-technological topics	No	High
Which raw Material is especially important for the future considering a time frame until 2050?	critical raw materials, metals/industrial minerals/construction minerals with high demand	
Future topics	System innovation including business models, regulation etc.; circular economy	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure

Basic information

Project title:	Defi 1 - Climate Change and Natural	Web Page:	www.agencerecherche.fr
Funding Organisation	Agence nationale de la recherche (France)		
Time frame	Annual - figures for 2014 - 2016	Budget:	0,7 Mio €
Contact person:	Darmendrail Dominique	E-Mail:	dominique.darmendrail@agencerecherche.fr
Programme Owner			
Maturity:	Fundamental research, laboratory scale		
Eligible Beneficiaries:	University, Research Institute, SME		
Number of Projects:	2	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, critical raw materials (according to EU Ad-hoc working group)	
Biotic Material	No	
Innovative extraction and harvesting of raw materials	Yes	
Resource efficient processing and refining of raw materials	No	
Recycling of raw materials from products, buildings and infrastructure	No	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	No	
Which raw Material is especially important for the future considering a time frame until 2050?	-	
Future topics	-	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials

Basic information

Project title:	EPA Research Programme	Web Page:	http://www.epa.ie/researchandeducation/research/
Funding Organisation	Irish Environmental Protection Agency		
Time frame	Ongoing	Budget:	9 Mio €
Contact person:	J. Derham	E-Mail:	j.derham@epa.ie
Programme owner and programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept, pilot trial		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company, NGO's, community groups		
Number of Projects:	100	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics, pollutants such as SOx, NOx, hydrocarbons	Very high
Biotic Material	Yes, forest based materials, biomass, microbes, bio-waste	Very high
Innovative extraction and harvesting of raw materials	No	High
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	No	High
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, intelligent packaging solutions, improve the re-usability of construction materials	Very high
Circular economy and recycling policies	Yes, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products	High
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy, international cooperation	Very high
Other topics	Yes, re-mining of former mine waste for CRM, other; Environmental Pollution control of former mine sites; Risk assessment for former mine sites; Mine effluent treatment (e.g. reed beds)	-
Which raw Material is especially important for the future considering a time frame until 2050?	Phosphates; CRMs; Al, Zn, Fe, Ni	
Future topics	Land use planning/sterilization; Community gain; Legacy management; Marine mining; Better regulation/integrated permitting; BAT; exploration innovation	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	ERA-MIN 2	Web Page:	http://www.finep.gov.br (Website of the organization)
Funding Organisation	Financiadora de Estudos e Projetos (Brazil)		
Time frame	2016 - 2021	Budget:	1,4 Mio €
Contact person:	Denise Reigada	E-Mail:	dreigada@finep.gov.br
Neither programme leader nor programme manager			
Maturity:	Fundamental research		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company		
Number of Projects:	0	Average Funding per project:	max. 1 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, critical raw materials (according to EU Ad-hoc working group)	Very high
Biotic Material	No	Very low
Innovative extraction and harvesting of raw materials	Yes, automated mining, deep-sea mining, environmental-friendly forest operations (harvesting, transport and management)	Very high
Resource efficient processing and refining of raw materials	No	High
Recycling of raw materials from products, buildings and infrastructure	Yes, construction and demolition waste recycling	Very high
Advanced use and substitution	Yes, renewable energy solutions, development of new biobased products	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes, improve the re-usability of construction materials	High
Circular economy and recycling policies	Yes, landfill ban for recyclable waste and incineration ban for certain waste	High
Logistics, transport and optimised raw material flows along the value chain	No	Low
Non-technological topics	Yes, international cooperation	Very high
Which raw Material is especially important for the future considering a time frame until 2050?	Liquid rejects originated from the confeccion of electronic boards for communication devices	
Future topics	Subsea Mining	

Basic information

Project title:	European and International Cooperation	Web Page:	http://uefiscdi.gov.ro/articole/4374/Subprogramul-32-Orizont-2020.html
Funding Organisation	Unitatea Executiva pentru Finantarea Invatamantului Superior, a Cercetarii, Dezvoltarii si Inovarii (UEFISCDI) (Romania)		
Time frame	2015 - 2020	Budget:	
Contact person:	Manole Mihaela	E-Mail:	mihaela.manole@uefiscdi.ro
Programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company, NGO		
Number of Projects:	35	Average Funding per project:	max. 100.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	
Biotic Material	Yes, forest based materials	
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, geomodels resp. resource/wood quantity and quality assessment, automated mining, mining of small deposits, alternative mining, deep-sea mining, environmental-friendly forest operations (harvesting, transport and management)	
Resource efficient processing and refining of raw materials	Yes	
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in catalysts, substitution of CRM in photovoltaic materials, substitution of non-renewable with renewable raw materials, substitution of CRM in super alloys and steels alloyed with scarce elements, renewable energy solutions, substitution of indium in transparent conductive layers, substitution of CRM in light sources, substitution of CRM in hard materials, development of new biobased products	
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, intelligent packaging solutions, improve the re-usability of construction materials	
Circular economy and recycling policies	Yes, qualitative targets, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	
Logistics, transport and optimised raw material flows along the value chain	Yes	
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy, international cooperation	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Research Projects	Web Page:	http://www.fwo.be/en/fellowships-funding/research-projects/research-project/
Funding Organisation	Fonds Wetenschappelijk Onderzoek - Vlaanderen (FWO) (Belgium)		
Time frame	current	Budget:	115 Mio €
Contact person:	Olivier Boehme	E-Mail:	olivier.boehme@fwo.be
Programme owner and programme manager			
Maturity:	Fundamental research		
Eligible Beneficiaries:	University, research institute		
Number of Projects:	1388	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, all materials	
Biotic Material	Yes, all materials	
Innovative extraction and harvesting of raw materials	No	
Resource efficient processing and refining of raw materials	No	
Recycling of raw materials from products, buildings and infrastructure	No	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	No	

Basic information

Project title:	Forest raw material and biomass	Web Page:	http://www.formas.se/en/#decided (not specific only to these calls)
Funding Organisation	The Swedish Research Council Formas		
Time frame	2014 - 2017	Budget:	45 Mio €
Contact person:	Karin Perhans	E-Mail:	karin.perhans@formas.se
Programme owner and programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept		
Eligible Beneficiaries:	University, research institute		
Number of Projects:	70	Average Funding per project:	max. 1 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	No	
Biotic Material	Yes, forest based materials, algae, energy crops	Very high
Innovative extraction and harvesting of raw materials	Yes, geomodels resp. resource/wood quantity and quality assessment, environmental-friendly forest operations (harvesting, transport and management)	High
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	No	High
Advanced use and substitution	Yes, substitution of CRM in batteries, substitution of non-renewable with renewable raw materials, renewable energy solutions, development of new biobased products	High
Product design optimising use of raw materials and increasing quality recycling	Yes, intelligent packaging solutions	High
Circular economy and recycling policies	No	High
Logistics, transport and optimised raw material flows along the value chain	Yes	High
Non-technological topics	Yes, international cooperation	Very high
Other topics	Yes, Genetics and tree breeding, micro- and macroalgae, sustainable forestry , policy and economics, biorefinery and biotechnology	
Future topics	Policy, economics, business models, consumer behaviour and responsibility, technology push vs. market pull, citizen perceptions	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	GSI Research Funding programme	Web Page:	www.gsi.ie/research
Funding Organisation	Department of Communications, Energy and Natural resources (Ireland)		
Time frame	2016 - 2020	Budget:	5 Mio €
Contact person:	Aoife Braiden	E-Mail:	aoife.braiden@gsi.ie
Programme Owner and Programme Manager			
Maturity:	Fundamental research, laboratory scale, proof of concept, pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	University, Research Institute, SME, Large Company		
Number of Projects:	5	Average Funding per project:	max. 100.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group)	
Biotic Material	No	
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, mining of small deposits, alternative mining	Very high
Resource efficient processing and refining of raw materials	No	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling	High
Advanced use and substitution	No	Low
Product design optimising use of raw materials and increasing quality recycling	No	Very low
Circular economy and recycling policies	No	Very low
Logistics, transport and optimised raw material flows along the value chain	Yes	low
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy, international cooperation	Very high
Other topics	Yes, aggregates and building materials	-
Future topics	Geological aspects of exploring and exploiting resources	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
C. Improving logistics and Europe’s waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Inova Mineral	Web Page:	http://www.finep.gov.br/apoio-e-financiamento-externa/programas-e-linhas/programas-inova/inova-mineral
Funding Organisation	Financiadora de Estudos e Projetos (Brazil)		
Time frame	2017 - 2020	Budget:	347 Mio €
Contact person:	Henrique do Vale	E-Mail:	hvasquez@finep.gov.br
Programme Owner & Programme Manager			
Maturity:	Fundamental Research, Laboratory scale, Proof of concept, Pilot trial, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	University, Research Institute, SME, Large Company		
Number of Projects:		Average Funding per project:	

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, Construction minerals, Industrial minerals, Critical raw materials (according to EU Ad-hoc working group), Other: Fertilizers and Coal	Very high
Biotic Material	No	Very high
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, Geomodels resp. resource/wood quantity and quality assessment, automated mining, mining of small deposits, alternative mining, environmental-friendly forest operations (harvesting, transport and management)	Low
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	No	High
Advanced use and substitution	Yes, renewable energy solutions	Very high
Product design optimising use of raw materials and increasing quality recycling	No	Low
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	No	-
Other topics	Yes, Mineral Fertilizers: Alternative sources and New product processes, Environmental-friendly technologies for mine exploitation and mineral processions, Efficient uses for Brazilian mineral coal, Development of new Equipments, Machines, Systems and Softwares for mineral exploration, mining, processing and refining.	
Which raw Material is especially important for the future considering a time frame until 2050?	Bio-Polymers, Graphite (and other raw materials with 2d potential), Potash, phosphate, Silicon	
Future topics	-	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials

Basic information

Project title:	Investissements d'avenir	Web Page:	ademe.fr/invest-avenir
Funding Organisation	ADEME Agence de l'environnement et de la maîtrise de l'énergie (France)		
Time frame	2010 - 2017	Budget:	500 Mio €
Contact person:	Rachel Baudry	E-Mail:	rachel.baudry@ademe.fr
Programme Manager			
Maturity:	Pilot trial, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	SME, Large Company		
Number of Projects:	30	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, critical raw materials (according to EU Ad-hoc working group), plastics	High
Biotic Material	No	
Innovative extraction and harvesting of raw materials	No	
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling	Very high
Advanced use and substitution	No	High
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design	Very High
Circular economy and recycling policies	No	High
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	No	Very high
Which raw Material is especially important for the future considering a time frame until 2050?	metals (critical and 'big')	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	Programa de cooperacion internacional	Web Page:	www.conicyt.cl/pci
Funding Organisation	Comisión Nacional de Investigación Científica y Tecnológica (Chile)		
Time frame	open	Budget:	
Contact person:	Pedro Figueroa	E-Mail:	pfigueroa@conicyt.cl
Programme Owner			
Maturity:	Fundamental Research, Laboratory scale, Proof of concept, Pilot trial, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	University, Research Institute, Public authority, SME, Large Company		

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	
Biotic Material	Yes, forest based materials	
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, geomodels resp. resource/wood quantity and quality assessment, automated mining, mining of small deposits, alternative mining, deep-sea mining, environmental-friendly forest operations (harvesting, transport and management),	
Resource efficient processing and refining of raw materials	yes	
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, innovative sorting and detection systems,	
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in catalysts, substitution of CRM in photovoltaic materials, substitution of non-renewable with renewable raw materials, substitution of CRM in super alloys and steels alloyed with scarce elements, renewable energy solutions, substitution of indium in transparent conductive layers, substitution of CRM in light sources, substitution of CRM in hard materials, development of new biobased products	
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, intelligent packaging solutions, improve the re-usability of construction materials,	
Circular economy and recycling policies	Yes, qualitative targets, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components,	
Logistics, transport and optimised raw material flows along the value chain	yes	
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy, international cooperation,	
Other topics	Yes,	
Which raw Material is especially important for the future considering a time frame until 2050?		
Future topics		

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Proyectos De Investigación Fundamental Orientada Y Acciones Complementarias Dentro Del Programa Estatal De I+D+I Orientada A Los Retos De La Sociedad Y Específicamente Dentro Del Reto De Seguridad Y Calidad Alimentaria, Actividad Agraria Productiva Y Sostenible, Sostenibilidad De Los Recursos Naturales E Investigación Marina Y Marítima		
Web Page:	http://www.idi.mineco.gob.es/portal/site/MICINN/menuitem.7eeac5cd345b4f34f09dfd1001432ea0/?vgnextoid=83b192b9036c2210VgnVCM1000001d04140aRCRD		
Funding Organisation	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria		
Time frame	2013 - 2016	Budget:	14 Mio €
Contact person:	Jesus Jimenez	E-Mail:	jesus.jimenez@inia.es
Maturity:	Fundamental research		
Eligible Beneficiaries:	University, research institute, SME		
Number of Projects:	200	Average Funding per project:	max. 100.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	No	High
Biotic Material	Yes, forest based materials	Very high
Innovative extraction and harvesting of raw materials	Yes, environmental-friendly forest operations (harvesting, transport and management)	Very high
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	No	High
Advanced use and substitution	Yes, renewable energy solutions	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design	High
Circular economy and recycling policies	Yes, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	Very high
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	No	
Which raw Material is especially important for the future considering a time frame until 2050?	wood	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	r+Impuls - Innovative Technologies for Resource Efficiency - Impulses for Industrial Resource Efficiency	Web Page:	www.r-plus-impuls.de
Funding Organisation	Forschungszentrum Jülich GmbH (Germany)		
Time frame	2015 - 2019	Budget:	20 Mio €
Contact person:	Anja Degenhardt	E-Mail:	a.degenhardt@fz-juelich.de
Programme Manager			
Maturity:	Pilot trial, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	University, Research Institute, SME, Large Company		
Number of Projects:	10	Average Funding per project:	max. 1 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	Very high
Biotic Material	No	Very high
Innovative extraction and harvesting of raw materials	No	High
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in catalysts, substitution of CRM in photovoltaic materials, substitution of CRM in super alloys and steels alloyed with scarce elements, substitution of indium in transparent conductive layers, substitution of CRM in light sources, substitution of CRM in hard materials	Very high
Product design optimising use of raw materials and increasing quality recycling	No	Very high
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	No	Very high
Non-technological topics	No	Very high

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure

Basic information

Project title:	r³ Innovative Technologien für Ressourceneffizienz – Strategische Metalle und Mineralien	Web Page:	http://www.r3-innovation.de/
Funding Organisation	Forschungszentrum Jülich GmbH (Germany)		
Time frame	2011 - 2016	Budget:	42 Mio € (30 Mio € public funding)
Contact person:	Andreas Jacobi	E-Mail:	a.jacobiqfz-juelich.de
Programme Manager			
Maturity:	Laboratory scale, Proof of concept, Pilot trial		
Eligible Beneficiaries:	University, Research Institute, public authority, SME, Large Company		
Number of Projects:	27	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group)	Very high
Biotic Material	No	High
Innovative extraction and harvesting of raw materials	No	High
Resource efficient processing and refining of raw materials	No	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in photovoltaic materials, substitution of indium in transparent conductive layers,	High
Product design optimising use of raw materials and increasing quality recycling	Yes, critical raw materials in products	Very high
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	No	High

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling

Basic information

Project title:	Renewable Resources	Web Page:	http://www.fnr.de/projektfoerderung/fuer-antragsteller/foerderprogramm-nachwachsende-rohstoffe/
Funding Organisation	Agency for Renewable Resources (FNR) (Germany)		
Time frame		Budget:	61 Mio €
Contact person:	Boris Vashev	E-Mail:	b.vashev@fnr.de
Programme Manager			
Maturity:	Fundamental research, laboratory scale, Proof of concept, Pilot trial, Pre-Competitive demonstration reference		
Eligible Beneficiaries:	University, research Institute, public authority, SME, large company		
Number of Projects:	675	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	No	
Biotic Material	Yes, forest based materials, all non-food biomass and applications	Very high
Innovative extraction and harvesting of raw materials	Yes, geomodels resp. resource/wood quantity and quality assessment, environmental-friendly forest operations (harvesting, transport and management)	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	Yes, substitution of non-renewable with renewable raw materials, renewable energy solutions, development of new biobased products,	Very High
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, intelligent packaging solutions, improve the re-usability of construction materials	Very high
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	Yes	Very high
Non-technological topics	Yes, international cooperation	High
Which raw Material is especially important for the future considering a time frame until 2050?	Cellulose, starch, sugar, proteins and vegetable oils	
Future topics	- Sustainable provision of biotic raw materials today and in the future and level playing field with fossil-based competitors - Adaptation to climate change and reduction of GHG emmissions of the forest-based sector and agriculture	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Scientific Research and Technological Development Projects in all scientific domains	Web Page:	http://www.fct.pt/apoios/projectos/index.phtml.en
Funding Organisation	Fundação para a Ciência e a Tecnologia (Portugal)		
Time frame	2015 - 2018	Budget:	118,7 Mio €
Contact person:	Dina Carrilho	E-Mail:	dina.carrilho@fct.pt
Programme owner and programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept, pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company		
Number of Projects:	3000	Average Funding per project:	max. 100.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	Very high
Biotic Material	Yes, forest based materials	Very high
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, geomodels resp. resource/wood quantity and quality assessment, automated mining, mining of small deposits, alternative mining, deep-sea mining, environmental-friendly forest operations (harvesting, transport and management)	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in catalysts, substitution of CRM in photovoltaic materials, substitution of non-renewable with renewable raw materials, substitution of CRM in super alloys and steels alloyed with scarce elements, renewable energy solutions, substitution of indium in transparent conductive layers, substitution of CRM in light sources, substitution of CRM in hard materials, development of new biobased products	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, intelligent packaging solutions, improve the re-usability of construction materials	Very high
Circular economy and recycling policies	Yes, qualitative targets, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	Very high
Logistics, transport and optimised raw material flows along the value chain	Yes	Very high
Non-technological topics	No	Very high
Which raw Material is especially important for the future considering a time frame until 2050?	metallic minerals, industrial minerals and construction minerals	
Future topics	The FCT funding programme is open in all scientific domains therefore all topics are relevant for our funding programme. Nevertheless, the mining industry in EU must be revitalised to become modern, strong and responsible by increasing the domestic production and reducing the dependence on imports. Continuous (long-term) investments in research should aim at: i)new concepts, technologies and improved models to be used in mineral exploration;(ii) the long-term availability of mineral resources and estimation of the multi-element reserve base in compliance with international classifications of resources and reserves; iii) adequate mixings of raw-material sources (primary and secondary).	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Security of Supply of Mineral Resources	Web Page:	http://www.nerc.ac.uk/research/funded/programmes/minerals/
Funding Organisation	Sustainable Materials Engineering Ltd (UK)		
Time frame	2012 - 2019	Budget:	17,7 Mio € (11,6 Mio € public funding)
Contact person:	Anthony Hartwell	E-Mail:	susmateng@gmail.com
Programme manager			
Maturity:	Proof of concept		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company		
Number of Projects:	4	Average Funding per project:	max. 5 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, elements critical for Green Energy technologies	Very high
Biotic Material	No	
Innovative extraction and harvesting of raw materials	Yes, geomodels resp. resource/wood quantity and quality assessment, mining of small deposits, deep-sea mining	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	No	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	
Logistics, transport and optimised raw material flows along the value chain	No	Very high
Non-technological topics	No	High
Other topics	Yes, the projects look to address sustainability across the mineral supply chain from the development of the mineral resource	-
Which raw Material is especially important for the future considering a time frame until 2050?	Cobalt, Selenium, Tellurium, Rare Earth elements, and some associated elements	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials

Basic information

Project title:	Several Programs: Bottom up approach	Web Page:	http://www.idi.mineco.gob.es/portal/site/MICINN/menuitem.94f5cc1dd5adb3dc81ebe01001432ea0/%253Fvgnextoid%253Dfae4b97
Funding Organisation	Ministerio de Economía y Competitividad (Spain)		
Time frame	3 years	Budget:	
Contact person:	Falcón Severino	E-Mail:	severino.falcon@mineco.es
Programme owner and programme manager			
Maturity:	Fundamental research, laboratory scale		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company		
Number of Projects:		Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes	
Biotic Material	Yes	
Innovative extraction and harvesting of raw materials	Yes	
Resource efficient processing and refining of raw materials	Yes	
Recycling of raw materials from products, buildings and infrastructure	Yes	
Advanced use and substitution	Yes	
Product design optimising use of raw materials and increasing quality recycling	Yes	
Circular economy and recycling policies	Yes	
Logistics, transport and optimised raw material flows along the value chain	Yes	
Non-technological topics	Yes	
Other topics	Yes, the MINECO funding program is a botom up. Projects are funded according to the excellences of the proposals.	

VERAM Classification

Strategic theme	**Research and innovation area**
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Smart & Green Growth – clean transition to the bioeconomy	Web Page:	http://www.tekes.fi/en/programmes-and-services/tekes-programmes/smartgreen-growth--clean-transition-to-the-bioeconomy/
Funding Organisation	Innovaatiorahoituskeskus Tekes (Finland)		
Time frame	2016 - 2018	Budget:	300 Mio € (150 Mio € public funding)
Contact person:	Absetz Ilmari	E-Mail:	ilmari.absetz@tekes.fi
Programme owner			
Maturity:	Laboratory scale, proof of concept, pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	University, research institute, SME, large company, start-up companies		
Number of Projects:	46	Average Funding per project:	max. 500.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, plastics, soil	High
Biotic Material	Yes, forest based materials, bio waste	Very high
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, environmental-friendly forest operations (harvesting, transport and management)	Low
Resource efficient processing and refining of raw materials	Yes	High
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	Very high
Advanced use and substitution	Yes, substitution of CRM in batteries, development of new biobased products	High
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, intelligent packaging solutions, improve the re-usability of construction materials	Very high
Circular economy and recycling policies	Yes, landfill ban for recyclable waste and incineration ban for certain waste, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	Very high
Logistics, transport and optimised raw material flows along the value chain	Yes	Low
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy	Very high
Other topics	Yes, water solutions	-
Which raw Material is especially important for the future considering a time frame until 2050?	Forest based, circular economy, waste as raw material	
Future topics	Immaterial substitution of raw materials	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	Strategic innovation Programmme for Mining and Metal Producing Industry (STRIM)	Web Page:	www.sipstrim.se
Funding Organisation	VINNOVA, Verket för innovationssystem (Sweden)		
Time frame	2013 - 2022	Budget:	60 Mio € (30 Mio € public funding)
Contact person:	Susanne Gylesjö	E-Mail:	susanne.gylesjo@vinnova.se
Programme owner and programme manager			
Maturity:	Fundamental research, laboratory scale, proof of concept, pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	University, research institute, public authority, SME, large company, NGO		
Number of Projects:	36	Average Funding per project:	

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, industrial minerals, critical raw materials (according to EU Ad-hoc working group)	Very high
Biotic Material	No	
Innovative extraction and harvesting of raw materials	Yes, new exploration technologies, geomodels resp. resource/wood quantity and quality assessment, automated mining, mining of small deposits, alternative mining	Very high
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	Yes	High
Advanced use and substitution	Yes	High
Product design optimising use of raw materials and increasing quality recycling	No	High
Circular economy and recycling policies	Yes	Very high
Logistics, transport and optimised raw material flows along the value chain	Yes	High
Non-technological topics	Yes, improving research and innovation coordination, improving Europe's raw material strategy, international cooperation	Very high
Other topics	Yes, Social License to operate, diversity (incl gender) in mining , attractive workplaces	-
Which raw Material is especially important for the future considering a time frame until 2050?	no specific priorities	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A1. Innovative extraction and harvesting of raw materials A2. Resource efficient processing and refining of raw materials A3. Recycling of raw materials from products, buildings and infrastructure
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:	TERM Bioraffinage	Web Page:	http://www.rvo.nl/sites/default/files/2013/10/Presentatie%20Edith%20Engelen,%20Bioraffinage%20AgNL%20%5BCompatibiliteitsmodus%5D_0.pdf
Funding Organisation	Netherland Enterprise Agency		
Time frame	2010 - 2015	Budget:	30 Mio € (10 Mio € public funding)
Contact person:	Engelen Edith	E-Mail:	edith.engelen@rvo.nl
Programme manager			
Maturity:	Pilot trial, pre-competitive demonstration reference		
Eligible Beneficiaries:	SME, large company		
Number of Projects:	13	Average Funding per project:	max. 1 M €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	No	High
Biotic Material	Yes, forest based materials, all biomass	Very high
Innovative extraction and harvesting of raw materials	No	Low
Resource efficient processing and refining of raw materials	Yes	Very high
Recycling of raw materials from products, buildings and infrastructure	No	High
Advanced use and substitution	No	High
Product design optimising use of raw materials and increasing quality recycling	No	Very high
Circular economy and recycling policies	No	Very high
Logistics, transport and optimised raw material flows along the value chain	No	High
Non-technological topics	No	Very high
Which raw Material is especially important for the future considering a time frame until 2050?	All biomass	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A2. Resource efficient processing and refining of raw materials

Basic information

Project title:	Two Programs: "Circular Economy Demonstration Projects Programme" and "Ecoinnovation Projects Programme"	Web Page:	www.ihobe.eus
Funding Organisation	Ihobe, Basque Environmental Agency (Spain)		
Time frame	"Circular Economy Programme": 2014-2016; "Ecoinnovation Programme" from 2016 onward	Budget:	2,2 Mio € (1,37 Mio € public funding)
Contact person:	Elgorriaga Ander	E-Mail:	ander.elgorriaga@ihobe.eus
Programme owner and programme manager			
Maturity:	Proof of concept, pre-competitive demonstration reference		
Eligible Beneficiaries:	Public authority, SME, large company		
Number of Projects:	43	Average Funding per project:	max. 100.000 €

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, metals, construction minerals, industrial minerals, critical raw materials (according to EU Ad-hoc working group), plastics	Very high
Biotic Material	No	High
Innovative extraction and harvesting of raw materials	No	Very high
Resource efficient processing and refining of raw materials	No	Low
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling, packaging recycling, construction and demolition waste recycling, innovative sorting and detection systems	High
Advanced use and substitution	Yes, substitution of heavy REE in magnets, substitution of CRM in batteries, substitution of CRM in super alloys and steels alloyed with scarce elements	Very high
Product design optimising use of raw materials and increasing quality recycling	Yes, Eco-design, critical raw materials in products, improve the re-usability of construction materials	Very high
Circular economy and recycling policies	Yes, waste collection systems and Extended Producer Responsibility Schemes, innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products, extraction, separation and fractionation of paper and wood components	High
Logistics, transport and optimised raw material flows along the value chain	Yes	Very high
Non-technological topics	No	High
Other topics	Yes, green Supply Chain Management related with Sustainable Product Design , remanufacturing	-
Which raw Material is especially important for the future considering a time frame until 2050?	Non Biotic: addressing losses and upcycling of Nb, Cr, Ni, Co, W, V, Mg, ...in alloys and also Al, Sn, Cu	
Future topics	EC Instruments like - Export of WEEEs to third part certificated recyclers (Organization Environmental Footprint, EU Standard to be requested) - LCA Passport for materials. Like Ecodesign Directive, a minimum to be required if to be used in EU-USA-Japan - Change the ELV, WEEE Directives formulating environmental/economic value objective more tan tonnes - Clear Remanufacturing Support Legislation (with tax deductions or reduced VAT) - Reduced Taxes to recyclers - Full innovation of Extended Product Responsibility Legislation (collective and individual) - Support of Servitization of EU Industry as basis for a strong product durability policy - Widening the scope of Ecodesign Directive to other products and revising existing ones, but ensuring necessary ressources of EC (not like now, shown in COOLPRODUCTS report) and ensuring Control of the member states (now quite low control!)	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A3. Recycling of raw materials from products, buildings and infrastructure
B. Advanced use and substitution of raw materials	B6. Product design optimising use of raw materials and increasing quality recycling
C. Improving logistics and Europe's waste management framework	C8. Logistics, transport and optimised raw material flows along the value chain

Basic information

Project title:		Web Page:	www.vin.bg.ac.rs (Webpage of the organisation)
Funding Organisation	Vinča Institute of Nuclear Science (Serbia)		
Time frame		Budget:	
Contact person:	Snezana Pasalic	E-Mail:	snezana.pasalic@vinca.rs
Programme manager			
Maturity:	Proof of concept		
Eligible Beneficiaries:	Research institute		
Number of Projects:		Average Funding per project:	

Research & Innovation Area

Topics / raw materials	Addressed by the funding programme?	Importance for the future
Non Biotic material	Yes, construction minerals	
Biotic Material	No	
Innovative extraction and harvesting of raw materials	No	
Resource efficient processing and refining of raw materials	No	
Recycling of raw materials from products, buildings and infrastructure	Yes, end-of-life products recycling	
Advanced use and substitution	No	
Product design optimising use of raw materials and increasing quality recycling	No	
Circular economy and recycling policies	No	
Logistics, transport and optimised raw material flows along the value chain	No	
Non-technological topics	Yes, international cooperation	

VERAM Classification

Strategic theme	Research and innovation area
A. Technologies for primary and secondary RM production	A3. Recycling of raw materials from products, buildings and infrastructure

3.2 Presentation of results

Out of 28 EU countries, 13 have replied to the survey. Missing: Greece, Lithuania, Estonia, Luxembourg, Czech Republic, Slovakia, Slovenia, Bulgaria, Cyprus, Malta, Croatia, Denmark, Italy, Hungary and Latvia. Additionally 4 non-EU countries have answered: Brazil, Chile, Norway and Serbia.

Answers (by country) in total:

(1) Austria, Belgium, Chile, Finland, Great Britain, Netherlands, Norway, Poland, Portugal, Romania, Serbia, (2) Brazil, Ireland, (3) France, Sweden, (4) Spain and (5) Germany.

Table A.2. Percentage of the EU-countries that have answered, according to number of inhabitants

13 answered	**inhabitants (in million)**	**15 not answered**	**inhabitants (in million)**
Austria	8,5	Greece	11,3
Belgium	11	Lithuania	3
Finland	5,4	Estonia	1,3
France	65,8	Luxembourg	0,54
Germany	80,2	Czech Republic	10,5
Ireland	4,6	Slovakia	5,4
Netherlands	16,7	Slovenia	2
Poland	38,5	Bulgaria	7,3
Portugal	10,6	Cyprus	0,9
Romania	19	Malta	0,425
Spain	46,7	Croatia	4,3
Sweden	9,2	Denmark	5,6
Great Britain	63	Italy	60
		Hungary	10
		Latvia	2
Total	**379,2**	**Total**	**124,565**
Answered have	**75,27 %**	Not answered have	**24,73 %**

Source: https://www.bundesregierung.de/Webs/Breg/DE/Themen/Europa/EUErweiterung/_node.html

Table A.3. Percentage of the EU-countries that have answered, according to GDP

13 answered	GDP (in million €)	Greece	GDP (in million €)
Austria	412.189	Lithuania	179.081
Belgium	402.270	Estonia	36.288
Finland	204.015	Luxembourg	19.526
France	2.142.022	Czech Republic	45.288
Germany	2.903.790	Slovakia	154.939
Ireland	185.412	Slovenia	75.215
Netherlands	653.476	Bulgaria	37.246
Poland	412.189	Cyprus	42.011
Portugal	174.384	Malta	17.506
Romania	150.665	Croatia	7.962
Spain	1.058.469	Denmark	43.085
Sweden	429.468	Italy	256.938
Great Britain	2.217.872	Hungary	1.616.048
		Latvia	103.303
		Greece	24.058
Total	**11.346.221**	**Total**	**2.658.494**
Answered have	**81,02 %**	Not answered have	**18,98 %**

Source: http://www.economic-growth.eu/Seiten/AktuelleDaten/Daten2014.html & bei Luxemburg: http://www.economic-growth.eu/Seiten/AktuelleDaten/Daten2013.html

Evaluation of particular statements

Maturity of projects: The results regarding to the **maturity of the projects** show that most of the projects are on a proof of concept level quickly followed by laboratory scale, pilot trail and Fundamental Research. The least of the projects are on a pre-Competitive demonstration reference level.

Fundamental Research:	17/31
Laboratory scale:	20/31
Proof of concept:	21/31
Pilot trail:	17/31
Pre-Competitive demonstration reference:	13/31

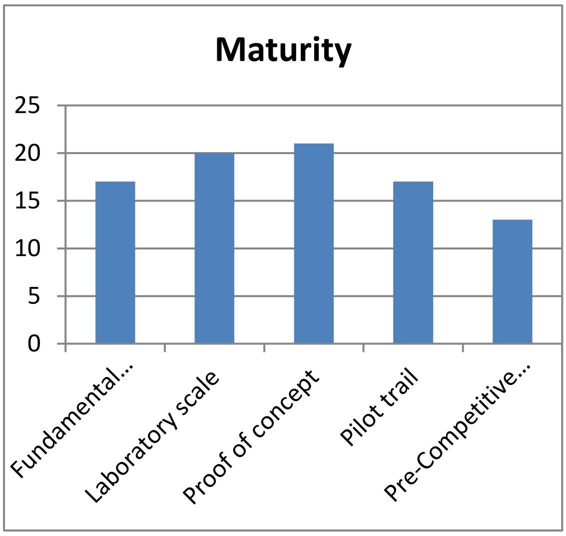


Figure A.1. Maturity

Eligible Beneficiaries: For most of the projects SMEs are **eligible beneficiaries**, closely followed by research institutes, universities and large companies. Public authorities are clearly on the last rank and therefore at least of all possible eligible beneficiaries.

University:	25/31
Research institute:	26/31
Public authority:	18/31
SME:	27/31
Large company:	24/31

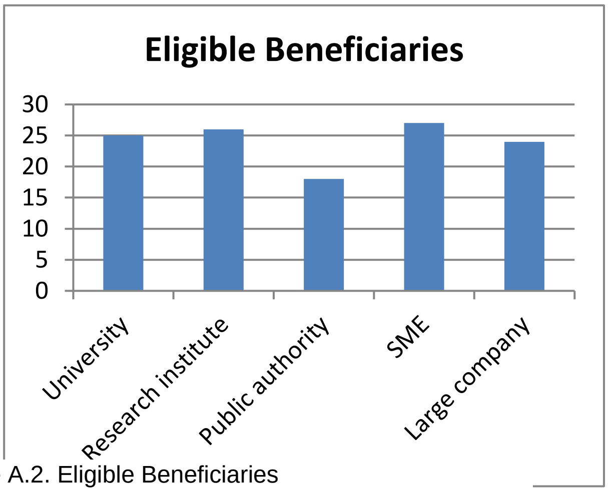


Figure A.2. Eligible Beneficiaries

Programme Owner / Manager: It can be seen that the majority of the projects are organised by organisations which are **programme owner and programme manager** at the same time, closely followed by organisations which are only programme manager. Only a small amount of organisations are programme owners (slightly more than 10 %) and even fewer (about 6,5 %) are none of it.

Only Programme Owner:	3/31
Only Programme Manager:	12/31
Both:	14/31
None of it:	2/31

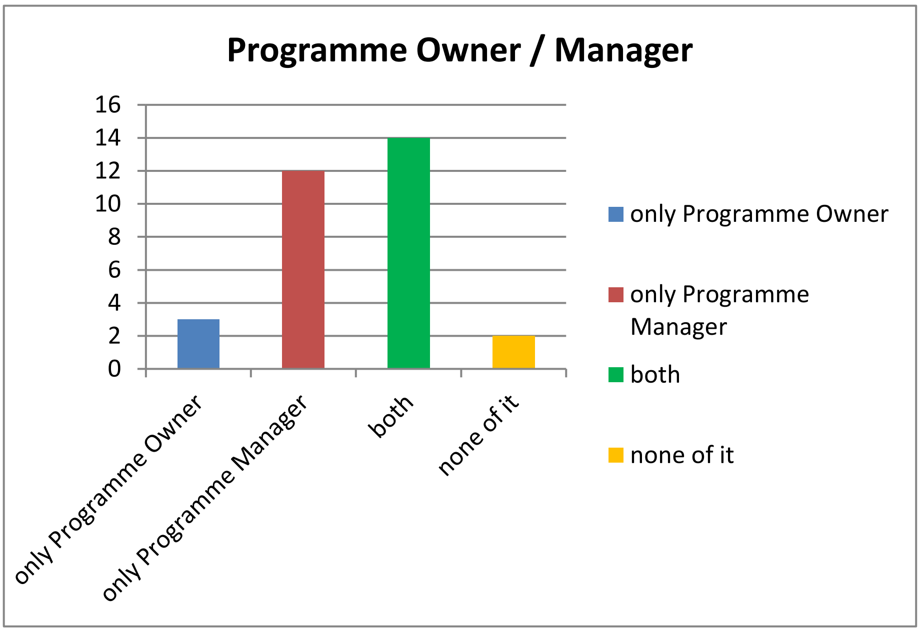


Figure A.3. Programme Owner / Manager

Biotic / abiotic Materials: The majority of projects are only about **abiotic materials**, followed by both abiotic and biotic materials (rank 2), which means that all in all almost 75 % of the projects are about abiotic materials. This is followed by projects dealing only with biotic materials (about 23 %), which means that all in all approximately 55 % of the projects deal with biotic materials.

Only biotic materials:	7/31
Only abiotic materials:	13/31
Biotic and abiotic materials:	10/31
Neither nor:	1/31 (Poland)

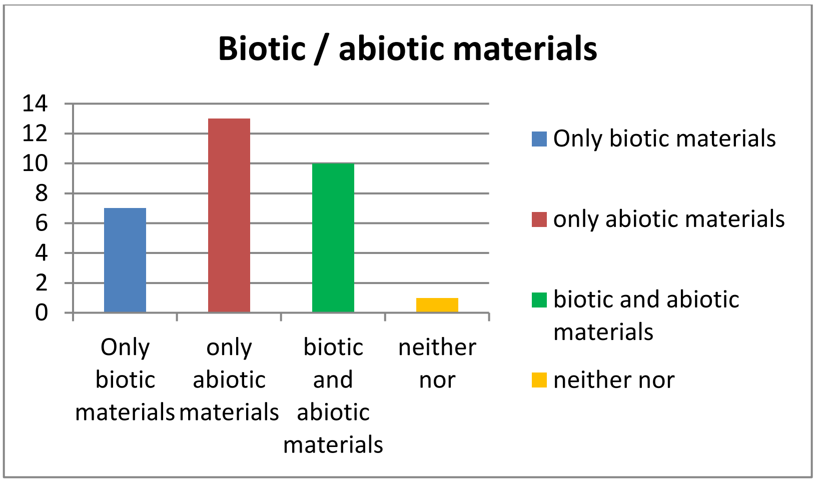


Figure A.4. Biotic / abiotic Materials

Kind of materials: Most of the programmes do research on **metals and critical raw materials**, which is followed by forest based materials. On rank three, we can see both construction minerals and industrial minerals and on the last rank plastic. The survey shows that 3/31 funding programmes do research with none of those materials.

