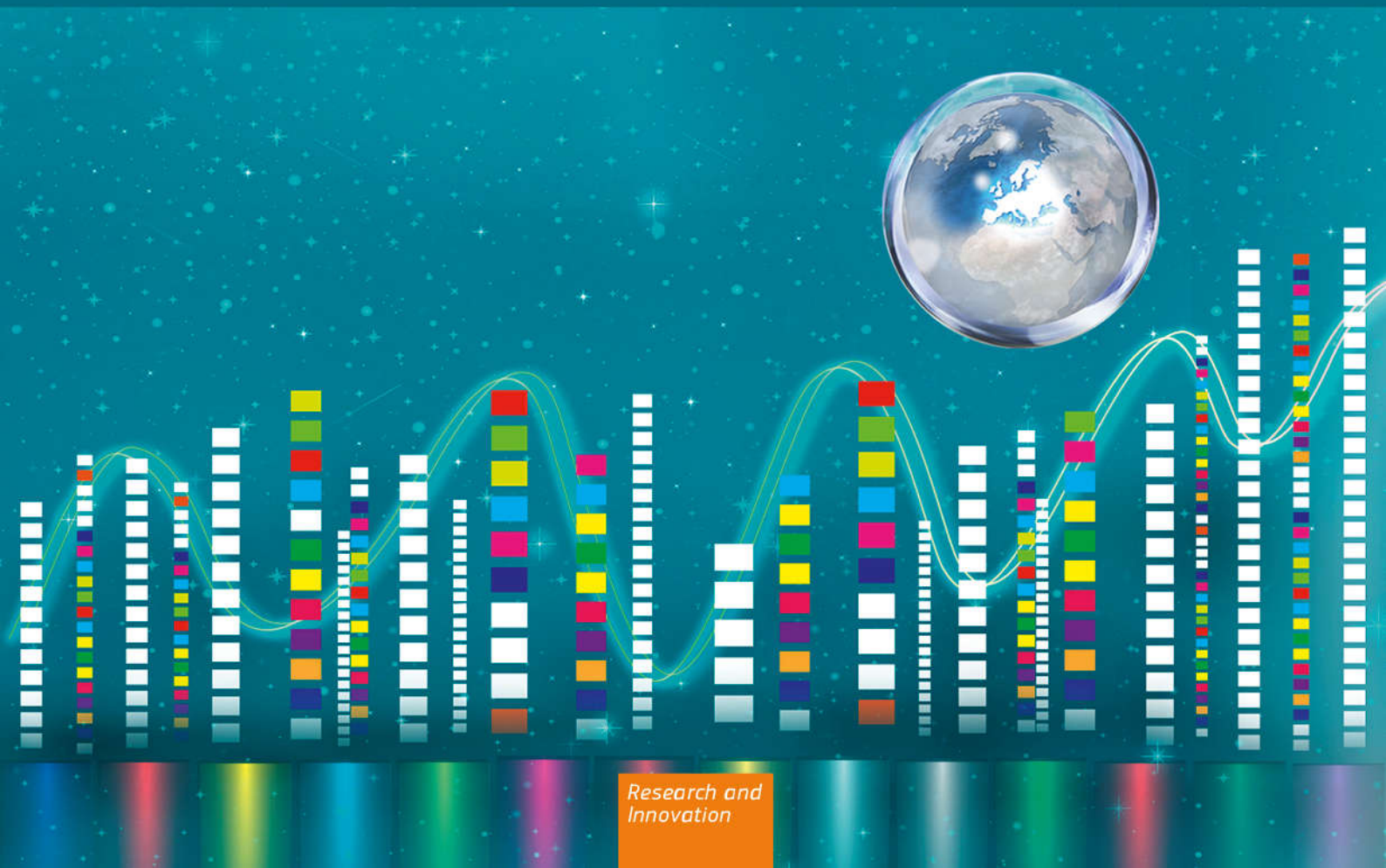
European Commission

Meeting Societal Challenge 2

Portfolio Analyses, Impact Assessment and Approaches to examining how Framework Programmes from FP5 to Horizon 2020 address Societal Challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy

Expert Group Report



Research and Innovation

EUROPEAN COMMISSION

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Directorate-General for Research and Innovation

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CONTENTS

ABBREVIATIONS

ARD	Agricultural research for development
BSE	Bovine spongiform encephalopathy (‘Mad-cow disease’)
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
CP	Collaborative project
CSA	Coordination and support action
EATiP	European Aquaculture Technology and Innovation Platform
EC	European Commission
ERA	European Research Area
ERA-NET	European Research Area Network
ETP	European Technology Platform
EU	European Union
EU15	The 15 countries who joined the EU before 1 May 2004
EU12/13	The 12 or 13 member states that joined the EU on or after 1 May 2004
FA	Fisheries and aquaculture
FAFB	Food, agriculture, fisheries and biotechnology
FAO	Food and Agriculture Organization of the United Nations
FMO	Fisheries management organization
FP	Framework Programme
H2020	Horizon 2020
HEE	Higher education establishment
ICPC	International Cooperation Partner Country
IMP	Integrated Marine Policy
IPR	Intellectual property right
JPI	Joint Programming Initiative
MSFD	Marine Strategic Framework Directive
MS	Member State
KBBE	Knowledge-based bioeconomy
NCP	National Contact point
NGO	Non-government organization
OTH	Other types of participants
PFP	Private for profit organisation
PUB	Public body
R&D	Research and development
RD&I	Research, development and innovation
RES	Public/semi-public research organisation
RFO	Research funding organisation
RPO	Research providing organisation
RTD	Research and technical development
SME	Small and medium-sized enterprises
SSP	Scientific support to policy

ABBREVIATIONS OF THE EUROPEAN UNION'S MEMBER STATES

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FR	France
FI	Finland
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SE	Sweden
SK	Slovakia
UK	United Kingdom

GLOSSARY

Definitions of some terms as they are used in this report are provided here.

Annual work programmes
These are the European Commission's documents setting out the calls for individual research and innovation projects. The annual work programmes also set out some policy context and relevant programme-wide objectives.

Bio-based industries
The bio-based industries are the industrial sectors outside the traditional wood products sector that use renewable raw materials for industrial processing into non-food products such as advanced transportation fuels, chemicals, and other materials.

Bioeconomy
The bioeconomy is that part of the economy based on the production of renewable biological resources and their conversion into food, feed, renewable non-food products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical and energy industries. The relevant food, fisheries, forestry and new non-food sectors have a turnover of about €1.5 trillion in the EU, about €1 trillion of which is in food chains. The traditional forest-based sector (wood, paper and pulp) accounts for most of the remaining €0.5 trillion.[1] [2]

Biotechnology (general)
The application of biological knowledge for the improvement of organisms for an industrial or agricultural process or the application of a process involving the use of organisms.

Biotechnology (FAFB research activity)
The biotechnology theme as Activity 3 under the FP7 Cooperation Programme Theme 2 (FAFB). The full title of the activity is 'Life sciences, biotechnology and biochemistry for sustainable non-food products and processes'.

Cross-thematic funding
The funding of projects from more than one programme theme (FP7) or from more than one Societal Challenge (in H2020).

Description of Work (DoW)
The DoW is the project plan as appended to a project contract. It is based closely on the project proposal submitted in response to the call topic. The DoW is typically a long and complex document setting out the background, research plans, allocation or resources and responsibilities in detail.

Direct users
Direct users (or primary users) are those people or organisations who are the immediate users of the results and upon whom impact depends either through their own actions or the actions of other users that they influence or support.

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[1] Clever Consult, 2010. The knowledge-based bioeconomy in Europe: achievements and challenges.
[2] BECOTEPS 2011. The European Bioeconomy in 2030 - Delivering sustainable growth by addressing the Grand Societal Challenges, March 2011 (the White Paper from the BECOTEPS project)

ERA-NET
An ERA-NET is a collaboration between national and regional public funding bodies of the Member States and Associated States. Through the ERA-NET scheme, the EU funds the networking of activities conducted at national or regional level to enable the mutual opening of national and regional research programmes. The scheme enables national systems to take on tasks collectively that they would not have been able to tackle independently.

Framework Programme
The European Union's investment in research, technological development and innovation is organised in Framework Programmes that bring together a diverse range of European research activities. There were seven Framework Programmes until 2013. The framework programmes up until Framework Programme 6 (FP6) covered five-year periods, but from Framework Programme 7 (FP7) ran for seven years.

Food, agriculture and fisheries, and biotechnology (FAFB)
This is one of 10 thematic areas (Theme 2) in the Cooperation programme of the European Union's 7th Framework Programme for Research, Technological Development and Demonstration Activities (FP7).

Innovation
Innovation is finding a better way of doing something. Innovation differs from invention in that innovation refers to the use of a better novel idea or method, whereas invention refers more to the creation of the idea or method itself.

Impact area
An impact area is a specific part of the economy, society or public sector where the project outputs are used to generate wider economic, social and environmental impact.

Impact community
The impact communities are those groups of people and businesses that are expected to lead in the using of project results in impact areas converting them into wider impact.

Primary user
Primary users (or direct users) are those people or organisations who are the immediate users of the results and upon whom impact depends either through their own actions or the actions of other users that they influence or support.

Joint Programming Initiative (JPI)
An EU supported mechanism to facilitate strategic coordination of national research programmes. JPIs engage in joint programming to pool national research efforts. This seeks to make better use of Europe's public R&D resources and to tackle common European challenges more effectively in key areas. The focus is at the programme level complementing ERA-NETs that pool resources at the project level.

Secondary user
A secondary user is someone who acts on the results of a project through the influence and decisions made by primary or direct users. Secondary users are not connected to RD&I processes but generate impact from RD&I by using the knowledge and technology output of projects in their roles in society, the economy and the public sector.

Technology transfer
Technology transfer is the process of transferring skills, knowledge, technologies, methods of manufacturing, samples of manufacturing and facilities among governments or universities and other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials or services.

Topic
The text in annual work programmes where the European Commission sets out the requirements at the project level. Each project is set up in response to a topic. Each topic describes the activity expected in the project, the background and purpose, and the expected impacts. It also sets out any specific requirements such as a minimum of the EU contribution to be allocated to SMEs.

PREFACE

The purpose of activities under Societal Challenge 2 (SC2) in Horizon 2020 is to improve the performance of farms, forests, fisheries and the related value chains, and to support the full range of social and environmental services that biological resources provide. This is served when projects support new practices, technologies, products, and evidence-based policy-making. After the completion of the Interim Evaluation of Horizon 2020, the European Commission (EC) asked us in early 2017 to explore how Framework Programmes have addressed SC2 using portfolio analysis and impact assessment and to investigate new approaches to evaluation. It is commendable that the EC went beyond its formal evaluation obligations to provide us with the opportunity to freely explore our ideas and to examine nearly two decades of research and development projects relevant to SC2.

Assessing the impact of Framework Programmes is difficult. There is no counter-factual and the relevant change processes are complex. Our biological and related natural resources are very diverse and dispersed across Europe. Impact cannot be just 'remote sensed' and conventional methods for assessing programme performance are not adequate. This report is about the work of a group of ten experts who conducted a detailed systematic direct 'close-to-the-ground' investigation of how impact for SC2 is generated.

We treated the challenge set for us by the EC as a research project. Thanks to unprecedented access to programme records going back 20 years and the group's careful curation and analysis of programme data, we were able to examine the links between projects, links between project participants within consortia, links to the users of project results and to the users' activities. At each step of the way, we asked ourselves the question: are the data valid and reliable? This substantial data curation work would not have been possible without the excellent support of our secretary, Grischa Hadjamu.

The European Union's research and development investments relevant to SC2 extend back to the earliest days of the European Union (as the European Economic Community). They have had a major impact to the extent that this research and development community is one of the most European of professional groups. It was a pleasure to work with such a well-balanced and committed expert team and to be able to guide the fruitful and collegial interaction with committed EC officials. The Framework Programmes add unique value for Europe and we hope this report is a contribution to the development of them so that impact for Europe is increased further.

Donal Murphy-Bokern and Katerina Moutou.

1. EXECUTIVE SUMMARY

Horizon 2020 invests in research, development, innovation and associated activities within three pillars, one of which addresses societal challenges. This report provides an account of investigations of how EU-funded projects in Framework Programmes running over two decades have served Societal Challenge 2 (SC2): Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy. The overall goal was to assess the impact of a large project portfolio related to SC2, including through the development of new approaches to programme assessment, also in the context of development of research and innovation strategy in Societal Challenge 2.

Based on previous work, especially the Interim Evaluation of SC2 in H2020, this work started with the acknowledgement of the great difficulty in assessing programme impact. The links between EU investment in SC2 and societal outcomes are extremely complex, indirect, and subject to numerous factors other than those impacted on by EU Framework Programmes. Our three approaches were: surveying of project coordinators; impact mapping of the project portfolio to examine the connections between projects, direct users and their activities; and the surveying of the users of project outputs. This complements the statistical, indicator-based approach used by traditional programme evaluation. It used content-rich and expert-based enquiry into project content and links with change in society through the user communities and their activities, especially innovation. To our knowledge, this is the first portfolio assessment that systematically considers FP5, FP6 and FP7 and Horizon 2020 activities aligned to SC2 within a common framework. Delphi surveying was employed to explore the views of research users that are active in selected communities of innovators targeted by SC2-aligned research across the four Framework Programmes. The results showcase the potential and limitations for in-depth analysis provided by each approach in an attempt to validate the approaches developed.

The surveying of coordinators yielded valuable insights that enabled characterisation of the programmes' expected impacts and mapping of these onto some contemporary priorities. This builds on a similar analysis carried out in 2011. However, the response rate was low. Ex-post surveying that relies on the voluntary participation of coordinators is not effective. It did not yield a powerful data set, especially for the two programmes that ended long enough ago to have fully realised impacts (FP5 and FP6). Coordinators' insights can contribute to programme evaluation but a much denser set of data is required gathered systematically through contractual obligations on coordinating organisations to supply impact information during the project implementation and after a suitable period has elapsed to allow project outputs and outcomes to be realised.

The impact mapping of the portfolio addressed four related questions: Who are the direct users of project outputs? What do they use outputs for? What type of organisations participated in and coordinated projects? What is the subject content of projects. This shows in a content-rich way how programmes generate impact via the programme processes, projects, participants and pathways. In short, it examines the programmes from the perspective of those upon whom impact depends: the users and innovators. This provided insights into changes in the portfolio over time in terms meaningful to users and innovators. 'Impact communities' who operate in 'impact areas' and the

corresponding sub-portfolios of projects can be identified by combining information on projects' direct users and their activities. This provides a powerful way for probing the portfolio for impact in terms directly related to how impact is generated by users of specific sets of projects. The Delphi method was successfully used to generate robust and unique evidence about the views of six impact communities.

Even though it was provisional and dependent on expert judgement, the categorisation of project activity and content in the impact mapping provided useful indications of changes in emphases in the portfolio. Surprisingly, process engineering turned out to be a widely supported category of R&D activity. Also, the consistently high investment in projects aimed specifically at communications and networking shows that a disconnect between R&D activities and users is not due to a lack of investment in communication activities, especially considering that individual project consortia also invest in communications and knowledge or technology transfer activity.

Impact mapping information was linked to information on the corresponding project participants and coordinators. From 19,713 participations in 1,898 projects, strengths and weaknesses in pathways to impact embedded in the portfolio were identified. This insight into participation aligned strongly with evidence obtained from user communities. It strongly confirmed users' perception of a profound disconnect between activities and drivers in the universities and research organisations that coordinate most of the projects and the needs of users.

While a comprehensive evaluation of the impact of H2020 was not the goal of this study, the work supports some relevant observations. Programmes have changed in line with EU priorities. Trends in portfolio development, especially the changes in emphasis on different types of direct users, confirm that H2020 SC2 is in general more focused on economic impacts compared with previous programmes. Furthermore, the programme has successfully combined economic, environmental and social objectives within projects, which is the essence of sustainable development and essential for alignment to contemporary societal priorities. The impacts identified support the higher level H2020 expected impacts and are well-aligned to the United Nations Sustainable Development Goals. In addition, projects have paved the way to FOOD 2030 and the recently published "Strategic approach to EU agricultural research and innovation". We therefore conclude that in terms of the general direction of project activities, H2020 and its predecessors are well aligned to contemporary societal challenges. Our analysis uniquely traces this alignment back to FP5 which started in 1998. This indicates beneficial continuity in a number of areas at the programme level combined with growth of new areas and 'sun-setting' of others. This work did not extend to an analysis of the content and performance of projects, but the identification of impact areas and impact communities provides a rational framework for such targeted project content-based impact assessment. The portfolio impact mapping was able to pin-point effects of the expansion of the use of the SME instrument and the establishment of the BBI-JU in terms of participation, coordination, direct users and impact areas. This also shows very clearly that the target research and innovation community will respond well to the introduction of new types of project instruments aimed at innovators.

However, there is clearly a great need to better connect the core research and technology development effort with users, especially innovators, who drive impact. There is evidence from a number of perspectives of a profound disconnect between academic research-based activity and innovators across much of the programme. For research and technical development projects, this disconnect has actually increased from FP5 to H2020. This is a substantial challenge.

The large effort in data curation yielded new insights into the long-term effects of past changes. The change from FP5 to FP6 in 2002 caused a substantial increase in the gap between research and innovation as indicated by data on participation and especially coordination. A marked decline in the involvement of non-academic organisations and innovators in coordinating projects between FP5 and FP6 was associated with the shift towards large projects. Ironically, the drive to large projects arose from efforts to support impact and innovation by integrating diverse research and innovation actors within projects, for example following the 'fork-to-farm' principle. However, this reduced the influence of innovators due to the increased complexity of setting up and leading such large and complex projects. Linked to this, the profile of coordination from FP6 onwards reveals remarkable stability in the types and location of coordinating organisations for projects focused on research and technical development, i.e., the core of the programmes. The domination of certain combinations of countries and academic organizations in participation and especially coordination, and the funding differences between countries, remained broadly similar despite the great changes in the EU over this period. Of the top 10 country/organisation type combinations, research organisations in France and institutions in the Netherlands are consistently prominent. This study did not address the issue of proposal success rate directly. However, it yielded users' views that confirm the problem of low success rates identified in the ex-post evaluation of FP7 and which is reported to have intensified in H2020.[3]

The portfolio mapping and the coordinators' survey offered strong indications that the SC2-aligned projects have been contributing to several elements of those FOOD 2030 across the FP, and a close correspondence between the SC2 major impacts and FOOD 2030 was traced. The 11 SDGs identified as related to the SC2 impacts offer a valid basis for the global discussion about EC-funded research and can become a chart onto which R&I activities can be mapped.

Pointers for future programme planning

In general, the FPs going right back to FP5 are relevant to current priorities. However, portfolio features point towards a deeply in-grained challenge in participation and coordination with respect to engaging and supporting innovators and other users. Previous studies[4] also indicated that programme planning does not have the benefit of a content/impact-oriented programming framework that allows specific scientific or technical targets to be identified early, resourced and

[3] Moran, N. et al. (2015). Horizon 2020. The insider's guide. Science Business Publishing.
[4] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

pursued coherently in relation to the relevant impact areas and user communities. Related challenges for programme management can be summarised as: anticipating and articulating societal challenges and 'missions' into forward-looking strategic research targets; building effectively on existing programme outputs and resources; reducing barriers to access for a wider range of participants across Europe; and driving a profound change that connects research and technical development with users and innovators by supporting innovation-led R&D.

Although still a prototype that needs validation, the type of portfolio impact mapping framework described here can support programme managers in the very challenging task of articulating societal challenges or missions into cutting edge scientifically and technically coherent targets that relate better to targeted users and their activities.

Connecting sources of knowledge and technology with users and innovators in wider society is a very urgent goal. This has consequences for programme design, the formulation of calls and topics, the selection/design of instruments, and the support of knowledge and technology acquisition. More must be done to encourage leadership by innovators and other users. The disruptive effects of the SME and BBI-JU instruments show that change is possible if instruments that drive change towards innovation-led research (complementing research-led innovation) are used. With the exception of the SME and BBI-JU projects, the resilient dominance of a few member state/organisation-type combinations in participation and especially in coordination is remarkable. The Interim Evaluation report discussed the question of broad topics versus more focused topics[5] and drew attention to the consequences of different approaches to topics for participation. There is evidence from several sources that topic calls for large projects that have broad scopes and a broad range of project impacts favour coordination by large academic organisations. Project opportunities for small to medium-sized research and technical development projects offered to non-academic innovator-led consortia in response to good ideas (bottom-up) could make a big difference. These would support innovation-led collaborative R&D. Such an initiative would give innovators the opportunity to address the broad strategic priorities set out in work programmes with their focused ideas in a flexible way. Opportunities for re-submission of competitive unfunded proposals would reduce the proposal application 'all-or-nothing' risks and barriers that now greatly discourage non-academic leadership of consortia.

Our portfolio analysis shows that the EC has consistently invested about 8 to 10% of funds in networking and communication projects. This is in addition to the communication efforts within RD&I projects, which often account for a further 5 to 10% of project funds. Therefore, we conclude that communication of results has been well-resourced and the challenge is more to do with the nature and structure of their activities rather than their funding. The portfolio framework explicitly identifies impact areas and impact communities along with the corresponding projects. This can be used to prioritise, rationalise and professionalise this activity. This would move communication and networking activity from the project to the sub-programme and impact community level with the

[5] European Commission 2017. Commission Staff Working Document. Interim Evaluation of Horizon 2020. Annex 2 page 680

double benefit of reducing the complexity of RD&I projects and establishing more efficient mechanisms for supporting knowledge and technology acquisition by users and innovators.

There are already some examples to work with. The Thematic Networks set up within the European Innovation Partnership (EIP) for Agriculture and Innovation[6] network research teams and users in specific thematic areas to generate knowledge outputs for the EIP. In the marine and maritime areas, the Columbus Project aims to capitalise on the European investment in marine-related research by ensuring accessibility and uptake of research outputs by end-users: policy, industry, science and wider society.[7]

More emphasis on content-oriented evaluation conducted by sector (thematic) experts is required to address the difficult task of impact evaluation. While previous evaluations each used different approaches, each commenced with the expectation that indirect, top-down, and statistical approaches would yield insights into links between programme investments and changes in society (impact) using for example bibliographic analysis, searches for references to the programme in literature on legislation, survey data, and auditing of patenting activity. The difficulty of assessing impact this way became evident as each evaluation progressed and each turned later to expert judgement. This study provides a framework for placing content-oriented evaluation at the core of the evaluation process from the outset. This will allow a wide range of probing investigations that focus directly on the links between who is leading and conducting projects, project contents, their users, and what their users do with results to generate impact. Reliable, curated data and information is a prerequisite for robust analysis of outputs, results and impacts that a subsequent assessment can rely upon.

A harmonization of the type and quality of impact-related data collected from consortia (coordinators) is important for future assessment and planning. The collection should be systematic and the provision of data should become a contractual obligation to ensure the continuum required for following the effect of evolving strategies in EU research funding. To this end, the European Commission's Continuous Reporting System already established for projects funded in H2020 can be used by the coordinators and the beneficiaries as early as the start of the project. Job creation within the consortium, performance of SMEs participating in the consortium, projects outputs and open sharing of data and other resources are already mandatory information collected through the Continuous Reporting System.

Lastly, in driving future programmes and supporting greater impact it is important to continuously remind all actors that the purpose of the programme is to address a societal challenge through collaboration across the EU, complementing national and EU funding that supports the basic sciences, and national research that also supports societal challenge targets. The programme is there to serve society; it is not the property of the academic research community. This position within the wider H2020 effort must be continuously recognised in programme planning and implementation.

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[6] https://ec.europa.eu/eip/agriculture/en/about/thematic-networks-%E2%80%93-closing-research-and
[7] http://www.columbusproject.eu/aquaculture

2. INTRODUCTION AND BACKGROUND

Horizon 2020 invests in research, development and associated activities within three pillars, one of which addresses societal challenges. This report provides an account of investigations of how EU-funded projects in Framework Programmes have served Societal Challenge 2 (SC2): Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy.

The Interim Evaluation of Framework Programme 7 (FP7)[8] (referred to from here as the Interim Evaluation) and especially the ex-post evaluation of FP7[9] revealed the difficulties in using top-down impact assessment approaches, for example programme-wide patent searching and bibliographic analysis, for assessing the connections between investments in research, development and innovation (RD&I) projects and the broad societal impacts that the Framework Programmes seek to support. The interim assessment of Horizon 2020 (H2020)[10,11], which we contributed to, examined the intervention logic behind the SC2 part of the programme and concluded that in terms of programme structure, H2020 coherently addresses SC2 using the available project instruments. The work reported here complements the Interim Evaluation of H2020 with in-depth investigations focused on the content and structure of the portfolios. This had two main purposes: the development of new content-oriented approaches to assessing the impact of past and ongoing RD&I activities and the development of recommendations relating to portfolio development and management.

At the outset in February 2017, the European Commission asked us as members of the Interim Evaluation Expert Group for an innovative wide-ranging investigation to complement the Interim Evaluation. As authors of that report, we had already concluded that assessing the impact of Framework Programmes is a quantitative way is extremely difficult if not impossible. There is no counter-factual for a RD&I programme such as H2020. The links between EU investment in RD&I and the societal outcomes that these investments seek to support are extremely complex, indirect, and subject to numerous factors other than those impacted on by the programme, including the effect of related national programmes. Against this background, the overall goal of this work is to build on the Interim Evaluation to develop new approaches to programme assessment and support the development of research and innovation strategy in Societal Challenge 2, particularly post H2020. Specifically, the work set out to:

[8] Horvat, M., Ricci, A., Casal, M., Griniece, E., Pianta, M. Tjell, J.C. (2011). Impacts of EU Framework Programmes (2000-2010) and prospects for research and innovation in food, agriculture, fisheries and biotechnologies. Final Report, European Commission Brussels.

[9] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

[10] European Commission 2017. Commission Staff Working Document. Interim Evaluation of Horizon 2020.

[11] European Commission 2017. Commission Staff Working Document. Interim Evaluation of Horizon 2020. Annex 2.

1. examine how the H2020 projects and participants relate to areas of impact[12] and the corresponding impact communities[13] and to combine this information with corresponding information for Framework Programmes 5, 6 and 7;
2. from 1, assess impacts through impact communities considering the evolution of activities over FP5 to H2020;
3. conduct a survey of coordinators of projects in FP5 to H2020 supporting a comparison with the results of a survey of FP6 and FP7 project coordinators conducted in 2011;
4. analyse the results of 1, 2 and 3, the Phase I report, previous programme evaluations, and the output of a number of research strategy reports (including report of programming activities) to provide input into the development of the next Framework Programme; and
5. produce a report to the European Commission that will make a substantial contribution to the strategic development and implementation of new FP activities.

We conducted the work as a research project systematically combining data curation, testing the reliability of data, data analysis, and thematic knowledge. We tested hypotheses through portfolio impact mapping covering FP5 to H2020; associated probing of how the user communities' views of the programme and how impacts are delivered; and a survey of coordinators. This served a synthesis primarily aimed at developing recommendations for future programme development.

These approaches were influenced by two precursors in previous evaluations: 1. the interim evaluation of FP7 included a survey of coordinators to gather evidence about the impact of the programme[14]; and 2. the ex-post evaluation of Theme 2 in FP7[15] showed that 'top-down' methods of analysing research performance such as those that use bibliographic analysis, patent searching, and searching policy documents were unlikely to provide all the evidence needed for impact assessment. In recognition of that constraint, the 'agriculture' sub-panel that worked on the ex-post evaluation of FP7 conducted some rudimentary content-oriented portfolio analysis which has been developed in this study.

Some historical background

This study is unique in how it integrates data from FP5 to H2020 and therefore some historical background helps in understanding the work. Historical background was described in a previous report[16] and this is represented here.

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[12] An impact area is a specific part of the economy, society or public sector where the project outputs are used to generate wider economic, social and environmental impact.

[13] The impact communities are those groups of people and businesses that are expected to lead in the using of project results in impact areas converting them into wider impact.

[14] Horvat, M., Ricci, A., Casal, M., Griniece, E., Pianta, M. Tjell, J.C. (2011). Impacts of EU Framework Programmes (2000-2010) and prospects for research and innovation in food, agriculture, fisheries and biotechnologies. Final Report, European Commission Brussels.

[15] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

[16] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission. https://publications.europa.eu/en/publication-detail/-/publication/d61e714d-cdd0-4d75-8004-51d55a5bdba2

A commitment to invest in the science-based improvement of activities relevant to SC2 goes back to the founding of the Common Agricultural Policy in 1963 and the Common Fisheries Policy in 1970. Investment in RD&I related to SC2 is one of the most longstanding EU activities. SC2 has, through analogous parts of FP5, FP6 and FP7, roots in the FP4 FAIR programme that operated from 1994-1998. Relevant policy debate in the mid-1990s was dominated by concerns of over-supplied food commodity markets in Europe, animal disease outbreaks and food safety implications of the BSE crisis. In addition, organic farming and its markets were on the rise. This policy environment had a major impact on the development of FP5 (1998 – 2002) and especially FP6 (2002 – 2006), which in turn provided the backdrop to the development of FP7 and H2020. Throughout these two decades, there has been increased emphasis on wider impacts of FP investment in society and this is a key driver of changes in how the FPs are developed, structured and managed.

Framework Programme 5 (1998-2002): The FP5 thematic programme '*Quality of life and management of living resources*' was aimed at enhancing the quality of life of European citizens and improving the competitiveness of European industry. This was partly a response to over-supplied food commodity markets. Key Action 5 (KA5) of this programme dealt specifically with the sustainable production and exploitation of biological resources, with emphasis on research covering the whole production chain. Research on animal health and welfare, and natural resource protection expanded. Forest science focused on environmental performance, management, operations, and wood technology. Fisheries and aquaculture research promoted an integrated approach to the development of new concepts for the sustainable management and production linking resource conservation, means of capture, market requirements, reduced impact on ecosystems, diversification of cultivated species, improvement of production techniques and disease control. There was also emphasis on enabling and more basic biological research reflecting the expansion in the molecular biology at the time, and was manifested in a distinct programme area called 'Cell Factory' which was a precursor of work for the bio-based sector in H2020, including in the Bio-based Industries Joint Undertaking (BBI-JU).

FP5 marked a distinct change in direction from a science-led approach in earlier Framework Programmes towards wider societal impact, manifest most clearly in the title of the relevant thematic programme area '*Quality of life and management of living resources*'. A new proposal assessment system was introduced to focus on benefits for society. This was developed as the 'Impact' criterion in FP6 and FP7.

Framework Programme 6 (2002-2006): The public policy debate in the lead up to FP6 was dominated by food safety and animal health concerns. There remained also concerns about the over-supply of food from European farms. The word 'agriculture' was removed from the programme title. This, combined with the alliterative phrase 'from farm-to-fork', focused projects on questions relevant to consumers with diverse project activities integrated along reversed supply chains in Thematic Priority 5 ('Food Quality and Safety'). This meant that questions relevant to consumers were the starting point of all research. Agriculture in general and forestry in particular were side-lined in FP6, and even animal health and welfare was relied on investment in policy-oriented applied research in a separate funding stream (Scientific Support to Policies; SSP). The integration

along supply chains was also associated with a very significant increase in the size of projects, both in terms of the number of partners and in terms of funding.

Thematic Priority 5 "Food Quality and Safety" also supported better seafood and other marine resources production, improving the knowledge about diseases, health conditions and processing. However, as for animal health, the majority of fisheries and aquaculture R&D was funded to address policy problems via pragmatic and much more applied research in the SSP funding stream.

Framework Programme 7 (2007-2013): The Food, Agriculture, Fisheries and Biotechnologies (FAFB) programme (Theme 2 of FP7) set out to support Europe in a global economy while protecting our environment and social model. FP7 had a big influence on the development of H2020 and so detail is provided here.

FAFB was focused on the sustainable management, production and use of biological resources (farms, fisheries and forests). In addition, funds were allocated specifically to support life sciences and biotechnologies, particularly for research relevant to the bio-based industries. The programme foundations were laid mostly in 2005 and 2006 when it was becoming clear that the Lisbon Strategy to promote sustainable growth and social cohesion had weaknesses. It pre-dated Europe 2020 and it was developed prior to two crises: the global food crisis of 2007-2008 and the financial crisis that emerged in the same period.

There were a number of important driving influences at the outset of FP7, particularly the outputs of 7 European Technology Platforms (ETP) and the work of advisory committees such as the Standing Committee for Agricultural Research (SCAR).

A main driver in the food area was the concern about the safety of food chains, as well as diet-related diseases and food choices to help to fight diet-related disorders (e.g. obesity, allergies) and infectious diseases. The importance of the ETP "Food for Life" as a driver is also evident from the topics.

The Lund Declaration[17] was the first major European statement on research policy that emerged during FP7 (in 2009). This presented a high-level statement of changes required to the European research system as a whole. It called for research processes to be based on understanding of the interaction between "bottom-up" and "top-down" initiated research. It also called for attention to be given to more systematic division of labour between European, national and regional research programmes; better links between research and policy; and a risk-tolerant and trust-based approach in research funding.

The Europe 2020 Strategy replaced the Lisbon Strategy. This provided a backdrop to the development of H2020 and it is now the European Union's ten-year growth and jobs strategy that was launched in 2010. It is about creating the conditions for a smart, sustainable and inclusive

[17] Swedish Presidency of the European Council. 2009. The Lund Declaration. Europe must focus on the grand challenges of our time.

growth through more effective investments in education, research and innovation; a decisive move towards a low-carbon economy, and with a strong emphasis on job creation and poverty reduction.

A range of policy documents such as the European Biodiversity Strategy[18] were also of relevance. In addition, there were more scientific or technical drivers emerging at Member State level, most notably the IAASTD report in 2009[19] which concluded that the main challenge for agricultural knowledge, science and technology is to increase productivity considering the multi-functionality of agriculture; the "Reaping the benefits" report[20] and the UK food and farming Foresight Report.[21] The UK Foresight Report drew attention to the confluence of demand growth, impact on the environment, constraints of the supply side, and climate change in what was termed "a perfect storm". This was supported by the 3rd SCAR Foresight Report[22] in 2011 which highlighted the role of public agricultural research in supporting transition towards more sustainable food consumption and production in a resource-constrained world. The report drew attention to the need to take planetary boundaries seriously; resource scarcities; the need to better understand agricultural systems; diversity and resilience; the need to consider 'sufficiency' linking food consumption with production; fit-for-purpose agricultural knowledge and innovation systems; a long-term view in agricultural research policy; new ways of policy coordination; and the need for mission oriented research.

The Marine Strategy Framework Directive (MSFD) was adopted in June 2008. It made clear that science and technology support the reconciling of promotion of sustainable economic growth in sea-based activities with environmental conservation ("Blue Growth"). The European Strategy for marine and maritime research[23] recognised that RTD efforts are necessary to increase their eco-efficiency and offer solutions to overcome the unsustainable use of resources and a list of research topics requiring cross-thematic approach to reap the full potential of the seas were identified. The implementation of this strategy gave rise to the ambitious FP7 initiative "*The Ocean of Tomorrow*" with a total EU contribution of €196 million in 2010-2013 (cross-thematic FP7 funding). A part of this cross thematic funding (€79 million) came from the FAFB programme budget.

In addition, at the later phase of FP7, an important policy driver was the strategy for "Innovating for Sustainable Growth: A Bioeconomy for Europe"[24] adopted by the European Commission in 2012. This strategy proposed a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges. The strategy covered the whole bioeconomy but included measures specifically relevant to the bio-based sector. It made reference to the Lead Market Initiative (LMI) on bio-based products, the Blue Growth initiative, and the Renewable

[18] COM 2011, 244. Our life insurance, our natural capital: an EU biodiversity strategy to 2020.
[19] IAASTD 2009. Agriculture at a crossroads. International Assessment of Agricultural Knowledge, Science and Technology Development. Synthesis Report.
[20] Royal Society 2009. Reaping the benefits. Science and the sustainable intensification of agriculture.
[21] Foresight 2011. The future of food and farming. UK Government Office for Science.
[22] SCAR 2011. Sustainable food consumption and production in a resource-constrained world. 3rd SCAR Foresight Exercise.
[23] COM2008. A European strategy for marine and maritime research. A coherent European Research Area framework in support of a sustainable use of oceans and seas.
[24] COM 2012 60. Innovating for Sustainable Growth: A Bioeconomy for Europe.

Energy and Fuel Quality Directives' targets and the Strategic Energy Technology plan. There was emphasis on infrastructural measures which related specifically to the biorefinery concept.

Compared with FP6, FP7 reintroduced agricultural production research with clear tangible farming and agricultural system targets. There was also increased support for research on bio-refineries, marine biotechnology, cellular production platforms for materials, fine chemicals, including biopharmaceuticals, traits for biomass for energy applications, waste utilisation, environmental issues and cross-cutting sustainability issues. There was emphasis on production agricultural research and its efforts to address farming and agricultural system targets, and therefore in line with the drivers already described. Over agriculture and fisheries, resource protection and management could be regarded as the major underlying theme. At the start, more emphasis was placed on small and medium size collaborative research projects (compared with FP6). As the programme progressed, there was increasing emphasis on the participation of SMEs (which was made mandatory in many topics), linked to a drive from the EC to support innovation. Projects also increased in size as the programme progressed, particularly in biotechnology from 2011 onwards.

Horizon 2020: Societal Challenge 2 in H2020 follows very closely the FAFB theme in FP7. The trend established in FP7 of increased emphasis on innovation was reinforced with the introduction or significantly increased use of instruments specifically for this purpose. The BBI-JU in effect ring-fenced a very substantial investment for projects led by the bio-based industry sector. The SME instrument (which was used in FP5) was revived and provided SMEs with the opportunity to lead relatively small innovation projects focused on their individual needs for specific products and services.

In general, the drivers behind H2020 are similar to those behind FP7, especially the later stages of FP7: the challenge of increased demand for food to be met in an environmentally sustainable manner. Technological advances are required to drive efficiency in order to meet the growing demand for safe and healthy food while accommodating growth in the bio-based industries to reduce Europe's dependence on fossil resources and to create jobs and green growth. Technological advances are also central to unlocking the potential of the seas and oceans and to boosting Blue Growth. Societal Challenge 2 comprises five activity lines[25]:

1. Sustainable agriculture and forestry.
2. Sustainable and competitive agri-food sector for a safe and healthy diet.
3. Unlocking the potential of aquatic living resources.
4. Sustainable and competitive bio-based industries and supporting the development of a European bio economy.
5. Cross-cutting marine and maritime research.

[25] Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC.

This programme has a financial envelope of EUR 3.85 billion[26] for the period 2014-2020, of which EUR 800 million has been allocated to the BBI JU. By the end of 2016, approximately 43% of the total SC2 budget had been allocated (EUR 1.64 billion) via two biennial work programmes covering the main SC2 calls (WP2014-15 and WP2016-17) and three work programmes covering the BBI calls (2015, 2016 and 2017). It is developed and managed jointly by DG RTD and DG AGRI. The implementation of calls and the day-to-day management of grant agreements have been delegated to EU Executive Agencies (mainly REA, to a limited extent EASME and INEA).

[26] This figure was later reduced to EUR 3.70 billion following the 'taxation' of H2020 to provide budget resources to the European Fund for Strategic Investment (EFSI) set up in 2015.

3. PORTFOLIO IMPACT MAPPING

The impact potential of a programme is determined by the content of the projects, the primary or direct users of the project outputs, and users' activities impacted on. Portfolio analysis often examines R&D programmes from the perspective of the funding organisation examining the funding instruments used, the funding of sub-programme areas, institutions funded etc. from an administrative viewpoint. In other words, such analyses are often concerned with 'inputs'. Here we examine the portfolio from an outcome and impact perspective examining the direct users of the project outputs; what user activities are impacted on by the projects (impact areas); and what type of project activity (e.g. R&D discipline or technical area) was supported. By direct users we mean those people or organisations who are the immediate users of the results and upon whom impact depends either through their own actions or the actions of other users that they influence or support. Users' activities (primary and secondary) that are impacted on by the R&D are 'impact areas'. Groups of primary and secondary users related to specific impact areas are 'impact communities'. Understanding the portfolio from this user/impact perspective allows changes in how impact areas and communities are addressed over time to be examined because the classification of users and their activities is programme and funding instrument neutral. In addition, impact communities so identified can be examined in detail in impact assessment, for example by using the Delphi survey technique. Probing of past projects within impact areas can contribute to the future programme development and strategy.

The methodology used for the investigations reported here is set out in detail in Annex 1. In summary, a bottom-up approach was taken. Lists of all possibly relevant projects from all areas of FP5, FP6, FP7 and H2020 were extracted from the EC's computer-based records and screened to identify all projects aligned to SC2. The project titles for all SC2 aligned projects and the abstracts for the FP6, FP7 and H2020 projects were inspected to identify the direct user addressed by each project and the main relevant user activity. The main project activity was also typed in this bottom-up way. The overall result was a coding of the whole portfolio of projects based on expert impact-related assessment of them rather than a pre-determined administrative classification.

3.1. Portfolio overview

Our screening showed that the 'Food Quality and Safety' thematic area of FP6 and the Knowledge-Based Bioeconomy area of FP7 aligned closely to the SC2 area in H2020. In contrast, work in FP5 corresponding to SC2 was spread across five Key Action areas within the 'Quality of Life and Management of Living Resources' thematic area. The manual inspection of each project title and abstract resulted in the identification of the whole SC2-relevant portfolio as outlined in Annex 1.
It should be noted that the data for H2020 relate only to the early phase of the programme up until 31 December 2016. It will run until 2020.

We can see that until 31 December 2016, the European Union committed 4.3 billion Euros to 2,305 projects in FP5, FP6, FP7 and H2020 that support or potentially support SC2. We believe this list of projects is an accurate reflection of the investment in all framework programme activity aligned to

SC2. However, there are some relevant activities not captured. These include some relevant Marie Curie fellowships and some SME projects in FP7. However, these are minor compared with the portfolio described here. Research supported by the European Research Council which might in the longer term be supporting of SC2 is not considered because it is not designed to address Societal Challenges in terms of how H2020 is organised.

3.2. Direct users

Which main direct users did we identify for each project?

It must be kept in mind that this analysis focuses on the direct (primary) users of project outputs. These are not to be confused or interchanged with all the user beneficiaries of project outputs. This is particularly important where the policy community is the direct and primary user that stimulates impact through other secondary users. Also, R&D used directly by the policy community should not be confused with policy R&D. A large proportion of R&D projects impact on farmers, fishers, the food sector etc. through the policy actions and decisions.

As set out in Annex 1, the initial screen of projects identified more than 20 categories of direct users. This was rationalised to 11 categories using expert judgement as set out in Annex 1 to facilitate trend analyses and identification of the major changes in terms of the programmes' approaches to users. While we sought to consolidate users as much as possible, distinct user groups such as fishers which were the direct users for only a small proportion of projects remained identified.

Over the four FPs (FP5 to H2020), the policy community was the largest group of direct users in terms of the EU contribution to research with a total of 1,351 million Euros (27% of total expenditure (Figure 1). This was followed by the food industry with 720 million Euros, and by the bio-based industries with 709 million Euros. Farmers are fourth with 671 million Euros. By 'farmers' we mean all who cultivate plants and keep livestock, including fish.

This analysis also identified the plant and animal breeding industry as a significant direct user of project outputs, being the direct user of outputs from projects receiving nearly 10% of funding. The pharmaceutical and fine chemical sector is also important with 4%. Although a very substantial investment is made in research on fisheries, only a small proportion of this is for fishers as direct users. Most of fisheries research depends for impact on the policy community as a direct user.

There were substantial differences between FPs in the ranking of expenditure in terms of primary users (Figure 1, Figure 2, Figure 3, Figure 4). Public policy was the largest group in FP5, FP6 and FP7 in terms of EU expenditure on projects for which it is the main primary user. The prominence of policy as a primary user was the highest in FP6 accounting for 45% of EU expenditure. This declined to 27% in both FP7 and H2020 (up to early 2016). Farmers as primary users accounted for 20% of EU expenditure in FP5, which was the highest proportion aimed at farmers as primary users

of all four FPs. This declined in absolute and relative terms (to 14%) in FP6. It remained at 14% in FP7 and has risen to 17% in H2020.

The biggest single change throughout the four FPs was the increase in absolute and relative levels of expenditure on projects for which the bio-based industries are the main primary user of results. This rose from 7% in FP5 (58 million Euros, including relevant research in the 'Cell Factory' Key Action Area) to 27% in H2020 (228 million Euros). The bio-based industries are now by far the most important single category of direct users in H2020.

If we classify projects under 'policy', 'farmers', 'breeders' 'international development community' and 'fishers' as delivering results that are used mainly in the public domain while those under 'food industry', 'bio-based industry', 'pharma', 'engineering' and 'Blue Growth' as primarily in the private domain, we can see that there has been a steady shift from public to private primary users. This means there has been a shift from reliance on public routes to impact to private routes. The private category accounted for about 30% of EU project expenditure in FP5 and FP6. This increased to about 45% in FP7 and H2020.

While data obviously show major trends from the past, such as the high emphasis on policy in FP6 and the shift of resources to the bio-based industries in FP7 and H2020, trends for the future are also indicated: for example the initiation of work for the Blue Growth sector in FP7 which has grown in H2020. This is directly related to the Blue Growth Strategy. This is an integrated approach considering all marine and maritime sectors, sea basins and knowledge and surveillance needs to harness the vast potential of the oceans and seas in a sustainable manner. This illustrates how framework programmes respond to such policy initiatives.

3.3. Impact areas

What areas of activity in farming, business and wider society were impacted mainly by project results?

As set out in Annex 1 (Methodology), the expert assessment identified 40 areas of impact (impact areas) with one main impact area identified for each project. The allocation of the EU funding to projects according to the main impact area is shown in Figure 5 and 6. While we sought to consolidate impact areas as much as possible, distinct small impact areas remained identified so that the breadth and diversity of programme targets is captured adequately.

It must be noted that only one impact area was identified for each project. Also, several impact areas are closely related. For example, 'genetic resources' relates only to projects that impact on the management of genetic resources through relevant policies. Projects about the use of genetic resources in plant or animal breeding are allocated to the relevant applications: 'minor crops', 'major crops', 'livestock' etc. These impact through the breeding industry. The following provides a summary of each impact area, in ascending order of importance as indicated by the EU contribution to projects.

Bioeconomy policy: This comprises five projects in FP7 and two in H2020. Here the term 'Bioeconomy' is used only for projects that impact on the bioeconomy concept and policy. Five impact through 'policy' as the main primary user, one through the international development community.

