European Commission

Evaluation study on Excellent Science in the European Framework Programmes for Research and Innovation – Horizon 2020

Phase 1 Final Study Report

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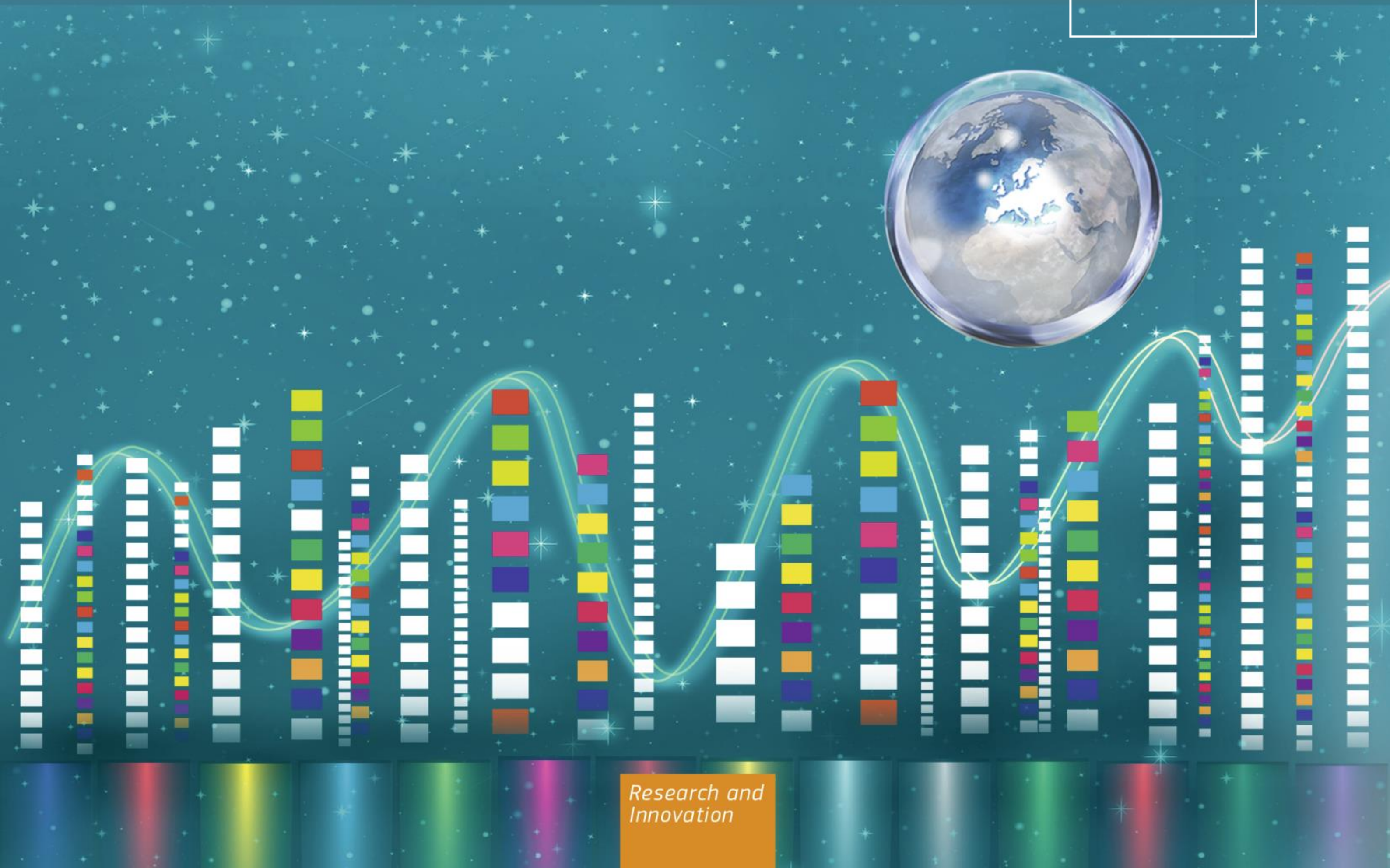
Independent
Expert
Report



Research and Innovation

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European Commission
Directorate-General for Research and Innovation
Contacts Katerina Aristodemou (DG RTD), Adeline Kroll (DG RTD), Benjamin Turner (ERCEA)
Email RTD-G2-SUPPORT@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

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EUROPEAN COMMISSION

Evaluation study of the European Framework Programmes for Research and Innovation for Excellent Science – Horizon 2020

Phase 1 Final Study report

Evaluation in support of the ex-post evaluation of the European Framework Programme for Research and Innovation Horizon 2020

PPMI: Mantas Budraitis, Rūta Dėlkutė, Dovydas Caturianas, Joona Nikinmaa, Paulius Pranckevičius

IDEA Consult: Lidia Núñez, Laura Lecluyse, Emma Legein

UNU-MERIT: Ad Notten, Nordine Es-Sadki, René Wintjes, Fabiana Visentin, Tommaso Ciarli, Davide Bonaglia, Bula Sanditov, Yagmur Yildiz, Diego Chavarro

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Executive summary

This evaluation study, performed in line with the Better Regulation Guidelines, serves as an input into the *ex-post* evaluation of Horizon 2020, the EU framework programme for Research and Innovation 2014-2020. Horizon 2020 was adopted in the context of the Europe 2020 Strategy, and was designed to drive economic growth and create jobs by coupling research and innovation (R&I), with an emphasis on excellent science, industrial leadership and tackling societal challenges.

This study assesses the overall contribution of Horizon 2020 to excellent science across the framework programme with a particular focus on the activities under Pillar 1, Excellent Science (i.e. the European Research Council (ERC), Marie Skłodowska-Curie Actions (MSCA), European research infrastructures (INFRA), and Future and Emerging Technologies (FET)), as well as the horizontal pillars Spreading Excellence and Widening Participation (SEWP) and Science with and for Society (SwafS). The study builds on the Horizon 2020 intervention logic and relies on a wide range of methods. These include (but are not limited to) desk research, a broad-scope interview programme, 15 case studies and four international benchmark studies, a survey programme, a bibliometric analysis, econometric modelling, and the analysis of (unstructured and EC monitoring) data. The findings of the study respond to a set of evaluation questions covering the five evaluation criteria: relevance, coherence, efficiency, effectiveness and EU added value. This study places a stronger focus on the key findings, conclusions and recommendations in relation to efficiency, effectiveness and EU added value, as the other evaluation criteria are analysed in greater depth by other ongoing studies.

This evaluation study shows that the framework programme and its objectives and activities are considered **relevant** in the light of Europe's challenges and priorities. During Horizon 2020, there was a shift towards more impact-oriented research, being the programme less prescriptive in terms of specific research or the technological areas to be addressed. Bottom-up and top-down approaches within Horizon 2020 were aligned with both excellent research and societal challenges. This mix of approaches is complementary and allows for a better coverage of research needs and policy priorities. It is, however, important to bear in mind that the various pillars and the bottom-up and top-down approaches each had a different focus. This diversity of instruments also comes with certain limitations in terms of navigability between different EU-level instruments: the large number of different instruments creates a rather complex R&I support framework. This complicates the search for opportunities and relevant calls, especially for those entities that are new to the framework programme.

Overall, there is a strong **coherence** between different parts of the Horizon 2020 programme, particularly in terms of addressing societal challenges and cross-cutting issues in Europe. Similarly, Horizon 2020 programme parts – MSCA, FET, the ERC and INFRA – strongly complemented each other in the production of excellent science. The research activities funded under MSCA and the ERC were especially coherent, with the ERC under Horizon 2020 being considered a natural next step in a researcher's career after participating in MSCA. Evidence indicates that the ERC funds a broad portfolio of projects that provide a high degree of complementarity with the themes and challenges covered by the rest of Horizon 2020. At the same time, evidence indicates that Horizon 2020 was highly complementary to other support schemes at EU and national levels. In particular, this is due to Horizon 2020 being the sole EU programme supporting transnational R&I activities and networks, including partnerships with Member States, businesses and foundations. In addition, the study findings indicate that Horizon 2020 partnerships were complementary both with each other and with other parts of the programme, especially through the contributions they have made to common higher-level goals while using different instruments, covering different technology readiness levels (TRLs), and attracting different types of stakeholders.