Forest Based Materials:	15/31
Metals:	18/31
Construction minerals:	14/31
Industrial Minerals:	14/31
Critical raw materials:	18/31
Plastic:	12/31
None of those:	3/31

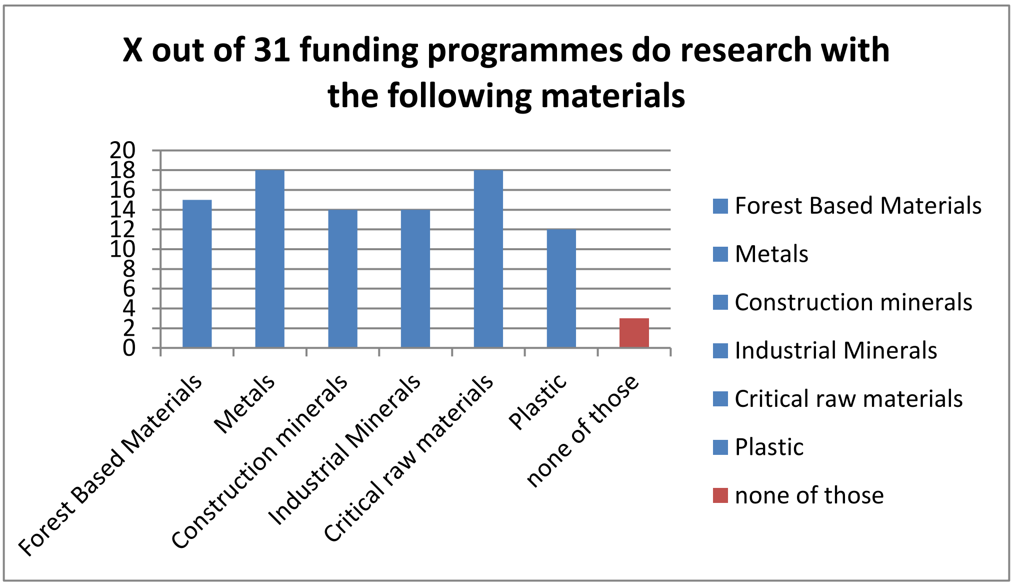


Figure A.5. Research with certain materials

Topics adressed:

The survey shows that the majority of the funding programmes address the topic "resource efficient processing and refining of raw materials", followed by the topics "recycling of raw materials from products, buildings and infrastructure", "advanced use and substitution" and "innovative extraction and harvesting of raw materials" together with "product design optimising use of raw materials and increasing quality recycling".

Slightly more than 50 % of the funding programmes address the topics "Circular economy and recycling policies". About 45 % deal with the topics "Logistics, transport and optimised raw material flows along the value chain" and "Non-technological topics" and on the last rank can be seen "any other raw material related topic", where interviewees could add additional topics as for example "CO_2-utilisation and CO_2-separation", "aggregates and building materials" and "genetics and tree breeding" to name just some of them.

Detail of the topics adressed

1.	Innovative extraction and harvesting of raw materials	19/31
2.	Resource efficient processing and refining of raw materials	22/31
3.	Recycling of raw materials from products, buildings and infrastructure	21/31
4.	Advanced use and substitution	20/31
5.	Product design optimising use of raw materials & increasing quality recycling	19/31
6.	Circular economy and recycling policies	16/31
7.	Logistics, transport and optimised raw material flows along the value chain	14/31
8.	Non-technological topics	14/31
9.	Any other raw material related topic	12/31

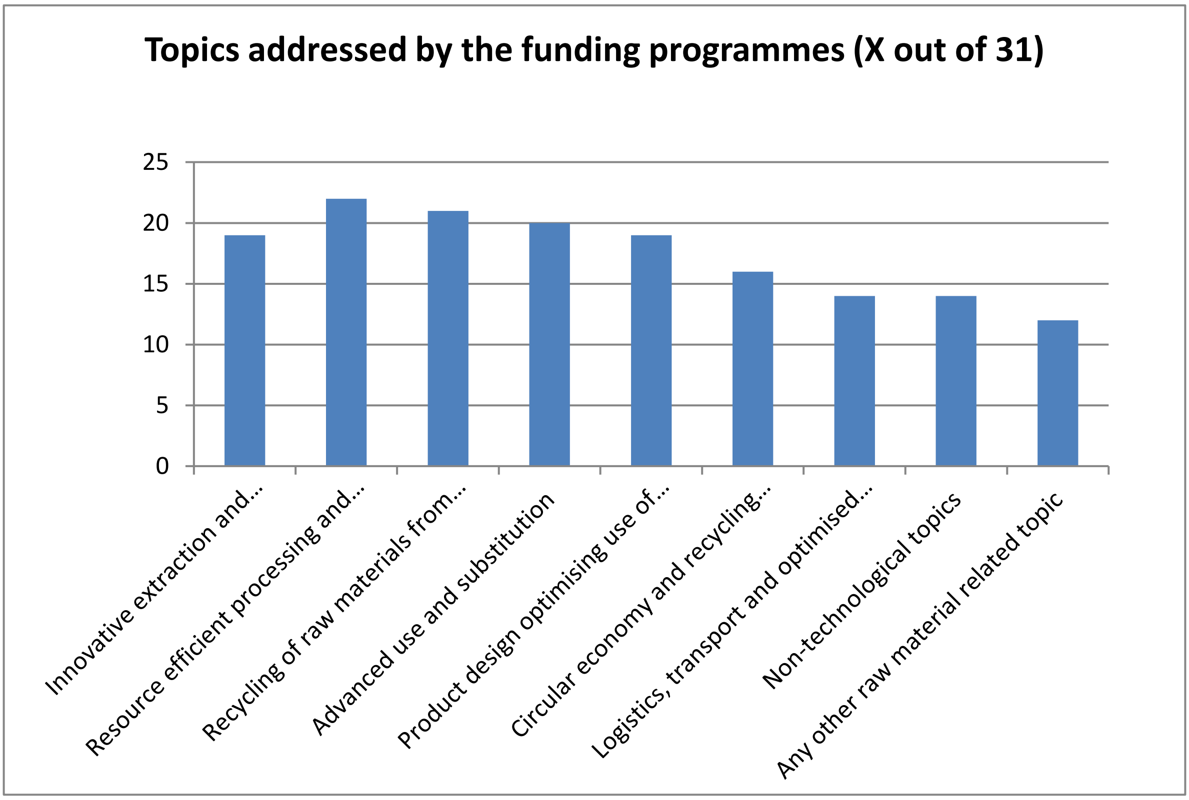


Figure A.6. Topics addressed by the funding programmes

Topic 1: Innovative extraction and harvesting of raw materials

From all the interviewees that have answered to meet the topic **"Innovative extraction and harvesting of raw materials"** by their funding programme, the clear majority do research about "Environmental-friendly forest operations (harvesting, transport and management)". This topic is followed by "Geomodels resp. resource/wood quantity and quality assessment". Almost 37 % of the funding programmes address the topic "new exploration technologies", which is closely followed by the three topics "automated mining", "mining of small deposits" and "alternative mining". Barely fewer projects are amongst other topics about "deep-sea mining".

Innovative extraction and harvesting of raw materials	**19/31**
1.1 New exploration technologies	7/19
1.2 Geomodels resp. resource/wood quantity and quality assessment	10/19
1.3 Automated mining	6/19
1.4 Mining of small deposits	6/19
1.5 Alternative mining	6/19
1.6 Deep-sea mining	5/19
1.7 Environmental-friendly forest operations (harvesting, transport, management)	12/19

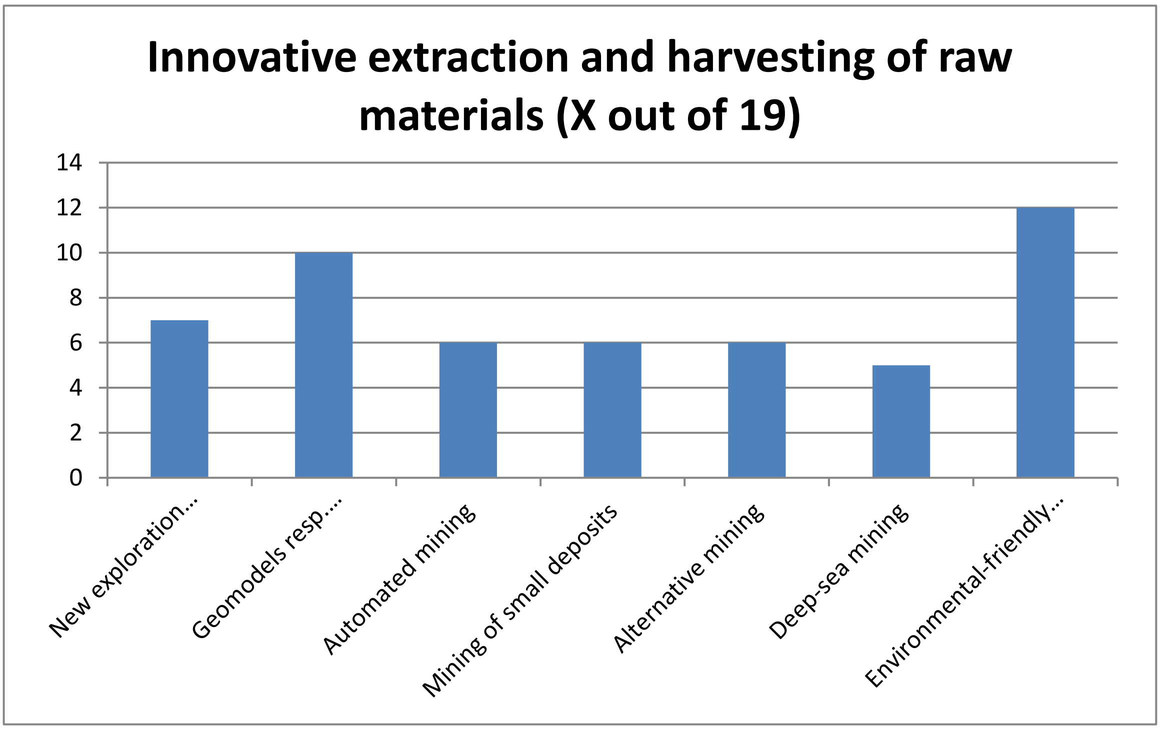


Figure A.7. Innovative extraction and harvesting of Raw Materials

Topic 2: Resource efficient processing and refining of raw materials

The survey clearly shows that amongst all that have answered their programmes deal with the topic "**recycling of raw materials from products, buildings and infrastructure**", address the field of "end-of-life products recycling". On rank two and three are the topics "packaging recycling and Innovative sorting and detection systems" and on the last rank "construction and demolition waste recycling".

Topic 3: Recycling of raw materials from products, buildings and infrastructure

In the topic 3 the theme “End-of-life products recycling” ist the most frequently mentioned. “Packaging recycling” and “Innovative sorting and detection systems” are also mentioned quite often.

Recycling of raw materials from products, buildings and infrastructure	**21/31**
3.1. End-of-life products recycling	16/21
3.2. Packaging recycling	12/21
3.3. Construction and demolition waste recycling	9/21
3.4. Innovative sorting and detection systems	11/21

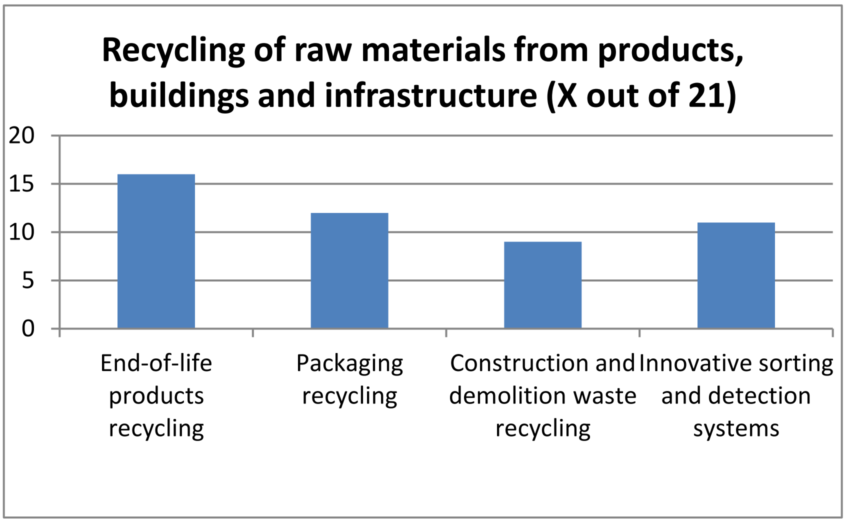


Figure A.8. Recycling of raw materials from products, buildings and infrastructure

Topic 4: Advanced use and substitution

The survey shows that in the area of advanced use and substitution, “renewable energy solutions” is clearly the topic mostly addressed by the funding programmes. The “development of new biobased products” is on rank two followed by “substitution of non-renewable with renewable raw materials” (3), “Substitution of CRM in batteries” (4) and “substitution of heavy REE in magnets” (5). The rest of the topics were chosen by less than 30 % of the interviewees.

Advanced use and substitution	**20/31**
4.1. Substitution of heavy REE in magnets	7/20
4.2. Substitution of CRM in batteries	8/20
4.3. Substitution of CRM in catalysts	5/20
4.4. Substitution of CRM in photovoltaic materials	6/20
4.5. Substitution of non-renewable with renewable raw materials	9/20
4.6 Substitution of CRM in super alloys & steels alloyed with scarce elements	6/20
4.7 Renewable energy solutions	13/20
4.8 Substitution of indium in transparent conductive layers	6/20
4.9 Substitution of CRM in light sources	5/20
4.10 Substitution of CRM in hard materials	5/20
4.11 Development of new biobased products	11/20

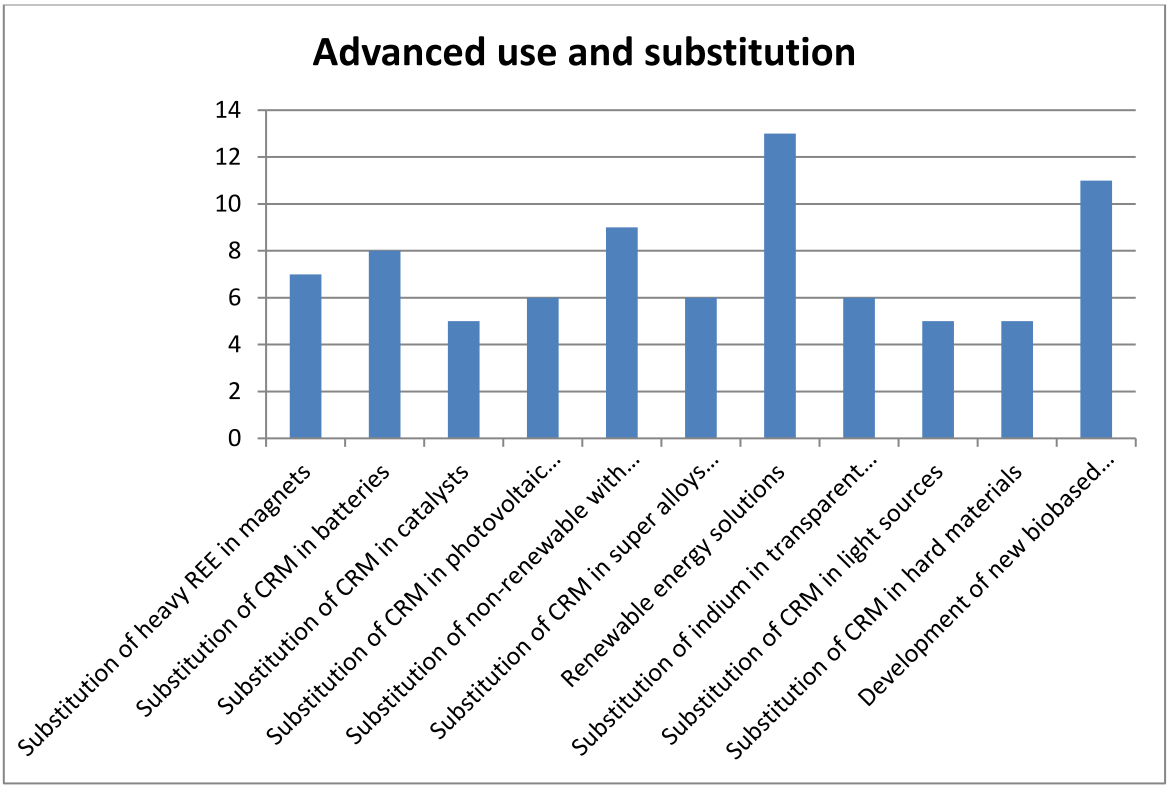


Figure A.9. Advanced use and substitution

Topic 5: Product design optimising use of raw materials & increasing quality recycling

In the area of “Product design optimising use of raw materials and increasing quality recycling”, on average the answers were not very distributed, as all the topics have been chosen by between 47 and 58 % of the interviewees.

Product design optimising use of raw materials & increasing quality recycling	**19/31**
5.1. Eco-design	11/19
5.2. Critical raw materials in products	9/19
5.3. Intelligent packaging solutions	10/19
5.4. Improve the re-usability of construction materials	10/19

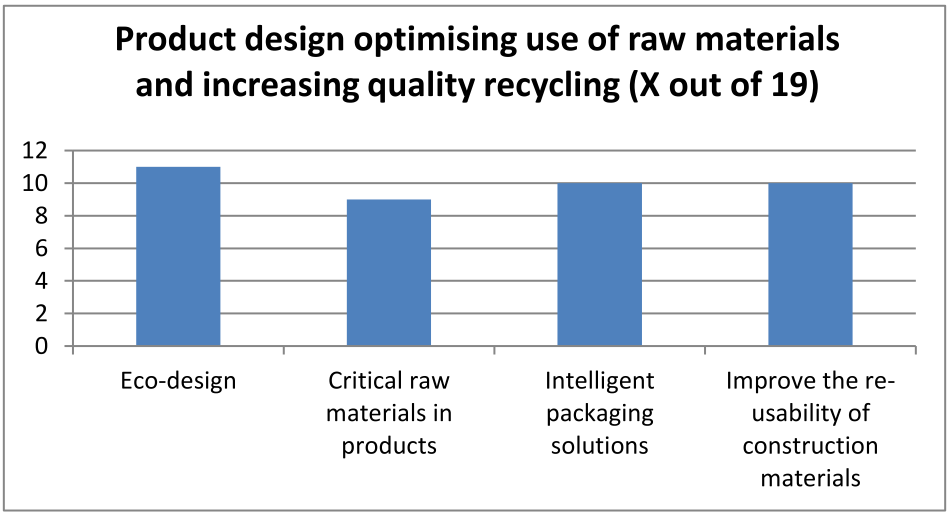


Figure A.10. Product design optimising use of raw materials and increasing quality recycling

Topic 6: Circular economy and recycling policies

The survey shows that in the area of **circular economy and recycling policies**, "innovative approaches and infrastructures for reuse and recovery of end-of-life consumer products" is the topic mostly addressed by the funding programmes, closely followed by the topic "Extraction, separation and fractionation of paper and wood components". Then follow both the topics "landfill ban for recyclable waste and incineration ban for certain waste" and "waste collection systems and Extended Producer Responsibility Schemes". "Qualitative targets" is the topic addressed by the minority of the funding programmes.

Circular economy and recycling policies	**16/31**
6.1. Qualitative targets	5/16
6.2. Landfill ban for recyclable waste and incineration ban for certain waste	8/16
6.3. Waste collection systems and Extended Producer Responsibility Schemes	8/16
6.4. Innovative approaches & infrastructures for reuse & recovery of end-of-life consumer products	10/16
6.5. Extraction, separation and fractionation of paper and wood components	9/16

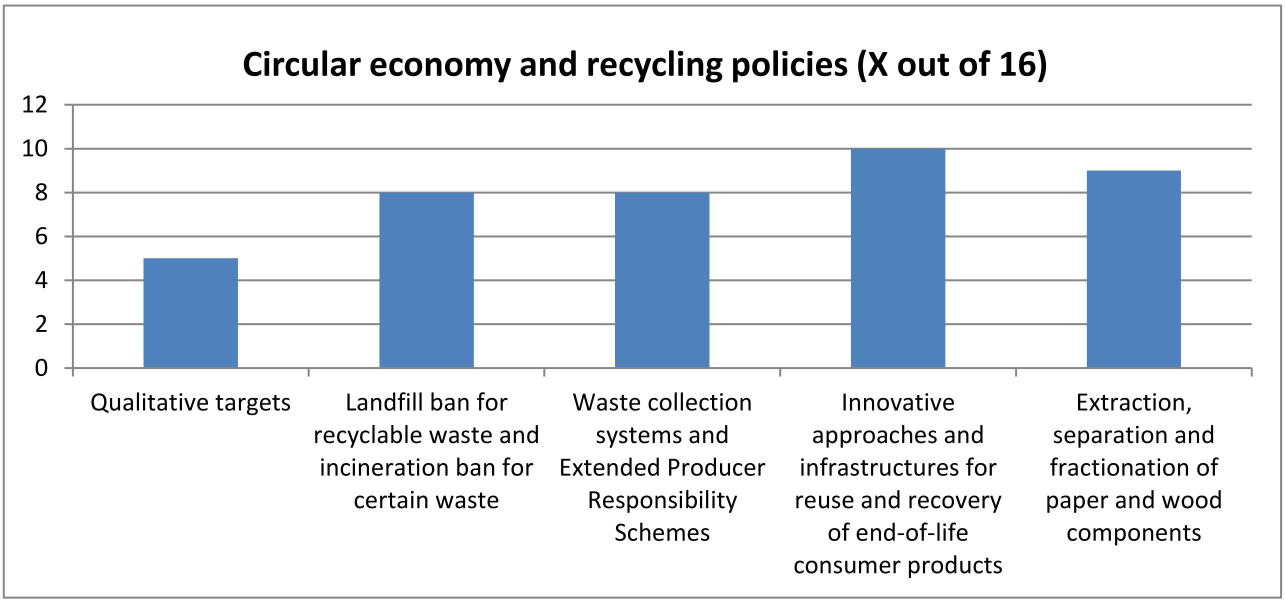


Figure A.11. Circular economy and recycling policies

Topic 8: Non-technological topics

The survey shows that amongst all that have answered their programmes deal with **non-technological topics**, most of these programmes address the area of “International cooperation” (about 79 %). The topics “improving Europe's raw material strategy” and “improving research and innovation coordination” are both on rank two.

Non-technological topics	14/31
8.1 Improving research and innovation coordination	7/14
8.2 Improving Europe's raw material strategy	7/14
8.3 International cooperation	11/14

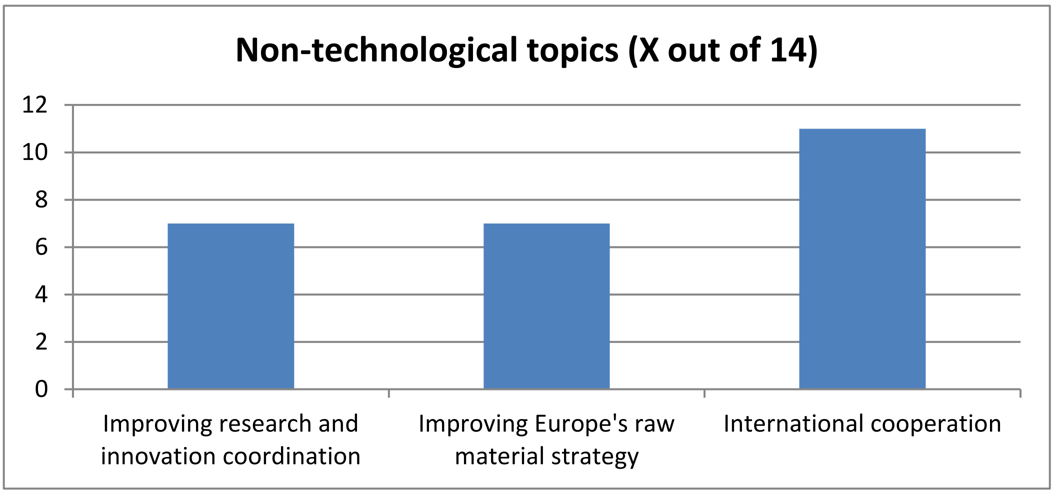


Figure A.12. Non-technological topics

Top 9: Any other raw material related topics

- Mineral Fertilizers: Alternative sources and New product processes.
- Environmental-friendly technologies for mine exploitation and mineral processions.
- Efficient uses for Brazilian mineral coal.
- Development of new Equipments, Machines, Systems and Software for mineral exploration, mining, processing and refining.
- Water solutions
- LCA methodology
- Prospective studies
- Material flow analysis
- Social science on consumer behavior
- CO2-utilisation and CO2-separation
- Aggregates and building materials
- re-mining of former mine waste for CRM, other; Environmental Pollution control of former mine sites; Risk assessment for former mine sites; Mine effluent treatment (e.g. reed beds)
- Green Supply Chain Management related with Sustainable Product Design
- Remanufacturing
- The MINECO funding program is a bottom up. Projects are funded according to the

excellence of the proposals.
- Social License to operate
- Diversity (incl gender) in mining
- Attractive workplaces
- Genetics and tree breeding
- Micro- and macroalgae
- Sustainable forestry
- Policy and economics
- Biorefinery and biotechnology
- The projects look to address sustainability across the mineral supply chain from the development of the mineral resource.

Importance of the topics for the future

Table A.4. Importance of the topics for the future

Importance of the topics for the future	very low	low	High	very high	no answer
Non Biotic material			7	13	11
Biotic Material		1	3	13	13
Innovative extraction and harvesting of raw materials		3	8	11	9
Resource efficient processing and refining of raw materials		1	10	12	8
Recycling of raw materials from products, buildings and infrastructure		1	11	10	9
Advanced use and substitution		2	10	10	9
Product design optimising use of raw materials and increasing quality recycling	1	2	9	10	9
Circular economy and recycling policies	1		11	11	8
Logistics, transport and optimised raw material flows along the value chain	1	4	12	5	9
Non-technological topics		1	8	12	10

In the following, the diagrams show the opinions of the interviewees regarding to the importance of the topics for the future.

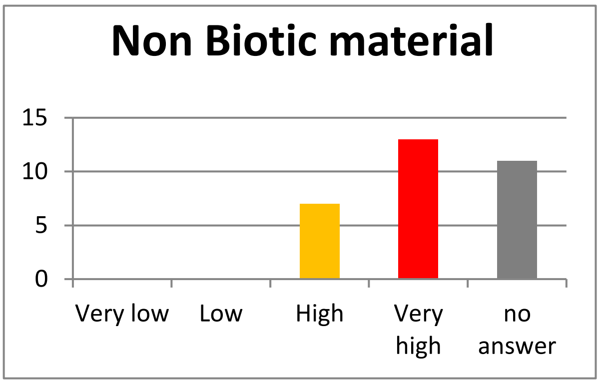


Figure A.13. Non biological material

Of all the interviewees having answered to this question, the majority think that non biotic material is a very important topic for the future. The rest of those who answered to this question think that it is an important topic.

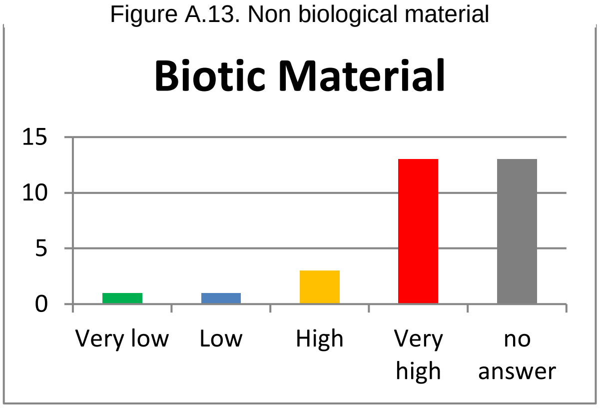


Figure A.14. Biotic material

Of the interviewees having answered to this question, the clear majority think that biotic material is a very important topic for the future. The rest of those who answered to this question, think that it is an important topic. A smaller amount of the interviewees think that it is an important topic and the rest of those having answered (one each), think it is not that much / not at all very important.

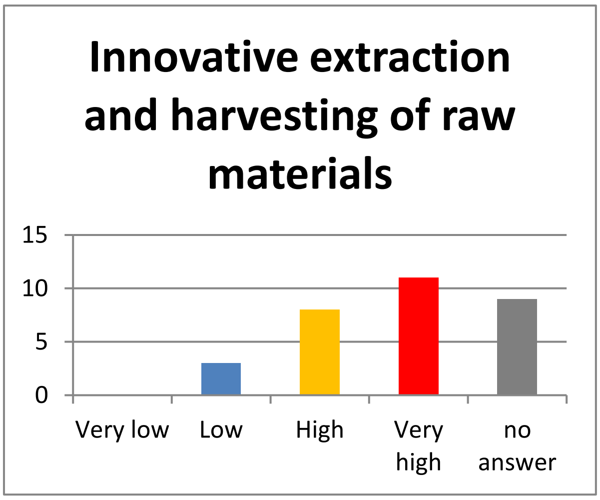


Figure A.15. Innovative extraction and harvesting of raw materials

Regarding to the importance of innovative extraction and harvesting of raw materials, the majority think that the topic is very important, followed by interviewees thinking of it as important and only 3/31 interviewees see this topic as not very important.

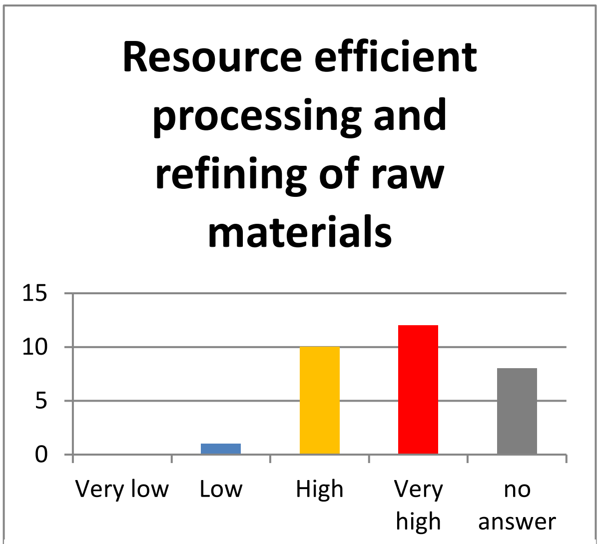


Figure A.16. Resource efficient processing and refining of raw materials

The survey shows that referring to the importance of resource efficient processing and refining of raw materials, the majority think that the topic is very important, closely followed by interviewees thinking of it as important and only 1/31 interviewees sees this topic as not very important.

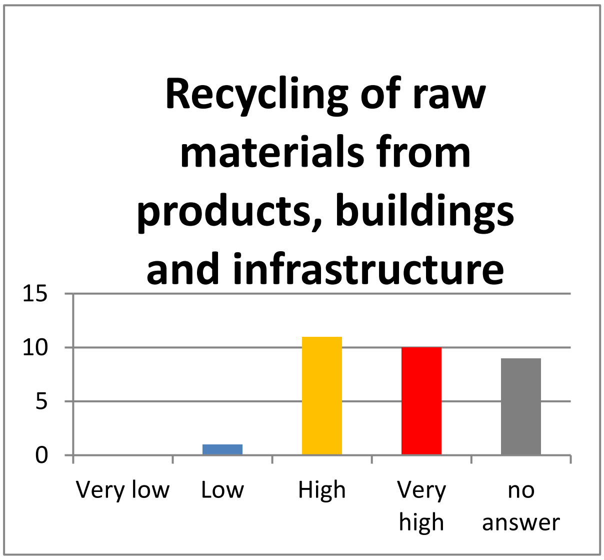


Figure A.17. Recycling of raw materials from products, buildings and infrastructure

Coming to the topic recycling of raw materials from products, buildings and infrastructure, the majority of the interviewees think that this topic is important, very closely followed by rating the topic as very important. Only one interviewee thinks that this topic is not very important.

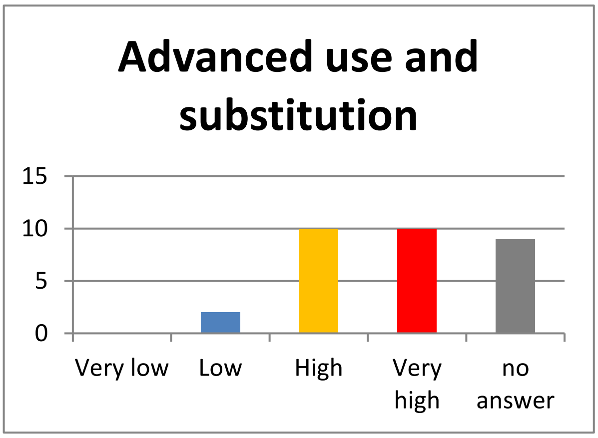


Figure A.18. Advanced use and substitution

Regarding to the topic advanced use and substitution, exactly the same amount of interviewees think that the topic is important or very important. Only two interviewees see that topic as not important.

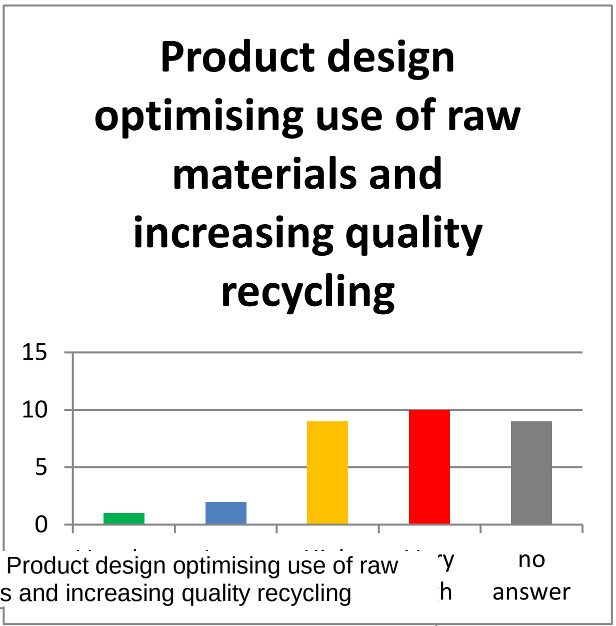


Figure A.19. Product design optimising use of raw materials and increasing quality recycling

The majority of the interviewees are of the opinion that Product design optimising use of raw materials and increasing quality recycling is a very important topic, closely followed by interviewees seeing it as important. Only a small amount thinks that the topic is not very or not at all important.

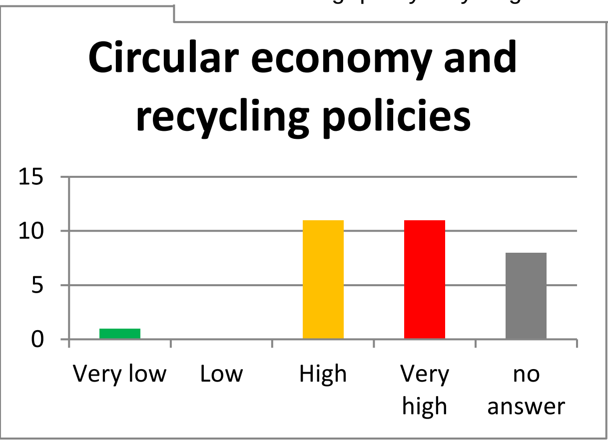


Figure A.20. Circular economy and recycling policies

Regarding to the topic advanced use and substitution, exactly the same amount of interviewees think that the topic is important or very important. Only one interviewee thinks that the topic is not important at all.

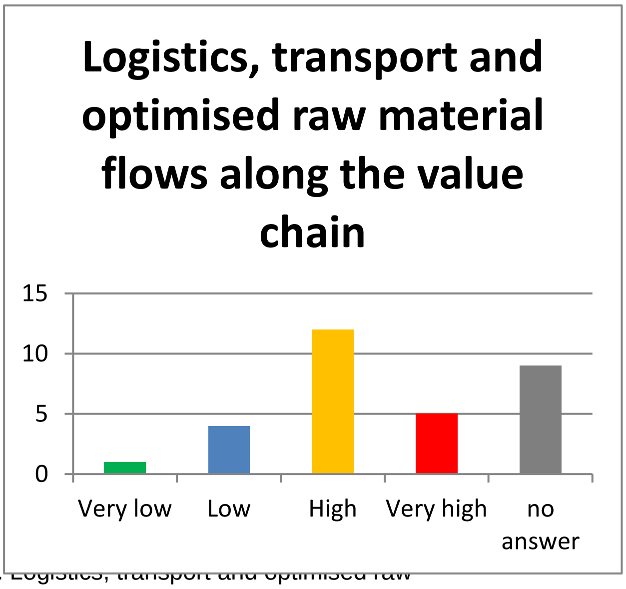


Figure A.21. Logistics, transport and optimised raw material flows along the value chain

Regarding to the topic logistics, transport and optimised raw material flows along the value chain, it can be seen that the majority ranks the topic as high and only 5/31 rank it as very high. Four of the interviewees think that the topic is not very important, which is the highest amount of interviewees rating a topic as not very important in this part of the survey. One interviewee sees the topic as not important at all.

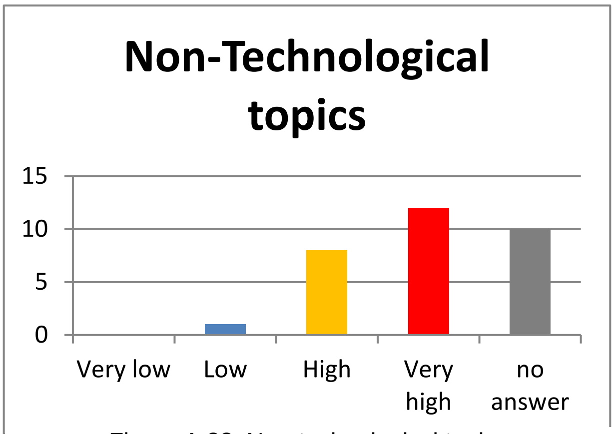


Figure A.22. Non-technological topics

The majority think that the non-technological topics are very important, followed by interviewees thinking that the topics are important and only one interviewee ranking it as not very important.