Genetic resources policy: Six projects in FP5 and three in FP6. As described above, these are projects that impact on genetic resources policy, not the use of collection or use of genetic resources. It should be noted that there is substantial activity in H2020 in this area in projects established after 31 December 2016.

Food security policy: Five projects in FP7 support food security policy. Four impacted through 'policy' while one was more closely related to the food industry. This R&D included some work on food systems generally.

Pulp and paper: Pulp and paper production was the main target of eight projects in FP5 (10.5 million Euros), delivered mostly through the bio-based industries with one project focused on forestry.

Bees and honey: Eight projects (11.1 million Euros) focused on matters related mainly to the keeping of bees and production of honey. Four impacted through bee keepers ('farmers') and four through the food industry. This type of project was funded in all four FPs and includes four projects aimed specifically at SMEs.

Grassland: The EU has invested 14.2 million Euros in projects related specifically to grassland. This is in addition to other projects on livestock that affect grassland. Nine projects were funded in FP5, one in FP7 and two in H2020 (one of which is a phase 1 SME project). The direct users are the farmers and the breeding industry.

Pesticide safety: This comprises quite a broad range of regulatory and technical activities in 19 projects (13 in FP5, 4 in FP6 and 2 in H2020) aimed specifically at assuring safe pesticide use. Thirteen of these impact through the policy community, with the remaining six impact through the food industry, the pharmaceutical industry, and engineering sector.

Wood products manufacturing: We identified a cluster of 23 projects in FP5 (15.6 million Euros) that impact on the wood products industry, mainly through the forestry and the wood products sector. No analogous R&D in the subsequent programmes was identified.

Meat: Twenty projects in FP5, one in FP6 and seven projects in H2020 were primarily about meat processing and these impacted mostly through the food industry. Sixteen were projects supporting SMEs directly and this partly explains this impact area concentration in FP5 and H2020.

Addressing antibiotic problems: Our inspection of the projects indicated that addressing antibiotic resistance was a distinct impact area separate from wider animal health and welfare activities.

Thirteen projects were funded (21.3 million Euros): three in FP5, two in FP6, three in FP7 and five in H2020. The five H2020 projects are all first phase SME projects with just 50,000 Euros each allocated. The major research was in FP7 with two projects for policy and one primarily impacting through the pharmaceutical sector.

Wine and beer: 30 projects impacted mainly on the wine and beer sectors – especially wine. Most of this was in FP5 (24 projects) with one project in FP7, and five projects in H2020. SME support projects account for 22 of the 30 projects and impact is generated through the food industry and farmers.

Trade: Trade policy was identified as an impact area for 18 projects distributed across FP5, 6 and 7 with a total EU contribution of 30.5 million Euros. Some of this work was closely related to EU enlargement and all but one project impacted through the policy community.

EU enlargement: The expert group identified policy relating to the enlargement of the EU as a distinct impact area. 31 projects with a total of 32.9 million Euros all addressed enlargement through the policy community. In line with the timing of enlargement, most of these were in FP6. There are none so far in H2020.

Soil protection and management: This emerged as an activity supported by projects that is distinctive from related agronomic activities. Twenty-nine projects with an EU contribution of 36.2 million Euros impact on soil protection and management mainly through farmers and policy makers. Twenty of these were in FP5 and five are in H2020. Projects specifically for SME played a significant role.

Algae: The EU contributed 42.8 million Euros to 18 projects spread across FP5, FP7 and H2020 focused on developing algae production. SME support projects account for all the work in H2020.

Rural and regional development: This is a distinctive impact area with 37 projects and an EU contribution of 43.0 million Euros. The work is spread throughout FP5 to FP7 with more than half of the projects in FP5. Most projects impact through policy as the main direct user, complement by a few working through farmers and the food industry.

Biomass: The EU has invested 50.5 million Euros in 18 projects, mostly in FP5 and especially FP7. This work impacts through plant breeders (the breeding industry), the bio-based industry, and farmers.

GMO policy: This work is mainly about the assessment of any risks arising from the use of genetic modification. It accounts for 53.3 million Euro from the EU spent on 20 projects spread quite evenly over FP5, FP6 and FP7.

Organic farming and food: R&D impacting specifically on organic farming and food was supported in all four programmes (total EU contribution 68.7 million Euros) with impact generated through farmers, policy makers and the food industry.

Plant health policy: This is also mostly about plant health risks directly relevant to public policy, for example policy measures to prevent and control exotic pests and diseases. All four programmes included projects impacting on plant health policy with a total EU contribution of 60.4 million Euros. This impact area is distinct from the impact of the control of endemic diseases on farm crops.

Biomaterials: R&D supporting the production and use of biomaterials received significant support in FP5 (23 projects) and FP7 (10 projects). A total of 37 projects were funded with a EU contribution of 75.6 million Euros. All but one of the projects impact through the bio-based industries sector. Engineering was a dominant discipline used in the projects.

Dairy: Dairy production was identified as the main impact area for 45 projects with an EU contribution of 83.8 million Euros. 26 of these were in FP5, 12 in FP7 and seven are in H2020. SME supporting projects account for five of the seven in H2020. This R&D impacted on dairy production through farmers, the breeding sector and the food industry. The projects included a wide range of activities: engineering, genetics for animal breeding, nutrition, animal reproduction, detection/monitoring.

General agriculture: Agriculture here as an impact area is about impacts on agriculture in general, complement other more specific parts of agriculture. A total of 58 projects with an EU contribution of 87.2 million Euros spread quite evenly between the programmes impacted on agriculture in general. The main direct user was the policy community followed by farmers. The main activities were economics/marketing, policy analysis and communication-networking. This impact area complements and is closely associated with others such as impacts areas related to production and to soil protection and management.

Environment and biodiversity: A total EU contribution of 111.7 million Euros was made for R&D in 46 projects impacting specifically on the environment and biodiversity. 27 projects were in FP5. A large proportion of the work impacted on the aquatic environment with a wide range of scientific disciplines used. Policy makers were the major route to impact.

Forestry: The EU spent 120.8 million Euros on 69 projects that impact mainly through forestry. Forestry as an impact area has been subject to very great fluctuations in funding of relevant Framework Programme R&D projects. 50 projects (50.3 million Euros) were supported in FP5. Only two were supported in FP6. This was followed by nine in FP7 and eight in Horizon 2020. These projects impacted through the plant breeding industry, the forestry sector, and the policy community.

Blue Growth: 'Blue Growth' is a term used for a long term strategy to support sustainable growth in the marine and maritime sectors as a whole. Our analysis distinguishes between aquaculture and other traditional activities and 'Blue Growth' as a distinct and new concept. The EU contributed a total of 127.1 million Euros to Blue Growth projects in FP7 and H2020. Impact is generated through the bio-based sector, the pharmaceutical sector, and the engineering sector.

Value chain development: We identified a distinct but broad range of impact activities that we termed 'value-chain development'. The EU contributed 145.7 million to 58 projects that are quite evenly distributed between the four FPs. In terms of expenditure, the importance of this impact area has gradually increased and is a significant part of H2020. The food industry and the bio-based sector are the main direct users.

Minor crops: The analysis identified 'minor crops' as a distinct impact area, which is even sometimes explicitly stated. Minor crops include all horticultural crops and are characterised often by high value per unit land area. Other minor crops are niche variations of major crops, such as spelt wheat. Support for minor crops was provided throughout the four FPs with the impact area particularly prominent in FP5 and H2020. Impact is generated largely through farmers and the breeding industry.

Functional food: Projects that support the development of various types of functional food products were a significant feature of FP5 and a consistent component of all FPs with a EU contribution of 153.5 million Euros in 77 projects. The food industry is by far the most important direct user. The R&D activity included a wide range of disciplines including nutrition, product development and engineering.

Livestock: Livestock production as a distinct activity (complementing other aspects of agriculture and aquaculture) was the focus of 79 projects with an EU contribution of 157.9 million. The investment is spread quite evenly through the four FP. This should not be regarded as the full extent of R&D relevant to livestock production as projects supporting other impact areas such as 'agriculture', 'organic' 'grassland' and 'environment and biodiversity' are also relevant. The projects impacted through farmers, the breeding industry, and the engineering sector. A wide range of project activities were involved.

Fisheries management: 135 projects supported fisheries management, with a total EU contribution of 175.5 million Euros. This impact area was most prominently supported in FP5 and the investment in it steadily declined up until H2020. Public policy is by far the most important route to impact, and this route is the means by which the very largest proportion of 'fisheries' research impacts indirectly on fishers.

Food manufacturing: Food manufacturing emerged as a major impact area with 184.9 million Euros invested by the EU in 169 projects. These were prominent in FP5, FP7 and H2020.

Aquaculture: 194.3 million Euros has been invested by the EU in projects impacting mainly on aquaculture. Aquaculture is an area that has received consistent support throughout the four FPs with a dip in FP6. The route to impact is through farmers, the breeding industry, and policy.

Research policy: Research per se was identified as an important impact area, especially in FP6, FP7 and H2020. These projects are about supporting research programme development in particular

through research policy. This includes 47 ERANET and investment in communications and networking.

Food and health: 53 projects impacting mostly in terms of food and health received 222 million Euros from the EU. FP6 and FP7 were particularly strong in this impact area. Policy was the main route to impact. This area complements food safety.

Ligno-cellulose processing, biorefining, biofuels: This impact area has been supported by 249.6 million Euros funding from the EU with 64% of this committed in H2020, following a commitment of 49.4 million in FP7. Impact is generated mainly through the bio-based sector. Policy and farmers are also direct users of some projects. Various types of engineering dominate the project activities.

Chemicals: Complementing lingo-cellulose processing, biorefining and biofuels, the production of other chemicals emerged as a very significant area of impact with 292.4 million Euros invested by the EU in 85 projects. This was a particularly prominent area in FP7. The direct users are mainly the bio-based industry sector, the pharmaceutical industry, and the Blue Growth sector.

Food safety: A total of 314.8 million was invested by the EU in 145 projects supporting food safety measures specifically. The food industry and policy were the main direct users and the projects included a wide range of activities, including work on detection methods and sensors. Work supporting food safety was particularly prominent in FP6, but has declined significantly in H2020.

Animal health and welfare: The EU invested 322.1 million Euros in 146 projects primarily concerned with animal health and welfare. Reflecting the various animal health crises of the 1990s and early years of this century, this impact area was very prominent in FP6 and FP7. There has been a marked decline in EU investment in H2020. The main direct users are the policy community and the pharmaceutical industry. Despite the very strong role of policy as a direct user of this research, the research itself is very strongly characterised by the relevant biological sciences. It impacts on livestock production through the decisions made by the policy community.

Major crops: The largest impact area across the four FPs was the production of our major crops. These are generally our dominant arable crops including wheat, barley, maize, sugar beet, potatoes, and the grain legumes. These crops account for a very large proportion of the EU agricultural area which are the basic resource foundation of much of the bioeconomy. The EU invested 367.7 million in relevant research with this impact area being particularly prominent in FP7 following relatively little emphasis in FP6. The direct users of research are farmers, the breeding industry, engineering, and the pharmaceutical industry.

As with the direct users, changes in the portfolio in terms of emphasis on public or private goods can be made. From this, the proportion of investment in impact areas with a primarily public character, including in areas such as major crops where knowledge and technology is primarily in the public domain, was 60% in FP5, 79% in FP6, 59% in FP7 and is 43% in the early stages of H2020.

3.4. Impact communities

The combination of direct users and impact areas allows us to identify 'impact communities' and the projects relevant to them. We can for example identify all the projects most relevant to farmers who grow major arable crops, or projects aimed at farmers who produce milk. We can also examine policy impact communities, for example projects supporting policymakers in the management of fisheries.

This capability to probe the portfolio in terms of direct users and impact areas enables the systematic consideration of users and their activities in the future development the portfolio. It also supports deep probing of the portfolio for evidence of impact and factors that affect impact.

3.5. Project activities

The third dimension we identified was the main project activity. The 'bottom-up' assessment of each project identified a total of 77 project activities. The top 50% of these ranked according to the EU contribution to projects over the four framework programmes is presented in Figure 7. This analysis is preliminary and the range identified is strongly influenced by the individual approaches taken by the analysts. Nevertheless, categorising project content or research discipline identifies important changes in portfolios. This fine-scale categorization enables a detailed probing of the portfolio on the basis of the project content which of course is an important consideration in portfolio management.

Responses to urgent challenges in each programme can be seen, for example the investment in prion biology in FP6 following the BSE crisis. We can see that some types of project activity have steadily grown while investment in others has declined markedly.

4. PARTICIPATION AND COORDINATION

The portfolio analysis reported in Section 2 examined the funded project activity, the relevant impact areas in society and in the economy, and the primary users addressed by projects. Here we examine the portfolio in terms of the project participants.

By its very nature, impact in SC2 has a strong geographic character since agriculture, forestry, fisheries and all rural activities are linked to place. Furthermore, the ethos and motives within the project consortia with respect to the range of scientific, economic, social and environmental impacts is influenced by the type of organisations participating in and leading the projects.

The methods used here (Annex 1) involved gathering data on each participant in each project over the four FPs. A total of 19,713 participations in 1,897 projects were examined. Financial data for each participant in each project were collected, checked, and integrated into the database. Each participant was also categorised as either:

1. a research organisation (RES);
2. a higher education establishment (HEE);
3. a private for profit organisation (PFP);
4. a public body (PUB); or
5. other (Other).

These data required very careful preparation. Even after this preparation, there are considerable limitations. For example, a large number of organisations use several names to an extent that was impossible to analyse the participation of individual organisations. Even the participant identifier code (PIC number) proved unreliable as several organisations used several numbers over the course of the four programmes. The opposite was also true: some organisations with fundamentally different institutional characters and purposes use the same PIC code and name due to for example participation in the name of a parent government department. In addition, data on the allocation of EU funds to individual participants was not available and instead we used data on the contribution requested by participants. Of the 1,098 projects in FP5, we had reliable participation information on 691 projects. Coverage of FP6, FP7 and H2020 is complete. Comparison of the total sums requested and total EU contributions showed that the sums requested and the EU contributions are very closely related so we used the data on sums requested with confidence.

4.1. Range and diversity of organisations participating

It was not possible to calculate the number of organisations that participated in FP5. We know that 2,104 different organisations participated in 691 of the 1098 projects in FP5. 2,303 different organisations participated in FP6; 3,283 participated in FP7; and 1,778 participated in the H2020 projects under examination. Broadly speaking and considering the limitations of the data, we concluded that the number of participating organisations has remained relatively stable between FP5 and FP7.

Taking into consideration that the data for FP5 are not complete, there is evidence that FP5 supported relatively high rates of participation from non-academic organisations, especially compared with FP6 (Figure 8). The participation of private-for-profit organisations recovered in FP7 where participation of SME to target levels was required by many call topics. High participation of non-academic organisations in H2020 is due to the SME projects and the BBI JU.

4.2. Where is the EU contribution (funding) going?

Particularly for SC2 which covers many activities that are bound to place, the impact of R&D is strongly influenced by where it is conducted. Here we address the question: where is the EU funding going?

The EU expanded east in 2004 with the accession of the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia), plus two Mediterranean countries (Malta and Cyprus). Bulgaria and Romania followed in 2007, followed by Croatia in 2013. Despite this huge change, we can see from Figure 9 that the funding differences between countries have remained broadly similar over the three FPs for which we have reliable data (FP6 to H2020). Reflecting Figure 8, the funding of private-for-profit organisations grew substantially from FP6 to H2020, both in real and relative terms (Figure 10, Figure 11).

For most projects, the results are published and are freely available to all. Therefore, it can be argued that the nature and location of coordination and participation does not necessarily affect the use of results in generating impact provided the results are disseminated. This may apply in areas such as vaccine development or research for policy making. However, in practice, where project work is conducted and where/how it is coordinated has a profound effect on impact in many areas. This is especially the case in SC2 where so much of the impact is location specific in farming, fisheries, forestry, and rural activities generally. The history of development in agriculture indicates that the co-location of R&D activity with the use of results in farming has a positive effect on non-academic impact, for example this is evident from the role of the land-grant colleges of the USA.[27] We examined the relationship between the location of work in projects that we categorised as 'for farmers' as primary users and the agricultural land resource base. We used the 'impact areas' categorisation to filter out those projects not related to land-based farming (aquaculture and algae). Project expenditure in non-EU countries was filtered out. FAOSTAT data on the agricultural land areas in the EU member states were compared proportionally with funding for these projects aimed at land-based farmers. The results are shown in Figure 12. It is very clear that the investment in projects primarily aimed at farmers is not geographically related to the agricultural land resource that the projects could or should impact on. Figure 13 shows the level of EU contribution to these projects in terms of Euros per hectare over FP6, FP7 and H2020. This varies from less than 1 Euro/ha for many new member states to more than 10 for Denmark, Belgium and the Netherlands. Broadly speaking, the funding of projects for which farmers are the primary users is largely going

[27] http://ext.wsu.edu/documents/landgrant.pdf

to the EU15 in projects led overwhelmingly by participants in the EU15. However, the great need and potential for development in farming exists in the EU13.

By using the impact oriented categorisation of projects (primary users and impact areas) we have been able to easily examine the extent of the co-location of project activity and impact potential focused on a part of the portfolio where such co-location is an important factor. This is just one example of the sort of portfolio probing that that is possible and necessary if portfolios are to be developed to impact of specific impact areas and communities.

4.3. Who is coordinating the projects?

The coordination of projects is key in setting the ethos and priorities for the day-to-day work and the emphasis placed by consortia on various types of impact. It is reasonable to expect that project consortia coordinated by academic organisations will emphasise academic outputs and impacts, whereas coordination by commercial and other non-academic organisations is more likely to give more emphasis on other types of impact relevant to societal challenges. Figure 14 shows changes in the number of projects coordinated by different types of participants.

The data in Figure 14 illustrate a general feature of the FPs. FP5 was distinctly different to FP6 and FP7 with a large number of relatively small projects. This was associated with a relatively greater diversity in the coordinating organisations. For the data we have in FP5, 42% of the projects were led by non-academic organisations, the remainder were led by universities and research organisations. It is reasonable to assume these non-academic organisations (private for profit, public bodies, and 'other' organisations) are more directly associated with the use of research and generating impact. The equivalent number for FP6 was 18% with a particularly big drop in coordination by private-for-profit organisations (from 28% to 6%). Leadership by non-academic organisations declined further in FP7 to 11% with the role of private-for-profit in coordination dropping to 5%. This further decline in FP7 was despite a significant increase in the participation of non-academic organisations in FP7, driven probably by mandatory requirements to engage SMEs. In short, the drive to direct resources to SMEs in FP7 resulted in SMEs being engaged in projects led by academic organisations rather than to an increase in SME leadership in the programme. It is noteworthy that the high level of non-academic leadership in FP5 is associated with the programme's structure which supported a large number of small projects.

H2020 shows a significant increase in the non-academic leadership of projects. However, close inspection of the data shows that this is due almost entirely to the projects in the BBI JI, which are targeted specifically at and for the bio-based industries, and to the SME instrument. Of the 368 projects in H2020 in place by 1 January 2017, 34 are BBI projects and 204 are SME projects. This leaves 130 projects that as collaborative Research and Innovation Action (RIA) and Coordination and Support Action (CSA) projects are broadly analogous to those in the previous FPs. Of these, only 11 (9%) are led by a non-academic organisation. The number led by public bodies and 'other' types of organisations are 6 and 3 respectively. While H2020 is very different to FP5 in many

respects, their portfolio profiles suggest that more opportunities for small projects favours leadership by non-academic organisations more directly involved in generating impact (Figure 15).

Categorisation of projects by the EC allowed the core R&D effort to be identified as projects on 'research and technological development'. The coordination of these projects was examined with results presented in Figure 16 and Figure 17. The proportion of research and technological development projects coordinated by non-academic organisations declined substantially in FP6, recovered in FP7, but has declined again in H2020.

The portfolio data were not sufficiently accurate to allow a meaningful analysis of participation at the level of individual organisations. To consider patterns in coordination, we examined a combination of country and organisation types because the relevant data are reliable (Figure 18, Figure 19, Figure 20, Figure 21, Figure 22). In line with findings above, there is evidence of a more heterogeneity in coordination in FP5 than in FP6 and FP7 with the top 10 country/organisation type combinations accounting for less than two thirds of the EU contribution. Of these top 10, research organisations in France and academic organisations in the Netherlands are consistently prominent. Perhaps reflecting the emphasis on animal health and food safety, UK research organisations played a major role in leading in FP6 and UK higher education institutions topped FP7 in terms of project coordination. The comparison between Figure 20 and Figure 22 is strong evidence of the stability of coordination patterns between programmes in the core R&D areas that are unaffected by the new SME and BBI-JU instruments. It also shows clearly that the RD&I community does respond to new instruments that specifically support leadership by innovators and non-academic partners. These analyses relate to the whole Framework Programmes and might mask important features of coordination in parts of programmes. Concentration of participation or coordination in research for particular impact communities could have far-reaching consequences not evident from programme-level analyses. To examine patterns at a level relevant to impact communities, projects with the following impact areas were examined: breeding of major crops, fish farming, and food manufacturing. The results are shown in Figure 23, Figure 24, Figure 25, Figure 26, Figure 27, and Figure 28. These areas were chosen because of their overall significance and because they were examined in terms of user perceptions.

For projects with a total EU contribution of 101 million Euros impacting on fish farmers, over 80% were coordinated by the top 10 country/organisation type combinations with research organisations in France, Norway and Spain accounting for nearly two thirds of coordination. The data also indicate an increased concentration of coordination in relatively few types of organisations from FP5 to H2020 (Figure 23). Academic organisations completely dominated coordination in FP7 and H2020.

A similar pattern is observed for research supporting the breeding of major crops where a total of 195 million Euros was invested by the EU. Non-academic organisations were not involved in coordinating any of these projects in FP6, FP7 and H2020. Nearly a quarter of the portfolio was coordinated by organisations in and associated with Wageningen University. A further fifth was coordinated by INRA. A wide range of UK academic organisations accounted for a further quarter.

Spanish and German research organisations are relatively prominent in the remaining third of the portfolio.

Food manufacturing is a very large industry with profitable companies who run large private R&D programmes. It is therefore not surprising that some of the research supporting food manufacturing is coordinated by private-for-profit organisations in all FPs except FP6. Nevertheless, academic organisations also dominated this applied research activity aimed mostly at improving manufacturing processes in the private sector. Dutch research organisations were again prominent along with German and Spanish research organisations. Spanish and Dutch private-for-profit organisations ranked in the top 10 country/organisation type groups.

The evidence presented above points towards remarkable stability across FP6, FP7 and H2020 programmes in terms of the types and locations (member states) of coordinating organisation. However, there is evidence from comparing Figure 20 and Figure 21 that there was some disruption of this pattern in H2020. However, we can see from comparing Figure 20 and Figure 22 that the difference between FP7 and H2020 is due to the effect of the BBI-JU and SME projects. For all other tapes of projects, the pattern of project coordination is very similar for both programme.

5. PERCEPTIONS OF USER COMMUNITIES (DELPHI)

The Delphi method is a technique to establish consensus about the topic being investigated through analysis and convergence of opinions from respondents, usually experts commenting within their domain of expertise. It is an iterative process that collects and refines the views of a group and establishes an understanding of their positions. We followed the methodology set out in Annex 1 and reported the results in detail in Annex 2. A summary of results is provided here. We start with external experts' reports of using project outputs. This is followed by consideration of the reports from those who did not use research results. The barriers to use are discussed and matters relevant to programme design and strategy are discussed. Finally we summarise respondents recommendations for future programmes.

5.1. Methodological challenges

A most striking feature of our use of the Delphi method to survey users' views is the low response rate. Only 16 of the 73 identified experts responded to the Round 1 request, and 13 responded in Round 2. This is especially striking because we focused on key individuals in organisations whose core business is the expert representation of the relevant user communities. These are organisations representing farmers and pre-farm supply businesses such as breeders, and organizations representing the post-farm various sectors and relevant industry generally. To our knowledge this low rate of response cannot be due to survey fatigue. The original design of the Delphi survey was structured around 6 thematic panels: dairy farming, cereal and grain legume crop breeding, selection/breeding in aquaculture, lignocellulose processing, bio-based materials and polymers, and food industry with respect to food safety. However, responses for each panel were not sufficient to support separate assessments. Thus, we opted for a non-thematic second round including all the experts who responded to the first round into one cross-area panel.

Despite this, we conclude from analysing responses that the Delphi method has great potential as a tool for examining the impact of the programmes and identifying barriers to impact, especially when targeted at impact communities to examine specific impact communities and areas.

5.2. Use of research results

Respondents indicated that some project outputs are already being used by users interviewed. These responses indicate that Framework Programme projects have contributed to the development of new breeding schemes for dairy cows, new management and monitoring tools to improve sustainable dairy production, more informed use of genomic selection, new models to support on-farm decision at different levels: animal fertility, herd management and socio economic impact, more efficient selection programmes in terms of genetic disease resistance, deliver new microbial strains for the production and improved technological processes, deliver new products from the first production of microfibrillated cellulose. Some features of these reports of use include: the existence of an innovation framework to incorporate results into practice, for example the incorporation of results

of dairy genetics research into on-going dairy cattle breeding programmes; close connections between researchers and industry; and projects that support industry actors directly – e.g. the SME instrument.

5.3. Non-use of project outputs

In general, respondents acknowledged the scientific achievements of the Framework Programmes but consistently drew attention to weaknesses in using results in generating impact. In the case of the people surveyed here, this starts with their own non-use of programme results and outputs. Respondents who did not make significant use of Framework Programme projects' outputs and results argue that projects are not focused on their needs. As a result, the outputs require further development which users cannot undertake with their own resources alone. Respondents reported failed attempts to use project outputs due to results remaining within academic organisations. The weak connection between research and industry is consistently referred to with academic researchers being perceived as not connected to real problems. The further development needed incorporating technologies into users' activities requires tangible and intangible resources. Even when investments to use research results are not so large, there is another cost identified by respondents which prevents generating impact from research results: the cost of searching for the specific outputs. Apart from access issues, respondents recognise a difficulty in mapping results to specific projects derived from the lack of a clear attribution of programme activities to results, outputs and outcomes perceived by users. Therefore, respondents acknowledge that they may be secondary and tertiary users of results without being fully aware of the connection with the original research.

5.4. Barriers

According to respondents the main weaknesses of the Framework Programmes in terms of impact generation lie in the programme structure and strategy, particularly in the type of project funded, project size, in the type of institutions funded, and in the programme content. They draw attention particularly to the lack of mechanisms for supporting the transfer of scientific outputs into marketable products and services and to the lack of alignment of project activities with the needs and roles of regulatory authorities.

With reference to the type of project funded, respondents share the opinion that projects are too speculative (with low technology readiness levels) and are not supposed to produce mature and usable technologies. The projects focus on scientific observation and formulation of technology concepts without validation and/or demonstration in industrially relevant environments. Projects are conducted to generate scientific insights rather that innovative products. Consequently, respondents do not expected that they will lower production and market risks.

Also the scale of projects is questioned: large projects and requirement for multidisciplinary and multi-sectoral collaborations across a broad area of activity are considered to be expensive in administrative, coordination, personnel and managerial terms and they are not considered to give

good value for money. Users recommend funding smaller more focused outstanding projects with more defined impacts. Awarding smaller grants will make the funding pie go further in terms of impact. They also criticise programme management and organization considering the costs of proposal preparation prohibitive high considering the low success rate. The probability of getting a grant is too low, it takes significant time and resources to coordinate with partners and prepare a proposal and much effort which could be put into research activities is being wasted. These resources are finally no longer available for the "real" research work and, in particular, for the effective dissemination of the results to the end user. Therefore, the external experts consulted in this Delphi survey consistently ask for a better balance between small, medium and large projects.

Another concern is about the type of institutions funded. Users recognise that funding is very concentrated in terms of participants and that large universities and research organisations and bigger companies are advantaged. These institutions are regarded as having no ambition in relation to impact and innovation. They are not market-oriented and not interested in producing impacts but just in obtaining funding to finance their research activities. The greater employment prospects of academics appear to be the main outcome of funded projects. Users perceive a cultural problem at the heart of academic organisations that are leading the great majority of projects. At a career development level, publications and academic prestige are more rewarded than applied research and business development.

Users identify also two factors as potentially impeding full effectiveness of Framework Programmes in terms of impact production. The first relates to market uptake and commercialisations. The second relates to the lack of capacity of Framework Programme projects to address regulation issues. With reference to market uptake and commercialisation one of the main problems in delivering close-to market outputs and innovation in products, services and processes (proof-of-concept, demonstration activities, innovations on the market and on the production) is recognised in the transfer of scientific outputs into marketable products and services. According to the user, more could be done to alleviate barriers preventing scientific research from reaching users, for example, through effective mentoring and coaching schemes for transferring results from research institutions to users.

Experts call for the involvement of public policy and regulatory authorities which are according to them are not well represented in Framework Programmes projects. The triple helix model which involves industry, government and universities in the development of research and innovation seems to be the framework they expect will increase societal impacts. Respondents recognise that most of the achieved results can only produce impact with a change or adaptation in regulation.

5.5. Recommendations of respondents

Respondents share the opinion that in order to increase the impact of Framework Programmes, more involvement of immediate users of project results in R&D projects is needed. Project need to include more closer-to-market activities and end-users and demand-side approaches. They call for a user innovation model in which users are involved from the beginning of the projects and take the

lead in developing new solutions that match their industry needs starting from consumer, market or production problems. According to them, this model is able to minimise dissemination costs and shorten the time until application and impact.

Respondents highlight the need for mapping and attributing definite outputs to specific Framework Programme projects in order to clarify the particular contribution of an intervention. They also stress the need for a long-term access to results which in addition to supporting users helps prevent duplication of research at European, national and regional levels. These mechanisms could synthesise results of past and current research projects, identify users of these results and ensuring the transfer of these results to those that can use them. Project websites, even if maintained, are not sufficient. Results should be presented in a way tailored to users. Moreover, the use of research results should be monitored and measured.

According to experts, more balance must be found between levels of TRL set as eligibility criteria. Moreover, a future Framework Programme should pay more attention to integrating regulators as key actors.

From a thematic point of view, respondents identify three main challenges requiring urgent action in future programmes. The first one emerges from responses from selection/breeding in aquaculture experts and consists in the need for a strategic targeting of a limited number of species (maximum 10 species). The second one concerns greater investment in genomic research. The third one is about multi-product biorefineries to support product diversification in bio refineries to address current underutilization and mitigate market variations. Biorefineries should learn from the oil refinery industry which produce a palette of products and utilize its feedstock completely for products. Future Framework Programmes should encourage the diversification of biorefinery products to include some high volume bulk products (fuels, energy, power, platform chemicals, commodity plastics) in combination with low volume high value products (specialties, performance chemicals, etc.).

6. COORDINATORS' VIEWS AND REPORTS

EU funded projects are designed and executed by project participants to address the challenges set out in specific call topics and to contribute to the overall objectives of work programmes. These programme and call topic objectives are defined by painstaking processes involving policy makers, administrators, stakeholders, entrepreneurs and wider society. The research actors respond to individual call topics proposing projects to generate outputs and results that become tools in the hands of direct users, who subsequently generate impact.

A survey of coordinators of SC2-aligned projects was undertaken to collect information about the outputs and the results of their projects as well as about the elements of cooperation and open innovation. In addition, the survey collected their views on who the direct users of these output can be, the contribution to impacts, and the significance of EU funding in support of their research. The survey used an electronic questionnaire that was distributed to the coordinators of 1,728 projects SC2-aligned projects funded in FP5, FP6, FP7 and H2020 (Annex 1). The coordinators reported achievement of outputs and their personal views. The survey did not lead to any direct measurements and for this reason this study is based on results, outputs and impacts reported by their coordinators.

A previous survey addressing coordinators and industrial partners of projects funded in FP5, FP6 and FP7 was run for first time in 2010 in the context of the impact assessment of EU Framework programmes (2000-2010) and prospects for research and innovation in Food, Agriculture, Fisheries and Biotechnologies.[28] One aim of the current survey was to repeat the 2010 investigation and so it used a similar design. The questionnaire used in the previous survey was amended to provide information that would allow identification of the groups of users who benefitted from the projects and to estimate how outputs and results of projects are linked to impacts generated. Specifically, the survey addressed the contribution to open innovation, regional and local economies, job creation and policy along with the contribution to Sustainable Development Goals (SDG), competitive EU economies and strong communities, mitigating and adapting to climate change, safeguarding resources, ecosystems and biodiversity, and safe and high quality food for all citizens. Overall, the information and views collected provided insight into a) coordinators' perceptions of the contribution of their project to different types of impacts, and b) structural and operational characteristics of the EU-funded research.

6.1. Overview of the survey

Overall, 342 (19.8%) of the 1,728 coordinators responded to the survey. The response rate for projects funded in FP5 and FP6 was lower than the average, resulting in inadequate representation

[28] Horvat, M., Ricci, A., Casal, M., Griniece, E., Pianta, M. Tjell, J.C. (2011). Impacts of EU Framework Programmes (2000-2010) and prospects for research and innovation in food, agriculture, fisheries and biotechnologies. Final Report, European Commission Brussels.

of these two Framework Programmes and imposing significant limitations in the analysis of data with respect to Framework Programmes. Despite the fact that FP7 and H2020 are both well represented, the information provided differed in perspective. Responses from FP7 coordinators mostly related to completed projects whereas responses from H2020 coordinators concerned projects under progress thereby reporting *foreseen* outputs, results and impacts.

The complete data set was analysed to compare differences between different types of coordinating organizations and categories of funded activities. Three main categories of funded activities were identified: a) research and technological development, b) support to R&D activities, and c) close to market research/innovation. Each funding instrument used in the four Framework Programmes under study was assigned by the EC to one of these three categories. Research and technological development, and support to R&D activities were represented in all FPs while close-to-market research/innovation was represented only in responses from H2020 funded projects despite the fact that a great number of such projects were also funded in FP5 (Table 3). 51% of the responses from H2020 were from coordinators of close-to-market research/innovation projects and another 33% were research and technology development projects. In FP7, research and technology development projects constituted 84% of the responses. Overall, the research and technological development projects were the best represented in the dataset with 20% of the population responded to the survey. In contrast, the representation of the other two categories was much lower with approximately 9% of the population responded to the survey (Table 3). This skewed representation placed a limitation on the use of the survey that was carefully considered in the interpretation to the results. The complete list of funding instruments per category of funded activity is provided in Annex 1.

Higher education institutions and public or semi-public research organizations constituted 65% of the coordinating organisations that responded to the survey. Another 26% were private companies of any size. Three types of private companies were distinguished in the survey: young innovative companies (YICs) with less than 250 employees, younger than six (6) years and with R&D spending over 15% of operating expenses; small- and medium-sized enterprises (SMEs; less than 250 employees); and large enterprises (LE; more than 250 employees). SMEs represented 15% of the responses. Interestingly, in H2020 only 35% of the responses derived from traditional research actors, i.e. higher education and public/semi-public research organizations, whereas there was a strong presence of LEs and YICs in comparison to previous FP.

Applied research (47%) was the main type of reported activity carried out by the responding organizations, followed by basic research (24%) and development (26%). A shift to development was traced in H2020 with a reduction in mainly basic research (Table 4). Given that half of the responses in H2020 came from close to market research/innovation projects coordinated by private companies which coordinated only about one third of projects (Figure 8) this shift can be the result of the skewed representation in H2020 and cannot be further assessed.

The subjective nature of the survey data and the skewed representation of the different FPs and project categories in the cohort limit the power of this survey in assessing the impact of EU-funded

research. The extent to which the data collected were informative is further discussed along with suggestions for future improvements.

6.2. The users of EU-funded research

The coordinators reported the scientific community as the one most benefited by the EU funded projects followed by the industrial actors and the policy makers (Figure 29). Projects coordinated by higher education institutions, public or semi-public research organizations and large enterprises appeared to generate impacts for the benefit of the scientific community, whereas projects coordinated by YICs and SMEs benefitted mostly the industry. However, the benefits for the scientific community and the students decreased in H2020 and increased for the farmers. Equally, according to coordinators there was a decrease in the benefits for policy makers and a small decrease for the industry in H2020.

6.3. Contribution to societal impacts

The questionnaire contained a pre-defined list of *expected* impacts that was compiled by the Expert Group. The Expert Group identified the *expected* impacts using as guidance the impacts listed in the SC2 logic of intervention[29] and the priorities of the SC2 work programmes[30] (Annex 1). The list of expected impacts was wide and dispersive in order to be self-explanatory in the questionnaire. The individual impacts were subsequently mapped on four major SC2 impacts (Annex 1) by the thematic experts:

- Securing safe and high quality food for all.
- Mitigating and/or adapting to climate change.
- Safeguarding resources, ecosystems and biodiversity.
- Competitive European economy and strong communities.

Almost one third of the coordinators reported no contribution to SC2 major impacts. A further 10% reported only one major impact. Interestingly, 14% of the projects are reported by their coordinators to have contributed to all four categories, and another 28% to three different categories.

Overall, 26% of the coordinators reported contributing to securing safe and high quality food for all, whereas more than 60% of the projects reported contribution to safeguarding resources, ecosystems and biodiversity, and to competitive European economy and strong communities (Figure 30).

Only 6% of the project coordinators reported impacts contributing solely to a competitive European economy and strong communities, whereas half of them reported combined contribution to safeguarding resources, ecosystems and biodiversity, and to competitive European economy and

[29] European Commission (2017). Commission Staff Working Document. Interim Evaluation of Horizon 2020. Annex 2.
[30] European Commission (2013). Horizon 2020 Work Programme 2014-2015; 9. Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy

strong communities. Another 35% of coordinators reported a combination of impacts to competitive European economy/strong communities and mitigation/adaptation to climate change. Equally, 36% of the projects are reported by their coordinators as generated impacts to safeguarding resources, ecosystems and biodiversity, and to mitigating/adapting to climate change (Figure 31).

This strongly reported link between improvement of the European economy and positive impact on the environment and mitigation of climate change is a strong indication that the coordinators and the research consortia consider economic growth and environmental responsibility are not exclusive of each other.

The four major SC2 impacts also took into consideration and reflected upon the four R&I priorities identified by FOOD 2030[31] are:

- nutrition for sustainable and healthy diets;
- climate smart and environmentally sustainable food systems;
- circularity and resource efficiency for food systems; and
- innovation and empowerment of communities.

Given that a thorough mapping of the EU-funded research will be pivotal in the R&I strategic planning of FOOD 2030, the survey offers important input to the logic of intervention of FOOD 2030 and contributes to creating a framework for the assessment of the impacts expected.

6.4. Contribution to 2030 Agenda for Sustainable Development

The expected impacts of SC2 are not limited to the European borders and their international dimension was assessed through the prism of the Sustainable Development Goals (SDGs)[32] as set by the United Nations (Annex 1). In order to do that, the individual impacts listed in the questionnaire were mapped on the SDGs by the thematic experts and using the *Commission staff working document SWD(2016) 390 final: Key European action supporting the 2030 Agenda and the Sustainable Development Goals*[33] as guidance (Table 5). The 2030 Agenda for Sustainable Development consists of 17 SDGs and the European Union has undertaken a series of initiatives, domestically and externally, in support of the SDGs. According to this mapping, the EU-funded research aligned to SC2 was reported by the coordinators as having contributed to 11 of the 17 SGDs:

[31] European Commission (2016). European research and innovation for food & nutrition security. Food 2030 High-level conference background document.
http://ec.europa.eu/research/bioeconomy/pdf/food2030_conference_background.pdf
[32] http://www.un.org/sustainabledevelopment/sustainable-development-goals/
[33] Commission staff working document SWD(2016) 390 final: Key European action supporting the 2030 Agenda and the Sustainable Development Goals

SDG1: End poverty in all its forms everywhere.
SDG2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
SDG3: Ensure healthy lives and promote well-being for all at all ages.
SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
SDG9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
SDG10: Reduced inequalities.
SDG11: Sustainable cities and communities.
SDG12: Ensure sustainable consumption and production patterns.
SDG13: Take urgent action to combat climate change and its impacts.
SDG14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
SDG15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Based on the replies of coordinators, we can say that by contributing to the competitiveness of EU economies and to stronger communities, funded projects also contributed to SDG 8 (Decent work and economic growth), SDG 9 (Industry, innovation and infrastructure) SDG1 (End poverty), SDG10 (Reduce inequalities) and SDG11 (Sustainable cities and communities). By addressing the issue of climate change, funded projects also contributed to SDGs 13 (Climate action). By contributing to safeguarding of resources, biodiversity and ecosystems, funded projects contributed to SDG 12 (responsible production and consumption) and SDG 14 (Life below water) and SDG 15 (Life on land). By contributing to food security and safety, funded projects contributed to SDGs 2 (Zero hunger), SDG 3 (good health and well- being) and SDG 12 (responsible production and consumption).

The majority of the coordinators reported contributing to more than one SDG (
Figure **32**). Ensuring sustainable consumption and production patterns (SDG12), promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG8), and building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (SDG9) were the top three SDGs the coordinators reported contribution to (Figure 32).

Sustainability and action against climate change had a strong presence in the reported impacts and in a higher number of projects food production and improved sourcing went hand-by-hand with sustainability and environmental responsibility issues.

An increased contribution to SDG1, SDG3, SDG13 and SDG14 was reported in H2020 compared with FP7. On the contrary, FP7 projects reported a higher contribution to SDG8, SDG9 and SDG15 than those of H2020 (Figure 33).

Contribution to specific SDGs (SDG1, SDG3, SDG8, SDG9, SDG10, SDG13 and SDG14) was more frequently reported by coordinators that were private entities (Figure 34).

Impacts on policy

41% of the coordinators reported a high to very high contribution to evidence-based policy and 86% of the coordinators reported that their project benefited policy-makers to at least some extent. One third and one fifth of the projects reported input to national/ regional policies and international agreements/ conventions, respectively.

Direct dissemination of results to policy makers (via workshops, etc.) was the most common tool employed by projects to generate impact on policy, followed by intervention on policy development (strategy papers, expert groups, etc.) and publication of policy recommendations. One fifth of the coordinators reported publication of policy recommendations, whereas only 37 coordinators reported that a reference of their project appears in some legislative document (Figure 35).

The responses revealed that the coordinators had a wide perspective of the potential impacts of their projects on different dimensions of policy and they could capture the attribution of their project to these impacts. High emphasis on policy development was traced in the majority of the reports, with 80% of the 'support to R&D activities' projects reporting a high and very high contribution to policy, followed by 48% of the 'research and technology development' projects.

Impacts on economic growth

Almost half of the coordinators reported contributing to the creation of new economic markets or value chains. This is in good agreement with the high number of coordinators reporting contribution to competitive European economy and strong communities (Figure 30).

An interesting observation is that half of the large enterprises coordinating projects did not report contributing to the creation of new economic markets or value chains, whereas the most positive responses came from SME coordinators. SMEs as coordinators reported the creation of non-EU markets as well as the creation or reshaping of EU markets most frequently. Projects led by YICs were reported as particularly active in creating new value chains (Figure 36). These are compelling indications of the differences between different types of coordinating organisation with regard to impact-relevant priorities. A possible explanation is that large enterprises are oriented to strengthening their position in global established markets whereas SMEs and YICs use innovation to create a new market niche and ease competition. However, the smaller representation of large enterprises in our sample compared with SMEs means these indications must be treated with caution.

A high number of coordinators (62%) reported an impact on regional economies through different attributes explored by the questionnaire. Farmers of all kinds were identified as users benefitted in 44% of the coordinators' reports (Figure 37). An equal number of coordinators reported contributing to growth of existing sectors in the local economy and valorisation of local products, whereas one third of the coordinators reported contributing to the diversification of the local

economy. In addition, one third of the coordinators reported high and very high input into national and regional policies that can be an important factor for the development of regional economies.

One third of the coordinators reported significant economic impact in coastal, rural and less-developed areas. Rural areas received more attention compared with coastal and other less-developed areas, regardless the type of organization coordinating the projects.

Job creation regionally was an impact reported by 44% of the coordinators. Projects coordinated by private companies reported higher contribution to local job creation that those coordinated by public entities. YICs (73%) and SMEs (62%) as coordinators reported the most frequently impact on local job creation and half of their projects contributed also to the growth of existing sectors in the local economy.

Job creation

The coordinators were asked to estimate the number of direct and indirect jobs created by the project. The results are reported in Table 6. 64% of the coordinators did not provide estimates. Another 13% reported that their project did not create any jobs. As a result, only 113 coordinators across all FP reported job creation and provide estimates. Projects coordinated by YICs reported the highest contribution to job creation (73%) followed by those coordinated by SMEs (62%).

Half of the projects coordinated by higher education institutions and public or semi-public research organizations reported the creation of temporary scientific jobs, occupied almost exclusively by young people. Permanent scientific jobs were created through projects led by large enterprises. Half of the projects coordinated by YICs reported the creation of temporary and permanent technical jobs, yet only half of them were occupied by young people. The same was observed for projects led by SMEs that were successful in creating permanent scientific and technical jobs, yet none of those were occupied by young people.

According to responses, temporary administrative positions were mostly created through projects led by higher education institutions whereas projects led by YICs and large enterprises were more successful in creating permanent administrative positions.

Coordinators reported only rarely the creation of more than 15 positions, either temporary or permanent. A high number of temporary positions of all kinds were reported in a few projects led by either higher education institutions or large enterprises. Job creation is undoubtedly a much desired impact to rate within the EC priorities for 2015-2019[34] and it is important to observe consistent job creation through the EU-funded research in order to assess that impact. The response rate to the survey has made clear that such reporting should be mandatory for the coordinators and become a contractual obligation that it is fulfilled through the means provided by the continuous reporting of each project. It is only then that reliable numbers can be collected for the all projects allowing an in-depth analysis of the impact of EU-funded research on job creation.

[34] https://ec.europa.eu/commission/priorities_en

6.5. The project outputs and results

Besides reporting their views on the impacts of the projects, the coordinators provided their opinion on how project achievements, the outputs and the results of the projects, have contributed to generation of impacts. Outputs represent the immediate products of the projects, such as publications, prototypes, or new data, that are usually achieved during the implementation phase of the project. Results refer to medium-term achievements that are based on the project outputs, such as evidence-based policy making or the creation of a new company to exploit the project outputs. Outputs and results contribute to impacts that represent higher level effects with broad reflection on the society, the environment, the economy and the structures. Links between project characteristics and their outputs, results and impacts were investigated.