The study finds that the implementation and management of Horizon 2020 and the programme parts under analysis (ERC, MSCA, INFRA, FET, SEWP and SwafS) were **efficient** and cost-effective. Despite the large number of applications received, the process of concluding grant agreements was swift: the average time-to-grant period for Horizon 2020 and its separate pillars was below the target of 8 months. The time taken to make the payments was also fast, with 91.5% of all payments being made within the legal targets. The attractiveness of the framework programme led to the problem of oversubscription, and thus low overall success rates for applications (11.5% versus 18.5% in FP7). The highest levels of competition were found in Pillar 2 (with a success rate of 8%), and in Pillar 1 (with a success rate of 10%), leaving many high-quality applications unfunded. In theory, to fund all high-quality proposals submitted Horizon 2020, an additional EUR 183 billion would have been needed. Furthermore, evidence shows that, from the perspective of research outputs, the majority of Horizon 2020 projects were implemented in a cost-effective way, meaning that the volume of outputs produced was proportional to the EC contribution. The ERC and MSCA were the most cost-effective, with 90.9 and 85.9 publications per EUR 10 million, respectively.

With regard to **effectiveness,** Horizon 2020 has produced 138,888 peer-reviewed publications. Pillar 1 displays the highest number of publications, primarily thanks to the ERC and MSCA. The most frequent outputs of Horizon 2020 projects were articles (75%), followed by conference papers (17%) and reviews (7%). Of the peer-reviewed publications produced under Horizon 2020, 3.9% appeared among the 1% most-cited publications. Horizon 2020 has strengthened the scientific position of the EU worldwide: the framework programme has higher publication citation scores than any other funder selected for benchmarking in most of the disciplines analysed – both in terms of its share of the top 1% most-cited publications and the average normalised citation score of its publications. Horizon 2020 contributed to the development of future and emerging research and technology fields, with the largest contribution in terms of number of publications coming from Pillar 1 (Excellent Science). In relative terms, Pillars 2 (Industrial Leadership) and 3 (Societal Challenges) displayed higher shares of publications linked to these research and technology fields.

Horizon 2020´s open access principles and requirements had a strong positive impact in terms of open access rates (82% across Horizon 2020), which are comparable to those obtained at international level by those research funders that are more advanced in this domain. However, not all of the data produced complied with FAIR principles, and differences emerged between disciplines and between programme parts. From the perspective of the programme's structuring effect, Horizon 2020 has achieved a strong structuring effect on the European research landscape, facilitating the emergence of thousands of new collaborations between researchers. The findings of the publication network analysis show that the number of co-author pairs counted after the end of Horizon 2020 projects was higher than those counted before. Furthermore, at the time of the evaluation, the specific KPI target values set for the particular Horizon 2020 programme parts within the scope of this study have either been reached (ERC, FET – number of publications; INFRA and SwafS) or are close to being reached (MSCA and FET –number of patents).

In addition, the programme has largely supported the international mobility of researchers, contributing to the circulation of talent and knowledge across the ERA and strengthening researchers´ skills. While there is qualitative evidence pointing to the positive effects of the programme on researchers´ career prospects, Horizon 2020 data does not allow a systematic analysis across all programme parts as data at the level of individual researchers was only collected in the context of MSCA and the ERC. In addition, Horizon 2020 has had a positive effect in terms of improving and aligning organisational practices and structures; enhancing the quality of training; career development; human resource practices; and working conditions. However, Horizon 2020 – and specifically, the monitoring approach followed in SEWP and SwafS – was insufficiently well tailored to measure the impact of the programme in terms of structural changes at institutional, regional or national levels. Horizon 2020 has also played a pivotal role in promoting the development of pan-EU research infrastructures, thereby contributing to the realisation of the ESFRI Roadmap. The support provided was consistent with the ESFRI roadmap, and helped to reduce the fragmentation of the R&D landscape and avoid duplication of efforts in R&D investments.

Horizon 2020 has provided significant **added value** in addition to what would otherwise have been created by the actions of Member States alone, through national or regional funding. The study indicates that the EU added value provided by Horizon 2020 consisted of supporting research that is larger-scale (i.e. larger research teams) and more complex (in terms of research methods and research areas covered), as well as more ambitious than would have been possible without the programme's support. Other key aspects of Horizon 2020 EU added value include the pooling of a critical mass of expertise, skills and resources; economies of scale; support for international mobility and the training of researchers. In addition, it has provided access to research infrastructures over and above what would be available to researchers at national level. Lastly, EU-wide competition between top-level researchers in Europe has contributed to increasing both the quality of research proposals and the general level of research excellence.

Based on the key findings and conclusions of this evaluation study, several **lessons have been identified that can contribute to the design of future framework programmes**:

- Horizon 2020's bottom-up and top-down approaches were aligned with both excellent research and societal challenges. The mix of approaches has proved complementary, allowing for better coverage of research needs and policy priorities. It is, however, important to bear in mind that the various pillars and the bottom-up and top-down approaches each had a different focus. (Relevance).

- A large number of different EU-level instruments support R&I and, despite existing complementarities, this creates a landscape that is complex to navigate – particularly for entities without previous experience of Horizon 2020. Coherence between Horizon 2020 and other EU-level instruments could be improved by strengthening and institutionalising the communication and coordination between the EU-level bodies that are involved in the management and implementation of the EU's various R&I support initiatives. (Coherence)

- **The major challenge for Horizon 2020 and all of its programme parts within the scope of this study was oversubscription,** which resulted from the programme's high level of attractiveness and its limited budget. Further simplification measures alone are unlikely to tackle this inefficiency. Room still exists for strengthening the **Seal of Excellence** (SoE) initiative, even though this initiative alone cannot fully address the issue of Horizon 2020's oversubscription, due to limited national and regional budgets and different policy priorities at regional and national levels. Nevertheless, with the cooperation of national funding bodies, the initiative could be strengthened via the wider use of other funding sources such as the Cohesion Fund and Recovery and Resilience Fund. (Efficiency)

- Horizon 2020's focus on excellent science should be maintained in future framework programmes in order to continue consolidating the EU's position worldwide in terms of scientific production and innovation. Nevertheless, efforts are still required to ensure that further progress is made across the EU, given the persistence of low participation rates among organisations from **widening countries**. Further steps would need to be taken to integrate the widening dimension into other pillars as well. (Effectiveness)

- While Horizon 2020 encompassed many projects contributing to the **skills** of researchers, the framework programme could benefit from a clearer strategy, objectives, operationalisation and targets regarding its contribution to researchers' skills. The EU Competence Framework for Researchers could contribute to the development of a common vision regarding skills development. (Effectiveness)

- Efforts to continue fostering the application of **open science** need to be continued. These could encompass better communication (e.g. with regard to the activities and mission of the European Open Science Cloud initiative); broader support for the provision of training in open science; as well as fostering the convergence of practices around a common vision through joint actions with Member States and national research funding organisations. (Effectiveness)

- Improvements would be welcomed in the approach used to monitor the impact of the programme in terms of **inducing** institutional or structural **change** at organisational, regional or national level. Room for improvement also exists in relation to **data collection** regarding the communication and dissemination of actions funded by Horizon 2020. (Effectiveness)

- The implementation of **Responsible Research and Innovation (RRI)** could be facilitated by focusing on individual components, introducing clear and measurable targets, and developing knowledge hubs focusing on specific components (following the example of the European Institute for Gender Equality, EIGE, with regard to the Gender Equality Plan). (Effectiveness)

- Potential for improvement remains in the **exploitation, development and commercialisation of research results**. Several approaches could be adopted to achieve this. These include strengthening the attention paid to developing regional/local ecosystems, strengthening collaboration between actors throughout the innovation cycle across pillars, and fostering connections with Smart Specialisation Strategies. (Effectiveness)