Annex 4: Data on RM investment in European industry (4.1)
BUILDING MATERIALS

Table A.5. Building Materials

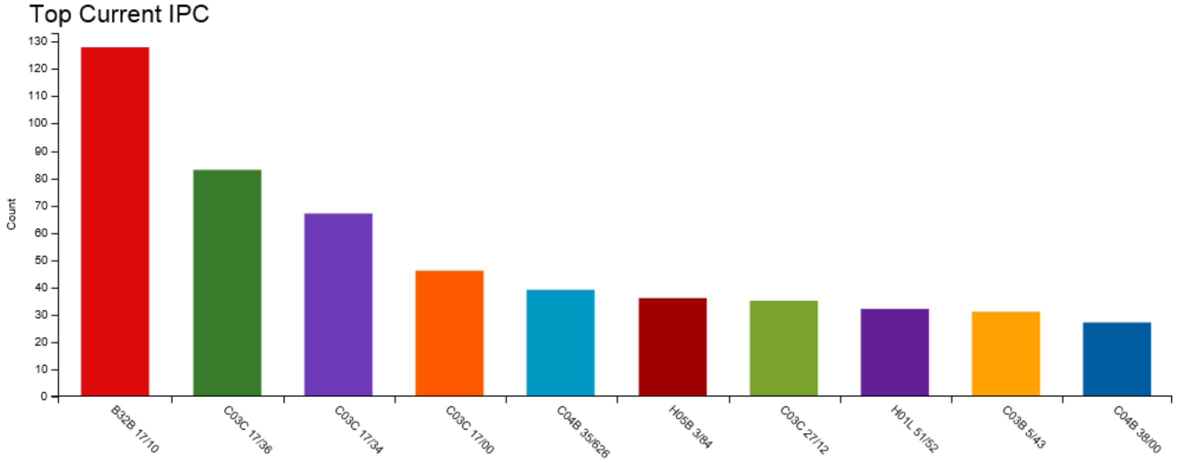
SAINT-GOBAIN S.A.	
Sector	**Logo**
Building Materials – Glass & Ceramics	SAINT-GOBAIN
Headquarter	
La Défense, Courbevoie, France	
Website	
http://www.saint-gobain-glass.com/	
Description	
Saint-Gobain S.A. is a French multinational corporation, founded in 1665 in Paris, producing several building materials, among which glass and ceramics, representing the company's core business. The company also produces other construction materials, such as cement, and a variety of high-performance materials. Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate structural and mechanical properties of glasses, both from an experimental and a theoretical points of view (modelling). The chemical content of different compounds for the production of glasses appear to be another important topic of scientific publications. Also some studies on mortars and cements composition are reported. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that Saint Gobain concentrates its research activities mainly in glass chemical composition and glass processing sectors. The IPC codes analysis shows a predominance of patents in the layered products field, reflecting the interest of the company in the improvement of glass sheets properties; also chemical composition of glasses and processes for manufacture and shaping glass appear to be an important field of application of company's researches. At the same time, ceramics and refractory materials are a field of research and innovation as it is possible to observe in the map of patents topics.	
Scientific Papers Affiliation (2011-2016)	
Number: 33	
Examples of relevant Scientific Publications:	
The impact of iron content in oxidation front in soda-lime silicate glasses: An experimental and comparative study *Journal of Non-Crystalline Solids, Volume 380, 15 November 2013, Pages 86-94* F. Pigeonneau, S. Muller Experiments on the oxidation front in two soda-lime silicate glasses melted at 1400 °C are first reported. The length of the oxidation front is proportional to the square root of time and the kinetics is three times slower when the iron content changes from 0.08 to 0.64 wt.%. A theoretical model is drawn assuming that the oxidation process is driven by the diffusion of oxygen coupled to the oxidation–reduction reaction of iron. From scaling analysis, numerical and self-similar solutions, the length of the oxidation front as a function of time is rescaled taking into account the iron content and the oxygen saturation in molten glass. The experimental results of oxidation front merge in a master curve demonstrating the relevance of the theoretical developments.	
Plastic deformation and residual stresses in amorphous silica pillars under uniaxial loading *Acta Materialia, Volume 60, Issue 15, September 2012, Pages 5555-5566* R. Lacroix, G. Kermouche, J. Teisseire, E. Barthel We have carried out uniaxial compression of micron-scale amorphous silica pillars. We have measured load–displacement curves and observed the morphology of the pillars after unloading, providing strong evidence for large plastic deformations. Minor cracking is also observed, with a well-defined pattern. We find that the van Mises stress in compression is comparable to the intrinsic tensile strength of silica. Precise analysis of the deformation of the pillars has been carried out by finite element modelling (FEM) using the constitutive equation determined previously (G. Kermouche et al., Acta Materialia, 56 (2008) 3222), which quantitatively takes into account densification, shear flow and strain hardening. The residual stress distribution we predict by FEM matches the observed crack pattern well. Finally the calculated stress fields in pillar compression and cone indentation are compared. We propose an interpretation of the contrasts in terms of confinement.	
Modelling of the conductive heat transfer through nano-structured porous silica materials *Journal of Non-Crystalline Solids, Volume 363, 1 March 2013, Pages 103-115* R. Coquard, D. Baillis, V. Grigorova, F. Enguehard, D. Quenard, P. Levitz There is currently a growing interest in nano-structured silica based materials due to their remarkable thermal properties. These materials are notably used in Vacuum Insulating Panels (VIP). Their exceptional insulating performances have been demonstrated experimentally for a relatively long time. But the heat transfer mechanisms occurring in this kind of materials remain relatively badly known due to the nanometric dimensions and to the complexity of the porous structure. Therefore, the present study aims to develop a numerical model for estimating the magnitude of conductive heat transfer inside nano-structured silicas using a realistic representation of their complex porous structure. The model takes into account the special porous morphology of the materials at both the nanometric and microscopic scale. Moreover, the conduction heat transfer at the nanometric scale is treated using a numerical resolution of the Boltzmann equation since the validity of the macroscopic laws is then questionable. The computations are conducted using phonon properties of silica obtained in the literature. A parametric study allows us to analyse the influence of	

structural characteristics and thermo-physical properties on the insulating performances and thus to highlight the most important parameters.

Published Patents (2011-2016)

Number: 857

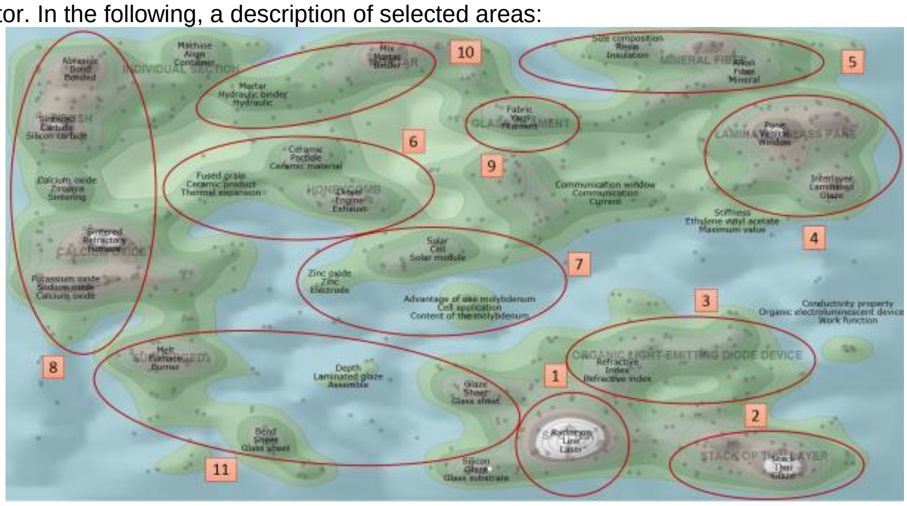
IPC Codes



B32B Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form
C03C Chemical composition of glasses, glazes, or vitreous enamels; Surface treatment of glass; Surface treatment of fibres or filaments from glass, minerals or slags; Joining glass to glass or other materials
C04B Lime; Magnesia; Slag; Cements; Compositions thereof, e.g. mortars, concrete or like building materials; Artificial stone; Ceramics; Refractories; Treatment of natural stone
H05B Electric heating; Electric lighting not otherwise provided for
H01L Semiconductor devices; Electric solid state devices not otherwise provided for
C03B Manufacture or shaping of glass, or of mineral or slag wool; Supplementary processes in the manufacture or shaping of glass, or of mineral or slag wool

Map of patents Topics

The map of patents topics for Saint Gobain highlights the most important research fields for the company in the Glass & Ceramics sector. In the following, a description of selected areas:



1. Thin films deposition methods (protective layers, coatings)
2. Glasses with improved thermal properties for heating glazing and solar cells applications
3. Materials for Light emitting diode devices (LEDs)
4. Laminated glass panels having electrically switchable optical properties
5. Mineral fiber and mineral wool: compositions and applications
6. Ceramic materials: composition, honeycomb elements and applications
7. Materials for solar cells and Fuel cells (mainly Solid Oxide Fuel Cells)
8. Ceramics and refractory materials: melting methods and devices
9. Glass yarns for reinforcement of other materials
10. Mortar compositions
11. Glass shaping, working and assembling

SCHOTT AG

Sector	Logo

Building Materials – Glass & Ceramics	
Headquarter	
Mainz, Germany	
Website	
http://www.schott.com/	

Description

Schott AG is an international manufacturing group of glass and glass-ceramics. The company is head-quartered in Mainz, Germany.
Concerning the scientific publications, the activity emerges to be strongly dedicated to glass-ceramics and, in particular, to crystallization and crystalline structures. In this field, particular attention is given to solar energy materials and solar cells.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the main topics are related to chemical composition of glasses, also appearing from the IPC codes analysis.
Contemporarily, corresponding with the same IPC code, joining processes for glasses appear to be an important topic of patents publication. The other relevant code emerging from the analysis concerns layered products and is related to layered glass sheets. Glass manufacturing appear to be the field of major interest for the company also from the analysis of the map of patents topic, further reported.

Scientific Papers Affiliation (2011-2016)

Number: 19

Examples of relevant Scientific Publications:

Study on the crystallization behaviour and thermal stability of glass-ceramics used as solid oxide fuel cell-sealing materials

Journal of Power Sources, Volume 196, Issue 21, 1 November 2011, Pages 9046-9050

Dieter Gödeke, Ulf Dahlmann

Glass ceramics are commonly used as sealing materials for planar solid oxide fuel cells (SOFCs). The major requirements of stack and module builders for these materials are the stability of the coefficient of thermal expansion (CTE), excellent bonding (sticking) behaviour and the absence of volatile ingredients, which can lead to changes of the material properties and the sealing ability. SCHOTT Electronic Packaging has developed special glasses and glass-ceramics for various solid oxide fuel cell designs and operating temperatures. The glass compositions are based on the system $MgO–Al_2O_3–BaO–SiO_2–B_2O_3$. In this study the evaluation of the developed materials was done by high temperature aging tests for up to 1000 h, high temperature XRD-studies and Rietveld calculations, combined with scanning-electron microscope analysis. Samples of these aged samples were chemically analysed by XRD and wet chemical methods. Results show that after thermal aging of the glasses barium silicates accompanied by barium–magnesium silicates are the major crystalline phases of the glasses. The crystal phases remain stable during high temperature aging tests, indicating a low driving force of material change. The experimental results are compared to phase diagrams by phenomenological and thermochemical considerations.

Fabrication of highly porous glass filters using capillary suspension processing

Separation and Purification Technology, Volume 149, 27 July 2015, Pages 470-478

Johannes Maurath, Jens Dittmann, Niko Schultz, Norbert Willenbacher

We present a novel, capillary suspension based processing route for sintered glass filters with porosities ⩾50% at average pore sizes between 1 and 50 μm. This new kind of glass filters exhibits narrow pore size distribution and uniform pore structure. Pores are exceptionally smooth and round. Accordingly, permeability and mechanical strength of these filters excel that of similarly processed ceramic and commercial glass filters significantly. Mechanical strength at a given porosity is much higher than that of commercial glass filters and reaches values similar to that of ceramic filters with distinctly higher matrix strength. Absolute values are well predicted by the Gibson & Ashby model $\sigma_c/\sigma_{f,0} = B_0(1 - \varepsilon)^z$ with $B_0 = 0.8$. Liquid permeability varies with pore size according to Darcy's law but absolute values are clearly higher than that for ceramic filters at given pore size as expected from the smoother pore structure. Gas permeability is especially high at pore sizes <10 μm and exceeds that of ceramic and commercial glass filters significantly. Moreover, this results in a weaker than quadratic pore size dependence. This is presumably due to slip effects occurring especially in small pores and narrow necks of the novel glass filters.

Micro-Raman mapping on layers for crystalline silicon thin-film solar cells

Journal of Crystal Growth, Volume 314, Issue 1, 1 January 2011, Pages 53-57

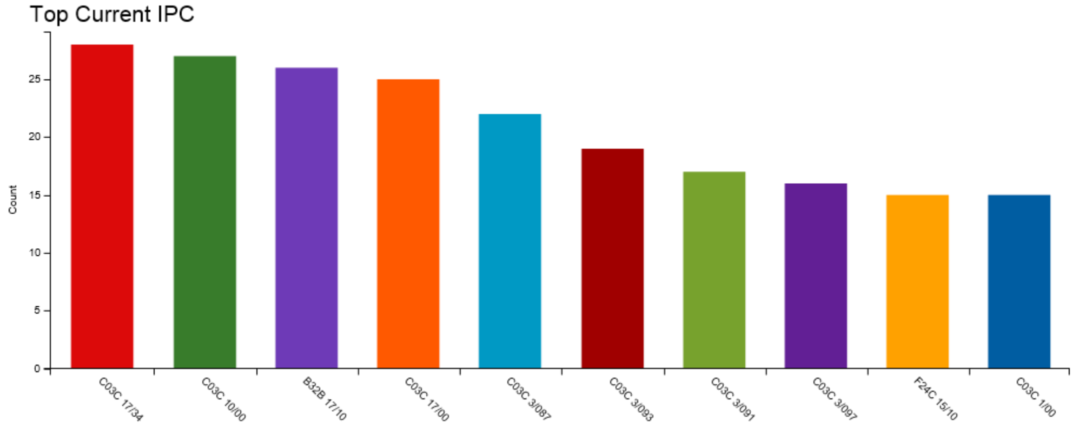
T. Kunz, M.T. Hessmann, B. Meidel, C.J. Brabec

Micro-Raman mappings have been used for characterization of our layers system developed for thin-film silicon solar cells. For the cubic SiC barrier layer a preferential orientation of the grains in 〈1 1 1〉 direction normal to the substrate was revealed. A high density of stacking faults resulted in the splitting of transversal optical (TO)-phonon modes, usually only observed in several non-cubic SiC polytypes. Within the silicon layers, which were obtained by zone melting recrystallization (ZMR) and subsequent epitaxial growth, a high residual stress of about 625 MPa was measured near the boundary towards the SiC layer. Outside of this boundary no residual stress could be detected, in spite of commonly found twin boundaries. Thus the main origin of residual stress in the silicon layers is due to the different expansion coefficients of the respective layers, while grain boundaries have no dominant effect.

Published Patents (2011-2016)

Number: 248

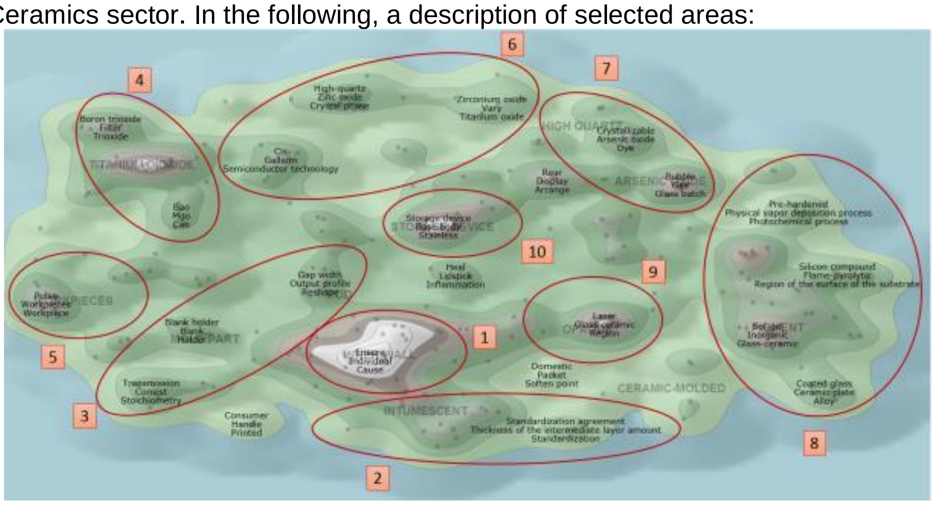
IPC Codes



C03C Chemical composition of glasses, glazes, or vitreous enamels; Surface treatment of glass; Surface treatment of fibres or filaments from glass, minerals or slags; Joining glass to glass or other materials
B32B Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form
F24C Other domestic stoves or ranges; Details of domestic stoves or ranges, of general application

Map of patents Topics

The map of patents topics for Schott AG highlights the most important research fields for the company in the Glass & Ceramics sector. In the following, a description of selected areas:



1. Devices and methods for glass manufacturing
2. 3. Production methods for glass components production
4. Glass and glass-metals compounds: compositions and additives
5. Perforated workpieces production
6. 7. Glasses and glass-ceramics: compositions and related applications
8. 9. Glass-ceramics substrates: materials and producing methods
10. Feed-through for energy storage devices

INDUSTRIAL METALS

Table A.6. Industrial Metals

THYSSENKRUPP AG	
Sector	**Logo**
Industrial metals – Steel	
Headquarter	
Duisburg and Essen, Germany	
Website	
https://www.thyssenkrupp.com/	

Description

Thyssenkrupp AG is a European multinational conglomerate corporation based in Duisburg and Essen, Germany. Thyssenkrupp is one of the world's largest steel producers, but also provides components and systems for the automotive industry, elevators, escalators, material trading and industrial services.
Concerning the scientific publications, the activity emerges to be strongly dedicated to the study of mechanical properties of different types of steel, varying chemical composition, surface treatments and coatings. Also creep and failure mechanisms are often investigated. Another field of research are the properties of other alloys, different from steel, and of composite materials.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that ferrous-metals and alloys occupy a relevant role in registered patents, as it is possible to infer from IPC code analysis. Also innovations in sheet metal processing are reported to be relevant for patent publication. The topic analysis shows the same fields of research and innovation, focusing particularly on innovative processes for steel forming and coating.

Scientific Papers Affiliation (2011-2016)

Number: 29

Examples of relevant Scientific Publications:

Hydrogen diffusion and trapping in Ti-modified advanced high strength steels

Materials & Design, Volume 92, 15 February 2016, Pages 450-461

Nicholas Winzer, Oliver Rott, Richard Thiessen, Ingo Thomas, Klemens Mraczek, Thomas Höche, Louise Wright, Matous Mrovec

The influence of Ti on hydrogen diffusion and trapping in various advanced high strength steels was investigated. Electrochemical hydrogen permeation tests were performed on various model steels, with and without Ti, with benchmark tests performed using a commercial steel variant. The hydrogen trapping parameters for each steel were determined by fitting the permeation curves with a finite element model based on the McNabb and Foster equations using least squares minimisation. The influence of Ti on the hydrogen trapping parameters was greatly dependent on microstructure, with ferrite-containing grades being most affected. The results are inconsistent with hydrogen trapping by TiC particles, but consistent with trapping by boundaries between neighbouring ferrite and martensite grains.

Zr-based conversion layer on Zn-Al-Mg alloy coated steel sheets: insights into the formation mechanism

Electrochimica Acta, Volume 137, 10 August 2014, Pages 65-74

Thomas Lostak, Artjom Maljusch, Björn Klink, Stefan Krebs, Matthias Kimpel, Jörg Flock, Stephan Schulz, Wolfgang Schuhmann

Zr-based conversion layers are considered as environmentally friendly alternatives replacing trication phosphatation in the automotive industry. Based on excellent electronic barrier properties they provide an effective corrosion protection of the metallic substrate. In this work, thin protective layers were grown on novel Zn-Al-Mg alloy coated steel sheets by increasing the local pH-value at the sample surface leading to deposition of a Zr-based conversion layer. For this purpose Zn-Al-Mg alloy (ZM) coated steel sheets were treated in an aqueous model conversion solution containing well-defined amounts of hexafluorozirconic acid (H2ZrF6) and characterized after different immersion times with SKPFM and field emission SEM (FE-SEM)/EDX techniques. A deposition mechanism of Zr-based conversion coatings on microstructural heterogeneous Zn-Al-Mg alloy surfaces was proposed.

Reactive wetting during hot-dip galvanizing of high manganese alloyed steel

Surface and Coatings Technology, Volume 205, Issue 10, 15 February 2011, Pages 3319-3327

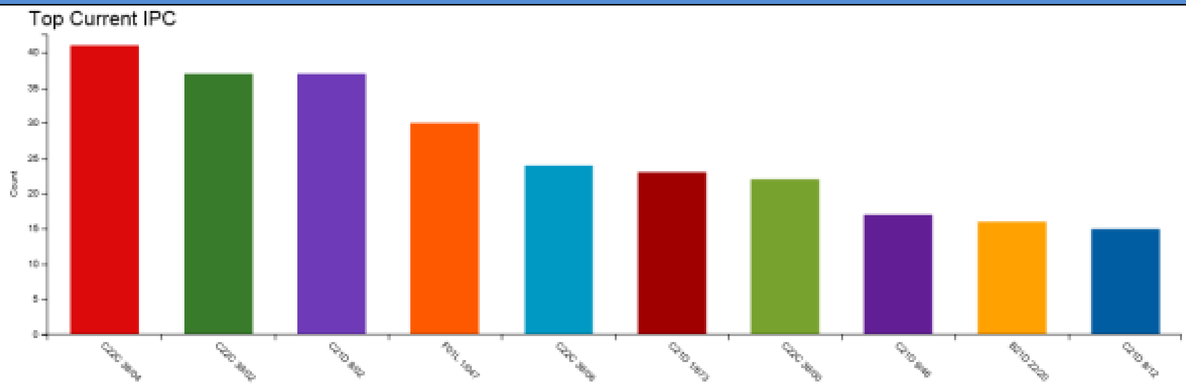
Marc Blumenau, Martin Norden, Frank Friedel, Klaus Peters

The present study discusses reactive wetting during hot-dip galvanizing of high Mn alloyed steel (X-IP1000, 23 wt.% Mn) and is focused on investigating the influence of the metallic Mn concentration in the steel bulk composition on phase formation at the interface steel/coating. Samples were in-line bright annealed (1100 °C/ 60 s in N2-5%H2 at DP −50 °C) prior hot-dipping to avoid external MnO on the steel surface. This approach was applied to avoid influencing the wetting reaction by an aluminothermic MnO reduction, because this is considered to lead to an unwanted zeta-phase (FeZn13) formation in the coating by hot-dipping of Mn alloyed steels (< 5.0 wt.% Mn). The influence of hot-dipping parameters, which are contributing to the kinetics of the wetting reaction, was examined in terms of varying bath-Al content (0.17 and 0.22 wt.%), bath temperature (440–500 °C) and strip entry temperature (420–520 °C). The structure and chemical composition of both galvanized coating and interface steel/coating were characterized. While external MnO was verifiably avoided, brittle zeta-phase distinctively appeared at the interface steel coating together with the typical Fe_2Al_5 phase. This shows that the model of aluminothermic MnO reduction failed in the present case. This study suggests an alternative model explaining the appearance of zeta-phase with the removal of bath-Al by metallic Mn, which is dissolved/the steel bulk into the Zn bath. The present investigation shows that alloying elements in the steel bulk may influence coating quality not only “indirectly” by external formation of nonwettable oxides, but also “directly” by influencing phase equilibria and kinetics of the wetting reaction. Understanding these phenomena will improve processing of (high) alloyed steel concepts as well as industrial Zn bath management.

Published Patents (2011-2016)

Number: 693

IPC Codes



C22C Alloys
C21D Modifying the physical structure of ferrous metals; General devices for heat treatment of ferrous or non-ferrous metals or alloys; Making metal malleable by decarburisation, tempering, or other treatments
F01L Cyclically operating valves for machines or engines
B21D Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; Punching

Map of patents Topics

The map of patents topics for

Thyssenkrupp highlights the most important research fields for the company in the Steel sector. In the following, a description of selected areas:
1. Steel production: composition and manganese content
2. 3. Metal coating for steel products
4. Layered structures of metal sheets
5. Metals for magnet production
6. Raw materials and coke: transport and pre-treatments for steel production
7. Operative conditions
8. Processes for steel production

ARCELORMITTAL S.A.

Sector	Logo
Industrial metals – Steel	ArcelorMittal
Headquarter	
Luxembourg, Luxembourg	
Website	
http://corporate.arcelormittal.com/	

Description

ArcelorMittal S.A. is a Luxembourg multinational steel manufacturing corporation headquartered in Avenue de la Liberté, Luxembourg. It was formed in 2006 from the takeover and merger of Arcelor by Mittal Steel. ArcelorMittal is the world's largest steel producer.
Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate steel mechanical properties, for different processed steels. Another field of research is about different industrial processes for steel working, such as stamping and rolling. Also composites, using steel sheets as a component, are reported to be an innovative field of publication.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that coating of metallic materials represents the main IPC code for registered patents in the last years. The following one is represented by alloys. Also registered patents show that innovative metal processes owned a relevant position in the research efforts carried out by the company, together with the continuous study on compositions to be used for improving steel properties.

Scientific Papers Affiliation (2011-2016)

Number: 120

Examples of relevant Scientific Publications:

Damage and fracture of dual-phase steels: Influence of martensite volume fraction

Materials Science and Engineering: A, Volume 646, 14 October 2015, Pages 322-331

Q. Lai, O. Bouaziz, M. Gouné, L. Brassart, M. Verdier, G. Parry, A. Perlade, Y. Bréchet, T. Pardoen

The influence of the martensite volume fraction (Vm) on the damage and fracture behavior of dual-phase steels was studied by combining experiments and micromechanical modeling. A transition in the dominating damage mechanism is observed when varying Vm. Martensite fracture dominates the void nucleation process at high Vm, while interface decohesion prevails at low Vm. Damage accumulation accelerates when Vm increases, resulting in a decrease of the fracture strain. Brittle fracture areas are observed in uniaxial tensile specimens for a sufficiently high Vm. The damage mechanisms and evolution are rationalized using a micromechanical analysis based on periodic finite element cell calculations. The results show that Vm is a key factor for controlling the balance between strength and fracture resistance.

Chemical profile identification of fugitive and confined particle emissions from an integrated iron and steelmaking plant

Journal of Hazardous Materials, Volumes 250–251, 15 April 2013, Pages 246-255

Dany Hleis, Ignacio Fernández-Olmo, Frédéric Ledoux, Adib Kfoury, Lucie Courcot, Thérèse Desmonts, Dominique Courcot

The aim of this study is to obtain the characteristic inorganic chemical profile of important particle sources identified in the integrated iron and steel process: sintering, blast furnace, steelmaking and desulfurization slag processing. A complete chemical and physical characterization program was developed: particle size distribution, chemical analysis, XRD, SEM-EDX and TGA/DTA. The sample collected from the sinter stack showed high levels of K and Cl^-, followed by Fe, NH_4^+, Ca, Na and Pb. The profile of the dust samples taken from the sinter cake discharge zone was quite different, showing higher amounts of Fe, Ca and Al, and lower amounts of K, Cl^-, Na and Pb. Dust samples collected from the blast furnace (BF) and steelmaking cast house may be distinguished from each other based on the higher levels of Fe (hematite and magnetite) and lower levels of Ca, Zn and C (graphite) found in BF dust. High levels of Ca and Fe were found in samples taken from the desulfurization slag processing area. Such information can be useful for source apportionment studies at receptor sites that could be influenced by iron and steelmaking plant emissions.

Advances in the development of corrosion and creep resistant nano-yttria dispersed ferritic/martensitic alloys using the rapid solidification processing technique

Ceramics International, Volume 40, Issue 9, Part A, November 2014, Pages 14319-14334

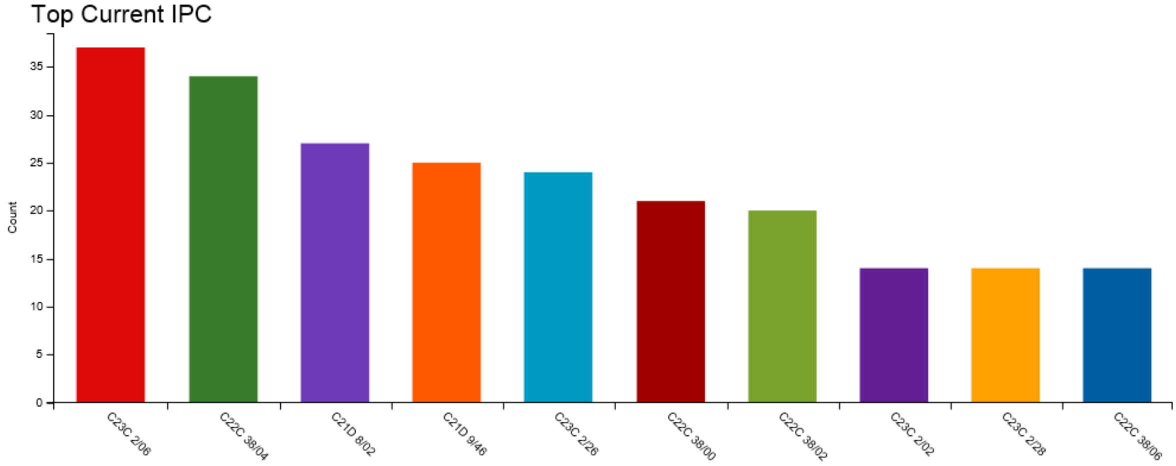
K. Verhiest, S. Mullens, I. De Graeve, N. De Wispelaere, S. Claessens, A. De Bremaecker, K. Verbeken

High-temperature creep and corrosion resistant nano-dispersed ferritic/martensitic (F/M) alloys (such as a T91 steel), or other 'the oxide dispersion strengthened (ODS) steels', are under consideration for nuclear applications because of their high-temperature mechanical properties. They consist typically of a high-chromium steel structure dispersed and reinforced by a dispersion of nano-sized rare-earth metal oxides, typically yttrium oxide (Y_2O_3). In this study, the production of ODS based on T91 is examined by adding a 0.3 wt% colloidal Y_2O_3 dispersion to a T91 steel melt in combination with metallic yttrium (YM). The production of the following systems is evaluated: T91–Y_2O_3, T91–YM and T91–YM–Y_2O_3. At first, it was found that when YM is added to a steel melt, internal oxidation occurs. Furthermore, it was shown that the T91 system with addition of Y_2O_3 in combination with rare-earth metal YM, creates a homogeneously dispersed ODS T91 material. Moreover, the role of YM as a possible surface active element lowering the surface tension at the contact interface is studied. High-temperature contact angle wetting tests between Y2O3 ceramic substrates in contact with an T91 and a [T91+YM] melt, combined with auger-electron spectroscopy (AES), indicate the influence of YM on the surface activity of Y2O3 in contact with T91. After YM addition, the contact angle between T91 and the Y2O3 substrate lowers down to angles below 90°.

Published Patents (2011-2016)

Number: 204

IPC Codes



C23C Coating metallic material; Coating material with metallic material; Surface treatment of metallic material by diffusion into the surface, by chemical conversion or substitution; Coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapour deposition, in general
C22C Alloys
C21D Modifying the physical structure of ferrous metals; General devices for heat treatment of ferrous or non-ferrous metals or alloys; Making metal malleable by decarburisation, tempering, or other treatments

Map of patents Topics

The map of patents topics for ArcelorMittal highlights the most important research fields for the company in the Steel sector. In the following, a description of selected areas:

1. Hot rolling process
2. 3. 4. Composition and microstructure of alloys (steels)
5. Metallic coating for steel products
6. 7. Operative conditions and process requirements
8. Metal sheets for Building cover or concrete reinforcement

CONSTELLIUM	
Sector	**Logo**
Industrial metals – Aluminium & alloys	
Headquarter	
Amsterdam, Netherlands	
Website	
http://www.constellium.com/	

Description

Constellium is a global producer of aluminium semi-products with headquarters in Amsterdam, Netherlands. It was created when Rio Tinto sold off Alcan Engineered Products to Apollo Management (51%) and FSI (10%) in 2011.
Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate mechanical properties of aluminium and its alloys (especially Al-Cu-Li alloys) with different shapes: fractures, compression properties and other are experimentally proved. The research is particularly focused on alloy sheets and solid foams.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the main IPC code for registered patent corresponds to the change of physical structure of non-ferrous metals or alloys. Another Code appearing to be used for patents registration is related to the application of produced materials. These materials, and in particular alloy sheets find their best application in vehicles construction, and this makes Constellium strongly linked with both the automotive and the aeronautics industries as can be seen in the further map of patents topics.

Scientific Papers Affiliation (2011-2016)

Number: 15

Examples of relevant Scientific Publications:

On the role of microstructure in governing fracture behaviour of an aluminum–copper–lithium alloy

Materials Science and Engineering: A, Volume 586, 1 December 2013, Pages 418-427

B. Decreus, A. Deschamps, P. Donnadieu, J.C. Ehrström

The influence of precipitate microstructure on fracture mechanisms is studied in a recently developed Al–Cu–Li alloy, AA2198. The intra-granular and inter-granular microstructures are varied independently by changing the quench rate from the solution heat treatment, the amount of pre-stretching and the heat treatment time. Fracture toughness is evaluated by short bar chevron tear tests that make possible to evidence clearly the mechanisms of inter-granular fracture. It is shown that intergranular ductile fracture significantly occurs in all conditions of heat treatment where substantial precipitation has taken place. This mechanism is mainly controlled by the state of inter-granular precipitation and plays a major role to determine the value of transverse fracture toughness, while the strength and ductility of the alloy are mainly controlled by the state of intra-granular precipitation.

Grain scale modeling of the bendability of AA6xxx Al alloy sheet

Materials Science and Engineering: A, Volume 583, 20 October 2013, Pages 96-104

Laurent Mattei, Dominique Daniel, Gilles Guiglionda, Nicolas Moulin, Helmut Klöcker, Julian Driver

Bending sheet metal is a common shaping operation but, at high strains, may lead to failure that is difficult to predict from either standard mechanical tests or models. A recent experimental study of bending AA 6xxx sheet for automotive applications has shown that through-thickness strain localization controls damage development. Here, a new finite element microstructure based model of the standard bending test is introduced to predict strain localization during bending. The sheet metal is modeled as a grain aggregate, each grain having its own flow stress. The model is validated by comparison with a standard model and experimental results through an analysis of the critical plastic strain at the outer surface. It is applied to the bending of industrial AA6xxx sheet alloys and correctly describes the respective influences of sheet thickness, grain size and shape, and work hardening. In particular the model brings out the primary importance of large-strain hardening and the flow stress distribution width. It can be used to give simple guidelines for designing highly bendable sheet metal.

Processing and structures of solids foams

Comptes Rendus Physique, Volume 15, Issues 8–9, October–November 2014, Pages 662-673

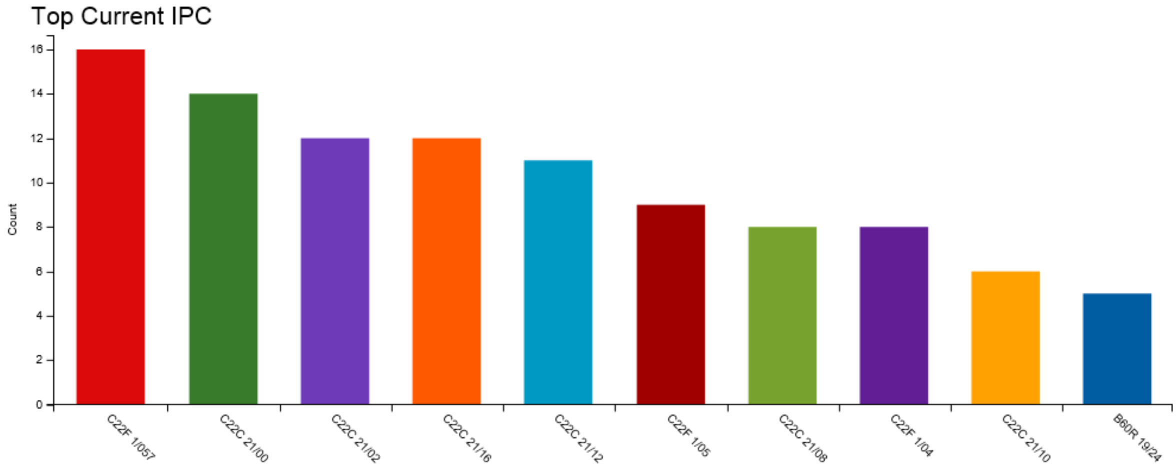
Luc Salvo, Guilhem Martin, Mathieu Suard, Ariane Marmottant, Rémy Dendievel, Jean-Jacques Blandin

This paper aims at presenting the main processing routes that are used to produce foams in their general definition and the typical structure that can be obtained according to the process. We first describe the main classification of the foam according to the level of porosity (open cells, closed cells, partially open cells and mixed cells). We present briefly the main processes to obtain such structures (non-removable space holder stacking and impregnation, removable space holder, foaming from gas or from precursor and shortly additive manufacturing) with a specific focus on the metal foam processing. We finally indicate the main structure that can be obtained with these types of processes and the main characteristics that are necessary to quantify at the various scale of the structure.

