Foresight

Material Resource Efficiency

Targeted scenario N°11

Glimpses of the future from the BOHEMIA study

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Research and Innovation

EN

***Material Resource Efficiency* - Targeted scenario N°11**

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EUROPEAN COMMISSION

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Directorate-General for Research and Innovation

2018

About BOHEMIA

BOHEMIA is a foresight study (contract N° Contract PP-03021-2015) designed specifically to support the preparation of the next framework programme.

The study put forward policy recommendations for the next framework programme, based on a foresight processes involving scenario development, a Delphi survey and an online consultation.

As part of its recommendations, the study identified 19 likely future scenarios with disruptive implications and associated priority directions for EU research and innovation.

The full range of the results of the study is available at https://ec.europa.eu/research/foresight

Targeted scenario N° 11

Material Resource Efficiency

Summary

It is 2040. Sustainable consumption patterns, truly circular production-consumption networks, and shifts to less harmful, often renewable resources have made Europe less dependent on natural resources, more self-sufficient and more competitive in its industries. In addition, environmental degradation has been reversed.

UN Sustainable Development Goals (SDGs) most relevant to this scenario:

The scenario

It is 2040. The European economy is less dependent on natural resources and more self-sufficient than anytime since the beginning of the century. There have been shifts to less material-intensive consumption patterns, to the closing of material loops through re-use and recycling, to the substitution of material resources by less harmful, often renewable ones, and to environmentally benign resource extraction methods.

Circular economy principles are applied across all systems of production and consumption, from agro-food to electronic goods. Consumer preferences have shifted towards services and products with longer life-time, prompting changes in product and service design (e.g. modular design, design for recycling, etc.), but also in business models (e.g. shift to services, sharing).

The use of rare earths has been reduced by 80% compared to 2016 figures. After having met the targets of the EU circular economy package of 2016, progress slowed down as physical and organizational barriers became more challenging to resolve. The target of recycling more than 90% of all waste physically or energetically has yet to be achieved. Recovered metals from landfills (e.g. aluminium, iron, copper, silver, gold,) contribute substantially to supply, but still provide less than 50% of the EU's demand.

Materials' substitution has implications throughout the entire production process and requires significant investments. Not all candidate materials fulfil initial expectations, for technological and economic reasons as well as for concerns about unexpected health risks. Renewable materials and the bio-economy play a more significant role, for the less harmful environmental effects associated with their use and their contribution to reducing dependency on non-European sources. Their significant economic promise has been used sustainably, managing the environmental consequences of their extraction and use.

Improved extraction and processing methods for all natural resources and environmental remediation techniques (including local geo-engineering) have enabled improvements in the European environment. Combining mining with the deposition of carbon-rich minerals offsets the damage caused by the extraction against climate related benefits. Deep sea mining was seen as a promising option in the times of increasing needs for "rare earths". However, it never quite took off, as it was tangled with environmental concerns and legal issues regarding the right to exploit offshore deep-sea resources, liabilities for environmental damages and the settling of international disputes. In the meantime, substitutability and the circular economy have alleviated the upward pressure in the prices of rare materials.

Relevance for Europe

Dependence on critical materials is a strategic issue, especially when these materials play key roles in important infrastructures, such as defence equipment.

The environmental damage caused by material extraction and by waste management is an important concern in Europe, as well as globally. By making more out of scarce natural resources, environmental damage is kept within the limits of planetary boundaries.

By strengthening R&I, Europe has the opportunity to play a leading role globally in the provision of solutions for efficient resource use. And so much so that Europe is home to a world-leading environmental services industry, which is set to expand massively into resource management roles in industrial value chains.

Contribution towards the SDGs

Finding alternative solutions to the use of scarce and critical natural resources is core to the achievement of the Sustainable Development Goals No. 12 on Responsible Consumption and Production and No. 3 on Good Health and Wellbeing, but also relevant to all other environment-related goals addressing water supply (6), energy (7), sustainable cities (11), climate action (13), life below water (14) and life on land (15).

Implications for EU policy

There are a number of EU policies that need to progress in synch to promote a more self-sufficient circular economy. Agriculture, Environment, Trade, Industry, Research and Innovation are at the core. Also external policies need to address the strategic implications for countries on which Europe depends for the supply of critical materials and resources.

As an overarching principle, the internalisation of environmental and social costs would provide a strong economic lever and incentive optimising resource efficiency in production and consumption.

More specifically, environmental regulation is an important demand-side driver of change towards realising extensive re-use and re-cycling, as are labour regulations when it comes to improving working conditions in resource-extracting and processing industries.