- It is important to further develop the capacities of the MSCA in order to **elicit structuring impacts** on participating organisations. The MSCA bring significant added value through their structuring effects and harmonisation of practices. MSCA have enormous potential to elicit structural impacts on participating organisations, especially since they promote the diffusion of best practices and processes, gender equality, and contribute to the harmonisation and standardisation of specific programmes. Greater attention could be given to identifying, maintaining and amplifying those aspects of each action that can contribute to this goal. (EU added value)

Key definitions, acronyms and glossary

AI	Artificial intelligence
AI4EU	European AI-on-demand platform and ecosystem
ANR	French National Research Agency
APC	Article processing charge
ARC	Australian Research Council
CC	Creative Commons license
CERC	Canada Excellence Research Chairs
CET	Clean energy technologies
CFI	Canada Foundation for Innovation
COFUND	Co-funding of Regional, National and International Programmes (MSCA)
COST	European Cooperation in Science & Technology
CSA	Coordination and support action
CSO	Civil society organisation
DN	Doctoral networks (MSCA, Horizon Europe)
EC	European Commission
EDI	European Data Infrastructure
EIC	European Innovation Council
EIT	European Institute of Innovation and Technology
EIT KIC	European Institute of Innovation and Technology Knowledge and Innovation Community
EOSC	European Open Science Cloud
EPSCoR	Established Program to Stimulate Competitive Research. (A programme of the National Science Foundation (NSF), US.)
ERA	European Research Area
ERC	European Research Council
ERDF	European Regional Development Fund
ERIC	European Research Infrastructure Consortium
ER	Experienced researcher
ESFRI	European Strategy Forum on Research Infrastructures
ESI funds	European Structural and Investment Funds
ESR	Early-stage researcher
EU-13	The 13 new Member States added since 2004: Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.
EU-15	The 15 countries that were already EU Member States prior to the accession of the new candidate countries on 1 May 2004. The EU-15 comprises: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
EU-28	The 28 countries that comprised the EU Member States until 2020, when the UK withdrew: Belgium, Bulgaria, the Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and the United Kingdom
EUA	European University Association
FAIR	Findability, accessibility, interoperability and reusability
FCT	Portuguese Foundation for Research and Technology
FP	Framework programme

FWCI	Field-weighted citation index
FWF	Austrian Science Fund
GDPR	General Data Protection Regulation
GEP	Gender Equality Plan
H2020	Horizon 2020
HLEG	High-level expert group
HPC	High-performance computing
ICO	Industrial contact officer
IDT	Innovative Doctoral Training
IF	Individual fellowship (MSCA)
ILO	Industrial liaison officer
IMPRS	International Max Planck Research Schools
INFRA	Research infrastructures (part of the Horizon 2020 programme)
IoT	Internet of Things
ITN	Innovative Training Networks; activity in the Marie Skłodowska-Curie Actions
ITN	Innovative Training Networks (MSCA)
JPI	Joint programming initiative
JU	Joint undertaking
KIP	Key Impact Pathway
KPI	Key performance indicator
LGBTI	Lesbian, gay, bisexual, transgender and intersex
MCAA	Marie Curie Alumni Association
MLE	Mutual learning exercise
MS	Member State
MSCA	Marie Skłodowska-Curie Actions
NPC	National contact point
NQIA	National Quantum Initiative Act
NREN	National research and education network
NSF	National Science Foundation (US)
NWO	Dutch Organisation for Scientific Research (NL)
OECD	Organisation for Economic Co-operation and Development
OpenAIRE	An open scholarly communication infrastructure that captures Horizon 2020 publications, datasets and other research outputs
ORCID	Open Researcher and Contributor ID, a unique, persistent identifier provided free of charge to researchers
ORDP	The Open Research Data Pilot
PPP	Public-private partnerships
PPTop1%	Top 1% most highly cited publications in a given disciplinary field
PSF	Policy support facility
P2P	Public-public Partnerships
QC	Quantum computing
QCN	Quantum Community Network
R&D	Research and development
R&I	Research and innovation
RDI	Research, development and innovation

REA	European Research Executive Agency
RI	Research infrastructure
RIA	Research and innovation action
RII	Research infrastructure improvement, a component of the NSF EPSCoR programme
RISE	Research and Innovation Staff Exchange (MSCA)
RRI	Responsible research and innovation
RTO	Research and technology organisation
S&T	Science and technology
SDG	Sustainable Development Goal
SEWP	Spreading Excellence and Widening Participation (part of the Horizon 2020 programme)
SiS	Science in Society (part of the FP7 programme)
SMEs	Small and medium-sized enterprises
SoE	Seal of excellence
SRIA	Strategic Research and Innovation Agenda
STEM	Science, technology, engineering and mathematics
SwafS	Science with and for Society (part of Horizon 2020 programme)
TNA	Transnational access
ToRR	European Commission tool for tracking research results
TRL	Technology readiness level
URI	Dataset with a persistent identifier and an identifier to the data file
VA	Virtual access
VAT	Value-added tax
WF	Widening fellowship
WIRE	Week of Innovative Regions in Europe, annual conference

1. Introduction

1.1. Purpose of the study

On 20 December 2021, the Directorate-General for Research and Innovation initiated an evaluation study of the European framework programmes for Research and Innovation for Excellent Science. The study activities kicked off in 2022, and have been guided by the Tender Specifications under Specific Contract No RTD/2021/SC/025 LC-01774602 implementing Framework Contract N° 2018/RTD/A2/OP/PP-07001-2018.

Unlike the interim evaluation of Horizon 2020, which was coordinated by the Evaluation Unit of the Commission's Directorate-General for Research and Innovation with the support of a Working Group drawn from the services of the R&I family DGs and an inter-service group also comprising other Commission services, the Excellent Science study is implemented by external experts – PPMI, in collaboration with IDEA Consult and UNU-MERIT, Maastricht University.

Among other objectives, the study will support the *ex-post* evaluation of Horizon 2020, and the interim evaluation of Horizon Europe. Accordingly, the study is being implemented in **two phases**:

- Phase 1: supporting the *ex-post* evaluation of Horizon 2020;
- Phase 2: supporting the interim evaluation of Horizon Europe.

This **back-to-back study approach** ensures that the evaluation methodologies (including indicators) used in both phases are aligned. Furthermore, it condenses together all evaluation evidence and offers comparable findings drawn from the underlying analyses, with everything being presented in a single report. The end goal of the study is to identify what worked well and what worked less well, to highlight the lessons learned, and to provide actionable recommendations for both the short-term and longer-term improvement of the framework programme.

1.2. Scope of the study

The scope of the study has four main dimensions: **thematic**, **geographic**, **temporal**, and the **scope of the evaluation**.

Thematic scope: this study covers the area of excellent science under Horizon 2020 and Horizon Europe. In Phase 1, this includes the following programme parts: the European Research Council (ERC), Marie Skłodowska-Curie Actions (MSCA), European research infrastructures (INFRA), and Future and Emerging Technologies (including Flagships), as well as Spreading Excellence and Widening Participation (SEWP) and Science with and for Society (SwafS), as well as the analysis of the contribution made to excellent science across the whole Horizon 2020 programme (including the JRC and open science aspects)[1].

Geographic scope: the geographic scope of the study is the EU-28 (the EU Member States for the period 2014-2020, including the UK) and associated Horizon 2020 countries.

Temporal scope: the study considers the whole period covered by the Horizon 2020 programme (2014-2020).

Evaluation questions scope: in line with the Better Regulation Guidelines, this study addresses specific evaluation questions structured around five evaluation criteria:

- **Relevance**: assessment of whether the original objectives of Horizon 2020 are still relevant and how well they still match the current needs and problems.

1 In Phase 2, the study will cover the following programme parts: the European Research Council (ERC), Marie Skłodowska-Curie Actions (MSCA), Research infrastructures (INFRA), including the European Open Science Could (EOSC) Partnership, activities under the horizontal pillar on 'Widening Participation and strengthening the European Research Area', and the contribution made to excellent science across the whole Horizon Europe programme (including the JRC and open science aspects).

- **Coherence**: how well (or not) the different actions work together, internally and in conjunction with other EU interventions/policies.
- **Efficiency**: the relationship between the resources used by Horizon 2020 and the changes it has generated.
- **Effectiveness**: how successful Horizon 2020 has been in achieving or progressing towards its objectives.
- **EU added value**: an assessment of the value resulting from Horizon 2020 that is additional to the value that could have resulted from interventions carried out at regional or national levels.