Project outputs

Coordinators were asked to evaluate the importance of various project outputs in generating impacts. New data, articles in peer reviewed journals, wider dissemination and outreach publications and new decision support tools and policy recommendations were considered the most important outputs across FP (Figure 38). New concepts and theories, testing methods, innovative processes, products and services were reported by 38-48% of the coordinators.

There were differences between types of coordinating organisation in terms of reported outputs. Coordinators in higher education institutions reported mostly production of articles in peer reviewed journals, books, guidelines and training manuals, new decision support tools and policy recommendations, and wider dissemination and outreach publications, whereas coordination by private companies reported more often innovative processes, new products and services, prototypes and patent applications as important outputs. Private companies with less than 250 employees were dynamic in filing patent applications, whereas large enterprises promoted new concepts and theories and new testing methods (Table 7).

This difference is also traced between research and technological development projects and close to market research/innovation projects (Table 8). Coordinators of research and technological development projects tended to report a high variety of outputs, ranging from new data, articles in high impact journals and new concepts and theories, to wider dissemination and outreach publications and new decision support tools/policy recommendations (more than half of respondents reported these outputs as being highly important). The variety of the reported outputs reflects the complex nature of these projects, i.e. large multi-disciplinary projects with a blend of basic and applied research and technological development that are more often coordinated by higher education institution or public/semi-public research organizations.

Coordinators of close to market projects report slightly more market oriented outputs: new products/services and innovative processes, prototypes, new data, new concepts and new theories were reported as highly important by over half of the respondents (Table 8).

Patents granted are the most frequently reported in close-to-market projects: around one fifth of the projects do so. The relatively small proportion reporting granted patents may have several

explanations. First, around one third of these projects are Phase I SME projects and around one third of surveyed close-to-market projects were unfinished at the time of the survey. Projects tend to apply for patents towards the end of the project life, and the granting of patents generally after the project is completed. Second, some firms may opt for 'tacit' cooperation/links instead of formal management and protection of IP, as has been reported in previous studies. In addition, the coordinators filling in the survey are not necessarily aware of the patents filed or granted by other partners. Responses on patents should therefore be viewed as the lower bound estimate of the patent outputs in EC funded projects. More accurate estimates can be obtained in future programmes if reporting of patents resulting from the project is made a contractual obligation for beneficiaries.

Support to research and development projects report a smaller range of outputs: new decision support tools/policy recommendations and wider dissemination and outreach publications were reported as highly important by at least half of the respondents (Table 8). This is consistent with the smaller scope of such projects aimed at reinforcing research networks and R&D capabilities at the national level.

Project results

Improved resource efficiency and evidence-based policy were the results that were considered as very important for the generation of impacts. One fifth of the coordinators also reported importance of the establishment of more resilient agricultural and forestry practices that help maintain ecosystems and to safeguarding the natural resources on which agricultural production depends (Figure 39). Evidence-based policy making was more frequently reported by coordinators that were higher education institutions and or public/semi-public research organizations (Table 9).

A collective 15.6% of the respondents reported the creation of new private companies that were mostly young innovative companies. Interestingly, public or semi-public research organizations as coordinators reported the highest rates of creation of YICs. YICs as coordinators reported high importance of the development of new added value products of terrestrial and aquatic origin, reduced of food waste and reduced fossil fuel imports.

Close-to-market research/innovation projects reported most frequently the high and very high importance of firm creation in generating impacts. Given that all of these are projects funded in H2020 and most of them are still on-going, it will be interesting to monitor the creation of firms after the lifetime of the project to verify the capacity of the project outputs to create new firms.

Perhaps surprisingly, ‘support to research and development’ projects report more result categories as highly important compared with ‘research and technological development’ projects. One possible explanation for this is that the coordinators of ‘support to research and development’ projects reported not only on the direct results of their actions, but also on indirect results, i.e. the results of subsequent research made possible by their work. It is plausible to assume that indirect results are less accurately reported than direct project results. Reported results of ‘support to research and development’ actions are therefore not necessarily comparable to reported results of ‘research and technological development’ projects.

Open science and innovation
One out of three coordinators reported creation of a multi-disciplinary ecosystem and 13% of the projects used open innovation platforms. Free sharing of research outputs was limited to 24 % and half of these projects were coordinated either by higher education institutions or public/semi-public research organizations. Projects coordinated by large enterprises tended not to promote the free sharing and use of open innovation platforms (Figure 40).

Projects coordinated by large enterprises were the most active in establishing collaborations with higher education institutions and public/semi-public research organizations outside the consortium, located within the EU. In addition, one out of three large enterprises as coordinators reported establishing collaborations with YIC and other large enterprises within the EU (Table 10). YICs as coordinators reported a high number of collaborations outside the consortium with all types of entities within the EU, whereas in some cases the reported even collaborations with higher education institutions and public/semi-public research organizations outside the EU.

SME as coordinators reported the most frequently collaboration with other entities outside the EU. Half of the higher education institutions as coordinators reported collaborations with other higher research institutions and public or semi-public research organizations, whereas public or semi-public research organizations appeared less active in establishing collaborations outside the consortium than the higher education institutions.

Overall, 88.5% of the projects reported that the FP have facilitated the expansion of their long-term network of partners beyond the consortium and in half of the cases these were EU-15 partners, whereas EU-13 partners and partners from outside EU constituted 25%, respectively (Figure 41). Projects led by large enterprises reported the lowest rates of expansion of their partner network.

A great deal of projects reported to enhancing their network with other Framework Programme projects (52.4%) and launching new EU projects (43.6%). One in five projects carried out research in European technology platforms. The frequency of these activities was the highest in FP7 and declined at the FP6 levels in H2020. Projects led by SEM and public/semi-public research organizations reported to smallest use of European technology platforms.

6.6. Recommendations and suggestions from coordinators

The survey concluded with suggestions for improvement by the coordinators. The major suggestions that appeared the most frequently in the responses were the following:

Increase the budget and investment in research. Many coordinators pointed out that research funding is a very positive investment the EU. However, securing research funding is an extremely competitive process that ultimately excludes many good ideas from funding. An increased budget could release the existing potential for research and innovation and allow the participation of a higher number of entities. Decreasing the required effort for a successful proposal and keeping the bureaucracy to a minimum would also make the process of proposal application and project implementation more attractive.

Differentiate the character and size of projects. Respondents often call for increased flexibility during proposal application and project implementation phases. Their views reflect the need to achieve a balance between focus and flexibility and allow for a responsive creative space in the proposals and projects to take up and exploit ideas and outputs as soon as they appear.

The size of the projects received much consideration by the coordinators. They were critical of the big collaborative projects due to the burden of the demanding administration and management. Very frequently, they suggested the compilation of smaller consortia that require a smaller management investment and more bottom-up projects is preferred. FP5 was the FP that they appeared to prefer in this matter.

There were concerns expressed that most research projects are dominated by well known (and often very big) research groups. This is in close agreement with the trends revealed by the portfolio analysis (Section 2). The coordinators recommend actions towards improving networking experiences and reducing bureaucracy to make it easier for SMEs, NGOs and local/regional authorities to participate.

The current funding scheme for SME received much recognition and appreciation. It was stated that starting with a Phase 1 feasibility study prior to a full Phase 2 project is smart and improves the use of Phase 2 funds. The SME instrument has benefits that go beyond the funded activity per se. It provides business platforms with high level of support in terms of coaching, networking, and support for activities that are attractive to in terms of 'investor readiness'. These coordinators' views echoed the conclusions of the impact report of the SME instrument "Accelerating Innovation in Europe" [35] and reinforce the positive aspects of a small-sized, focused projects with clear market expectations for innovation.

Communication and uptake of the outputs of the projects. Communicating the outcome of successful projects is regarded as an area that requires improvement. This appeared to be the most frequent suggestion in the responses received regardless the type of the project and its outputs. The suggestions for improved communication span from the EC to stakeholders to innovators and to citizens.

The coordinators pointed out that currently focus remains more on disseminating the results at events with the hope that it will lead to impact at a European level whereas the focus should be more at the commercialization stage. The respondents highlighted the lack of mechanisms in place for knowledge uptake and connection of knowledge production with innovation in general. The recommendations include the inclusion of a qualified communication manager or a communication partner in the consortium that translates the research outputs into user-friendly messages to civil society and exploit projects' results by involving final users; a coordinated facilitation of the communication plan of the different projects funded through for example workshops and events,

[35] "Accelerating Innovation in Europe" H2020 SME instrument impact report (2017)

especially to stakeholders and policy makers; a new funding tool that will support successful projects to take selected outputs to advanced TRLs and to the market.

The recommendations indicated a shift in the way the coordinators view the function of the EC-funded research in an innovation demanding market environment. This was particularly the case of the SME acting as coordinators. They responded enthusiastically to the questionnaire in line with their reported interest in sharing insights, building bridges with other research actors, networking to increase their efficiency. To that direction, there were also suggested routes for a project: organization of innovation/ commercialisation workshops for all funded projects at advanced stages of implementation and tailored financial support for successful outputs that have reached TRL7 or TRL8 and can be scaled up to TRL9.

Policy and socioeconomic impacts were also of relevance and the coordinators commented frequently on the need for more integrated action between the different DGs and with the European Research Agency as joint forces to capture the capacity of projects to influence policies. For environmental impacts, it was also recommended that the EC organises workshops between the projects for policy makers.

Overall, the recommendations show that when it comes to communication, knowledge uptake and exploitation to innovate, there is a need for a more systematic and holistic approach that ensures all key actors are in place and interact effectively to achieve the much desired impacts. There is a recognition that actors with novel capacities and functions are required to achieve the expected impact.

7. CONCLUSIONS

Here we conclude by outlining new approaches for assessing the impact of RD&I programmes; observations relevant to the assessment of the impact of H2020 with respect to SC2; and providing messages relevant the planning of future programmes.

At the outset in February 2017, the European Commission asked us as members of the Interim Evaluation Expert Group for an innovative wide-ranging investigation to complement the then just completed Interim Evaluation. Against this background, the overall goal of the work reported here was to develop new approaches to programme assessment and support the development of research and innovation strategy in Societal Challenge 2, particularly post H2020. We combined a number of straight-forward content-oriented approaches to evaluation: the surveying of project coordinators' views; portfolio impact mapping, i.e., the analysis of the content of the portfolio in terms of the direct users of project results, the user activities impacted on, and the project activity; and the analysis of the views of representatives of those expected to use project results. In essence, this complements the statistical, top-down and indirect indicator-based approach used by traditional programme evaluation with a content-rich and expert-based enquiry into project content and project links with change in society through the user communities and their activities, especially innovation.

We developed a uniform and impact/content oriented analytical approach (portfolio impact mapping) and applied it to all SC2-aligned projects funded over four Framework Programmes (FP5 to H2020). The whole portfolio consisted of 2,305 projects funded until 31 December 2016, and represented 4,323 million Euros invested by the European Union. To our knowledge, this is the first portfolio assessment that in addition to examining H2020, also systematically considers FP5, FP6 and FP7 activities aligned to SC2 within a common user and use orientated mapping framework. No pre-defined categories or framework were used and the categorization of projects for impact mapping was the work of thematic experts using expert judgement. The process therefore described what they observed rather than fit a pre-existing framework to the programmes. A main outcome of this was the development of a highly curated database compiling the information of all SC2-aligned projects. This portfolio impact mapping was complemented with two other approaches. Delphi surveying was employed to explore the views of research users that are active in selected communities of innovators targeted by SC2-aligned research across the four FPs. In addition, a parallel survey of coordinators similar to one conducted for FP5-FP7 in 2010 was conducted to investigate the views of the researchers who generate knowledge that is expected to subsequently support impact.

7.1. Approaches to programme impact assessment

Programme evaluation frequently concentrates on assessment of programme implementation through analysis of types of programme investments (inputs), and on linking changes in the economy or society (i.e., programme impact) to programme investments using for example intervention logics. Comparison with a counterfactual supports such evaluation. Based on previous

work[36] [37], especially the Interim Evaluation of SC2 in H2020, the starting point of this work was our awareness of the great difficulty in assessing programme impact. The links between EU investment in SC2 and societal outcomes are extremely complex, indirect, and subject to numerous factors other than those impacted on by EU Framework Programmes. The major objective of this study was to develop new approaches.

Surveying project coordinators

The response rate in our survey of coordinators was not adequate to yield a powerful data set, especially for the two programmes that ended long enough ago to have fully realised impacts (FP5 and FP6). However, the limited data gathered shows that coordinators' insights can contribute to programme evaluation. We conclude that ex-post surveying that relies on the voluntary participation of coordinators is not effective. A much denser set of data is required. Coordinators insights are valuable but these need to be gathered systematically through contractual obligations on coordinating organisations to supply impact information during the project implementation and after a suitable period has elapsed to allow project outputs and outcomes to be realised. This will deliver dense coverage and allow a well-founded view of the expected impacts to be generated by impact assessors. With such obligatory data gathered routinely, the evaluation work would therefore concentrate on assessing such existing data rather than surveying coordinators.

Portfolio impact mapping for content-based programme evaluation

Portfolio impact mapping addressed four related questions directly relevant to impact: Who are the direct users of project outputs? What do they use outputs for? What type of organisations participated in and led projects? What is the subject content of projects? The answers reveal in a content-rich way how investment in the programme is connected to its impact via the programme processes, participants and pathways. In short, it views the programmes from the perspective of those upon whom wider impact depends: the users and innovators.

Identifying direct users and users' impacted activities: The portfolio impact mapping effectively provided insights into changes in the portfolio over time. It demonstrated that the information generated can be used to answer questions about portfolio trends relevant to expected impacts. For example, the policy community was identified as the largest group of primary users in terms of the EU contribution over the four FPs with differences in emphasis on public policy issues between programmes. In line with this, the biggest single change throughout the four FPs was the increase in absolute and relative levels of expenditure on projects for which the bio-based industries are the main primary user of results. There was a shift from public routes (policy) to impact to private routes, e.g., the bio-based industries. The private category accounted for about 30% of EU project expenditure in FP5 and FP6. This increased to about 45% in FP7 and H2020.

[36] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

[37] European Commission 2017. Commission Staff Working Document. Interim Evaluation of Horizon 2020.

Closer to specific innovators and other users, we demonstrated that 'impact communities' and corresponding sub-portfolios can be identified by combining information on projects' direct users and their activities. This provides a powerful way for probing the portfolio for impact in terms directly related to how impact is generated by users of specific sets of projects. For the purpose of a limited number of case studies, we selected 6 impact communities and the corresponding projects from the many possible combinations of direct users and impact areas we identified. The identification of these impact communities and 'their' projects can be used for in-depth case studies of the content and coherence of portfolios in a way directly relevant to users and impact areas, including analysis of the specific user communities' views of programme implementation, effectiveness and impact.

An in-depth analysis of the content and output of the projects for these impact communities in these case studies was outside the scope of this study, but we clearly demonstrated how such analysis can be prepared. It provides timelines of project investment in relation to very specific groups of users and specific user activities allowing deep investigation of the coherence of the programme and the linkages to impact and innovation, supported by systematic assessment of users' views. Even though our use of the Delphi method to access users' views was constrained by time and response rate, it proved effective in generating robust and unique evidence about the programme from the users' perspective.

Project content: While the main project content is easy to define for many projects, for others categorisation is subject to the judgement and perspective of the assessor. For example, is a project about networking research providers a communication activity or a research strategy activity? For this reason, this categorisation as we have conducted can only be used as a general guide.

Despite these constraints, assessment of project content yielded useful and sometimes surprising insights. For example, a large proportion of projects could be categorised as about process engineering. Also, the consistent significant investment in projects focused on communication and networking to improve uptake of project results was also highlighted indicating that the perception of deficits in this area are not due to lack of funding.

Participants and coordination: Impact areas and user communities were linked to information on the corresponding project participants and coordinators. This completed the information chain by identifying who is participating and leading projects for different direct users and their impact areas. The quality of data deposited in the relevant EC databases imposed a major challenge in this endeavour. In addition, there are several cases that original input to the database was miscoded and a thorough curation of data was imperative before proceeding with analysis.

From 19,713 participations in 1,898 projects we identified key information on the strengths and weaknesses of pathways to impact embedded in the portfolio. This insight into participation aligned strongly with evidence obtained from corresponding user communities.

Assessment of users' views: Although constrained by time and a relatively low response rate from those surveyed, the Delphi method can generate unique and robust evidence directly related to the

generation of impact. Key constraints reported were the lack of emphasis within project consortia on the needs of users; barriers to non-academic partners getting involved in relevant projects, especially as coordinators, difficulty in accessing results; the high investment still needed to use results in new concepts, products and services. The user communities surveyed also recognised that the projects are broadly relevant to their needs, that some do use some results, and that they may be using programme outputs more than they realise due to the difficulty in tracing current innovation and practice back to underpinning research. The respondents shared the opinion that the type of project funded, in particular the scale of project funded, the type of institutions funded, and the programme content significantly influences the potential for generating impact. There is consensus that more focused smaller projects with more defined impacts, mature TRL would create more opportunities for consortia coordinated by non-academic leaders more focused on market-oriented innovation.

We conclude strongly that the use of Delphi, targeted within case studies using a user/impact portfolio framework as we have developed has great potential for impact assessment. It however requires a clear supporting portfolio framework (like the one we developed), commitment from user experts, insightful analysis of responses, and time.

7.2. Impact

While a comprehensive evaluation of the impact of H2020 was not the goal of this study, the work allows us to report some relevant observations.

Trends in portfolio development, especially the changes in emphasis on different types of direct users, confirm that SC2 is in general more focused on economic impacts compared with previous programmes. Furthermore, evidence from project coordinators indicates strongly that the programme has successfully combined economic, environmental and social objectives within projects, which is the essence of sustainable development. The SC2 impacts support the higher level H2020 impacts and are well-aligned to the United Nations Sustainable Development Goals. We therefore conclude that in terms of the general direction of project activities, H2020 and its predecessors are well-aligned to contemporary societal challenges. This study did not extend to an analysis of the content and performance of projects, but the identification of impact areas and impact communities provides a rational framework for such targeted project content-based impact assessment. The portfolio impact mapping was able to pin-point effects of the expansion of the use of the SME instrument and the establishment of the BBI-JU in terms of participation, coordination, direct users and impact areas.

However, our analysis of the portfolio and the associated case studies of specific groups of research users (‘Impact communities’) revealed a great need to better connect the core research and technology development effort with users, especially innovators, who drive impact. There is evidence from a number of perspectives of a profound disconnect between academic research-based activity and users, especially innovators, across most of the programme. The evidence indicates that for the core R&D activities, this disconnect has actually increased from FP5 to H2020. This is a

substantial challenge that requires a number of approaches that the ideas explored in this study can be used to identify and develop.

Assessments since 2010 concentrated on FP6 and FP7. This study uniquely made an in-depth analysis of FP5 along with analysis of subsequent programmes. The effort in data curation that this involved was paid off with new insights into the long-term effects of changes made nearly two decades ago. The change from FP5 to FP6 caused a substantial increase in the gap between research and innovation as indicated by analysis of participation and especially coordination. This has remained wide since. This study has revealed several sources of evidence that pointing to the conclusion that the decline in the involvement of non-academic organisations and innovators in leading projects between FP5 and FP6 was associated with the shift to large projects. Ironically, the drive to large projects was associated with efforts to improve impact and innovation by integrating research and innovation actors along value chains ('fork-to-farm') within projects. As indicated by levels of non-academic coordination of projects, this reduced the influence of innovators and other users due to the increased complexity of setting up and leading such projects. Linked to this, the profile of coordination over the three FPs for which we have reliable data (FP6 to H2020) reveals remarkable stability in the types and location of coordinating organisations for projects focused on research and technical development, which are the core of the programme. The domination of certain combinations of countries and types of organizations in participation and especially coordination, and the funding differences between countries, remained broadly similar despite the great changes that have occurred in the EU over this period. Of the top 10 country/organisation type combinations, research organisations in France and higher education institutions in the Netherlands are consistently prominent.

SC2-aligned impacts and SDG and FOOD 2030 R&I priorities

The EU supports the Sustainable Development Goals (SDGs) within the EU and outside its borders. The mapping of impacts reported by the coordinators indicated that the FP have played an important role in creating the knowledge and innovation basis required for realizing the SDGs in the European context. In addition, the portfolio analysis and the coordinators' survey have provided strong evidence that SC2-aligned research has paved the way to FOOD 2030 and the resources produced in the context of the present survey can provide granular input in the R&I prioritization of FOOD 2030 and the recently published "Strategic approach to EU agricultural research and innovation".

The portfolio mapping and the coordinators' survey offered strong indications that the SC2-aligned projects have been contributing to several elements of FOOD 2030 across the FPs, and a close correspondence between the SC2 major impacts and FOOD 2030 was traced. The 11 SDGs identified as related to the SC2 impacts offer a valid basis for the global discussion about EC-funded research and can become a chart onto which R&I activities can be mapped ad hoc.

7.3. Pointers for future programme planning

In general, the FPs going back to FP5 are relevant to current priorities. However, portfolio features point towards a deeply in-grained challenge in participation and coordination with respect to engaging and supporting innovators and other users. Previous studies[38] also indicated that programme planning does not have the benefit of a content/impact-oriented programming framework that allows specific scientific or technical targets to be identified early, resourced and pursued coherently in relation to the relevant impact areas and user communities. Related challenges for programme management can be summarised as: anticipating and articulating societal challenges and 'missions' into forward-looking strategic research targets; building effectively on existing programme outputs and resources; reducing barriers to access for a wider range of participants across Europe; and driving a profound change that connects research and technical development with users and innovators by supporting innovation-led R&D.

Although still a prototype that needs validation, the type of portfolio impact mapping framework described here can support programme managers in the very challenging task of articulating societal challenges or missions into cutting edge scientifically and technically coherent targets that relate better to targeted users and their activities.

Connecting sources of knowledge and technology with users and innovators in wider society is a very urgent goal. This has consequences for programme design, the formulation of calls and topics, the selection/design of instruments, and the support of knowledge and technology acquisition. More must be done to encourage leadership by innovators and other users. The disruptive effects of the SME and BBI-JU instruments show that change is possible if instruments that drive change towards innovation-led research (complementing research-led innovation) are used. With the exception of the SME and BBI-JU projects, the resilient dominance of a few member state/organisation-type combinations in participation and especially in coordination is remarkable. The Interim Evaluation report discussed the question of broad topics versus more focused topics[39] and drew attention to the consequences of different approaches to topics for participation. There is evidence from several sources that topic calls for large projects that have broad scopes and a broad range of project impacts favour coordination by large academic organisations. Project opportunities for small to medium-sized research and technical development projects offered to non-academic innovator-led consortia in response to good ideas (bottom-up) could make a big difference. These would support innovation-led collaborative R&D. Such an initiative would give innovators the opportunity to address the broad strategic priorities set out in work programmes with their focused ideas in a flexible way. Opportunities for re-submission of competitive unfunded proposals would reduce the proposal application 'all-or-nothing' risks and barriers that now greatly discourage non-academic leadership of consortia.

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[38] European Commission (2014). An ex-post evaluation of the rationale, implementation and impacts of EU Seventh Framework Programme (2007-2013), Cooperation Theme 2: Food, agriculture and fisheries, and biotechnology. Report to the European Commission.

[39] European Commission 2017. Commission Staff Working Document. Interim Evaluation of Horizon 2020. Annex 2 page 680

Our portfolio analysis shows that the EC has consistently invested about 8 to 10% of funds in networking and communication projects. This is in addition to the communication efforts within RD&I projects, which often account for a further 5 to 10% of project funds. Therefore, we conclude that communication of results has been well-resourced and the challenge is more to do with the nature and structure of these activities rather than their funding. The portfolio framework explicitly identifies impact areas and impact communities along with the corresponding projects. This can be used to prioritise, rationalise and professionalise this activity. This would move communication and networking activity from the project to the sub-programme and impact community level with the double benefit of reducing the complexity of RD&I projects and establishing more efficient mechanisms for supporting knowledge and technology acquisition by users and innovators.

There are already some examples to work with. The Thematic Networks set up within the European Innovation Partnership (EIP) for Agriculture and Innovation[40] network research teams and users in specific thematic areas to generate knowledge outputs for the EIP. In the marine and maritime areas, the Columbus Project aims to capitalise on the European investment in marine-related research by ensuring accessibility and uptake of research outputs by end-users: policy, industry, science and wider society.[41]

More emphasis on content-oriented evaluation conducted by sector (thematic) experts is required to address the difficult task of impact evaluation. While previous evaluations each used different approaches, each commenced with the expectation that indirect, top-down, and statistical approaches would yield insights into links between programme investments and changes in society (impact) using for example bibliographic analysis, searches for references to the programme in literature on legislation, survey data, and auditing of patenting activity. The difficulty of assessing impact this way became evident as each evaluation progressed and each turned later to expert judgement. This study provides a framework for placing content-oriented evaluation at the core of the evaluation process from the outset. This will allow a wide range of probing investigations that focus directly on the links between who is leading and conducting projects, project contents, their users, and what their users do with results to generate impact. Reliable, curated data and information is a prerequisite for robust analysis of outputs, results and impacts that a subsequent assessment can rely upon.

A harmonization of the type and quality of impact-related data collected from consortia (coordinators) is important for future assessment and planning. The collection should be systematic and the provision of data should become a contractual obligation to ensure the continuum required for following the effect of evolving strategies in EU research funding. To this end, the European Commission's Continuous Reporting System already established for projects funded in H2020 can be used by the coordinators and the beneficiaries as early as the start of the project. Job creation within the consortium, performance of SMEs participating in the consortium, projects outputs and open sharing of data and other resources are already mandatory information collected through the

[40] https://ec.europa.eu/eip/agriculture/en/about/thematic-networks-%E2%80%93-closing-research-and
[41] http://www.columbusproject.eu/aquaculture

Continuous Reporting System. Additional important information to subsequently drive impact evaluation includes the identification of knowledge outputs, potential users and pathways to generate impact; description of strategy to involve end-users in the design of the project and pathways to impact; contribution to competitiveness of European economic sectors and regional economies; pathways to creation of new value chains and markets; contribution to EU and regional/ national policies, international conventions/ agreements/ SDGs; means required to achieve an impact on policies.

Lastly, in driving future programmes and supporting greater impact it is important to continuously remind all actors that the purpose of the programme is to address a societal challenge through collaboration across the EU, complementing national and EU funding that supports the basic sciences, and national research that also supports societal challenge targets. The programme is there to serve society; it is not the property of the academic research community. This position within the wider H2020 effort must be continuously recognised in programme planning and implementation.

8. FIGURES AND TABLES

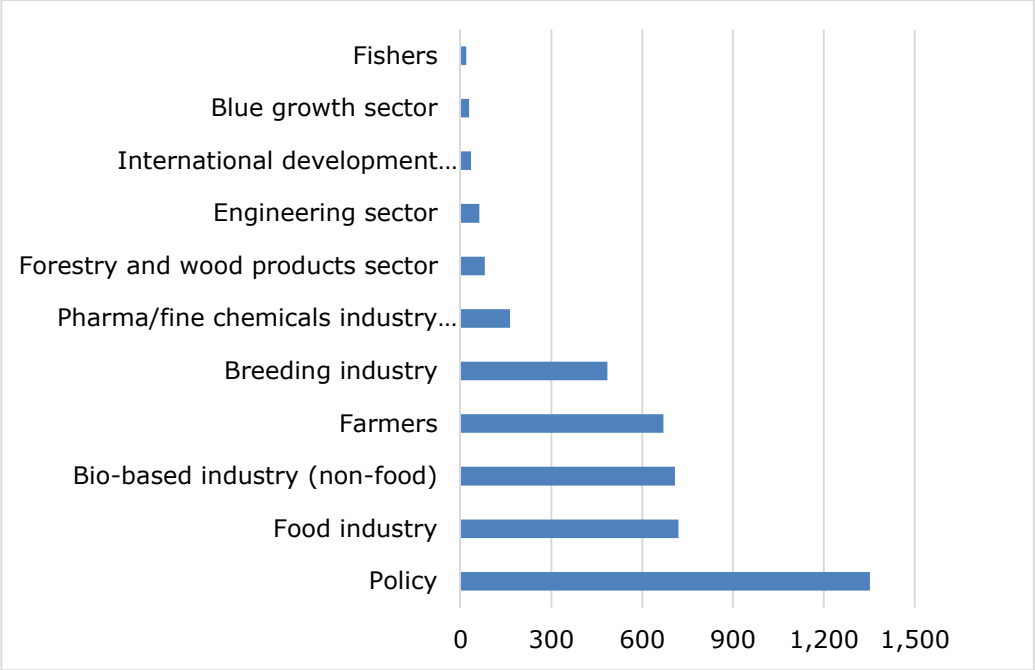

Figure 1. EU expenditure (million Euros) in the FP projects identified as aligned to Societal Challenge 2 categorised according to the main primary user of each project's results.

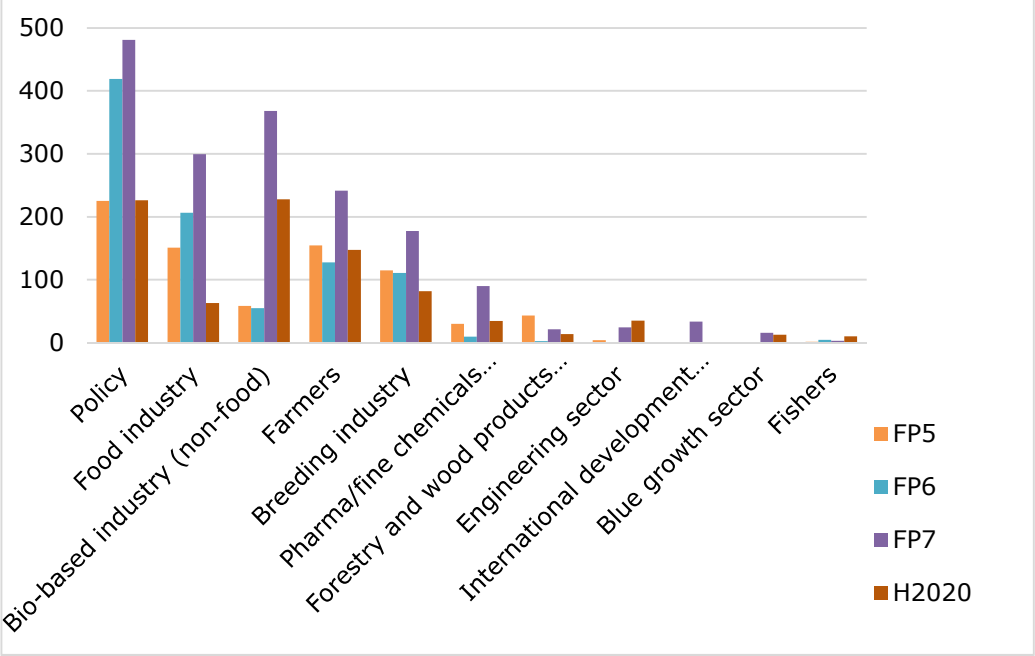

Figure 2. Changes in the EU contribution of funds (million Euros) to projects aligned to the 11 primary user groups the four framework programmes.

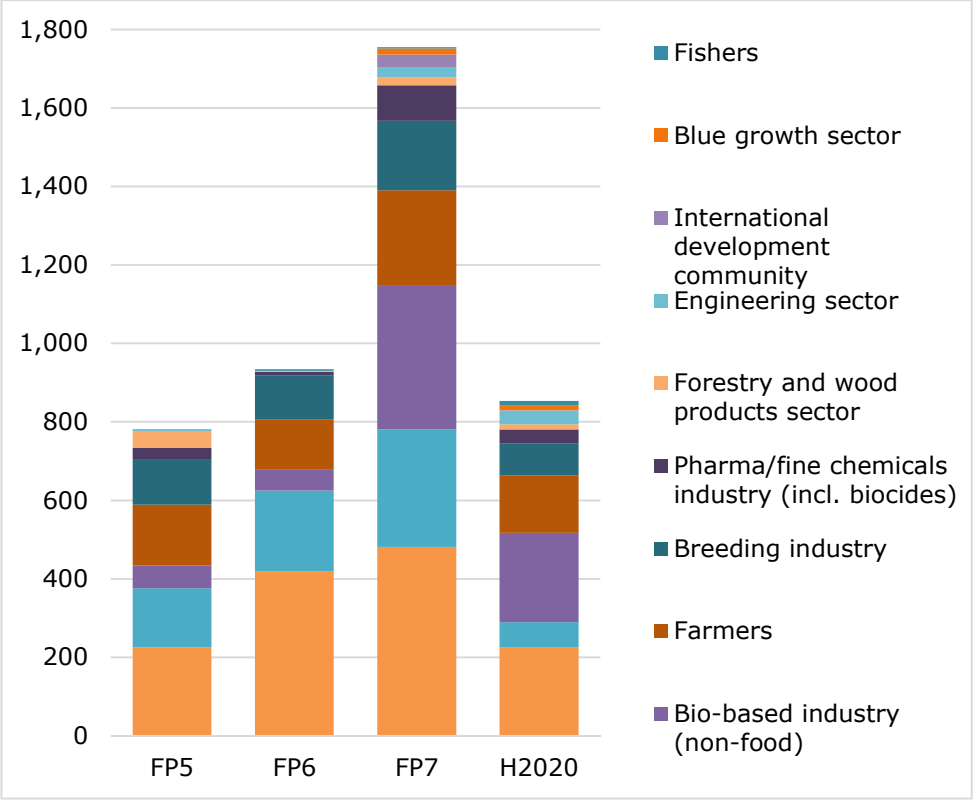

Figure 3. EU contribution (million Euros) to projects as categorised by their primary users.

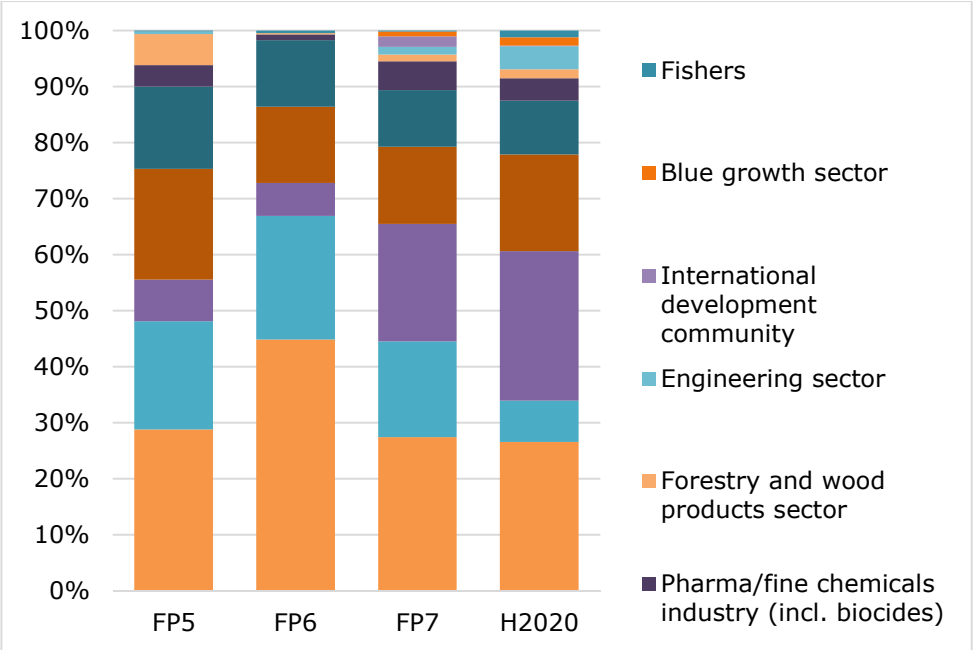

Figure 4. The relative allocation (%) of EU expenditure in terms of projects' primary users in FP5 to H2020.

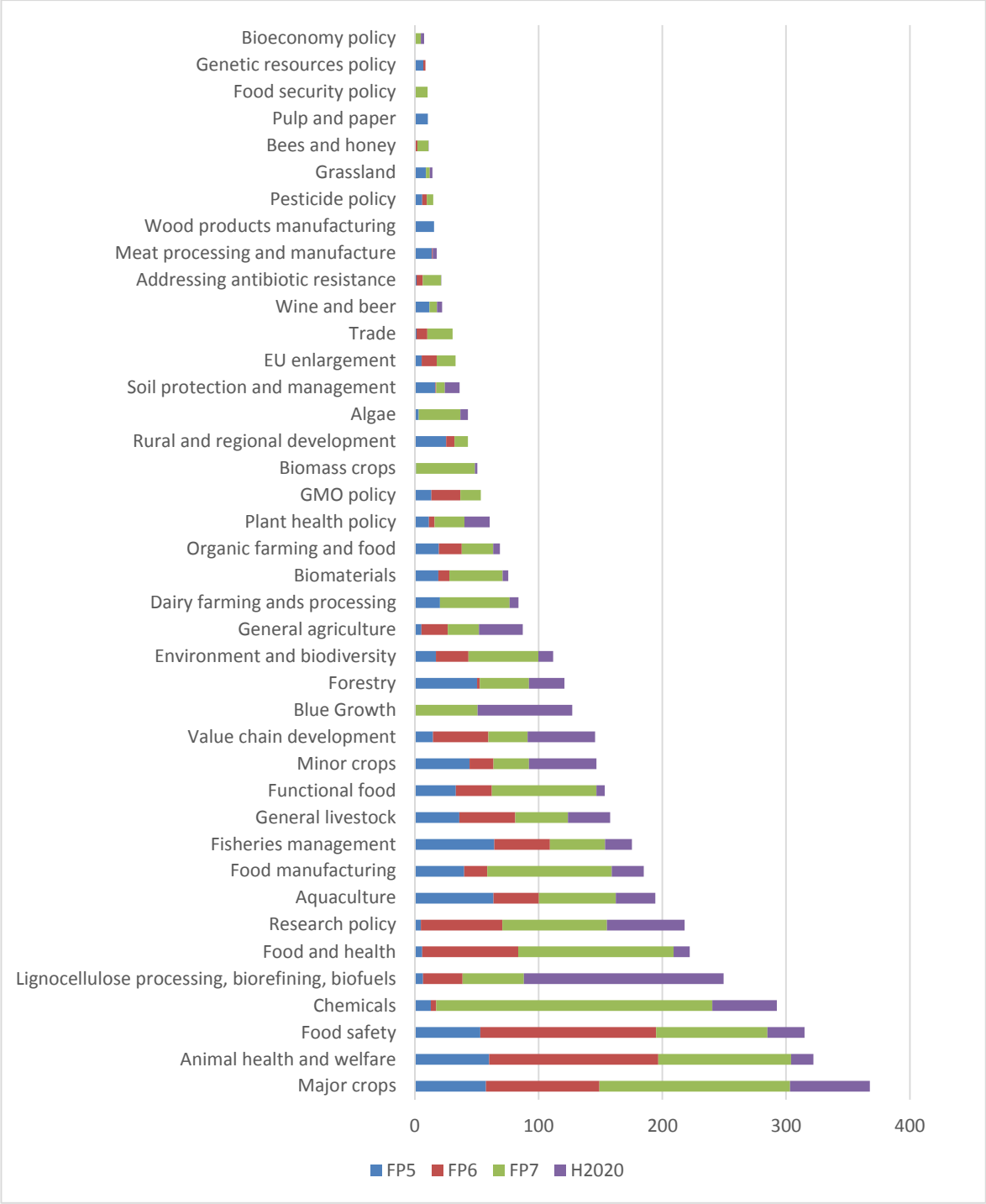

Figure 5. EU expenditure (million Euros) for projects' main impact areas.

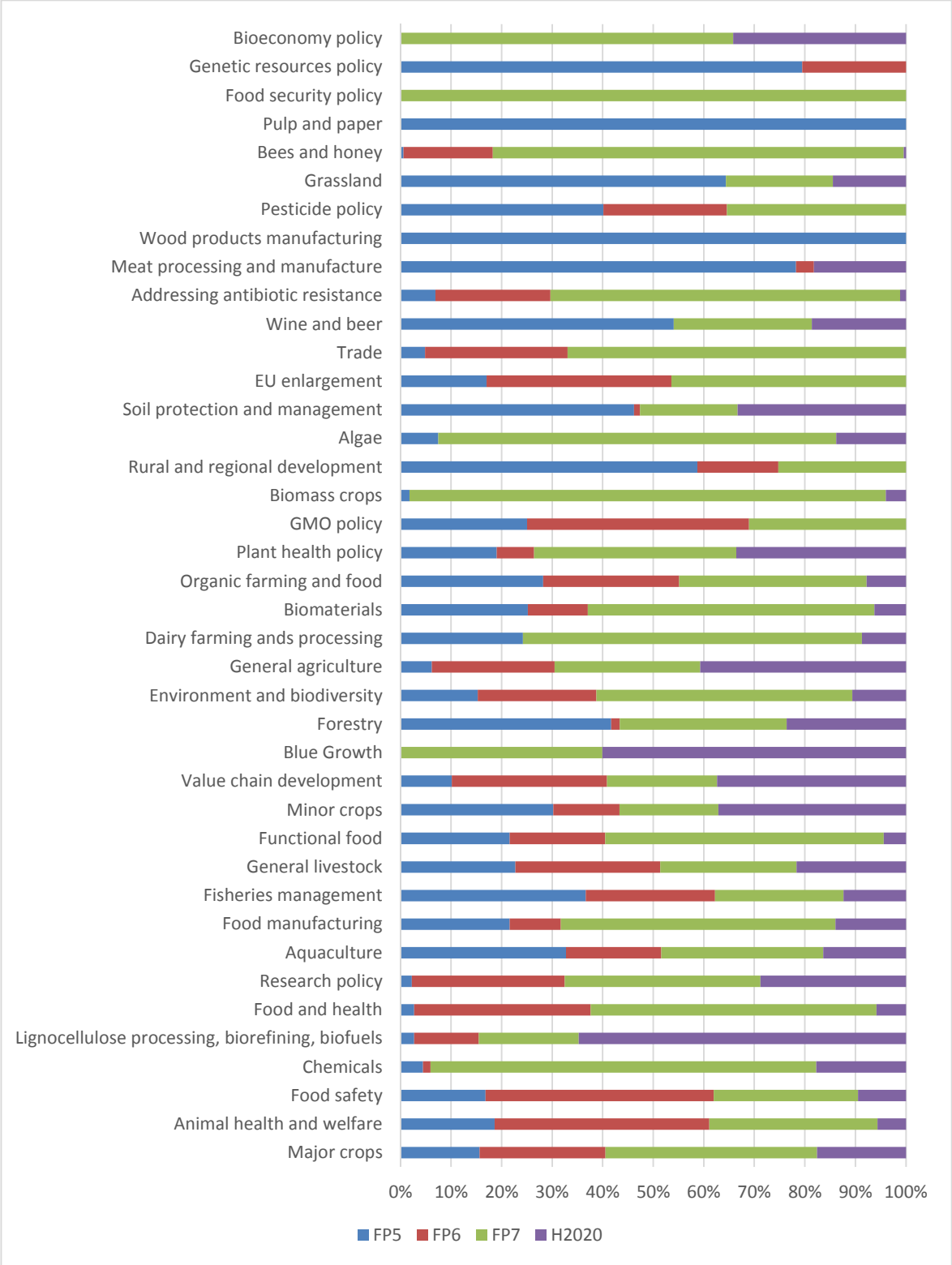

Figure 6. The relative allocation of EU expenditure in terms of projects' main impact areas in FP5 to H2020.

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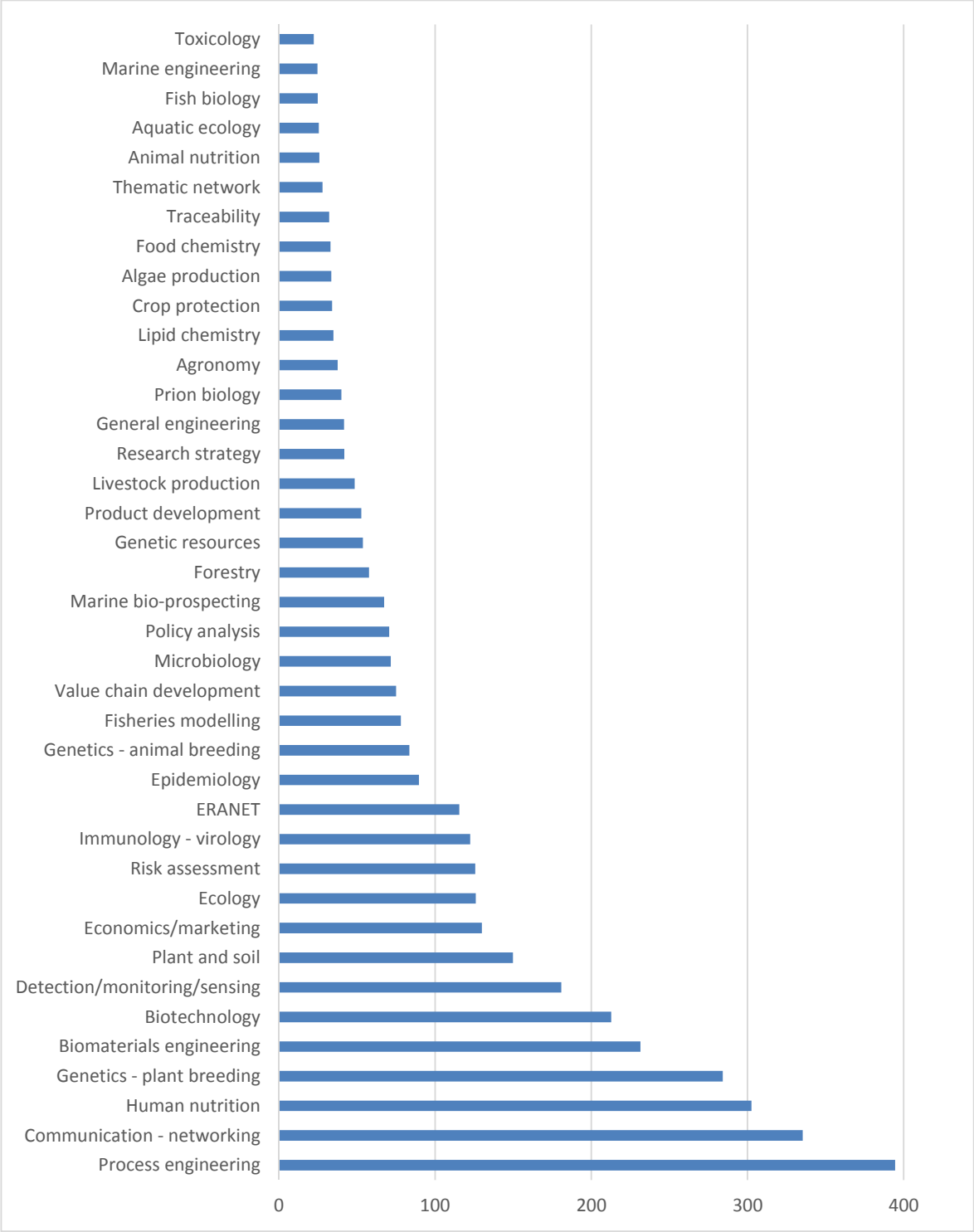

Figure 7. Ranking of the top 50 project activities quantified in terms of the funding of projects (million Euros, FP5 to H2020).