Future Directions for EU R&I policy recommended by the public consultation

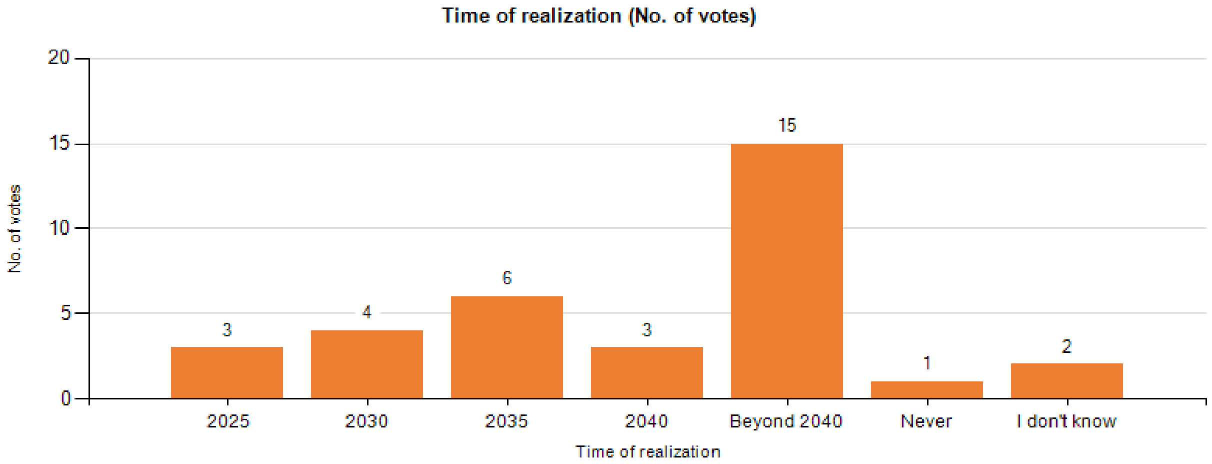
- **Environmental impact assessment**
- **Solutions for more efficient and sustainable use of materials in products over the entire life cycle**
- **More cost-efficient technologies for extraction of valuable materials from waste**
- **Circular industrial systems design**
- **Behavioural changes on the supply and demand side in response to incentives**
- **"No-waste" policies. Everything has to be brought back without loss of quality.**
- **Science-based approach to regulatory and policy decision-making**
- **Eco-efficient materials**
- **Use of solar energy for generation of electricity and storage to chemical energy**
- **New substitutes for rare materials**
- **Research focusing on renewable materials and their split up/recycling in early development process**

Annex: Relevant Data from the Delphi Survey

The Delphi survey of the BOHEMIA study asked experts about the time of realization of 143 statements about the future, and about the relevance of Research and Innovation for that realization, or about the relevance of the realization for Research and Innovation policy. The experts were asked to justify their judgements with arguments. The whole data set has been published and can be found at: https://ec.europa.eu/research/foresight

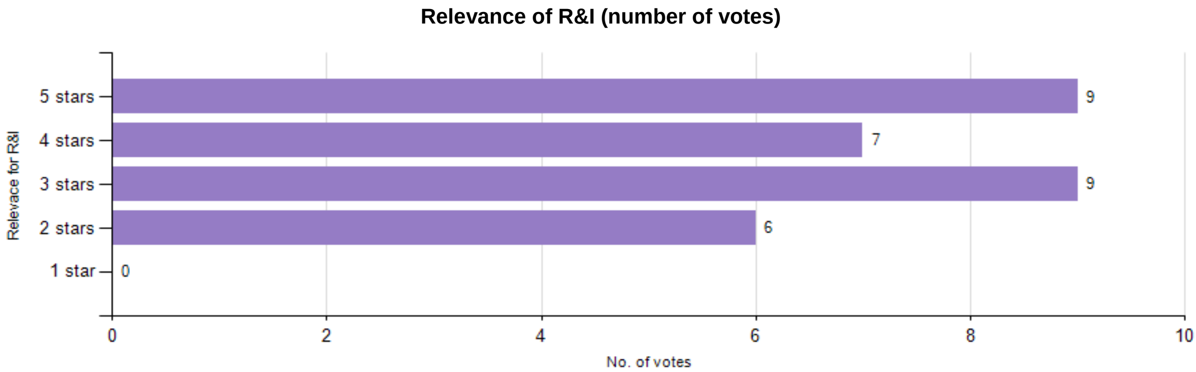
This annex includes the parts of the data set that are relevant to this scenario.