For relevance and coherence, Phase 1 provides aggregated findings (at the level of Horizon 2020 as a whole). These are presented in Sections 4.1 and 4.2, respectively. Efficiency, effectiveness and EU added value have been analysed in Phase 1 both at the level of individual programme parts (presented in Annex 1), and at the level of Horizon 2020 as a whole (Sections 4.3, 4.4 and 4.5 of this report, respectively). A full list of evaluation questions covered in Phase 1 of the study is included in Annex 2 of this report.

2. Background to the initiative

2.1. Description of the initiative and its objectives

The FPs are the EU's main instruments for funding R&I in Europe. Horizon 2020 was the eighth EU FP for R&I, covering the period from 2014 to 2020, with a budget of nearly EUR 80 billion[2].Adopted in the context of the Europe 2020 Strategy, Horizon 2020 had the objective of contributing to building a society and economy based on knowledge and innovation across the Union by leveraging additional research, development and innovation funding, and contributing to the attainment of research and development targets. In doing so, it supported the implementation of the Europe 2020 Strategy and other Union policies, as well as the achievement and functioning of the European Research Area (ERA).

The three pillars of Horizon 2020 were the following:

- **Pillar 1: Excellent Science.** The activities under this pillar aimed to reinforce and extent the excellence of the Union´s science base. The Excellent Science pillar supported world-class and fundamental research and science in Europe, by developing, attracting and retaining research talent and supporting the development of the best research infrastructures.
- **Pillar 2: Industrial Leadership.** This pillar supported areas such as key technologies and advanced manufacturing across existing and emerging sectors. It also aimed at attracting more private investment into R&I and increasing innovative SMEs in Europe. Technology deployment and key Enabling Technologies had a critical role in this pillar.
- **Pillar 3: Societal Challenges.** This pillar supported R&I aimed at addressing grand challenges, thereby targeting society and citizens (e.g. climate, environment, energy, transport). It supported the development and valorisation of breakthrough solutions coming from multidisciplinary collaborations to contribute to the transitions the EU is facing.

Horizon 2020 represented a substantial change in comparison to the Seventh Framework Programme (FP7), which ran from 2007 to 2014. Among its key changes (novelties), the most notable are the following: a **wider coverage of technology readiness levels** (including higher TRLs above TRL4-5); a greater focus on industrial leadership (Pillar 2); and **greater attention to societal challenges** (Pillar 3) through multidisciplinary research and input from civil society. In addition, greater attention (and budget) was given to activities such as pilot lines and/or demonstration/pilot activities. As can be seen from the visual above, Horizon 2020 was structured according to three mutually reinforcing pillars.

The **structure of the Excellent Science pillar** was as follows:

- **ERC**: the European Research Council, for frontier research by the best individual teams;
- **MSCA**: Marie Skłodowska-Curie actions, providing training and career development opportunities;
- **FET**: future and emerging technologies for collaborative research to open up new fields of innovation;

2 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en#:~:text=Post%2Dprogramme%20documents-,What%20was%20Horizon%202020%3F,of%20nearly%20%E2%82%AC80%20billion.

- **INFRA**: research infrastructures (including e-infrastructure) to ensure access to world-class facilities.

In addition to its three pillars, Horizon 2020 had two specific objectives:

- **SEWP**: Spreading Excellence & Widening Participation, and
- **SwafS**: Science with and for Society

2.2. Baseline

FP7, the predecessor to Horizon 2020, was designed to strengthen industrial competitiveness and to meet the research needs of other EU policies. The programme aimed to contribute to the creation of a knowledge-based society, building on a European Research Area and complementing activities at a national and regional level. The programme consisted of four programmes – Cooperation, Ideas, People and Capacities – which focused on the promotion of excellence in scientific and technological research, development and demonstration. FP7 also supported research actions carried out by the Joint Research Centre (JRC).

As presented in greater detail below, this study presents four main indicators of scientific performance under Horizon 2020. While these indicators were developed by the study team to assess the performance of Horizon 2020 in this dimension, similar indicators can be found in the literature aimed at assessing the contribution of FP7 to excellent science. This selection of indicators hence constitutes an approximate baseline for the indicators presented in this evaluation study.

Table 1: Indicators of scientific performance in Horizon 2020 and in the Seventh Framework Programme

Indicator - Horizon 2020	Indicator – Seventh Framework Programme
Scientific excellence	
SCI1: field-normalised citation score (MNCS/CNCI/FWCI)	Field-weighted citation impact.
SCI2: number/share of top 1% most cited publications – the number/share of publications produced under the FP that ranked in the top 1% in terms of citations received in their field and year.	Share of the priorities´ publications in the top 1% and top 5% highly cited publications.
SCI3: contribution to new/emerging research fields – the number/share of FP projects that contributed with seminal research into new and fast-growing research topics (i.e. FP publications that were among the Top 1% of publications in a field that was also a new field of research).	Not applicable.*
Structuring effect (creation and sustainability of networks)	
SC4: Structuring effect of FP funding – the number/share of projects in which research networks were substantially strengthened and maintained after the end of EU funding, by programme area.	Share of FP7 participants that started to publish jointly due to their participation in an FP7-funded project, and continued to do so after the end of the project.

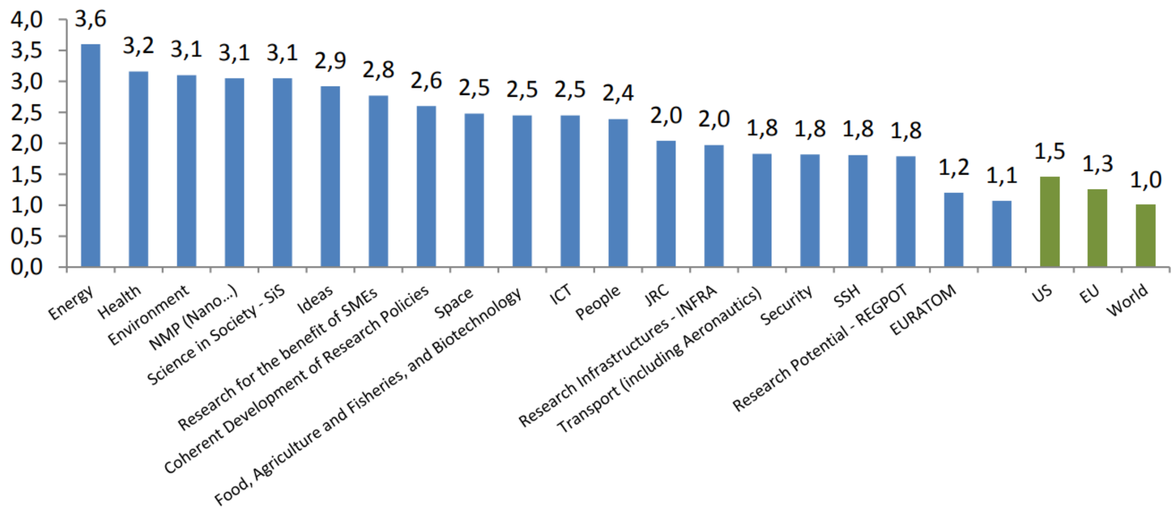
*No comparable indicator was included in the *ex-post* evaluation of FP7. Source: Ex-post Evaluation of the Seventh Framework Programme (Commission Staff Working Document, SWD(2016)).

It is important to note that there are important limitations and caveats to consider when comparing the indicators for FP7 with those used for Horizon 2020. First, the data stemming from FP7 and Horizon 2020 are not always comparable, due to the different reporting mechanisms in place under both programmes. Second, the *ex-post* evaluation of FP7 and the present evaluation study of Horizon 2020 were carried out at the end of their respective programmes, but at a time when not all projects had been closed. Third, it was not always possible to identify an indicator in the *ex-post* evaluation of FP7 that was comparable to the ones used in this evaluation study – this is most notable in the case of indicator SCI3 (Contribution to new/emerging research fields).