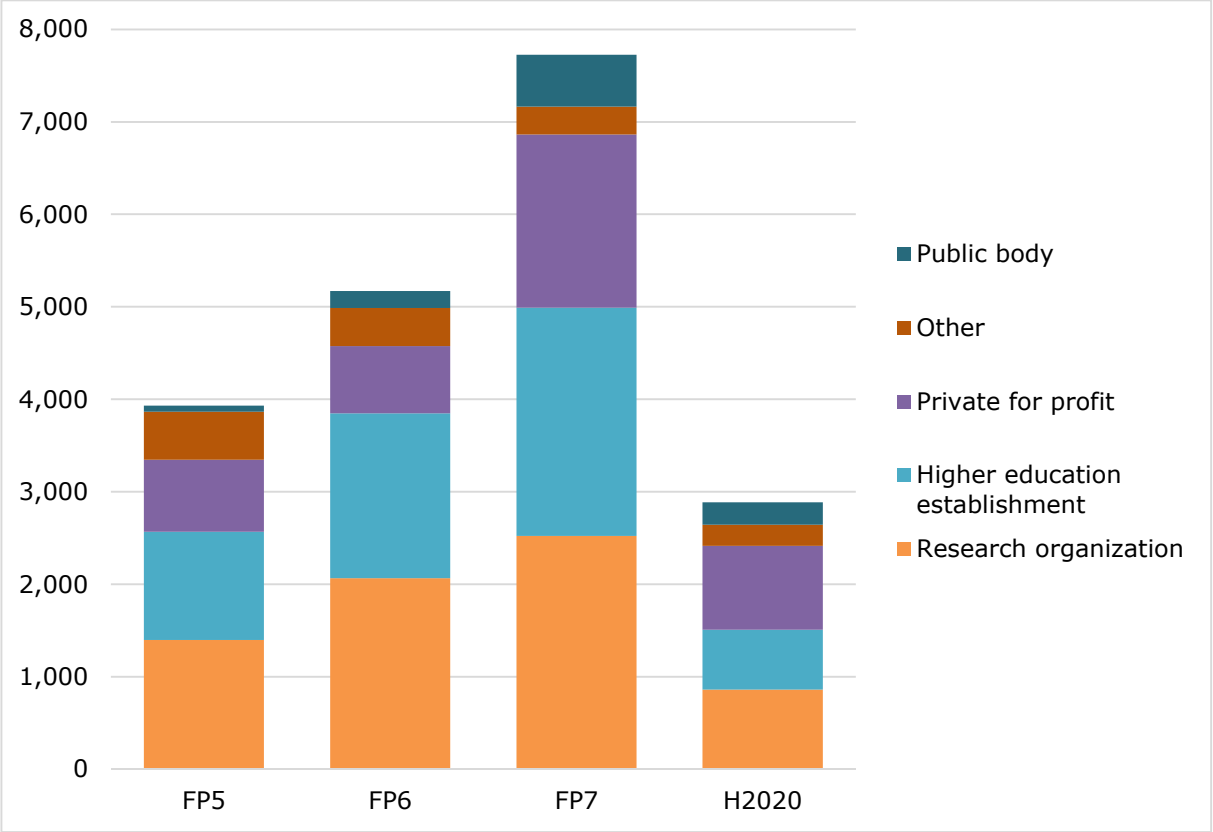

Figure 8. Number project participations in the four Framework Programmes for each organisation type. For FP5, the data relate to 691 of the 1,098 projects in FP5. There is complete coverage of the other Framework Programmes.

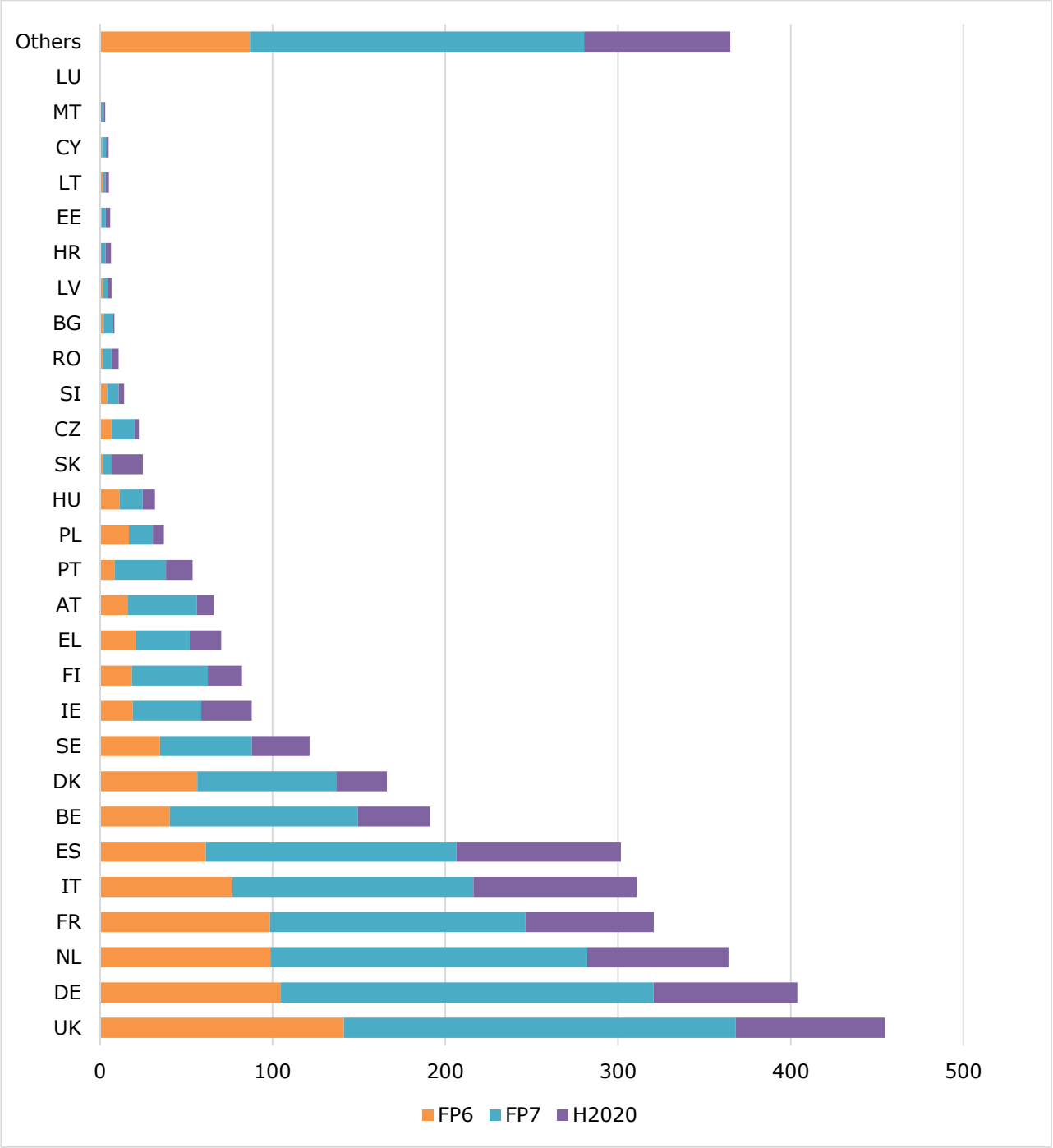

Figure 9. Requested contributions (million Euros) for funded projects for each of the EU member states and for other countries. The requested contributions and the EU contributions are very closely related.

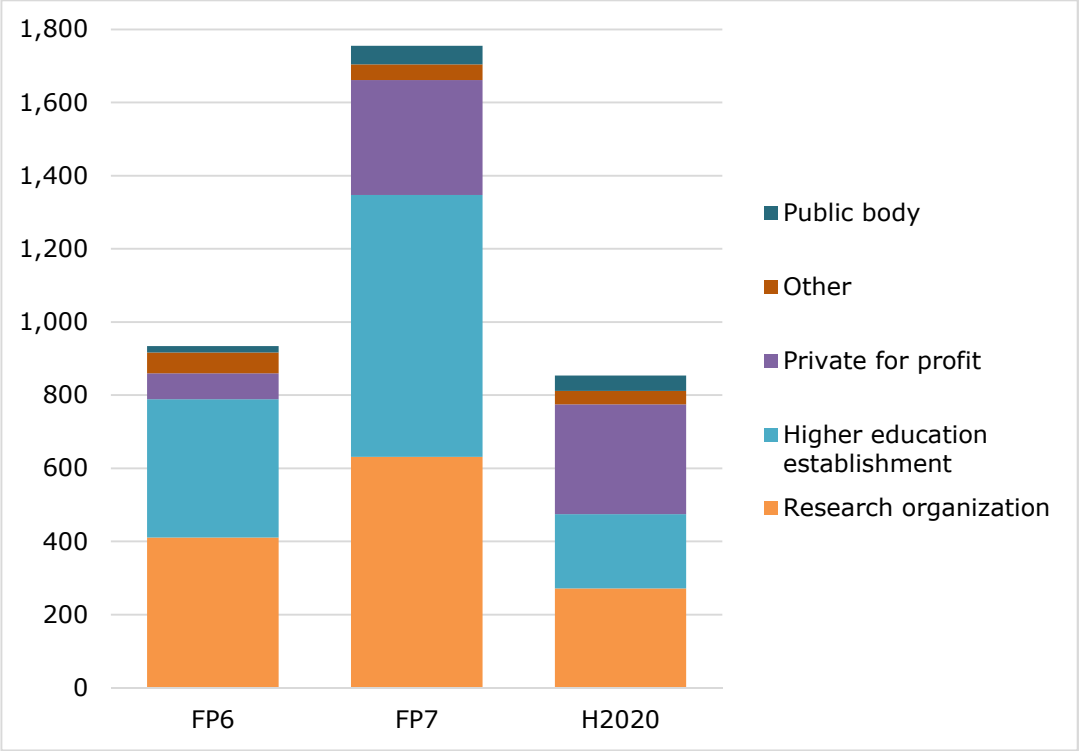

Figure 10. Requested EU contribution (million Euros) for projects in FP6 to H2020 for different types of participant organisations.

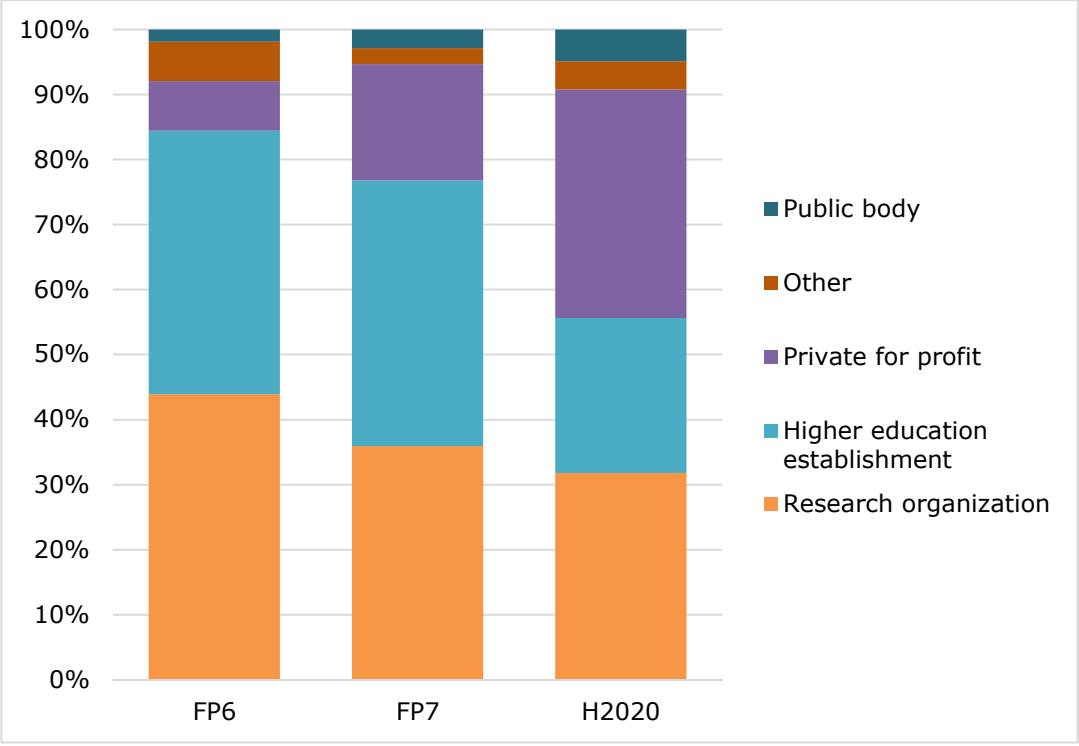

Figure 11. Relative changes (%) in requested EU contributions for the types of participant organisations.

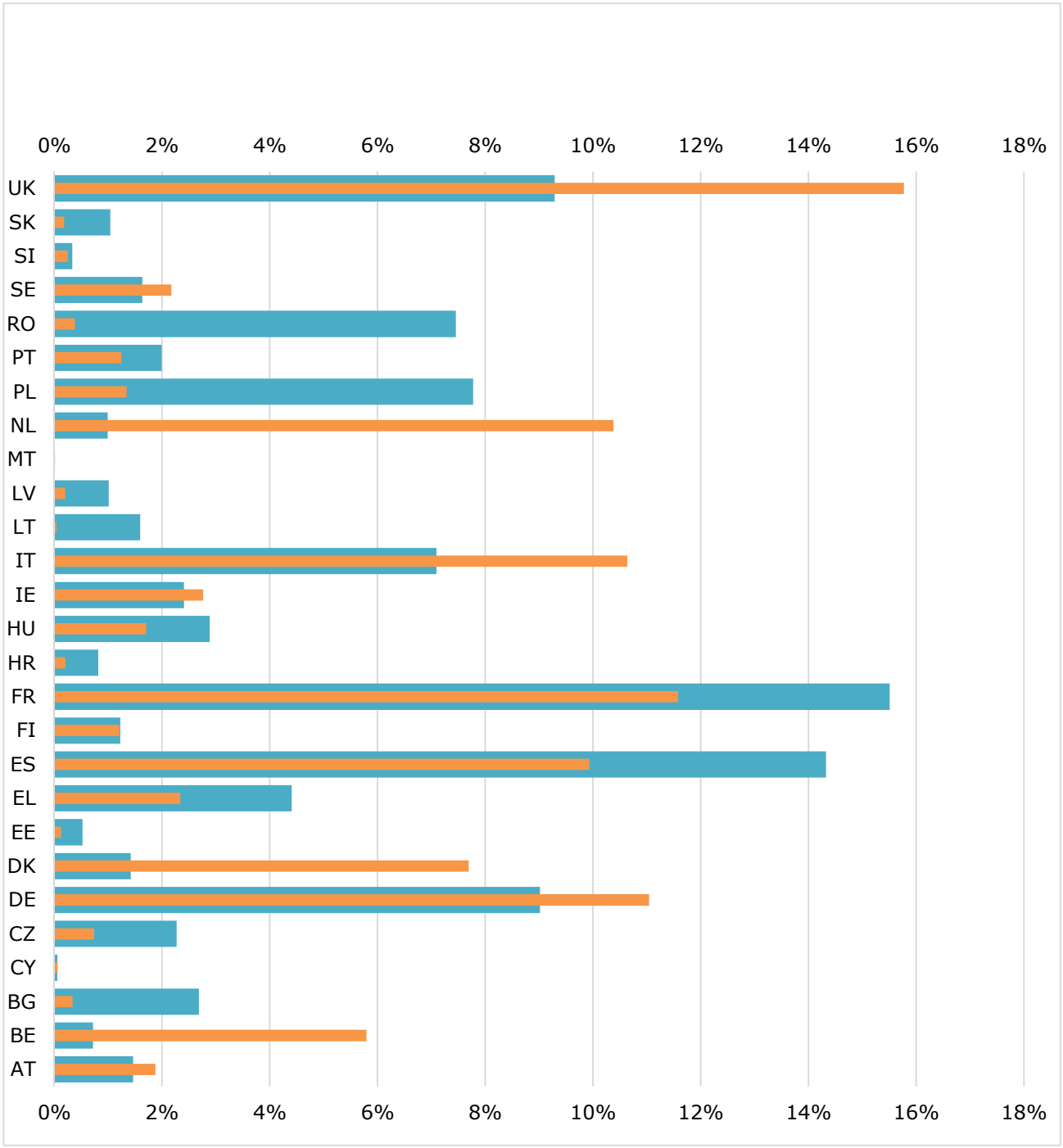

Figure 12. Proportion (%) of total EU contribution requested by project participants in EU member states for projects that address land-based farmers as primary users (narrow orange bars) and the proportion (%) of the EU agricultural area in each member state (wide blue bars). Luxembourg is not included due to there being no financial data on Luxembourg-based participants in these projects.

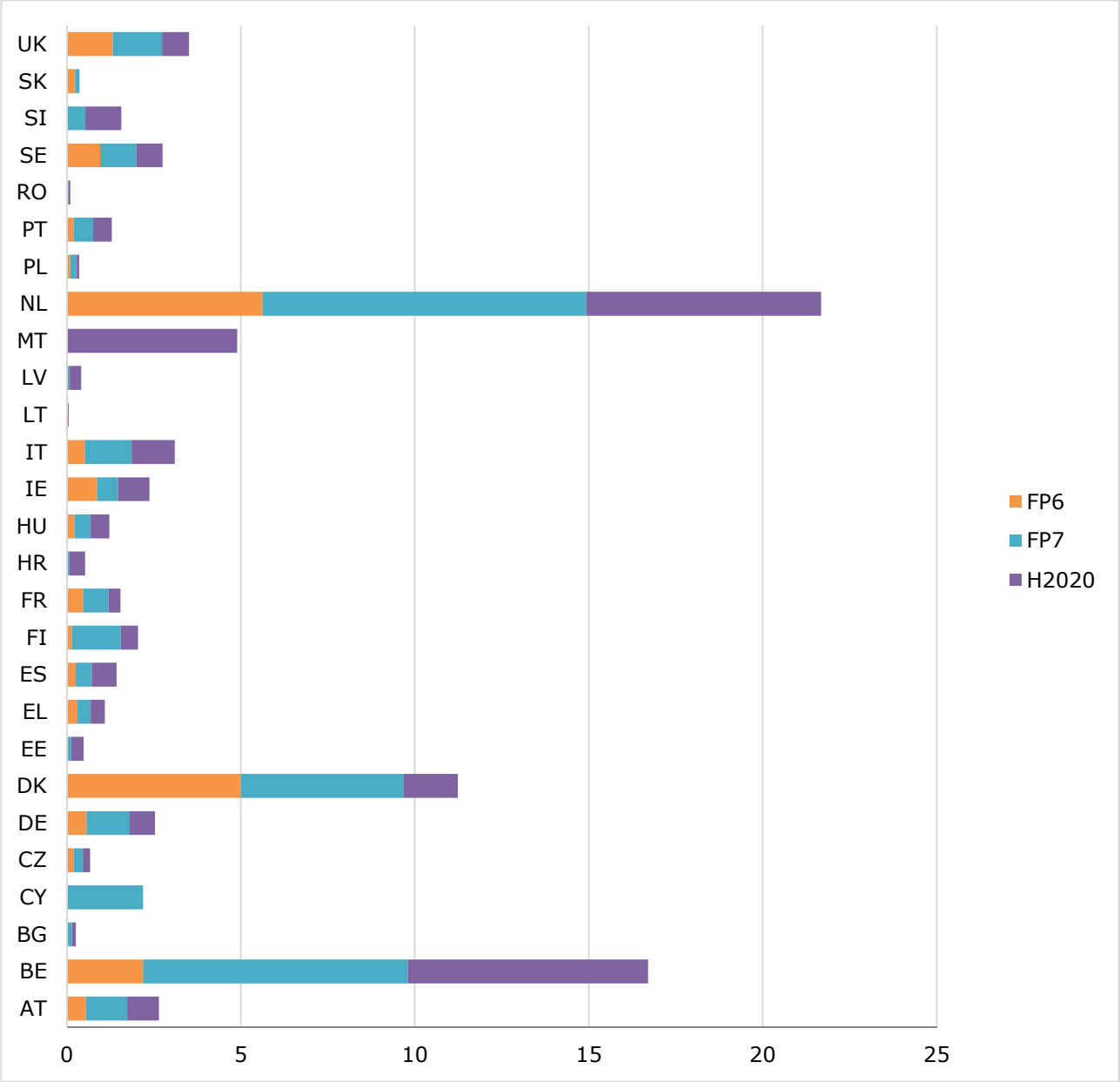

Figure 13. The EU contribution to projects which address land-based farmers as primary users expressed as Euros per hectare agricultural land in each member state. It is important to appreciate that this relates only to research that is used directly by land-based farmers, not all agricultural research.

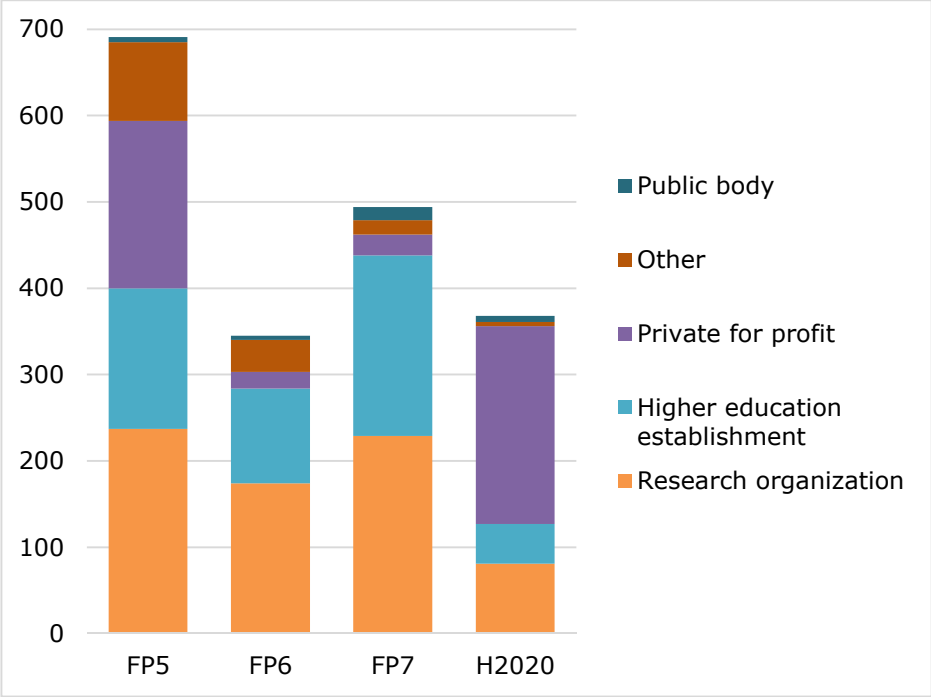

Figure 14. The number of projects coordinated in the four FPs for each organisation type. For FP5, the data relate to 691 of the 1,098 projects in FP5. There is complete coverage of the other programmes.

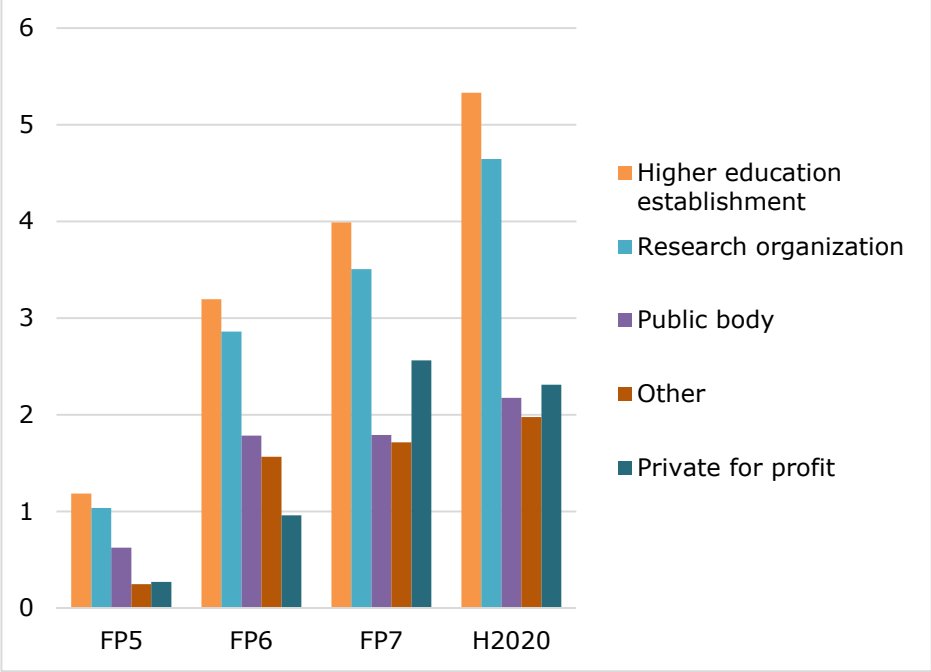

Figure 15. The average EU contribution (million Euros) to projects categorised by the type of coordinating organisation (FP5 to H2020, excluding all SME projects and all BBI JU projects in H2020).

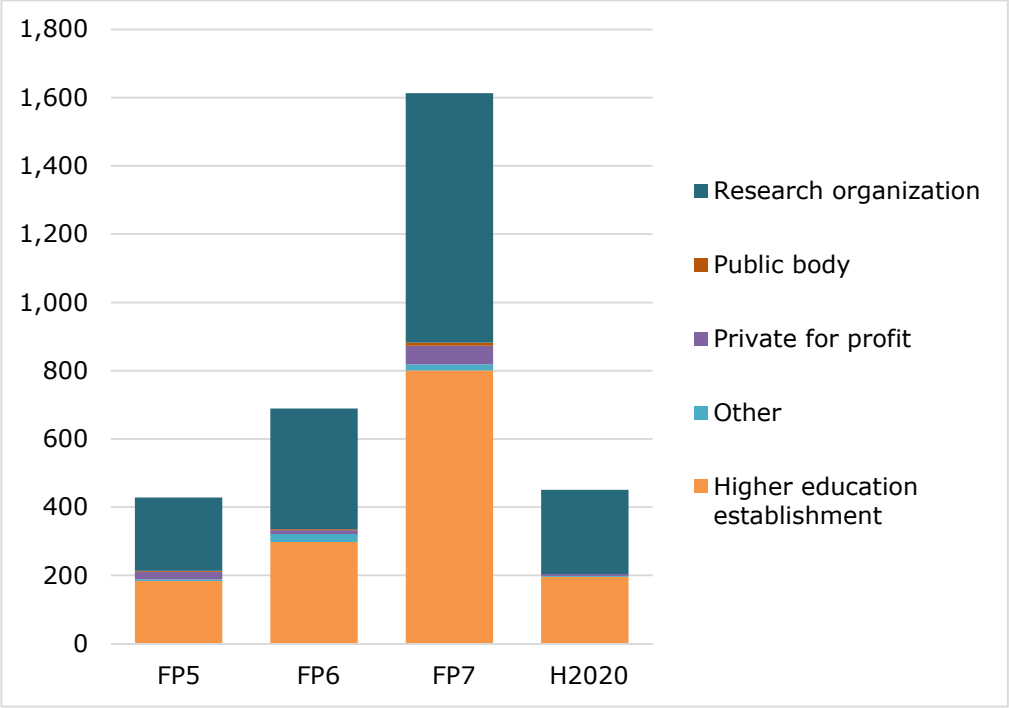

Figure 16. EU contribution (million Euros) to research and technological development projects categorised according to the type of project coordinating organisation.

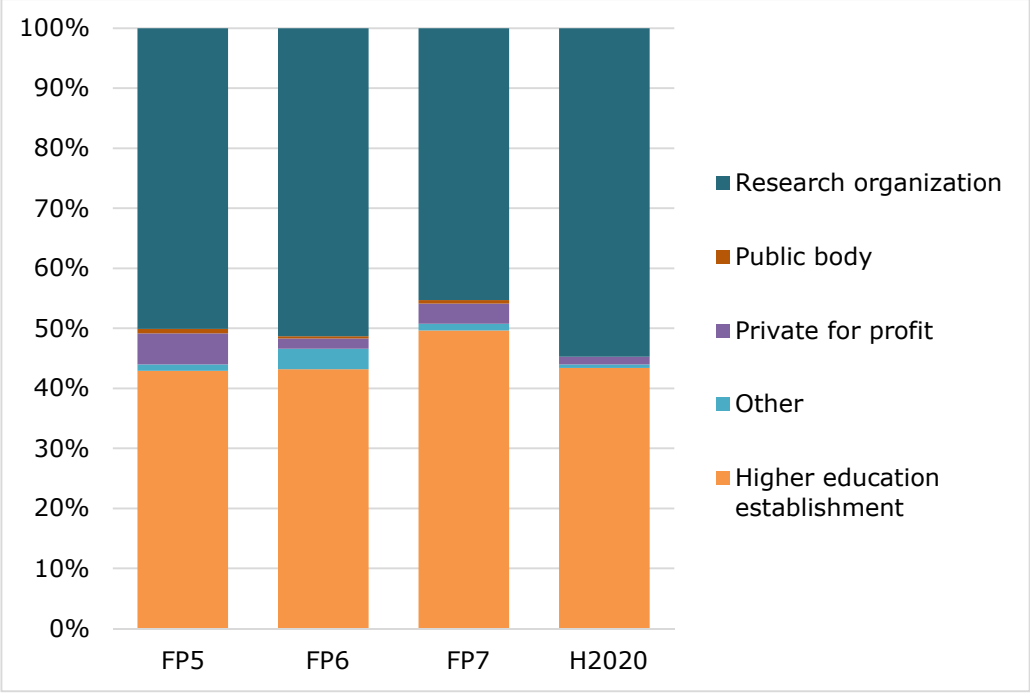

Figure 17. EU contribution (million Euros) to research and technological development projects categorised relatively according to the type of project coordinating organisation.

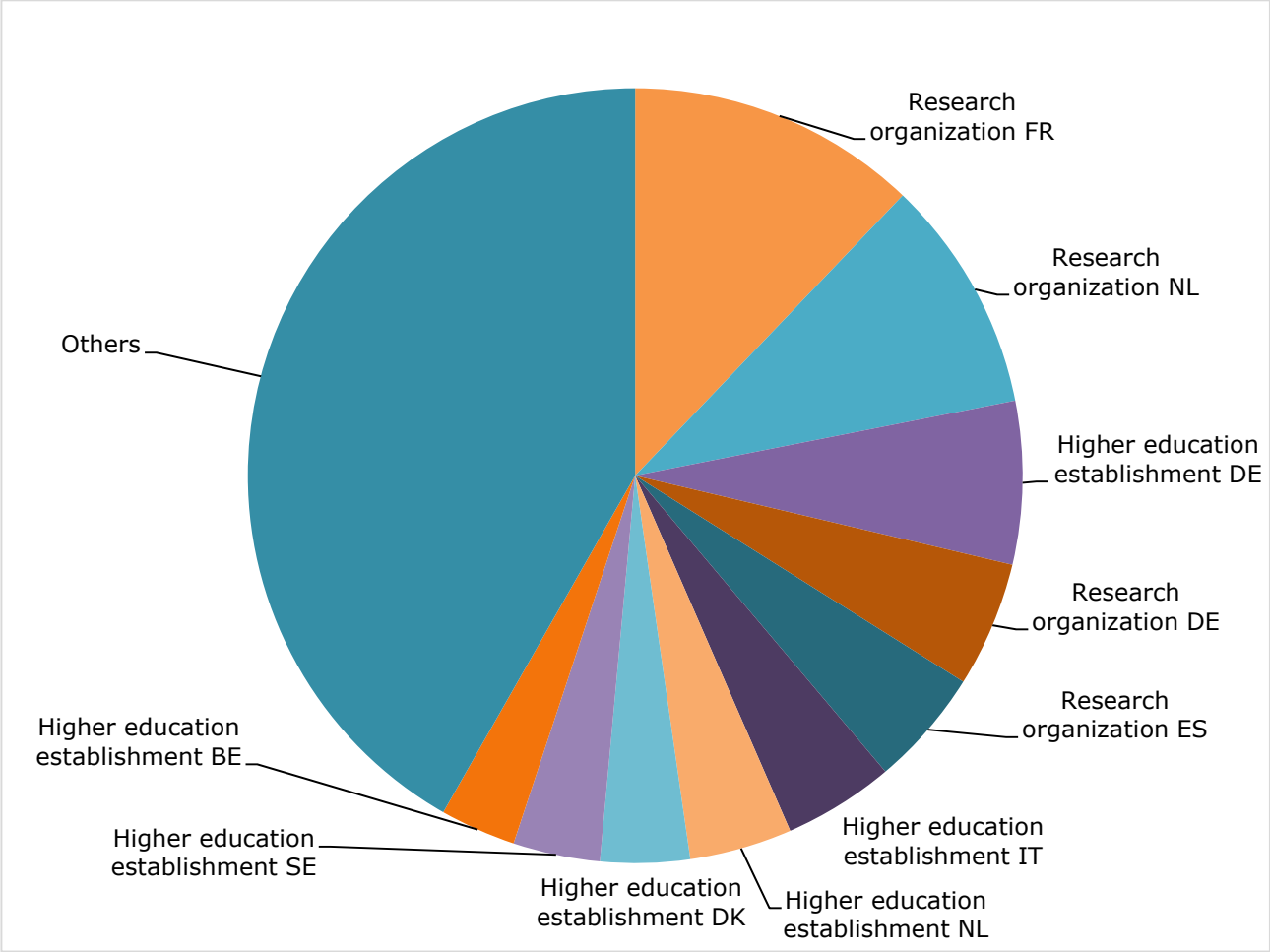

Figure 18. The distribution of the EU contribution to 690 projects in FP5 for coordinating organisation type/country combinations. Due to missing data, this relates to 690 of the 1,098 projects in FP5.

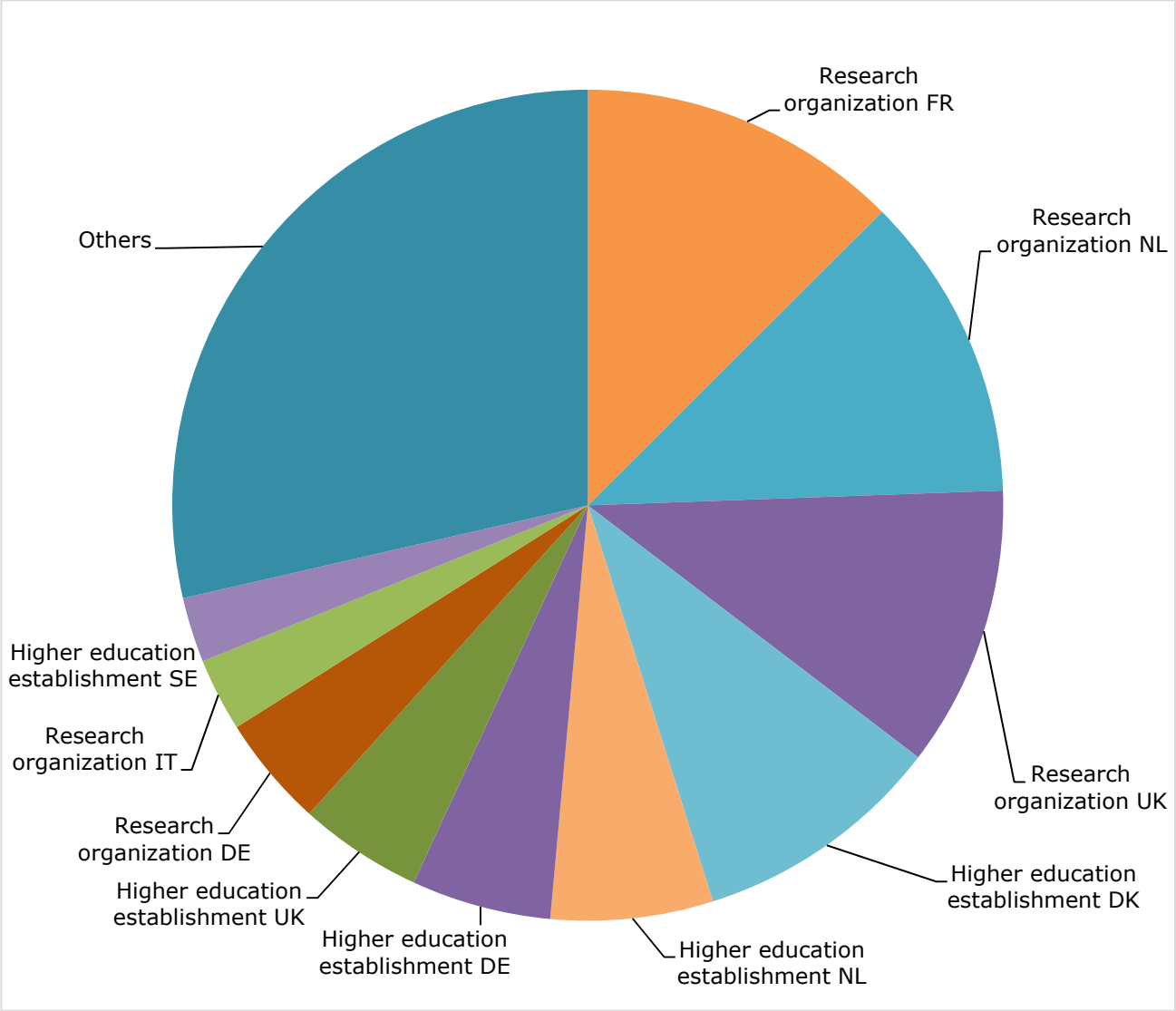

Figure 19. The distribution of total project EU contributions in FP6 in terms of the different coordinating organisation type/country combinations.

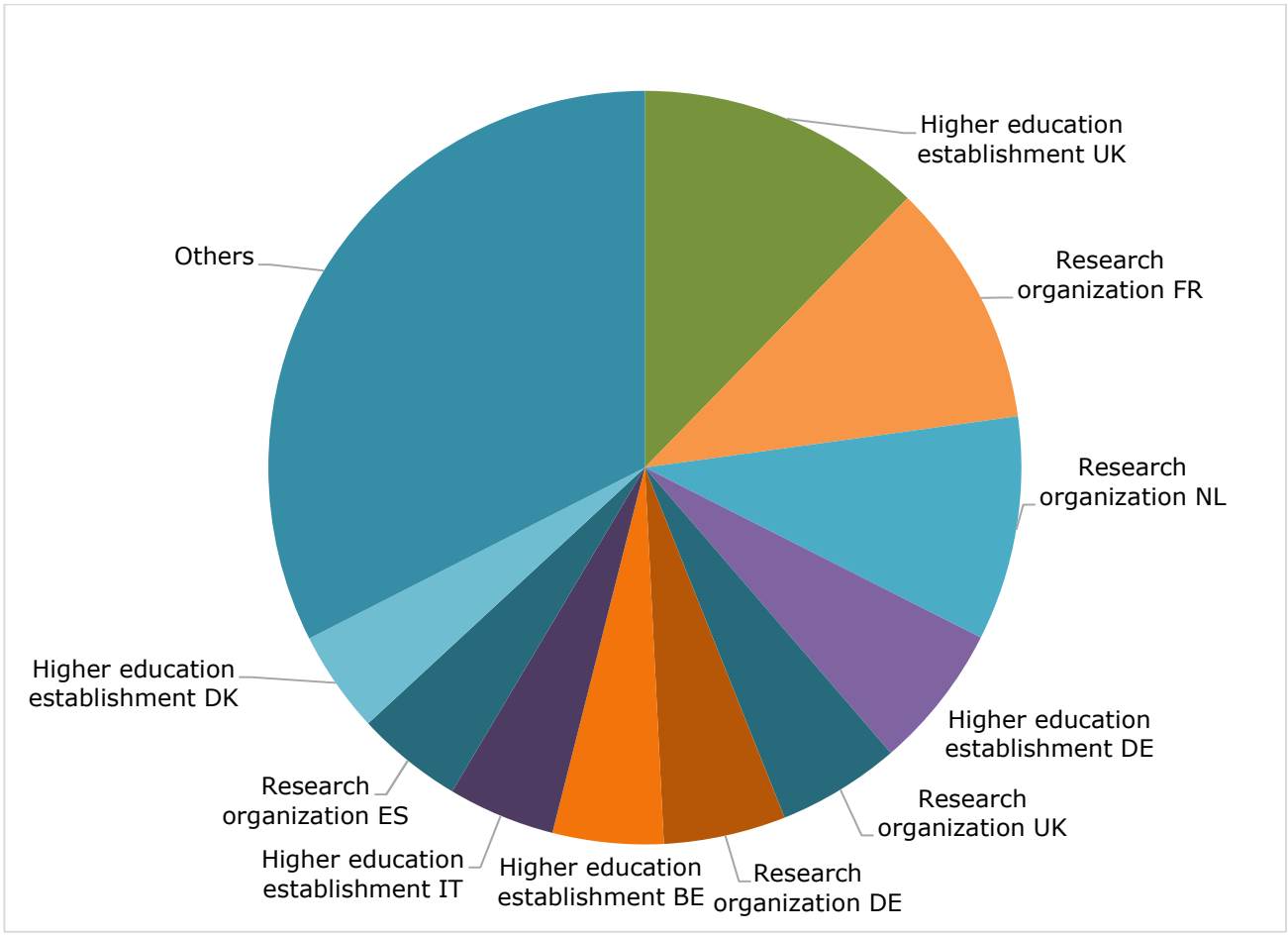

Figure 20. The distribution of total project EU contributions in FP7 in terms of the different coordinating organisation type/country combinations.

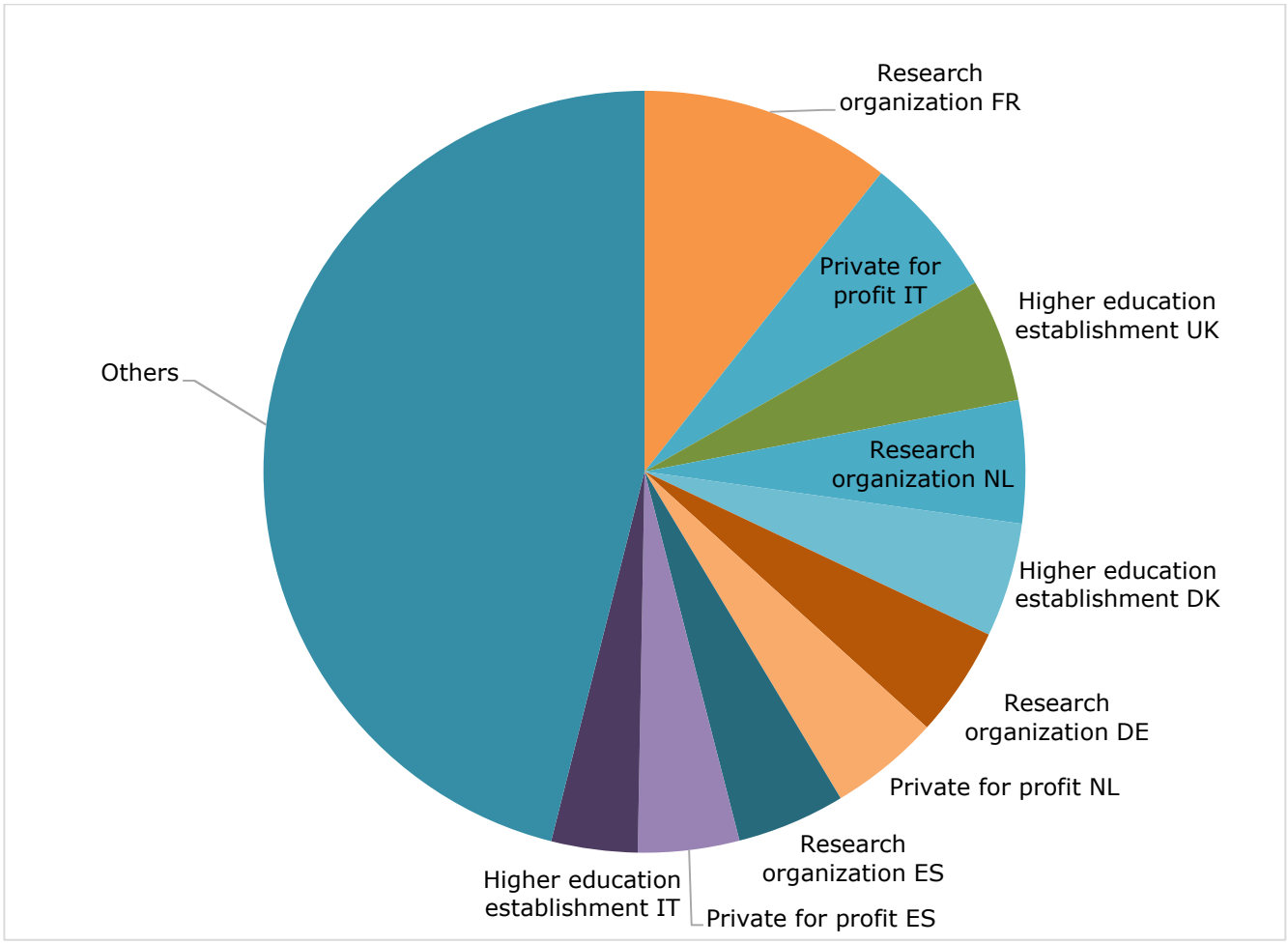

Figure 21. The distribution of total project EU contributions in Horizon 2020 in terms of the different coordinating organisation type/country combinations.