30% and more of the resources needed for electronic devices come from deep sea mining



Number of respondents : 32

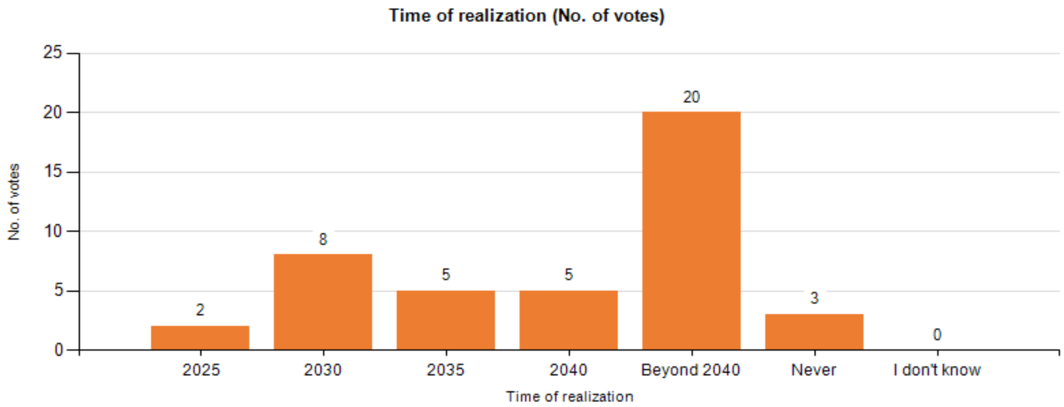
Arguments regarding the time of realization	**No. of votes**
Deep sea mining is a promising future option for primary supply of raw materials. However, the legal framework for exploitation is still being developed and there are only permits for exploration	19
Deep sea mining is a challenge for the environment, and needs a lot of energy. Therefore, it will take a long time before it becomes a reality. "Conventional" mining can also develop a lot, and prevails.	17
Polymetallic nodules can be mined from the deep sea – small lumps of rock that contain up to 28% metal – ranging in size from a golf ball to a potato, which contain, e.g. 26% Manganese, 6% Iron, 5% Silicon, 3% Aluminium, 1.4% Nickel, 1.3% Copper etc.	10
Continuing improvements in recycling and reuse and improvements in recovery from existing mines is likely to reduce the attractiveness of deep ocean mining.	9
Deep sea mining is environmentally critical and should be avoided.	4
Asteroid mining potentially can yield a greater variety of materials than deep sea mining. 16 Psyche is a metallic asteroid that could potentially supply such needs.	3



Average: 3.61 **Dispersion:** 1.23

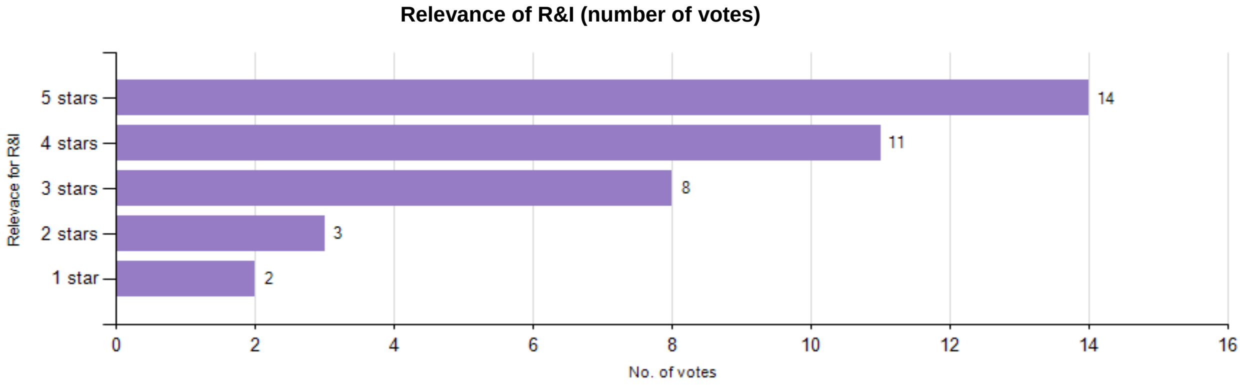
Arguments regarding the relevance of R&I	No. of votes
Lack of knowledge of the deep-sea environment necessitates a careful approach and needs further research.	26
Exploit the synergies in R&D with regards to exploration, extraction and processing.	11
We have a lack of knowledge on what kind of impacts tech and accelerated activities could have to environment. An increase of this knowledge is necessary.	11
Development of alternatives to current electronics materials including graphene, carbon nanotubes, etc. may warrant more research than deep sea mining.	6
Research is required regarding the ethics and impact of deep sea mining	6
Asteroid mining is a clear alternative to deep sea mining and may potentially have much greater total returns to Europe. The Solar System contains many orders of magnitude the resources on Earth.	2

CO2 capture from the air is applied in all EU capitals, urban and industrial areas in the EU (including CO2 conversion to permanently storable substances, for example, mineralization)