The following paragraphs present the main indicators used to assess the performance of FP7 in relation to scientific performance (i.e. scientific excellence and structuring effects), followed by other insights related to excellent science that were included in the *ex-post* evaluation of FP7. The section concludes with the expectations expressed for Horizon 2020, based on the Impact Assessment of Horizon 2020 (2012).

Excellent scientific production: the *ex-post* evaluation of FP7 involved several indicators of the programme's performance in terms of the production of excellent research. These indicators showed that 1) the field-weighted citation impacts for all programme parts were above the EU average, and in most cases were above the US average (see Figure 1); and 2) that an important share of FP7 publications were among the top 1% highly cited publications, and that these shares tended to be above the EU and US averages in their respective disciplines (Figure 2). Particularly relevant to this study is the fact that 30% of the publications under the Ideas programme (ERC) were cited in top 5% of highly cited publications, and 8% in the top 1% highly cited.

Figure 1 Field-weighted citation impact of publications (2007-2015)



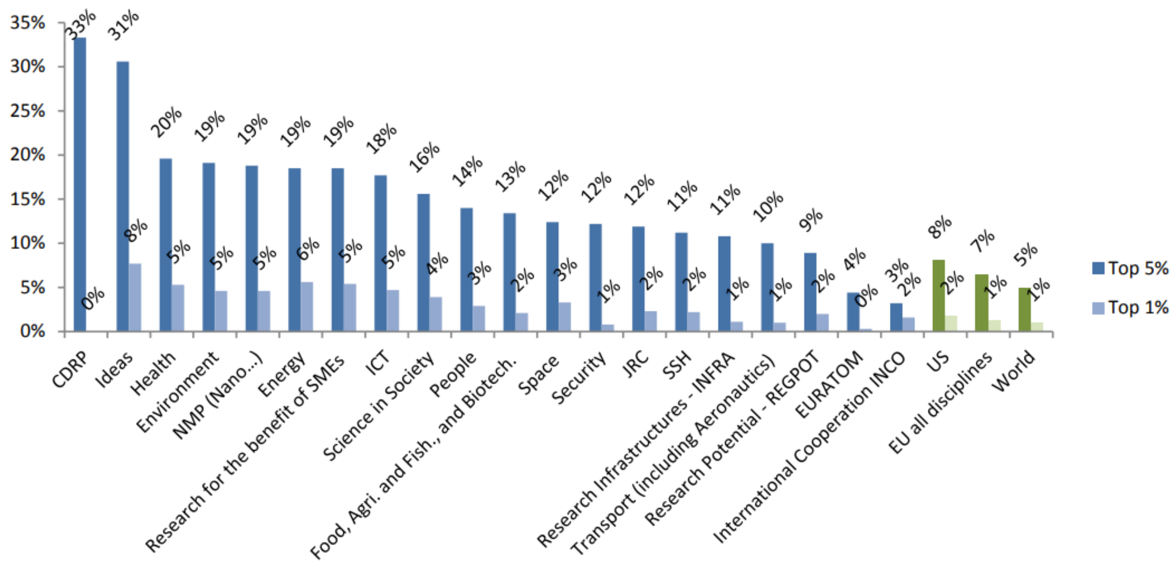
Source: Ex-post Evaluation of the Seventh Framework Programme. Commission Staff Working Document. SWD(2016) 2 final. SciVal based on CordaSesam-Respir[3].

The *ex-post* evaluation concluded that FP7 had promoted ground-breaking research, particularly through its Ideas programme, which covered the ERC. In addition, support for frontier research – which, by definition, can be a risky endeavour – was enhanced. The number of publications that acknowledged ERC funding in top-rated scientific journals, as well as Nobel Prizes and Fields medals received by ERC grantees, attested to ERC grants becoming a mark of scientific excellence.

Structuring effect (creation and sustainability of networks): the *ex-post* evaluation of FP7 indicated that almost half of FP7 participants continued to publish jointly after the end of their FP7 projects (see Figure 3). In this regard, the performance of the Cooperation Programme was particularly outstanding, although it should be noted that this was also the largest component of FP7. This finding is also aligned with the fact that this programme part aimed to foster collaborative research across Europe along several key thematic areas. Under the People programme, Marie Curie Actions (MCA) showed a very high impact on collaboration patterns: in a survey of beneficiaries, 90% indicated that the programme had strengthened research collaboration, while 87% indicated that it had had an effect on new collaborations or business enterprises.

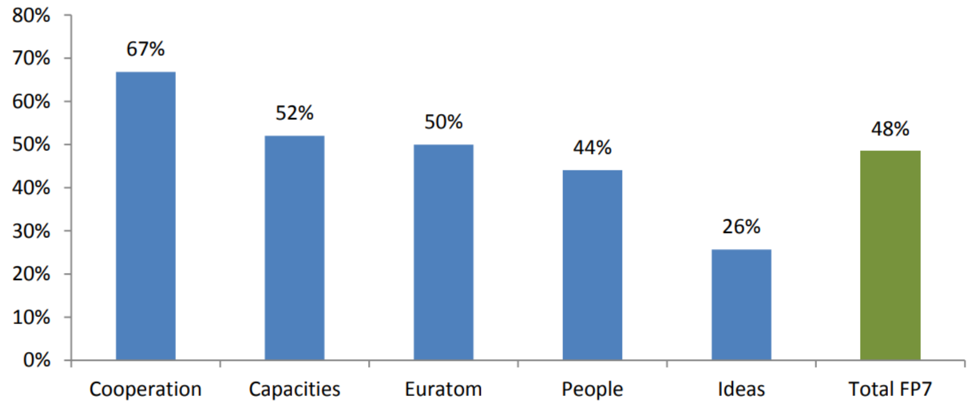
3 https://eur-lex.europa.eu/resource.html?uri=cellar:2994759f-bf8c-11e5-9e54-01aa75ed71a1.0001.04/DOC_1&format=PDF

Figure 2 Share of the priorities´ publications in the top 1% and top 5% highly cited publications (2007-2015)



Source: Ex-post Evaluation of the Seventh Framework Programme. Commission Staff Working Document. SWD(2016) 2 final. SciVal based on CordaSesam-Respir[4].

Figure 3 Share of researcher pairs that published jointly in FP7 and continued to do so after the completion of the project



Source: Ex-post Evaluation of the Seventh Framework Programme. Commission Staff Working Document. SWD(2016) 2 final. DG RTD based on OpenAire data[5].

Other indicators relating to excellent science: as mentioned above, the framework programmes not only provide outputs relating to the production of scientific excellence or the structuring effect of the programme (i.e. collaboration patterns), they also have impacts at other levels relating to excellent science. With regard to these, several key aspects were highlighted in the *ex-post* evaluation of FP7:

- The programme Ideas demonstrated its ability to attract excellent researchers and become a benchmark of individual excellence.
- The programme People set a European standard for the doctoral training of a new generation of excellent scientists. The *ex-post* evaluation indicated that People created the necessary conditions for an open labour market in researchers, as well as supporting their geographical mobility.
- The programme Cooperation facilitated transnational collaboration and thus provided a platform for the best minds to work together to contribute to solving major societal challenges.

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4 https://eur-lex.europa.eu/resource.html?uri=cellar:2994759f-bf8c-11e5-9e54-01aa75ed71a1.0001.04/DOC_1&format=PDF

5 Ibid.

- Lastly, the programme Capacities supported the involvement in European research of excellent organisations from the SME sector, civil society, new EU Member States and developing countries.

Another important aspect of scientific production is the extent to which it is made accessible to the wider community. During FP7, the first steps were taken towards promoting **open access**. The I evaluation of FP7 indicated that 54% of publications stemming from the programme were published in open access, with 44% in closed access. The interpretation of such figures and comparisons with similar indicators for Horizon 2020 should be approached with caution, as these figures were not based on the full set of publications coming from FP7 projects, given that the *ex-post* evaluation was carried out before all FP7 projects were closed. The evaluation of FP7 also indicated that there had been an upward trend in the uptake of open access, which suggests that the final numbers at the end of FP7 would probably have been higher than those reported in the study.