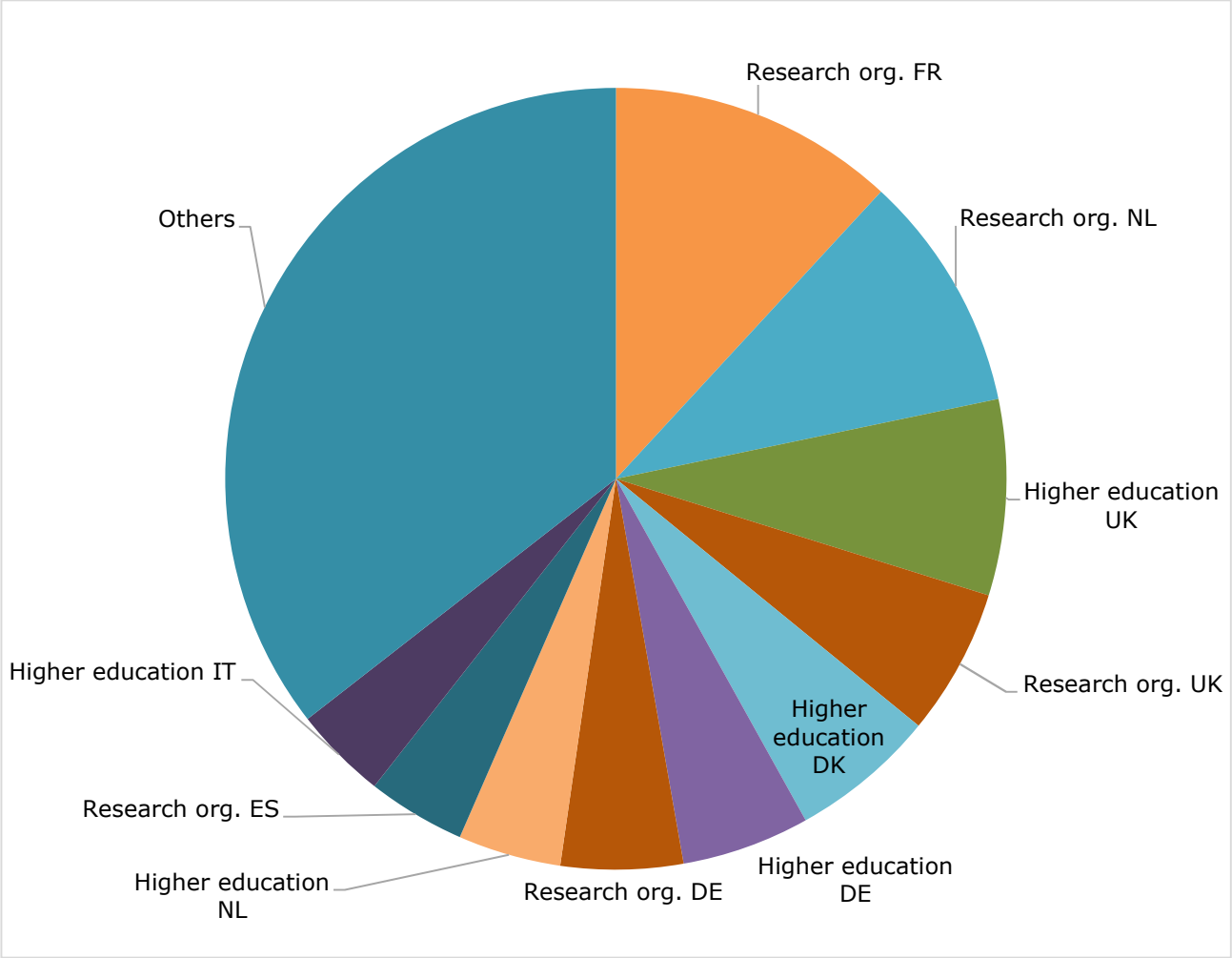

Figure 22. The distribution of total project EU contributions in Horizon 2020, excluding SME and BBI-JU projects, in terms of the different coordinating organisation type/country combinations.

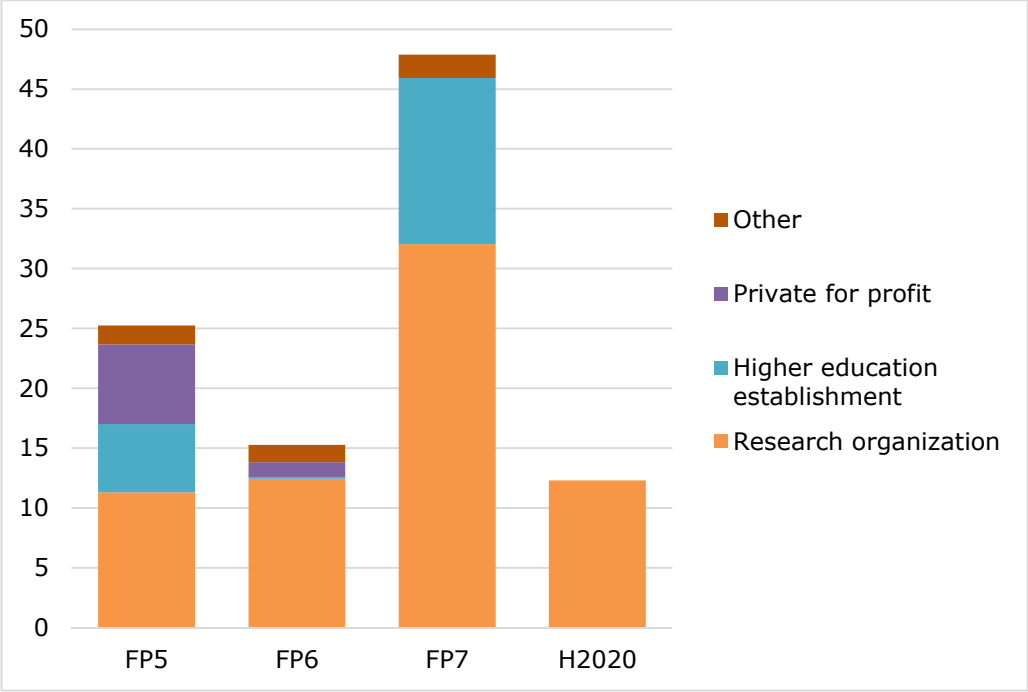

Figure 23. EU contribution (million Euros) to projects for fish farmers categorised by the type of coordinating organisation.

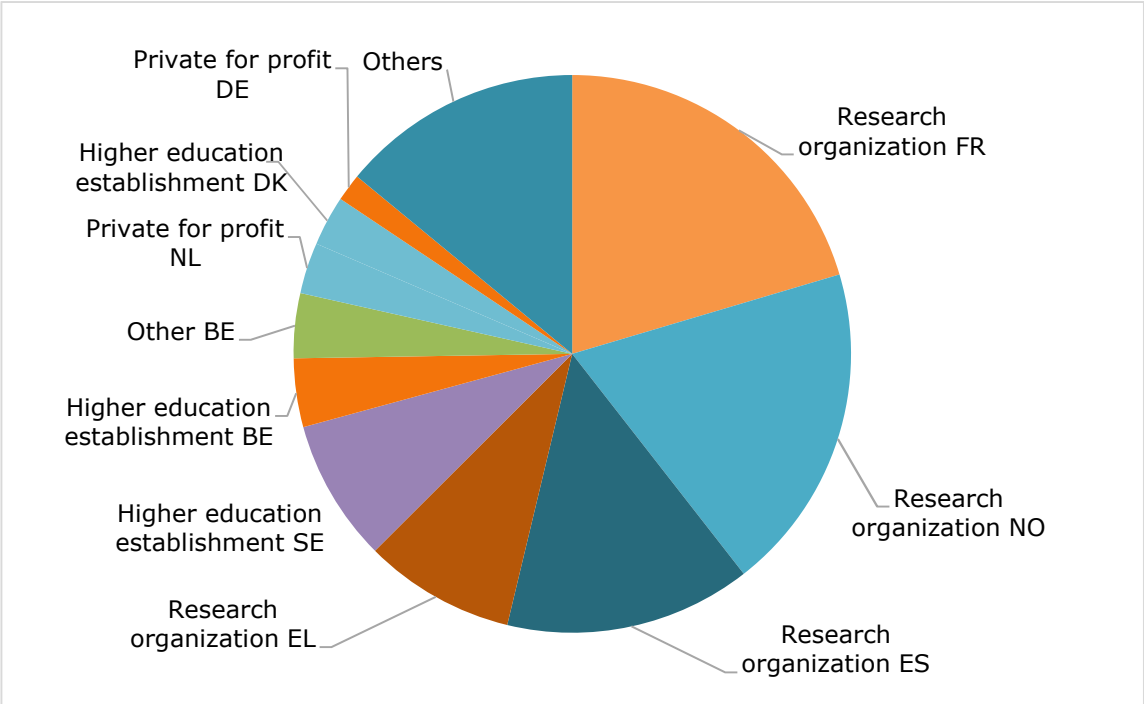

Figure 24. The distribution of total project EU contributions to projects for fish farming in terms of the different coordinating organisation type/country combinations (FP5 to H2020).

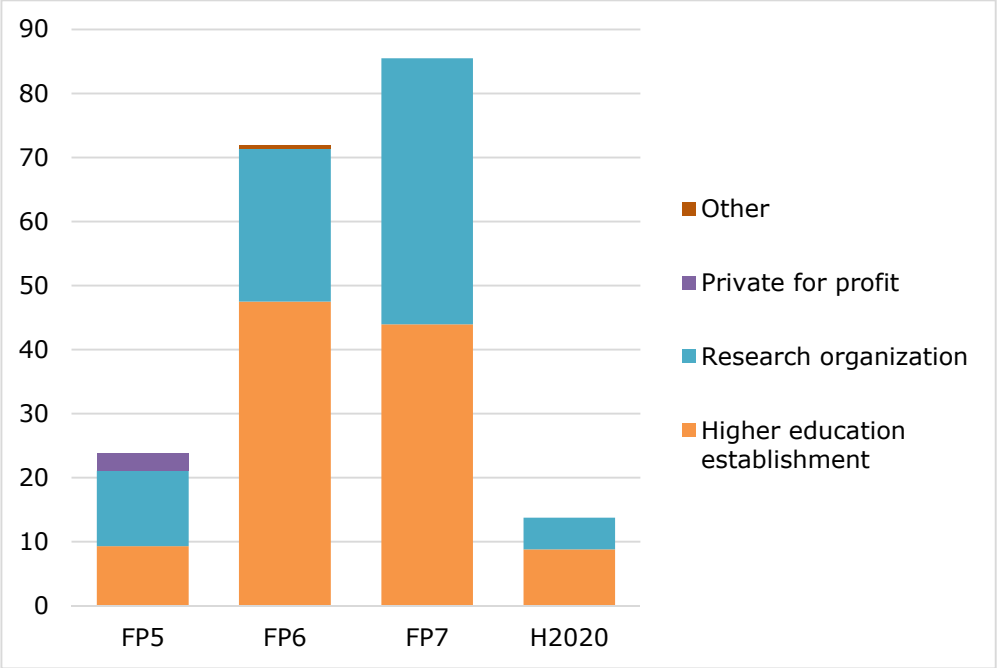

Figure 25. EU contribution (million Euros) to projects for major crop breeding categorised by the type of coordinating organisation.

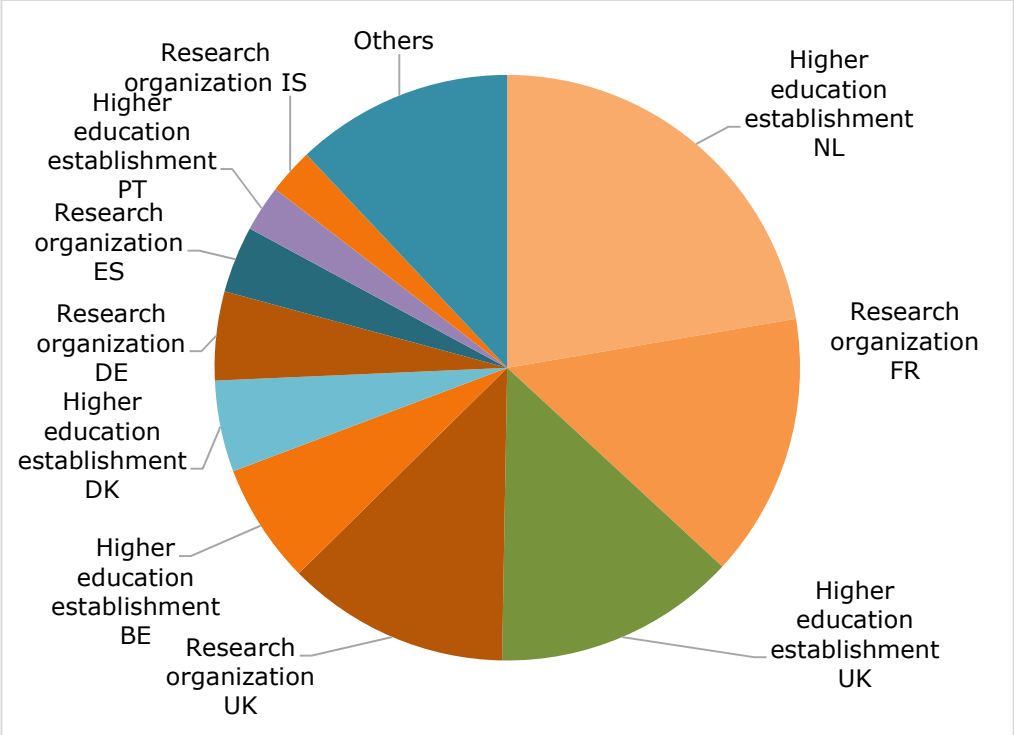

Figure 26. The distribution of total project EU contributions to projects for major crop breeding in terms of the different coordinating organisation type/country combinations (FP5 to H2020).

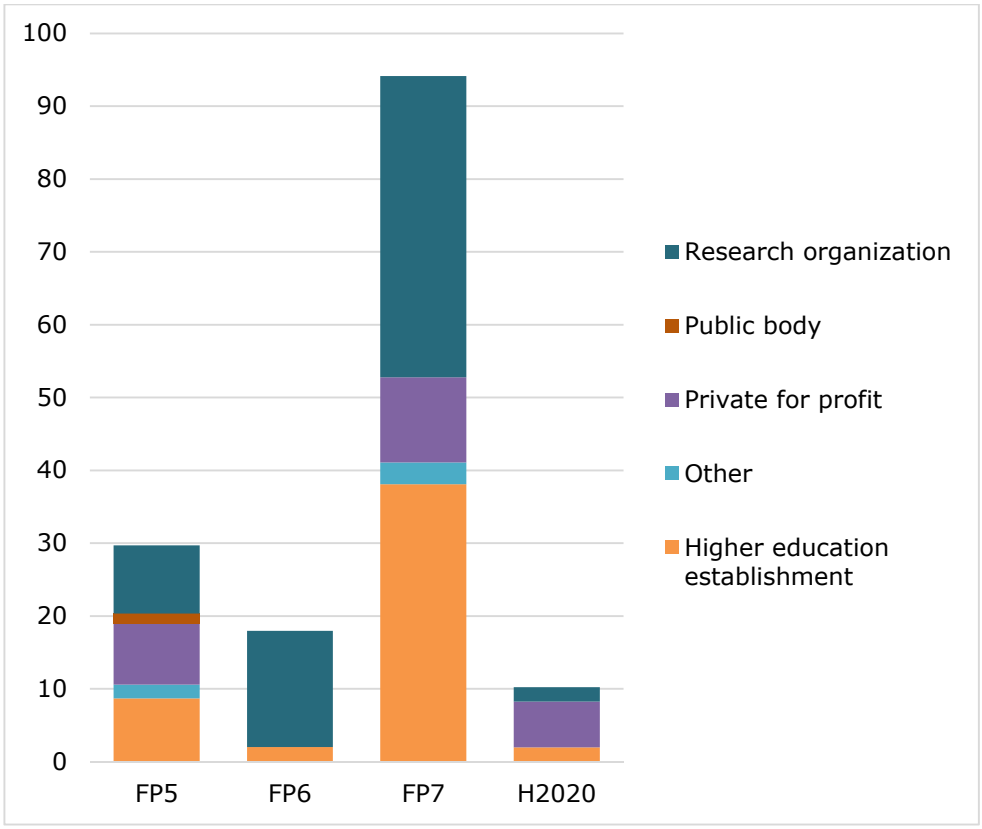

Figure 27. EU contribution (million Euro) to projects for food manufacturing categorised by the type of coordinating organisation.

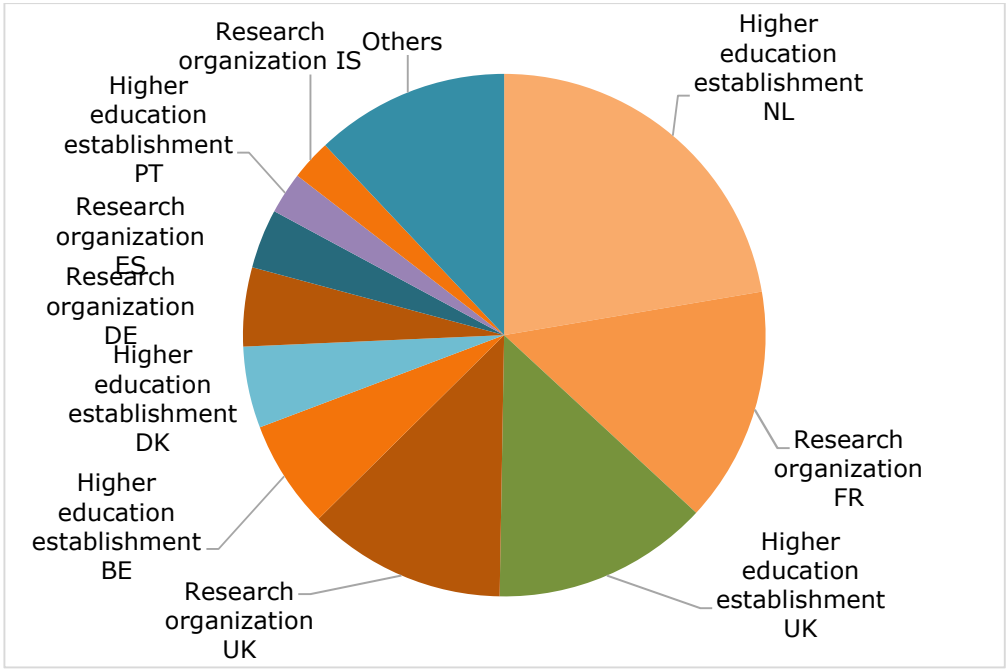

Figure 28. The distribution of total project EU contributions to projects for food manufacturing in terms of the different coordinating organisation type/country combinations (FP5 to H2020).

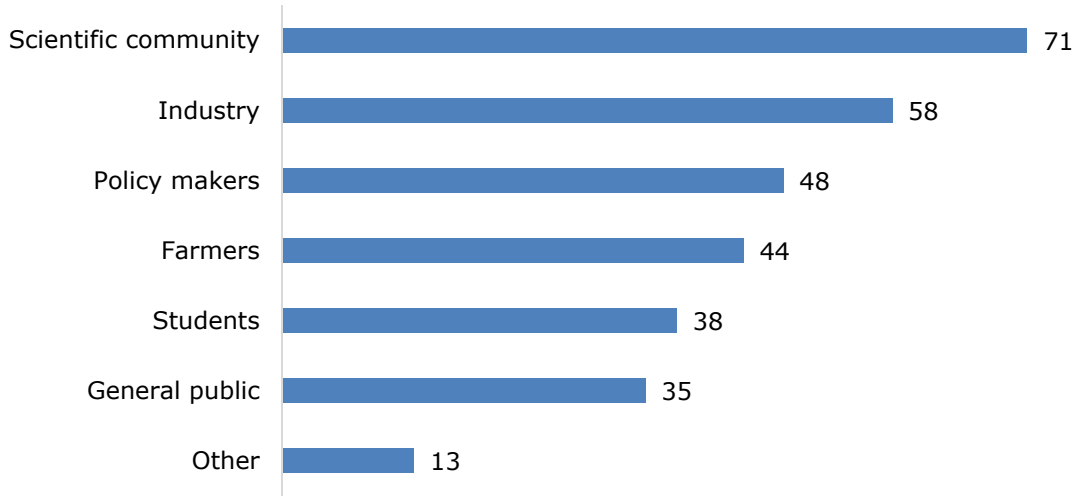

Figure 29. Percentage of projects targeting different types of users of projects across FP

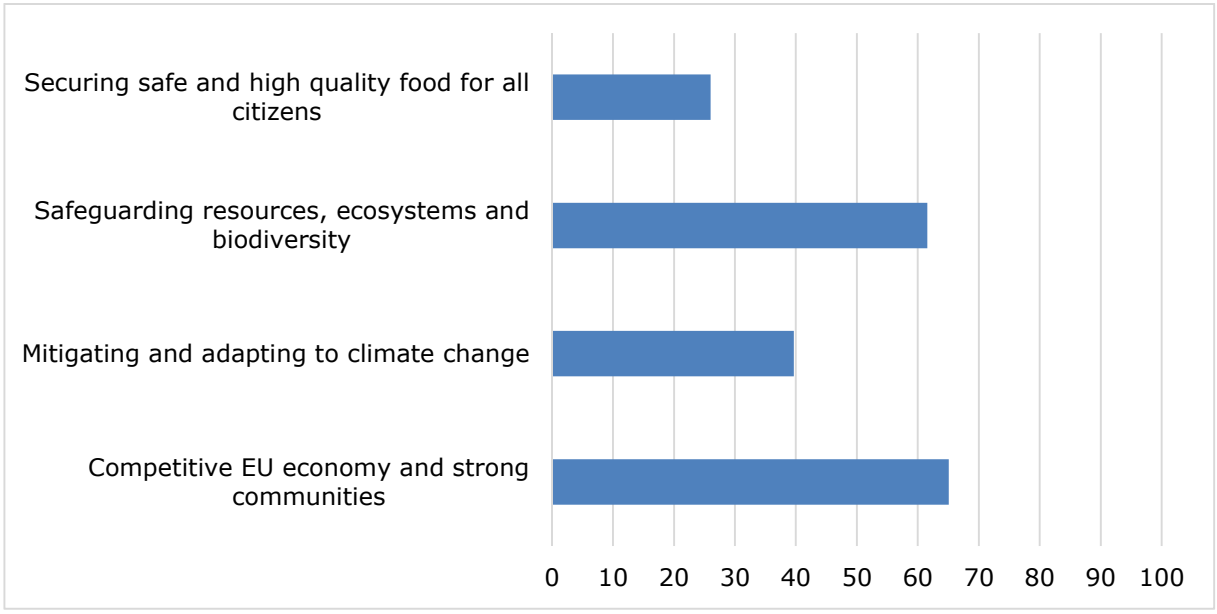

Figure 30. Percentage (%) of coordinators reporting contributions to different major impacts. Most coordinators reported more than one type of impact.

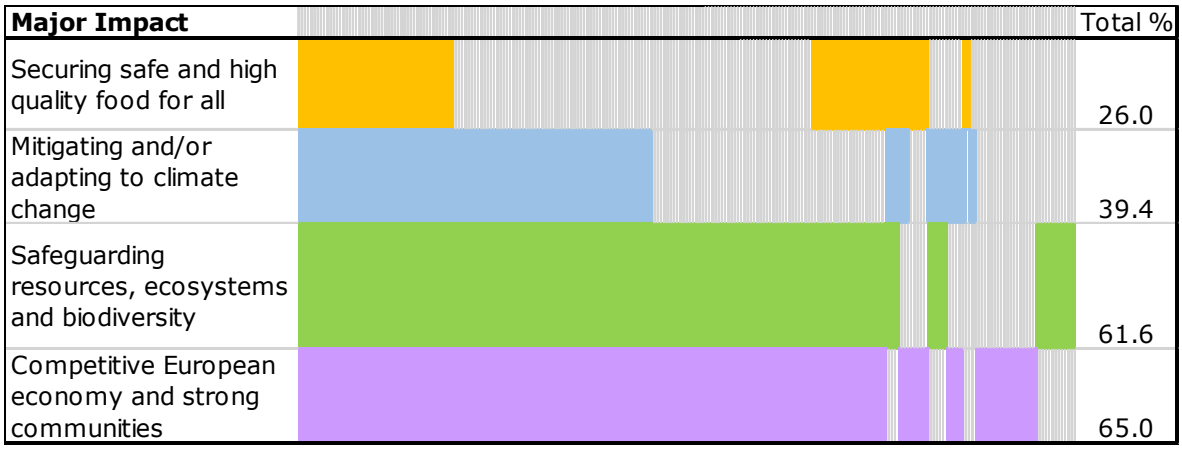

Figure 31. Heat map of the combinations of major impacts reported by the coordinators. The areas covered in the heat map are proportional to the percentages reported. The vertical grey bars represent the surveyed projects. The coloured coverage from left to right represents the projects reported to support the major impacts. The high degree of overlap between coverage of different impacts reflects the degree to which individual projects serve several impacts.

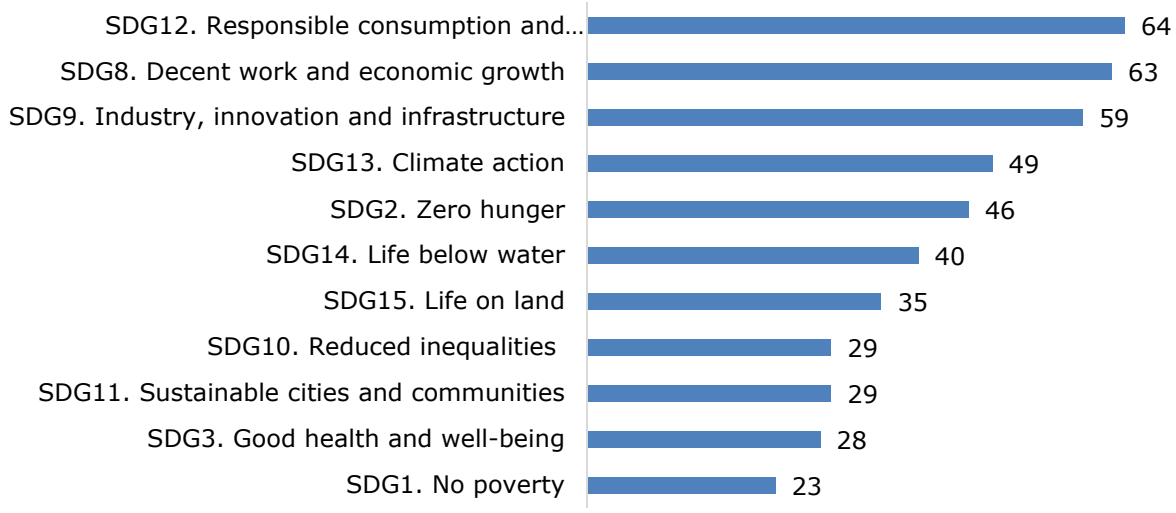

Figure 32. Percentage (%) of coordinators reporting contributions to different SDG.

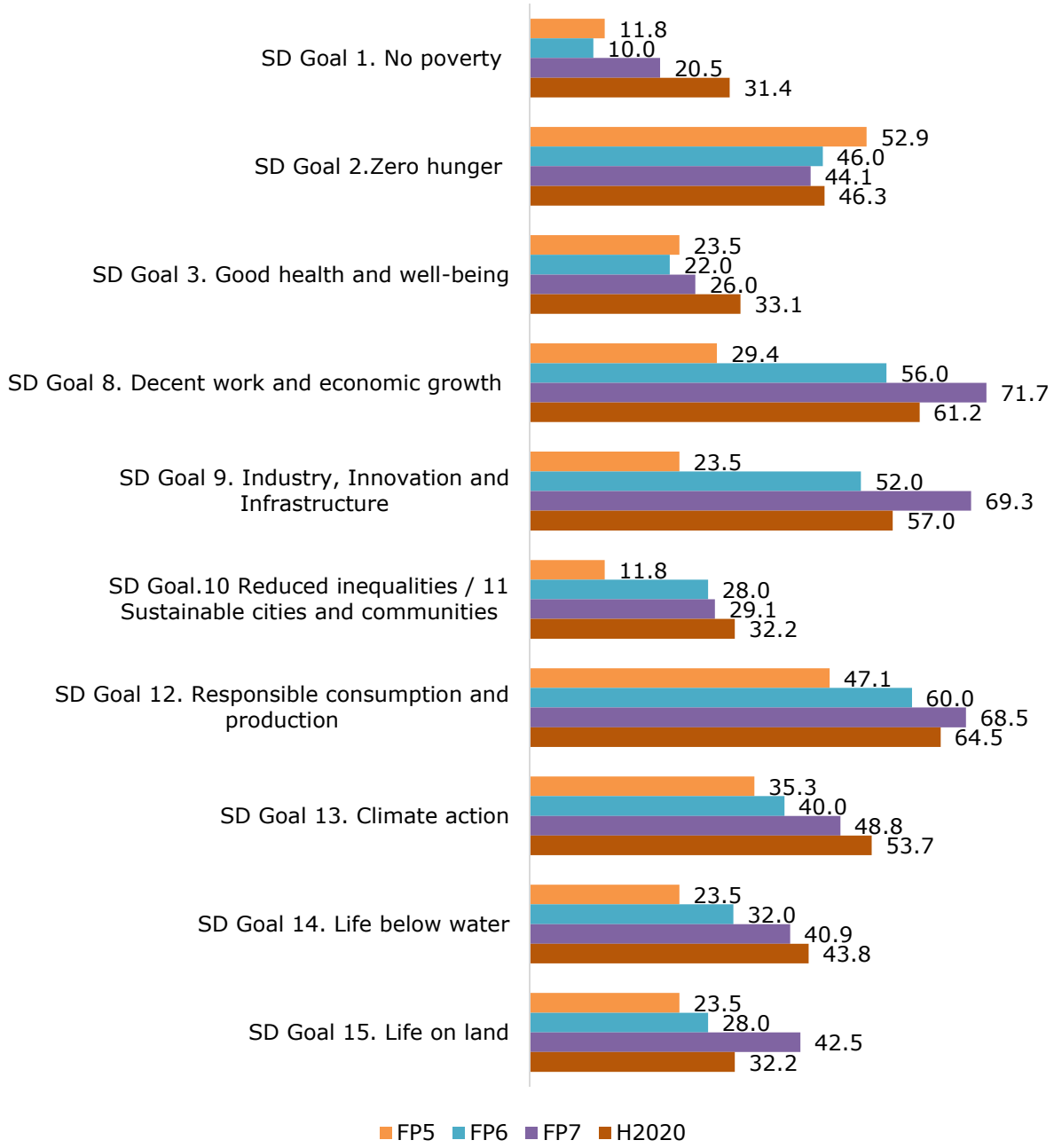

Figure 33. Percentage (%) of contribution to SDG reported in different Framework Programmes.

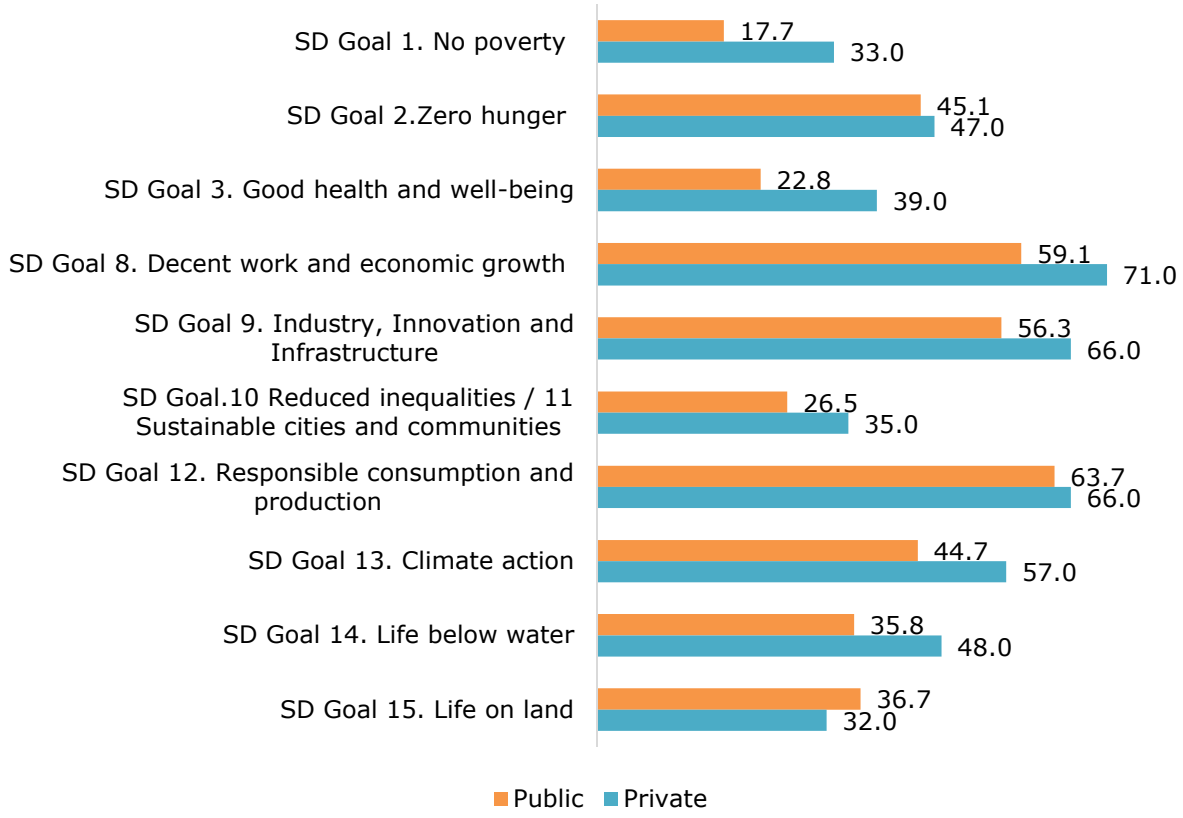

Figure 34. Percentage of public vs private coordinators reporting contribution to different SDG.

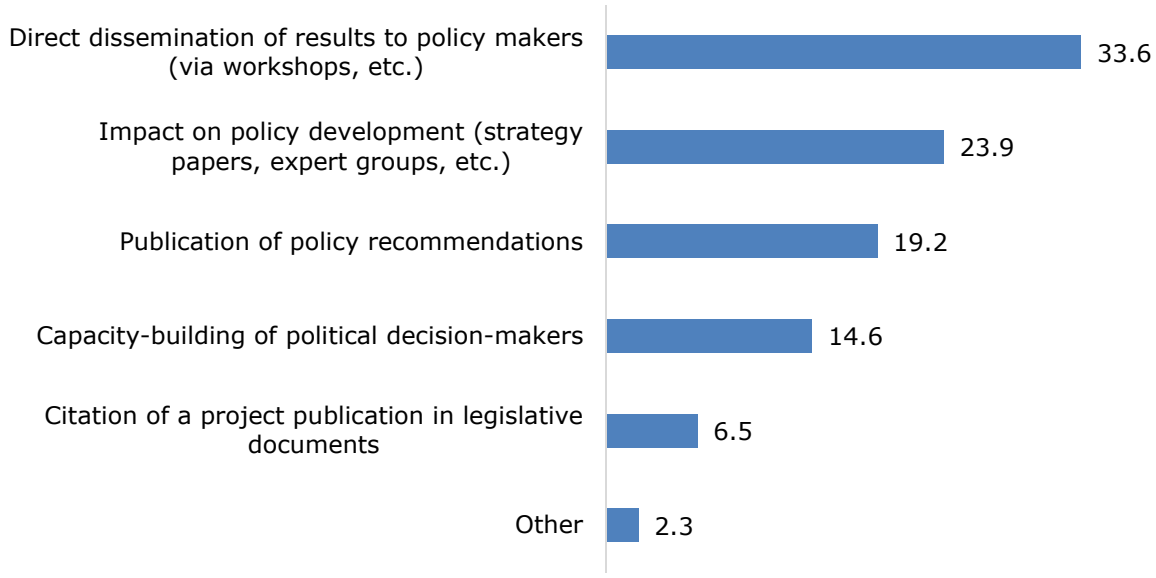

Figure 35. Means used by projects to create impact on policies.

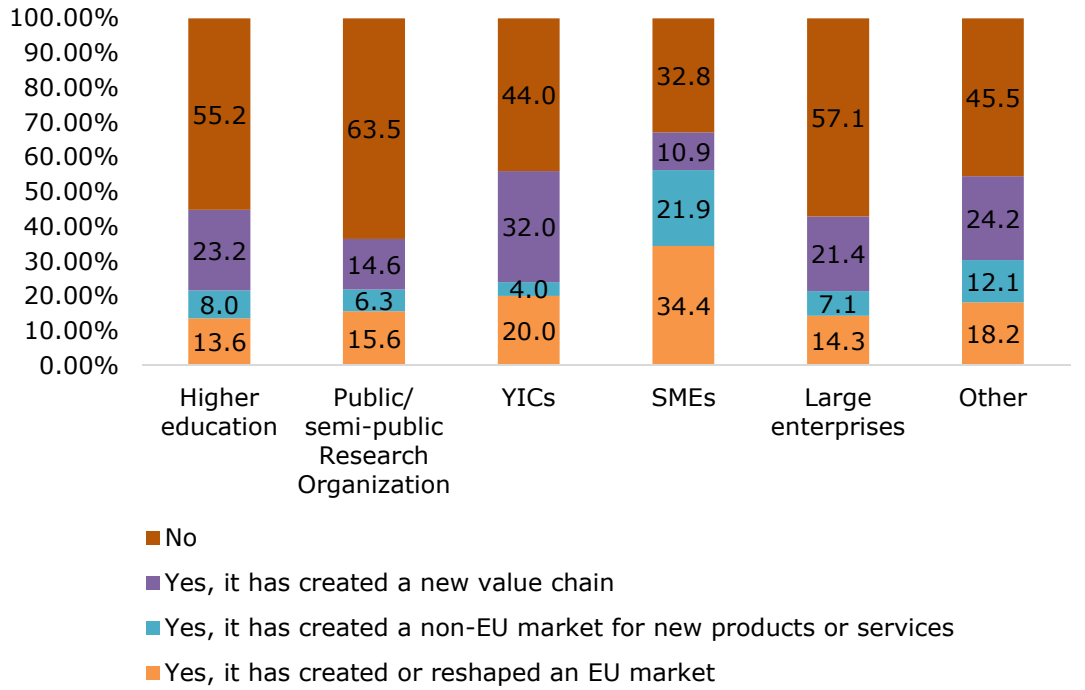

Figure 36. Percentage (%) of coordinators categorised by organisation type reporting a contribution to creation of new markets or value chains.

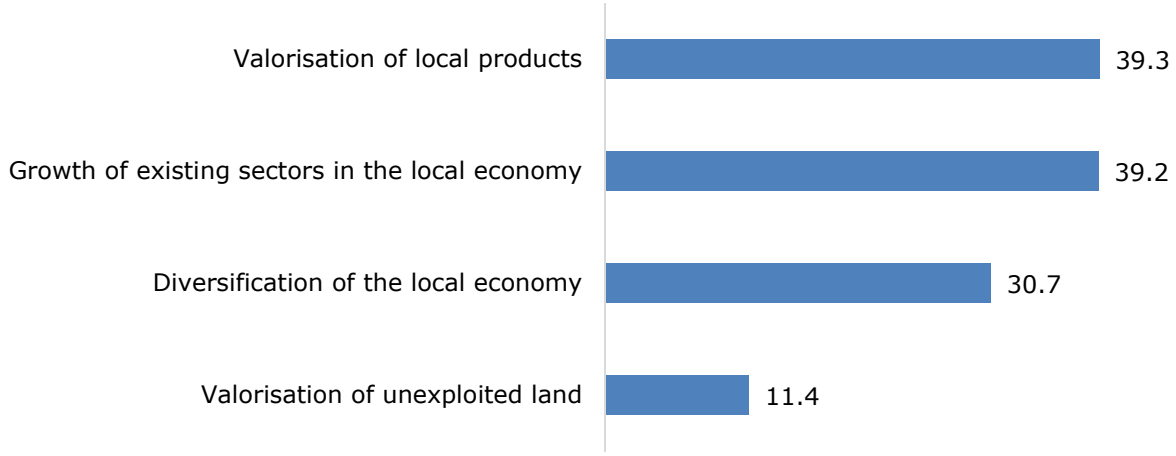

Figure 37. Percentage (%) of coordinators reporting specific impacts on regional economy.

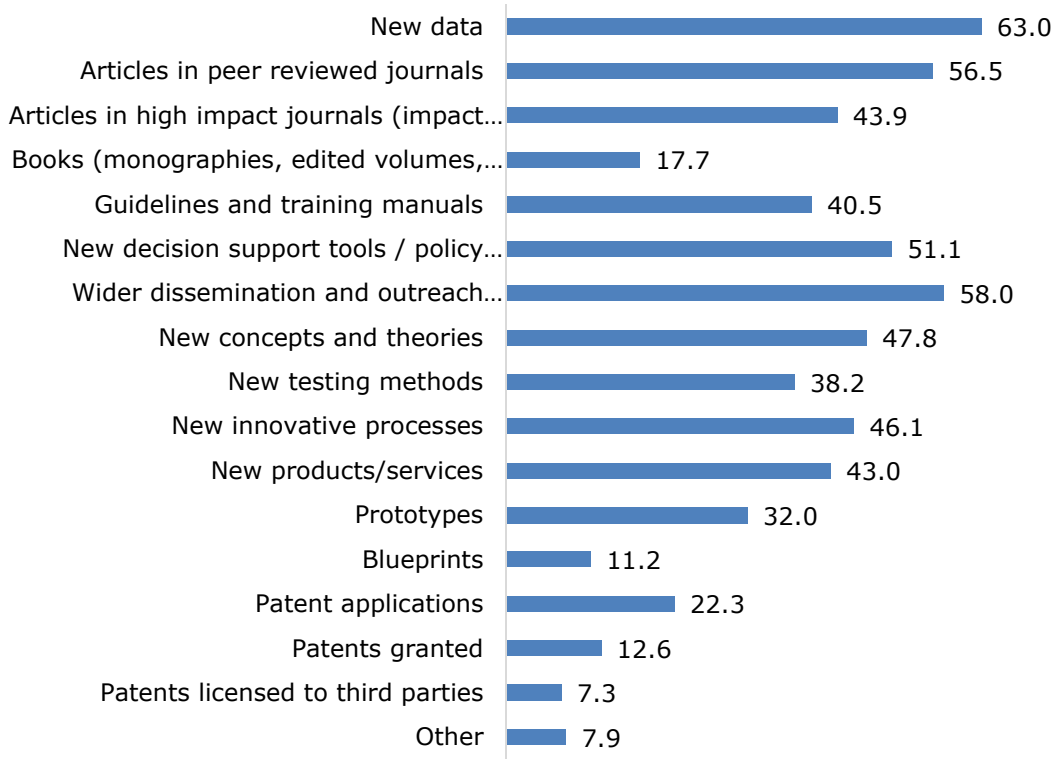

Figure 38. Percentage of coordinators reporting important outputs for generation of impacts

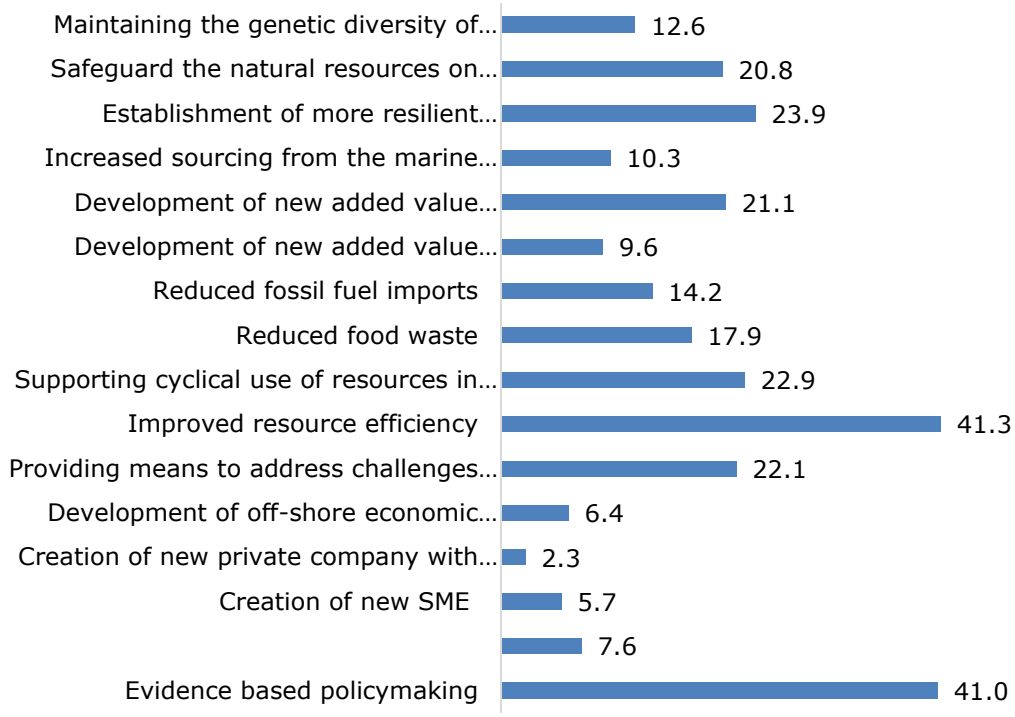

Figure 39. Percentage of coordinators reporting important results to generation of impacts.