Number of respondents : 41

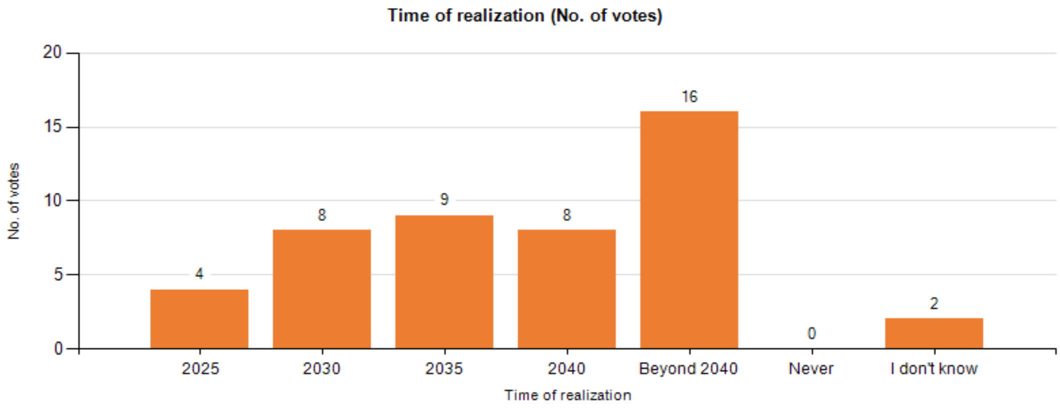
Arguments regarding the time of realization	**No. of votes**
The demand for carbon capture is huge.	27
Forests could be used to capture CO2 in wood products and subsitute fossil energy.	12
Synthetic biology and ecological engineering can be a cheap and scalable solution for earth terraformation.	10
Multiple alternatives to carbon sequestration are available including reduced CO2 generation, artificial photosynthesis, planting of forests, conversion of bogs to cranberry farming, and other options.	9
Petra Nova (produced by a Japanese Company) collects 90% of the CO2 emitted by a factory, up to 5000 tonnes per year.	5
Carbonclean technology (produced by an Indian company) is converting CO2 into baking soda – and could lock up 60,000 tonnes of CO2 a year.	5
Carbon capture from flue gas will be much more efficient than from the air (as in CCS).	4
Those technologies are far beyond what has been achieved for renewable-based electricity.	4
Using more wood in the construction industry would keep carbon captured.	3



Average: 3.84 **Dispersion:** 1.36

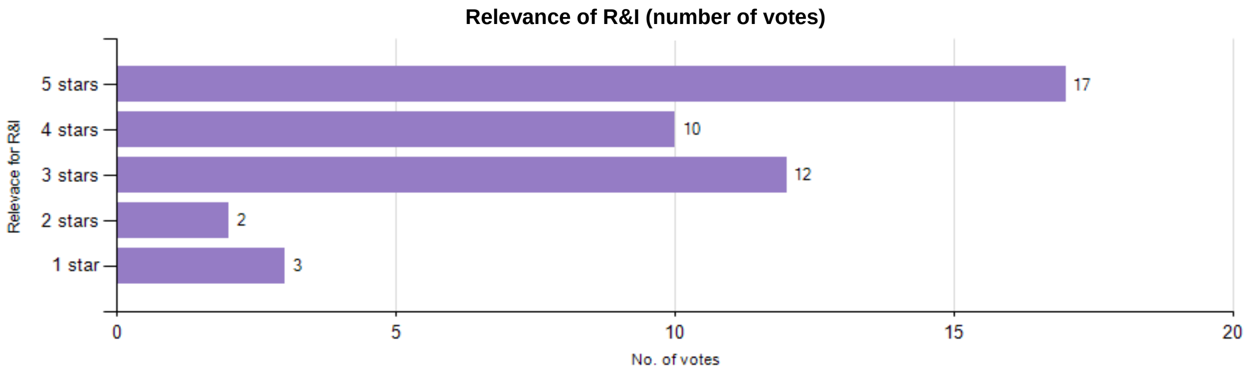
Arguments regarding the relevance of R&I	**No. of votes**
Europe is not at the forefront of these technologies, so it needs to scale up its relevant R&D.	28
Options that reduce energy use and reduce carbon production are more sustainable. Remaining carbon can be offset through planting trees or synthetic biology approaches that use the CO2.	14
Research on membrane technology for CO2 capture will bring together many researchers, stakeholders and private companies.	14
There is a promising line of research that needs to continue: US researchers have taken another step closer to developing a scalable option to capture and store carbon dioxide (CO2) using a new technique that involves injecting liquefied gas into ancient	6
artificial photosynthese could be an option	6
Researchers found that commonly used industrial minerals called zeolites could significantly improve the energy efficiency of "carbon capture" technology. More research is needed to expand on this promise.	5
Research on new ecosystems combining synthetically modified and autochthonous organisms is needed.	4
easy-to-use and cheap materials and processes are required for this	3
no need to capture so much CO2 once renewable electricity is available	3
Research on carbon storage technologies need to focus on the robustness of storage	2

The fact that more than 80% of all materials across industries can be substituted ensures an efficient utilization of resources in bio- and fossil-based production systems



