



Foresight

The Bioeconomy

Targeted scenario N°2

**Glimpses of the future
from the BOHEMIA study**



Bioeconomy - Targeted scenario N°2

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EUROPEAN COMMISSION

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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° 2

Bioeconomy

Summary

The Bio-economy promises to be a major contributor to European economic growth and re-invention with impacts on all sectors. Technological advances are set out to replace finite resources and conventional industrial processes, with processes and components that are biologically derived. In the long term, Bio-economy will be a major contributor to climate mitigation and to the transition to a circular economy.

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



The scenario

It is 2040. Europe's economy is largely bio-based and production is highly decentralized.

The Bio-economy fosters technological breakthroughs that permeate all sectors including agriculture and food production, energy, industrial applications, chemical industry and healthcare industry.

Biotechnological processes have been widely deployed across industrial sectors and to a variety of waste management situations. Phosphorus is collected from wastewater, raw materials are sourced from recycling and land- and aquatic-based sustainable primary production, and biotechnologically enabled CO₂ capture facilities begin to appear across the EU. CO₂ re-use from European industrial production is already widespread. Urban bio-waste is collected separately and used to make high-value bio-based products. Urban greening in the context of bio-refitting of cities led to additional benefits such as cleaner air, walkability/cyclability, and to re-valuation of property prices.

The development of Bio-economy led to the development and spread of biotechnical production systems and processes. New material substitutes have been deployed across industries, and have increased efficiency of resource utilization in bio-based and fossil-based production systems. The value generated per unit of biological resources has been radically increased, keeping the value of such resources in the economy for longer and implementing the principle of cascading use of biomass. Large-scale deployment of biotechnologies has created important sources of economic revenue. Industrial applications and processes are increasingly relying on biological organisms. For example, new synthetic molecules and organisms with functional properties that did not exist in 2016 are used in more than 70 % of heavy industrial production processes (i.e., fuel production, waste stream management, etc.). New ways have been found to recover naturally occurring complex molecules and avoid the loss of value that results from breaking them down.

The wetware revolution is responsible for breakthroughs in decentralized production capacities ('cell factories') across numerous industrial sectors, enabling a large portion of industrial needs for chemicals to be produced through bio-based processes in a more circular economy. Modular bio-refineries that house combined facilities for cell factories, enzymatic processes, and chemical processes are still improving, but already alleviate security concerns regarding biomass supply.

Innovation in bioengineering has resulted in numerous products and features that were not possible with conventional technology of the early 21st century, such as bioengineered wearable electronics or temperature adapting clothing. Tailored food additives are produced to suit specific metabolic requirements of different demographic segments.

Relevance for Europe

The Bio-economy at large promises to be a major contributor to the European economy, society and the environment. It can drive industrial change towards a new techno-economic system that will compete and combine with non-biological production. Technological advances are set out to replace finite resources and conventional industrial processes, with processes and components that are biologically derived. Bio-based processes are expected to be more sustainable, using renewable resources and emitting less CO₂. In theory, this would enable climate mitigation and foster a transition to an ever more circular economy - decentralized, addressing problems of pollutant and waste management, and resource scarcity, while simultaneously enabling breakthroughs in food quality and availability, advanced medical treatments, industrial products with new functionalities, energy, materials environmental services and others.¹ European leadership in the Bio-economy can

¹ see e.g. OECD (2013): Green Growth in Cities, Paris; Perez et al. (2016): Changing gear in R&I: green growth for jobs and prosperity in the EU, European Commission, Brussels; Mathijs, E. et al. (2016): Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy - A Challenge for Europe, SCAR, Brussels; German Bioeconomy Council (2015): Global Visions for the Bioeconomy – an International Delphi-Study, Karlsruhe; Arnold 2017, Langholtz, M.H. et al. (2016): Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, US Department of

ensure economic growth as well as progress in achieving environmental and climate goals. The decentralized vision can better reflect societal needs, and steers away from the vision of industrial monoculture and towards local solutions and decentralized living.

Contribution towards the UN Sustainable Development Goals (SDGs)

The Bio-economy is important for several Sustainable Development Goals. It can contribute to end hunger, to responsible consumption and production patterns (SDG 12), achieve food security and improved nutrition (SDG 2), to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (SDG 9), contribute to the availability and sustainable management of water and sanitation for all (SDG 6), provide access to affordable, reliable, sustainable and modern energy for all (SDG 7), and especially promotes sustainable economic growth (SDG 8) by developing new markets and employment potentials. Goals 13 (Climate Action), SDG 14 (Ocean-based Life and Health), 15 (Land-based Life) and 17 (International Partnerships) are tackled by a strong, functioning Bio-economy.