Baseline per framework programme part: in addition to indicators of scientific performance at the level of the framework programme, KPIs were attached to the distinct parts of the programme in accordance with their specific objectives[6]. Annex 12 lists the KPIs for the parts of Horizon 2020 covered by this study, their links to the Key Impact Pathways (KIPs) under Horizon Europe, and, when available, their baseline value (FP7).

Expectations for Horizon 2020: based on the Impact Assessment of Horizon 2020 performed in 2012, the main expectations for Horizon 2020 in comparison to a continuation of the situation under FP7 were as follows:

- As under FP7, Horizon 2020 was expected to achieve critical mass at programme and project level. At the same time, it was expected to enhance the promotion of scientific and technological excellence and allow greater flexibility.
- Administrative costs for applicants and participants were expected to reduce drastically, which was expected to significantly improve accessibility, in particular for SMEs, and to increase levels of support from all types of stakeholders.
- The knowledge triangle and broader horizontal policy coordination were expected to be enhanced through a single framework that integrated research, innovation and researcher training and skills development, and by explicitly defining links with other policies.
- Scientific, technological and innovation impacts were expected to be enhanced through the provision of seamless support from scientific idea to marketable product; stronger output orientation; better dissemination of research results; clearer technological objectives; enhanced industrial and SME participation and, thus, enhanced leverage, funding of demonstration activities, and provision of innovation financing and support.
- In combination with its clarity of focus and high-quality intervention logic, enhanced scientific, technological and innovation impacts were expected to translate into greater economic competitiveness downstream, as well as social, environmental and EU policy impacts.

2.3. Methodology

The findings of this study have been derived through the following key methods:

- **Desk research** of previous evaluations and studies, reports by EU institutions, Work Programmes, relevant annual reports, and data on evaluated parts of the programme and on Horizon 2020 overall provided by the European Commission.
- **15 case studies** – two case studies focusing on the ERC, three on the MSCA, two on FET, two on INFRA, one on SwafS, two on SEWP, and three on transversal issues and topics. See Table 2 for a full list of case studies.

6 European Commission, Directorate-General for Research and Innovation, Horizon 2020 indicators : assessing the results and impact of Horizon, Publications Office, 2015, https://data.europa.eu/doi/10.2777/71098

Table 2: List of case studies

No.	Title of case study
CS1	ERC impact on creating new or pushing existing frontiers of science
CS2	Achievement of commercial and/or social innovation potential of ERC projects that received ERC Proof of Concept funding
CS3	Impact of the MSCA IF on strengthening human capital in research and innovation
CS4	Inclusiveness and gender dimension in the MSCA
CS5	Structuring impact of MSCA ITNs on doctoral programmes
CS6	FET Graphene Flagship
CS7	FET Human Brain Flagship
CS8	Impact of the framework programme on the creation of new excellent services
CS9	Fostering knowledge creation through transnational access
CS10	Building the territorial dimension of SwafS partnerships
CS11	Contribution of framework programme in integrating research groups from widening countries
CS12	Impact of framework programme in improving quality (and coverage) of research in widening countries
CS13	Contribution of the framework programme to some emerging areas of science and technology such as artificial intelligence, quantum computing, clean energy technologies
CS14	Impact of the framework programme on fostering diffusion of knowledge and open science
CS15	Impact of the framework programme in spreading excellence across the Union

- **Four benchmark case studies** (see Table 3).

Table 3: List of benchmark reports

No	Benchmark title
Benchmark 1	National Science Foundation (NSF): Established Program to Stimulate Competitive Research (EPSCoR) and the Broadening Participation Portfolio (US)
Benchmark 2	Canada Excellence Research Chairs Programme (CERC)
Benchmark 3	Max Planck Centres and Dioscuri Centres of Scientific Excellence
Benchmark 4	National Natural Science Foundation of China (NSFC)

- **224 interviews** with programme managers, researchers, relevant stakeholders, beneficiaries and EC officials.
- A **survey programme,** consisting of **six online questionnaires**:
  - Horizon 2020 MSCA, SEWP, INFRA and SwafS beneficiary organisations
  - Horizon 2020 MSCA, SEWP, INFRA and SwafS unsuccessful applicant organisations
  - Horizon 2020 MSCA IF fellows
  - Horizon 2020 MSCA IF unsuccessful applicants
  - Horizon 2020 ERC principal investigators
  - Horizon 2020 ERC unsuccessful applicants
- **Bibliometric analysis** of peer-reviewed research output reported for Horizon 2020 projects, validated and matched in Scopus and analysed using SciVal data. These data are supplemented with CORDA data in order to evaluate the impact of Horizon 2020 funding, and the foci of its various programmes, on the productivity and quality of research under Excellent Science. The indicators used to measure the performance of Horizon 2020 and its programmes are aligned with methods used earlier during the interim evaluation and in the recent JRC report, as well as Horizon Europe's KIP1, and feature metrics such as FWCI and PPTop1%.
- **Econometric modelling/counterfactual analysis** has been used to support the Horizon 2020 *ex-post* evaluation through the performance of two separate counterfactual analyses. These consist of multiple econometric models, each with a different focus and different level of sophistication.
  - The first analysis consists of a productivity model that looks at Horizon 2020 as a whole, and its programme parts in particular. This model answers questions regarding the performance and impact of Horizon 2020 project funding on academic output.
  - The second analysis focuses specifically on the ERC and MSCA-IF (sub-) programmes and uses different econometric models. This analysis looks at the career impact of Horizon 2020

funding using pre- and post-grant data, with the aim of discovering whether ERC and MSCA fellowships are related to higher research productivity (post-grant).

A range of additional methods were also used to support the analyses, such as network analysis, analysis of Sustainable Development Goals (SDGs), patent analysis, and analysis of Innovation Radar data. For a full list of methods, please see Annex 2.

2.4. Limitations

The most important limitation of this study is the fact that, by the time the available data were analysed for this evaluation study (mid-2022), only **38% of projects in Pillar 1 of Horizon 2020 were closed**[7]. This is an aspect that needs to be kept in mind when interpreting the figures and results included in this study. The share of closed projects in Pillar 1 ranged from 52% for the MSCA to 18% for the ERC. The relevant shares for SEWP and SwafS were 32% and 34%, respectively. This study therefore only reflects part of the output and impact of the framework programme on excellent science: 62% of projects funded under Horizon 2020 will continue to produce outputs over the coming months and, in some cases, even years.

Furthermore, while this study builds on a wide range of **indicators**, there is not always a completely comparable baseline figure available that can serve as a reference to compare the evolution of the performance of the framework programmes over time (e.g. comparing Horizon 2020 with previous framework programmes). In addition, it is important to note that the **bibliometric analysis** performed for this study was based on the data concerning the research outputs of EC-funded projects under Horizon 2020, received by the European Commission. These data may be subject to omissions and potential errors due to the voluntary reporting process. This limitation has been mitigated by a thorough data cleaning, validation and enrichment process performed by the study team. At the same time, some Horizon 2020 programme parts are 'tail-heavy', meaning that funding increased towards the end of the framework programme. Given the time lag in publishing research results, this means that many outputs are still yet to be developed and reported. Annex 2 to this report includes an **overview of the methodologies that were applied in this study, together with the main limitations** of each.

3. Implementation state of play

This section provides a brief overview of the **state of play with regard to the implementation of the Horizon 2020 framework programme** (FP) in the areas covered by the study, including the distribution of proposals and selected projects, EU contribution, types of participating organisations, types of instruments, types of actions, thematic areas of the work programme, geographical distribution and country performance. The figures shown below are based on the latest eCorda projects dataset (received from the European Commission on 4 April 2022).