Number of respondents : 44

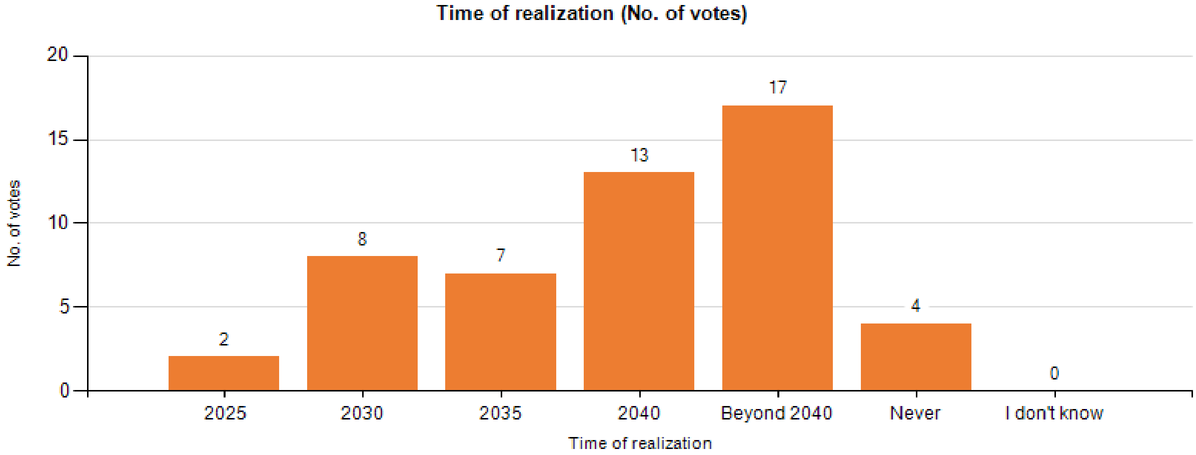
Arguments regarding the time of realization	**No. of votes**
Transition towards smart and efficient use of resources is necessary to make it possible.	38
With some materials, this is possible, but 80% is a very high number and needs a lot of time.	26
The shift to a decentralised circular economy could reduce the demand for virgin materials in manufacturing by 50 percent, and greatly reduce the need for long-distance transport, in addition to bio.	16
What precisely is the question, or statement.	3
Synthetic biology is a reality and will be the key to propelling the next bioeconomic based system.	3
Substitution of one material for another whose supply is not assured is not useful.	2



Average: 3.82 **Dispersion:** 1.41

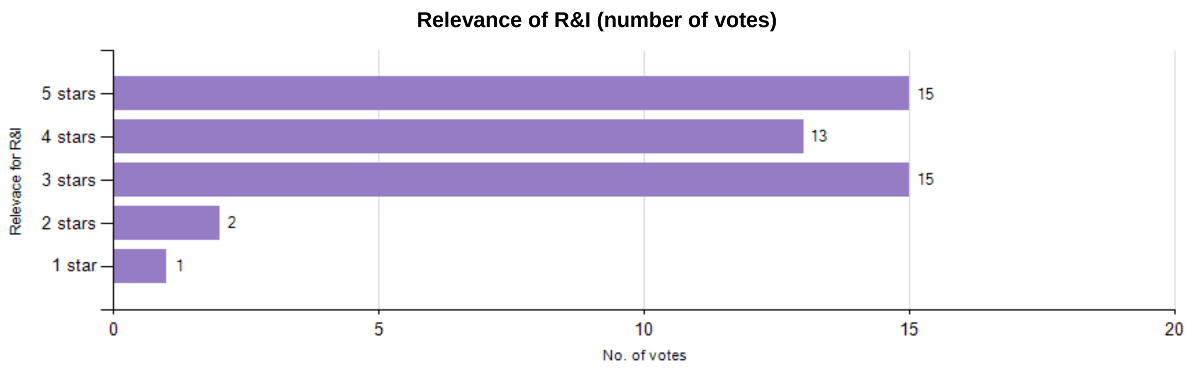
Arguments regarding the relevance of R&I	**No. of votes**
It's not only a question of research; networks of industries have to be built in order to make these exchanges possible.	35
Research needs to look into the safety, security and sustainability of the substitution materials.	29
This substitution demands a rethink of the whole material extraction and supply process and market.	16
Novel products have to be designed in the context of reuse and recycling.	11
The question is not clear	4
Systemic innovation to remove the barriers to such substitution will be essential - and this needs global co-operation	1

More than 90% of all materials and waste is physically recycled or re-used energetically in the circular economy