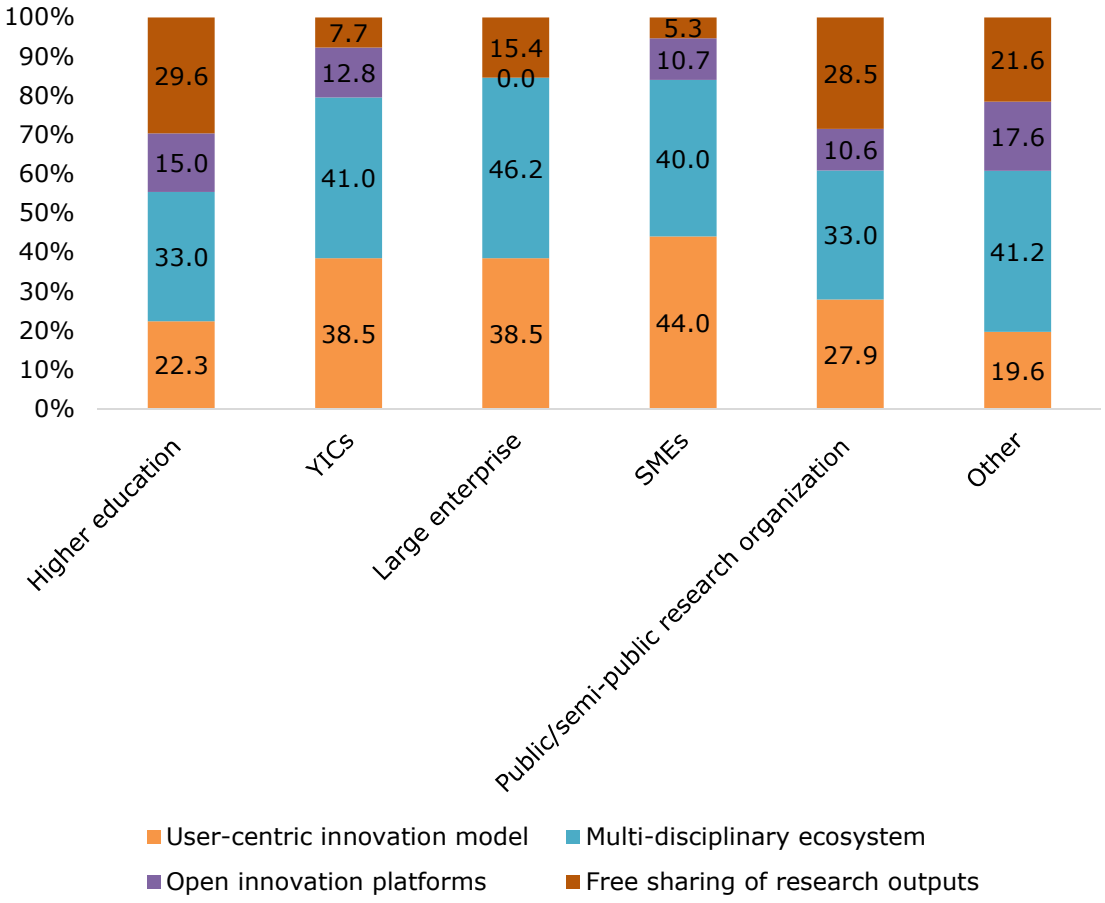

Figure 40. Percentage (%) of coordinators categorised by organisation type reporting applying open science and innovation approaches.

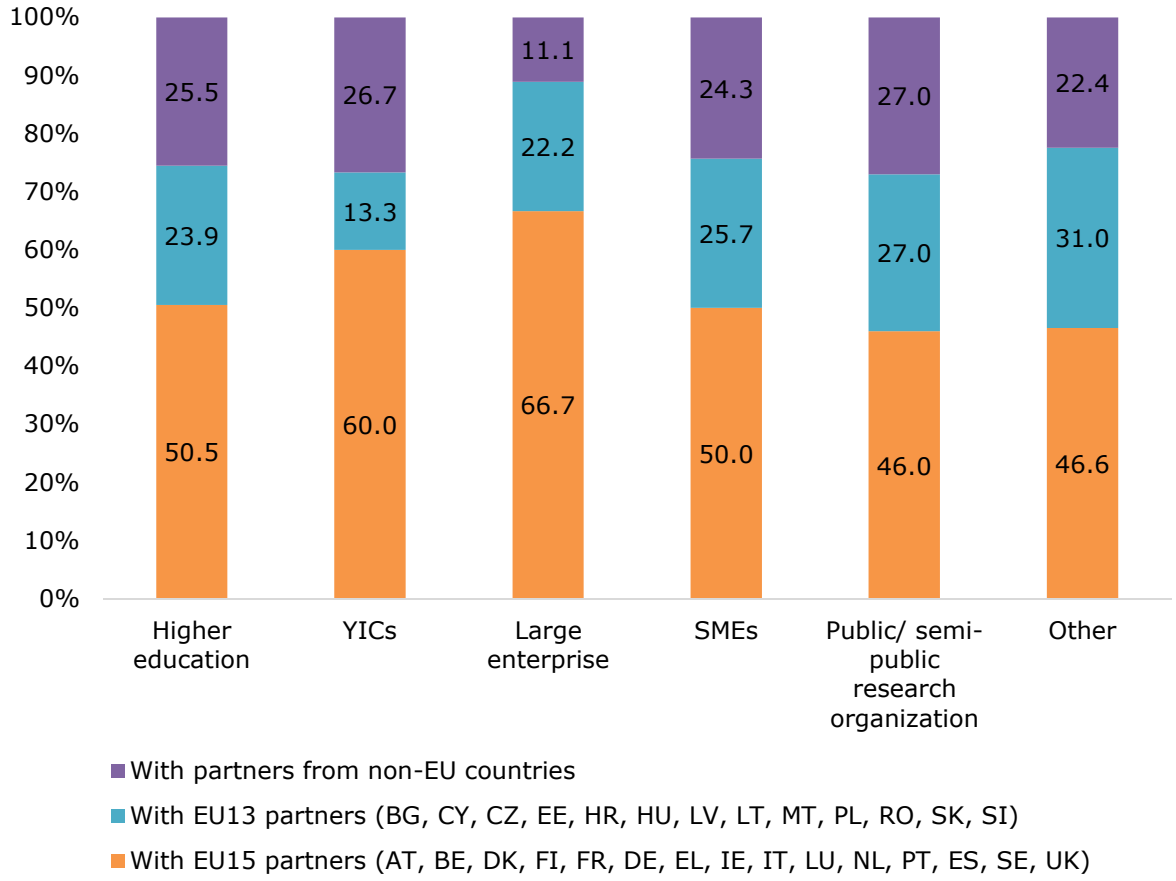

Figure 41. Percentage of coordinators categorised by organisation type reporting expansion of long-term network of collaborators from different countries.

Major Impact	SDGs	FOOD 2030	
Securing safe and high quality food for all			**NUTRITION for sustainable and healthy diets**
Mitigating and/or adapting to climate change			**CLIMATE smart and environmentally sustainable food systems**
Safeguarding resources, ecosystems and biodiversity			**CIRCULARITY and resource efficiency of food systems**
Competitive European economy and strong communities			**INNOVATION and empowerment of communities**

Figure 42. Links between SC2 Major Impacts, the UN SDGs and the themes in FOOD 2030.

Table 1. Overview of the project portfolio in FP5 to H2020 that supports Societal Challenge 2

Framework Programme	Number of projects	EU contribution (million Euros)
Framework Programme 5 (FP5)	1,098	782
Framework Programme 6 (FP6)	345	934
Framework Programme 7 (FP7)	494	1,754
Horizon 2020 (H2020, to 31.12.2015)	368	853
Total	2,305	4,324

Table 2. Response rate to the survey addressed the coordinators per FP

	Population		Sample	
Framework Programme	Count	%	Count	%
H2020	365	*21.1*	121	*35.4*
FP7	514	*29.7*	135	*39.5*
FP6	386	*22.3*	56	*16.4*
FP5	463	*26.8*	30	*8.8*
TOTAL	1728	*100.0*	342	*100.0*

Table 3. Response rate to the survey (sample) addressing the coordinators per FP and category of funded activity

	Support of R&D		Research and technological development		Close to market research/ innovation	
Framework Programme	Sample	Population	Sample	Population	Sample	Population
H2020	19	55	40	82	62	231
FP7	20	106	107	388	0	0
FP6	13	161	37	183	0	1
FP5	1	168	16	415	0	331
TOTAL	53	490	200	1068	62	563

Table 4. Number of coordinators responded to the survey per FP, category of funded activity, type of coordinating organization and type of project activity

	FP5		FP6		FP7		H2020	
	Count	%	Count	%	Count	%	Count	%
Category of funded activity								
Research and technological development	16	94.1	35	72.9	108	84.2	40	33.0
Support to R&D activities	1	5.9	13	27.1	20	15.8	19	15.7
Close to market research/innovation	0	0	0	0	0	0	61	51.3
Total	17	100.0	48	100.0	128	100.0	120	100.0
Type of coordinating organization								
Higher education institution	13	76.5	17	35.4	61	47.7	18	15.0
Public/semi-public research organization	3	17.6	20	41.7	47	36.7	24	20.0
YIC	0	0	0	0	1	0.8	21	17.5
SEM	0	0	2	4.2	6	4.7	40	33.3
Large enterprise	1	5.9	2	4.2	0	0	8	6.7
Other	0	0	7	14.5	13	10.1	9	7.5
Total	17	100.0	48	100.0	128	100.0	120	100.0
Type of project activity*								
Basic Research	15	42.9	21	25.9	55	27.0	32	15.8
Applied Research	14	40.0	42	51.9	103	50.5	85	42.1
Development	6	17.1	15	18.5	35	17.2	77	38.1
Other	0	0	3	3.7	11	5.4	8	4.0
Total	35	100.0	81	100.0	204	100.0	202	100.0

**Multiple answers were allowed to cover for projects with mixed activities*

Table 5. Survey impacts that contribute to Sustainable Development Goals (SDGs). The mapping was performed according to the European Commission strategies and policies to serve UN SDGs as they are presented in the Commission staff working document (2016) 390 final

Survey impacts	SDG
Economic growth	8
Creation of new jobs	1, 8
Improved competitiveness of European biobased industry	8, 9
Improved competitiveness of European aquatic and marine industry	8, 9
Improved competitiveness of European food industry	8, 9
Improved competitiveness of European forestry industry	8, 9
Improved sustainability of European biobased industry	12, 15
Improved sustainability of European aquatic and marine industry	12, 14
Improved sustainability of European food industry	12
Improved sustainability of European forestry industry	12
Improved competitiveness of EU agriculture	8, 9
Improved sustainability of EU agriculture	12
Reduced (negative) environmental impacts	13
Improved working conditions	3
Strengthened rural economies	10, 11
Strengthened coastal economies	10, 11
Improved food security	2
Improved food safety	2
Increased high-quality food supply	2
Supporting climate smart and environmentally sustainable food production systems	12, 13
Reduced hunger/malnutrition in the world	2
Healthier diets	3
More sustainable diets	2, 3

Table 6. Percentage of responding coordinators of different types that reported the creation of temporary and permanent jobs

Type of Job	Higher education institutions	Public/semi-public research organizations	YICs	SMEs	Large enterprises
Temporary scientific jobs	53.1	55.4	36.4	27.1	27.3
Temporary scientific jobs for young people	53.2	50.0	22.7	18.8	9.1
Temporary technical (e.g. engineering) jobs	29.3	37.2	54.5	20.8	18.2
Temporary technical jobs for young people	21.1	30.9	27.3	20.8	0.0
Temporary administrative jobs	40.3	20.3	22.7	20.8	18.2
Temporary administrative jobs for young people	20.2	6.4	4.5	12.5	9.1
Permanent scientific jobs	28.4	17.0	36.4	20.8	45.5
Permanent scientific jobs for young people	19.3	13.9	13.6	10.4	9.1
Permanent technical jobs	12.8	10.6	50.0	33.4	45.5
Permanent technical jobs for young people	9.2	7.4	22.7	20.8	18.2
Permanent administrative jobs	11.0	7.5	31.8	18.8	36.4
Permanent administrative jobs for young people	4.6	4.3	18.2	12.5	9.1

Table 7. Percentage of different types of coordinating organizations reporting high/very high importance of outputs in contribution to impacts

Outputs	Higher education	Public/ semi-public research organization	YICs	SMEs	Large enterprises	Other
New data	69.9	61.6	72.7	49.0	80.0	50.0
Articles in peer reviewed journals	75.0	68.4	10.0	18.7	36.4	48.3
Articles in high impact journals (IF>3)	64.5	45.1	10.0	13.1	18.2	42.9
Books (monographies, edited volumes, etc.)	27.7	16.6	0.0	6.4	9.1	21.5
Guidelines and training manuals	48.1	47.3	23.8	21.3	27.3	39.3
New decision support tools / policy recommendations	60.2	57.2	23.8	29.7	36.4	57.1
Wider dissemination and outreach publications	70.8	59.4	20.0	37.5	54.6	65.5
New concepts and theories	46.1	46.7	59.1	47.9	72.8	37.9
New testing methods	37.5	41.8	36.3	31.9	54.6	34.5
New innovative processes	37.6	37.0	57.1	64.6	54.6	58.6
New products/services	31.4	33.0	63.7	68.8	63.7	44.8
Prototypes	20.6	22.0	54.5	60.4	45.5	32.2
Blueprints	15.3	9.0	4.8	6.5	10.0	17.8
Patent applications	18.8	16.3	54.5	33.3	18.2	10.7
Patents granted	11.9	12.2	13.6	16.6	0.0	10.7
Patents licensed to third parties	6.0	4.4	9.5	17.4	0.0	7.1
Other	3.6	13.3	0.0	6.8	25.0	10.0

Table 8. Percentage of importance of different outputs in the three categories of funded activity in the generation of impacts across FPs

	Importance	Support to R&D	Research and technological development	Close-to.market research and innovation	Total
Wider dissemination and outreach publications	No importance	0.0	0.0	13.3	2.6
	Low	10.0	8.1	23.3	11.4
	Medium	24.0	20.8	26.7	22.5
	High	22.0	37.1	18.3	30.9
	Very high	38.0	29.4	8.3	26.7
	Not applicable	6.0	4.6	10.0	5.9
	Total	100.0	100.0	100.0	100.0
Guidelines and training manuals	No importance	3.9	4.1	11.7	5.6
	Low	15.7	23.6	20.0	21.6
	Medium	17.6	17.9	23.3	19.0
	High	17.6	26.2	16.7	22.9
	Very high	27.5	18.5	5.0	17.3
	Not applicable	17.6	9.7	23.3	13.7
	Total	100.0	100.0	100.0	100.0
Books (monographs, edited volumes, etc.)	No importance	12.0	12.6	27.1	15.3
	Low importance	20.0	22.5	22.0	22.0
	Medium Importance	14.0	24.6	10.2	20.0
	High importance	12.0	12.6	6.8	11.3
	Very high importance	10.0	6.8	0.0	6.0
	Not applicable	32.0	20.9	33.9	25.3
	Total	100.0	100.0	100.0	100.0
Articles in peer reviewed journals	No importance	8.0	2.0	21.7	6.8
	Low importance	16.0	5.0	23.3	10.3
	Medium Importance	20.0	15.0	11.7	15.2
	High importance	14.0	35.5	8.3	26.8
	Very high importance	18.0	39.0	6.7	29.4
	Not applicable	24.0	3.5	28.3	11.6
	Total	100.0	100.0	100.0	100.0
Articles in high impact journals (impact factor over 3)	No importance	6.0	9.1	21.1	10.8
	Low importance	22.0	10.6	21.1	14.4
	Medium Importance	16.0	14.1	15.8	14.8
	High importance	12.0	31.3	5.3	23.3
	Very high importance	12.0	27.3	3.5	20.3
	Not applicable	32.0	7.6	33.3	16.4
	Total	100.0	100.0	100.0	100.0
Patent applications	No importance	24.0	24.9	6.6	21.1
	Low importance	14.0	11.9	9.8	11.8
	Medium Importance	2.0	10.4	19.7	10.9

	High importance	0.0	13.0	32.8	14.8
	Very high importance	4.0	6.2	13.1	7.2
	Not applicable	56.0	33.7	18.0	34.2
	Total	100.0	100.0	100.0	100.0
Patents granted	No importance	26.5	27.6	18.3	25.6
	Low importance	14.3	10.4	13.3	11.6
	Medium Importance	2.0	4.7	8.3	5.0
	High importance	0.0	8.9	11.7	8.0
	Very high importance	0.0	3.6	10.0	4.3
	Not applicable	57.1	44.8	38.3	45.5
	Total	100.0	100.0	100.0	100.0
Patents licensed to third parties	No importance	24.5	32.8	20.7	29.1
	Low importance	16.3	6.8	8.6	8.7
	Medium Importance	2.0	5.2	10.3	5.7
	High importance	0.0	3.6	12.1	4.7
	Very high importance	0.0	1.6	6.9	2.3
	Not applicable	57.1	50.0	41.4	49.5
	Total	100.0	100.0	100.0	100.0
Prototypes	No importance	18.8	18.5	1.6	15.1
	Low importance	14.6	10.3	8.2	10.5
	Medium Importance	6.3	12.3	18.0	12.5
	High importance	4.2	10.3	16.4	10.5
	Very high importance	2.1	16.9	49.2	21.1
	Not applicable	54.2	31.8	6.6	30.3
	Total	100.0	100.0	100.0	100.0
New products/services	No importance	12.2	13.1	3.2	10.9
	Low importance	12.2	9.4	4.8	8.9
	Medium Importance	12.2	17.8	12.9	15.9
	High importance	6.1	18.3	25.8	17.9
	Very high importance	20.4	17.8	50.0	24.8
	Not applicable	36.7	23.6	3.2	21.5
	Total	100.0	100.0	100.0	100.0
New innovative processes	No importance	8.0	11.4	4.9	9.5
	Low importance	10.0	5.2	3.3	5.6
	Medium Importance	8.0	23.8	16.4	19.7
	High importance	14.0	19.7	26.2	20.1
	Very high importance	26.0	20.7	41.0	25.7
	Not applicable	34.0	19.2	8.2	19.4
	Total	100.0	100.0	100.0	100.0
New concepts and	No importance	4.0	8.7	11.3	8.4

theories	Low importance	10.0	9.2	9.7	9.4
	Medium Importance	22.0	20.9	12.9	19.5
	High importance	10.0	31.1	27.4	26.9
	Very high importance	18.0	18.9	27.4	20.5
	Not applicable	36.0	11.2	11.3	15.3
	Total	100.0	100.0	100.0	100.0
New testing methods	No importance	10.4	13.7	8.2	12.1
	Low importance	10.4	10.7	14.8	11.4
	Medium Importance	14.6	15.7	9.8	14.4
	High importance	6.3	21.8	16.4	18.3
	Very high importance	18.8	19.3	21.3	19.6
	Not applicable	39.6	18.8	29.5	24.2
	Total	100.0	100.0	100.0	100.0
New data	No importance	8.3	4.1	8.5	5.6
	Low importance	8.3	4.1	3.4	4.6
	Medium Importance	12.5	17.9	16.9	16.8
	High importance	18.8	33.2	37.3	31.7
	Very high importance	20.8	36.7	20.3	31.0
	Not applicable	31.3	4.1	13.6	10.2
	Total	100.0	100.0	100.0	100.0
New decision support tools / policy recommendations	No importance	1.9	4.7	16.9	6.6
	Low importance	5.8	10.9	16.9	11.2
	Medium Importance	7.7	14.6	10.2	12.5
	High importance	25.0	22.4	11.9	20.8
	Very high importance	48.1	30.2	13.6	30.0
	Not applicable	11.5	17.2	30.5	18.8
	Total	100.0	100.0	100.0	100.0
Blueprints	No importance	12.8	22.8	20.7	20.7
	Low importance	10.6	7.4	10.3	8.5
	Medium Importance	6.4	7.9	17.2	9.5
	High importance	8.5	5.8	3.4	5.8
	Very high importance	2.1	5.3	6.9	5.1
	Not applicable	59.6	50.8	41.4	50.3
	Total	100.0	100.0	100.0	100.0

Table 9. Percentage of high/very high importance of different results to generation of impacts by different types of coordinating organizations

Results	Higher education	Public/semi-public Research Organization	YICs	SMEs	Large Enterprise	Other
Maintaining the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks	44.6	35.8	50.0	20.0	20.0	37.5
Safeguard the natural resources on which agricultural production depends	53.5	36.2	43.8	56.0	16.7	38.9
Establishment of more resilient agricultural and forestry practices that help maintain ecosystems	57.5	48.4	50.0	46.2	28.6	47.1
Increased sourcing from the marine environment	20.8	29.8	20.0	37.5	60.0	50.0
Development of new added value products of terrestrial and aquatic origin	51.4	41.2	61.1	46.2	33.3	50.0
Development of new added value products from wood and other lignocellulosic sources	22.0	27.3	33.3	14.3	37.5	56.3
Reduced fossil fuel imports	28.6	28.0	41.2	40.6	37.5	40.0
Reduced food waste	33.9	38.9	66.7	45.2	14.3	61.9
Supporting cyclical use of resources in the economy	44.9	46.2	66.7	57.6	44.4	60.0
Improved resource efficiency	69.8	60.3	76.2	71.1	45.5	81.5
Providing means to address challenges related to market disruptions and the functioning of the food chain	54.8	38.2	60.0	72.7	28.6	57.9
Development of off-shore economic activities	18.4	18.6	26.7	30.8	16.7	62.5
Creation of new private company with >250 employees	3.8	0.0	0.0	1.1	4.2	0.0
Creation of new SME	7.8	5.3	10.0	1.1	10.6	3.4
Creation of new Young Innovative Company	6.9	42.8	9.1	2.2	8.5	0.0
Set up new research infrastructure	25.5	24.7	20.0	22.2	27.3	7.1
Knowledge ready for practice	57.9	56.5	40.0	72.4	54.6	42.8
Development of industry standards	15.7	9.1	21.1	19.5	20.0	18.5
Development of new technologies	31.4	35.9	54.5	59.6	54.5	46.5
Input to national of regional policies	38.2	37.7	15.0	13.0	27.3	48.1
Input to international agreements/conventions	24.7	24.2	15.8	11.1	9.1	23.1
Evidence based policymaking	81.2	75.7	53.3	37.9	50.0	69.2

Table 10. Percentage of different coordinating organizations reporting establishing collaborations outside the consortium

		Higher education	YICs	Large Enterprise	SMEs	Public/ semi-public research organization.	Other	Total
YIC	Within-EU	37.2	52.6	37.5	15.6	16.4	16.7	27.3
	Non-EU	1.2	0.0	0.0	3.1	2.7	0.0	1.7
	Both	1.2	5.3	0.0	3.1	5.5	4.2	3.3
	Not Applicable	60.5	42.1	62.5	78.1	75.3	79.2	67.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SME	Within-EU	46.3	50.0	25.0	48.9	42.4	30.8	43.7
	Non-EU	2.1	0.0	0.0	6.7	0.0	3.8	2.2
	Both	5.3	5.6	25.0	15.6	8.2	11.5	9.0
	Not Applicable	46.3	44.4	50.0	28.9	49.4	53.8	45.1
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Large enterprise	Within-EU	33.3	43.8	37.5	45.2	27.1	26.1	33.2
	Non-EU	1.1	0.0	0.0	9.7	4.3	4.3	3.4
	Both	10.3	6.3	12.5	9.7	10.0	13.0	10.2
	Not Applicable	55.2	50.0	50.0	35.5	58.6	56.5	53.2
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Higher education institutions	Within-EU	50.0	61.1	88.9	48.6	42.4	37.0	48.2
	Non-EU	0.0	5.6	0.0	2.9	1.2	7.4	1.8
	Both	35.8	5.6	0.0	14.3	32.9	22.2	27.9
	Not Applicable	14.2	27.8	11.1	34.3	23.5	33.3	22.1
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Public or semi-public Research Organisation	Within-EU	53.1	61.1	71.4	51.4	45.3	30.8	49.3
	Non-EU	2.0	5.6	0.0	2.7	5.8	3.8	3.7
	Both	26.5	5.6	0.0	5.4	32.6	34.6	24.3
	Not Applicable	18.4	27.8	28.6	40.5	16.3	30.8	22.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Other	Within-EU	10.6	8.3	0.0	5.3	17.8	22.2	13.1
	Non-EU	0.0	0.0	0.0	0.0	2.2	5.6	1.4
	Both	2.1	0.0	0.0	0.0	4.4	11.1	3.4
	Not Applicable	87.2	91.7	100.0	94.7	75.6	61.1	82.1
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

ANNEX 1: METHODOLOGY

This paper records the methods used by the Interim Evaluation Expert Group's investigation of approaches to portfolio analysis and impact assessment. The overall purpose is to develop methods for the assessment of the impact of Framework Programme activities supporting Societal Challenge 2 and to provide input into the development of the next Framework Programme.

This purpose was pursued through investigation of the whole portfolio of the projects in FP5 to Horizon 2020 (projects started before 1 January 2017) that align with Horizon 2020 Societal Challenge 2. We identified 2,305 projects with a total EU contribution of 4,324 million Euros. The investigation involved:

1. portfolio impact mapping with a 'bottom-up' and project content-based analysis of the portfolio in terms of the main primary users, relevant users' activities ('impact areas'), and the main subject area of each project;

2. an analysis of users' perceptions of the impacts within user communities (combinations of primary users and their activities) identified in 1; and

3. a survey of project coordinators' views and reports of the outputs and impacts of the projects. The survey was set up according to the standards of a previous survey conducted in 2010, and it was expanded to include additional investigation relevant to the European Commission's definitions of relevant impacts and the UN's Sustainable Development Goals (SDG).

The portfolio impact mapping (1) provides an overview of how the portfolio relates to direct users and their activities (impact areas). The analysis of users' perceptions (2) provides insights into how potential users and beneficiaries of project activities perceive impacts. The survey of coordinators (3) provides insight into how project consortia (represented by their coordinators) view the impact of their work. A graphical overview of the methodology in this report is illustrated in Figure 43.

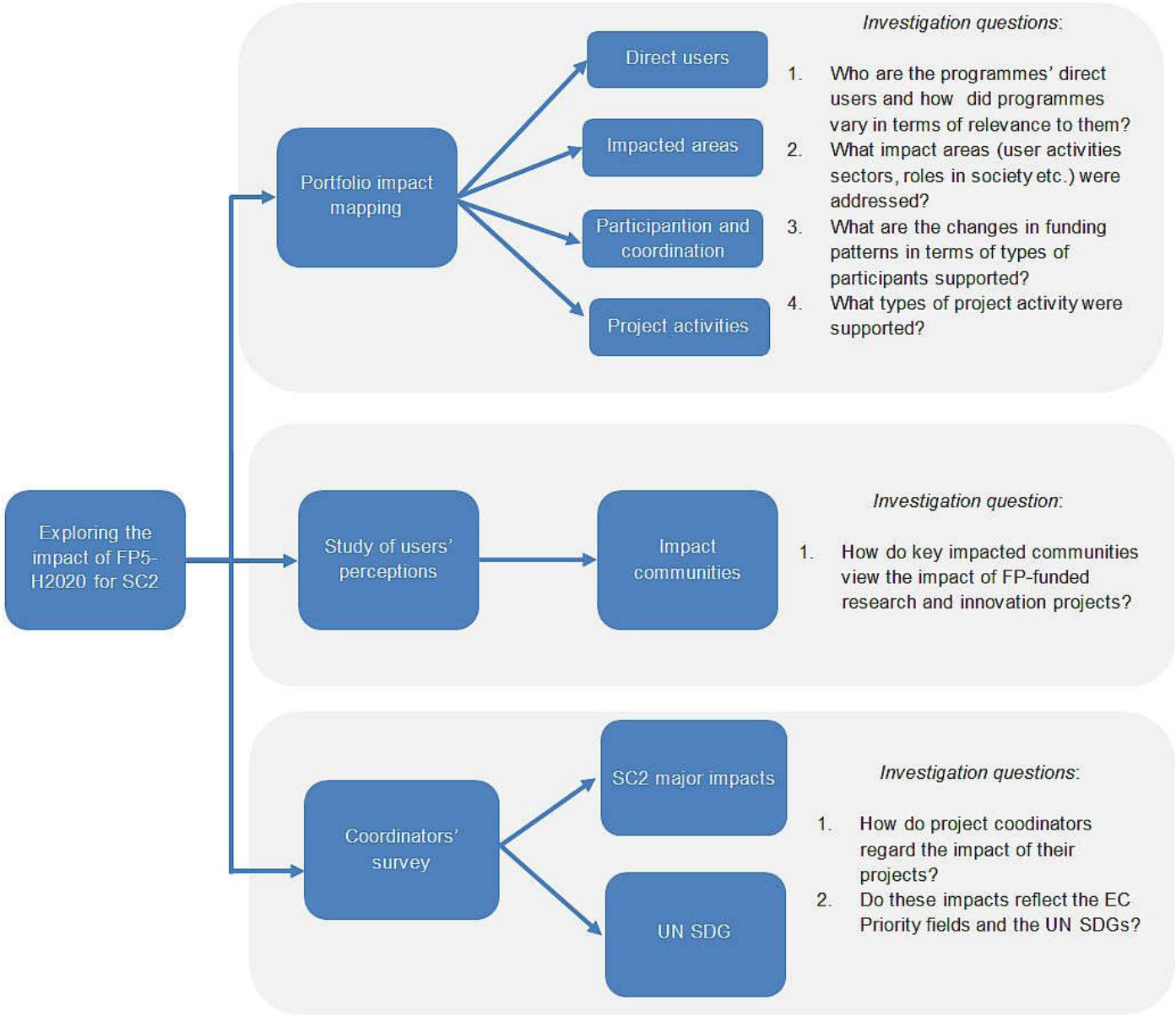

Figure 43. Overview of the methodological framework

Portfolio impact mapping

This work addressed two questions: what direct (primary) users and users' activities (impact areas) are supported by the portfolio and how has the funding of participants developed in relation to the increased emphasis on broad societal impact (SC2). Impact in terms of SC2 depends on direct users using outputs to innovate in relevant impact areas. The underlying idea is that examination of the portfolio in terms of its direct users, their relevant impact areas, and the type of project activity supported provides a basis and framework for examining impact, assessing trends, and input into further programme planning.

Step 1: Identifying the SC2-aligned projects
A list of projects from all the relevant parts of the Framework Programmes potentially aligned to SC2 was compiled for each programme (FP5 to Horizon 2020). The *Food Quality & Safety – From Farm to Fork* programme in FP6 and the *Knowledge-Based Bioeconomy programme area (KBBE)* in FP7 were tightly aligned to SC2 in Horizon 2020. In contrast, SC2-supporting projects in FP5 were found in five FP5 programme areas: *Food, nutrition and health; Control of infectious diseases; The "Cell Factory"; Sustainable agriculture, fisheries and forestry;* and *Support to research infrastructures*. Therefore a very large number of projects needed to be assessed individually for relevance to SC2. In most cases, this could be done from the project name. It was noticeable that project names in FP5 were more focused and indicative of relevance to users and impact areas compared with projects in subsequent programmes.

In addition to identifying SC2 projects across a wide range of programme areas, areas of the programme expected to be aligned to SC2 contained projects that do not support SC2 in Horizon 2020. This is mostly due to the "Excellent Science" pillar in Horizon 2020 and FP7 that supports fundamental curiosity-driven research through the European Research Council separately from Societal Challenge activities. In earlier Framework Programmes, themed areas aligned to SC2 (e.g. *Food Quality & Safety – From Farm to Fork*) included both basic research analogous to "Excellent Science" and the applied research analogous to SC2. Such projects in earlier FPs that support Excellent Science rather than SC2 were identified and categorized as outside the SC2-aligned project portfolio. Absence of indication of any application or relevance to any application in the title or abstract was the main criterion for allocating a project to Excellent Science rather than SC2.

This basic screening identified 2,305 SC2-aligned projects across the four programmes as follows: FP5: 1,098; FP6: 345; FP7: 494; Horizon 2020: 368.

Step 2: Categorising the direct (primary) users
The next step was to categorise each project according to the main direct user of the project results. 'Direct users' are those actors who are the first users of project outputs. This was done in a bottom-up way using expert judgement to identify the main direct user by reading the project title and abstract. This process depends on subjective expert judgement about the identity of the main direct user for each project. Therefore, to support a common unified approach, all projects were provisionally classified by two thematic experts (agriculture, food, bio-based economy; and

fisheries/aquaculture). These classifications were validated by the other thematic experts for individual thematic areas.

Step 3: Categorising the impact areas
The next step was to identify the impact areas. These 'impact areas' are the users' (primary and secondary) activities that generate impact. In conjunction with Step 2, the same two experts conducted this analysis initially, and their categorisation was subsequently validated by the other thematic experts.

Step 4: Categorising the project activities
The first results of Step 2 and Step 3 indicated that categorising of the projects' main activity in technical or scientific discipline terms would be a useful extra category. Using the procedures for Step 2 and 3, each project was categorized for the main subject area in the same way, and validated using all thematic experts.

Step 5: Consolidation
A major purpose of the portfolio analysis is to allow changes in portfolio over time that are relevant to impact and impact potential to be identified. This trend analysis requires consolidation of categories. Through repeated inspections and consolidation of the categorisations, 11 categories of direct users, 40 impact areas and 77 project activity areas were defined.

Study of users' perceptions
The aim here was to gain insights into users' perceptions of the outcomes and impacts. This was done by conducting a Delphi survey of users.

Impact areas and user communities
Combinations of categories of direct users and their impact-related activities (impact areas) identified in the portfolio analysis allowed the identification of 'impact communities'. These are groups of actors that share an interest in and act on a distinct part of the project portfolio, e.g., groups or sectors involved in farming and forestry, marine-based activities and the bio-based industries. Six 'impact communities' were identified for the purpose of conducting case studies across the programme to ensure the survey was representative of the portfolio that is directly relevant to users. These user communities were identified using the following criteria:

1. spread across the Horizon 2020 Societal Challenge 2 sub-programme areas: agriculture and forestry, food, aquatic resources and marine, and bio-based industries;
2. representativeness of private sector user communities (not policy);
3. coverage of a substantial activity in the SC2 area; and
4. presence of relevant projects in most or all of the four Framework Programmes under examination.

The six 'impact areas/impact communities' selected are presented in Table 1, as is the number of projects in the different FPs related to these impact areas and communities.

Table 11. Basic portfolio data by impact communities (EU contribution is in 1,000 Euros)

Impact communities		FP5	FP6	FP7	H2020	Total
Dairy farmers	No. of projects	11	1	8	4	24
	EU contribution	12,215	525	38,446	4,096	55,282
Cereal and grain legume crop breeders	No. of projects	23	8	21	1	53
	EU contribution	23,934	50,077	89,319	3,430	166,759
Aquaculture selection/ breeding sector	No. of projects	6	5	1	2	14
	EU contribution	6,750	6,102	6,000	14,000	32,851
Lignocellulose processing industry	No. of projects	1	3	4	14	22
	EU contribution	430	19,395	23,393	103,350	146,568
Bio-based materials and polymers sector	No. of projects	8	1	3	7	19
	EU contribution	10,328	8,983	19,082	19,882	58,275
Food industry with respect to food safety	No. of projects	42	35	22	12	111
	EU contribution	27,353	141,485	89,948	29,766	288,553

The Dephi method

The Delphi method is a technique to establish consensus in the topic being investigated through analysis and convergence of opinions from respondents, usually experts within their domain. It is an iterative process that collects and refines the anonymous judgments of a set of experts using a series of questionnaires interspersed with iterations and controlled feedbacks. The method involves the repeated individual questioning of the experts through a series of rounds. In each round, every participant takes part in an interview, usually through a semi-structured questionnaire. The first round is exploratory. Each subsequent round/questionnaire is developed based on the results of the previous round. For each round, the researcher collects, edits, sums up comments and reasons underlying opinions and views, and returns a statement of the position of the whole panel and the participant's own positions to each participant.

The Delphi Method has three key features:

1. anonymity: respondents are anonymous to each other but not to the researcher. This reduces the effect of dominant individuals and minimizes the effect of group dynamics such as manipulation or social pressure to conform to others in the group;
2. iteration: participants are allowed to refine their views in light of the progress of the group's work from round to round; and
3. controlled feedback: participants are informed of the other participants' opinions, perspectives and judgements and provided with the opportunity to clarify or change their views.

This explorative method as used here aimed neither to be representative of the population of user communities nor of the population of projects funded under the FP. Its main aim was to test and develop a way of systematically accessing users insights into impact and to gain input into establishing priorities and approaches for future FP. Its main criterion is qualitative in nature and the expert selection within the selected user communities provides confidence that all relevant

issues are appropriately defined (fullfilling the criterion of saturation in qualitative analysis). The Delphi method was used to engage the external experts in user communities during June 2017-July 2017. The briefings and questions for Round 1 are provided in Annexes 3 to 8. The briefing and questions for Round 2 are provided in Annex 9.

The following steps were used to conduct the Delphi study:

Step 1: Selection of candidate external experts
The selection of the experts representing the six impact communities involved non–probability sampling techniques (purposive sampling): participants are selected for a purpose, i.e., their expertise and their deep understanding of the programme. For each of the six impact communities, the relevant thematic expert in the Expert Group identified at least 10 external experts in the relevant impact communities. The criteria were: a research user's perspective; spread across the 'impact community'; relevant geographic representation; and, where relevant, an ability to represent primary producers (farmers). All external sector experts were expected to have long experience in the specific sector; be familiar with impact generation through R&D investments; be familiar with Framework Programmes; and represent industry or other sectors. Some academic scientists were included where they were expected to have the broad experience needed to assess sector impact. A total of 73 experts were identified evenly distributed across the six case study user communities.

Step 2: Informing and inviting the experts
Experts were contacted in order to request participation through an invitation letter explaining the Delphi study, the criteria for the identification of experts and the procedures required for the Delphi study (the commitment required and the use that will be made of the information provided). An accreditation letter from Dr John Bell representing the European Commission was enclosed.

The response rate was low, even after follow-up personal letters and reminders from the Expert Group Chairmen. Only 16 experts offered to participate, well below that required to conduct six individual Delphi investigations. It was decided to pool the experts into one Delphi investigation for the whole SC2 programme area.

Table 12. Number of experts approached and their participation for each of the six user communities.

Impact communities	No. of experts invited	First round No. of responses	Second round No. of responses
Dairy farmers	14	4	3
Cereal and grain legume crop breeders	11	5	4
Fish breeders (aquaculture)	10	3	2
Lignocellulose processors	10	3	3
Bio-based materials and polymers sector	10	0	0
Food industry with respect to food safety	18	1	1
Total	73	16	13

Step 3: First-round questionnaire

Each expert who agreed to participate received a briefing pack describing the project portfolio under analysis and a glossary of terms (see Annexes 3 to 8). All rounds of questioning were carried out using email as the communication channel and a web application for the survey (surveymonkey). Thus, the experts also received an internet link to the survey questionnaire with the following set of questions:

1. What in your view have been the main outcomes and impacts of Framework Programme R&D projects in your area?
2. Considering the extend of the R&D activities set out, your own goals and wider societal goals, what outcomes and impacts do you think should be now emerging from the Framework Programmes?
3. Please describe how and why the Framework Programmes' impacts as you perceive them match those you have for your area of work.

Fourteen experts provided responses in Round 1.

Step 4: Second-round questionnaire

After the completion of the first round questionnaire, experts received a record of their answers, a summary of the wider group's responses and a further short questionnaire (second round questionnaire - Annex 9). Of the 14 contacted in the second round, 13 responded.

Coordinator survey: Assessment of impact based on ex-post evaluation

The starting point of the survey were the impacts identified for the interim evaluation of H2020 SC2[42], combined with previous EC surveys[43] for SC2-related projects. The design of the survey took into account two important requirements:

[42] Interim Evaluation of Horizon 2020: Societal challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy, pp. 98. European Commission, DG Research and Innovation (Decemberr 2016).

1. the need for a comprehensive view of the possible impacts from the relevant projects and the facility to back-trace from these impacts to results and outputs; and
2. a balance between covering a large number of possible impacts, results and outputs and avoiding a long complex survey questionnaire and "survey fatigue" within the targeted population of coordinators.

The full questionnaire compiled for the survey is available in Annex 10. It covered the following topics:

- General information regarding the project and the project coordinator's organization.
- Importance of project impacts achieved, together with descriptions of the most important project impacts.
- Identification of user groups that benefitted (and to what extent they benefitted) from the project.
- Importance of outputs of the project.
- Project characteristics in terms of user-centric innovation model approach, involving a variety of different actors, open innovation platforms, and open access.
- Within-EU and outside EU scientific research cooperation by type of partner;
- Creation of new markets or value chains.
- Impact on regional economy.
- Economic impact on coastal, less-developed, or rural areas.
- Direct and indirect job creation by the project.
- Policy impact of the project.
- Project influence on long-term network of partners.
- Additionality of the FP funding.

The survey uses Likert-scale questions to provide quantitative data relating to results, outputs and impacts of surveyed projects. In addition, a series of open questions were used. A number of impact-related questions have been preserved from the previous EC survey to maintain, to the extent possible, comparability with previous evaluation exercises.

Impacts

The questionnaire contained a pre-defined list of impacts that was compiled by the expert group and were identified as expected impacts according to the logic of intervention, the priorities of the Societal Challenge 2 Work Programme and the results of the Interim Evaluation of H2020 SC2. Considering that the list of expected impacts was broad, the items were further categorized according to two different classifications identified by the research group.

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[43] "Stock taking of results and impacts of RTD funded projects" survey for FP6 and FP7 (DG RTD annual report on programme evaluation activities 2011 – European Commison (2012)) & European Commision (2011). Innovation in Food, Agriculture, Fisheries and Biotechnologies.

First, the expected impacts listed in the questionnaire were aggregated into four major SC2 impacts (Table 13):

- Securing safe and high quality food for all.
- Mitigating and/or adapting to climate change.
- Safeguarding resources, ecosystems and biodiversity.
- Competitive European economy and strong communities.

Second, the contribution of the SC2-relevant research to the 2030 Agenda for Sustainable Development was assessed by linking the impacts listed in the questionnaire to 11 out of the 17 UN Sustainable Development Goals that were considered to contain particulars of the SC2 priorities (Table14).

Sampling

The unit of analysis is FP5, FP6, FP7 and H2020 SC2-related projects approved for funding and started by 1 January 2017. The reference population is the coordinators of 2,305 projects.

The survey was electronically distributed to the target population. In order to increase the response rate, an introduction letter by the EC and the EC electronic survey distribution channel was used. The survey was distributed on 25th April 2017 and two reminders followed (on May 8 and May 15, 2017). Not all project coordinators could be reached because of missing coordinator details, leaving us with 1,728 projects addressed in the survey. Missing e-mail addresses mainly related to FP5 projects.

Table 13. List of SC2 expected impacts included in the questionnaire and categorization into four major SC2 impacts

Expected SC2 impacts (as included in the questionnaire)	Major Impacts
Improved food security	**Securing safe and high quality food for all**
Improved food safety	
Increased high-quality food supply	
Reduced hunger /malnutrition in the world	
Healthier diets	
More sustainable diets	
Reduced (negative) environmental impacts	**Mitigating and adapting to climate change**
Improved sustainability of European biobased industry	**Safeguarding resources, ecosystems and biodiversity**
Improved sustainability of European aquatic and marine industry	
Improved sustainability of European food industry	
Improved sustainability of European forestry industry	
Improved sustainability of EU agriculture	
Economic growth	**Competitive EU economies and strong communities**
Creation of new jobs	
Improved working conditions	
Improved competitiveness of European biobased industry	
Improved competitiveness of European aquatic and marine industry	
Improved competitiveness of European food industry	
Improved competitiveness of European forestry industry	
Improved competitiveness of EU agriculture	
Strengthened rural economies	
Strengthened coastal economies	

Validity and reliability

At the end of the first deadline set by the research group, the active response rate was 13%. The overall response rate increased by 7% after reminders and 342 coordinators responded. Therefore, 20% of the population was surveyed. However, an ex-post data cleaning procedure revealed 24

responses as out of scope due to low relevance of the projects for SC2 that was later revealed by our expert opinion. Moreover, three respondents were removed as they were identified as duplicate. So the final sample includes 315 projects and unit response rate was 18.2%. The majority of respondents are H2020 or FP7 project coordinators projects, while there is an under-representation of FP5 and FP6 coordinators (Table 15).

Table 14. Sustainable Development Goals (SDG) of the United Nations Organisation to which SC2-relevant research contributes

UN Sustainable development goals	
SD Goal 1	End poverty in all its forms everywhere
SD Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
SD Goal 3	Ensure healthy lives and promote well-being for all at all ages
SD Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SD Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SD Goal 10	Reduced inequalities
SD Goal 11	Sustainable cities and communities
SD Goal 12	Ensure sustainable consumption and production patterns
SD Goal 13	Take urgent action to combat climate change and its impacts
SD Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SD Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Table 15. Coordinator survey: response rate after reminders

	Population		Sample	
Framework Programme	Count	%	Count	%
H2020	365	21.1	121	38.4
FP7	514	29.7	127	40.3
FP6	386	22.3	50	15.9
FP5	463	26.8	17	5.4
Total	1728	100.0	315	100.0

The item response and internal coherence of the survey responses was high, except for the question (Q11) intended to estimate direct and indirect jobs created by the project (so far = at this moment). Many respondents did not answer this question or provided text answers instead of numbers. The open questions (which received a large number of responses) were:

Q3A: Please briefly describe the most important impact of the project (response rate: 89.8%).

Q12A: Can you give any concrete examples of how your project results have influenced or impacted upon policy development? (response rate: 60.6%).

Q15A: What would have been the main differences without EU Framework Programme funding? Please elaborate upon content, focus, network and impacts of the project (response rate: 80.0%).

Q16: Do you have any suggestions on how Framework Programmes could be improved in order to increase their contribution to socio-economic and environmental impacts? (response rate: 64.8%).

The answers to these questions were analyzed with content analysis. Content analysis was used to identify the appropriate "keywords", "themes" and "categories" for analysing the open questions: each answer to an open question was first coded using an open coding approach and inductive classification procedures. The results were then classified into categories of nominal variables. Two methodological experts performed the content analysis. Then, thematic experts validated the categorization and assessed the quality of the content analysis results (inter-coder reliability). The thematic experts performed and checked the coding and the categorization of the answers, interpreting and comparing the results in order to achieve a fixed and shared classification.

Data analysis

The data analysis aimed to analyze the differences by user groups and to examine the impact areas of the projects. Univariate analysis was performed to show the main trends in the data. Bivariate analysis was performed using the following variables: framework programme, type of coordinating organization, type of research carried out (basic, applied, development), and category of funded activity. The later variable was created by assigning all types of funding instruments employed from FP5 to H2020 into three categories: a) Support to R&D activities; b) Research and technological development; and c) Close to market research/innovation (Table 16).