3.1. Overview of Horizon 2020 projects and proposals

This study focuses on the EU's portfolio of R&I activities in Pillars 1 (Excellent Science), 4 (SEWP) and 5 (SwafS) of Horizon 2020. Based on the administrative data received by the study team, the ERC, with an EU contribution of EUR 13.5 billion, was the largest programme part. This was followed by MSCA (EUR 6.5 billion), FET (EUR 2.6 billion) and INFRA (EUR 2.4 billion). SEWP and SwafS attracted EUR 1 billion and EUR 0.5 billion, respectively. When considering the data in the remaining parts of the study, it is important to emphasise several key aspects:

- While **the six programme parts analysed** contribute to Horizon 2020's general objective of strengthening the EU's research excellence and capacities, each of them has **different target groups and intervention logics**, and they are implemented via different actions/funding mechanisms. For example, ERC and MSCA both fund individual grants, yet have very different objectives. The intensity of funding is very different, too – for the ERC, the average grant size is around EUR 1.7 million, compared with EUR 0.5 million for the MSCA. INFRA and FET mainly use the RIA funding instrument, yet these interventions are very different. INFRA funds large-scale

7 This means that projects had the status "Closed" in the Corda dataset shared with the study team.

research infrastructure projects, while in FET the research is much more focused on cross-disciplinary research into future technology and breakthrough innovations.

- There is also **substantial heterogeneity within the programme parts analysed**. The bulk of the ERC's portfolio in is invested in Starting Grants, Consolidator Grants and Advanced grants, but this programme part also funds a substantial number of Proof-of-Concept grants characterised by their own logic and substantially smaller shorter duration. MSCA funds individual grants, but also host-driven collaborative R&I projects (under its ITN and RISE actions). SEWP and SwafS fund several distinct programme areas that target the needs of specific target groups.

The heterogeneity of these programme parts is both desirable and challenging to implement. If the various programme parts target different beneficiaries, activities and TRL levels, this suggests that there is no duplication of effort and that the EU's resources are being more efficiently and effectively spent. At the same time, R&I activities must remain coherent and reinforce/complement each other to maximise impact. This is analysed in greater detail in the sections of the study that cover the questions of Relevance and Coherence (see Sections 5.1 and 5.2).

It is important to note that FET underwent substantial changes during the final years of Horizon 2020. Specifically, its FET Open and FET Proactive parts transitioned into EIC Pathfinder, and moved from the more basic science-driven 'Excellent Science' pillar in Horizon 2020 to 'Innovative Europe' pillar in Horizon Europe which is in general more market-driven. The related R&I activities are analysed in a parallel evaluation study of the EU FPs for R&I for an Innovative Europe, which covers the EIC programme.

Further analysis of EU administrative data reveals that 38% of projects in Pillar 1 of Horizon 2020 had been closed by mid-2022 (with status = CLOSED in the Corda dataset shared with the team). This share ranged from 52% for MSCA to 18% for the ERC. The share of closed projects was between 32% and 34% for SEWP and SwafS. It is important to note that this phenomenon is not specific to the programme parts analysed in this study. Three main factors contributed to this phenomenon:

- The delayed launch of the Horizon 2020 programme resulted in the first calls for proposals being launched in the second half of 2014. Given that another 7-8 months are required to conclude grant agreements (up to 12 months in the ERC programme), the first R&I activities began in 2015. Following grant signature, a typical FP grant lasts 3 years, although in some programmes, such as the ERC, a majority of projects have a duration of 5 years. Lastly, it may take several more months to accept final project deliverables and close a project. This means that the projects finalised by the time of analysis in mid-2022 were mostly signed in 2016 or earlier.
- The European Commission accelerated its spending on most programme parts in the final years of Horizon 2020. Average grant size increased almost two-fold over the course of Horizon 2020. The total amount of EU contribution also grew during the final years of Horizon 2020. For the ERC and MSCA, for example, the EU spent about 30% more in the final years of Horizon 2020 compared with 2014-2016 calls.
- The COVID-19 pandemic disrupted the smooth implementation of EU R&I activities, resulting in a greater than usual number of requests for grant amendments and time extensions. This affected, to varying degrees, most projects that began or were ongoing in 2020.

These three factors combined mean that a comparatively large share of R&I activities in the programme parts analysed were still ongoing at the time of the evaluation. This caveat will prove important when analysing certain results and impacts, especially their scientific/technological/economic impact, structuring effect and other areas of impact.

Annex 11 of this report presents a more detailed overview of each programme part analysed in this study. This presents the number of projects, participations and EU contributions by grant type, as well as the number and share of eligible proposals received and the success rates of proposals (both by programme and call year).

Table 4: Number of projects and EU contribution by call year (EU contribution in million EUR)

Programme part	Indicator	2014	2015	2016	2017	2018	2019	2020	Total	Share of closed projects
ERC	Number of projects	1,072	1,100	1,102	1,168	1,108	1,155	1,176	7,885	18%
	EU contrib	1,734.7	1,793.7	1,754.9	1,914.5	2,001.0	2,114.8	2,222.0	13,536.7	
FET	Number of projects	92	0	148	2	355	45	0	642	27%
	EU contrib.	479.3	0	444.0	176.0	1,034.8	474.5	0	2,608.7	
MSCA	Number of projects	1,721	1,502	1,600	1,663	1,761	1,862	2,059	12,168	52%
	EU contrib.	862.4	817.3	843.6	900.6	1,004.3	1,066.7	1,096.4	6,591.3	
INFRA	Number of projects	105	0	95	3	137	6	4	351	43%
	EU contrib.	629.2	0	586.4	25.4	1,096.8	66.8	33.0	2,437.6	
SEWP	Number of projects	49	67	86	1	282	2	1	488	34%
	EU contrib.	228.8	67.3	230.5	0.2	406.8	82.1	0.2	1,015.9	
SwafS	Number of projects	51	0	48	3	112	4	44	262	32%
	EU contrib.	105.4	0	109.0	1.9	192.1	2.3	84.1	494.7	

Source: compiled by the study team using eCorda data per master call year.

3.2. Overview of data on Horizon 2020 participants

In total, there were just over 60,000 participations in the programme parts analysed, which collectively received a total EU contribution of EUR 26.5 billion. Higher or secondary education institutions (HEIs) were the main beneficiaries of EU funding in all programme parts except for INFRA, where research and technology organisations (RTOs) received the largest share of EU funding. Overall, HEIs and RTOs received 91% of funding in the programme parts analysed. Private for-profit enterprises (PRCs) received 5.5% of the total EU contribution; however, their share was substantially larger in FET (17% of total EU contribution in the programme), MSCA (10.3%) and SwafS (10%).

Table 5: Number of participations and EU contribution (in million EUR) by organisation type *

	Programme part	Higher or secondary education (HEI)	Other	Private for-profit (excl. education) (PRC)	Public body (excl. research and education)	Research and technology organisation (RTO)	Total
ERC	Number of participations	7,335	38	197	36	2,429	**10,035**
	EU contribution	10,104.1	16.7	120.7	21.3	3,274.6	**13,537.3**
	Share of EU contribution received	74.6%	0.1%	0.9%	0.2%	24.2%	**100.0%**
FET	Number of participations	2,643	81	1,439	149	1,432	**5,744**
	EU contribution	1,326.8	29.2	442.3	50	760.4	**2,608.7**
	Share of EU contribution received	50.9%	1.1%	17.0%	1.9%	29.1%	**100.0%**
MSCA*	Number of participations	19,609	751	6,537	522	5,608	**33,027**
	EU contribution	4,479.3	86.5	679.8	130.4	1,215.6	**6,591.6**

	Programme part	Higher or secondary education (HEI)	Other	Private for-profit (excl. education) (PRC)	Public body (excl. research and education)	Research and technology organisation (RTO)	Total
	Share of EU contribution received	68.0%	1.3%	10.3%	2.0%	18.4%	**100.0%**
INFRA	Number of participations	2,843	453	733	361	3,347	**7,737**
	EU contribution	626.5	189.4	165.5	81.2	1,373.6	**2,436.1**
	Share of EU contribution received	25.7%	7.8%	6.8%	3.3%	56.4%	**100.0%**
SEWP	Number of participations	904	40	73	85	500	**1,602**
	EU contribution	443.2	290.8	11.1	8.7	262.1	**1,015.9**
	Share of EU contribution received	43.6%	28.6%	1.1%	0.9%	25.8%	**100.0%**
SwafS	Number of participations	1,181	411	293	199	508	**2,592**
	EU contribution	259.5	64.6	49.4	21.7	99.7	**494.8**
	Share of EU contribution received	52.4%	13.1%	10.0%	4.4%	20.1%	**100.0%**

Source: compiled by the study team using Corda data. *For MSCA-COFUND, not all participants are included in the analysis due to data limitations. For more information, see Annex 1.