Implications for EU policy

The Bio-economy relates to land and aquatic primary production for food and industrial markets and to environmental regulation. The Common Agricultural Policy, Health and Consumer Protection policy, Environment Policy are amongst the most concerned. The deployment of biotechnology also raises issues of intellectual property concerning living organisms, and carries a number of ethical concerns. Trade policy and the Common Market are also concerned.

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

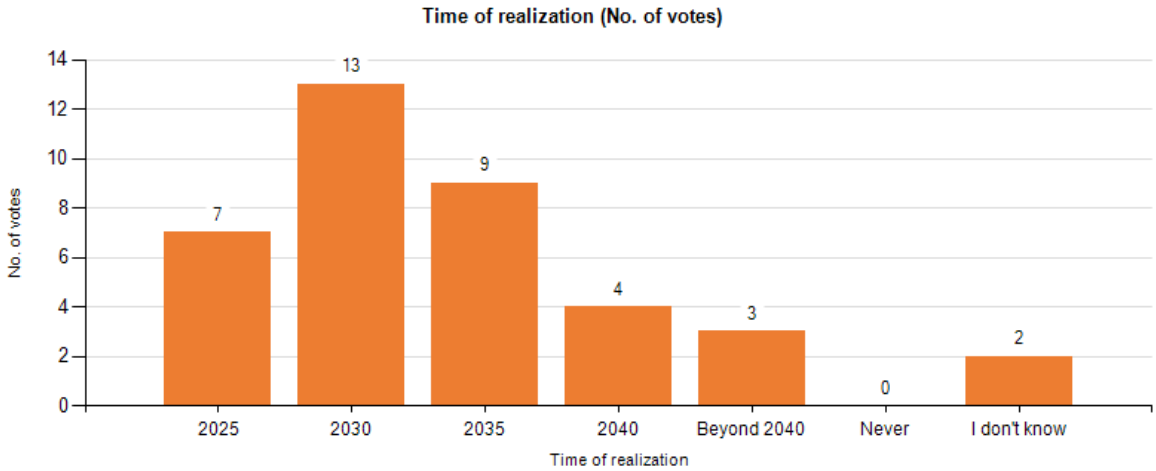
- **Developing and testing new circular bio-economic processes**
 - **Assessments in a sustainable biomass production (incl. aquaculture)**
 - **Carbon capture and re-use**
 - **Testing bio-engineering technologies in the everyday-lives of citizens (real-time labs, living labs)**
 - **Developing new bio-based production processes, e.g. hydrogen or synthetic biology**
 - **Make -omics technologies (genomics, proteomics or metabolomics) and bioinformatics applicable**
 - **Understanding and applying systems biology Large-scale production in bio-refineries**
 - **Regulations for genetic and epigenomic engineering approaches (incl. Intellectual Property Rights)**
 - **Villages as resources and processing hubs for energy and food businesses (agro-center with resources and processing)**
-

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>

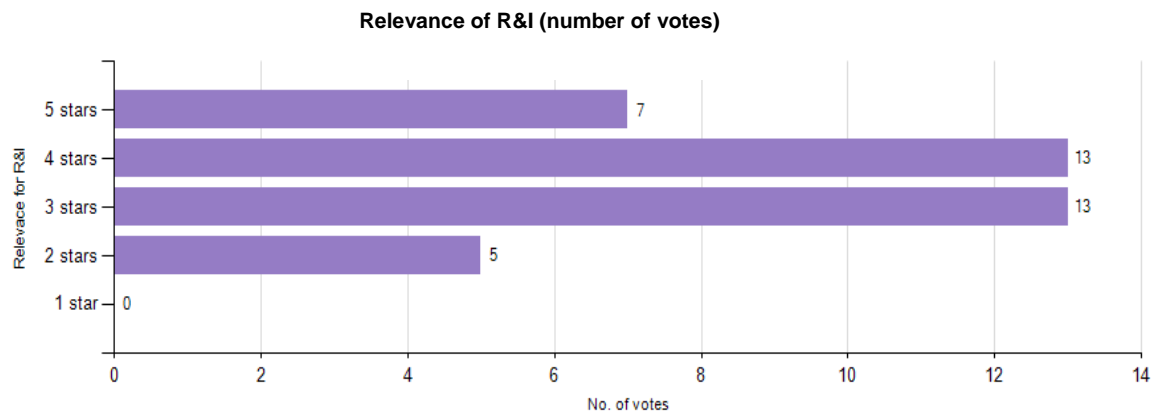
This annex includes the parts of the data set that are relevant to this scenario.