Number of respondents : 50

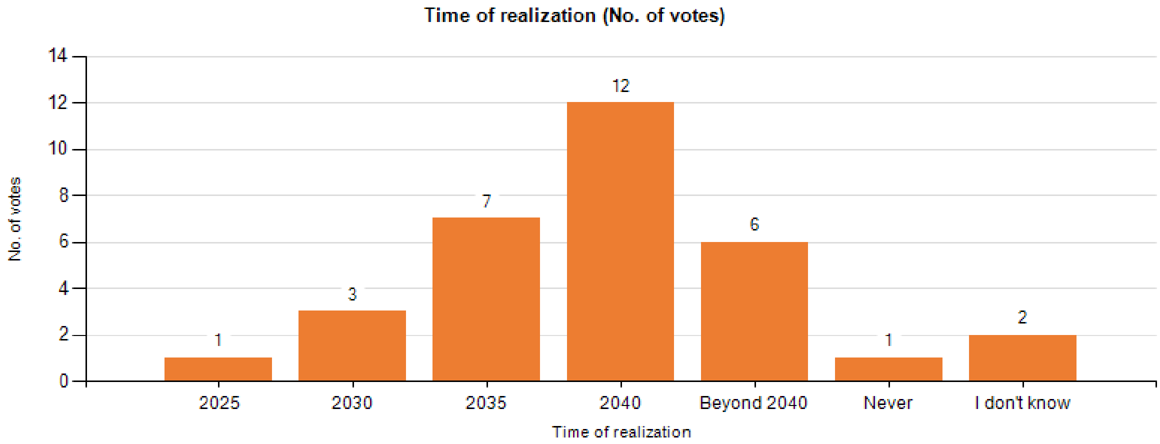
Arguments regarding the time of realization	**No. of votes**
Current recycling rates vary widely depending on the waste stream or country. A single figure of 90% may be inaccurate and too ambitious in some cases.	27
The European Commission adopted an ambitious Circular Economy Package, which includes a common EU target for recycling 65% of municipal waste by 2030.	26
A high level of recycling requires massive investment.	23
As consistent progress has been made in life-cycle assessment methodologies, there will be more public pressure to recycle and reuse.	20
This figure can only be achieved if it includes the reuse and service-life extension of goods, which is not subject to the second-law of thermodynamics and prevents waste rather than manage it.	16
Large scale utilisation of biowaste is a clear trend.	11
The main problem will be to curb the current inertia of the free market and the current consumption strategies.	7
Technically and politically, it is not a difficult target.	3
The re-use sector within the recycling sector has the potential of creating a huge amount of jobs for low-skilled people.	1



Average: 3.85 **Dispersion:** 0.98

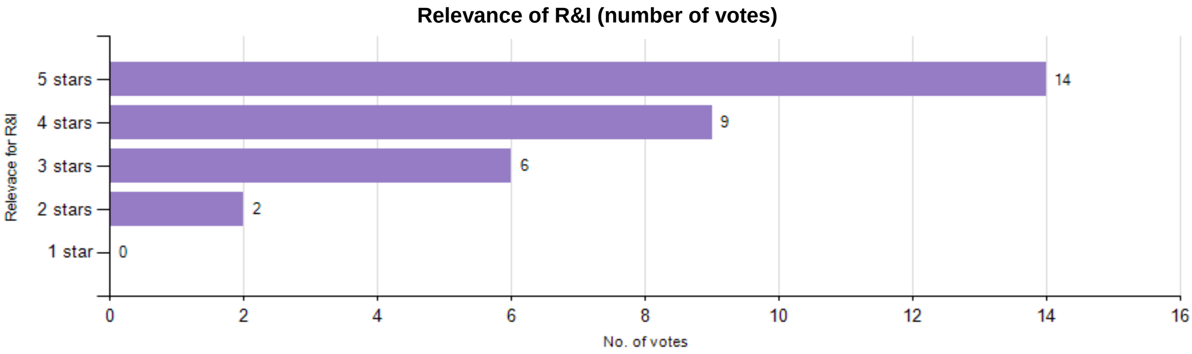
Arguments regarding the relevance of R&I	No. of votes
There is need for more efficient recycling technologies, among others because this is a promising market, which makes it an area that is therefore ripe for research.	33
Life Cyle Assessment for sustainable production needs a standardised approach in order to provide consistent results to policy makers.	26
There is a need for more efficient and non-destructive collection of end-of-life goods as well as new sorting techniques for material mixes to achieve a high purity of the materials to be recycled.	14
RI is needed to delink atoms instead of recycling waste, resulting in high purity resources instead of secondary materials, eg depolymerisation, delaminating, decoating, devolvanisation of tyres.	10
There is a need for research on how to push societies into a path of less waste production	9
products conception should involve this target	3

The use of rare earth elements and metals in electronics (for example Scandium, Yttrium etc.) is reduced by 80% (compared to today) without hampering technical progress