Published Patents (2011-2016)

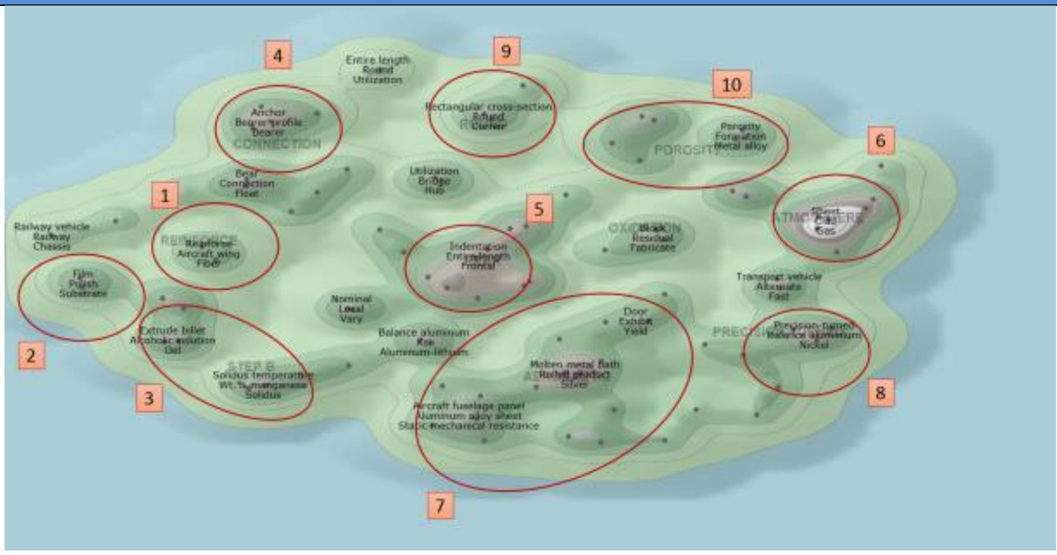
Number: 92

IPC Codes



C22F Changing the physical structure of non-ferrous metals or non-ferrous alloys
C22C Alloys
B60R Vehicles, vehicle fittings, or vehicle parts, not otherwise provided for

Map of patents Topics



The map of patents topics for Constellium highlights the most important research fields for the company in the Aluminium and Alloys sector. In the following, a description of selected areas:

1. Fiber metal laminate for aircraft manufacture
2. Aluminium substrate for photovoltaic applications
3. Surface treatment of extruded billet and quench systems
4. Assembling methods and connection elements
5. Bumpers: materials and shaping
6. Aluminium alloys strips and sheets for heat exchangers
7. Aluminium-copper-lithium alloys for different applications
8. Alloys precision turning
9. Semi-finished products shaping and working
10. Aluminium alloys casting and welding

RIO TINTO	
Sector	**Logo**
Industrial metals – Aluminium & alloys	RioTinto
Headquarter	
London, United Kingdom	
Website	
http://www.riotinto.com/	

Description

Rio Tinto is a British-Australian multinational and one of the world's largest metals and mining corporations. The company was founded in 1873, when a multinational consortium of investors purchased a mine complex on the Rio Tinto river, in Huelva, Spain, from the Spanish government. Although primarily focused on extraction of minerals, Rio Tinto also has significant operations in refining, particularly for refining bauxite and iron ore.

Concerning the scientific publications, the activity emerges to be strongly dedicated to primal refining of raw materials. The main research activities are focused on hydrometallurgy and electrochemical processes for metal refining. Also mechanics of materials are often investigated. Corrosion is another research field of interest that appears to be a key aspect for the company because of its strong linked with electrochemical processes.

Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the majority of published patents present the IPC code corresponding with 'Processes for the electrolytic production, recovery or refining of metals'. This clearly confirm that electrochemistry is the field in which Rio Tinto spend the majority of efforts to bring innovation in Europe.

Scientific Papers Affiliation (2011-2016)

Number: 8

Examples of relevant Scientific Publications:

Layer growth mechanisms on metallic electrodes under anodic polarization in cryolite-alumina melt

Corrosion Science, Volume 79, February 2014, Pages 159-168

M. Oudot, L. Cassayre, P. Chamelot, M. Gibilaro, L. Massot, M. Pijolat, S. Bouvet

The anodic behavior of Fe, Ni, Co electrodes was investigated in a cryolite-alumina melt at 960 °C, by electrochemical techniques, microstructural characterizations and thermodynamic calculations, to provide a fundamental understanding of layers formation at metal (M) electrode surface. At low overpotential, anodic dissolution of M occurs; when the Mn+ concentration at the surface reaches saturation, a $M_xAl_{3-x}O_4$ spinel phase precipitates. Then, a dense M_yO layer grows at the metal/spinel interface. As for Fe, polarization at higher overpotentials lead to the same layers of spinel and monoxide, but pores at the metal/Fe_yO interface cause loss of adhesion of the oxide film.

Deformation and cracking during sintering of bimaterial components processed from ceramic and metal powder mixes. Part I: Experimental investigation

Mechanics of Materials, Volume 53, October 2012, Pages 123-131

G. Largiller, D. Bouvard, C.P. Carry, A. Gabriel, J. Müller, T. Staab

Parts composed of two ceramic–metal composite layers have been fabricated by co-sintering of two powder blends. The major constituent was the ceramic powder in one blend and the metal powder in the second one. This paper focuses on the mechanical analysis of the co-sintering process. This process has been observed thanks to an original optical dilatometry set up that provided images of the component in the course of sintering cycle. These images allowed following component shape changes throughout the thermal cycle and also evidenced the formation of cracks at the edges of a part at particular stages of the sintering cycle. These phenomena are interpreted from the mismatch between the densification kinetics of each powder blend sintered alone. In a companion paper the results of a finite element simulation of cosintering are compared to the experimental data displayed in the present paper.

Oxidation kinetics of a Ni–Cu based cermet at high temperature

Corrosion Science, Volume 68, March 2013, Pages 154-161

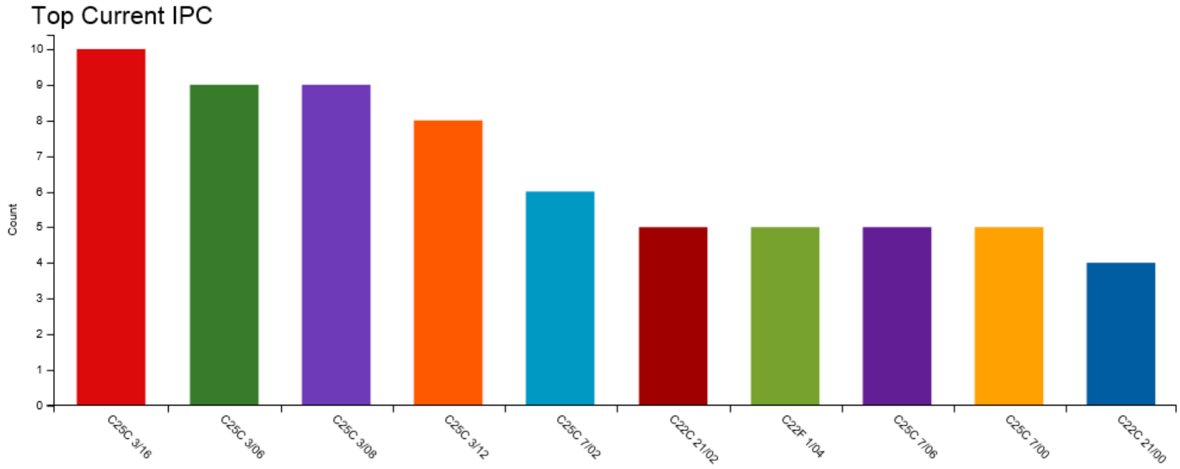
C. Honvault, V. Peres, L. Cassayre, P. Chamelot, P. Palau, S. Bouvet, M. Pijolat

The oxidation kinetics of a cermet composed of Ni–Cu alloy and nickel ferrite was studied by thermogravimetry at 960 °C under oxygen in the range 0.5–77 kPa. After an initial mass increase up to 15 g/m2 due to oxidation of surface metallic particles, the mass change was attributed to both outwards NiO growth and internal oxidation. Above 40 g/m2, the NiO scale thickness remained constant and the oxidation kinetics followed a complete parabolic law. The variations of the kinetic rate with oxygen partial pressure allowed to propose mechanisms, rate-controlling steps and kinetic laws in both transient and long term oxidation periods.

Published Patents (2011-2016)

Number: 63

IPC Codes



C25C Processes for the electrolytic production, recovery or refining of metals; Apparatus therefor C25C Processes for the electrolytic production, recovery or refining of metals; Apparatus therefor
C22C Alloys
C22F Changing the physical structure of non-ferrous metals or non-ferrous alloys

Map of patents Topics

The map of patents topics for Rio Tinto highlights the most important research fields for the company in the Aluminium and Alloys sector. In the following, a description of selected areas:
1. High strenght aluminium alloys: compositions and possible application routes for heat exchangers
2. Aluminium based electrodes
3. Aluminium based conductive materials and electrolytic cells
4. Hydrometallurgy
5. Metalworking processes and machineries innovations
6. Powder materials processing

CHEMISTRY

Table A.7. Chemistry

HALDOR TOPSØE	
Sector	**Logo**
Chemistry - Catalysis	HALDOR TOPSØE
Headquarter	
Ravnholm, Denmark	
Website	
http://www.topsoe.com/	
Description	
Haldor Topsøe is a Danish catalysis company founded in 1940 by Dr. Haldor Topsøe. Haldor Topsøe specialises in the production of heterogeneous catalysts and the design of process plants based on catalytic processes. Focus areas include the fertiliser industry, chemical and petrochemical industries, and the energy sector (refineries and power plants). Concerning the scientific publications, the activity emerges to be strongly dedicated to catalytic materials. Different studies on catalytic materials properties are carried out in order to characterize surface properties (surface areas, active sites, pore volume, etc.) and morphology. The research of optimal catalyst properties for different reactions is a strong carrier of innovation in such materials. Different dopants for surface functionalization are continuously investigated, together with different types of supports to maximise reaction activity or expected products. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that different areas of interest in the chemistry field are object of Haldor Topsøe's research activities. The most frequent IPC code for selected patents is related to processes for the direct conversion of chemical energy into electrical energy (batteries). Other important fields in which innovations have been patented are related to different chemical processes or materials.	
Scientific Papers Affiliation (2011-2016)	
Number: 61	
Examples of relevant Scientific Publications:	

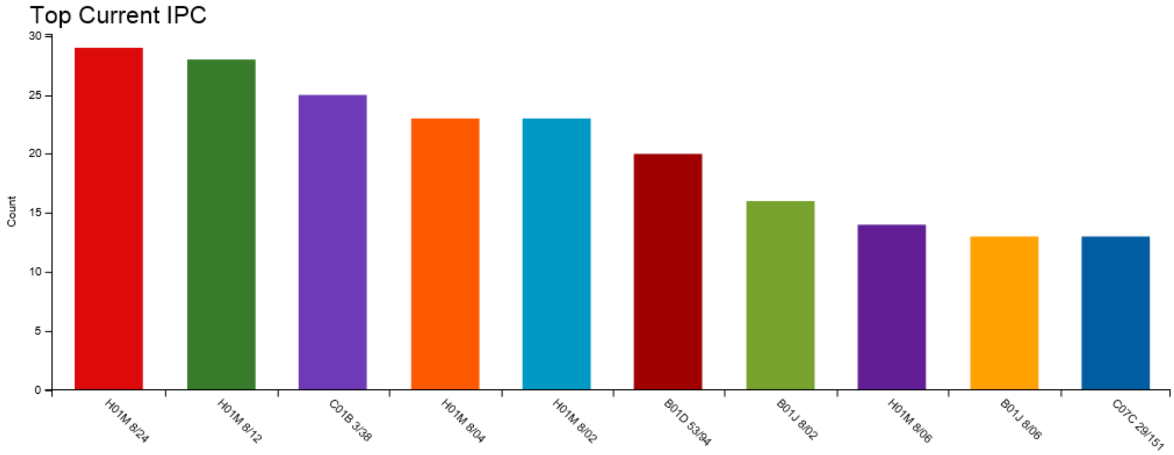
Improving the sintering resistance of Ni/Al2O3 steam-reforming catalysts by promotion with noble metals *Applied Catalysis A: General, Volume 498, 5 June 2015, Pages 117-125* Fernando Morales-Cano, Lars Fahl Lundegaard, Ramchandra R. Tiruvalam, Hanne Falsig, Martin Skov Skjøth-Rasmussen The role of Rh, Ir and Ru promoters on the structural properties and catalytic behavior of Ni/α-Al_2O_3 catalyst during steam methane reforming (SMR) was investigated. The catalysts were subjected to aging treatments at 800 °C and P_{H_2O} = 22 bar g in order to induce sintering of the metal nanoparticles and alloying between Ni and the promoters. The crystallite sizes and the extent of alloying were determined in the reduced and aged catalysts by combination of in situ extended X-ray absorption fine structure (EXAFS), X-ray powder diffraction (XRPD), transmission electron microscopy (TEM) and X-ray energy dispersive spectroscopy (STEM-XEDS) mapping. The results reveal that the degree of alloying between Ni and Rh or Ir promoters increases during the aging process, as a result of the high mobility of the nickel species and diffusion into the FCC structures of Rh and Ir. Moreover, the formation of Ni–Rh and Ni–Ir alloy particles has a positive effect in mitigating the sintering of the nickel particles. In contrast, sintering inhibition effect of Ru was poorer due to its lower miscibility in nickel as well as its lower sintering resistance under the aging conditions employed. Based on density functional theory (DFT) calculations the diffusion of the Ni atoms into the lattice structure of Ru is energetically not favorable, whereas Ni atoms are equally stable in the first and second surface layers of Ir and Rh. Hence, a synergistic effect between Ni and Rh or Ir is achieved due to the alloy formation leading to conservation of larger active metal surface area and consequently to superior SMR activity with respect to the monometallic systems.
Whisker carbon in perspective *Catalysis Today, Volume 178, Issue 1, 15 December 2011, Pages 42-46* S. Helveg, J. Sehested, J.R. Rostrup-Nielsen A summary is given of the work that aims at describing the parameters guiding the formation of whisker carbon as well as at understanding the growth mechanism. David Trimm played an important role in the pioneering work. The present knowledge is illustrated by recent high-resolution electron micrographs.
High surface area calcite *Journal of Crystal Growth, Volume 371, 15 May 2013, Pages 34-38* L.N. Schultz, M.P. Andersson, K.N. Dalby, D. Müter, D.V. Okhrimenko, H. Fordsmand, S.L.S. Stipp Calcite ($CaCO_3$) is important in many fields—in nature, because it is a component of aquifers, oil reservoirs and prospective CO_2 storage sites, and in industry, where it is used in products as diverse as paper, toothpaste, paint, plastic and aspirin. It is difficult to obtain high purity calcite with a high surface area but such material is necessary for industrial applications and for fundamental calcite research. Commercial powder is nearly always contaminated with growth inhibitors such as sugars, citrate or pectin and most laboratory synthesis methods deliver large precipitates, often containing vaterite or aragonite. To address this problem, we (i) adapted the method of carbonating a $Ca(OH)_2$slurry with CO_2 gas to develop the first simple, cheap, safe and reproducible procedure using common laboratory equipment, to obtain calcite that reproducibly had a surface area of 14–17 m^2/g and (ii) conducted a thorough

characterization of the product. Scanning electron microscopy (SEM) revealed nanometer scale, rhombohedral crystals. X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and infrared spectroscopy (IR) confirmed highly crystalline, pure calcite that more closely resembles the dimensions of the biogenic calcite produced by algae in coccoliths than other methods for synthesizing calcite. We suggest that this calcite is useful when purity and high surface area are important.

Published Patents (2011-2016)

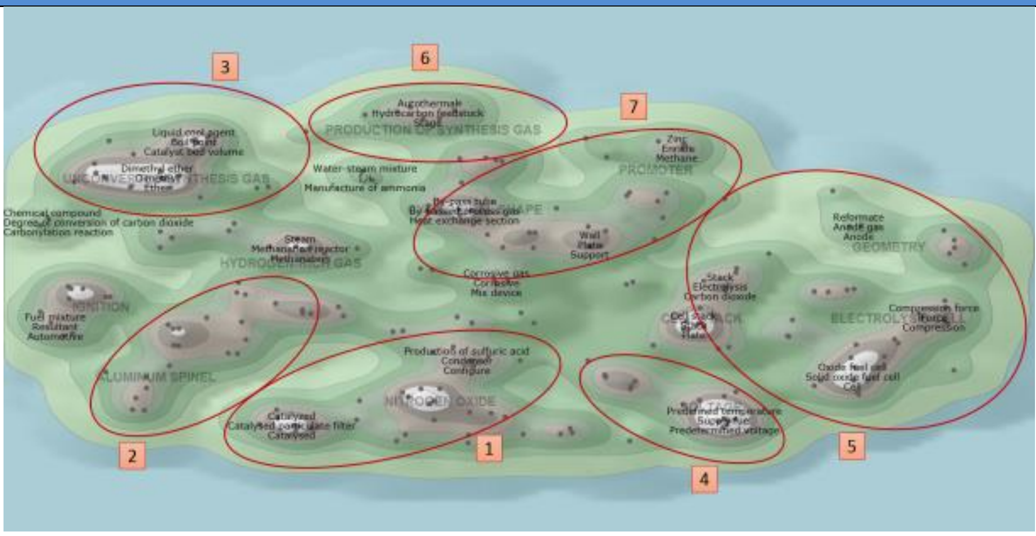
Number: 230

IPC Codes



H01M Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
C01B Non-metallic elements; Compounds thereof
B01D Separation
B01J Chemical or physical processes, e.g. catalysis, colloid chemistry; Their relevant apparatus
C07C Acyclic or carbocyclic compounds

Map of patents Topics



The map of patents topics for Haldor Topsøe highlights the most important research fields for the company in the Catalysis sector. In the following, a description of selected areas:

1. Purification of exhaust gases processes and catalysed filters
2. Catalysers for hydrocarbon conversion
3. Processes for the production of different gaseous chemical compounds
4. High temperature fuel cells (SOFC): materials and design
5. Materials for electrolytic cells or fuel cells
6. Hydrocarbons reforming
7. Reactors and other equipment for chemical industry

JOHNSON MATTHEY	
Sector	**Logo**
Chemistry - Catalysis	
Headquarter	
London, United Kingdom	
Website	
http://www.matthey.com/	

Description

Johnson Matthey is a British multinational speciality chemicals and sustainable technologies company headquartered in the United Kingdom. The Company is organized in five different branches: Emission Control Technologies, Process Technologies, Precious Metal Products, Fine Chemicals and New Businesses.

Concerning the scientific publications, the activity emerges to be strongly dedicated to catalytic materials. The researches mainly focused their attention on activity and selectivity of different catalysts, coupled with a range of different support materials. Preparation methods permitting to obtain the best active sites surface configuration, to improve catalytic materials properties, are also a returning field of research. An important field of research is represented by Platinum and Palladium oxidation catalysts that find application in diesel vehicles for the processing of exhaust gases.

Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the majority of selected patents belong to the IPC code category of separation. The analysis of the map of patents topics that the company is active in the fields of catalysis in several ways: reactors, purification and separation systems, particulate filters, etc.

Scientific Papers Affiliation (2011-2016)

Number: 55

Examples of relevant Scientific Publications:

Increased NO_2 concentration in the diesel engine exhaust for improved Ag/Al_2O_3 catalyst NH_3-SCR activity

Chemical Engineering Journal, Volume 270, 15 June 2015, Pages 582-589

Wentao Wang, Jose M. Herreros, Athanasios Tsolakis, Andrew P.E. York

Increasing the NO_2 availability in some aftertreatment systems enhance their performance in reducing pollutants from internal combustion (IC) engines but result in significant fuel economy and CO_2 emissions penalties. The presence of NO_2 in the engine exhaust gas enhances the regeneration of the Diesel Particulate Filters (DPFs) and can improve the activity of the catalysts in reducing NO_x emissions in the selective catalytic reduction (SCRs) process. In this work the production and the role of the increased NO_2 concentration in the Ag/Al_2O_3 catalyst for the SCR process of NO_xremoval at low exhaust gas temperatures under real engine operation has been investigated. We have increased the NO_2 concentration available for the SCR process with (i) the addition of different NH_3 and H_2 mixtures upstream the SCR catalyst and/or (ii) by the use of a Pt based Diesel Oxidation Catalyst (DOC) in front of the Ag/Al_2O_3-SCR catalyst. In the case of NH_3 and H_2 mixtures additions, H_2 enhances the NO_2 production on the Ag/Al_2O_3 catalyst, leading in promoting the “Fast-SCR” like reaction by utilising the available NH_3 mainly at low reaction temperature. The incorporation of the DOC in front of the Ag/Al_2O_3 showed the same effect as it enhanced the NO_2 availability for the SCR process.

Influence of surface structures, subsurface carbon and hydrogen, and surface alloying on the activity and selectivity of acetylene hydrogenation on Pd surfaces: A density functional theory study

Journal of Catalysis, Volume 305, September 2013, Pages 264-276

Bo Yang, Robbie Burch, Christopher Hardacre, Gareth Headdock, P. Hu

The selective hydrogenation of acetylene to ethylene on several Pd surfaces (Pd(1 1 1), Pd(1 0 0), Pd(2 1 1), and Pd(2 1 1)-defect) and Pd surfaces with subsurface species (carbon and hydrogen) as well as a number of Pd-based alloys (Pd–M/Pd(1 1 1) and Pd–M/Pd(2 1 1) (M = Cu, Ag and Au)) are investigated using density functional theory calculations to understand both the acetylene hydrogenation activity and the selectivity of ethylene formation. All the hydrogenation barriers are calculated, and the reaction rates on these surfaces are obtained using a two-step model. Pd(2 1 1) is found to have the highest activity for acetylene hydrogenation while Pd(1 0 0) gives rise to the lowest activity. In addition, more open surfaces result in over-hydrogenation to form ethane, while the close-packed surface (Pd(1 1 1)) is the most selective. However, we also find that the presence of subsurface carbon and hydrogen significantly changes the reactivity and selectivity of acetylene toward hydrogenation on Pd surfaces. On forming surface alloys of Pd with Cu, Ag and Au, the selectivity for ethylene is also found to be changed. A new energy decomposition method is used to quantitatively analyze the factors in determining the changes in selectivity. These surface modifiers are found to block low coordination unselective sites, leading to a decreased ethane production.

The importance of “going nano” for high power battery materials

Journal of Power Sources, Volume 219, 1 December 2012, Pages 217-222

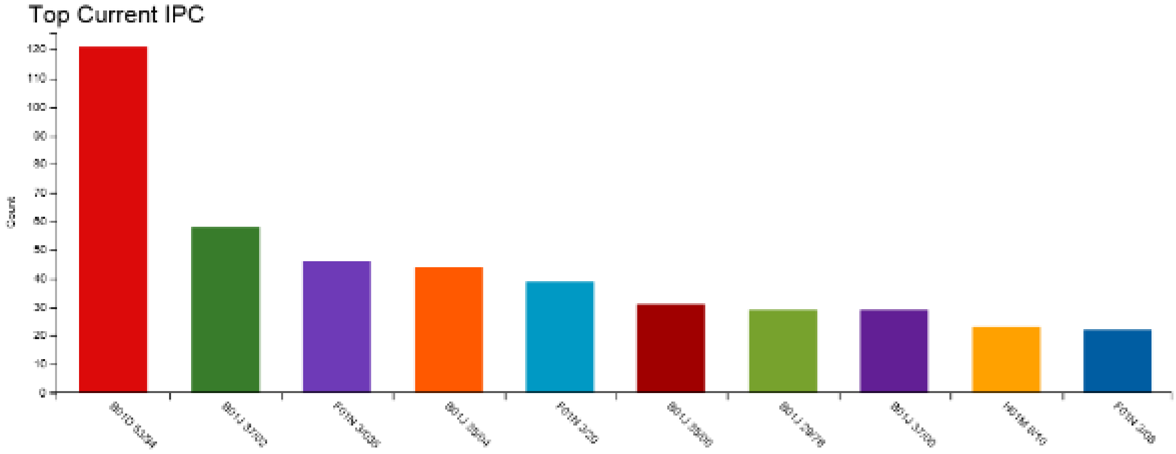
Dominic Bresser, Elie Paillard, Mark Copley, Peter Bishop, Martin Winter, Stefano Passerini

The electrochemical performance of spinel $Li_4Ti_5O_{12}$ (LTO) nanoparticles synthesized by flame spray pyrolysis with an average diameter of approximately 20–30 nm is reported in this manuscript and compared with that of micro-sized LTO particles (1–2 µm) formed by a thermal post-treatment of the nanoparticles. The significantly advanced high rate capability of nano-sized LTO is evidenced by the results from the galvanostatic tests with applied current densities of up to 17.5 A g^{-1}, corresponding to a full (dis-)charge of the cell within less than 40 s. For nano-sized LTO, specific capacities of 115 and 70 mAh g^{-1}were obtained for applied rates of 10 C and 100 C, respectively, thus confirming the essential influence of particle size of lithium titanate on its high rate capability and practical power density. Moreover, a capacity retention of around 94.8% was observed after 1000 cycles at 10 C, presenting LTO nanoparticles synthesized by FSP as highly promising anode material for high power lithium-ion battery applications.

Published Patents (2011-2016)

Number: 438

IPC Codes



B01D Separation
B01J Chemical or physical processes, e.g. catalysis, colloid chemistry; Their relevant apparatus
F01N Gas-flow silencers or exhaust apparatus for machines or engines in general; Gas-flow silencers or exhaust apparatus for internal-combustion engines
H01M Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy

Map of patents Topics

The map of patents topics for Johnson Matthey highlights the most important research fields for the company in the Catalysis sector. In the following, a description of selected areas:

1. Catalysts and processes for exhaust gas treatment
2. Catalysed soot filters and monolith substrates for catalysts deposition
3. Membranes and electrodes for fuel cells applications
4. Catalysed reactors, sorbents for purification processes and zeolites catalysts
5. Catalysts, adsorbers and methods for the production and separation of chemical compounds

BASF SE	
Sector	**Logo**
Chemistry – Fine Chemicals	BASF We create chemistry
Headquarter	
Ludwigshafen, Germany	
Website	
https://www.basf.com/	

Description

BASF SE is the largest chemical producer in the world and is headquartered in Ludwigshafen, Germany. The BASF Group comprises subsidiaries and joint ventures in more than 80 countries and operates six integrated production sites and 390 other production sites in Europe, Asia, Australia, Americas and Africa. Concerning the scientific publications, the activity emerges to be dedicated to a wide range of different topics related with chemistry. The main research area highlighted by the analysis is related with the production of polymeric materials. Also a number of studies on chemical and mechanical properties of these materials have been selected. Another field of research is related with different molecules finding application as raw materials for chemicals production. Other materials have to be mentioned as important fields of scientific research, in particular silica and alumina supports for different application in the chemical industry and carbon fibers, finding many applications, among others in composite production. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that chemicals production strongly characterize the research privately carried out by Basf. The IPC code analysis for selected patents shows that the company is active in continuous research for new molecules both for organic and inorganic compounds. Also processes for chemicals production are an important field for patents publication.

Scientific Papers Affiliation (2011-2016)

Number: 63

Examples of relevant Scientific Publications:

Carbon fibers prepared from ionic liquid-derived cellulose precursors

Materials Today Communications, Volume 7, June 2016, Pages 1-10

Johanna M. Spörl, Antje Ota, Sunghee Son, Klemens Massonne, Frank Hermanutz, Michael R. Buchmeiser

Cellulose derivative fibers were prepared via phosphorylation of cellulose with the ionic liquid (IL) 1,3-dimethylimidazolium methyl-H-phosphonate [MMIM]+[MMP]− in the spinning dope and subsequent fiber formation in a dry–wet-spinning process. The thus obtained precursor fibers were carbonized at different temperatures. In order to receive carbon fibers in high carbonization yields, the degree of substitution (DS) was adjusted. The rheological behavior of the spinning dope was studied and the spinning and carbonization parameters were optimized. Moreover, the precursor fiber tensile and structural properties were compared to pure cellulose fibers. According to thermal analysis coupled with evolved gas analysis (TGA-EGA) of the derivative and pure cellulose fibers, the carbonization yields could be almost doubled via the applied functionalization of cellulose and differences in the relative amounts of released gases during carbonization were studied. Both, precursor and carbon fibers were analyzed by, wide-angle X-ray scattering (WAXS), Raman spectroscopy, scanning electron microscopy (SEM), and tensile testing.

Synthesis of acrylates from olefins and CO2 using sodium alkoxides as bases

*Catalysis Today, **In Press, Corrected Proof**, Available online 13 April 2016*

Simone Manzini, Núria Huguet, Oliver Trapp, Rocco A. Paciello, Thomas Schaub

We have discovered a simple procedure for an industrially applicable alternative synthesis of sodium acrylate via the catalytic carboxylation of ethylene with CO_2. We identified tert-butoxide as suitable base in this catalytic transformation, which was excluded in previous reports, based on investigations on the stability of the corresponding carbonates. In addition, we were able to access a completely zinc-free procedure for the sodium acrylate formation by introducing a regeneration step during the catalyst recycle. Due to the basicity of the sodium tert-butoxide, it was also possible to carboxylate different terminal and internal olefins, which could not be achieved using the previously reported nickel system using phenolate bases.

Controlled synthesis of crosslinked polyamide 6 using a bis-monomer derived from cyclized lysine

Polymer, Volume 55, Issue 23, 5 November 2014, Pages 5991-5997

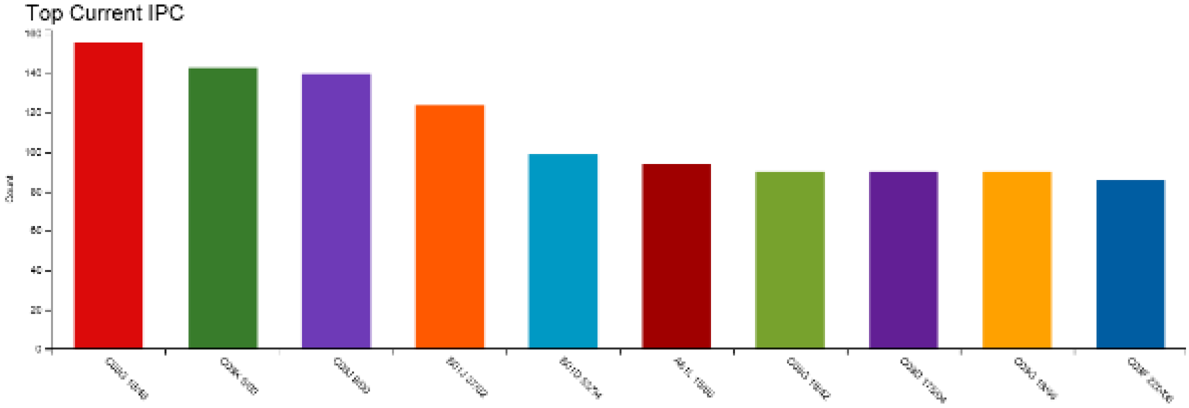
Hassen Bouchékif, Deniz Tunc, Cédric Le Coz, Alain Deffieux, Philippe Desbois, Stéphane Carlotti

The controlled synthesis of polyamide 6 chemical networks by anionic ring-opening copolymerization of ε-caprolactam (CL) with synthesized bis-ε-caprolactam derived from α-amino-ε-caprolactam, *i.e.* N-functionalized α-amino-ε-caprolactam bis-monomers, using sodium ε-caprolactamate as an initiator and hexamethylene-1,6-dicarbamoylcaprolactam as di-functional fast activator was examined in bulk at 140 °C. An urea-based bis-monomer and CL were first shown to copolymerize with a decreasing polymerization rate due to side reactions. On the contrary, quantitative copolymerization of CL with various amounts of bis-N(2-oxo-3-azepanyl)-1,6-tetramethylenediamide, an amide-based bis-monomer, leads to fast kinetics similar to the homopolymerization of CL. Crosslinked PA6 with network exhibiting elastic or viscoelastic behaviors, depending on the amount of crosslinker, were observed and characterized by swelling in hexafluoroisopropanol, dynamic mechanical analysis and rheology measurements. Crystallinity and swelling were shown to decrease with the increasing content of the crosslinking agent.

Published Patents

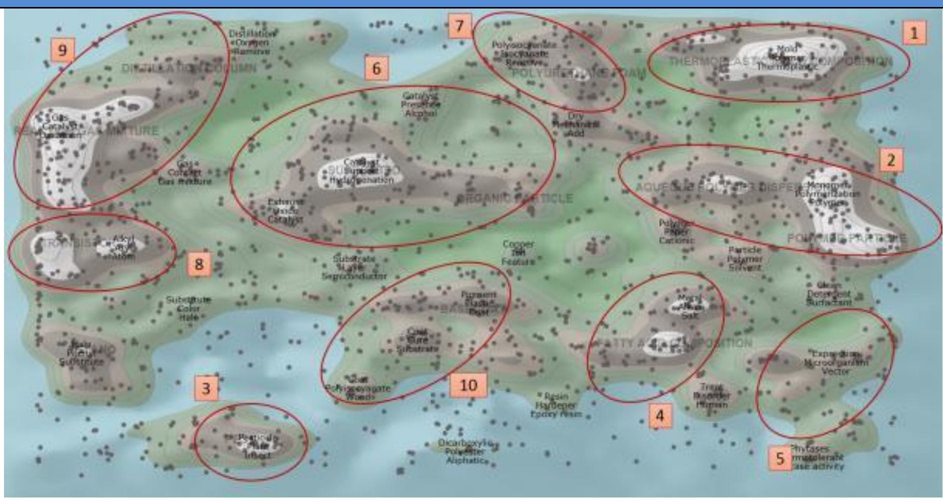
Number: 5981

IPC Codes



C08G Macromolecular compounds obtained otherwise than by reactions only involving unsaturated carbon to carbon bonds
C08K Use of inorganic or non-macromolecular organic substances as compounding ingredients
C08J Working-up; General processes of compounding; After-treatment not covered by subclasses c08b, c08c, c08f, c08g or c08h
B01J Chemical or physical processes, e.g. catalysis, colloid chemistry; Their relevant apparatus
B01D Separation
A61L Methods or apparatus for sterilising materials or objects in general; Disinfection, sterilisation, or deodorisation of air; Chemical aspects of bandages, dressings, absorbent pads, or surgical articles; Materials for bandages, dressings, absorbent pads, or surgical articles
C09D Coating compositions, e.g. paints, varnishes, lacquers; Filling pastes; Chemical paint or ink removers; Inks; Correcting fluids; Woodstains; Pastes or solids for colouring or printing; Use of materials therefor
C08F Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds

Map of patents Topics



The map of patents topics for Basf highlights the most important research fields for the company in the Fine Chemicals sector. In the following, a description of selected areas:
1. Thermoplastic materials
2. Polymerization and monomer/polymer preparation
3. Compounds used as pesticides: production and composition
4. Methods for producing metal salts and other metal-compounds
5. Bio-chemistry and enzyme synthesis
6. Catalysts composition and sharacterization
7. Polyurethane foam chemical characterization
8. Organic compounds for electronic applications
9. Reactions and separation processes in gaseous and liquid states
10. Coatings composition

AIR LIQUIDE

Sector	Logo

Chemistry – Fine Chemicals	AIR LIQUIDE
Headquarter	
Paris, France	
Website	
www.airliquide.com	

Description

Air Liquide is a French multinational company which supplies industrial gases and services to various industries including medical, chemical and electronic manufacturers. Founded in 1902, it is the world's first largest supplier of industrial gases by revenues and has operations in over 80 countries.
Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate the properties of steels, their surface characterization and their mechanical properties under different conditions. In particular steels properties are evaluated in case of interactions with several gaseous compounds (hydrogen, water vapour, carbon dioxide, methane, gas mixtures, etc.) in order to optimize the materials for industrial applications such as gas storage and transport.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that, according with the main activity of the company, liquefaction and separation of gases appear to be the main fields of application of published patents, as is possible to infer from IPC codes analysis. The analysis of map of patents topics shows that also rare earths and metalworking processes appears to important fields of research.

Scientific Papers Affiliation (2011-2016)

Number: 25

Examples of relevant Scientific Publications:

Hydrogen storage – Industrial prospectives

International Journal of Hydrogen Energy, Volume 37, Issue 22, November 2012, Pages 17364-17372

Hervé Barthélémy
The topic of this paper is to give an historical and technical overview of hydrogen storage vessels and to detail the specific issues and constraints of hydrogen energy uses. Hydrogen, as an industrial gas, is stored either as a compressed or as a refrigerated liquefied gas. Since the beginning of the last century, hydrogen is stored in seamless steel cylinders. At the end of the 60 s, tubes also made of seamless steels were used; specific attention was paid to hydrogen embrittlement in the 70 s. Aluminum cylinders were also used for hydrogen storage since the end of the 60 s, but their cost was higher compared to steel cylinders and smaller water capacity. To further increase the service pressure of hydrogen tanks or to slightly decrease the weight, metallic cylinders can be hoop-wrapped. Then, with specific developments for space or military applications, fully-wrapped tanks started to be developed in the 80 s. Because of their low weight, they started to be used in for portable applications: for vehicles (on-board storages of natural gas), for leisure applications (paint-ball) etc.… These fully-wrapped composite tanks, named types III and IV are now developed for hydrogen energy storage; the requested pressure is very high (from 700 to 850 bar) leads to specific issues which are discussed. Each technology is described in term of materials, manufacturing technologies and approval tests. The specific issues due to very high pressure are depicted. Hydrogen can also be stored in liquid form (refrigerated liquefied gases). The first cryogenic vessels were used in the 60 s. In the following, the main characteristics of this type of storage will be indicated.

CO2-based methanol and DME – Efficient technologies for industrial scale production

Catalysis Today, Volume 171, Issue 1, 10 August 2011, Pages 242-250

Florian Pontzen, Waldemar Liebner, Veronika Gronemann, Martin Rothaemel, Bernd Ahlers
The conversion of CO_2 with H_2 to methanol (MeOH) over a commercial Cu/ZnO catalyst (Süd-Chemie, Germany) was studied under process conditions. The obtained results showed a good stability of the catalytic system and a large potential for a CO_2 emission reduction with simultaneous production of MeOH or dimethyl ether (DME) as bulk chemicals or alternative fuels. If H_2 is obtained from renewable or CO_2-neutral sources (e.g. biomass, solar, wind or nuclear energy), respectively, a potentially CO_2-neutral cycle is possible. Compared to the conventional synthesis gas based technologies like the Lurgi MegaMethanol® process, the CO_2-based process shows lower productivities. However, since the overall reaction is less exothermic, lower temperature peaks and lower byproduct contents are found at similar process conditions. The higher purity is beneficial for further chemical conversions, like the DME synthesis. In the Lurgi MegaDME® technology, DME is produced efficiently in terms of costs and energy demand and can be used as alternative fuel for diesel engines. The MegaDME technology, based on the Lurgi MegaMethanol® process, allows overall capacities of up to 1.5 million t a^{-1} DME in a single process train from syngas generation via Methanol synthesis, to DME synthesis and product purification without parallelized equipment.