More than half the fish for human consumption in the world are produced by aquaculture including offshore aquaculture



Number of respondents: 37

Arguments regarding the time of realization	No. of votes
The resources for ocean fishing are diminishing very fast.	40
According to World Bank and FAO, aquaculture will provide close to two thirds of global fish consumption by 2030.	23
Microplastics in ocean waters lead increasingly to microplastics in fish meat, making it unfit for human consumption. Fish farming with water filtration will provide higher quality fish.	13
Fisheries and aquaculture assure the livelihoods of 10–12% of the world’s population (according to The State of World Fisheries and Aquaculture/ FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS).	5
Integrated ocean aquaculture with pollution-reducing plants like hyacinths in floating-island concept may increase yields, clean waters up, and produce healthier fish.	5
Fish nutrition science is producing resource efficient solutions. Also, GMOs will provide new sources of key fatty acids.	5
EU overall output has been more or less constant in volume since 2000 whereas global production, at the same time, has been growing by nearly 7% per year.	4

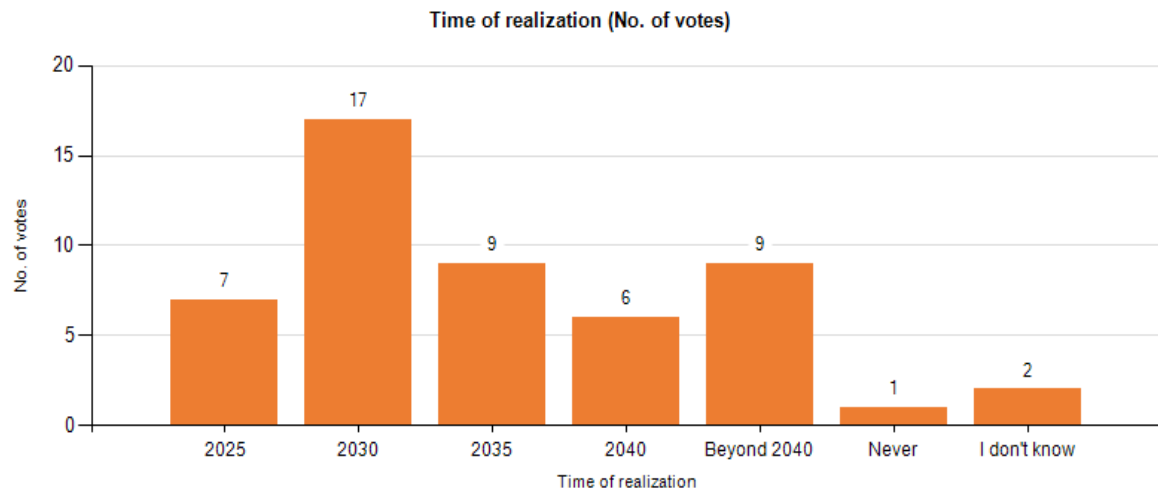


Average: 3.58

Dispersion: 0.87

Arguments regarding the relevance of R&I	No. of votes
Aquaculture nutrition and aquatic physiology represent important research areas.	32
Further research in this area is needed to develop and multiply the flora and fauna in the aquatic environment.	23
Up to 30 percent of farmed salmon are unfit for consumption because of illness. Research in fish health is needed.	9
We need GM-bred traits in oilseeds for key fatty acids.	5
Research is required on the impact of aquaplastics on suitability of aquacultured fish for human consumption.	5
Environmental impacts of aquaculture need to be understood, up to the point that lack of adequate water quality will harm production	5