Table 16. Correspondence between types of action and category of funded activity

FP	Type of action	Acronym of type of action	Category of funded activity
FP5	Shared-cost research and technological development project	TA01	Research and technological development
FP5	Shared-cost demonstration project	TA02	Close to market research/innovation
FP5	Shared-cost combined projects	TA03	Research and technological development
FP5	Co-operative research projects (CRAFT)	TA06	Close to market research/innovation
FP5	Exploratory awards	TA08	Close to market research/innovation
FP5	Concerted actions	TA17	Support to R&D activities
FP5	Support to networks	TA16	Support to R&D activities
FP5	Marie Curie Training Fellowships	TA09/TA10/ TA12	Other
FP5	Accompanying measures	TA23/TA18/ TA19	Support to R&D activities
FP6	Integrated Project	IP	Research and technological development
FP6	Specific Targeted Research Project	STREP	Research and technological development
FP6	Co-operative research projects	CRAFT	Research and technological development
FP6	Networks of Excellence	NOE	Support to R&D activities
FP6	Coordination actions	CA	Support to R&D activities
FP6		SSA	Support to R&D activities
FP7	Small or medium scale focused research actions (STREP)	CP-FP	Research and technological development
FP7	Large Scale Integrating Projects (“IP”)	CP-IP	Research and technological development
FP7	SICA – Specific International Cooperation Actions	CP-SICA	Research and technological development
FP7	Networks of Excellence	NOE	Support to R&D activities
FP7	Coordination actions	CSA-CA	Support to R&D activities
FP7	Specific Support Actions	CSA-SSA	Support to R&D activities
H2020	Research and Innovation Action	RIA	Research and technological development
H2020	Coordination and support actions	CSA	Support to R&D activities
H2020	SME Instrument	SME	Close to market research/innovation
H2020	Innovation action	IA	Close to market research/innovation
H2020	ERA-NET Cofund	ERA-NET Cofund	Support to R&D activities
H2020	Fast track to innovation	FTI	Close to market research/innovation
H2020	COFUND (European Joint Programme)	COF	Support to R&D activities
H2020	BBI-Innovation Action Demonstration	BBI-IA-DEMO	Close to market research/innovation
H2020	BBI-Innovation Action Flagship	BBI-IA-FLAG	Close to market research/innovation
H2020	BBI-Research and Innovation Action	BBI-RIA	Research and technological development
H2020	BBI-Coordination and support actions	BBI-CSA	Support to R&D activities
H2020	Prize	Prize	Other

The original impact variables were measured with a Likert scale. Therefore, before proceeding with the classification of the impacts according to the two categorizations, each variable was dichotomized by reducing the answer categories in this way:

Category	Coding	Label
No Contribution	0	No
Low Importance	0	No
Medium Importance	0	No
High Importance	1	Yes
Very High Importance	1	Yes
Not Applicable	Missing	

ANNEX 2: THE DELPHI SURVEY OF EXTERNAL EXPERTS

This annex records the results of the Delphi survey of sector experts. Full details of the methodology are provided in Annex 1.

The Delphi survey was carried out in two rounds. In the first round we received 14 responses from invitations to 73 representatives of impact communities to participate in this assessment of the impact of Framework Programmes. Fourteen of these responded in Round 1 and 13 responded also the second round questionnaire. As detailed in Annex 1, invitations concentrated on people whose work is concerned with representing the relevant impact communities in relation to strategic matters such as the direction of public R&D. The response rate was too low to allow investigation at the level of the impact communities and so these were pooled to examine views of the impact of the Framework Programmes together. The overall purpose is to test ways of assessing the impacts of Framework Programmes and provide input into the development of future Framework Programme activity in the Societal Challenge 2.

Responses to the Round 1 questions

Round 1, Question 1: What in your view have been the main outcomes and impacts of Framework Programme R&D projects in your area?

The responses to this question can be categorised as insight into the results and technical outcomes of projects; comments on the effects of Framework Programmes on the relevant research communities and on the research itself (outcomes for research); and reflections on impact.

Project outputs and outcomes

Six of the 16 responses commented on scientific or technical outputs and outcomes, mostly in a neutral or matter-of-fact way without judging their usefulness or effectiveness. Many of these related to plant breeding. Outputs and outcomes include

"*new breeding tools (array-based genotyping, diagnostic markers, genes, etc.) and improved germplasm (e.g. landraces, introgression lines, etc.) providing an excellent started point for increasing an efficiency of cereals breeding, reducing a breeding cycle and improvement of yield and yield stability by reduction of plant diseases, increasing an adaptation to abiotic stress conditions (e.g. drought, frost, etc.), new strategies for adaptation, and more efficient use of resources (e.g. nutrient)….From a plant breeders perspective, this leads to plant material for further pre breeding / breeding; efficient use of genetic resources; enhancement of scientific knowledge (methodology...); better use of plant nutrients resources (sustainability). This translates into better adapted varieties for farmers.*"

For dairy farming, a wide range of outcomes are mentioned such as the improvement of the nutraceutical properties of milk and dairy products through the use of pasture, or through the organic or low-input production systems; reduction of N surplus through improved farming practices (organic and low-input); better cattle welfare either by improving the knowledge about

risk factors or by generating practical on-farm solution to reduce them; and new technologies such as robotic milking and grazing.

In the lignocellulose processing area, a reply outlined that while there is no or limited application so far, the main outcomes have been very much in the development of fibre fractionation technologies (including with enzymes, and similar technologies) as well as in the development of micro-fibrillated and nano-fibrillated cellulose. Significant research has also been invested into valorisation of lignocellulosic resources into liquid biofuels for transport.

Overall, these replies confirm that primary users and innovators recognise that the project activities can potentially provide relevant applied knowledge and tools for breeders, farmers etc. that can later be used to develop impact. The scientific and technical outputs listed by respondents are well-aligned with what is expected of public applied research in this area.

Project outcomes

Four respondents commented on outcomes within the research community and on research. One critical comment was that "*the main output appears to be the employment prospects of a large number of academics"*. Other comments on the impacts on the science base draw attention to the creation of a "*solid background for future development in the area of food safety*"; and "*notable amount of basic information has been accumulated for the main fish European aquaculture species*". For lignocellulose processing, a reply drew attention to the focus on 'basic R&D' and the resulting strong knowledge base making Europe world-leading in this area.

The more fundamental or basic characteristic of much of the plant breeding research is commented on: "*Within the projects listed there are some which could be considered 'blue sky' (is this the correct funding mechanism?) but others that are highly speculative yet could provide significant changes (positive) in production e.g. changing the converting plants from C3 to C4...*"

The effect of the collaboration itself is also commented on: "*Excellent collaboration….leading to an impressive body of scientific publications and basic knowledge. Agricultural R&D is seen as an integrated cross-EU activity which is an important contribution*".

Impact

Six respondents provided comments on impact itself. These were generally down-beat. The overall impression is that while the programmes may have delivered in terms of investment in research and in terms of project outputs/outcomes, the translation into societal (SC2) impacts is weak.

In line with the reference to 'blue-skies' research mentioned above, several respondents commented on the type of project funded with consensus that emphasis on basic R&D and speculative projects is adversely affecting impact:

"FP5, FP6 and FP7 were too focused on basic R&D without supporting the market up-take of basic knowledge and technologies".

"Projects funded do not provide significant changes in production and tangible benefits for production and industry competitiveness and do not deal with the real production risks".

It was also stated that the type of institutions funded (research institutions, universities) are not interested in producing impacts but just in obtaining funding to finance their ordinary activities:

"the main output appears to be the employment prospects of a large number of academics",

"We feel that NOT the common outcome (any innovation, improvement, etc. of dairy farming) is in the focus of the project partners but only the distribution of the funds and the own topic of the individual project partner", and *"we ask ourselves if this is really the most efficient and most effective way to generate a research outcome with impact on practical dairy farming? We are sure that there are more efficient ways to do it with the fund available... e.g., supporting organisations like ours that has already a farmer network but that are maybe too small to apply for an EU projects because of the very difficult and resource-consuming application process".*

Respondents also mentioned low effectiveness in terms of knowledge/technology/results transfer/accessibility of results/transfer of scientific results into marketable products and services:

"To me, it seems that not much information/results from these EU projects is really ending up at farm-level".

"Bearing in mind the huge resources applied (for which the EU should be congratulated) there should now be some outcomes being integrated into breeding programmes. I am not aware of this happening (this may be because I am not connected to any of the large companies that may be involved). Translation, in my view, should be through the private sector. The public sector is notoriously slow in developing impact and we do not have the luxury of time for both environmental or health benefits. I do wonder how well connected these R&D activities are with the market place. This is not about 'selling' but translation. I would have thought that by now we would be seeing impacts upon breeding strategies and within 5-7 years variety development in the market place".

"The market position for such biochemicals has turned out to be more risky than expected, particularly because of low oil prices, few incentives to change over to biobased chemicals and low interest from both brand owners and consumers. Most projects have been focusing on one single product, often energy carriers like fuels and biomass for heat and electricity, which are low value, large volume products. Lately, more of the focus has turned over to higher value chemicals, with lower market volumes. Still the biorefinery industry need to learn the lesson from oil refineries, which combine low value high volume products (to achieve economy of size) with a range of high value low volume products (which will bring the most of the profit)".

"The framework projects have identified areas where research and new knowledge is essential for further progress. This is true for many aquaculture species. The outcome has mainly affected the major species (salmon, trout, bass, bream). In these species we can see that breeding programmes have been started, and a rising understanding of the importance of genetic progress. In recent

years genome mapping and development of chip arrays has been started in several species. The impact in breeding is still to be seen".

Those answering that they can see some impacts of Framework Programme R&D projects in their area identify the effect in terms of combining technologies and practical applications for industry. For technical combinations the following was reported:

"implementation of new management methods to better combine new technologies such as robotic milking and grazing"

"genomic resources and their integration"

"essential parameters from quantitative genetics, to say heritabilities and correlations related to the main traits"

For practical applications for industry. The following was reported:

"In the last projects, an effort has been applied to disseminate and develop practical applications for industry through establishment of consortia, pilot experiences for further application, and integrating the best selection strategy within a cost-benefit balance, which is essential for improving European aquaculture".

"Adapted varieties for farmers".

"Valorisation of lignocellulosic resources into liquid biofuels for transport".

"Development of fibre fractionation technologies (including with enzymes, and similar technologies)".

"Development of micro-fibrillated and nano-fibrillated cellulose".

"Practical on-farm solution to reduce risk factor and improve cattle welfare".

"Improvement of the nutraceutical properties of milk and dairy products through the use of pasture, or through the organic or low-input production systems - reduction of N surplus through improved farming practices (organic and low-input) - better cattle welfare either by improving the knowledge about risk factors or by generating practical on-farm solution to reduce them".

"Technologies for converting lignocellulosic biomass to fuels and chemicals".

"Genetic parameters of disease resistance, how to use genomic information for improving accuracy of selective breeding".

"New breeding tools (array-based genotyping, diagnostic markers, genes, etc.), new deep knowledge (e.g., genomics, plant physiology, etc.) and improved germplasm (e.g. landraces, introgression lines, etc.) created an excellent started point for increasing an efficiency of cereals breeding, reducing a breeding cycle and improvement of yield and yield stability by reduction of plant diseases, increasing an adaptation to abiotic stress conditions (e.g., drought, frost, etc.) and more efficient use of resources (e.g., nutrient)".

Round 1, Question 2
Considering the extend of the R&D activities set out, your own goals and wider societal goals, what outcomes and impacts do you think should be now emerging from the Framework Programmes?

Responses can be categorised as comments on what impacts could be expected (Impact expectations), comments on how impact can be developed from existing research (Developing impact), and suggestions for further project activity (Future activity).

Impact expectations
Reflecting responses to Question 1, one response suggested that given the investment made *("for which the EU should be congratulated*"), there should now be some outcomes being integrated into practice (plant breeding): "*I would have thought that by now we would be seeing impacts upon breeding strategies and within 5-7 years variety development in the market place. From my own perspective I would have expected to see some engagement with regard to developing novel breeding strategies - whether this be for example through incorporating novel germplasm or genomic selection models."*

Developing impact
Respondents see impacts emerging from the following areas:

Production improvement, scalable industrial applications, technology implementation
"The vast basic information gathered along these years and the important consortia created involving the main research groups and industry in these framework programmes should be capitalized to get real results in farms to improve production and to provide more safety food for consumers, within a sustainable framework. Efforts should be focused on the most advanced species to develop direct applications to industry for improving growth and achieving more robust brood-stock in pilot programmes. This would serve to assess the input of new technologies within a cost-benefit framework to be scalable at industrial production. The less advanced aquaculture species, characterized by more spread production, should follow a different approach. Indeed, important investment has been done in these species to develop top technologies, but the weakness of the industry due to dispersion, has hampered their application to improve production. The important advances in genomics in these species could be capitalize by developing highly versatile molecular tools enabling genealogical traceability and evaluation of the main traits for selection through gathering big consortia which could permit lowering costs. In this sense, tools such as SNP chips, including markers associated with industrial traits, highly variable for parentage analysis and

distributed along the genome for intra-familiar genomic selection should be a target for species such as sea bass, sea bream, turbot, and molluscs, and even for the more advanced ones like salmon and trout".

"From my own perspective I would have expected to see some engagement with regard to developing novel breeding strategies - whether this be for examples through incorporating novel germ plasm or genomic selection models and variety development in the market place".

"A better understanding of the evolution of the consumer's demand towards animal welfare, products quality and origins, more collaboration between farmers of different backgrounds to share huge amount of practical knowledge on better sue of forages, better choice of buildings and equipment, more ecological techniques for soil preservation, better work organisation. Lots of solutions already tested but farmers need to see to implement".

"Breeding of high yielding varieties resistant to abiotic and biotic stress will play a key role; We would need produce more (and better quality) with less resources; Increase of genetic gain in plant breeding by applying add-on technologies (e.g. genome editing); Efficient, targeted and knowledge-based use of plant genetics resources; Grown a new generation of plant breeders and applied researchers by active participation in research projects connected academia and industry".

"I think it is a need to address the issues of IPR (access and rights to genetic resources in aquaculture), ethics and business models of selective breeding programs in Aquaculture when applying genomic information and new techniques such as CripsR Cas9. This is needed to understand the consequences of privatizing aquatic Genetic Resources by New techniques and in order to speed the adoption of selective breeding in aquaculture in Europe as well as worldwide".

Changing patterns of consumption

One respondent commented on the unpredictability of impact and the role of unexpected tipping points: *"Many technologies are ready for investments. As soon as the consumer brand owners are willing to buy biobased products preferentially, and authorities help kick-starting the markets, I expect the biobased chemicals and fuels markets do will take off and grow fast. The main uncertainty is the timing, when will this start. In May 2017 something happened in the US bioethanol market, where the lignocellulosic ethanol producers have been producing at below 15% of their capacity for several years, then suddenly from April 2017 at 7% of capacity, the production jumped to 40% of capacity and prices in California are at all-time high. When these movements start, we can expect very fast growth both in demand and supply. Consumer trends tend to change fast when they first start to move, could be triggered by unexpected happenings in media or elsewhere. Also, authorities can help kick-start such actions by use of obligations, public procurement etc. Subsidies are less efficient, and very unreliable, does not constitute a good basis for investments. Most important is that market regulations are stable and predictable. Quite a few brand owners are working seriously to convert to biobased chemicals. Once the opinion among consumers is starting to change, they will probably utilize this in positioning their brands, which will force others to follow. This will start an avalanche of activities. There are so many players that are waiting for the right time to move. Market incentives could help starting this avalanche."*

Health and risk assessment tools

"We need to provide to the European food industry with reliable ways to better assure safety of their products, thereby better protecting public health. This aspect has to be placed into the context of the changing social ecosystem in which the consumer is getting closer and closer to less processed foods, thereby increasing the risk of foodborne outbreaks. New risks are also coming along: virus and parasites. Especially for the latter, there is not a lot of work done and at the moment scientists are mainly focusing on detection methods, without really considering how to better control this risk".

"To improve the dairy sector concerning sustainability. Here it is important to consider all three aspects as environment, economic and social factors. Especially in the future disease control and correct use of antibiotics are important issues".

"In my opinion, today's dairy farming sector is called to revise its productive and management goals by reducing the emphasis put on milk yield and giving more room to issues like cattle health and environmental sustainability. We must consider that the improvement of health and longevity of the European dairy herds would have a relevant effect on the reduction in drug use for therapeutic reasons which is one of the most worrying issues for the European consumers. The parallel adoption of more sustainable management systems from an environmental point of view should improve the water and carbon footprint of the dairy sector. Both strategies should promote a more positive image at the eyes of the public opinion enhancing the social acceptability of the dairy sector".

Sustainable bio-based sector

"I believe that a sustainable bio-based economic sector should be considered as one of the pillars of the European economy also in the future … The EU has all the cards to become the leader… As the knowledge pool in the EU, related to lignocellulose processing, is substantial, next the FPs (H2020 and the next) should raise the role of innovation even further to secure the optimal utilisation of this knowledge pool in form of jobs, income, taxes, improved environment, etc. Importantly, when building the new lignocellulose processing businesses, one must not forget the existing lignocellulose processing businesses in the EU (for instance, building with wood and the "pulp & paper industry"). In other words, the new will most often be built on top of the existing, although also completely greenfield concepts and businesses might emerge".

"Quite a number of the explored bio-based solutions valorising renewable feedstocks still rely to a certain extent on other materials that therefore jeopardise their full recyclability, or composability, or biodegradability. The merits of bio-based products for the economy will deploy their full potential once their environmental sustainability will no longer be questioned. Bio-based products must sustain the comparison with fossil-based alternatives. The overall expected impact should be that bio-based products become a viable alternative to a growing number of fossil ones".

One response argued that the vast basic information gathered along these years and the important consortia created involving the main research groups and industry in these framework programmes

should be capitalized to get real results to improve production. This implies a degree of continuity and there is a suggestion that targeting is required: "*Efforts should be focused on the most advanced species …within a cost-benefit framework to be scalable at industrial production…important investment has been done in these species to develop top technologies, but the weakness of the industry due to dispersion, has hampered their application to improve production"*.

Future activity

Ten respondents provided suggestions for future activity. These are largely specific scientific and technical activities rather than suggestions on programme strategy. These include: animal disease control and antibiotics; consumer views on animal welfare, product quality and origin; integrated management systems with a managed reduction in dairy production intensity; networking of farmers to share practical knowledge; plant breeding for yield in stressed environments; incorporating new genetic tools into breeding programmes; knowledge-based use of genetic resources; developing knowledge-based plant breeding capacity and training for interaction between academia and industry; food safety research that addresses increasing risks due to consumer moves to less processed foods; new food safety hazard; targeted investment in fish genomics and breeding; efforts to secure and build on the European lead in the bio-based industries to generate social well-being in Europe; increased emphasis on innovation in the developing area of lignocellulose processing and value chain development considering the large capital investment and different capital circumstances in the wood products sector.

Overall there is an emphasis in responses on practical benefits and outputs instead on basic underpinning knowledge. There is also a call for integration of different disciplines.

Round 1, Question 3. Please describe how and why the Framework Programmes' impacts as you perceive them match those you have for your area of work.

Six respondents commented on how programme strategies addressed needs. Generally, programme emphasis on resource efficiency and more sustainable systems is endorsed. "*The main focus of the framework programmes on plant genetic resources, their characterization and access for breeders match exactly our expectations*". There is also support for the investment in knowledge exchange, for example between farmers as well as between research and farmers. But there are also some reservations expressed. One respondent drew attention to the risk and perception that the Horizon 2020 Programme may be unduly focused on extensive types of agriculture: "*The impacts stated in the objectives are laudable and appropriate. However the agenda is very much focused on extensive agriculture and there is a balance between extensive and intensive production which should be addressed. I see that the direction of travel is influenced by (sometimes) small pressure groups who perceive that intensive agriculture is bad*."

The high level of subscription to Horizon 2020 was commented on: *"Nowadays it is very complicated to get a proposal funded in the H2020, due to the high competition, aspect that was not so relevant in the FP7…. For a lot of Member States, FP are very important … it should be*

promoted a good distribution of funds among different countries and research groups, of course always based on excellence."

Echoing replies to the other questions, the need to invest in the exploitation of existing research is mentioned. A degree of continuity and follow-through is suggested: "*Enabling technologies, as well as innovative processes and products must therefore be further investigated, tested and developed at commercial scale"*. In this context, approaches such as the BBI JU are endorsed for supporting the industrial exploitation of results from past R&D.

The following areas are considered in line with users' needs:

"Development of basic genomic tools like maps, genome assembling and microarrays, application of them to identify candidate genes and markers for the main traits to be applied by industry to improve production".

"Development of traceability tools for aquaculture fish in wild populations and to ascertain the impact of farming in wild resources".

"Characterization of plant genetic resources and access for breeders".

"More efficient use of the ligno-cellulosic resources procured by the sector into higher added-value applications".

"Development of new varieties adapted to changing climatic conditions".

"Knowledge of existing traits in plant genetic material that needs to be investigated years before to have a basis for improved crop breeding to have new varieties with improved properties".

"Legume and minor cereal crops where only a relatively small number of plant breeders is working on in Europe".

"Improvement of cattle welfare".

"Development of organic and low-input dairy system".

"Improvement of the nutritional quality of milk and dairy products through the use of grazing systems or through the limited use of concentrates".

"More efficient selective breeding in a few aquaculture species".

"Reduce sensitivity to diseases and parasites of aquatic species". Responses to the Round 2 questions

Responses to the Round 2 questions

Round 2, Question 1
We are focused on the Societal Challenge 2 of Horizon 2020 (Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy). According to your previous answers to Question 1 of the first questionnaire (see briefing document), the main weaknesses of the Framework Programmes in terms of impact production lie in the programme structure (type of project and institutions funded) and in the programme content (lack of technology transfer). Whereas, the main strength lies in producing marketable combinations. Taking into consideration the answers and considerations from Question 1, and bearing in mind that we are most interested in your view as someone involved in using research outputs to generate impact, could you elaborate more on economic, social and health impacts deriving from the projects funded in your area?

Respondents identify the following hampering factors which prevents economic, social and health impacts being achieved:

Lack of alignment between the private sector, government and universities:
"In the field of food safety, the projects funded in H2020 had the main objective of reducing and containing health risks for the consumers. This is a pretty straightforward goal that is reached only if a number of subjects are actually involved. In my opinion, the economic, social and health impacts are measured when researchers, industry, regulatory agencies and European commission are actually well aligned".

"From the research point of view, H2020, and other previous programmes, have generated important knowledge in the food safety arena, which sometimes have been taken into consideration by regulatory authorities, other times not. I agree (partially) on the outcomes of the first questionnaire regarding the lack of connection between research institutions and industries, however those are not only the two actors involved in order to produce impact at European, and Worldwide, level".

"The focus of the funding programmes has been mostly on large volume low value products, mainly energy carriers like fuel, heat and power, in H2020 also somewhat on platform chemicals and materials (plastics), in anticipation of supporting political decisions. If commercially successful, these products approach large volume markets, and the environmental effect could be substantial. In a regime of relatively low oil prices, and pricing of products not reflecting the combined cost of production AND environmental burden of the products on society, very few bio-based products will be commercially attractive for the producers. Thus, the R&D/technology development part of the equation has been attacked by the funding programs BUT the economic part of the equation has not been followed up by regulations and incentives. In this view, still some further development is needed, but overall so far the EU funding programmes have been successful in developing the needed technologies, but the political decisions have not enabled exploitation".

Lack of market orientation:

"Considering the area of plant breeding, the impacts to date have not been proportional to the investments made in research. The majority of projects have been directed at developing underlying knowledge and underpinning technology and toolkits. These projects have delivered as outputs an impressive body of basic knowledge, data sets and tools which in turn have been used in later generations of projects to generate more fundamental knowledge. What has been less successful has been the translation of these outputs into outcomes relevant to day-to-day breeding activities and the demonstration of concrete outputs - i.e. the registration of varieties based on knowledge / technology developed within programs. To some extent this may be due to the nature of plant breeding, with long lead times between making crosses or selections and the release of varieties, but it is not clear to me that there exist pipelines of improved germplasm based on programme research outputs. This comment is made from the standpoint of an SME company - it is probably true that the larger, multinational breeding companies which have the size and resources to support breeding programmes already using advanced technologies have been in a position to exploit more the basic science which has been delivered, but this will have served to further exacerbate the difference between the major companies and the smaller independent and regional companies".

Projects seen as too large:
"I am not familiar with enough projects to draw specific conclusions. My perception is that whilst much is made of the economic, social and health impacts these are not seen. Perhaps it is too soon or perhaps there is not enough connectivity between the project leaders and the beneficiaries. Perhaps the projects are just too large - multi disciplinary approaches are valuable but sometimes smaller more focused projects can deliver benefits faster. I remember a project proposal being submitted only to be told that it was too small".

Lack of simplification in programme management and organization (too much bureaucracy for proposal preparation and submission, type of eligible costs):

"We need to engage with small businesses to deliver impact but minimise the amount of paperwork associated with EU projects. This latter acts as a disincentive to collaborate".

"In regard to SC2, the BBI JU is a significant step towards increasing the impact of the public investments, but from a company point-of-view, we still struggle with the fact that Capital expenditures are difficult to get included as eligible costs. When building businesses related to SC2, Capex is typically a major factor, both for SMEs and larger companies".

Among the impacts deriving from FPs they emphasize particularly:

Improved genetic potential:
"For instance, it is estimated that the annual saving of feed costs in Norwegian salmon industry resulting from genetic improvement in feed efficiency and 11 generations selection for faster (>doubled) growth amounted to USD 611 million". Furthermore, similar results of improved genetic growth rate has been obtained from selection in other aquaculture species such as tilapia and carp. As a result from the successful GIFt Project, genetically improved tilapia has been

spread worldwide and contributed to an extensive expansion of tilapia farming. This has given increased fish meat production and employment of people and value creation".

Virus eradication:
"In addition, the severe virus disease Infectious Pancreas Necrosis has been eradicated in the salmon industry due to selection for the identified QTL for IPN resistance, explaining > 90% of the variation in IPN resistance".

Animal health and welfare:
"In my area (low input dairy systems) the economic impact of FP7 project was to offer user's guide to farmers to reduce their production costs and improve health and welfare of animals thanks to grazing. The idea is to keep as many farmers as possible because they earn money and are happy to be dairy farmers. The better use of lands also provides non production services such as land use, land maintenance, biodiversity or landscapes".

Round 2, Question 2
Overall, in answers to Question 2 of the first questionnaire (see briefing document) there is an emphasis on changing of consumer patterns, sustainability, health and risk assessment tools and a call for scalable industrial applications. Based on your previous answers and considerations, and bearing in mind that we are most interested in your view as a user of research, please provide your views of the:- actual strengths and weaknesses in terms of the production of outcomes and generation of impacts of Framework Programmes: strategy, direction, management and implementation of a future Framework Programme in the context of maximising impact.

Respondents identify the lack of involvement of government and regulatory authorities, the lack of transfer of scientific outputs into marketable products and services and the large-scale projects as the main weaknesses in terms of the production of outcomes and generation of impacts from FPs.

Lack of involvement of government and regulatory authorities:
"*In order to maximize the impact, there is a need to have an engagement of all actors in the decision process from research to regulation. This may need a higher involvement of the regulatory agencies that at the moment are the ones probably less represented in the framework programme activities".*

"Regarding direction I, hence, urge the developers of FP structures to continue finding the balance between fundamental research and innovation, and to further develop the triple helix foundation through improved communication and respect among the actors. The JTIs, and especially the BBI JU, has, in my mind, been a huge success and something to build further on".

"Of course not all the results can be so directly used and exploited, and especially those related to safety have to be well evaluated. However, as indicated several times in my answers to this second questionnaire, there is a need to involve in regulation. For example, if I find a very interesting results that cannot be exploited because it needs a change in the European legislation or if it needs

to be regulated, then this is a big hurdle that industry will never push to have it passed, or at least SMEs will never push for it".

Lack of transfer of scientific outputs into marketable products and services which prevents scientific research from reaching users:

"*The weakness has been in achieving the translation of this knowledge into tangible impacts, such as patents, company start-ups, practical applied technologies, and products which actually enter the market to generate economic, social and economic benefits".*

"One of the reasons for this is ingrained in the European research culture where publications and academic prestige are still prized and rewarded (at a career development level) more than applied research and business development - in this, Europe still has a long way to go to match the US, Japan, Korea, etc. In future programmes in parallel with the development of new knowledge a significant proportion of funds should be directed at projects translating outputs into impacts".

Also the **scale of projects** represents a weakness in achieving impacts: large-scale schemes and requirement for multidisciplinary and multisectoral collaborations are considered to be expensive in administrative, coordination, personnel and managerial terms and they are not considered to give good value for money:

"Perhaps the projects are just too large - multi disciplinary approaches are valuable but sometimes smaller more focused projects can deliver benefits faster. I remember a project proposal being submitted only to be told that it was too small. We need to engage with small businesses to deliver impact but minimise the amount of paperwork associated with EU projects. This latter acts as a disincentive to collaborate".

"To my opinion, in each funded project more focus should be put on the research and the impact itself: Which (very clear formulated and comprehensibly) research question shall be answered in the project and how can the results be effectively distributed? Today, the funded projects are often very big with many organisations involved and different research questions/goals which leads to the problem that too much resources (labour, time, motivation) are needed to apply for the projects and to coordinate the projects and the people & organisations involved. These resources are finally no longer available for the "real" research work and, in particular, for the effective dissemination of the results to the end user".

"I think, it could be helpful to ask for smaller projects with a more clearly defined research question (not abstract) with less institutions involved and a much slimmer application procedure... to ensure that less resources are need for administrative and coordinative tasks and more available for research itself and in particular for the dissemination of the results".

"As indicated also in the previous answer, in the framework programmes, probably, not all the actors necessary to generate the foreseen impact are involved. In my opinion, a number of useful results were produced in several funded projects in FP5, FP6, FP7 and H2020, however not always

those resulted in a reduction of health risks for the consumers. As already mentioned, in H2020 probably the funding strategy, selecting one or two projects of big (or huge) dimensions for each call did not result in extremely high impacts. I may be wrong, however it is my impression that in FP7 a higher number of projects could be funded giving the opportunity to have more exploitable results to promote and transfer".

"A critical seen development during the past years of Pillar 3 is the trend to bigger projects with a high number of participants from various disciplines. For companies, in particular SME, participation is very difficult due to the fact, that they often felt lost with their specific needs after the project starts. This hinders the flow of results to create the impact that was foreseen before. The focus on precompetitive collaborative projects would allow a wide range of companies to generate impact, weather they were directly involved during the project or informed about the results during or after the project".

Respondents share the opinion that the main strength of the FP consists in the formation of pan European, cross-national and cross-sectoral research networks:

"The strengths of the Framework Programmes have been is the establishment of broad and effective pan-European research networks and the formation of cross-national collaborative communities in many research areas. There has been a very clear effect of putting EU research at a level at which it has reached a level of excellence which could not have been achieved at national level and has allowed competition at the highest international level. This has facilitated the training of researchers, has supported exchanges and mobility with the Community. The outcome in terms of academic science, knowledge and technology generation and publications have been very considerable".

"the + : give the possibility to researchers and institutions from diverse situations and regions to address same issue; also work with companies. Some have great impacts on farmers".

"The underlying strength of the FPs is the fact that they catalyse the formation of networks, both between organisations from different Member States, as well as between different types of organisations (from NGOs to large companies). I strongly believe that the world-leading projects and outcomes rely on an active triple-helix foundation, i.e. companies, governments and research & education organisations work closely together. Also, a successful regions has found a good balance between fundamental research and innovation. In the past, the FPs have been known to generate world-leading R&D results, but the implementation to generate innovations is lagging behind e.g. the USA. The H2020 has taken a step to correct the imbalance, but it is still not optimal".

With reference to future Framework Programmes and in order to increase their impact orientation, respondents provide several recommendations.

Higher involvement of immediate users of project results in order to ensure the innovation take-up:

"Generally speaking, I recommend more involvement from (private) industry from the start of R&D Projects. This should make the projects more practical, and more related to questions that breeders have to solve".

"I think it is a strength to involve industry actors in the research and innovation projects, such that they can influence the research and make it more relevant and applicable. Also, it will shorten the time until application and impact".

"It has been a weakness when industry actors have not been properly involved, and a strength when relevant stakeholders are involved. Consumer stakeholders are difficult to involve through other means that consumer surveys".

Mapping and attributing definite outputs to specific Framework Programme projects improvement in order to clarify the particular contribution of an intervention. Respondents also stress the **need for a long-term availability of results** which - apart from allowing end-user access to results - prevents the funding of redundant projects:

"The transfer and dissemination of project outcomes to a wider audience is most often the weakest point in creating impact. Besides that, the long term availability of results is essential: i) to reduce duplication of funded projects on EU and national/regional level and ii) allow future generation of impact from these results. The collaborative approach of H2020 Pillar 3 is a well-accepted and supported way of producing outcomes for innovative solutions with a high impact".

Mechanisms for accessing and taking up research outputs by end-users in order to discover results of past and current research projects, identify users of these results and ensure the transfer of these results to those that can use them:

"It would be very nice if there is a scouting actor, which is searching for exploitable results, is established and acts as facilitator for the results to have an impact at societal level".

More balance between levels of TRL set as eligibility criteria:

"This being said, the right balance must be found between fundamental and applied research, as well as between the levels of TRL set as eligibility conditions".

"A future Framework Programme should build on the past positive experiences and must balance basic and applied research to allow new innovative products and services based on excellent fundamental research".

A successful transition to circular economy which requires efforts on policy, regulation and technology development fronts:
"A weakness of the FPs are the lack of co-ordination with policies for the industries they focus on. For instance in the bio-chemicals, bio-materials, bio-fuels and bio-energy area, the policies are unreliable and changing, possibly because of lack of knowledge and lack of co-ordination. An

example, support of bio-fuels have been changing as evidence of the environmental effects of ILUC has developed. Besides, there is a discrepancy between policies for the use of biomass for energy and fuel or as chemicals and materials which is not logical and which does not support bio-refining, rather one-sided production of energy carriers (which is less profitable). The new Framework Programme should besides focus on a continued technology development, also focus on systems development (policies, value-chain organization, new interactions between players, need for new roles by industry, distributors, recycling companies and authorities) to enable a circular economy. For instance, design of products need to take into account the new needs of a circular industry. Today it is not clear what is the best option for returning a product back into use (re-use, recirculation, reformulation, energy recovery) and what the best way of doing this taking into account both economy and environmental impact. These systems need to be widely standardized to be efficient. We need to develop the framework for such a society and this must be developed with an interdisciplinary approach. This could be the enabler for right decisions within policies, regulations and technology development and enable co-ordination of all these".

From a thematic point of view, respondents identify three main challenges requiring urgent action under FP9. The first one emerges from responses from Selection/breeding in aquaculture experts and consists in the need for a strategic targeting on a limited number of species:

"There is also a need to focus the research and innovation in European aquaculture to a limited number of species, because it will take too long and too much resources to develop a big number of industries to become competitive With requested knowledge and needed infrastructure. Hence, probably max 10 species and not much more than 7 should be addressed".

"Concerning traits for improvement, disease/parasite resistance and Fish welfare are important in addition to Growth rate and feed efficiency".

The second one concerns a higher investment in certain types of research for the dairy sector:

"The dairy farming business is global, and it is a very competitive market. In the future, it is very important to address the future challenges concerning a higher productivity and effectiveness combined with a low carbon footprint, high animal welfare, low use of antibiotic, low emission of nitrogen and ammonia. We need more research in genomics, in housing systems that can combine high animal welfare with low emissions of ammonia and low cost. We need to have innovations in the area of monitoring of diseases and we need to implement new methods from other industries concerning monitoring of the animals in the stables, to detect eg. heat, lameness, etc. It could be some of the methods the car industry develop to have the cars without a driver. These data collecting technologies should be used to improve management in bigger herds so animal welfare and productivity reach new levels".

The third one is about multi-product biorefineries, a product diversification in bio refineries which in most cases are mono product to face actual underutilization and mitigate market variations:

"There has been an almost complete absence of learning from the oil refinery industry's 100 years of technology development. All oil refineries produce a palette of products and utilize their feedstock completely for products. Biorefineries, on the other hand, under development today even have only one product, for instance fuel, and can even theoretically only utilize half of the feedstock. We should encourage development and improvement of the business concepts, so the biorefineries develop technologies to produce a palette of products, some high volume bulk products (fuels, energy, power, platform chemicals, commodity plastics) in combination with low volume high value products (specialties, performance chemicals,…). This could improve the profit of biorefineries and support exploitation".

Round 2, Question 3

Did you, your organisation, or those you represent make significant use of Framework Programme projects' outputs? If yes, could you describe the FP project's outputs, how you used them and the factors that supported their use. If no, please comment on hampering factors.

It would appear that some project outputs are already being used by users interviewed. Users consulted declared to have used outputs from GPLUSE, PROLIFIC, REDNEX, MIDAIR, and EXILVA projects. These projects have contributed to provide new breeding schemes for dairy cows, new management and monitoring tools to improve sustainable dairy production, more informed use of genomic selection, new models to support on-farm decision at different levels: animal fertility, herd management and socio economic impact, more efficient selection programmes in terms of genetic disease resistance, deliver new microbial strains for the production and improved technological processes, deliver new products from the first production of microfibrillated cellulose:

"I know that research outputs from projects as Rednex and Gpulse has been important new knowledge, and has in one way or another been implemented in the breeding schemes for dairy cows in Denmark. The scientists work closely together with our breeding company. And the Danish dairy farmers use genomic selection in their selection of heifers and bulls".

"Also the outcome from MIDAIR and Profilac is important in the understanding of the challenges on the dairy farms".

"The farmers breeding organisation use the outputs from the projects concerning genomic selection. This is because of the tight relations between the industry and the researchers".

"In a way we also use the outputs from Profilac. Again here some of the Danish researchers that are part of the project also have close relations to the farmers organisations eg. our organisation, SEGES, which is owned by the farmers. Our role is to make knowledge transfer to the farmers. The researchers know what the challenges is on the dairy farm".
"The outputs from MIDAIR is important in relation to the overall discussion in EU concerning sustainability and ways to address this".

"As I represent a research organisation, we have used Research results from FP programme in terms knowledge to develop further and improve efficiency of aquaculture breeding research (methodology) and breeding programs. We work closely with industry actors (farming and breeding companies) to improve their selection programmes with respect to genetic disease (parasite) resistance and other traits of interest".

"In the last 10 years, we have been involved in several projects, funded under different schemes, which resulted in exploitable outcomes. Projects under support schemes (to SMEs or associations to SMEs) were the most successful since a direct support to those realities was developed. In this frame we have helped several segments of the food industry (mainly the one producing fermented foods) delivering new microbial strains for the production and improved technological processes. For instance, we have selected a strain of Saccharomyces cerevisiae in Piedmont that at the moment is used by a lot of wine producers for the production of Barbera wines, so I consider this results as a success".

"Yes, for instance in the biorefinery industry, the first production of microfibrillated cellulose is now up and running and commercial products are introduced into the market. We expect several more actors to come on stream. Successful technology development within funded projects have been successfully scaled up to commercial scale, in at least one case, others are following".

Respondents who did not make significant use of Framework Programme projects' outputs and results see as main hampering factors the type of results produced which are not focused correctly in terms of company needs so requiring further development:

"In the past, our company has tried to use the FP outputs (results), but unfortunately with quite small impact. They tend to stay in the universities and RTOs. The BBI JU, which is still very young, as an example, hopefully enables closing the gap by which the final development projects are focused correctly, in terms of company needs. This will then, in the future (later during H2020), improve the use of FP output in generating societal impact though company activities".

"In some cases, the connection between research and industry is weak or missing. In some cases the research topics are not well connected to "real" problems, but mostly of academic interest".

This further development consisting of incorporating technologies into users' activities requires tangible and intangible resources to access and exploit results and could not be carried out without further substantial investments in infrastructures and technologies:

"Our organization has made use of outputs at the level of publications, information and knowledge developed, but at the level of incorporation of technologies into our own R&D programmes this has not been possible because as an SME with a confined we do not have the level of infrastructure to be able to exploit many of the advances made - for example use technique such as marker-assisted selection or genomic selection tools".

Even when investments to use research results are not so high, there is another cost identified by respondents which prevents from using research results: the cost of searching for the specific outputs:

"The outputs just do not end up on our "desks" and, as a small organisation (financed only by its members), we don't have the resources to search for it actively all the time. We must use our resources efficiently in the interest of our members and partner. We could maybe use it more if it would be communicated actively (and personally) to us. Creating information is "easy" but making sure that it actually ends up at the person who could make use of it is the challenge".

Apart from accessing problems, respondents recognise a difficulty in mapping results to specific projects deriving from the lack of a clear attribution of programme activities to results, outputs and outcomes:

"I am sure we have used Framework outputs, but it is not always obvious that it is a framework result. When our geneticists, or scientists we collaborate with, for example use a new method for genomic calculation, it may be the result of a framework project, or not, and we may not know".

Conclusion

A synthesis of the survey material is provided in the main report. The first round of questions was reasonably successful in probing perceptions of impact of the users of research results. Overall, responses about outcomes and impact from this perspective endorsed the general scientific and technical direction of programmes and resulting programme outcomes, but fairly consistently drew attention to weaknesses in generating impact. This is particularly evident in responses relating to agriculture where impact depends on widespread adoption in a dispersed user community (farmers). Attention is drawn (in passing) to the dispersed nature of primary research users for much of SC2 (e.g., farmers) and it is implicit that this needs to be considered in efforts to improve impact. It is noticeable that in areas characterised by concentration of users (e.g. aquaculture, the food industry, and the bio-based sector), a gap between research outcomes and impact is less evident in responses.

ANNEX 3: DELPHI ROUND 1 BRIEFING FOR DAIRY FARMING

European Union Framework Programme research and development for Societal Challenge 2

Impact of past research and the way forward
Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy

Briefing for sector experts
Framework Programme Research supporting the dairy farming sector

Overview of research for dairy farmers

This study is part of a wide assessment of the direction and impact of Framework Programmes 5, 6, 7 and Horizon 2020 in the field of Food, Agriculture, Forestry, Fishery, Aquaculture, Bioeconomy carried out by an expert group (Annex 4 provides the list of the expert group members). The overall purpose is to provide input into the development of future Framework Programme activity in the Societal Challenge 2 area that currently aggregates all the above mentioned fields. You are invited to contribute to this Delphi study because you were identified as a recognised expert in this area of agriculture and because you represent the community impacted by the part of the programmes under analysis and the relative projects funded. In the following pages, you will find information about the R&D under analysis and the most relevant projects funded in your area.

A general overview of the development of agricultural research in the Framework Programmes, which was prepared by the Assessment Group, is presented in Annex 1. The Framework Programmes (FP) 5, 6, 7 and Horizon 2020 have invested a total of 55 million Euros in 24 R&D projects that are directly relevant to the dairy farming sector. This comprises 11 projects in FP5 (EU contribution of 12 million); one project in FP6 (EU contribution of 0.5 million); 8 projects in FP7 (EU contribution of 38 million); and four projects so far in Horizon 2020 (EU contribution of 4 million Euros). The projects outlined are presented in Annex 2.

Priorities varied between Framework Programmes and this is reflected in the type of research relevant to dairy farming that was supported. A significant proportion of the 'dairy farming' research in FP5 was aimed at improving feeding and management, with a smaller amount of research aimed at dairy cattle breeding. Research aimed primarily at dairy production was confined to just one project in FP6. Investment in dairy farming research was restored in FP7 with eight projects. Most of these emphasised genetic improvement for traits associated with reproduction and longevity.

To date, for the dairy farming sector, Horizon 2020 has focused on promoting technical change by promoting networking between research and farming through two Thematic Network projects.

There are also two SME projects relevant to dairy cow health. In addition to these project directly aimed at dairy producers, the programmes also supported a wide range of projects on animal health. These address for example BSE, antibiotic resistance, TB, and parasite control. These are directly relevant to animal health policymakers and to the pharmaceutical industry.

What is a Delphi survey?

The aim of this Delphi study is to get an insight into how the Framework Programmes are regarded by those who are expected to be impacted by them. To obtain valid opinion we need to consult key experts who are working in areas directly impacted by the programmes.

A Delphi enquiry is a technique that allows a group of experts to participate, jointly but anonymously, in analysing a complex issue. In our study, we envisage three rounds, each requiring about 15 minutes to complete a brief questionnaire.

For the first round we will ask you to complete the attached questionnaire. A glossary of terms used in the first round questionnaire is provided in Annex 3. After the completion of the first round questionnaire, you would subsequently receive a record of your answers, a summary of the wider group's responses and a further 15-minute questionnaire (second round questionnaire). The third and final round will proceed as round 2. Thus, your commitment in total is of one-hour maximum over a period of one to two months. In order to allow timely conclusion of the study we would respectfully request a response time of 1 week for completion of each round.

No personal information will be collected and survey responses will be collated anonymously using an identifying number known only to the participant and lead investigator. All responses received in the study will be strictly confidential, and your identity will not be divulged. Other members of the panel will not know who else is participating. Direct quotes to free-text answers may be used as part of the study report or later Delphi iterations, but these will be not be attributed to you or in any way be traceable to you.

Annex 1: Background to EU agriculture research[44]

The agricultural research (including animal health) in FP5, FP6 and FP7 evolved out of the FP4 FAIR programme that operated from 1994-1998. Overall, EU Framework Programme research in agriculture, food, fisheries and biotechnologies has been subject to successive changes in emphasis over the three previous Framework Programmes and Horizon 2020. Under FP5 it was addressed through the 'Quality of Life and Management of Living Resources' programme which particularly addressed food, biotechnology and primary production systems. FP6 emphasised food safety and quality, and consumer-related matters (fork-to-farm) in the 'Food quality and Safety' thematic priority. Complementing this, the Scientific Support to Policies (SSP) Programme addressed themes not directly related to consumer interests, for example some animal health issues and agricultural policies.

In FP7, food, agriculture, fisheries and biotechnology was integrated into a single theme taking into account global challenges such as food security and environmental changes. This general theme continued to be addressed under Societal Challenge 2 in Horizon 2020 (Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy).