Fatigue crack initiation and growth in a CrMo steel under hydrogen pressure

International Journal of Hydrogen Energy, Volume 40, Issue 47, 21 December 2015, Pages 17021-17030

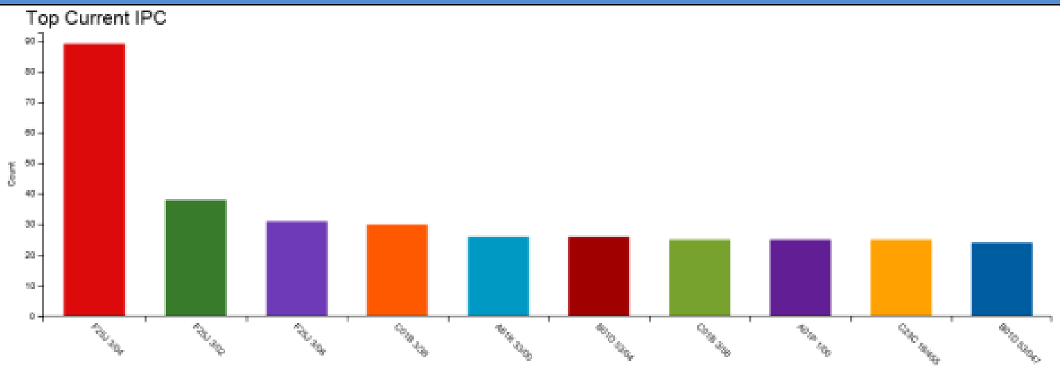
L. Briottet, I. Moro, M. Escot, J. Furtado, P. Bortot, G.M. Tamponi, J. Solin, G. Odemer, C. Blanc, E. Andrieu
Along the hydrogen supply chain, metallic components, such as pressure vessels, compressors and valves, are facing high pressure hydrogen gas. The object of this paper is to address microstructural as well as mechanical aspects of fatigue crack initiation and growth at room temperature in a quenched and tempered (Q&T) low alloy steel under hydrogen pressure in the range 0.5–35 MPa. For such steel, the need to perform tests in-situ under hydrogen pressure is required. The influence of hydrogen gas on the total life in terms of crack initiation and crack propagation is analyzed. The experimental techniques developed to detect crack initiation in a pressure vessel under hydrogen pressure are presented. Thanks to these technical developments the influence of hydrogen gas on the total life duration including crack initiation and crack propagation is analyzed. It is shown that the effect of hydrogen pressure on crack initiation is

important. At constant load ratio, the hydrogen pressure effect on fatigue crack growth (FCG) is dependent on the loading amplitude (in terms of ΔK). These results related to cracking behavior are enriched with information on fracture surfaces appearance. The results presented have been achieved within the European project MATHRYCE [1] dedicated to Material Testing and Recommendations for Hydrogen Components under fatigue. They are part of a process necessary to give a scientific background to the development of a design methodology where hydrogen enhanced fatigue damage is taken into account.

Published Patents

Number: 869

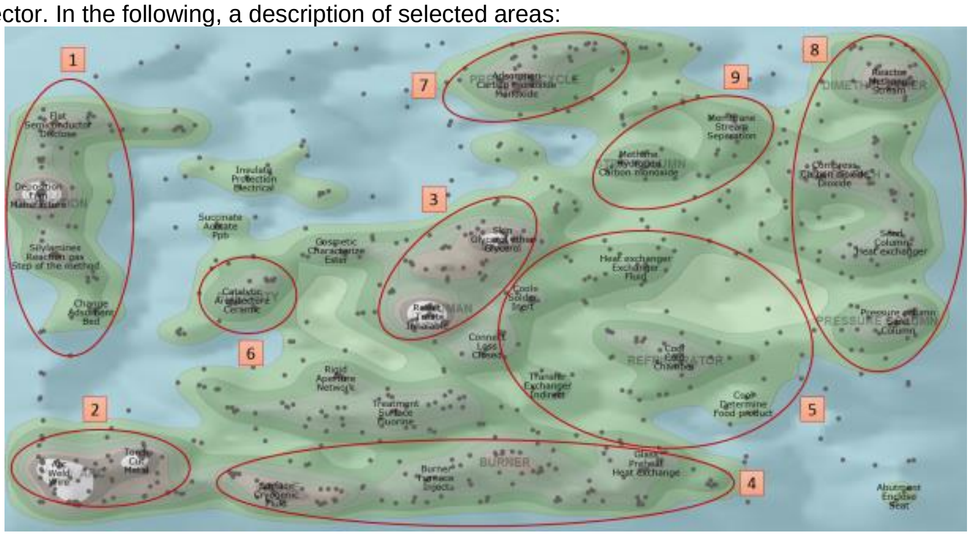
IPC Codes



F25J Liquefaction, solidification, or separation of gases or gaseous mixtures by pressure and cold treatment
C01B Non-metallic elements; Compounds thereof
A61K Preparations for medical, dental or toilet purposes
B01D Separation
A01P Biocidal, pest repellant, pest attractant or plant growth regulatory activity of chemical compounds or preparations
C23C Coating metallic material; Coating material with metallic material; Surface treatment of metallic material by diffusion into the surface, by chemical conversion or substitution; Coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapour deposition, in general

Map of patents Topics

The map of patents topics for Air Liquide highlights the most important research fields for the company in the Fine Chemicals sector. In the following, a description of selected areas:



1. Rare earths and other elements: precursors and deposition processes
2. Metalworking processes (mainly arc welding)
3. Raw ingredients for medical applications, molecular compounds for human health
4. 5. Heat exchangers and burners: materials and design
6. Catalysts and ceramic materials as catalyst supports
7. Adsorption and purification processes and materials
8. 9. Liquefaction and gas separation processes

ARKEMA

Sector	Logo
Chemistry – Bio-Plastics	
Headquarter	

Colombes, France	
Website	
http://www.arkema.com/	

Description
Arkema is a leading specialty chemicals and advanced materials company headquartered in Colombes, near Paris, France. Arkema is organized into three business segments: Coating Solutions, Industrial Chemicals and Performance Products. Concerning the scientific publications, the activity emerges to be dedicated to two different areas. On one hand, researches are related with polymers production from biomass and the evaluation of their properties. On the other, researches analyse properties and production procedures of wood-polymer composites for different applications. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the fields of innovation mostly investigated by Arkema belongs to polymers production and new bio-based materials, as is possible to infer from the IPC code analysis. The other field characterising Arkema patent portfolio is related to composites (layered products), in particular composed by wood and polymeric sheets.
Scientific Papers Affiliation (2011-2016)
Number: 12
Examples of relevant Scientific Publications:

Mechanical and interfacial properties of wood and bio-based thermoplastic composite

Composites Science and Technology, Volume 72, Issue 14, 17 September 2012, Pages 1733-1740

Fabien Sliwa, Nour-eddine El Bounia, Fatima Charrier, Gérard Marin, Frédéric Malet

The aim of this investigation was to study a new family of wood polymer composites with thermoplastic elastomer matrix (pebax® copolymers) instead of commonly used WPC matrices. These copolymers are polyether-b-amide thermoplastic elastomers which present an important elongation at break and a melting point below 200 °C to prevent wood fibers degradation during processing. Moreover these polymers are synthesized from renewable resources and they present a hydrophilic character which allow them to interact with wood fibers. We have used two pebax® grade with different hardness and three types of wood fibers, so the influence of the matrix and wood fibers characteristics were evaluated. Composites were produced using a laboratory-size twin screw extruder to obtain composite pellets prior to injection moulding into tensile test samples. We have evaluated fibers/matrix interaction by differential scanning calorimetry (DSC), infrared spectroscopy (IRTF) and scanning electron microscopy (SEM). Then, the mechanical properties, through tensile test, were assessed. We also observed fibers dispersion into the matrix by tomography X. DSC, IRTF and SEM measurements confirmed the presence of strong interface interactions between polymer and wood. These interactions lead to good mechanical properties of the composites with a reinforcement effect of wood fibers due also to a good dispersion of fibers into the matrix without agglomerate.

Influence of surface acid–base properties of zirconia and titania based catalysts on the product selectivity in gas phase dehydration of glycerol

Catalysis Communications, Volume 17, 5 January 2012, Pages 23-28

Dušan Stošić, Simona Bennici, Jean-Luc Couturier, Jean-Luc Dubois, Aline Auroux

The aim of this investigation was to study a new family of wood polymer composites with thermoplastic elastomer matrix (pebax® copolymers) instead of commonly used WPC matrices. These copolymers are polyether-b-amide thermoplastic elastomers which present an important elongation at break and a melting point below 200 °C to prevent wood fibers degradation during processing. Moreover these polymers are synthesized from renewable resources and they present a hydrophilic character which allow them to interact with wood fibers. We have used two pebax® grade with different hardness and three types of wood fibers, so the influence of the matrix and wood fibers characteristics were evaluated. Composites were produced using a laboratory-size twin screw extruder to obtain composite pellets prior to injection moulding into tensile test samples. We have evaluated fibers/matrix interaction by differential scanning calorimetry (DSC), infrared spectroscopy (IRTF) and scanning electron microscopy (SEM). Then, the mechanical properties, through tensile test, were assessed. We also observed fibers dispersion into the matrix by tomography X. DSC, IRTF and SEM measurements confirmed the presence of strong interface interactions between polymer and wood. These interactions lead to good mechanical properties of the composites with a reinforcement effect of wood fibers due also to a good dispersion of fibers into the matrix without agglomerate.

Glycerol conversion to acrylonitrile by consecutive dehydration over WO3/TiO2 and ammoxidation over Sb-(Fe,V)-O

Applied Catalysis B: Environmental, Volumes 132–133, 27 March 2013, Pages 170-182

Carsten Liebig, Sébastien Paul, Benjamin Katryniok, Cyrille Guillon, Jean-Luc Couturier, Jean-Luc Dubois, Franck Dumeignil, Wolfgang F. Hoelderich

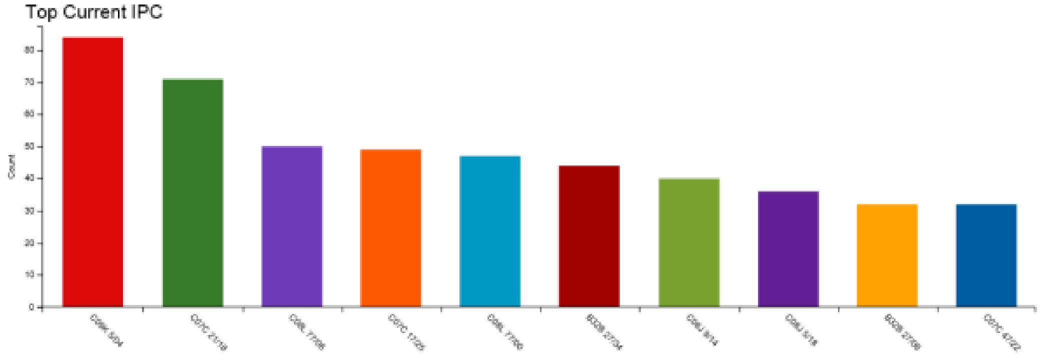
The indirect ammoxidation of glycerol to acrylonitrile *via* intermediate formation of acrolein was studied using a tandem reactor coupling a dehydration step with an ammoxidation step. For the first step of dehydration of glycerol to acrolein, we used a previously optimized WO_3/TiO_2 catalyst, while Sb-V-O or Sb-Fe-O catalysts were developed and used for the subsequent ammoxidation step. Especially, the Sb-Fe-O catalysts were found highly selective and thus were more-deeply investigated. The corresponding catalysts were characterized by nitrogen physisorption, X-ray powder diffraction, thermogravimetric analysis, X-ray photoelectron spectroscopy, and temperature-programmed reduction in the presence of H_2. We found that the presence of a $FeSbO_4$ mixed phase on the synthesized samples was correlated to a high selectivity to acrylonitrile. Further, we observed an increase in selectivity to acrylonitrile with the reaction time, which was explained by the progressive formation of additional amounts of $FeSbO_4$ on the catalysts during the reaction.

Finally, the reaction parameters (temperature, catalyst amount, molar NH_3/AC ratio and molar O_2/AC ratio) for the catalyst with an Sb/Fe molar ratio of 0.6 were optimized, whereby a maximum yield in acrylonitrile of 40% (based on glycerol) could be achieved.

Published Patents (2011-2016)

Number: 1039

IPC Codes



C09K Materials for applications not otherwise provided for; Applications of materials not otherwise provided for
C07C Acyclic or carbocyclic compounds
C08L Compositions of macromolecular compounds
B32B Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form
C08J Working-up; General processes of compounding; After-treatment not covered by subclasses c08b, c08c, c08f, c08g or c08h

Map of patents Topics

The map of patents topics for Arkema highlights the most important research fields for the company in the Bio-plastics sector. In the following, a description of selected areas:
1. Methods to produce bio-molecules from biomasses
2. Methods and synthesis of different compounds (amino acids and esters) froim natural sources
3. Organic compounds: composition and processes
4. Fuel cells membrane composition and methods for preparing
5. 6. Composites
7. Monomers and copolymers
8. Heat transfert fluids
9. Catalysts

NOVAMONT	
Sector	**Logo**
Chemistry – Bio-Plastics	
Headquarter	
Novara, Italy	
Website	
http://www.novamont.com/	

Description

Novamont S.p.A. is an Italian chemical industry, active in the sector of bioplastics. It was founded in 1990 by the Montedison Group. Its core product is Mater-Bi, a thermoplastic biodegradable material produced from maize starch. Concerning the scientific publications, the number of available material is limited. This is probably due to the strong competition in this sector and to the high level of awareness to keep processes and products information inside the company, avoiding the diffusion of information to other market competitors. The scientific publication available are about environmental impacts of bio-based polymers, and in particular their biodegradation in different conditions. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the main IPC code for patents publication correspond with the composition of macromolecular compounds from natural biotic resources. Also some publication related with innovative solutions for packaging are reported.

Scientific Papers Affiliation (2011-2016)

Number: 4

Examples of relevant Scientific Publications:

Environmental profile of a bio-based and biodegradable foamed packaging prototype in comparison with the current benchmark

Journal of Cleaner Production, Volume 102, 1 September 2015, Pages 493-500

Francesco Razza, Francesco Degli Innocenti, Antonio Dobon, Cesar Aliaga, Carmen Sanchez, Mercedes Hortal

post-consumer cushioning packaging waste made from expanded polystyrene or other conventional polymers is rarely recycled because of technical and economic constraints. Expanded packaging can also be made from renewable and biodegradable raw materials. In this case, the use of a renewable feedstock, such as starch, can reduce the oil dependence and biodegradability can enable the organic recycling of the final product. In this study, a life cycle assessment was performed on a prototype (a port-hole spacer for washing machines) developed in a research project by applying a biodegradable plastic expanded by means of microwave technology. Port-hole spacers for washing machines are mainly made from expanded polystyrene. Life cycle assessment results indicate that the prototype is characterized by a lower consumption of non-renewable energy resources (−50%) and lower greenhouse gas emissions (−60%) compared to the benchmark (expanded polystyrene packaging). This was mainly due to the use of a renewable feedstock (starch). The photochemical ozone creation potential resulted significantly lower (−90%) thanks to the abolition of the expanding agent (i.e. pentane) used in the polystyrene expansion process. The robustness of the results was assessed through data quality checks and a Monte Carlo simulation. A sensitivity analysis showed that the environmental profile of the prototype is mainly affected by the Land Use Change for global warming potential and by the type of starch used for eutrophication and acidification. The type of electricity used (i.e. fossil-based or renewable) for the microwave expansion process also affects the results. The use of biodegradable packaging makes it possible to increase the level of recovery by means of organic recycling. Considering the organic recycling rate in the countries where the washing machines are supplied it has been estimated that the cushioning packaging waste that goes to landfill would go from 52% (current scenario with expanded polystyrene packaging) to 37%, whereas recycling would go from 0.5% (mechanical recycling of expanded polystyrene) to 40% (organic recycling of the prototype). This paper shows that the use of a packaging system potentially suitable for inclusion in the industrial composting process opens new routes for waste treatment, thus increasing diversion from landfill. It can be argued that the combination of the use of renewable resources, and the possibility to get a compostable packaging product give rise to interesting future outlook. On one site a reduction of oil dependence can be achieved and, on the other side, the diffusion of packaging products not easy to recycle as post-consume waste and characterized by a very long persistence in the environment is reduced. This paper contributes to the current discussion on the benefits of bio-based and bio-degradable materials, whose production volumes are steadily increasing.

Kinetics of monomer biodegradation in soil

Journal of Environmental Management, Volume 93, Issue 1, January 2012, Pages 31-37

Michela Siotto, Elena Sezenna, Sabrina Saponaro, Francesco Degli Innocenti, Maurizio Tosin, Luca Bonomo, Valeria Mezzanotte

In modern intensive agriculture, plastics are used in several applications (i.e. mulch films, drip irrigation tubes, string, clips, pots, etc.). Interest towards applying biodegradable plastics to replace the conventional plastics is promising. Ten monomers, which can be applied in the synthesis of potentially biodegradable polyesters, were tested according to ASTM 5988-96 (standard respirometric test to evaluate aerobic biodegradation in soil by measuring the carbon dioxide evolution): adipic acid, azelaic acid, 1,4-butanediol, 1,2-ethanediol, 1,6-hexanediol, lactic acid, glucose, sebacic acid, succinic acid and terephthalic acid. Eight replicates were carried out for each monomer for 27–45 days. The numerical code AQUASIM was applied to process the CO_2 experimental data in order to estimate values for the parameters describing the different mechanisms occurring to the monomers in soil: i) the first order solubilization kinetic constant, K_{sol} (d^{-1}); ii) the first order biodegradation kinetic constant, K_b (d^{-1}); iii) the lag time in biodegradation, t_{lag} (d); and iv) the carbon fraction biodegraded but not transformed into CO_2, Y (−). The following range of values were obtained: [0.006 d^{-1}, 6.9 d^{-1}] for K_{sol}, [0.1 d^{-1}, 1.2 d^{-1}] for K_b, and [0.32–0.58] for Y; t_{lag} was observed for azelaic acid, 1,2-ethanediol, and terephthalic acid, with estimated values between 3.0 e 4.9 d.

Environmental implications of crude glycerin used in special products for the metalworking industry and in biodegradable mulching films

Industrial Crops and Products, Volume 75, Part A, 30 November 2015, Pages 29-35

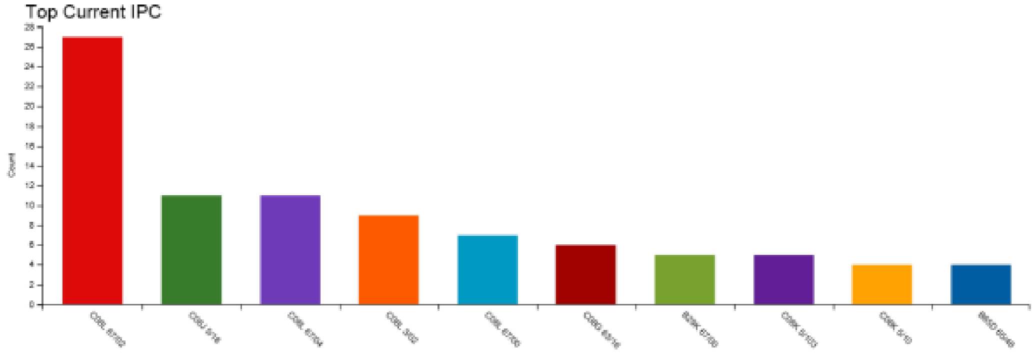
Lorenzo D'Avino, Gianni Rizzuto, Sara Guerrini, Marco Sciaccaluga, Eleonora Pagnotta, Luca Lazzeri

Crude glycerin from biodiesel supply chain can replace synthetic glycerol or other chemicals in industrial applications. To improve sustainability according to the biorefinery perspective, a purification phase will be carried out only if it is really necessary to reach standards for industrial processes or final products. In metal working, the use of crude glycerin-based hydraulic fluids, replacing mineral oil-based and glycol-based ones, has fulfilled industrial requirements and made it possible to increase (i) worker safety because of its non-flammability; (ii) biodegradability and (iii) time-life of the product due to anti-wear properties; in addition, post-use waste management will be simplified, due to the possibility to declassify fluids as special waste. In biodegradable mulching films, the replacement of synthetic glycerol was successful because it made it possible both to maintain the same compounding conditions and to obtain the same yields and film biodegradation in an agronomic trial on muskmelon. The benefits compared with conventional polyethylene films are the same as conventional readily biodegradable films. The key parameters in the analytical composition of glycerin concerning specific industrial applications are discussed; the environmental benefits in metal working fluid formulation and in mulching film compounding are then assessed.

Published Patents (2011-2016)

Number: 58

IPC Codes



C08L Compositions of macromolecular compounds
C08J Working-up; General processes of compounding; After-treatment not covered by subclasses c08b, c08c, c08f, c08g or c08h
C08G Macromolecular compounds obtained otherwise than by reactions only involving unsaturated carbon to carbon bonds
B29K indexing scheme associated with subclasses B29B, B29C or B29D, relating to moulding materials
C08K Use of inorganic or non-macromolecular organic substances as compounding ingredients
B65D Containers for storage or transport of articles or materials, e.g. bags, barrels, bottles, boxes, cans, cartons, crates, drums, jars, tanks, hoppers, forwarding containers; Accessories, closures, or fittings therefor; Packaging elements; Packages

Map of patents Topics

The map of patents topics for Arkema highlights the most important research fields for the company in the Bio-plastics sector. In the following, a description of selected areas:
1. Biodegradable polyester of natural origin: composition and production processes
2. Vegetable oils for elastomers composition
3. Biodegradable foamed products
4. Process for the production of bio-oligomers
5. Biodegradable polymer composition

LAFARGE-HOLCIM

Sector	Logo

Building Materials - Cement	LafargeHolcim
Headquarter	
Jona, Switzerland	
Website	
http://www.lafargeholcim.com/	

Description

Lafarge-Holcim is a manufacturer of building materials, primarily cement, aggregates and concrete. It was formed by the merger on 2015 of cement companies Holcim and Lafarge. The new company has a manufacturing capacity of 368.5 million tons a year.
Both the scientific publication and the published patents analyses collected data for Lafarge and Holcim separate companies, together with the merged company Lafarge-Holcim, existing from 2015 on.
Concerning the scientific publications, the activity emerges to be strongly dedicated to concrete, cement and mortars. In particular a field of research continuously investigated concerns mechanical properties of concrete, especially with numerical simulations approach. Another returning topic is related to hydration state in cementitious materials and cement microstructure. Also some publication regarding the recycling of concrete and aggregates, glass wastes or different cementitious materials have been published.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that Lafarge-Holcim turns its attention mainly on the composition of cementitious materials. This objective appears clear both in the IPC code analysis and in the map of patents topics, reported in the following. Another important field of publication for selected patents is about industrial production and processing of cementitious materials.

Scientific Papers Affiliation (2011-2016)

Number: 68 (3 Lafarge-Holcim; 47 Lafarge; 18 Holcim)

Examples of relevant Scientific Publications:

Performance of recycled aggregate concrete based on a new concrete recycling technology

Construction and Building Materials, Volume 95, 1 October 2015, Pages 243-256

Somayeh Lotfi, Manuel Eggimann, Eckhard Wagner, Radosław Mróz, Jan Deja

One of the main environmental challenges in the construction industry is a strong social force to decrease the bulk transport of the building materials in urban environments. Considering this fact, applying more in-situ recycling technologies for Construction and Demolition Waste (CDW) is an urgent need. The European C2CA project develops a novel concrete recycling technology that can be performed purely mechanically and in situ. The technology consists of a combination of smart demolition, gentle grinding of the crushed concrete in an autogenous mill, and a novel dry classification technology called ADR to remove the fines. The feasibility of this recycling process was examined in demonstration projects involving in total 20,000 tons of End of Life (EOL) concrete from two office towers in Groningen, The Netherlands. This paper concentrates on the second demonstration project of C2CA, where EOL concrete was recycled on an industrial site. After recycling, the properties of the produced Recycled Aggregate (RA) were investigated, and results are presented. An experimental study was carried out on mechanical and durability properties of produced Recycled Aggregate Concrete (RAC) compared to those of the Natural Aggregate Concrete (NAC). The aim was to understand the importance of RA substitution, w/c ratio and type of cement to the properties of RAC. In this regard, two series of reference concrete with strength classes of C25/30 and C45/55 were produced using natural coarse aggregates (rounded and crushed) and natural sand. The RAC series were created by replacing parts of the natural aggregate, resulting in series of concrete with 0%, 20%, 50% and 100% of RA. Results show that the concrete mix design and type of cement have a decisive effect on the properties of RAC. On the other hand, the substitution of RA even at a high percentage replacement level has minor and manageable impact on the performance of RAC. This result is a good indication towards the feasibility of using RA in structural concrete by modifying the mix design and using a proper type of cement.

Modeling the relationship between the shape and flowing characteristics of processed sands

Construction and Building Materials, Volume 104, 1 February 2016, Pages 235-246

Jérôme Tierrie, Hassan Baaj, Pierre Darmedru

The quality of processed sands is a critical issue for several construction applications (asphalt mixes, concrete, granular layers). The sand flow test is commonly used to control this quality. High accuracy video-capturing equipment is now also used to characterize the shape of aggregates. The objective of this study is to model the relationship between the actual shape of sand particles, measured using a video-capturing equipment, to the sand's flowing time in a hopper, in order to eliminate the need for sand flow laboratory measurements. Several samples of processed and natural sands were tested using on the sand flow test equipment used in the European standards. The shape of the particles was then analysed using a video-capturing equipment. A simple empirical relation was found between the shape factor of particles by Beverloo's law and the actual shape of particles, characterized by a shape index defined in this study. The results were then confronted with the sand test equipment specified in the ASTM standards, to validate this empirical relation. The coefficients in this new relation had to be experimentally determined according to definition of the particle's diameter, the video system, and the sand flow test equipment. The discharge coefficient was also taken into consideration. This is mainly experimental work; the physical explanation of this relation would have to be analysed in greater depth in the future.

NOx de-pollution by hardened concrete and the influence of activated charcoal additions

Cement and Concrete Research, Volume 42, Issue 10, October 2012, Pages 1348-1355

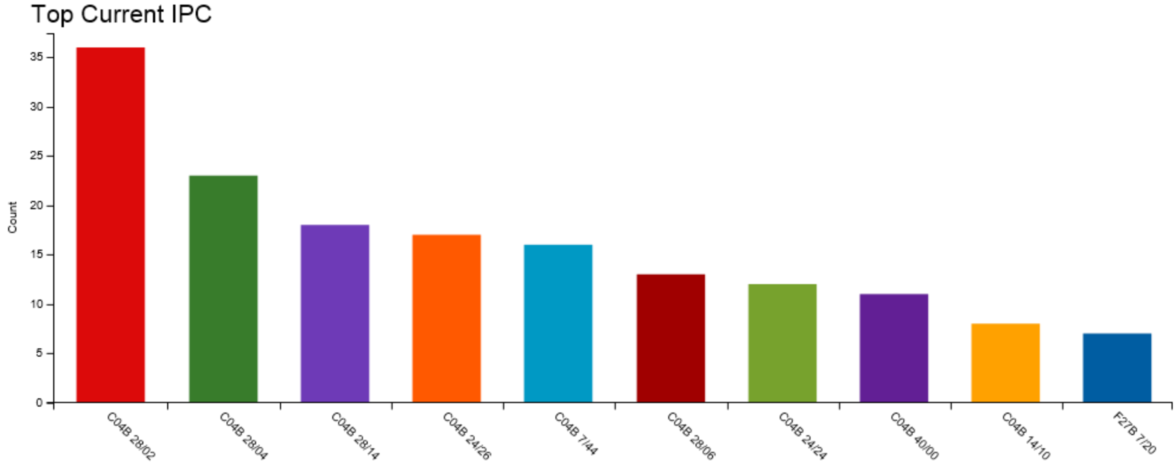
M. Horgnies, I. Dubois-Brugger, E.M. Gartner

The atmospheric pollution by nitrogen oxides affects the health of millions of people located in urban areas. Our work demonstrates that, even in the absence of photocatalysts, concrete walls can strongly absorb NO_2 and limit the intensity of pollution peaks. Our results show that concretes can continuously absorb a significant fraction of NO_2 from the surrounding atmosphere over long periods, probably due to a reaction with strongly alkaline cement hydrates. Moreover, the introduction of a small amount of activated charcoal into the concrete mix can significantly enhance and prolong this NO_2 absorption without greatly increasing total porosity or decreasing strength. We hypothesize that the NO_2 is adsorbed irreversibly by a neutralization reaction with the alkaline aqueous solution covering the surfaces of the hydrates and the activated charcoal. Simple calculations suggest that walls made of activated charcoal concrete could ameliorate the problem of NO_2 pollution peaks in road tunnels and parking garages.

Published Patents (2011-2016)

Number: 185

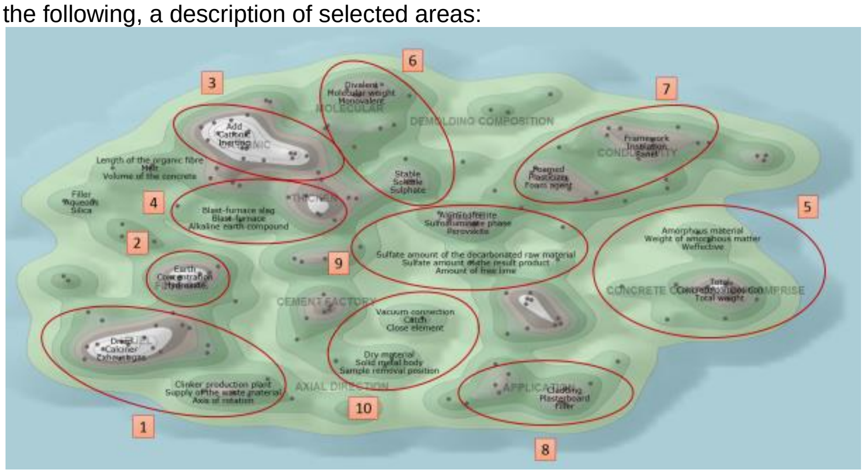
IPC Codes



C04B Lime; Magnesia; Slag; Cements; Compositions thereof, e.g. mortars, concrete or like building materials; Artificial stone; Ceramics; Refractories; Treatment of natural stone
F27B Furnaces, kilns, ovens, or retorts in general; Open sintering or like apparatus

Map of patents Topics

The map of patents topics for Lafarge-Holcim highlights the most important research fields for the company in the Cement sector. In the following, a description of selected areas:



1. Methods and devices for reprocessing organic waste materials in clinker production process
2. Carbon dioxide removal procedures
3. Methods for producing building mixtures including hydraulic and pozzolan materials
4. Clay-cointaining cementitious materials composition
5. Concrete composition
6. Hydraulic binders composition
7. 8. Foamed concrete and panels (sound adsorbing and insulate)
9. Additives for cement
10. Forming and moulding processes for concrete

HEILDBERGCEMENT AG

Sector	Logo
Building Materials - Cement	
Headquarter	

Heidelberg, Germany

Website

http://www.heidelbergcement.com/

Description

Heidelbergcement AG is a German multinational building materials company headquartered in Heidelberg, Germany. On 1 July 2016, Heidelbergcement AG completed the acquisition of a 45% shareholding in Italcementi S.p.A. becoming one of the leaders in the global market of aggregates, cement and concrete. Both the scientific publication and the published patents analyses collected data for Heidelbergcement and for Italcementi companies.
Concerning the scientific publications, the activity emerges to be strongly dedicated to cement production. More in detail, it is focused on new typologies of cements and concrete, researching new compositions of cementitious materials and new ways to recycle waste materials. Also processed sands appear to be a returning topic of research.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the composition of cementitious material strongly characterizes the majority of published patents. In particular the addition of polymeric molecules to cement appear to be an important field of innovation, together with the developing of innovative photocatalytic cements.

Scientific Papers Affiliation (2011-2016)

Number: 33 (22 Heidelbergcement; 11 Italcementi)

Examples of relevant Scientific Publications:

Development of an eco-friendly Ultra-High Performance Concrete (UHPC) with efficient cement and mineral admixtures uses

Cement and Concrete Composites, Volume 55, January 2015, Pages 383-394

R. Yu, P. Spiesz, H.J.H. Brouwers

This paper addresses the development of an eco-friendly Ultra-High Performance Concrete (UHPC) with efficient cement and mineral admixtures uses are investigated. The modified Andreasen & Andersen particle packing model is utilized to achieve a densely compacted cementitious matrix. Fly ash (FA), ground granulated blast-furnace slag (GGBS) and limestone powder (LP) are used to replace cement, and their effects on the properties of the designed UHPC are analysed. The results show that the influence of FA, GGBS or LP on the early hydration kinetics of the UHPC is very similar during the initial five days, while the hydration rate of the blends with GGBS is mostly accelerated afterwards. Moreover, the mechanical properties of the mixture with GGBS are superior, compared to that with FA or LP at both 28 and 91 days. Due to the very low water amount and relatively large superplasticizer dosage in UHPC, the pozzolanic reaction of FA is significantly retarded. Additionally, the calculations of the embedded CO_2 emission demonstrate that the cement and mineral admixtures are efficiently used in the developed UHPC, which reduce its environmental impact compared to other UHPCs found in the literature.

Development of Ultra-Lightweight Fibre Reinforced Concrete applying expanded waste glass

Journal of Cleaner Production, Volume 112, Part 1, 20 January 2016, Pages 690-701

R. Yu, D.V. van Onna, P. Spiesz, Q.L. Yu, H.J.H. Brouwers

This paper presents the development of Ultra-Lightweight Fibre Reinforced Concrete (ULFRC) applying expanded waste glass in form of lightweight aggregates. The modified Andreasen & Andersen particle packing model and an optimal amount of polypropylene fibres are utilized in the design and production of ULFRC. The density, mechanical properties and thermal conductivity of the developed ULFRC are measured and analysed. The ULFRC with a dry density of 750 kg/m^3 is produced. It is found that hybridization and an optimized amount of polypropylene fibres are beneficial for improving the mechanical properties of ULFRC. Moreover, compared to the other lightweight concretes with the same density, the ULFRC developed in this study has improved mechanical properties and lower thermal conductivity, therefore it can be utilized as a new material for the production of floating structures, insulating elements or even for load bearing applications. As sustainable development is currently a crucial global issue and various industries are striving to save the energy and lower the environmental impact, the developed ULFRC has a good prospect in the near future.

Laboratory Assessment of the Performance of New Hydraulic Mortars for Restoration

Procedia Chemistry, Volume 8, 2013, Pages 20-27

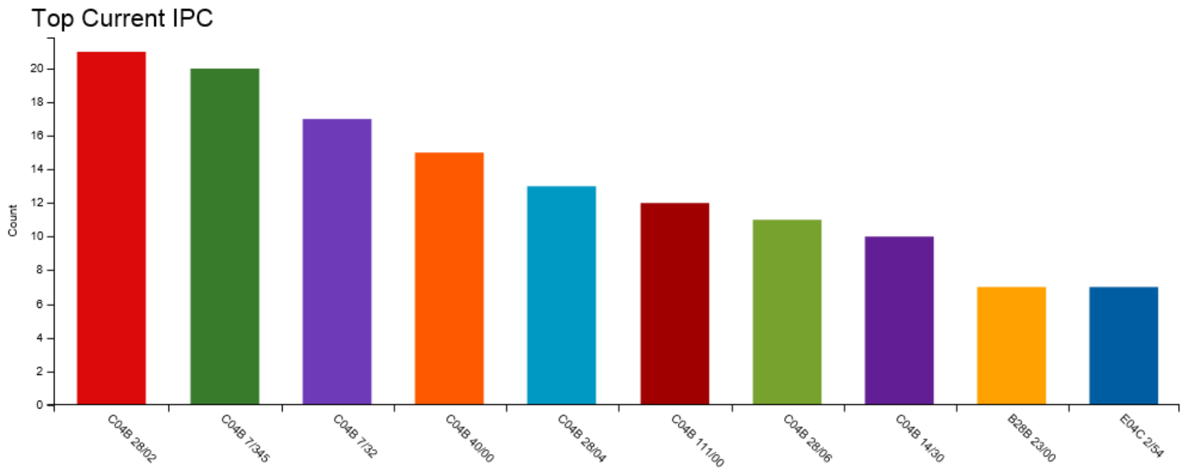
Nadia Bianco, Angela Calia, Giampiero Denotarpietro, Piero Negro

This study concerns the experimental activity for the set-up of new hydraulic mortars for restoration. Different mix were realized with specific attention to the needs required in the restoration field. Two new formulations were selected and their physical-mechanical properties were determined following the standards tests for mortars characterization. The durability of the new products was evaluated by salt ageing tests as well as their performance with respect to the migration of the saline solution within the stone/mortar system in terms of harmfulness.

Published Patents (2011-2016)

Number: 96

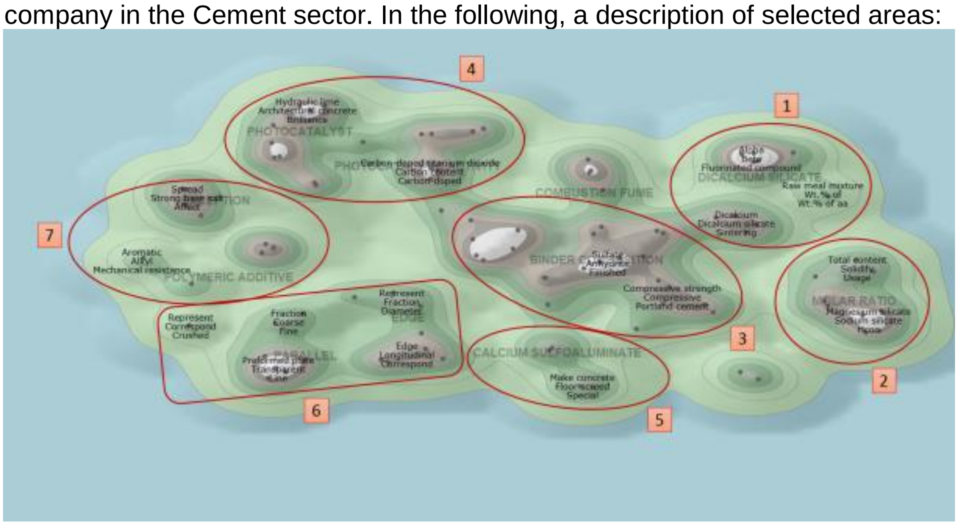
IPC Codes



C04B Lime; Magnesia; Slag; Cements; Compositions thereof, e.g. mortars, concrete or like building materials; Artificial stone; Ceramics; Refractories; Treatment of natural stone
B28B Shaping clay or other ceramic compositions, slag, or mixtures containing cementitious material, e.g. plaster

Map of patents Topics

The map of patents topics for Heidelbergcement (and Italcementi) highlights the most important research fields for the company in the Cement sector. In the following, a description of selected areas:



1. Additives for Portland cement
2. Belite as an additive for cement
3. Preparation of cementitious materials
4. Photocatalytic cements and composites
5. Calcium sulfoaluminate as cement additive
6. Composite panels of cementitious materials
7. Polymers and rubbers as additives for cementitious materials

FOREST-BASED

Table A.8. Forest-based

STORA ENSO OYJ	
Sector	**Logo**
Biobased materials – Pulp and Paper	
Headquarter	
Helsinki, Finland	
Website	
http://www.storaenso.com/	

Description

Stora Enso Oyj is a pulp and paper manufacturer headquartered in Helsinki, Finland, with significant operations in four continents. The company was formed by the merger of Swedish mining and forestry products company Stora AB and Finnish forestry products company Enso Oyj in 1998.
Concerning the scientific publications, the activity emerges to be dedicated to improve the efficiency and sustainability of pulp and paper production process in several ways. Studies investigate the extraction of valuable elements from waste flows for energy efficiency improvements. Also the optimization of supply chain is an issue of particular interest, with studies focused on the increase of efficiency of wood harvesting. Concerning the analysis of the patent portfolio owned in Europe, it can be seen that Stora Enso is active in many fields of research linked with pulp and paper production. The analysis of IPC codes of selected patents shows that the company is active in researching innovative pulp compositions and paper surface treatments. Also the field of composite materials is covered by published patents together with the one of innovative packaging solutions.