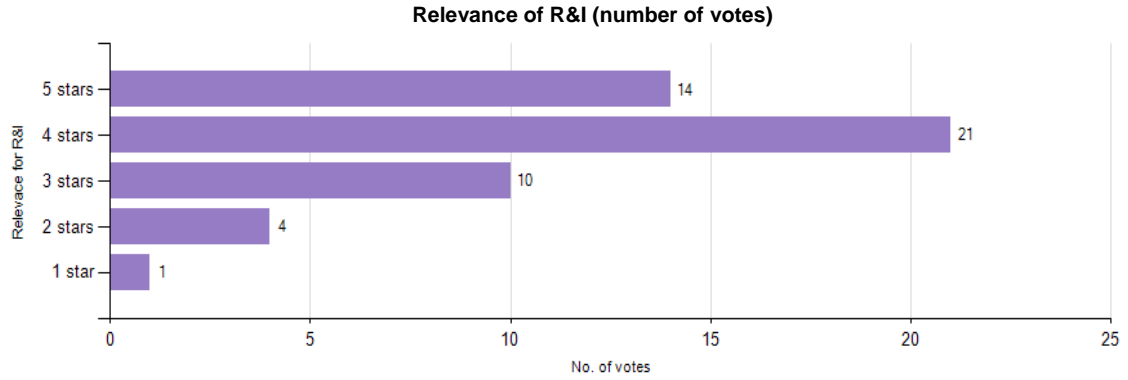
5 % or more of the production of food, medicine and bio-energy in the EU is based on algae



Number of respondents:

50

Arguments for time of realization	No. of votes
Industrial-scale demonstrations of sustainable algae cultures for biofuel production are available.	40
Algae research gives hope for renewable carbon-negative source of food and medicines.	29
Growing algae for food and biofuel contributes to the reduction of greenhouse emissions.	22
There are still simpler alternatives and options within the current land-based food system.	8

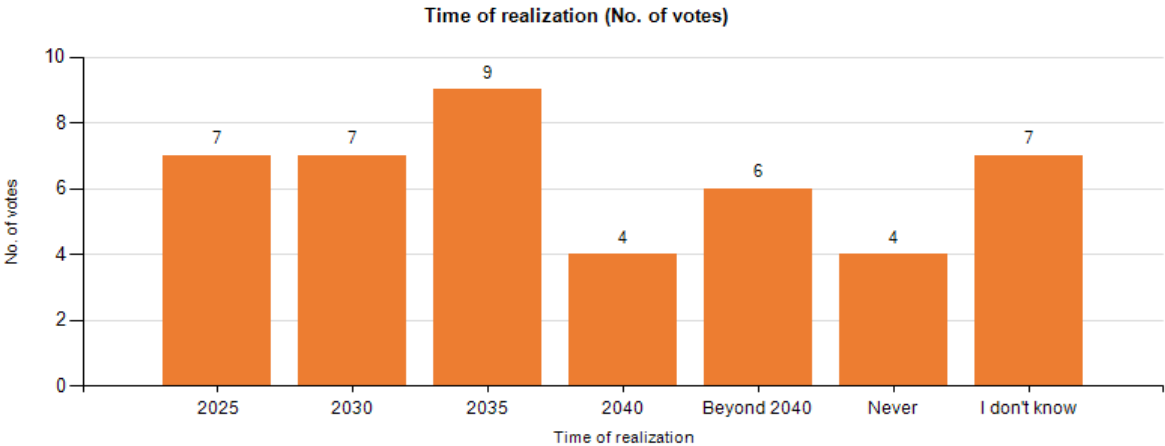


Average: 3.86

Dispersion: 0.96

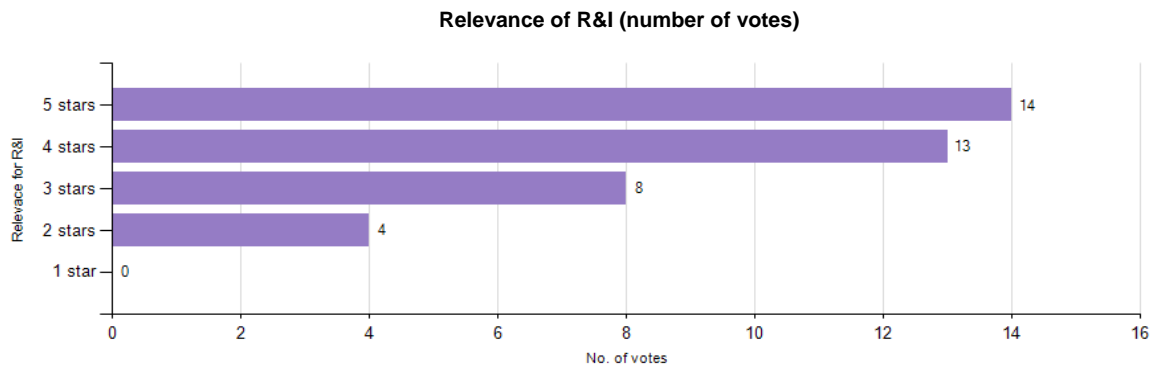
Arguments regarding the relevance of R&I	No. of votes
There is need for further research on the manufacture of bio-compounds from microalgae with applications in food production.	44
New research may exploit the ability of algae to produce lipids using energy from photosynthesis.	31
research on algal growth conditions and on which variety to use for which purpose is still required	15
Further research on bio-refinery of algae and consumer acceptance of algal products is required.	4