Framework Programme 5
Thematic programme: Quality of life and management of living resources

Key actions:

- Sustainable agriculture, fisheries and forestry and integrated development of rural areas including mountain areas
- Control of Infectious diseases
- The "Cell Factory"
- Environment and health
- Food, nutrition and health

FP5 reflected growing emphasis in society on sustainable development. In contrast to previous programmes, it took a more cross-cutting approach with research relevant to Societal Challenge 2 embedded in programme areas addressing aspects of quality of life such as health and living resources. The development of integrated food and non-food supply chains was a general underlying theme of agricultural research. Agricultural research was mainly funded under the 'Quality of life and management of living resources' theme (one of four in FP5). Under this theme, agriculture had its own Key Action (one of five under the Quality of Life theme: 'Sustainable agriculture, fisheries and forestry, and integrated development of rural areas including mountain

[44] Directorate RTD.E Biotechnologies, Agriculture, Food, 2011, *FP Impact Assessment in Food, Agriculture, Fisheries and Biotechnologies*, Stand-alone Report.
Directorate RTD.E Biotechnologies, Agriculture, Food, 2011, *Impacts of EU Framework Programmes (2000-2010) and prospects for research and innovation in agriculture, animal health and welfare, and forestry*, Thematic Report.
2016, *Interim Evaluation of Horizon 2020. Societal challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy*, Final Report.

areas'). Much of the animal health research was funded through a separate Key Action under the 'Quality of life and management of living resources' theme called 'Control of Infectious diseases' which dealt with the control of infectious diseases in animals and humans. Agricultural research was also funded under the actions 'Food, nutrition and Health' and 'Environment and Health'.

The programme aimed to develop knowledge and technologies for the production and exploitation of living resources, including forests, covering the whole production chain, taking into account the highly competitive international context and the need for adaptation to changes to the common agricultural and fisheries policies, while also providing the scientific basis for regulations and standards. Reflecting concerns about reduced commodity prices and over-production in Europe, there was an emphasis on supply chains – particularly post-farm activities in food, and whole supply chains in the bio-based (non-food) sector.

Framework Programme 6
Thematic areas: Food Quality and Safety (Priority 5); Specific activities (Priority 8)

Overall, primary agricultural production in general and forestry in particular were side-lined in FP6. The words 'agriculture and forestry' were removed from the name of the programme and the only research directly relevant to the environmental and economic performance of European agriculture was in the 'Food Quality and Safety' Thematic Priority 5 (TP5). Much of the research into animal diseases was carried out under 'Specific activities' covering a wider field of research in Priority 8. Under this priority, research in support to policies (scientific support to policies) was developed to address European policy challenges in agriculture and animal health and welfare.

The research generally focused on questions relevant to consumers and sought impact by integrating research along supply chain lines or in relation to areas of policy. The Integrated Project (IP) funding instrument was introduced to fund large projects that address wide areas of research activity related to a particular area of policy or agriculture. The aim of these large projects was to bring together primary research, development, demonstration and training activities providing a complete science and technology supply chain addressing relevant opportunities or challenges. The Networks of Excellence were also introduced providing funding for collaboration between existing research centres and existing resources leading to the development of common and shared resources.

Framework Programme 7
Programme: Cooperation

Key thematic area: Food, Agriculture and Fisheries, and Biotechnology - Knowledge Based Bio-Economy (KBBE) programme:
Activity 1: Sustainable production
Activity 2: Food quality and safety
Activity 3: Biotechnology

Food, agriculture and fisheries and biotechnology research was brought together as a theme (Theme 2) to build a European Knowledge Based Bio-Economy (KBBE) integrating all research relevant to the commercial exploitation of biological resources.

Research was focused on the sustainable management, production and use of biological resources, with more funds for life sciences and biotechnology and the convergence with other technologies. The overall aim was to provide new, safer, affordable, eco-efficient and competitive products from European agriculture, fisheries, aquaculture, feed, food, health, forest based and related industries. FP7 reintroduced production agricultural research and included projects that address clear tangible farming and agricultural system targets. Investment in the Integrated Project instrument introduced in FP6 to fund large projects involving complete science and technology supply chain was greatly reduced in FP7 as was the concept of the Network of Excellence. More emphasis was placed on small and medium size collaborative research projects.

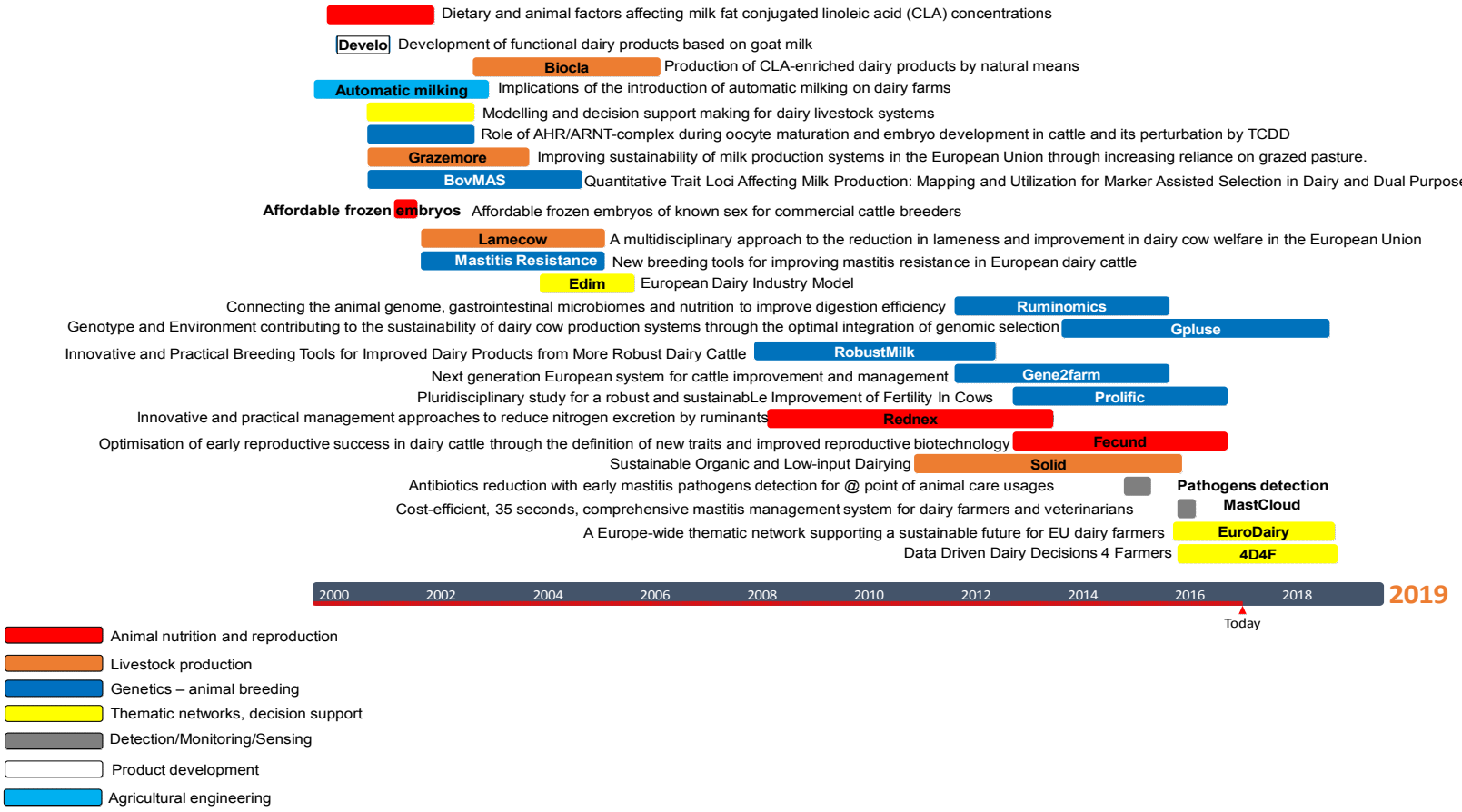
Horizon 2020
Programme: Societal Challenge 2 Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy

Funding activity lines:
2.1 Sustainable agriculture and forestry
2.2 Sustainable and competitive agri-food sector for a safe and healthy diet

In Horizon 2020 agricultural research is especially supported through ‘Sustainable agriculture and foresty’ and ‘Sustainable and competitive agri-food sector for a safe and healthy diet’ activity lines. The first activity line supports the development of knowledge, tools, services and innovations to support more productive, environmentally friendly resource-efficient and resilient agriculture and forestry systems that supply sufficient food, feed, biomass and other raw materials and deliver ecosystems services while at the same time protecting biodiversity and supporting the development of thriving rural livelihoods. The second activity line addresses food and feed security and safety, the competitiveness of the European agri-food industry and the sustainability of food production, processing and consumption. It covers the whole food chain and related services from primary production to consumption.

Annex 2: Details of projects supporting dairy farming

Gant chart showing the timing of projects from 2000 to 2019



Project details: short descriptions of the project proposals aimed at dairy farming

FP	Acronym	Title	Project activity	Abstract
FP5		Dietary and animal factors affecting milk fat conjugated linoleic acid (CLA) concentrations	Animal nutrition and reproduction	Investigation of animal and dietary factors influencing ruminant milk CLA production with a view to contributing to strategies for the sustainable production of health-promoting CLA enriched milk.
FP5	Develo	Development of functional dairy products based on goat milk	Product development	At the European level Greece and France account for 60 % of the goat milk production. Although the breeding systems are quite different in these countries, most of the goat milk is dedicated to the manufacture of traditional products. However, in order to respond to emerging consumers needs and dietary trends, Sees involved in the transformation of goat milk have to diversify their products. The aim of the exploratory phase is to prepare a Cooperative Research Project (CRAFT…
FP5	BIOCLA	Production of CLA-enriched dairy products by natural means	Livestock production	Conjugated linoleum acid (CLA), a natural component of milk fat exhibits several health promoting attributes, including protection against cancer, heart disease and obesity, diet-related diseases that contribute significantly to EU health-care costs. To confer the potential health benefits of CLA to humans, foods rich in CLA should be consumed. This project aims to develop dairy-based Functional Foods enriched in CLA, and evaluate their efficacy in humans. CLA enriched foods…
FP5	Automatic milking	Implications of the introduction of automatic milking on dairy farms	Agricultural engineering	The proposal aims at an integration of knowledge on, and developing solutions foray adverse effects of the introduction of automatic milking systems as a major technological innovation on dairy farms in EU member states. Topics addressed are adoption determinants, socio-economic impacts on farm level, consumer and Society acceptance, milking hygiene and milk quality, animal health and welfare, farm operation (including grazing) and management support requirements. Results should facilitate a smooth introduction of automatic milking without adverse, or even with positive, effects on farming conditions, well-being of cows, quality of milk and public acceptance, and complying with EU and national legislation. Objectives are to be achieved by an international and multidisciplinary research and dissemination approach, involving various research techniques.
FP5		Modelling and decision support making for dairy livestock systems	Thematic networks, decision support	Application of Decision Support Systems developed in the IERM to the dairy livestock systems of the Basque Country (mountainous region, North of Spain). Design of computer tools for advisory in renewable resources management optimisation.
FP5		Role of AHR/ARNT-complex during oocyte maturation and embryo development	Genetics - animal breeding	Project aims to determine the role of Air during acolyte maturation and embryo development in cattle and to investigate its role in mediating the effects of xenobiotics of anthropogenic origin (TCDD and PCB 126).

		in cattle and its perturbation by TCDD		
FP5	GRAZE MORE	Improving sustainability of milk production systems in the European Union through increasing reliance on grazed pasture.	Livestock production	Milk production systems based on a high reliance on grazed herbage offer a number of economic, animal welfare and environmental benefits. In order to increase uptake of such systems within the EU with particular application within the Atlantic Arc region, reliable decision support systems are required to assist the farmer in grassland management. This proposal brings together expertise from 5 member states within the EU to develop and validate European grass growth and herbage intake models and to incorporate these within a practical decision support system for use at farm level. At a EU level, the models developed in this project will enable examination of policy decisions on the relative competitiveness and economic sustainability of pasture-based production systems within individual member states.
FP5	BovMAS	Quantitative Trait Loci Affecting Milk Production: Mapping and Utilization for Marker Assisted Selection in Dairy and Dual Purpose Cattle.	Genetics - animal breeding	The proposal involves mapping QTL affecting milk production and associated traits by selective DNA pooling, in Simmental (dual-purpose); two Holstein anode (multicountry) Brown Swiss (dairy) cattle populations; and in a unique Simmental population produced by crossing a single F1 male (Red Holstein x Simmental) to Simmental as recurrent parent. High-resolution mapping will be carried out for some of the identified QTL, using selective recombinant genotyping within, and identical by descent mapping across the various populations. Allele frequency of QTL alleles, and marker heliotypes associated with positive and negative QTL alleles of active sires will be determined. Theoretical studies needed for use of QTL information for marker-assisted selection (MAS) will be carried out. The end product will be a body of QTL map information and sire marker/QTL information, and of validated methodologies for MAS for milk production traits in dairy and dual-purpose cattle.
FP5	Affordabl e frozen embryos	Affordable frozen embryos of known sex for commercial cattle breeders	Animal nutrition and reproduction	The high cost associated with conventional methods for producing and freezing bovine embryos restricts the use of the technology to the high value pedigree sector of the cattle breeding industry. Frozen embryos are an extremely cost effective and bio secures method for dissemination of bovine genetics. In order to promote the use of this valuable technology in the much larger commercial sector, this project seeks to significantly reduce frozen embryo production costs. In-vitro maturation, fertilisation and culture (IVP) of embryos provides the best opportunity for reducing the cost of production per se, but IVP embryos do not tolerate the freezing process well and calving rates after embryo transfer into recipients are not commercially acceptable. The purpose of the research is to develop an effective method for freezing IVP embryos by defining the culture and freezing media constituents, which are necessary to produce an embryo with good post-thaw viability. It will also be necessary to develop a method for packaging embryos for freezing, which complies with animal health regulations.
FP5	LAMECO W	A multidisciplinary approach to the reduction in lameness and improvement in	Livestock production	Lameness in dairy cows is a major economic and welfare problem. Interaction between husbandry systems, development of lameness and its biological causes are poorly understood. The project aim is to reduce lameness by identification and application of best practice and an understanding of underlying biological mechanisms. This will contribute to

		dairy cow welfare in the European Union		improved welfare, productivity and competitiveness in the EU dairy sector. A multidisciplinary approach using expertise in hoof trimming, housing/husbandry systems, fundamental biological research and quantitative statistic/ will provide an understanding of causes of lameness and will form the basis for sustainable prevention of lameness. Outputs: guidelines for minimal - lameness husbandry systems and training packages for the dairy sector. Socio-economic outcomes: reduced incidence of lameness, improved animal health and welfare, husbandry systems and product quality and increased productivity.
FP5	MASTITIS RESISTANCE	New breeding tools for improving mastitis resistance in European dairy cattle	Genetics - animal breeding	Selection based on phenotypes of disease and fitness traits is difficult, and thus breeding for improved disease resistance would benefit greatly from marker assisted selection (MAS). MASTITIS RESISTANCE aims at fine-mapping and characterising quantitative trait loci (QTL) affecting susceptibility and resistance to mastitis in European dairy cattle. Expected results are molecular genetic and statistical tools to improve cattle health either with MAS within breeds or with introgression of favourable QTL alleles to new breeds. The results will also provide a major step towards the understanding of the etiology of mastitis with respect to the infecting pathogen and pleiotropic effects of the QTL involved.
FP6	EDIM	European Dairy Industry Model	Thematic networks, decision support	The objective of the proposal is to design and use a set of complementary tools able to simulate the impact of alternative policy scenarios for the dairy sector over a medium term period. The consortium involved has already developed a set of two models which simulate the impact of dairy policies on the main markets variables for milk and 14 dairy products as well as the impacts on income and budgetary costs for the EU-15 at the Member State level for a ten years period. Thus the present proposal consists in: * Improving this existing tool to better represents the dairy industry in the EU-15. The improvements are related to re-estimation of model parameters (mainly related to milk supply and to consumers demand) and to obtaining a better representation of EU trade with the rest of the world. * Extending this tool to acceding countries. Due to time and data constraints, we propose a two level approach. For the main producing countries, we will develop a country module and for the remaining ones we will represent them as a single producing/trading area. * Developing complementary tools to perform more in depth analysis on specific issues. In particular, we will focus on the dynamics of farm structure and on the location of milk production at the regional level. In addition the impact of decoupling on quota rents and milk supply, as well as the potential impact of the different sources of imperfect competition in the dairy industry on milk price formation will be explored. * Using these tools to simulate dairy policy scenarios defined in close collaboration with DG Agri. Each of these items is defined as a workpackage of the project. An additional workpackage is devoted to data collection which is a key point for this project. Finally, a specific workpackage is designed for project management.
FP7	RUMINOMICS	Connecting the animal genome, gastrointestinal microbiomes and	Genetics - animal breeding	This project will integrate at the highest possible level expertise and technologies to increase the efficiency and decrease the environmental footprint of ruminant production, significantly advancing current knowledge in this sector. The project will exploit state-of-the-art –omics technologies to understand how ruminant gastrointestinal microbial ecosystems, or

		nutrition to improve digestion efficiency and the environmental impacts of ruminant livestock production		microbiomes, are controlled by the host animal and by the diet consumed, and how this impacts on greenhouse gas emissions, efficiency and product quality. New models and tools will be developed to enable the livestock industry to decrease environmental damage from methane and nitrogen emissions, and to improve efficiency of feed utilisation. A large-scale genetic association study involving 1000 dairy cows will relate feed intake, digestion efficiency, milk production/composition and methane emissions to the ruminal microbiome and host genome, leading to new indicator traits and tools for use in both traditional and genomic selection. Cow-reindeer metagenomic studies will establish how host species influence ruminal microbiology and function. Bovine twins studies will define how the rumen microbiome varies in an identical host genetic background. Nutrition work will assess how dietary oils, nitrogen and carbohydrates affect the ruminal microbiome and product quality. A meta-barcoding 16S rRNA analysis protocol will be developed to investigate ruminal microbiomes more accurately, rapidly and cheaply. Saliva and faeces will be analysed as possible tools for non-invasive assessment of ruminal microbiome and function. A novel method for on-farm methane analysis will be refined for easy application. Results will be publicly available through an online data warehouse that will provide tools to build new queries and create novel information. Transversal work packages include dissemination and industrial liaison, targeted towards the enlarged EU, and candidate and developing countries.
FP7	GPLUSE	Genotype and Environment contributing to the sustainability of dairy cow production systems through the optimal integration of genomic selection and novel management protocols based on the development	Genetics - animal breeding	The requirement for sustainable food production is a global issue to which the EU contributes as a major livestock producer. It is critical to improve animal production efficiency while sustaining environmentally friendly milk production. More profitable dairy production requires increased milk yield, cow health, longevity and fertility; reduced environmental footprint and optimised use of inputs. These are multifactorial problems to achieve. GplusE aims to identify the genotypes controlling biological variation in the important phenotypes of dairy cows, to appreciate how these are influenced by environmental and management factors and thus allow more informed and accurate use of genomic selection. GplusE will link new genomic data in dairy cows to a comprehensive array of phenotypic information going well beyond those existing traits recorded by dairy breeding organisations. It will develop systems that will focus herd and cow management on key time points in production that have a major influence on the rest of the productive cycle including efficiency, environment, physiological status, health, fertility and welfare. This will significantly advance the science, efficiency and management practices in dairy production well beyond the current state-of-the art. The major bioinformatics element of the proposal will illuminate the bovine genome and ensure a reverse flow of information to annotate human and other mammalian genomes; it will ensure training of animal scientists (PhDs & Postdocs) to a high skill level in the use of bioinformatics. The end result of this project will be a comprehensive, integrated identification of genomic-phenotypic associations relevant to dairy production. This information will be translated into benefits for animal breeding and management that will considerably improve sustainable dairy production. It will provide basic biological information into the

				mechanisms by which genotype, environment and their interaction influence performance.
FP7	RobustMilk	Innovative and Practical Breeding Tools for Improved Dairy Products from More Robust Dairy Cattle	Genetics - animal breeding	The objective of ROBUSTMILK is to develop new practical technologies to allow breeders to re-focus their selection to include milk quality and dairy cow robustness and to evaluate the consequences of selection for these traits taking cognisance of various milk production systems. Six research organisations, all with a strong network in the animal breeding industry, have agreed to share knowledge and resources to develop a strong research program to achieve this objective. Each partner has its own specialised expertise (phenotypic recording, statistics, genomics) and unique data available, in the form of milk quality and dairy cattle robustness. The overall objective is achieved by five integrated workpackages, each having their own objective: 1) Creation of a common data-base that includes unique and scarcely recorded phenotypic measurements for traits underlying robustness and milk quality, together with productivity records and fertility; 2) to develop phenotypic measurement tools for robustness (energy balance) and milk quality (lactoferrin and fatty acid composition) using mid-infrared spectrometry; 3) to develop statistical tools to select for robustness and milk quality (udder health and SCC) taking into account complex biological backgrounds; 4) to develop genomic tools for selection for productivity, robustness (fertility, energy balance and udder health) and milk quality traits (lactoferrin and fatty acid composition); and 5) integrating and disseminating knowledge on the consequences of selection practises on robustness and milk quality. ROBUSTMILK has the potential to enhance the competitiveness of European agriculture through the production of higher quality dairy products and more sustainable dairy production systems. ROBUSTMILK will contribute significantly towards the Knowledge Based Bio Economy objective of the EU, through a greater understanding of factors contributing to genetic variation and exploiting this variation in a sustainable manner in genetic improvement programmes.
FP7	GENE2FARM	Next generation European system for cattle improvement and management	Genetics - animal breeding	The Gene2Farm project will address the needs of the cattle industry, in particular of the SMEs and end users, for an accessible, adaptable and reliable system to apply the new genomic knowledge to underpin sustainability and profitability of European cattle farming. Gene2Farm will undertake a comprehensive programme of work from statistical theory development, through genome sequencing, to address new phenotyping approaches and the construction of tools, that will be validated in conjunction with SMEs and industry partners. Advanced statistical theory and applications will use the genomic and phenotypic information to optimise and customise genomic selection, breeding and population management and between breed predictions. The project will sequence key animals and exchange data with other international projects to create the most comprehensive bovine genome sequence database. Detailed analysis of these genome sequences will define genome structure, shared alleles, frequencies and historic haplotypes, within and between populations. This information will be used to optimise the informativeness of SNP panels and select SNPs to tag haplotypes, and hence ensure that genotype information can be used within and between breeds. The project will explore the opportunities for extended phenotypic collection, including the use of automated

				on farm systems and will develop standardisation protocols that, in consultation with ICAR, could be used by the industry for data collection and management. Developed tools will be tested and validated by demonstration in collaboration with dairy, dual purpose, beef and minority breed organisations. Finally a dissemination programme will ensure that training needs of the industry are served from an entry level training programme for farmers to advanced summer schools for the SMEs and expert user community.
FP7	PROLIFIC	Pluridisciplinary study for a RObust and sustainabLe Improvement of Fertility In Cows	Genetics - animal breeding	Intensive genetic selection in dairy cattle has resulted in a modern cows with very high milk yield but reduced fertility and poor calving performance. The sustainability of dairy cattle farming systems relies in large part on the ability of cows to maintain reproductive performance as they cope with the constraints imposed by environmental conditions and livestock practices. The strategic aim of this project is to unlock the potential for proactive herd management by providing the farmer with improved tools for on-farm reproductive monitoring and management. This will be achieved by a pluridisciplinary approach to eliminate the key scientific/methodological blockages and develop innovative solutions for a robust and sustainable improvement of fertility in cows. The project is structured in four R&D workpackages, one demonstration, one outreach and one management WP. The project will: 1) develop models to support on farm decision at different levels: animal fertility, herd management, and socio-economic impact for the farm and the farmer 2) identify genes and pathways involved in the adaptation of the reproductive function to different environmental conditions, especially low input feeding systems 3) identify the functional quantitative trait nucleotides for days till first luteal activity (based on progesterone measures) and estimate genomic breeding values using whole sequence information on individuals 4) study the adaptative response of animals to different feeding systems and management strategies 5) demonstrate the applicability of the knowledge and tools produced in the PROLIFIC project at the farm level 6) disseminate the knowledge produced in the project to the relevant stakeholders. PROLIFIC is a pluridisciplinary project taking advantage of the skills and expertise (modelling, molecular biology, genomics, phenotypic recording and statistics) of partners from all Europe. Seven research organizations, one industry and four SMEs are involved in the project
FP7	REDNEX	Innovative and practical management approaches to reduce nitrogen excretion by ruminants	Animal nutrition and reproduction	Dairying is an important sector of EU agriculture, but intensification has been accompanied by an increase in N surplus. This has a negative environmental impact on groundwater (pollution with nitrates), surface water (eutrophication) and on the atmosphere (de-nitrification and ammonia volatilisation). The EU seeks to stimulate measures that improve management of nutrients, waste and water as a start to move to management practices beyond “usual good-farming practice”. The objective of REDNEX is to develop innovative and practical management approaches for dairy cows that reduce nitrogen excretion into the environment through the optimization of rumen function, an improved understanding and prediction of dietary nitrogen utilization for milk production and excretion in urine and faeces. Novel tools for monitoring these processes and predicting the consequences in terms of N losses on–farm

				will be developed. At the centre of the project is a detailed mathematical model of N utilization by the cow which will act to integrate results from previous work and from new research carried out in the project. This interlinked research aims to improve the supply of amino acids to be absorbed relative to the quantity and quality of amino acids and carbohydrates in feed allowing a reduction in N intake. Research to understand amino acid absorption, intermediary utilization and the processes involved in the transfer of urea N from blood to the gastro-intestinal tract will further underpin model development and indicate strategies to reduce N losses. To predict N losses on-farm and the impact on profitability, a harmonised applied model will be derived from the mechanistic model and will be supported by tools to better describe feeds and biomarkers to indicate N status. Impact of the research will be enabled by dissemination and knowledge interaction using a participatory approach to include the views of stakeholders and recognition of the need to provide support to EU neighbours.
FP7	FECUND	Optimisation of early reproductive success in dairy cattle through the definition of new traits and improved reproductive biotechnology	Animal nutrition and reproduction	Good fertility is essential for the sustainability of livestock production. Of all livestock sectors, fertility of dairy cattle is raising the greatest cause for concern. Cow fertility has declined, particularly in Holstein cattle, from 80% pregnancy to first service 20 years ago to less than 40% today. Poor fertility is one of the main reasons for early culling, such that modern dairy cows complete fewer than 3 lactations, on average. The FECUND project will address the metabolic and genetic causes of low reproductive success of dairy cows in an interdisciplinary approach that will integrate in vivo and in vitro studies, biology, physiology, -omics technologies and bioinformatics. FECUND will focus on the early phases of reproduction from oocyte development to implantation of the conceptus. Starting from biological materials produced from high and low genetic merit cattle and from cows under energy stress of early lactation vs dry cows and heifers, FECUND will study, independently, the effects of genetics and metabolic stress on reproductive physiology to identify factors and early markers associated with high and low developmental potential, and with positive mother-conceptus interaction during the early stages of reproduction. These data will be mined to reveal physiological pathways and key candidate genes controlling variations of fertility. The biological knowledge created on early reproductive events in vivo will be validated in vitro, and extended to create further knowledge on the effects of the local environment on oocyte and embryo programming at the epigenetic level. Validated information will be used to improve herd management, gene assisted and genomic selection and assisted reproductive technologies, from in vitro ooctye maturation to optimised embryo culture. Information on biomarkers, indicator traits and improvements in assisted reproduction will be translated to applications that can be immediately implemented by SMEs.
FP7	Solid	Sustainable Organic and Low-input Dairying (SOLID)	Livestock production	Organic and low-input dairy farming systems are increasingly noted as delivering multifunctional benefits to the agricultural industry and society but technical and economic constraints prevent widespread adoption. SOLID will deliver an innovative toolbox of novel methodologies that will contribute to the competitiveness of the dairy industry and increase the effectiveness with which these benefits are delivered. SOLID facilitates the use of breeds and

				feeding strategies to maintain productivity, improve animal health and welfare while meeting the market requirement for high quality milk. A multidisciplinary team comprising academic and stakeholder (SME) partners from across Europe, encompassing dairy cows and goats, will identify and apply novel strategies at the farm level and throughout the supply chain. Innovative science and models, combined with a participatory approach, will tackle practical issues, and assess competitive sustainability and integration across a range of scales and geographical contexts. Proteomics combined with genotyping and calorimetry will be used to characterise and quantify dairy cow and goat breed adaptation to organic and low-input systems. Given the reliance of such systems on forage, SOLID will develop novel and sustainable feed resources and design a decision-support model to optimise the management of on-farm forage supply. Life cycle assessment tools will assess environmental sustainability of grassland-based multifunctional dairy systems. Analysis of the supply chain from fork to farm will quantify the acceptability of new strategies and enhance collaboration. An integrated assessment tool and socio-economic modelling will assess innovations on farms and along supply chains, and will predict the impact of more widespread adoption of low-input practises. Effective knowledge dissemination and exchange activities will target key stakeholder groups ensuring exploitation of outputs at animal, farm, region, sector and European levels.
H2020	Pathogens detection	Antibiotics reduction with early mastitis pathogens detection for @ point of animal care usages	Detection/Monitoring/Sensing	Blue4Green will develop a portable sample handling/sensing system for DNA and/or RNA fragments. The input to such a system is a raw sample of milk, containing the bacteria to be analysed that causes mastitis. Most of the time treatment starts without knowing the responsible pathogen. Often, the wrong (or not most optimal) antibiotic is used as treatment. When therapy fails, new mastitis incidences and prevalence's are rising. To test, at this moment farmers collect their samples in testing tubes. These tubes should be transported and send to a laboratory. Within the laboratory, the fluid is tested and the farmer receives the results within three (or more) days. The new technology, concerns a more rapid detection method. Within the technique of B4G, it is possible to know which pathogen is responsible for the inflammation to treat mastitis infection within three minutes instead of three days (or more) since the farmer can test it by himself. With a rapid mastitis pathogen test: - less mastitis incidences occur - reduce of revenue losses (less new infection) - there will be less use of unnecessary antibiotic - more milk will be produced - a better dairy cattle lifetime will be developed, resulting in a better return on investment for the farmer per cow Detecting mastitis at an early stage is a new competitive eco-innovative process that contributes to a more resource-efficient, sustainable circular economy. Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years. Growing competition for land, water, and energy, will affect our ability to

				produce food, as will the urgent requirement to reduce the impact of the food system on the environment. Extending the lifespan of dairy cattle by combating mastitis with better insights @ point of animal care using innovative diagnostics tools will lead to a proper use of resources hence a more the efficiency use of raw materials.
H2020	MastCloud	Cost-efficient, 35 seconds, comprehensive mastitis management system for dairy farmers and veterinarians	Detection/Monitoring/Sensing	On dairy farms, mastitis or udder inflammation often is the most common disease and the major reason for antibiotics use. Annual losses in the milk supply chain due to mastitis are estimated to be over 1 billion euro in Europe, with similar figures in other parts of the world. In order to reduce these losses, we propose an innovative Cloud-connected mastitis management system composed of an instrument and a modular software suite. Our solution will significantly improve resource efficiency and energy efficiency in the milk production industry. For the instrument, we use a widely accepted mastitis indicator: somatic cell count. We digitize and automate a famous test method: CMT (California Mastitis Test). The average measurement duration of the system will be 35 seconds for typical farm mastitis incidence rates and the operating cost will be less than 0.02 euro per test. The instrument comes with guaranteed high correlation with official lab results. We adopt recent evolutions in mobile devices and IT technologies in order to enable affordable smart farming and tele-vet services through automated analysis, dashboards and remote diagnosis modules. Through our embedded algorithms, we are putting into practice research from universities in Belgium and other countries around milk quality and animal health. Our solution will respond to the current tendency with less frequent official milk quality recordings by dairy herd improvement (DHI) associations, while instead enabling efficient on-farm measurements. The existing on-farm mastitis management systems on the market suffer from high operating costs, are too complex or unreliable hence are no solution for the majority of the 1.5 million dairy farms and their veterinarians in Europe. During Phase 1, we want to perform a feasibility study, to refine our cost and profit estimations with detailed figures and perform a design study. Finally we will create a detailed business plan.
H2020	EuroDairy	A Europe-wide thematic network supporting a sustainable future for EU dairy farmers	policy analysis, thematic networks, decision support	EuroDairy will foster development and dissemination of practice-based innovations in dairy farming on key sustainability issues for the post-quota era. Work Package 1 (Project co-ordination) oversees formation of the Thematic Network, ensures interconnectivity in generation, capture and demonstration of innovation and best practice, and reports project outputs including recommendations for further innovation-driven research. WP 2 (Network of innovating pilot farmers and Knowledge Transfer Centres) establishes a community of

				innovating dairy farmers which through experience and practice on their own farms, bring good ideas and implementable solutions to EuroDairy. The farms participate in regional multi-actor operational groups, and connect as a network to share knowledge across borders. WPs 3-6 focus on four key topics - Resource efficiency, Biodiversity, Animal care, and Socio-economic resilience. These WPs provide leadership, direction and technical expertise for the exchange of innovative thinking, tools, technologies and best practice across the thematic network (pilot farmers, Knowledge Transfer Centres, and regional operational groups). WP 7 (Synergies in scientific and practice-based knowledge) draws from WPs 3-6 to capture new insights from combining science with practice-based knowledge, including benefits and trade-offs in solutions identified. WP 8 (Production and communication of end-user materials) implements a mix of novel and tried-and-tested approaches to internal and external communications. A diverse range of end-user outputs will be produced, made widely accessible to farmers. EuroDairy supports H2020 objectives to increase productivity, improve competitiveness and impact less on the environment. Involvement of dairy levy bodies, farmers' organisations and cooperatives in an interactive, bottom-up approach will ensure practical relevance, and multiply benefits across Europe. Direct links to Hennovation and AgriSPIN, will add value to the project.
H2020	4D4F	Data Driven Dairy Decisions 4 Farmers	policy analysis, thematic networks, decision support	The Data Driven Dairy Decisions for Farmers (4D4F) thematic network will focus on the role which dairy animal and environmental sensors can play in collecting real time information to help make more informed decisions in dairy farming.The network will develop a Community of Practice comprised of farmers, farm advisors, technology suppliers, knowledge exchange professionals and researchers who will work together to debate, collect and communicate best practice drawn from innovative farmers, industry and the research community to facilitate the co-creation of best practice. The results will be communicated to farmers using best practice guides on the use of sensors and data analysis tools supported by videos, infographics and an online virtual warehouse of dairy sensor technologies.The network will include the development of Standard Operating Procedures (SOPs) which can be tailored to individual farms to help farmers and farm advisors adopt dairy sensor and data analysis technology. The SOPs will be developed by working groups of the Community of Practice including farmers, farm advisors, technology suppliers, knowledge exchange professionals and researchers, who will work together to develop farmer friendly SOPs.The on line Community of Practice and published communication tools will be complimented by on farm events and workshops to help farmers and farm advisors implement innovative sensor and data analysis technologies. The workshops and events will promote discussion between farmers and their peers on how best to use sensors and data analysis in their own businesses. This will lead to local peer to peer support to facilitate the adoption of data driven dairy decision making.The network will work closely with EIP Agri and at member state level it will work with existing EIP Operational Groups working on dairy data and sensors and, where suitable Operational Groups do not exist, it will work with local partners to develop new Operational Groups.

Annex 3: Glossary of terms[45]

Outputs

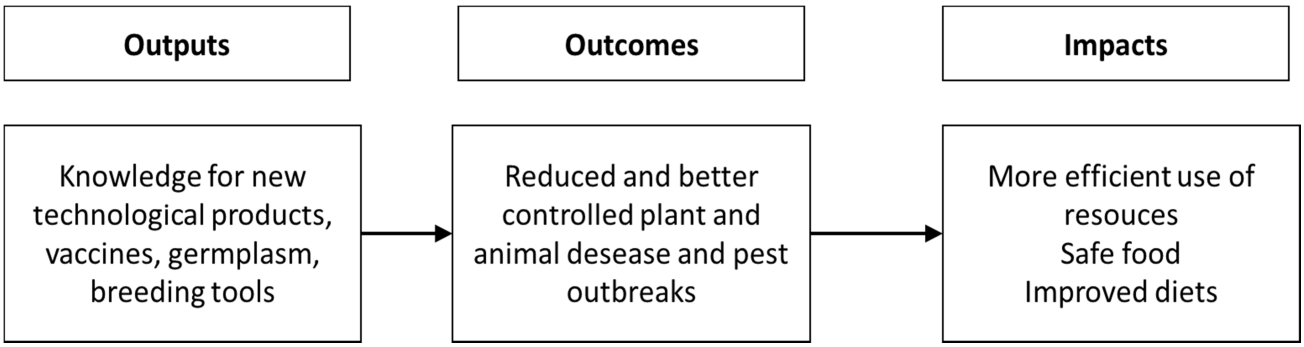
The results of programme/intervention activities. The direct products, deliverables, capital goods and services which result from a development intervention, in this case the funding of R&D projects. It may also include changes resulting from the intervention which are relevant to the achievement of outcomes.

Outcomes

The likely or achieved short-term and medium-term effects of an intervention's outputs. Effects or manifestations of outputs.

Impacts

Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. Cumulative effect of programmes/intervention over time, demonstrable contribution that intervention makes to science, economy, society, culture, policy, services, environment, quality of life and so on.



[45] Adapted from OECD Glossary of Key terms in Evaluation and Results Based Management http://www.oecd.org/dac/evaluation/glossaryofkeytermsinevaluationandresultsbasedmanagement.htm

ANNEX 4: DELPHI ROUND 1 BRIEFING FOR CEREAL AND GRAIN LEGUME CROP BREEDERS

European Union Framework Programme research and development for Societal Challenge 2

Impact of past research and the way forward
Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy

Briefing for sector experts

Framework Programme Research supporting cereal and grain legume crop breeding

Overview of research for cereal breeding

This study is part of a wide assessment of the direction and impact of Framework Programmes 5, 6, 7 and Horizon 2020 in the field of Food, Agriculture, Forestry, Fishery, Aquaculture, Bioeconomy. It is being carried out by an expert group (Annex 4 provides the list of the expert group members). The overall purpose is to provide input into the development of future Framework Programme activity in the Societal Challenge 2 area that currently aggregates all the above mentioned fields. You are invited to contribute to this Delphi study because you were identified as a recognised expert in this area of agriculture and because you represent the community impacted by the part of the programmes under analysis and the relative projects funded. In the following pages, you will find information about the R&D under analysis and the most relevant projects funded in your area.
A general overview of the development of agricultural research in the Framework Programmes, which was prepared by the Assessment Group, is presented in Annex 1. The Framework Programmes (FP) 5, 6, 7 and Horizon 2020 have invested a total of 217 million Euros in 53 R&D projects that are relevant to the cereal and grain legume crop breeding sector. This comprises 23 projects in FP5 (EU contribution of 24 million Euros); 8 projects in FP6 (EU contribution of 68 million Euros); 21 projects in FP7 (EU contribution of 89 million Euros); and 1 project so far in Horizon 2020 (EU contribution of 3.4 million Euros). The projects are presented in Annex 2.

Priorities varied between Framework Programmes and this is reflected in the type of research relevant to cereal and legume crop breeding that was supported. FP5 supported a diverse range of activities, most of which can be described as general support to the plant breeding research community. While most of the research was quite basic, it included some more specific targets such as in EUfaba. FP6 focused much of the funding on a four large projects that accounted for 61 million Euros. As in FP5, these projects generally underpinned the genetic improvement of crops but included some les general targets (e.g., grain legumes) and also included a wide range of activities from molecular biology through to value chain development and economic assessments. The projects funded under FP7 were generally smaller than in FP6, and more focused on particular types of crops or trait complexes such as root development or drought tolerance. There was

increased emphasis on genetic resources. FP7 also included a substantial investment in enabling (i.e. relatively basic) research. Horizon 2020 continued emphasis on genetic resources. One project focused of increasing crop diversity is relevant.

What is a Delphi survey?

The aim of this Delphi study is to get an insight into how the Framework Programmes are regarded by those who are expected to be impacted by them. To obtain valid opinion we need to consult key experts who are working in areas directly impacted by the programmes.
A Delphi enquiry is a technique that allows a group of experts to participate, jointly but anonymously, in analysing a complex issue. In our study, we envisage three rounds, each requiring about 15 minutes to complete a brief questionnaire.

For the first round we will ask you to complete the attached questionnaire. A glossary of terms used in the first round questionnaire is provided in Annex 3. After the completion of the first round questionnaire, you would subsequently receive a record of your answers, a summary of the wider group's responses and a further 15-minute questionnaire (second round questionnaire). The third and final round will proceed as round 2. Thus, your commitment in total is of one-hour maximum over a period of one to two months. In order to allow timely conclusion of the study we would respectfully request a response time of 1 week for completion of each round.

No personal information will be collected and survey responses will be collated anonymously using an identifying number known only to the participant and lead investigator. All responses received in the study will be strictly confidential, and your identity will not be divulged. Other members of the panel will not know who else is participating. Direct quotes to free-text answers may be used as part of the study report or later Delphi iterations, but these will be not be attributed to you or in any way be traceable to you.

Annex 1: Background to EU agriculture research[46]

The agricultural research (including animal health) in FP5, FP6 and FP7 evolved out of the FP4 FAIR programme that operated from 1994-1998. Overall, EU Framework Programme research in agriculture, food, fisheries and biotechnologies has been subject to successive changes in emphasis over the three previous Framework Programmes and Horizon 2020. Under FP5 it was addressed through the 'Quality of Life and Management of Living Resources' programme which particularly addressed food, biotechnology and primary production systems. FP6 emphasised food safety and quality, and consumer-related matters (fork-to-farm) in the 'Food quality and Safety' thematic priority. Complementing this, the Scientific Support to Policies (SSP) Programme addressed themes not directly related to consumer interests, for example some animal health issues and agricultural policies.

In FP7, food, agriculture, fisheries and biotechnology was integrated into a single theme taking into account global challenges such as food security and environmental changes. This general theme continued to be addressed under Societal Challenge 2 in Horizon 2020 (Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy).

Framework Programme 5
Thematic programme: Quality of life and management of living resources

Key actions:
Sustainable agriculture, fisheries and forestry and integrated development of rural areas including mountain areas
Control of Infectious diseases
The "Cell Factory"
Environment and health
Food, nutrition and health

FP5 reflected growing emphasis in society on sustainable development. In contrast to previous programmes, it took a more cross-cutting approach with research relevant to Societal Challenge 2 embedded in programme areas addressing aspects of quality of life such as health and living resources. The development of integrated food and non-food supply chains was a general underlying theme of agricultural research. Agricultural research was mainly funded under the 'Quality of life and management of living resources' theme (one of four in FP5). Under this theme, agriculture had its own Key Action (one of five under the Quality of Life theme: 'Sustainable agriculture, fisheries and forestry, and integrated development of rural areas including mountain

[46] Directorate RTD.E Biotechnologies, Agriculture, Food, 2011, *FP Impact Assessment in Food, Agriculture, Fisheries and Biotechnologies*, Stand-alone Report.
Directorate RTD.E Biotechnologies, Agriculture, Food, 2011, *Impacts of EU Framework Programmes (2000-2010) and prospects for research and innovation in agriculture, animal health and welfare, and forestry*, Thematic Report.
2016, *Interim Evaluation of Horizon 2020. Societal challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy*, Final Report.

areas'). Much of the animal health research was funded through a separate Key Action under the 'Quality of life and management of living resources' theme called 'Control of Infectious diseases' which dealt with the control of infectious diseases in animals and humans. Agricultural research was also funded under the actions 'Food, nutrition and Health' and 'Environment and Health'.

The programme aimed to develop knowledge and technologies for the production and exploitation of living resources, including forests, covering the whole production chain, taking into account the highly competitive international context and the need for adaptation to changes to the common agricultural and fisheries policies, while also providing the scientific basis for regulations and standards. Reflecting concerns about reduced commodity prices and over-production in Europe, there was an emphasis on supply chains – particularly post-farm activities in food, and whole supply chains in non-food.

Framework Programme 6
Thematic areas: Food Quality and Safety (Priority 5); Specific activities (Priority 8)

Overall, primary agricultural production in general and forestry in particular were side-lined in FP6. The words 'agriculture and forestry' were removed from the name of the programme and the only research directly relevant to the environmental and economic performance of European agriculture was in the 'Food Quality and Safety' Thematic Priority 5 (TP5). Much of the research into animal diseases was carried out under 'Specific activities' covering a wider field of research in Priority 8. Under this priority, research in support to policies (scientific support to policies) was developed to address European policy challenges in agriculture and animal health and welfare.

The research generally focused on questions relevant to consumers and sought impact by integrating research along supply chain lines or in relation to areas of policy. The Integrated Project (IP) funding instrument was introduced to fund large projects that address wide areas of research activity related to a particular area of policy or agriculture. The aim of these large projects was to bring together primary research, development, demonstration and training activities providing a complete science and technology supply chain addressing relevant opportunities or challenges. The Networks of Excellence were also introduced providing funding for collaboration between existing research centres and existing resources leading to the development of common and shared resources.

Framework Programme 7
Programme: Cooperation

Key thematic area: Food, Agriculture and Fisheries, and Biotechnology - Knowledge Based Bio-Economy (KBBE) programme:
Activity 1: Sustainable production
Activity 2: Food quality and safety
Activity 3: Biotechnology

Food, agriculture and fisheries and biotechnology research was brought together as a theme (Theme 2) to build a European Knowledge Based Bio-Economy (KBBE) integrating all research relevant to the commercial exploitation of biological resources.

Research was focused on the sustainable management, production and use of biological resources, with more funds for life sciences and biotechnology and the convergence with other technologies. The overall aim was to provide new, safer, affordable, eco-efficient and competitive products from European agriculture, fisheries, aquaculture, feed, food, health, forest based and related industries. FP7 reintroduced production agricultural research and included projects that address clear tangible farming and agricultural system targets. Investment in the Integrated Project instrument introduced in FP6 to fund large projects involving complete science and technology supply chain was greatly reduced in FP7 as was the concept of the Network of Excellence. More emphasis was placed on small and medium size collaborative research projects.

Horizon 2020
Programme: Societal Challenge 2 Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy

Funding activity lines:
2.1 Sustainable agriculture and forestry
2.2 Sustainable and competitive agri-food sector for a safe and healthy diet

In Horizon 2020 agricultural research is especially supported through 'Sustainable agriculture and foresty' and 'Sustainable and competitive agri-food sector for a safe and healthy diet' activity lines. The first activity line supports the development of knowledge, tools, services and innovations to support more productive, environmentally friendly resource-efficient and resilient agriculture and forestry systems that supply sufficient food, feed, biomass and other raw materials and deliver ecosystems services while at the same time protecting biodiversity and supporting the development of thriving rural livelihoods. The second activity line addresses food and feed security and safety, the competitiveness of the European agri-food industry and the sustainability of food production, processing and consumption. It covers the whole food chain and related services from primary production to consumption.

Annex 2: Details of projects supporting cereal and legume crop breeding

Timeline of projects in FP5