Scientific Papers Affiliation (2011-2016)

Number: 6

Examples of relevant Scientific Publications:

Total and extractable non-process elements in green liquor dregs from the chemical recovery circuit of a semi-chemical pulp mill

Chemical Engineering Journal, Volume 166, Issue 3, 1 February 2011, Pages 954-961

Kati Manskinen, Hannu Nurmesniemi, Risto Pöykiö

The total heavy metal concentrations in green liquor dregs investigated in this study were clearly lower than the current Finnish statutory limit values for fertilizer used in forestry. This is an advantage if applying for an environmental permit to utilize the green liquor dregs. They contained only carbonate minerals, were strongly alkaline (pH 11.7), and had a neutralizing value of 34.2% (Ca equivalents; d.w.), according to which 1.1 tonnes of green liquor dregs would be required to replace 1 tonne of a commercial ground limestone product produced by SMA Mineral Ltd. These properties support the utilization and re-use of this residue, for instance as a soil conditioning agent. Before such use, it would be necessary to assess the mobility of non-process elements in the dregs. Three-stage sequential extraction procedure development by the European Community Bureau of Reference (BCR) was therefore carried out, in which elements in the residue were fractionated between acid soluble (CH_3COOH; BCR 1), reducible (NH_2OH–HCl; BCR 2) and oxidizable (H_2O_2 + CH_3COONH_4; BCR 3) fractions. Except for Co and Ni, the highest extractable concentrations of non-process elements (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Mn, Mo, Pb, Sb, Se, V and Zn) were in the oxidizable fraction, although certain non-process elements were also extractable and quantitatively detectable in fractions BCR 1 and BRC 2. The results are discussed from various perspectives and in relation to observations in the literature concerning the release of heavy metals and sulphur from the sample matrix under different extraction conditions.

Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems

Journal of Cleaner Production, Volume 69, 15 April 2014, Pages 83-90

Sirkka Koskela, Helena Dahlbo, Jáchym Judl, Marja-Riitta Korhonen, Mervi Niininen

During a product's entire life cycle the significance of packaging varies in terms of environmental impacts. From the perspective of companies which manufacture packaging or packaging has an important role in their value chain it can be a relevant issue to focus on in their efforts to improve the environmental performance of their activities. The aim of this study was to compare the life cycle environmental impacts of a real product (bread) delivery system using either reusable HPDE plastic crates or recyclable corrugated cardboard (CCB) boxes for product transportation. In this paper we focused on the delivery systems (not the delivered product) covering the manufacturing of the crates/boxes, their use, the delivery routes from bakery to retailers and waste management/recycling of the crates/boxes. As a result we concluded that the recyclable CCB box system was a more environmentally friendly option than the reusable HPDE plastic crate system in all the studied impact categories based on the defined boundaries and assumptions. Transportation played a very important role in the environmental impacts of the analysed systems. Therefore, changes, e.g. in the weights of products and their secondary packaging or the transportation distances could affect the results considerably.

Excavator technology for increasing the efficiency of energy wood and pulp wood harvesting

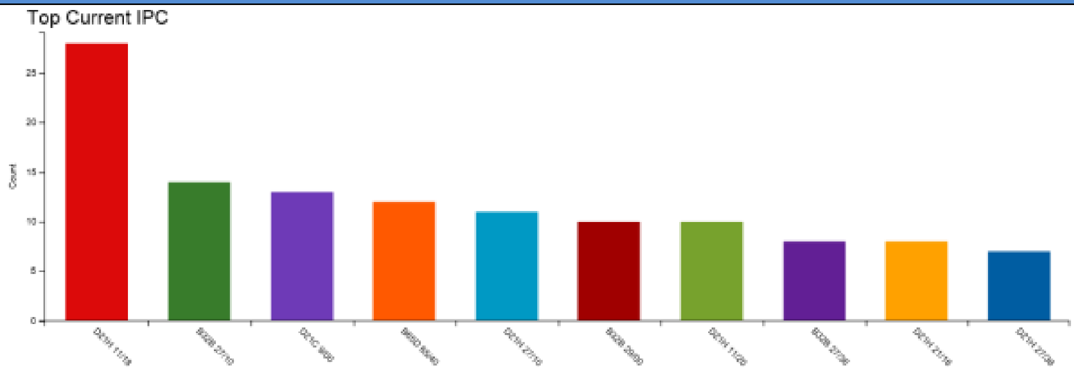
Biomass and Bioenergy, Volume 40, May 2012, Pages 120-126

Teijo Palander, Jouni Bergroth, Kalle Kärhä
In Finland, the harvesting of small-sized thinning wood will be doubled or even tripled over the current harvesting volume. A greater area of peatlands could be harvested during winter for energy and pulpwood if contractors adopted more carriers for harvester heads based on excavator technology. The purpose of this study was to investigate why excavator-based harvesters are not used more widely for wood harvesting in these forests. The study was implemented by conducting 46 personal interviews in 2006 and 2011. The interviewees formed five groups: contractors who used excavators for harvesting, contractors who owned excavators but did not use them for harvesting, harvester head manufacturers, officers of wood procurement organizations, and vendors of excavators. The Nordic tradition of timber harvesting using wheeled harvesters was the main reason for the limited use of excavator-based harvesters. In the follow-up (2011) lack of the forest-adapted excavators was the main reason. During this study, mixes of harvesting machines have not been increased to permit winter wood procurement, even though the number of annual working hours could be increased for both excavator-based and wheeled harvesters. Existing excavators could be used more efficiently by cooperating with energy and forest industry as well as with Forest Owners' Associations. In future, the potential of excavator technology could be realised by developing a more flexible Finnish wood procurement infrastructure that uses a wider range of harvesters in harvesting enterprises. This could also increase the overall cost efficiency of wood procurement by permitting the use of less expensive harvesting machines.

Published Patents (2011-2016)

Number: 185

IPC Codes



D21H Pulp compositions; Preparation thereof not covered by subclasses d21c, d21d; Impregnating or coating of paper; Treatment of finished paper not covered by class b31 or subclass d21g; Paper not otherwise provided for
B32B Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form
D21C Production of cellulose by removing non-cellulose substances from cellulose- containing materials; Regeneration of pulping liquors; Apparatus therefor
B65D Containers for storage or transport of articles or materials, e.g. bags, barrels, bottles, boxes, cans, cartons, crates, drums, jars, tanks, hoppers, forwarding containers; Accessories, closures, or fittings therefor; Packaging elements; Packages

Map of patents Topics

The map of patents topics for Stora Enso Oyj highlights the most important research fields for the company in the Pulp and Paper sector. In the following, a description of selected areas:
1. Packaging: methods for the production of containers and fibers orientation procedures
2. Methods for producing micro-fibrillated cellulose and composites
3. Innovative methods for paper making
4. 5. Surface treatments for paper
6. Betulin acid production procedures
7. Wood as building material

UPM-Kymmene Corporation

Sector	Logo

Biobased materials – Pulp and Paper	The Biofore Company UPM
Headquarter	
Helsinki, Finland	
Website	
www.upm.com	

Description

UPM-Kymmene Corporation is a Finnish forest industry company. UPM-Kymmene was formed by the merger of Kymmene Corporation and Repola Ltd and its subsidiary United Paper Mills Ltd in 1996. UPM products include pulp, paper, plywood, sawn timber, labels and composites, bioenergy, biofuels for transport, bio-chemicals and nano products. The company is the world's leading producer of graphic papers and second-largest producer of self-adhesive label materials.

Concerning the scientific publications, the activity emerges to be dedicated to characterize different materials of biological origin to be used as raw materials for the production of different products. Also researches on innovative applications for cellulose are reported to be developed.

Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that UPM-Kymmene is active in different fields, not only the ones traditionally covered by pulp and paper industry.

In fact, the IPC codes analysis shows that published patents belongs mainly to the 'traditional' field of pulp compositions and paper surface treatments. The following IPC code categories belongs to the innovative field of bio-refining, i.e. the production of oils and renewable diesel from biologic matter. Also composites and layered products appear an important field of patent publication as highlighted from the analysis of the map of patents topics.

Scientific Papers Affiliation (2011-2016)

Number: 7

Examples of relevant Scientific Publications:

Wood sulphate turpentine as a gasoline bio-component

Fuel, Volume 104, February 2013, Pages 101-108

Pekka Knuuttila

The most recent technical development of gasoline engines has brought thermal efficiency close to the diesel engine. This will add pressure to develop new pure bio-based hydrocarbon components for gasoline beyond what ethanol only now offers. Crude wood turpentine (CST) comprises an oil mixture of volatile unsaturated $C_{10}H_{16}$terpene isomers derived from pitch. Early attempts to use crude sulphate turpentine as motor fuels after a simple filtration were unsuccessful, leading to fast contamination of the motor oil with metal sulphides and severe corrosion of engine parts. To be a suitable bio-component in motor fuels, crude sulphate turpentine must be purified at least from all its sulphur compounds. In addition, excessive chemical unsaturation is undesirable because of the resin formation on the inlet valve stems and the reduced shelf-life of the fuel. In this study a commercially available hydrodesulphurization and hydrodewaxing catalyst is used successfully to remove both sulphur compounds, double bonds and cleave the bridging C–C bond from CST terpenes in the single reaction phase. The process conditions appeared to be an effective means to control the product composition and its value as a gasoline bio-component. Relative severe HDS reaction conditions favour the high octane aromatics, and cut down the high boiling point heterocyclics. The shape of the distillation curves of both 5% and 10% blends are very similar to that of standard E 95 gasoline. The f.b.p.'s are around 200 °C, well under the limit of the EN 228 gasoline standard of 210 °C.

Subtraction analysis based on self-organizing maps for an industrial wastewater treatment process

Mathematics and Computers in Simulation, Volume 82, Issue 3, November 2011, Pages 450-459

M. Heikkinen, H. Poutiainen, M. Liukkonen, T. Heikkinen, Y. Hiltunen

This paper presents an overview of an analysis method based on self-organizing maps (SOM) which was applied to an activated sludge treatment process in a pulp mill. The aim of the study was to determine whether the neural network modeling method could be a useful and time-saving way to analyze this kind of process data. The following analysis procedure was used. At first, the process data was modeled using the SOM algorithm. Next, the reference vectors of the map were classified by K-means algorithm into clusters, which represented different states of the process. At the final stage, the reference vectors of the map and the centre vectors of the clusters were used for subtraction analysis to indicate differences of the process states. The results show that the method presented here can be an efficient way to analyze the data of an activated sludge treatment process.

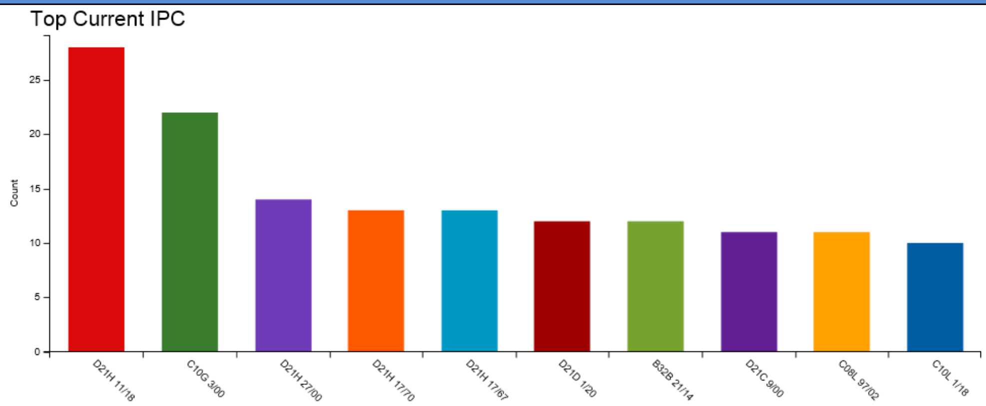
Nanofibrillar cellulose hydrogel promotes three-dimensional liver cell culture

Journal of Controlled Release, Volume 164, Issue 3, 28 December 2012, Pages 291-298

Madhushree Bhattacharya, Melina M. Malinen, Patrick Lauren, Yan-Ru Lou, Saara W. Kuisma, Liisa Kanninen, Martina Lille, Anne Corlu, Christiane GuGuen-Guillouzo, Olli Ikkala, Antti Laukkanen, Arto Urtti, Marjo Yliperttula

Over the recent years, various materials have been introduced as potential 3D cell culture scaffolds. These include protein extracts, peptide amphiphiles, and synthetic polymers. Hydrogel scaffolds without human or animal borne components or added bioactive components are preferred from the immunological point of view. Here we demonstrate that native nanofibrillar cellulose (NFC) hydrogels derived from the abundant plant sources provide the desired functionalities. We show 1) rheological properties that allow formation of a 3D scaffold in-situ after facile injection, 2) cellular biocompatibility without added growth factors, 3) cellular polarization, and 4) differentiation of human hepatic cell lines HepaRG and HepG2. At high shear stress, the aqueous NFC has small viscosity that supports injectability, whereas at low shear stress conditions the material is converted to an elastic gel. Due to the inherent biocompatibility without any additives, we conclude that NFC generates a feasible and sustained microenvironment for 3D cell culture for potential applications, such as drug and chemical testing, tissue engineering, and cell therapy.

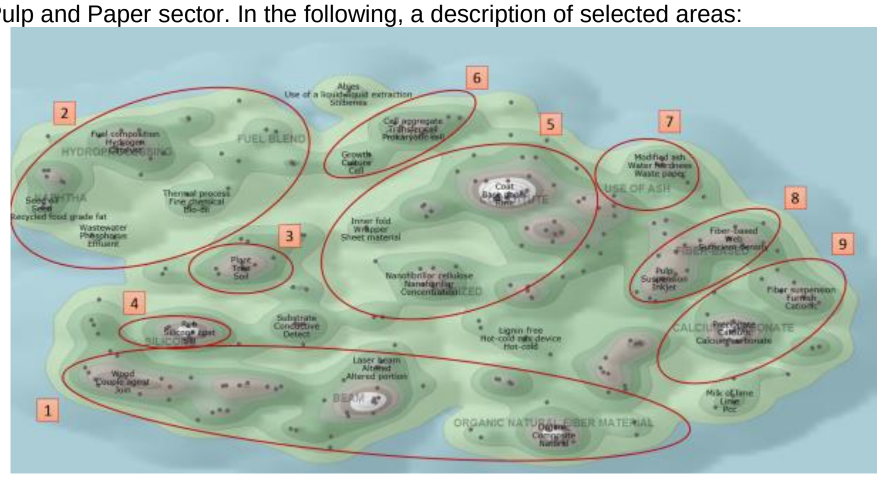
Published Patents (2011-2016)
Number: 272
IPC Codes



D21H Pulp compositions; Preparation thereof not covered by subclasses d21c, d21d; Impregnating or coating of paper; Treatment of finished paper not covered by class b31 or subclass d21g; Paper not otherwise provided for
C10G Cracking hydrocarbon oils; Production of liquid hydrocarbon mixtures, e.g. by destructive hydrogenation, oligomerisation, polymerisation; Recovery of hydrocarbon oils from oil-shale, oil-sand, or gases; Refining mixtures mainly consisting of hydrocarbons; Reforming of naphtha; Mineral waxes
D21D Treatment of the materials before passing to the paper-making machine
B32B Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form
D21C Production of cellulose by removing non-cellulose substances from cellulose- containing materials; Regeneration of pulping liquors; Apparatus therefor
C08L Compositions of macromolecular compounds
C10L Fuels not otherwise provided for; Natural gas; Synthetic natural gas obtained by processes not covered by subclasses c10g to or c10k; Liquefied petroleum gas; use of additives to fuels or fires; fire-lighters

Map of patents Topics

The map of patents topics for UPM-Kymmene Corporation highlights the most important research fields for the company in the Pulp and Paper sector. In the following, a description of selected areas:



1. Layered products (mainly plywood panels) and methods for processing and shaping them
2. Bio-fuels from natural sources and treatments for bio-refineries waste
3. Methods for forest and soil management
4. Silicon containing polymers
5. Paper: coating methods and packaging solutions
6. Bio-chemistry (enzymes and macro-molecular compounds)
7. Alternative use of ashes
8. Substrates and printing methods
9. Methods and pre-treatments for chemical compounds used in paper production process

TRANSPORT

Table A.9. Transport

VOLKSWAGEN GROUP	
Sector	**Logo**
Transport - Automotive	VOLKSWAGEN AKTIENGESELLSCHAFT

Headquarter	
Wolfsburg, Germany	
Website	
http://www.volkswagenag.com/	

Description

Volkswagen Group is a German multinational automotive manufacturing company headquartered in Wolfsburg, Lower Saxony, Germany. It designs, manufactures and distributes passenger and commercial vehicles and motorcycles, but also engines and turbo machinery and offers related services including financing, leasing and fleet management.
Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate different materials for automotive applications. In particular, research topics of interest include the characterization and performance evaluation of steel and metal sheets. Studies on plasticity and fracture evaluation, on welding techniques, on crack propagation and on manufacturing of steel sheets for car body structures are reported. Also studies on innovative materials such as carbon fiber and composites are important, related to their possible applications.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the main research field of patent application, according with IPC code analysis, is related with fuel cells for the automotive industry. Also the working and processing of metal sheets and the preparation of plastic materials to be shaped (for automotive components production) appear to be important field of research. Other fields of interest, emerging from the analysis of patents topics, are permanent magnet materials and layered materials.

Scientific Papers Affiliation (2011-2016)

Number: 20

Examples of relevant Scientific Publications:

Lignin – an alternative precursor for sustainable and cost-effective automotive carbon fiber

Journal of Materials Research and Technology, Volume 4, Issue 3, July–September 2015, Pages 283-296

Hendrik Mainka, Olaf Täger, Enrico Körner, Liane Hilfert, Sabine Busse, Frank T. Edelmann, Axel S. Herrmann
Lightweight design is an essential part of the overall Volkswagen strategy for reducing the CO2 emission. The use of carbon fiber reinforced polymers (CFRP) offers an enormous lightweight potential in comparison to aluminum, enabling a weight reduction, if a load-adapted (unidirectional) CFRP-design is used, of up to 60% in automobile parts without a degradation of the functionalities. Today, the use of CFRP is limited in mass series applications of the automotive industry by the cost of the conventional carbon fiber precursor Poly-Acrylic-Nitrile (PAN). Fifty percent of the cost of a conventional carbon fiber already belongs to the cost of the PAN precursor. The analysis of lignin as an alternative precursor shows clearly a significant reduction in the cost of CFRP and reduction of CO2 emission during carbon fiber production. This fact is essential to make carbon fibers ready for a mainstream use within the automotive industry. Key aspects are: the examination and quantification of lignin as an alternative precursor, the optimization of the manufacturing processes, the characterization and quantification of the properties of the novel carbon fibers within an established material pre-validation process and a final economic efficiency and sustainability analysis. Furthermore, the process ability and demonstrators as well as the suitability for high volume production of the developed processes are main issues for successful implementation in future lightweight vehicle concepts.

Plasticity and fracture modeling of the heat-affected zone in resistance spot welded tailor hardened boron steel

Journal of Materials Processing Technology, Volume 234, August 2016, Pages 309-322

T.K. Eller, L. Greve, M. Andres, M. Medricky, H.J.M. Geijselaers, V.T. Meinders, A.H. van den Boogaard
Five hardness grades of 22MnB5 are considered, covering the full strength-range from 600 MPa in the ferritic/pearlitic range to 1500 MPa in the fully hardened, martensitic state. These five grades form the basis for a hardness-based material model for the heat-affected zone found around resistance spot welds in tailor hardened boron steel. Microhardness measurements of resistance spot welds in all five grades are used to determine the location and shape of the heat-affected zone and for mapping of the hardness distributions into FE-models of the specimens used for model calibration. For calibration of the strain hardening of the heat-affected zone, a specially designed asymmetric uni-axial tensile specimen is used that features a well-defined strain field up to fracture initiation. Both the measured force–displacement curves and the strain fields are used as input for an inverse FEM optimization algorithm that identifies suitable strain hardening model parameters by minimizing the differences between experimental and simulated results. A strain-based fracture model is calibrated using a hybrid experimental/numerical approach, featuring two additional specimens in which fracture initiates in the HAZ under different stress states. Strain hardening and fracture strains are assumed to be linearly related to the as-welded material hardness. The calibration and modeling approach are validated by comparing measured and predicted force–displacement curves and strain fields of welded coupon tensile tests.

Carbon blacks for the extension of the cycle life in flooded lead acid batteries for micro-hybrid applications

Journal of Power Sources, Volume 239, 1 October 2013, Pages 483-489

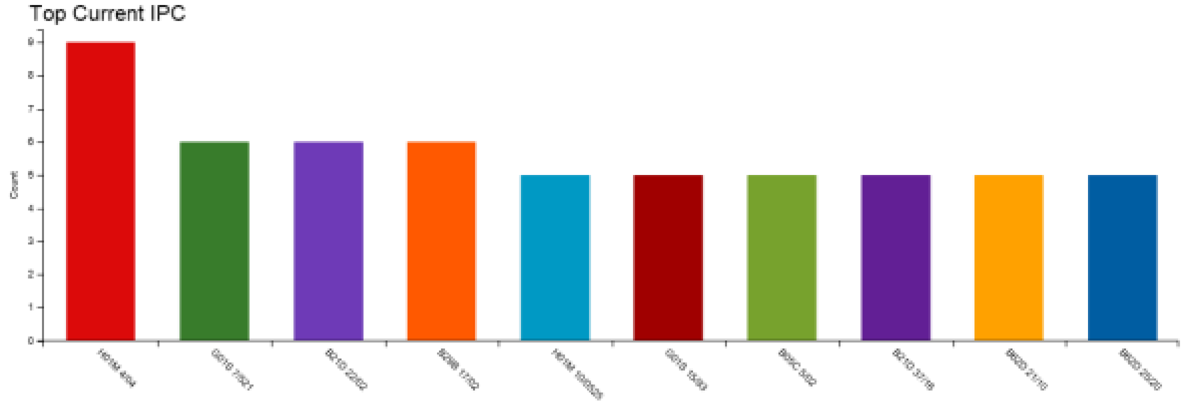
Ellen Ebner, Daniel Burow, Alexander Börger, Michael Wark, Paolina Atanassova, Jesús Valenciano
Different carbon blacks were added with quantities in between 0.2% and 2% to the negative active material of flooded lead-acid batteries. By scanning electron microscopy it can be shown that the carbons differ in aggregate structure and particle morphology. In order to test the effectiveness of the carbon blacks, the batteries were subjected to cycle tests with 17.5% depth of discharge. Batteries with carbons in the negative active masses display drastically decreased sulfation of the negative active masses. An extension of the battery lifetime by a factor of 2 could be determined compared to conventional batteries. Furthermore it was noticed that the battery cycle life is influenced by the dispersion properties of the carbon particles into the negative active mass. Particles

which are homogenously distributed into the negative active mass are able to act over the whole plate and therefore affect cycle life positively.

Published Patents (2011-2016)

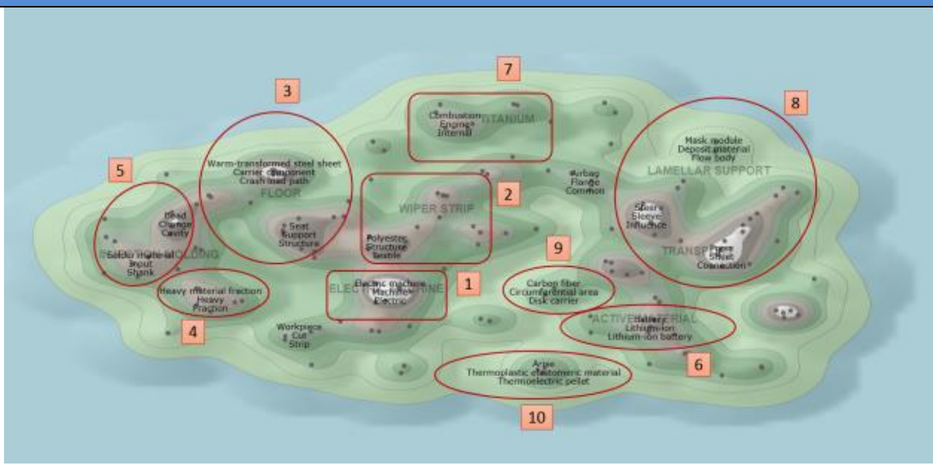
Number: 154

IPC Codes



H01M Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
G01S Radio direction-finding; Radio navigation; Determining distance or velocity by use of radio waves; Locating or presence-detecting by use of the reflection or reradiation of radio waves; Analogous arrangements using other waves
B21D Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; Punching
B29B Preparation or pretreatment of the material to be shaped, making granules or preforms, recovery of plastics or other constituents of waste materials containing plastics
B05C Apparatus for applying liquids or other fluent materials to surfaces, in general
B62D Motor vehicles; Trailers

Map of patents Topics



The map of patents topics for Volkswagen Group highlights the most important research fields for the company in the Automotive sector. In the following, a description of selected areas:

1. Permanent magnets and methods for producing them
2. Layered and fiber-reinforced polymeric materials
3. Metal sheet components
4. Methods for treating plastic-rich waste
5. Panels and composite sheet materials for automotive applications
6. Electrodes and electrolyte compositions for lithium-ion cells and fuel cells
7. Materials for engine manufacturing
8. Metalworking: connection of sheets and component and processing tools
9. 10. Innovative materials: polymers and carbon fiber

DAIMLER AG

Sector	Logo
Transport - Automotive	
Headquarter	
Stuttgart, Germany	

Website	
https://www.daimler.com/	DAIMLER

Description

Daimler AG is a German multinational automotive corporation. Daimler AG is headquartered in Stuttgart, Baden-Württemberg, Germany. As of 2014, Daimler owns or has shares in a number of car, bus, truck and motorcycle brands including Mercedes-Benz, Mercedes-AMG, Smart Automobile, Freightliner, Western Star, Thomas Built Buses, Setra, BharatBenz, Mitsubishi Fuso, MV Agusta as well as shares in Denza, KAMAZ and Beijing Automotive Group.

Concerning the scientific publications, the activity emerges to be strongly dedicated to optimise the properties of materials finding applications in motor vehicles. In particular research efforts have been made in the fields of sheet metal manufacturing and carbon fiber. Also woven-metal composites are an interesting innovation field explored. Other remarkable topics are smart textiles, fuel cells for automotive application and catalysts for Selective Catalytic Reduction (SCR), to treat exhaust gases from diesel engines.

Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that Daimler's research efforts are mainly linked with motor vehicle production, as highlighted by IPC codes analysis. More in detail, fuel cells for automotive and shaping of plastics appear to be the most relevant areas of interest for the company, according with published patents. Also composite materials are a field of patent publications as emerging from the analysis of map of patents topics.

Scientific Papers Affiliation (2011-2016)

Number: 24

Examples of relevant Scientific Publications:

16 - Automotive applications of smart textiles

Multidisciplinary Know-How for Smart-Textiles Developers, 2013, Pages 444-467

M. Wagner

Smart textiles have become a new topic in vehicle engineering. New applications in the automotive industry seem to have potential and may give access to entirely new system approaches. This chapter presents some of them and focuses especially on the potential of measuring physiological parameters such as heart rate, electrodermal activity and others. Investigations on prototype systems of car seats and steering wheels will be discussed.

Experimental and modeling study of a dual-layer (SCR + PGM) NH3 slip monolith catalyst (ASC) for automotive SCR aftertreatment systems. Part 1. Kinetics for the PGM component and analysis of SCR/PGM interactions

Applied Catalysis B: Environmental, Volumes 142–143, October–November 2013, Pages 861-876

Massimo Colombo, Isabella Nova, Enrico Tronconi, Volker Schmeißer, Brigitte Bandl-Konrad, Lisa Zimmermann

We present herein the first of two parts in the development and validation of a chemically and physically consistent mathematical model of a commercial dual-layer (SCR + PGM) monolithic NH_3 slip converter (ASC). The overall project followed a systematic approach of growing complexity, and its results emphasize the beneficial features of a dual-layer configuration with the SCR catalyst on top of the PGM component. Specifically, we report in this paper $NH_3/O_2/NO$—NO_2 steady-state and transient kinetic runs performed over the PGM component of the dual-layer NH_3 slip catalyst. The PGM component was tested in a representative temperature range (150–550 °C) in the form of precursor washcoat powders at high space velocities in order to gain kinetic information. From these data an original global PGM kinetic model was developed, which fully accounts for the effects of temperature and of NO_2/NO_x feed ratio (0–1) on NH_3 oxidation. The model considers NO_2 inhibition on NO oxidation, as well as a novel NO_2 inhibition effect on the NH_3oxidation reactions. Comparative $NH_3/O_2/NO\text{-}NO_2$ steady-state runs were performed also over two combinations of SCR + PGM powders (sequential double-bed and mechanical mixture). The N_2 selectivity was greater over the mechanical mixture, as in this configuration the unselective NH_3 oxidation products (NO_x) formed over the PGM catalyst had a chance to further react selectively with NH_3 over the SCR catalyst. Such a positive interaction between the PGM and the SCR catalytic chemistries was satisfactorily predicted by a model involving the simple superposition of the PGM and SCR kinetics. In the following part of the project the herein developed PGM kinetics, together with consistent SCR kinetics, will be incorporated in a novel dual-layer monolith catalyst model and validated against both lab-scale and engine test bench data collected over dual-layer ASC systems.

Effects of alloying elements in UHC-steels and consequences for the machinability

CIRP Journal of Manufacturing Science and Technology, Volume 10, August 2015, Pages 102-109

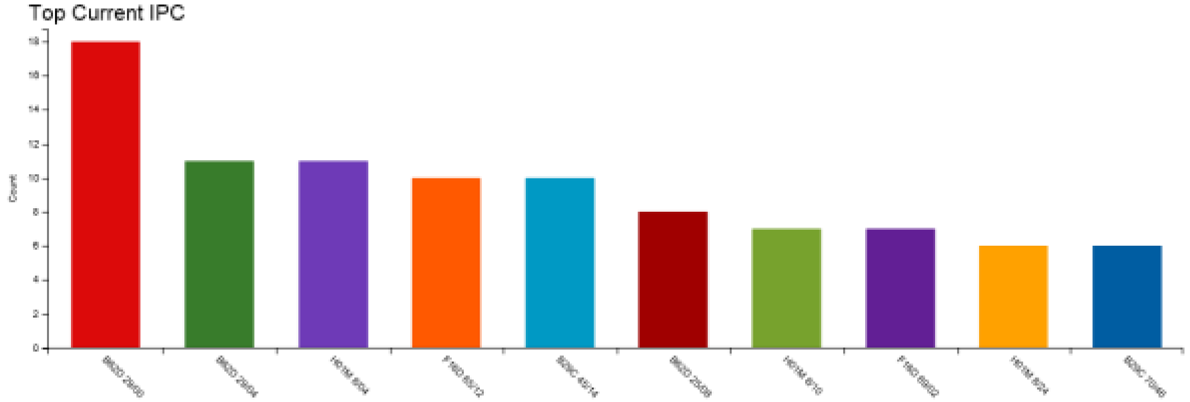
B. Denkena, T. Grove, M.A. Dittrich, C. Beiler, M. Lahres

Due to their high strength and reduced density aluminum-alloyed ultra-high-carbon steels (UHC-steels) show high potential for industrial applications. In an earlier study, segmented chip formation has been observed in turning alloyed UHC-steel. The formation of serrated chips imposes a limit on the productivity when machining this material. In order to enhance the machinability the chip formation mechanisms are investigated and recommendations for the tool design derived. Additionally, approaches for an optimized material processing (heat treatment) that improves the machinability are discussed. The recommendations are based on a detailed microstructure analysis by scanning electron microscopy (SEM), electron backscattering diffraction (EBSD), wavelength dispersive X-ray diffraction (WDX) and Auger electron spectroscopy (AES). Subsequent chip root experiments and micro indentation tests give further insight into the chip formation mechanisms. The observed chip formation mechanisms are connected to the obtained results on the microstructure of the aluminum-alloyed UHC-steel. It is shown that additional alloying components like chromium and manganese alter the microstructure and contribute to a serrated chip formation.

Published Patents (2011-2016)

Number: 163

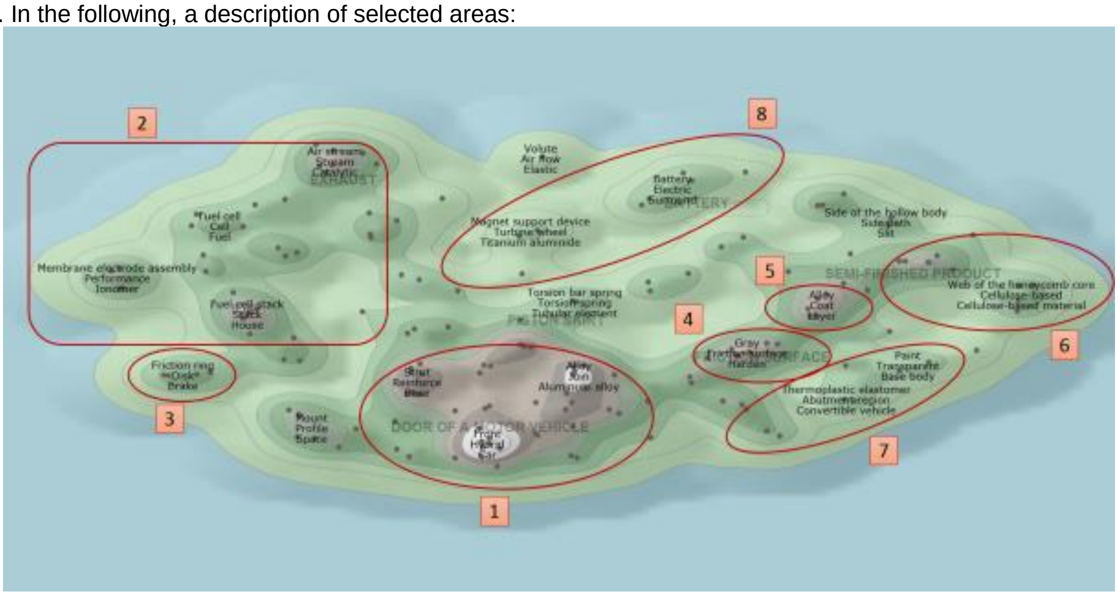
IPC Codes



B62D Motor vehicles; Trailers
H01M Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
F16D Couplings for transmitting rotation; Clutches; Brakes
B29C Shaping or joining of plastics; Shaping of substances in a plastic state, in general; After- treatment of the shaped products, e.g. repairing

Map of patents Topics

The map of patents topics for Daimler highlights the most important research fields for the company in the Automotive sector. In the following, a description of selected areas:



1. Composite materials for automotive applications
2. Materials and components for fuel cells manufacturing
3. 4. Brake discs materials
5. Aluminium and iron-based alloys as coating materials
6. Multi-layered and cellulose based materials
7. Elastomers and paints
8. Batteries for electrical vehicles

AIRBUS GROUP SE	
Sector	**Logo**
Transport – Aerospace	
Headquarter	
Leiden, Netherlands (headquarters) Blagnac, France (main office)	
Website	
http://www.airbusgroup.com/	
Description	
Airbus Group SE is a European multinational aerospace and defence corporation. Headquartered in Leiden, Netherlands, the group consists of the three business divisions Airbus, Airbus Defence and Space, and Airbus Helicopters. Concerning the scientific publications, the activity emerges to be strongly dedicated to composite materials for aeronautics. These materials are both metal sheets and composite sheets including nanocomposite materials, such as carbon-nanotubes functionalized materials. These innovative materials are investigated in their mechanical properties and damage response. Manufacturing processes are also object of study and scientific publications. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the materials related to aeronautics are the most important field of innovation for the company. Analysing the IPC codes of patents, the most important field of research appear to be shaping or joining of substances in a plastic state. The analysis of map of patents topics shows that composite materials and their production process are an important field of patent publication.	
Scientific Papers Affiliation (2011-2016)	
Number: 69	
Examples of relevant Scientific Publications:	

1 - Braiding processes for composites manufacture

Advances in Composites Manufacturing and Process Design, 2015, Pages 3-26

B. Arnold, A. Gessler, C. Matzner, K. Birkefeld

This chapter describes the current status of the production of carbon fiber preforms with braiding technology. It starts with a short introduction to the basics of braiding, typical machines, auxiliary devices and processes, and shows examples for automated preform production. The main part discusses the capabilities and limitations of the technology and the material performance that can be obtained with braiding. The chapter then continues with a detailed description of the advancements in the field of braiding simulation and closes with a short lookout on expected future trends.