Synthetically designed bacteria are licensed for use in food production in the EU (to grow food in urban bioreactors or microfermenters)



Number of respondents: 42

Arguments for time of realization	No. of votes
The use of "Designer organisms" in food production will face unprecedented opposition (for example, despite definitive evidence available for a while, GMOs are still not free of such opposition).	30
Particularly for a specific food component, additives.	17
The state of affairs in the statement will probably be true of sewage treatment and similar uses, but not of food.	10
Due to increased need for food, the opinions on GMO will change.	9
Synthetic biology can potentially produce fuels, nutrients for growing food, food additives, pharmaceuticals and specialty chemicals, but mass production of food end products faces barriers.	5
So far, the only available synthetic bacterium does nothing more than live and replicate - and even that only after years of trial and error attempts.	4
Dangers of rapid bacterial evolution creating unprecedented threats requires extensive, systemic research.	2
Synthetic biology is likely to be required to produce the variety of foods required for long duration space missions with no re-supply from Earth. Such technology may transfer to Earth use.	2



Average:

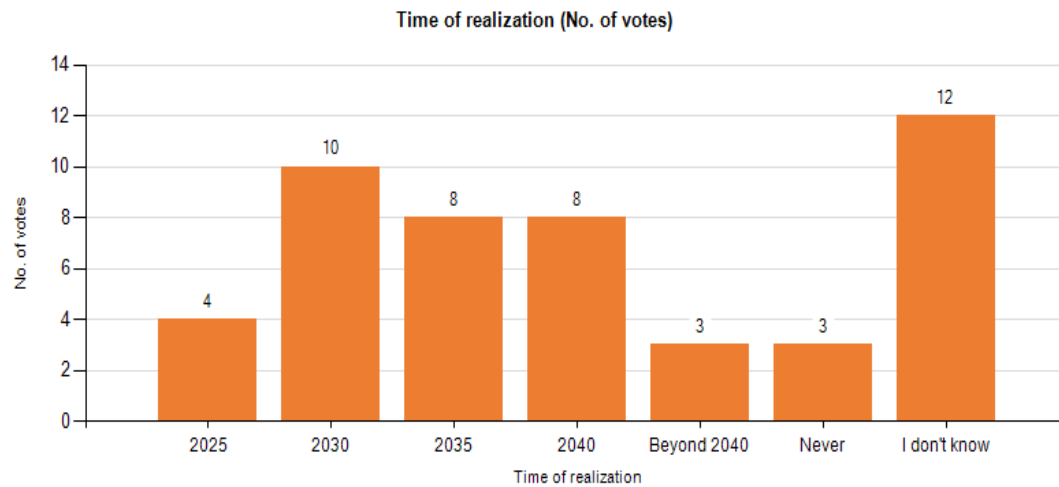
3.95

Dispersion:

0.96

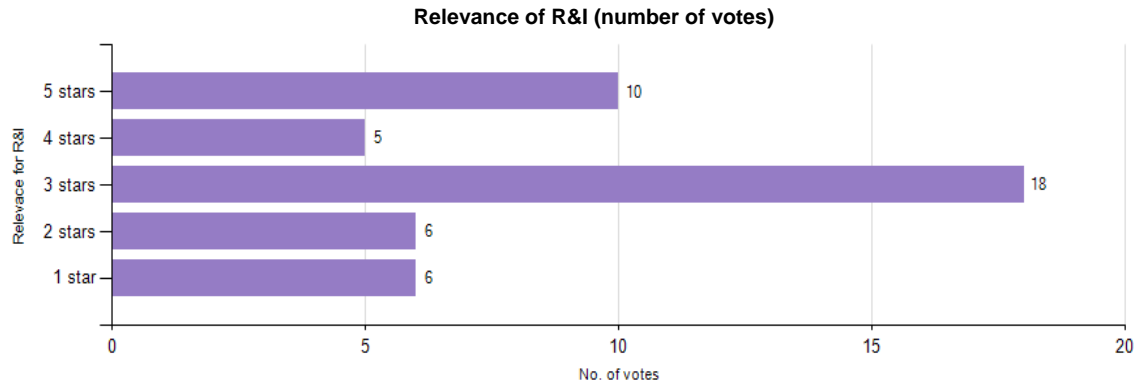
Arguments regarding the relevance of R&I	No. of votes
Impact on health will probably be the main field of research.	30
A lot remains unknown about the role of specific genes in bacteria.	17
Fairly dependent on societal acceptance	14
it is a niche for special foods e.g. to deal with allergies	11
Niche for designing special growth environments.	2
Space applications have the greatest near term demand for such technology.	1
Ecological engineering may widen use of such products but complex systems will need to be modeled. Insufficient to just produce the organism that can produce then outputs.	1
Required for long duration space missions may transfer to Earth use to fully realize recycling.	1

Heritage or heirloom vegetables make up 20% or more of the vegetables in the EU ecosystem



Number of respondents: 47

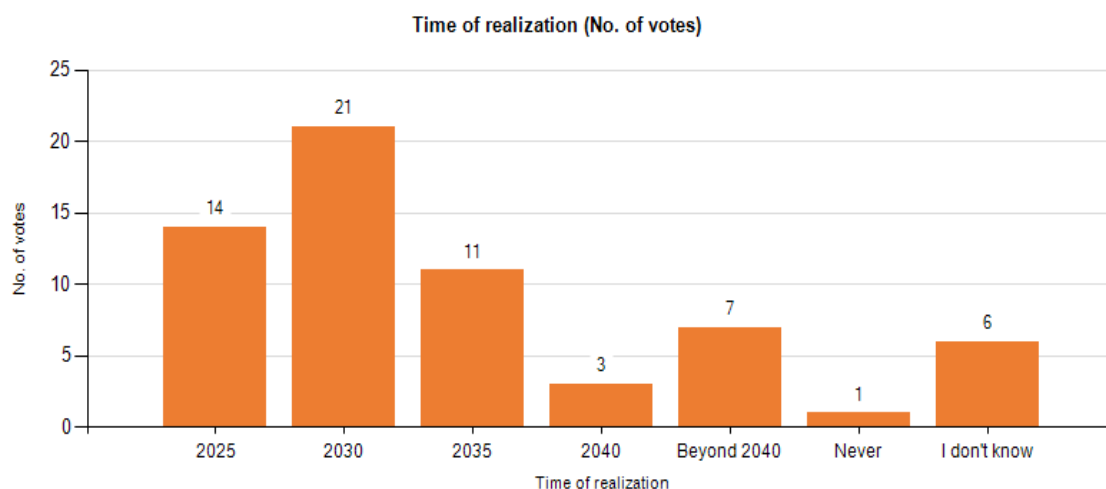
Arguments for time of realization	No. of votes
For a category of consumers interested in healthy eating, heritage vegetables may be an interesting niche market.	33
Heirloom varieties help strengthen small holder agriculture linked to the rediscovery of territory, agritourism and promotion of local food culture & identity.	27
Some older plant strains are assumed to be more healthy and contain more minerals or vitamins. They might be the first on the market.	20
Diversity-seeking behaviour increases the demand for 'different' vegetables, thus increases the demand for heirloom varieties.	15
The question is not clear: what is 20% of the EU ecosystem?	7
Heirloom vegetables, although adapted to local environments, tend to ripen at different stages, can't all be harvested at once, so are unsuitable for mass Agrifood.	2
Heritage and heirloom vegetables can be used as genetic resources for broadening the genetic diversity of modern vegetables.	2
Heirloom vegetables are rather having a nostalgic and cultural connotation. Nothing to do with food resilience... No sufficient yield for feeding the world. And... our taste changed!	2