Number of respondents : 32

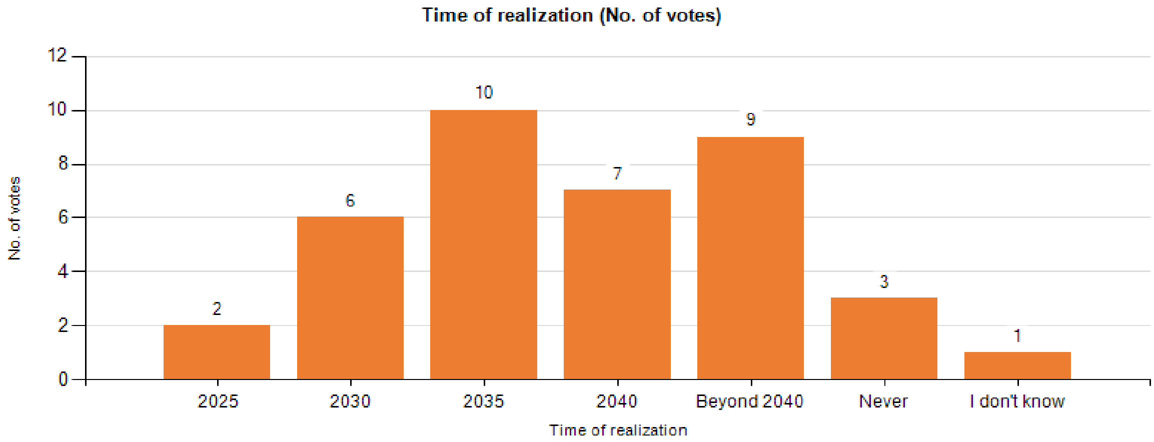
Arguments regarding the time of realization	**No. of votes**
The solution will change depending on the case and can come from more than one direction: substitution, increased recycling, better resource efficiency or sustainable primary production of CRM.	28
Technical solutions need inspiration and ideas; it is difficult to estimate when they arrive.	15
There is a flood of patents in Japan for materials that replace rare metals in electronic devices. It should also be possible to replace them in the EU industry.	10
Graphene and carbon nanotubes promise application in electronics that can reduce demand for rare earths.	5
There is a need to avoid exploiting deep sea bed for more rare materials, so they are to be 'replaced' and 'reduced'.	4



Average: 4.13 **Dispersion:** 0.88

Arguments regarding the relevance of R&I	No. of votes
More research is needed on technologies for the substitution of critical raw materials, processing, sorting and recycling, etc.	27
More research on efficient and selective recycling technologies is needed	15
The industry for electronic products is not large anymore in the EU. It is the question if it is worthwhile doing a lot of R&I for replacing these resources.	7
Graphene and CNTs hold promise of replacing rare earths in some applications. EU breakthroughs could give competitive advantage to mfg in EU.	4
Photonics is a key enabling technology in the EU and photonics is playing an increasing role in many products that were earlier primarily electronic. High priority area for research.	4
More research is needed on reducing and replacing rare materials in electronics.	3

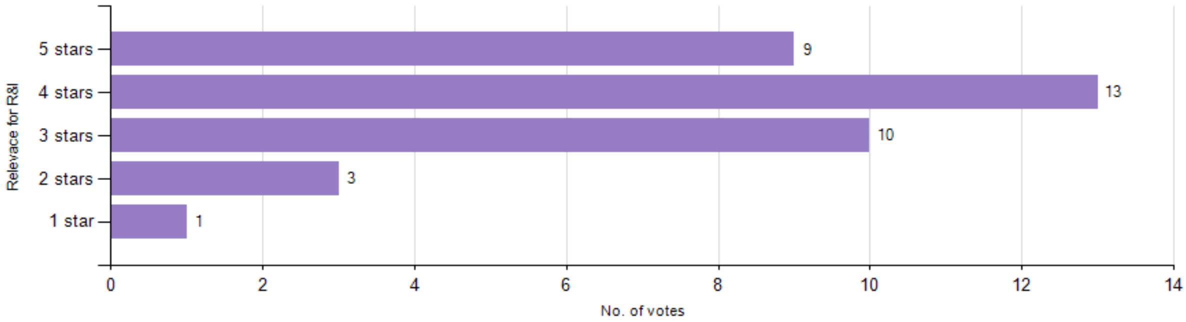
Metals (for example, aluminium, iron, copper, silver, gold) that are recovered from landfills meet 50% of the EU's demand



Number of respondents : 38

Arguments regarding the time of realization	**No. of votes**
Landfills have a large potential - but it is costly to recover metals from them.	33
As we do not have enough space for landfills in the EU, this will also save a lot of space.	15
The concentration of aluminum in many landfills is higher than the concentration of aluminum in bauxite from which the metal is derived.	12
Methods have to be put in place to avoid metals getting into landfills.	8
Why landfills? What is needed are systems to recover metals from the 'urban mine' - the stock of materials at the end-of-life of appliances etc. New primary resources will still be required.	2