An Industrial Workflow to Minimise Part Distortion for Machining of Large Monolithic Components in Aerospace Industry

Procedia CIRP, Volume 8, 2013, Pages 281-286

D. Chantzis, S. Van-der-Veen, J.Zettler, W.M. Sim

Part Distortion due to inherent residual stresses has resulted in recurring concession, rework and possibly scrap worth millions of € in the aircraft development and manufacturing life cycle. The paper presented here outlines an industrial solution based on years of fundamental research dated back to as early as mid-1990 to the development of a practical industrial solution to optimise part distortion in large monolithic components in the aerospace industry. The developed system was designed to empower manufacturing engineers at the shop floor level to help with their day to day activities from characterising residual stress profile in materials to numerical simulation to arrive at an optimised solution. The industrial technology suite includes the following technologies: (i) characterisation of inherent material residual stresses by adapting the established layer removal method for implementation on an industrial CNC machining centre; (ii) generation of residual stresses profiles using displacement measurements; and (iii) optimisation of part location in the materials through numerical modelling. The machine operator can characterise the bulk residual stresses in the materials on a standard CNC machining centre. The residual stresses profiles will subsequently be used as inputs via a user-friendly GUI, which will drive the numerical calculation to be performed remotely in supercomputers, in order to deliver an optimised solution.

New hybrid polymer nanocomposites for passive vibration damping by incorporation of carbon nanotubes and lead zirconate titanate particles

Journal of Non-Crystalline Solids, Volume 409, 1 February 2015, Pages 20-26

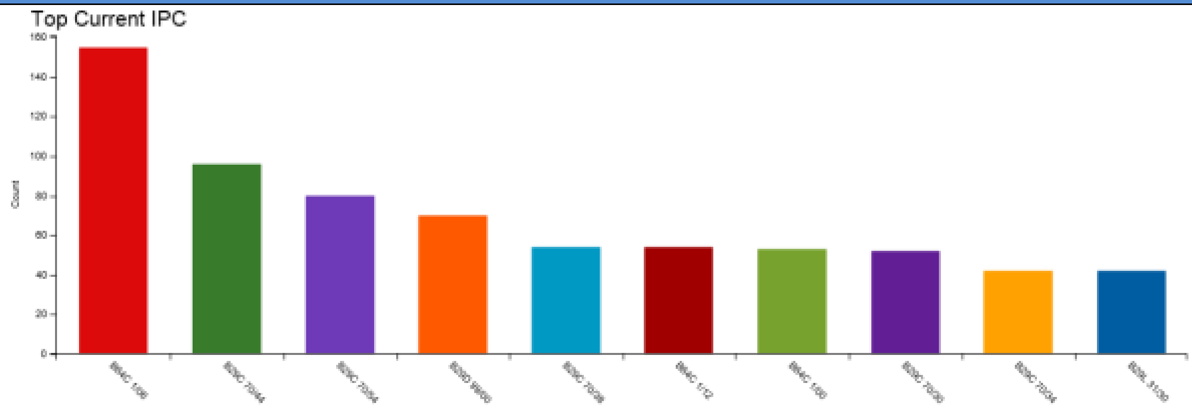
Delphine Carponcin, Eric Dantras, Guilhem Michon, Jany Dandurand, Gwenaëlle Aridon, Franck Levallois, Laurent Cadiergues, Colette Lacabanne

A new hybrid nanocomposite for vibration damping has been elaborated. Ferroelectric lead zirconate titanate particles and carbon nanotubes are dispersed simultaneously in an engineering semi-crystalline thermoplastic matrix by an extrusion processing. Ferroelectric particles have been made piezoelectric once incorporated into the polymer matrix through a poling step. The dynamic response of nanocomposites has been characterized by dynamic mechanical analysis and vibration test. The shear mechanical modulus exhibits an increase of the conservative and dissipative components after the poling step of nanocomposites. By vibration test, the first bending mode of the frequency response function has been followed and a significant damping inherent to poling is also recorded. These evolutions are heightened by the use of two constrained elastic layers. For the first time, a synergy between poled piezoelectric particles responsible for the transduction phenomena and conductive particles allowing a local dissipation of electric charges has been revealed by two complementary techniques for the improvement of the polymer damping.

Published Patents (2011-2016)

Number: 1241

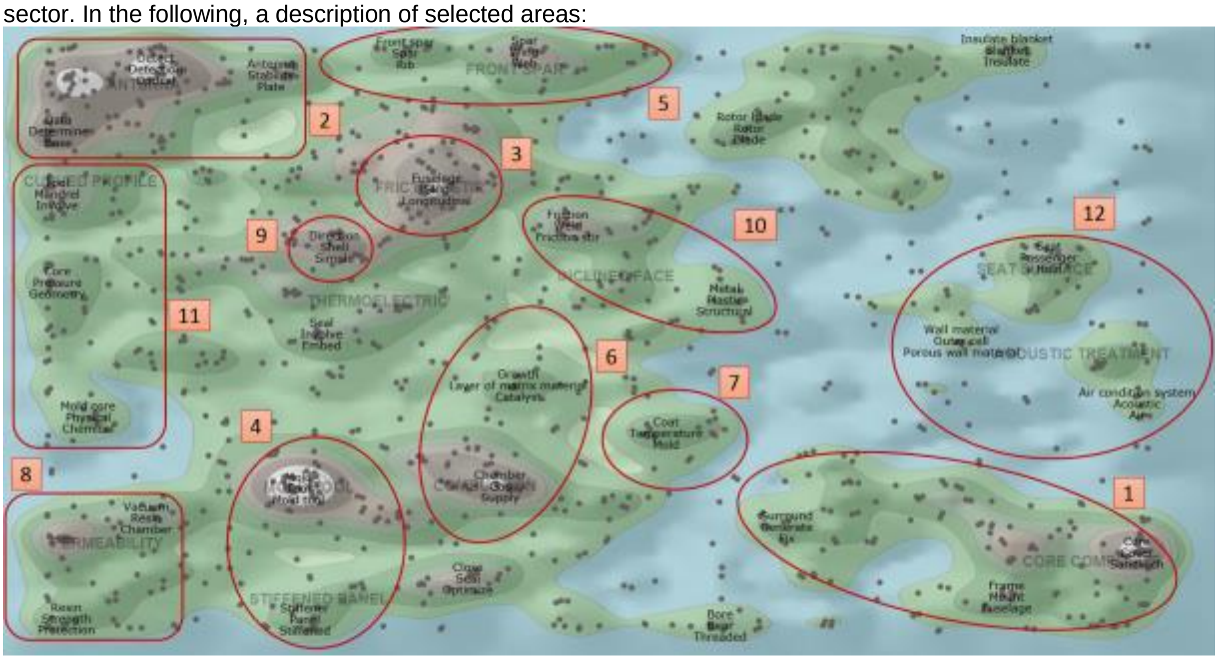
IPC Codes



B64C Aeroplanes; Helicopters
B29C Shaping or joining of plastics; Shaping of substances in a plastic state, in general; After- treatment of the shaped products, e.g. repairing
B29D Producing particular articles from plastics or from substances in a plastic state
B29L Indexing scheme associated with subclass B29C, relating to particular articles

Map of patents Topics

The map of patents topics for Airbus highlights the most important research fields for the company in the Aerospace sector. In the following, a description of selected areas:



1. Structural components for aeronautics applications (layered reinforced materials)
2. Methods and materials for materials testing and sensors for receiving signals (antennas)
3. 4. Fiber composite materials for aircrafts manufacturing
5. Composite structural parts: front spar structure
6. Combustion chamber : materials, design and catalytic system
7. Coating methods and materials for aerodynamics components
8. Polymeric resins
9. Additive manufacturing
10. Panels joint and friction stir welding
11. 12. Other methods for composite processing

ROLLS-ROYCE HOLDINGS PLC	
Sector	**Logo**
Transport – Aerospace	
Headquarter	
Buckingham Gate, City of Westminster, London, United Kingdom	
Website	
http://rolls-royce.com/	

Description

Rolls-Royce Holdings is a British multinational public holding company that, through its various subsidiaries, designs, manufactures and distributes power systems for aviation and other industries. It is the world's second-largest maker of aircraft engines. Rolls-Royce Holdings is headquartered in the City of Westminster, London.
Concerning the scientific publications, the activity emerges to be strongly dedicated to analyse mechanical properties of materials, particularly steels and other alloys, for energy production machineries, such as engines and turbines. In this context several studies on superalloys (Nickel-based), sintering mechanisms, fracture investigation, solidification and grain refinement have been carried out.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the company operates mainly in the field of machines and engines for energy production. Working and processing of metals and metal sheets appear to be an important field of patent publication, as highlighted from the analysis of the map of patents topics.

Scientific Papers Affiliation (2011-2016)

Number: 90

Examples of relevant Scientific Publications:

6 - Damage-tolerant composite structures by Z-pinning

Toughening Mechanisms in Composite Materials, 2015, Pages 161-189

I.K. Partridge, M. Yasaee, G. Allegri, J.K. Lander

This chapter presents a focused update and the addition of new information to published reviews of the manufacture and performance of Z-pinned composite structures, concentrating on the mechanisms of enhancement of delamination damage resistance. Special emphasis is placed on the effect of manufacturing routes in terms of generation of the mesostructure of the composite. Effects of manufacturing defects, such as Z-pin misalignment, on the apparent toughness of the composite are explored in experimental and modeling terms, detailing the use of single Z-pin coupons to generate data and to validate models. The strong relationship between the mesostructure of the Z-pinned composite and its performance in both in-plane and out-of-plane properties is highlighted in relation to the differences in dominant failure mechanisms between control and Z-pinned structural elements. The chapter concludes with an update on recent advances in modeling of the effects of load mixity on the apparent toughness of Z-pinned composites.

Effect of silicon additions on the high temperature oxidation behaviour of Cr–Cr_2Ta alloys

Intermetallics, Volume 32, January 2013, Pages 373-383

Ayan Bhowmik, Hon Tong Pang, Ian M. Edmonds, Catherine M.F. Rae, Howard J. Stone

The effect of Si additions between 0 and 15 at.% on the microstructure and oxidation resistance of Cr–Ta alloys has been studied. After annealing at 1300 °C for 500 h, the microstructures of the alloys were observed to consist predominantly of a Cr-rich solid solution and a Cr_2Ta Laves phase, with the Si partitioning preferentially to the Laves phase. Si was found to be beneficial to high temperature oxidation resistance, with the ternary alloys showing a lower weight gain than binary Cr–Ta alloys after isothermal exposure at 1100 °C for 100 h. However, no further improvement in oxidation behaviour under these conditions was achieved with increasing the Si-content beyond 7 at.%. The oxide scales formed on the alloys were found to comprise typically of Cr_2O_3 and mixed (Cr,Ta)-based oxides. The scales formed at 1100 °C and 1300 °C spalled readily, whilst those formed at 1000 °C showed better adherence to the substrate. Importantly, the presence of Si was also found to eliminate the internal nitridation otherwise encountered during the oxidation of binary Cr–Ta alloys. The formation of SiO_2 in the alloys was observed only at 1300 °C, where the alloys displayed a massive weight gain with rapid oxidation of the Cr-rich solid solution.

Chromia layer growth on a Ni-based superalloy: Sub-parabolic kinetics and the role of titanium

Corrosion Science, Volume 75, October 2013, Pages 58-66

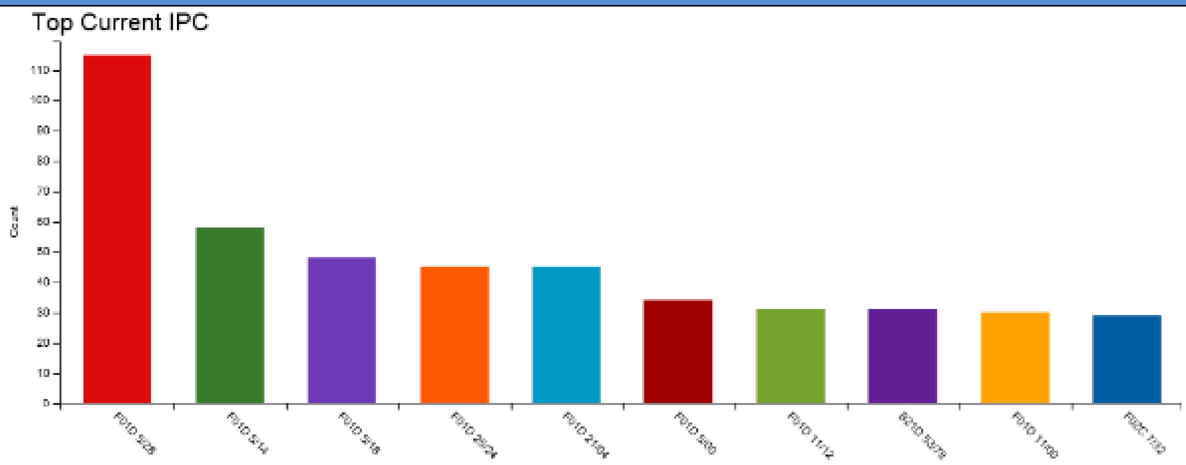
S. Cruchley, H.E. Evans, M.P. Taylor, M.C. Hardy, S. Stekovic

Oxidation of the Ni-based superalloy RR1000 has been undertaken in air over the temperature range 600–900 °C for times up to 5000 h. The surface oxide consisted of a protective Ti-doped chromia layer but with rutile forming on its outer surface. Sub-surface oxidation of Al and Ti also occurred. The thickening kinetics of the chromia layer were sub-parabolic with initial rates around two orders of magnitude higher than expected for Ti-free chromia. This enhancement and the sub-parabolic kinetics are accounted for by Ti-doping of the chromia layer. Over time the enhancement reduced because of Ti-depletion in the alloy.

Published Patents (2011-2016)

Number: 793

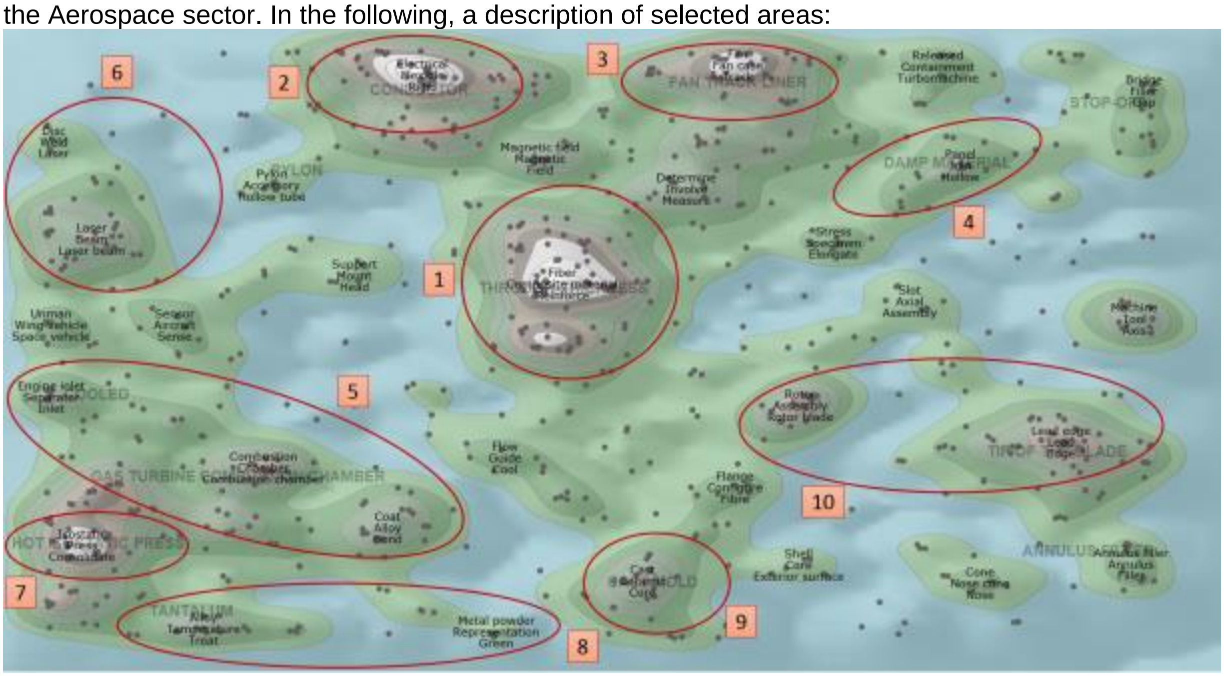
IPC Codes



F01D Non-positive-displacement machines or engines, e.g. steam turbines
B21D Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; Punching
F02C Gas-turbine plants; Air intakes for jet-propulsion plants; Controlling fuel supply in air-breathing jet-propulsion plants

Map of patents Topics

The map of patents topics for Rolls-Royce highlights the most important research fields for the company in the Aerospace sector. In the following, a description of selected areas:



1. Fiber reinforced layered materials and ceramic composite materials
2. Electrical connectors
3. Fan case for gas turbine engines
4. Panels and composites for aeronautics applications: manufacturing processes
5. Gas turbine combustion chambers
6. 7. Metalworking processes and machineries
8. Alloys (Titanium, tantalum, nickel) sheets
9. Metal casting process and materials for equipment
10. Gas turbine blades: materials and design

CONTINENTAL AG	
Sector	**Logo**
Transport - Tyres	
Headquarter	
Hanover, Germany	
Website	
http://www.conti-online.com/	

Description

Continental AG, commonly known as Continental, is a leading German automotive manufacturing company specialising in tyres, brake systems, automotive safety, powertrain and chassis components, tachographs, and other parts for the automotive and transportation industries.
Concerning the scientific publications, the activity emerges to be strongly dedicated to different branches related to the automotive industry. On one hand researches have been carried out in the field of rubber: studies on viscous models for rubber friction, experimental studies on properties and studies on polyurethane foams. On the other researches are related to stainless steels and in particular laser welding.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that tyres manufacturing is the main activity corresponding with IPC code analysis, followed by the chemical characterisation of compounds for tyre manufacturing. Composition of rubbers, different manufacturing processes and elements for tyres reinforcement are common fields of patents publication.

Scientific Papers Affiliation (2011-2016)

Number: 12

Examples of relevant Scientific Publications:

Investigation of the short-time high-current behavior of vias manufactured in hybrid thick-film technology

Microelectronics Reliability, Volume 51, Issue 7, July 2011, Pages 1257-1263

Dominique Ortolino, Jaroslaw Kita, Roland Wurm, Emmanuel Blum, Karin Beart, Ralf Moos

In this contribution, the short-time high-current behavior of electrical interconnects (through-metalized vias) manufactured in thick-film technology is investigated. Such vias are reliable devices for small currents, but their behavior when high currents are applied for short times has not been fully understood. Therefore, in a four-wire-setup, short-time high-current pulses were applied to single vias and the resulting transient voltage drops were measured. Furthermore, an FEM-model was developed to simulate this voltage drops as well as the time-dependent temperature distributions inside of the vias. Input parameters were material properties and sample geometries. The good agreement between the measured and the simulated time-dependent voltage drops validated the model. The resulting temperature distributions are an appropriate engineering tool for the further development of vias with respect to reliability and high ampacity.

Laser beam welding of dissimilar stainless steels in a fillet joint configuration

Journal of Materials Processing Technology, Volume 212, Issue 4, April 2012, Pages 856-867

M.M.A. Khan, L. Romoli, M. Fiaschi, G. Dini, F. Sarri

This paper investigates laser beam welding of dissimilar AISI 304L and AISI 430 stainless steels. Experimental studies were focused on effects of laser power, welding speed, defocus distance, beam incident angle, and line energy on weld bead geometry and shearing force. Metallurgical analysis was conducted on a selected weld only to show various microstructures typically formed at different zones and consequent change in microhardness. Laser power and welding speed were the most significant factors affecting weld geometry and shearing force. All the bead characteristics but radial penetration depth decreased with increased beam incident angle. The focused beam allowed selecting lower laser power and faster welding speed to obtain the same weld geometry. Weld shape factor increased rapidly due to keyhole formation for line energy input ranging from 15 kJ/m to 17 kJ/m. Fusion zone microstructures contained a variety of complex austenite–ferrite structures. Local microhardness of fusion zone was greater than that of both base metals.

Analysis of the effect of vibrations on the micro-EDM process at the workpiece surface

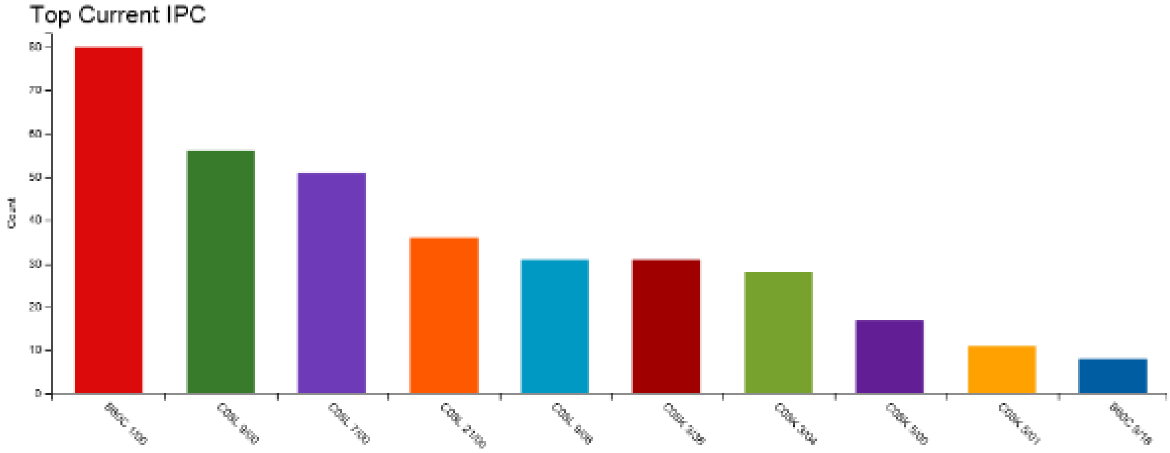
Precision Engineering, Volume 35, Issue 2, April 2011, Pages 364-368

R. Garn, A. Schubert, H. Zeidler

In this study, the effect of vibrations on the electrical discharges in the micro-EDM (electrical discharge machining) process was investigated. The electrical discharge machining of micro bores was chosen to represent a typical application. Using sophisticated measuring equipment to record and analyse current and voltage waveforms as well as electrode feeding during the process, deeper insight into the discharge mechanisms was achieved. It was found, that the micro-EDM boring process can be subdivided into three major parts, the start-up process, the major boring process and the workpiece breakthrough of the tool electrode. Extensive investigations have shown a delayed start-up process on the workpiece surface for conventional micro-EDM; however, this effect can be reduced by inducing vibration on the workpiece. The cause of this reduction was analysed by single discharge analysis which also provides a means to investigate the effect of vibration frequency.

Published Patents (2011-2016)
Number: 143

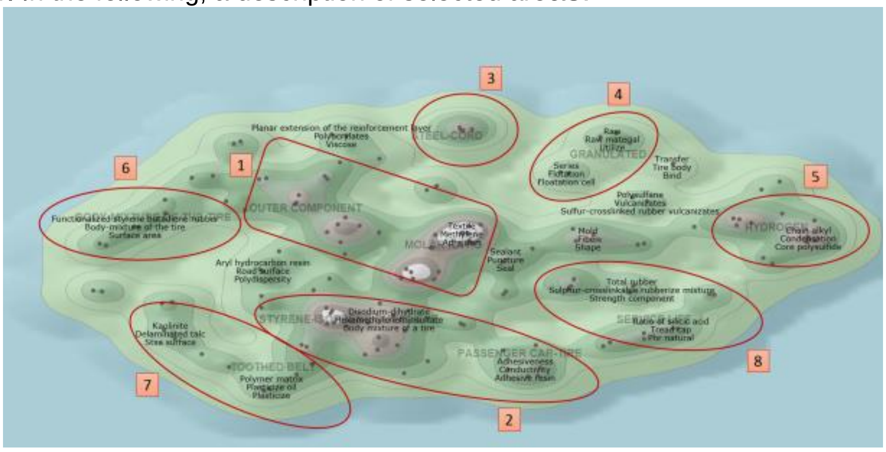
IPC Codes



B60C Vehicle tyres; Tyre inflation; Tyre changing; Connecting valves to inflatable elastic bodies in general; Devices or arrangements related to tyres
C08L Compositions of macromolecular compounds
C08K Use of inorganic or non-macromolecular organic substances as compounding ingredients

Map of patents Topics

The map of patents topics for Continental highlights the most important research fields for the company in the Tyres sector. In the following, a description of selected areas:



1. Rubber compounds for textile reinforcement in vehicle tyres
2. Rubber mixtures
3. Processes for separating unvulcanised rubber and steel-cord
4. Methods for manufacturing rubber granulates and powders
5. Rubber composition for vehicle tyres
6. 7. Functionalized rubbers
8. Sulphur containing materials and elastomers

MICHELIN

Sector	Logo
Transport - Tyres	
Headquarter	
Clermont-Ferrand, France	
Website	
http://www.michelin.com/	

Description

Michelin is a French tyre manufacturer based in Clermont-Ferrand in the Auvergne province of France. It is one of the three largest tyre manufacturers in the world along with Bridgestone and Goodyear. In addition to the Michelin brand, it also owns the BFGoodrich, Kleber, Tigar, Riken, Kormoran and Uniroyal (in North America) tyre brands.

Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate mechanical properties of rubbers and, in particular, deformation and fatigue crack growth. Also the reinforcement of elastomers and rubbers with particulate fillers is an active field of scientific research.

Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the efforts carried out by the company are mainly related with tyre manufacturing and innovative macromolecular compounds research, highlighted both from IPC code analysis and from the analysis of the map of patents topics.

Scientific Papers Affiliation (2011-2016)

Number: 33

Examples of relevant Scientific Publications:

Complex dependence on the elastically active chains density of the strain induced crystallization of vulcanized natural rubbers, from low to high strain rate

Polymer, Volume 97, 5 August 2016, Pages 158-166

Nicolas Candau, Laurent Chazeau, Jean-Marc Chenal, Catherine Gauthier, Etienne Munch

Strain Induced Crystallization (SIC) of Natural Rubbers (NR) with different network chain densities (*v*) is studied. For the weakly vulcanized rubber, the melting stretching ratio $\lambda_m$at room temperature is the lowest. This is correlated with larger crystallites in this material measured by in situ WAXS, suggesting their higher thermal stability. SIC kinetics is then studied via stretching at various strain rates (from 5.6×10^{-5} s^{-1} up to 2.8×10^{1} s^{-1}). For the slowest strain rates, SIC onset (λ_c) is clearly the lowest in weakly vulcanized rubber. By increasing the strain rate, λ_c of the different materials increase and converge. For the highest strain rates, λ_c values still increase but less rapidly for the weakly vulcanized sample. This complex dependence on the elastically active chains (EAC) density of SIC has been confirmed by in situ WAXS during dynamic experiments and interpreted as a consequence of both the polymer chain network topology and of the entanglements dynamics.

Theoretical modelling and experimental study of the fatigue of elastomers under cyclic loadings of variable amplitude

Comptes Rendus Mécanique, Volume 342, Issue 8, August 2014, Pages 450-458

Audrey Jardin, Jean-Baptiste Leblond, Daniel Berghezan, Maude Portigliatti

Deviations from Miner's linear law of cumulative damage have been modelled and observed many times for the fatigue of metals, but almost no analogous studies have been performed for elastomers. Such a study is reported here. A simple phenomenological model, applicable to any type of material and able to quantitatively reproduce such deviations, is presented first. This model is based on continuum damage mechanics. It relates the fatigue damage of the material to the number of cycles through some suitable evolution law, in which the derivative of damage is expressed as a non-factorizable function of the instantaneous load cycle and the damage itself. Fatigue experiments performed on "diabolo" specimens made of two different elastomeric materials and subjected to two successive cyclic loads of different amplitudes are then reported. Significant deviations from Miner's rule are observed: Miner's "total cumulated damage" may be lower or larger than unity by a small or large amount, depending on the sequence of loadings and the type of material. As a rule, the deviation from Miner's rule systematically changes sign upon reversal of the sequence of loadings. The model is shown to allow an acceptable reproduction of the experimental results, and especially of this systematic change of sign.

Depercolation of aggregates upon polymer grafting in simplified industrial nanocomposites studied with dielectric spectroscopy

Polymer, Volume 73, 2 September 2015, Pages 131-138

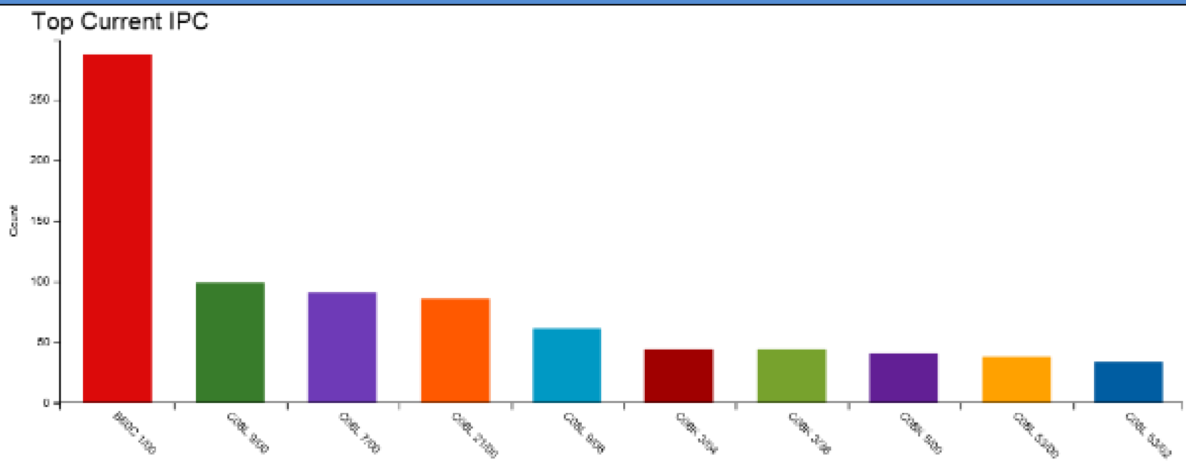
Guilhem P. Baeza, Julian Oberdisse, Angel Alegria, Kay Saalwächter, Marc Couty, Anne-Caroline Genix

The dynamics of polymer and filler in simplified industrial silica–styrene–butadiene nanocomposites (silica Zeosil 1165 MP, volume fraction 0–21%v) have been studied with broadband dielectric spectroscopy (BDS) and nuclear magnetic resonance (NMR). The fraction of graftable matrix chains was varied from 0 to 100%D3. The introduction of silica nanoparticles is shown to leave the segmental relaxation unaffected, an observation confirmed by the measurement of only a thin (some Angstroms thick) immobilized layer by NMR. The low-frequency measurements are resolved in two distinct dielectric Maxwell–Wagner–Sillars (MWS) processes of different behavior with respect to changes of large-scale silica structures induced by variations of filler fraction and grafting. It is found that increasing grafting leaves the first MWS-process unaffected, while it decreases the strength of the (slower) second MWS by about a decade. At constant silica volume fraction, this indicates depercolation of the filler, thereby providing a microscopic explanation of the evolution of rheological reinforcement. The sensitivity to large-scale reorganizations together with a characterization of local polymer dynamics provides insight over many length- and time-scales into structure and dynamics of nanocomposites, and thus the physical origin of the reinforcement effect.

Published Patents (2011-2016)

Number: 490

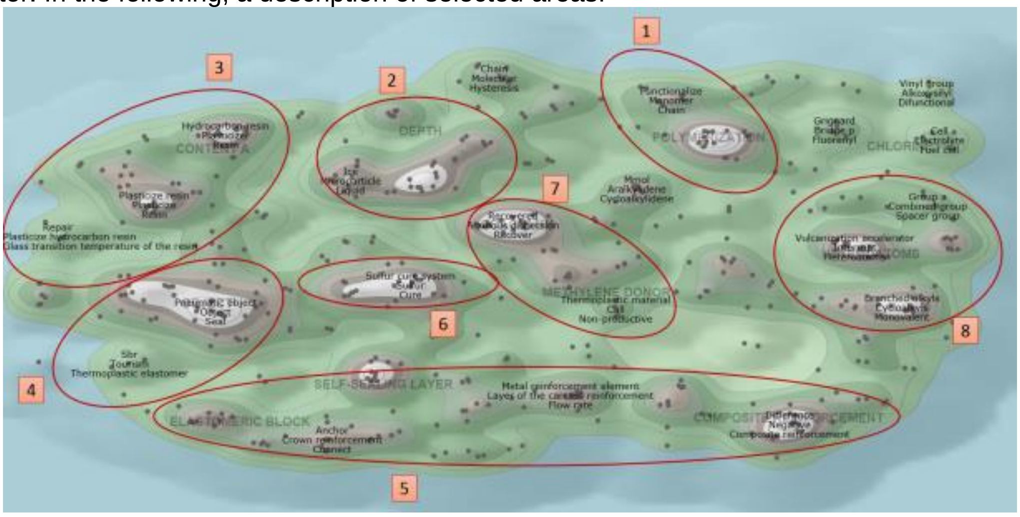
IPC Codes



B60C Vehicle tyres; Tyre inflation; Tyre changing; Connecting valves to inflatable elastic bodies in general; Devices or arrangements related to tyres
C08L Compositions of macromolecular compounds
C08K Use of inorganic or non-macromolecular organic substances as compounding ingredients

Map of patents Topics

The map of patents topics for Michelin highlights the most important research fields for the company in the Tyres sector. In the following, a description of selected areas:



1. Polymerization processes: monomers and catalysts
2. Rubber compositions for vehicle tyres
3. Reinforcing fillers and plasticizing resins
4. Self-sealing compositions for pneumatic objects
5. Reinforcement layers and elements for tyres: elastomeric, metallic and composite elements
6. Sulphur containing compounds
7. Methods for masterbach preparation (for additive inclusion)
8. Vulcanization accelerators and coupling agents

Pirelli & C. S.p.A	
Sector	**Logo**
Transport - Tyres	
Headquarter	
Milan, Italy	
Website	
www.pirelli.com	

Description

Pirelli & C. SpA is a multinational company based in Milan, Italy, formerly listed on the Milan Stock Exchange since 1922. The company is active in the fields of automotive and tyres, with its subsidiary Pirelli Tyre SpA.
Concerning the scientific publications, the activity emerges to be strongly dedicated to investigate mechanical and rheological properties of rubbers. Other remarkable fields of scientific publication are related to nanoparticles for rubber functionalization, rubber composites and solar energy materials.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the company is active in bringing innovation through the tyre sector, publishing patents on methods and materials for tyre reinforcement and novel compounds for rubber additivation. The most common topics for Pirelli published patents are reported in the following map of patents topics analysis.

Scientific Papers Affiliation (2011-2016)

Number: 12

Examples of relevant Scientific Publications:

The mechanisms of the sulphur-only and catalytic vulcanization of polybutadiene: An EPR and DFT study

European Polymer Journal, Volume 62, January 2015, Pages 222-235

D. Dondi, A. Buttafava, A. Zeffiro, C. Palamini, A. Lostritto, L. Giannini, A. Faucitano

The EPR investigation of the sulphur-only vulcanization of polybutadiene has afforded evidence of free radical activity and proposals for the identification of the paramagnetic intermediates are forwarded. Some of the species (polysulphonyl and sulphuranyl radicals) are thought to be direct evidence of a free radical component in the vulcanization mechanism. Indirect evidence of a vulcanization free radical mechanism comes also from other species, like stable tertiary carbon radicals and delocalized thiyl radicals which are characterised by absence of α and β hydrogen atoms. This structural feature is reckoned with sulphur induced dehydrogenation reactions which are known to be dominant at higher temperatures but are suggested to start to be active, as minor mechanism, already at the vulcanization temperatures. As a necessary support for the present and future vulcanization studies based on the EPR methodology, part of the work is devoted to a survey of all the possible radical intermediates and their properties which have been investigated with the help of DFT M.O. computations and specific ancillary EPR experiments to implement the available literature information. Amongst the results obtained is the observation that the g tensor of the polysulphanyl radicals RSradical dotn ($n \geqslant 2$) is invariant with respect to he number of sulphur atoms in the polysulphane chains; however, in conditions of high sulphur atoms concentration (as in molten sulphur), a significant decrease of gav is predicted to occur as a consequence of through-space spin exchange phenomena. Other results concern the free radical vulcanization chemistry of sulphur whose attitude to act as scavenger of polybutadiene allyl radicals has been assessed. The vulcanization carried out in presence of t-butyl benzothiazole sulphenamide and Zn stearate has afforded very similar EPR spectra together with a moderately faster radicals forming kinetics; this result is considered proof that no change of the vulcanization free radical component into polar or concerted mechanisms is induced by the catalyst and the promoter

Mechanical and rheological properties of natural rubber compounds containing devulcanized ground tire rubber from several methods

Polymer Degradation and Stability, Volume 121, November 2015, Pages 369-377

Ivan Mangili, Marina Lasagni, Manuela Anzano, Elena Collina, Valeria Tatangelo, Andrea Franzetti, Paola Caracino, Avraam I. Isayev

In the recent past we reported the investigation of different devulcanization processes of a ground tire rubber (GTR) such as supercritical fluid, ultrasonic and biological technologies. Each of these techniques had been previously optimized, focusing on the experimental combination of parameters providing the best devulcanization conditions. The present study aims to extensively compare the optimal conditions of these three different techniques for the devulcanization of a GTR. In particular the GTR and the devulcanizates by each technique were blended into raw natural rubber at a concentration of 10 phr. The rheological and mechanical properties of their vulcanizates were investigated and compared to find out the rubber providing the highest compatibility for compounding and revulcanization. In addition, a comparison of these results was made with the ones of raw natural rubber compound and vulcanizate.