Average: 3.16 **Dispersion:** 1.61

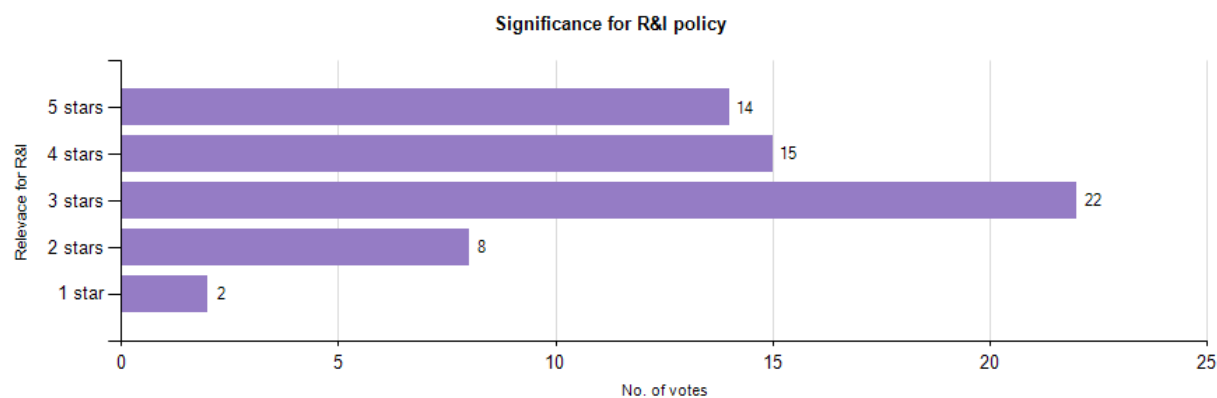
Arguments regarding the relevance of R&I	No. of votes
Biodiversity must be integrated into the development and implementation of other policies.	41
The exchange of seed needs to be promoted and enabled (it is currently illegal to buy or sell seed of some heirloom varieties)	24
European Agricultural Policies need to appreciate the quality of crop production in terms of contribution to crop diversification for sustainable agro-ecosystems and healthy food systems	22
The EU Biodiversity Strategy 2020 needs to expand to better address this issue.	12
The question is not clear	5

Systematic scanning of biodiversity to identify substitutes for drugs has become a global research endeavour



Number of respondents: 60

Arguments for time of realization	No. of votes
Different conditions around the planet offer a much greater diversity to search in than any individual country could.	58
Citizen science around the world could help considerably but the political will and digital infrastructures will take some time to build up.	41
Understanding mechanisms and laws for the interactions of drugs and organisms is very far from realization. Non-equilibrium states, multiscale approaches in machine learning and context dependent modeling are needed.	22
A nation state and the EU alone do not have the capacities.	16
Being aware of the side effects of drug therapy, modern solutions should be directed towards selective and personalized therapies, which can be achieved, e.g., by increased systematic scanning of biodiversity.	13
Scientific inertia ('labs and hard science' vs. 'softer science and the real world'), scientific arrogance (inventions vs. harnessing what already exists) and patentability reduce R&I efficiencies.	11
It is easier to find synthetic drugs instead of exploiting the last resources on earth.	10
This knowledge is available, but a global knowledge base is needed.	6
Economic interests being dominant in the medical field of research, no significant change could occur for now without evolution of the scientific democracy.	2



Average: 3.51

Dispersion: 1.16

Arguments regarding the significance for R&I policy	No. of votes
This requires a more open scientific endeavour, shorter patent times, the opening of the laboratory to the world, the breaking down of scientific silos, the opening up of the 'scientific method'.	44
Global challenges need global answers. But there is so much disagreement in the political world that a lot of science diplomacy is required.	37
Citizen scientists could very well decide to go faster than policy-makers in establishing the needed digital infrastructure to progress around health related matters (e.g. to food/lifestyle).	35
The teaming up of scientists and global diplomats is necessary for this to be achieved.	23
This requires also competencies in how to link up different innovation actors with different types of economic interest.	7
The main role of European policy is in regulating biodiversity. The role for EU R&I policy is more limited.	1
Research funding should end with the growth finality: drugs development generates cash when biodiversity solution doesn't.	1
There is a lack of evidence that such replacements will be effective.	1

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Overexploitation of natural environments, intensive agriculture, and climate change have triggered further declines in wildlife with dramatic impacts on biodiversity, while also causing pollution, erosion and other forms of harm. In response there was a change in the economic policy paradigm promoting sustainable business and consumption patterns that respect planetary boundaries, and more generally makes a case for the importance of biodiversity and nature-based solutions.

Studies and reports