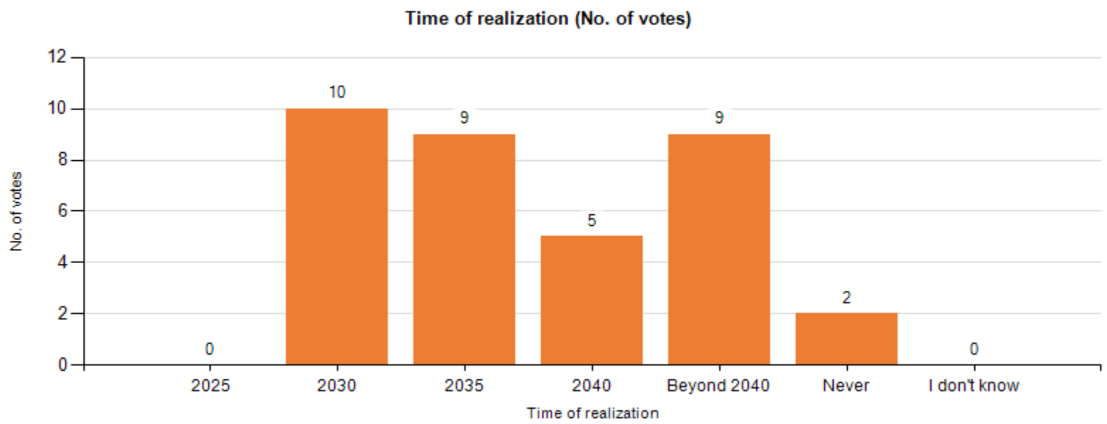
Relevance of R&I (number of votes)



Average: 3.72 **Dispersion:** 1.05

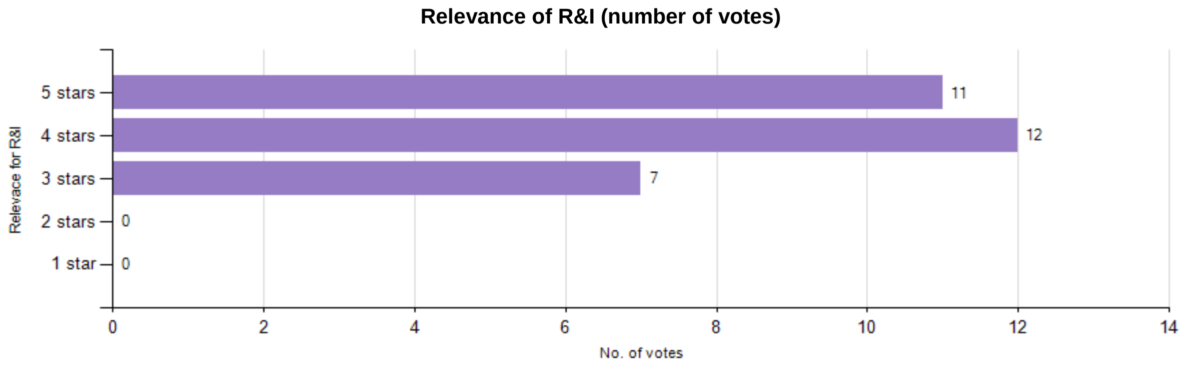
Arguments regarding the relevance of R&I	**No. of votes**
The new methods for material recovery need research to make them efficient - otherwise recovering is too expensive.	30
For every metal, new and efficient methods of recovery have to be developed.	20
Products are to be developed in a way it is easy to recycle precious materials and metals before they go to landfilling.	6
A new design paradigm with the life cycle of a product in mind shall become the norm.	4

Biological phosphate removal (BPR) allows 90% of the phosphorus from wastewater to be recycled



Number of respondents : 32

Arguments regarding the time of realization	**No. of votes**
Resources need to be recycled, but to remove 90% of the phosphorus from waste water is a very ambitious target.	24
BPR decreases water purification costs significantly.	9
Many wastewater treatment plants are required to remove phosphorous during the treatment process. This is an extremely resource-intensive process.	9
There are too many on-off and dispersed housing developments. Planning authorities need to better understand the negative implications of bad planning, for example bad planning in Ireland.	7
Synthetic biology combined with the traditional bioremediation strategies could be a plausible solution.	5
BPR is of the most economical and efficient methods for phosphorus removal.	4
Floating island approach to phosphorous and other pollutant removal shows promise.	2
Algal biotechnology can aid in "closing the loop" by nutrient- & water-recycling.	2
Dilution of waste makes phosphate recovery difficult. We need alternative strategies in housing.	1



Average: 4.13 **Dispersion:** 0.61

Arguments regarding the relevance of R&I	**No. of votes**
Implementation of EBPR to meet new or lower phosphorus limits should begin with a comprehensive/coordinated plan for the collection system.	15
The EU should support pilot plants to demonstrate the economic feasibility of different technologies.	15
Further understanding influent data analysis requirements and the role of fermentation is necessary for effective planning.	13
A better understanding is needed how phosphate can be avoided in products and porcesses.	6
EBPR operation in the field is still not well understood, although it is studied for many years. Alternative strategies via e.g. synthetic biology should be considered.	1

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It is 2040. Sustainable consumption patterns, truly circular production-consumption networks, and shifts to less harmful, often renewable resources have made Europe less dependent on natural resources, more self-sufficient and more competitive in its industries. In addition, environmental degradation has been reversed.

Studies and reports

Publications Office