The clay mineral modifier as the key to steer the properties of rubber nanocomposites

Applied Clay Science, Volume 61, June 2012, Pages 14-21

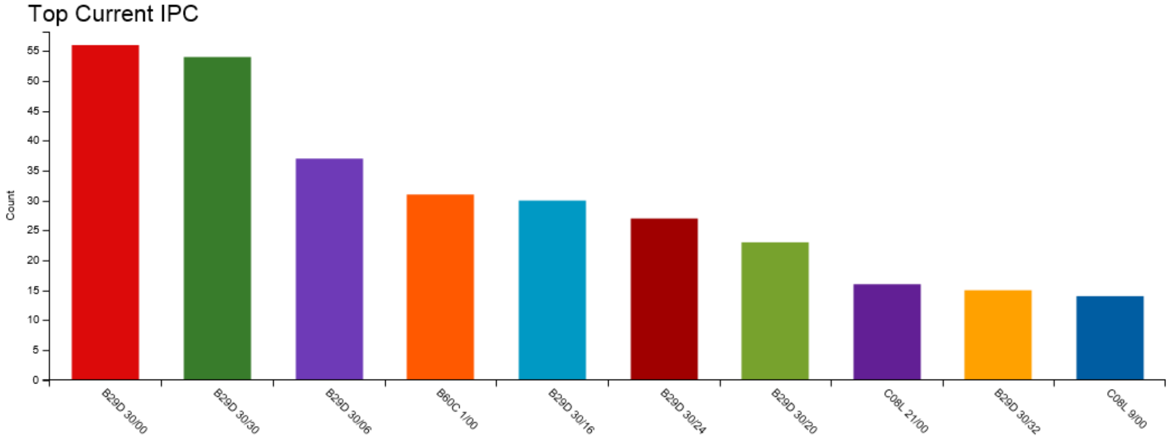
Lucia Conzatti, Paola Stagnaro, Giovanna Colucci, Roberta Bongiovanni, Aldo Priola, Angela Lostritto, Maurizio Galimberti

An innovative organoclay containing polybutadiene chains was prepared in order to make rubber nanocomposites based on natural rubber or styrene–butadiene copolymer. It was obtained by reacting a melanised polybutadiene oligomer with the single bond CH_2CH_2OH moieties present in the ammonium cation of a commercially available organoclay (Cloisite 30B). Elastomeric nanocomposites were also prepared with a reference organoclay, formed by intercalation during mixing with dialkyl dimethylammonium chloride. Sulphur cured nanocomposites were characterised in terms of curing kinetics, morphology, tensile and dynamic-mechanical properties; chemical interactions between the modifier of the new organoclay and the matrices can be inferred by experimental evidences.

Published Patents (2011-2016)

Number: 278

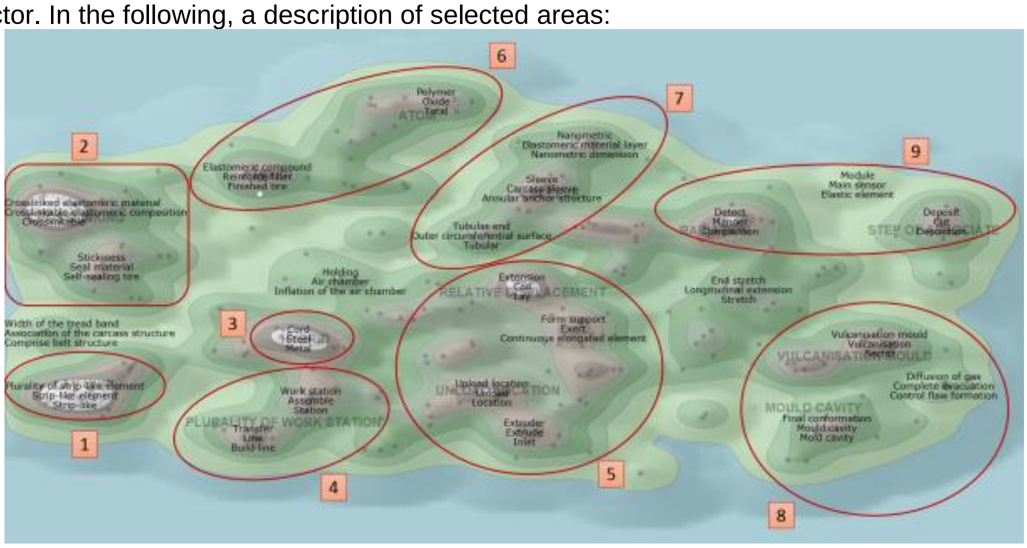
IPC Codes



B29D Producing particular articles from plastics or from substances in a plastic state
B60C Vehicle tyres; Tyre inflation; Tyre changing; Connecting valves to inflatable elastic bodies in general; Devices or arrangements related to tyres
C08L Compositions of macromolecular compounds

Map of patents Topics

The map of patents topics for Pirelli highlights the most important research fields for the company in the Tyres sector. In the following, a description of selected areas:



1. Processes for manufacturing reinforcing structures for vehicle tyres
2. Cross-linkable elastomeric compositions and self-sealing materials
3. Metal elements for tyres reinforcement
4. 5. Processes for producing tyres for vehicles
6. Elastomeric compounds and compositions
7. Plants and machines for producing tyres
8. Vulcanization process
9. Surface treatments for tyres

TELECOMMUNICATIONS

Table A.10. Telecommunications

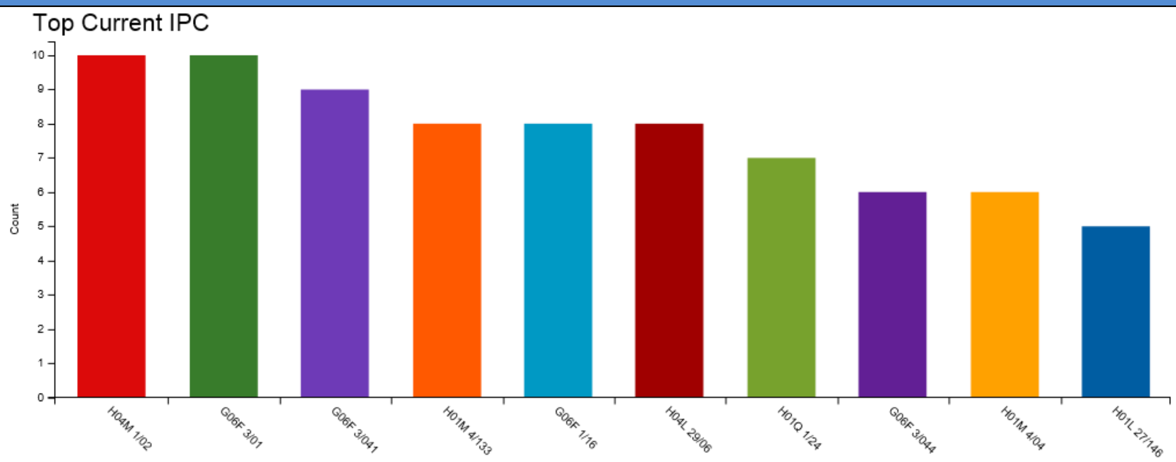
NOKIA CORPORATION	
Sector	**Logo**
Telecommunications - Electronics	NOKIA
Headquarter	
Espoo, Uusimaa, Finland	
Website	
http://www.nokia.com/	
Description	
Nokia is a Finnish multinational telecommunications and information technology company, founded in 1865. Nokia is headquartered in Espoo, Uusimaa, in the greater Helsinki metropolitan area. Concerning the scientific publications, the activity emerges to be strongly dedicated to innovative materials for electronics. Several studies are related to graphene and its application for flexible devices and energy storage appliances. Also studies on alkali metals and their applications are reported to be carried out, and some others on management and recycling of electronic waste. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that the company is active in the field of telecommunications, publishing several patents related to innovative materials and devices. The analysis of IPC codes shows that Nokia research is related to electronic and electric devices. Also the analysis of the map of patents topics, further reported, shows that the selected patents are linked with areas of interest of electric and electronic devices, such as batteries, sensors and electronics for mobile devices.	
Scientific Papers Affiliation (2011-2016)	
Number: 17	
Examples of relevant Scientific Publications:	
Management and recycling of electronic waste *Acta Materialia, Volume 61, Issue 3, February 2013, Pages 1001-1011* Pia Tanskanen Waste electrical and electronic equipment (WEEE) is one of the largest growing waste streams globally. Hence, for a sustainable environment and the economic recovery of valuable material for reuse, the efficient recycling of electronic scrap has been rendered indispensable, and must still be regarded as a major challenge for today's society. In contrast to the well-established recycling of metallic scrap, it is much more complicated to recycle electronics products which have reached the end of their life as they contain many different types of material types integrated into each other. As illustrated primarily for the recycling of mobile phones, the efficient recycling of WEEE is not only a challenge for the recycling industry; it is also often a question of as-yet insufficient collection infrastructures and poor collection efficiencies, and a considerable lack of the consumer's awareness for the potential of recycling electronics for the benefit of the environment, as well as for savings in energy and raw materials.	
Nickel and copper conductive patterns fabricated by reactive inkjet printing combined with electroless plating *Materials Letters, Volume 132, 1 October 2014, Pages 302-306* Dmitrii I. Petukhov, Marina N. Kirikova, Alexander A. Bessonov, Marc J.A. Bailey A simple, low-cost and easy scale-up technique for fabrication of conductive interconnects for flexible electronic devices is presented. A thin seed layer of nickel or copper was formed on the surface of PEN substrate via reactive inkjet printing of metal salt and reducing agent instead of traditional seed layers such as palladium nanoparticles and palladium or silver salts. For deposition of a uniform metal coating a polymer substrate patterned with the seed layer was immersed in an electroless plating bath. The electrical resistivity of deposited nickel–phosphorus and copper layers was 3.8 ± 0.2 mΩ·cm and 29 ± 2 μΩ·cm, respectively. The obtained structures possess excellent adhesion to polymeric substrates and reveal only slight decrease of conductivity after 20,000 bending cycles.	
Electrochemically exfoliated graphene oxide/iron oxide composite foams for lithium storage, produced by simultaneous graphene reduction and Fe(OH)3 condensation *Carbon, Volume 84, April 2015, Pages 254-262* Zhen Yuan Xia, Di Wei, Elzbieta Anitowska, Vittorio Bellani, Luca Ortolani, Vittorio Morandi, Massimo Gazzano, Alberto Zanelli, Stefano Borini, Vincenzo Palermo We describe the production of graphene-based composites for energy storage, obtained by a combination of electrochemical and solution processing techniques. Electrochemically exfoliated graphene oxide sheets (EGO) are produced using an original setup that allows fast expansion of graphite flakes and efficient exfoliation of expanded graphite *via* an electrochemical route. The sheets are deposited on a sacrificial nickel foam together with an iron hydroxide colloidal precursor. Calcination treatment simultaneously renders the EGO foam conductive and transforms $Fe(OH)_3$into hematite (α-Fe_2O_3), yielding a nanoporous Fe_2O_3 layer on the surface of the mesoporous EGO foam, creating an ideal structure for lithium storage. The obtained graphene/metal oxide hybrid is a continuous,	

electrically conductive three-dimensional (3D) composite featuring a hierarchical meso–nano porous structure. A systematic study of these composites, varying the Fe_2O_3:EGO ratio, is then performed to maximize their performance as nanostructured electrodes in standard coin cell batteries.

Published Patents (2011-2016)

Number: 150

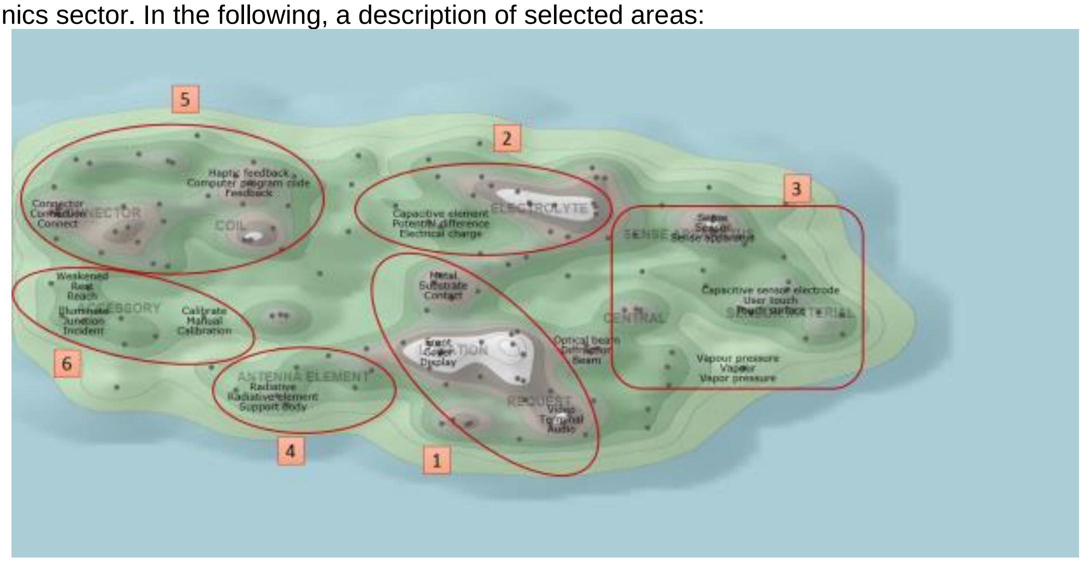
IPC Codes



H04M Telephonic communication
G06F Electric digital data processing
H01M Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
H04L Transmission of digital information, e.g. telegraphic communication
H01Q Aerials
H01L Semiconductor devices; Electric solid state devices not otherwise provided for

Map of patents Topics

The map of patents topics for Nokia highlights the most important research fields for the company in the Electronics sector. In the following, a description of selected areas:



1. Materials and methods for producing electronic apparatus (mainly displays) and metallic parts (covers and wires)
2. Batteries: materials and methods for electrolyte and graphene based electrodes
3. Sensors: materials and applications
4. Antenna elements
5. Mobile electronic devices: connectors and sound producing systems
6. Electrical components and devices

PHILIPS

Sector

Telecommunications - Electronics

Headquarter

Amsterdam, Netherlands

Website

http://www.philips.com/

Logo

Description

Koninklijke Philips N.V. is a Dutch technology company headquartered in Amsterdam with primary divisions focused in the areas of electronics, healthcare and lighting. It is one of the largest electronics companies in the world.
Concerning the scientific publications, the activity emerges to be strongly dedicated to a wide range of materials that find application in the electronics sector. A remarkable part of studies are related with materials used for the production and optimization of light-emitting diodes (LEDs). Other studies focus attention on innovative materials such as graphene-related materials and polymer nanocrystalline materials. Also materials to be used for solar cells have been object of study.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen, both from IPC codes analysis and from the analysis of map of patents topics that the sector in which Philips carries out major efforts is the light emitting diodes (LEDs) sector. In this field the company is active to explore new materials and methods for processing them.

Scientific Papers Affiliation (2011-2016)

Number: 40

Examples of relevant Scientific Publications:

Ferrites

Reference Module in Materials Science and Materials Engineering, 2016, Current as of 28 October 2015

P.J. van der Zaag

An introduction is given to the properties and applications of soft-magnetic ferrites. The origin of the magnetism in these spinel ferrites due to superexchange is explained. The developments in reducing the dissipation of ferrites, notably in MnZn- and NiZn-ferrites, for their main application in inductors and transformer cores are discussed. Finally, pointers are given to newly emerging applications of ferrites in thin films for integrated magnetic devices, tunneling magneto-resistance devices, and life science applications of Fe_3O_4 in magnetic beads for *in vitro* diagnostics and nanoparticles in biomedicine.

Increasing the cycle life of lithium ion cells by partial state of charge cycling

Microelectronics Reliability, Volume 55, Issue 11, November 2015, Pages 2247-2253

Hans de Vries, Thanh Trung Nguyen, Bert Op het Veld

In this study, the possibilities to enhance the cycle life of Li-ion cells were explored. Cells were charge-cycled in different ways. Discharging from the fully charged state down to several levels showed that the cycle life is determined by the total amount of transferred charge. Cycling a fixed amount of charge from a partially charged state leads to longer cycle life as the initial state of charge is lower. Impedance spectroscopy showed that the solid electrolyte interface forms the main contribution to the degradation of the cells

Electrophoretic deposition of graphene-related materials: A review of the fundamentals

Progress in Materials Science, Volume 82, September 2016, Pages 83-117

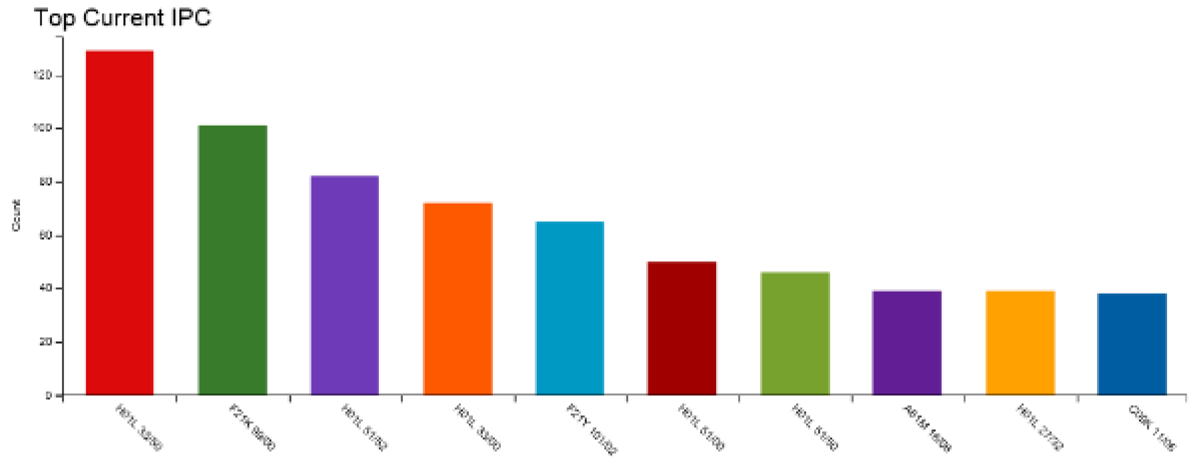
Mani Diba, Derrick W.H. Fam, Aldo R. Boccaccini, Milo S.P. Shaffer

The Electrophoretic Deposition (EPD) of graphene-related materials (GRMs) is an attractive strategy for a wide range of applications. This review paper provides an overview of the fundamentals and specific technical aspects of this approach, highlighting its advantages and limitations, in particular considering the issues that arise specifically from the behaviour and dimensionality of GRMs. Since obtaining a stable dispersion of charged particles is a pre-requisite for successful EPD, the strategies for suspending GRMs in different media are discussed, along with the resulting influence on the deposited film. Most importantly, the kinetics involved in the EPD of GRMs and the factors that cause deviation from linearity in Hamaker's Law are reviewed. Side reactions often influence both the efficiency of deposition and the nature of the deposited material; examples include the reduction of graphene oxide (GO) and related materials, as well as the decomposition of the suspension medium at high potentials. The microstructural characteristics of GRM deposits, including their degree of reduction and orientation, strongly influence their performance in their intended function. These factors will also determine, to a large extent, the commercial potential of this technique for applications involving GRMs, and are therefore discussed here.

Published Patents (2011-2016)

Number: 1657

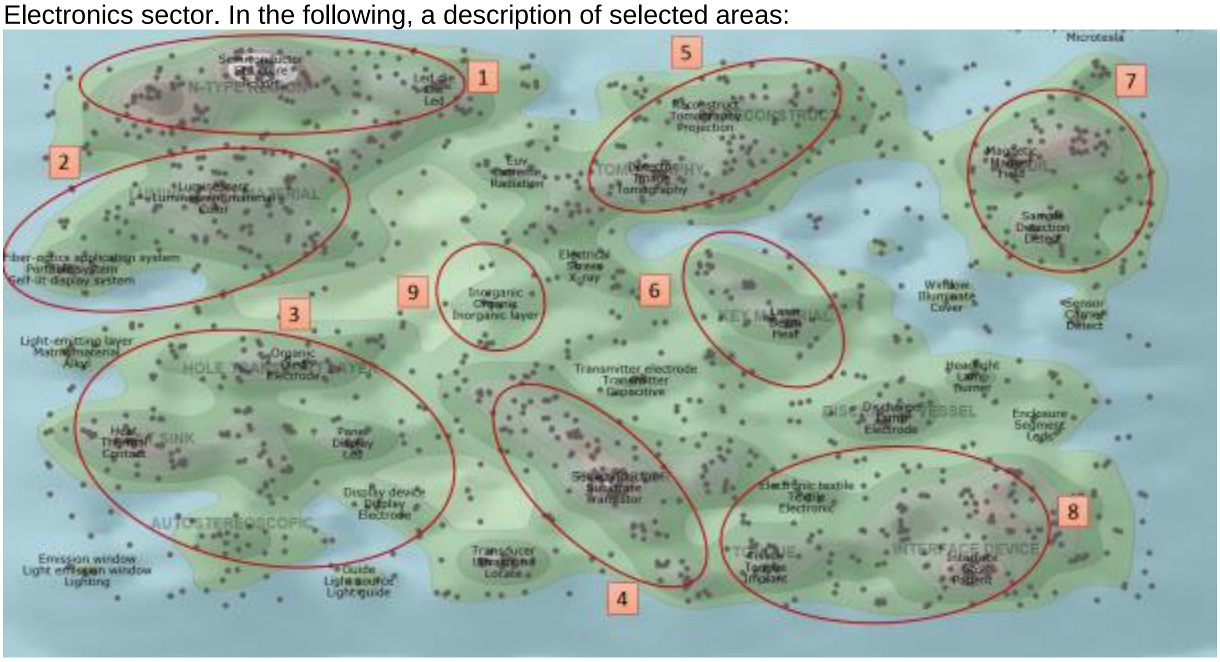
IPC Codes



H01L Semiconductor devices; Electric solid state devices not otherwise provided for
F21K Light sources not otherwise provided for
F21Y Indexing scheme associated with subclasses F21L, F21S and F21V, relating to the form of the light sources
A61M Devices for introducing media into, or onto, the body; Devices for transducing body media or for taking media from the body; Devices for producing or ending sleep or stupor
C09K Materials for applications not otherwise provided for; Applications of materials not otherwise provided for

Map of patents Topics

The map of patents topics for Philips highlights the most important research fields for the company in the Electronics sector. In the following, a description of selected areas:



1. Semiconductor light emitting devices (LEDs) and materials for LEDs manufacturing: polymers and nanostructured phosphors containing materials
2. Materials and additive compounds for coloured LEDs
3. Display devices, optical devices and lightning systems
4. Semiconductor devices and methods for manufacturing
5. Multilayered scintillator materials
6. Laser beam: materials and processing of lens
7. Magnets application in powder detecting devices and sensors
8. Electronic textiles for health applications
9. Multilayered encapsulating materials

SIEMENS

Sector	Logo
Telecommunications – Automation and Consumers products	

Headquarter	
Berlin and Munich, Germany	
Website	
www.siemens.com	

Description

Siemens AG is a German company headquartered in Berlin and Munich and the largest engineering company in Europe with branch offices abroad. The principal divisions of the company are Industry, Energy, Healthcare and Infrastructure & Cities, which represent the main activities of the company. Concerning the scientific publications, the activity emerges to be dedicated to a wide range of materials. Among the scientific researches it is possible to find publications on alloys and superalloys, investigating their properties and feasible applications. Also several studies concerning composite materials (fiber reinforced composites, glass-polymer composites, etc.) have been published. They are mainly focused on the characterization of materials, mainly evaluating their mechanical, thermal and electrical properties. Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that Siemens is active in different fields: Among others the field of innovative consumer products development and the field of metal processing appear to be the ones most investigated, as it is possible to infer from the further reported IPC code analysis and map of patents topics. Also innovations in the fields of composite materials, reinforced plastic materials and magnets occupy a relevant position among published patents.

Scientific Papers Affiliation (2011-2016)

Number: 57

Examples of relevant Scientific Publications:

Tape cast isotropic, fine-grained tungsten for thermo-cyclic loading applications

Fusion Engineering and Design, Volume 105, April 2016, Pages 39-52

Mathias Sommerer, Muyuan Li, Ewald Werner, Hubertus von Dewitz, Steffen Walter, Stefan Lampenscherf, Thomas Arnold

This paper introduces tape casting as a new route for the production of isotropic and fine-grained tungsten components. Microstructural and thermal properties of tape cast tungsten samples are determined. Thermal shock behavior according to the thermo-cyclic loading of standing X-ray anodes is investigated and compared to the behavior of a rolled tungsten grade. The development of surface roughness during the thermal shock loading is discussed in relation to the development of the grain structure and crack pattern. The fine-grained and stable microstructure of the tape cast material exhibits less roughening under such test conditions.

Effect of SO_2 and water vapour on the low-cycle fatigue properties of nickel-base superalloys at elevated temperature

Materials Science and Engineering: A, Volume 564, 1 March 2013, Pages 107-115

Johan J. Moverare, Gunnar Leijon, Håkan Brodin, Frans Palmert

In this study the effect of SO_2+water vapour on strain controlled low cycle fatigue resistance of three different nickel based superalloys has been studied at 450 °C and 550 °C. A negative effect was found on both the crack initiation and crack propagation process. The effect increases with increasing temperature and is likely to be influenced by both the chemical composition and the grain size of the material. In general the negative effect decreases with decreasing strain range even if this means that the total exposure time increases. This is explained by the importance of the protective oxide scale on the specimen surface, which is more likely to crack when the strain range increases. When the oxide scale cracks, preferably at the grain boundaries, oxidation can proceed into the material, causing preferable crack initiation sites and reduced fatigue resistance.

A new 12% chromium steel strengthened by Z-phase precipitates

Scripta Materialia, Volume 113, 1 March 2016, Pages 93-96

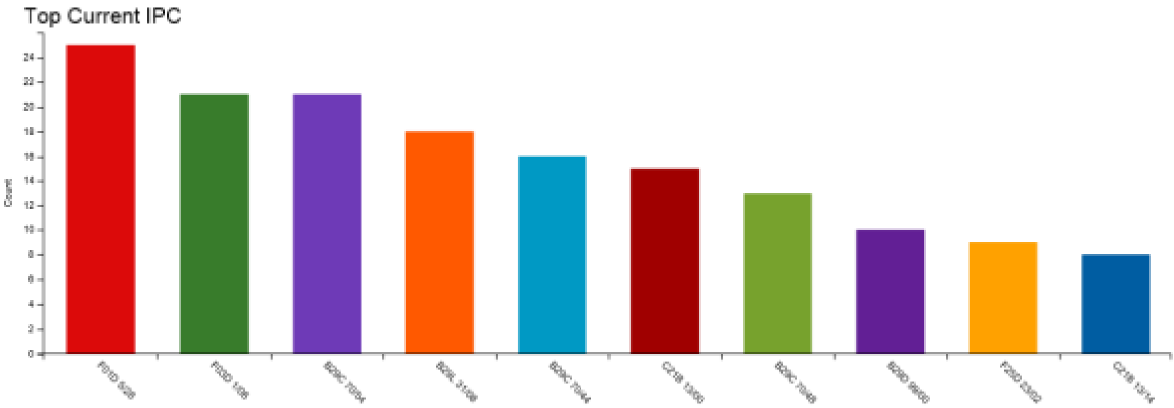
Fang Liu, Masoud Rashidi, Lennart Johansson, John Hald, Hans-Olof Andrén

In order to increase the corrosion resistance and simultaneously maintain the creep resistance of 9–12% Cr steels at 650 °C, a new alloy design concept was proposed, using thermodynamically stable Z-phase (CrTaN) precipitates to strengthen the steel. A new trial Z-phase strengthened 12% Cr steel was produced and creep tested. The steel exhibited good long-term creep resistance. Dense nano-sized Z-phase precipitates were formed at an early stage, and coarsened slowly. They remained small after more than 10,000 h.

Published Patents (2011-2016)

Number: 333

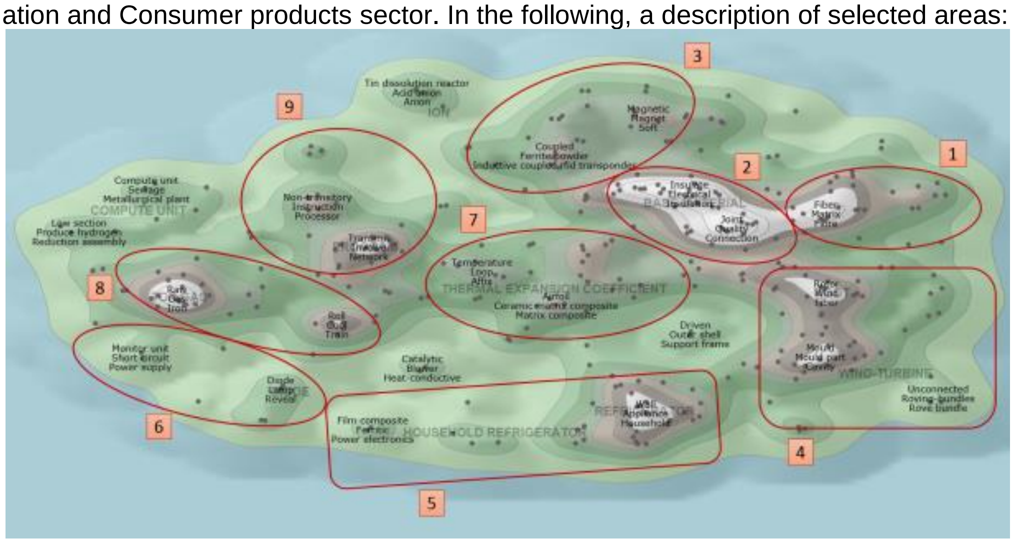
IPC Codes



F01D Non-positive-displacement machines or engines, e.g. steam turbines
F03D Wind motors
B29C Shaping or joining of plastics; Shaping of substances in a plastic state, in general; After- treatment of the shaped products, e.g. repairing
B29L Indexing scheme associated with subclass B29C, relating to particular articles
C21B Manufacture of iron or steel
B29D Producing particular articles from plastics or from substances in a plastic state
F25D Refrigerators; Cold rooms; Ice-boxes; Cooling or freezing apparatus not covered by any other subclass

Map of patents Topics

The map of patents topics for Siemens highlights the most important research fields for the company in the Automation and Consumer products sector. In the following, a description of selected areas:



1. Fiber or textile reinforced plastic materials and producing methods
2. Composite materials for electrical insulation
3. Magnets: applications in electrical machines
4. Wind turbines: materials for components production and processing methods
5. Refrigerator devices: wall materials and other parts manufacturing processes
6. Circuits and diodes materials
7. Ceramic matrix for SOFC applications
8. Methods and systems for processing metallic raw materials (iron, steel, etc.)
9. Electrical devices and systems

ABB	
Sector	**Logo**
Telecommunications – Automation and Consumers products	ABB
Headquarter	
Zurich, Switzerland	
Website	
www.abb.com	

Description

ABB (ASEA Brown Boveri) is a Swedish-Swiss multinational corporation headquartered in Zürich, Switzerland, operating mainly in robotics and the power and automation technology areas.
Concerning the scientific publications, the company's activity emerges to be strongly dedicated to industrial automation. This is closely linked with the field of Raw Materials in many cases, in particular for studies regarding predictive models, control strategies or optimisation procedures for industrial applications. Some reported studies refer to mines, rotary cement kilns, steel plants and pulp processes. Also some studies investigating material properties are reported.
Concerning the analysis of the patent portfolio owned in Europe, it can be clearly seen that ABB mainly focuses its research efforts on magnets, inductances and transformers, as reported in the IPC codes analysis graph. Also composites for different applications appear to be an important field for patents publication, as shown in the map of patents topics. Among others epoxy resins, insulating materials and materials applied in fuel cells construction, appear to be important field of patent publication.

Scientific Papers Affiliation (2011-2016)

Number: 37

Examples of relevant Scientific Publications:

Production Optimization and Scheduling across a Steel Plant

Computer Aided Chemical Engineering, Volume 29, 2011, Pages 920-924

Iiro Harjunkoski, Sleman Saliba, Matteo Biondi

This paper focuses on the planning and scheduling optimization of two processes in steel production, the melt shop and hot rolling. Important steps and challenges of bringing a scheduling model from a conceptual idea to an industrial solution that steers the complete production of a steel plant on a day-to-day basis are covered. Moreover, we discuss the main development steps and the embedding of a mathematical model based solution into a production system. Finally, we present some results based on real-world data from an industrial implementation.

Polymer-grafted Al_2O_3-nanoparticles for controlled dispersion in poly(ethylene-co-butyl acrylate) nanocomposites

Polymer, Volume 55, Issue 9, 25 April 2014, Pages 2125-2138

Martin Wåhlander, Fritjof Nilsson, Emma Larsson, Wen-Chung Tsai, Henrik Hillborg, Anna Carlmark, Ulf W. Gedde, Eva Malmström

We report a model system to control the dispersion and inter-particle distance of polymer-grafted Al_2O_3-nanoparticles in high molecular weight poly(ethylene-co-butyl acrylate). The proposed methods make it possible to extend the use of surface initiated atom transfer radical polymerization (SI-ATRP) in combination with more commercial grades of silanes and particles, showing the versatility of this polymerization process. The nanoparticles were surface-modified by an amine-terminated silane, forming multilayered silane coatings to which moieties capable of initiating ATRP were attached. Subsequently, "short" (DP: 117) and "long" (DP: 265) chains of poly(n-butyl acrylate) were grafted from the particles via SI-ATRP. The graft density was found to be in accordance with the density of the accessible amine groups and could therefore be assessed directly after the initial silanization step using UV–Vis spectrometry. From AFM micrographs, the grafted nanoparticles were found to be well-dispersed in the matrix. This observation was corroborated by a novel simulation method capable of transforming the inter-particle distances from 2D to 3D, for the closest and more distant neighbors. Further, we calculated the deviation ratios and concluded that the dispersions were homogeneous and that the inter-particle distances were related to the graft length. The homogeneous dispersions were explained by dominating enthalpic contributions of the polymer grafts to the nanocomposites in combination with shielding of the nanoparticle core–core attraction by the silane multilayer (similar to bimodal systems).

Influence of magnetic field-aided filler orientation on structure and transport properties of ferrite filled composites

Journal of Magnetism and Magnetic Materials, Volume 419, 1 December 2016, Pages 345-353

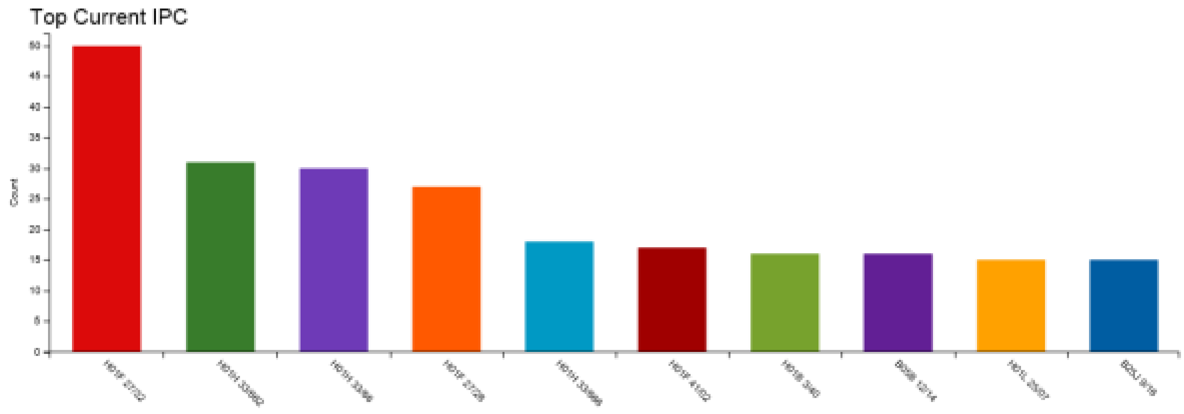
K. Goc, K. Gaska, K. Klimczyk, A. Wujek, W. Prendota, L. Jarosinski, A. Rybak, G. Kmita, Cz. Kapusta

Epoxy resins are materials commonly used for insulations and encapsulations due to their easy processing process and mechanical strength. For their applications in power industry and electronics the effective heat dissipation is essential, thus their thermal conductivity is one of the most important properties. Introduction of appropriate dielectric powders, preferably in an ordered way, can increase the thermal conductivity of the polymer while keeping its good electrical insulation properties. In this work we used strontium ferrite as a filler to study the evolution of the filler particles distribution in the fluid before curing. Magnetic ferrite particles were dispersed in liquid epoxy resin and formation of chain-like or more complex structures under applied external magnetic field was observed and investigated. Computer simulations made show that with increasing magnetic field these structures are characterized by longer chains, higher speed of particles displacement and stronger structural anisotropy. However, for highly-filled systems, stronger inter-particle interactions make the alignment process less effective. The effective thermal conductivity simulated with FEM methods increases with increasing filler content and the percolation threshold in aligned systems is achieved at lower filler concentrations than for reference isotropic samples. The results are compared with the experimental data and a good qualitative agreement is obtained.

Published Patents (2011-2016)

Number: 51

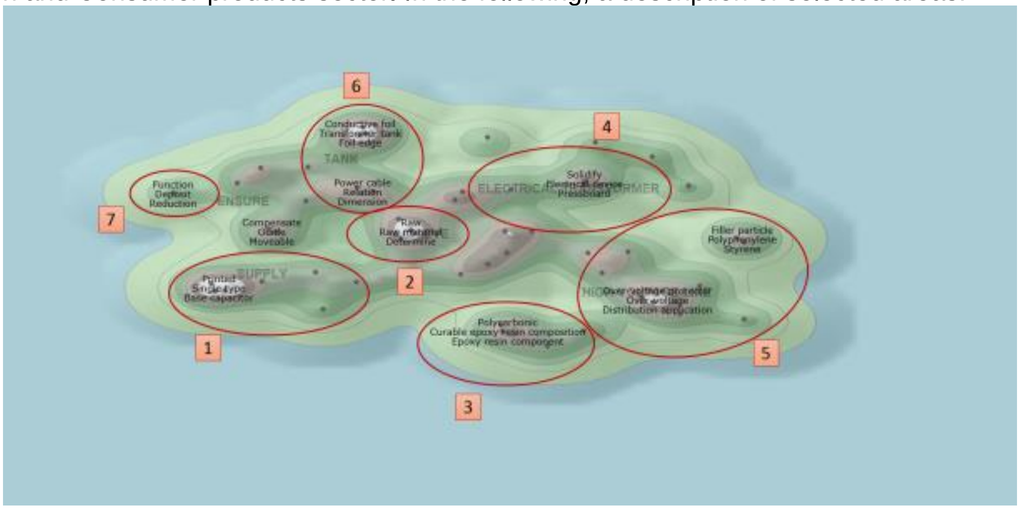
IPC Codes



H01F Magnets; Inductances; Transformers; Selection of materials for their magnetic properties
H01H Electric switches; Relays; Selectors; Emergency protective devices
H01B Cables; Conductors; Insulators; Selection of materials for their conductive, insulating, or dielectric properties
B05B Spraying apparatus; atomising apparatus; nozzels
H01L Semiconductor devices; Electric solid state devices not otherwise provided for
B25J Manipulators; Chambers provided with manipulation devices

Map of patents Topics

The map of patents topics for ABB highlights the most important research fields for the company in the Automation and Consumer products sector. In the following, a description of selected areas:



1. Composites for capacitors applications
2. Methods for calibrating raw material analysis
3. Epoxy resins compositions
4. Cellulose based electrically insulating materials
5. Insulating materials: nanostructured materials and composites
6. Electrical elements: bushings and cables
7. Fuel cells materials