Table 6 below shows the top 10 countries that received the largest amounts of EU funding. The list is led by the UK, which had 8,610 participating organisations and received EUR 4.2 billion of EU funding, followed by Germany (7,185 participations, EUR 4 billion) and France (5,949 participations, EUR 2.8 billion). Further breakdown of data by country shows that organisations from Germany were the most frequent beneficiaries under FET and INFRA, whereas organisations from the UK were the most frequent under the ERC and MSCA. In SEWP and SwafS, organisations from Germany, Spain and Belgium were the most frequent beneficiaries.

Table 6: Top 10 beneficiary countries in the programme parts analysed (in %)

Country	Number of participations	EU contribution received, million EUR	Average EU contribution per participation, million EUR
UK	8,610 (14.2%)	4,222.6 (16.8%)	0.5
DE	7,186 (11.8%)	4,038.9 (16.1%)	0.6
FR	5,949 (9.8%)	2,833.7 (11.3%)	0.5
NL	4,028 (6.6%)	2,225.5 (8.9%)	0.6
ES	5,053 (8.3%)	1,838.5 (7.3%)	0.4
IT	4,979 (8.2%)	175.2 (0.7%)	0.4
CH	2,370 (3.9%)	1,621.9 (6.5%)	0.7
BE	2,081 (3.4%)	1,222.2 (4.9%)	0.6
SE	1,757 (2.9%)	918.3 (3.7%)	0.5
Other	18,720 (30.8%)	6,004.4 (23.9%)	0.3

Source: compiled by the study team using Corda data.

4. Key evaluation findings

4.1. Relevance

This section evaluates the criterion of the relevance of the Horizon 2020 programme parts covered under the study. The findings presented here stem from the bibliometric analysis, the case studies and desk research carried out as part of this study. The insights gathered in the ongoing evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix are especially informative in answering these questions[8]. A full list of evaluation questions can be found in Annex 2 in this report.

- Evaluation questions RV1*, RV2, RV3, RV4, RV5 and RV6 have been answered for Phase 1 (Horizon 2020) by the 'Evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix'. The following section presents a summary of the findings from that study, which are more closely related to excellent science (hereon referred to as the 'relevance study').
- This study has gathered and analysed evidence to answer to question RV7 on the balance between the different approaches to supporting research. The main findings in relation to this question are also presented below.

Shifts in topic orientations and greater focus on impact: during Horizon 2020, there has been a general trend towards an increased focus on mission-oriented, impact-focused approaches. This trend was complemented by the opening up of consultation arenas (European R&I days, Green Deal public consultation), which led to the first steps in introducing societal needs into the last phase of Horizon 2020. This is shown in the relevance study, where the themes of climate change, digital transformation and mission-oriented research feature most prominently. Interviews with project beneficiaries carried out for the relevance study indicate that this increased focus on and consideration of societal impacts as a driving motivation for R&I funding is often accompanied by doubts about what is meant by 'societal impact', and how to define and operationalise it. For this reason, scientific publications very often remain one of the most important KPIs for projects and programme parts from the perspective of excellent science. Researchers have expressed concerns about the greater focus on technology readiness levels (TRLs): while this facilitates the measurement of impact and progress, some interviewees[9] raised doubts as to whether sufficient resources were being directed towards collaborative discovery research.

Global relevance across scientific disciplines: the bibliometric analysis carried out in the context of this study includes a comparison with other international funders[10]. It shows that publications associated with Horizon 2020 projects have the highest normalised citation score (1.99), indicating that publications resulting from Horizon 2020 projects have been cited twice as often as the world average. In particular, the impact of Horizon 2020 publications in multidisciplinary journals (3.19) is more pronounced than that of publications funded by other funders.

When considering the top 1% most-cited publications, Horizon 2020 again outperforms non-EC funding programmes. When considering the full publication output of Horizon 2020, 3.9% of all publications belong to the Top 1% most highly cited group (see more details in Section 4.4). The discipline in which Horizon 2020 publication make up the highest share (6.3%) of the Top 1% cited group is Law, Arts and Humanities. Conversely, Engineering Sciences and Natural Sciences make up a relatively low share of the most highly cited publications, with 3.2% and 3.1%, respectively. However, when comparing the performance of Horizon 2020 in Natural Sciences to that of other funders, Horizon 2020 comes second only to the United States National Science Foundation.

Open science policy and infrastructures: it is also important to note that Horizon 2020´s open science policy has proved very important in responding to the COVID-19 crisis. However, experience during the crisis has shown that there is still considerable potential to improve institutionalised frameworks and the infrastructure required to share data while complying with all data privacy requirements (e.g. with respect to patient data). Initiatives stemming from SwafS to improve knowledge with regard to open science have had a limited impact compared with the scope of the existing need. Other initiatives, such as the European Open Science Cloud (EOSC), under the Research Infrastructures Work Programme, have

8 The study team has consulted the draft version of the Second Interim report of this study.

9 Interviews carried out for this study and the evaluation study on the relevance and internal coherence of Horizon 2020.

10 The French National Research Agency (ANR), the National Science Foundation (NSF), Australian Research Council (ARC), the Portuguese Foundation for Research and Technology (FCT), Dutch Organisation for Scientific Research (NWO) and the Austrian Science Fund (FWF).

the potential to play a central role in the sharing of research data. Given that activities with regard to EOSC only started during the last phases of Horizon 2020, it is still too soon to assess their impact. In connection with this, the relevance study indicated that, according to some interviewees, the *ad hoc* implementation of the European COVID-19 Data Platform[11], developed as a use-case of the EOSC proved to be insufficient in the initial response to the COVID-19 crisis.

Responsiveness to target groups: the relevance study indicated that Horizon 2020 has been successful in responding to public research needs, and that such responses have been channelled through well-established consultation and communication mechanisms between the European Commission and umbrella organisations (EARTO, EUA, etc.).

- **Interdisciplinary research and diversity of funding instruments:** the increasing importance of interdisciplinary research in Horizon 2020 has also helped to meet public research needs. This has been achieved through support for various types of research activities, in and across different scientific fields, from discovery research to applied research, as well as various types of collaboration between academia and industry[12]. Horizon 2020 has also provided a wide diversity of funding instruments that respond to different needs, from mono-beneficiary grants for excellent individual researchers, to collaborative research between research institutions, industry, public bodies, broader society and SMEs[13].
- **Inclusiveness of civil society actors:** the importance given to the inclusion of civil society actors is an important development in Horizon 2020, in line with the principles of responsible research and innovation (RRI). However, the participation of such actors in Horizon 2020 remains low, with a share in overall participation of around 5.5% and a share of funding of only 4%, with large differences between programme parts. It should be noted that, despite these low figures, these shares constitute an increase compared with FP7: this indicates that the changes introduced during Horizon 2020 have made a difference, most notably the fact that civil society organisations (CSO) were no longer considered to be private companies, and could receive funding of up to 100%.

Increased role of top-down challenge-oriented approaches: interviewees for this study indicated concerns regarding the availability of sufficient funds for collaborative basic/discovery research. They indicated that, while this type of research is being developed by (some of) the partnerships, there is room to increase support for this type of research (and its visibility within the framework programme). At the same time, the relevance study indicates that Horizon 2020 has resulted in greater openness than the previous FP with regard to modes of implementation (e.g. research projects, co-funded activities, prizes, financial instruments, public procurement) as defined in a guideline for the EC units and representatives responsible for drafting the work programmes.

The ERC, MSCA, INFRA[14] and SEWP retained their bottom-up approaches throughout Horizon 2020, with researchers having complete flexibility over the topics to be researched with the support of the programme. On the one hand, the ERC and MSCA are highly valued for the freedom they provide to work in any scientific area: this is often associated with increased potential to lead to innovative and frontier research results. On the other hand, it is interesting to note that SEWP and, to some extent, INFRA, were the main programme parts focusing on bottom-up collaborative research, showing an imbalance in the availability of opportunities for this type of research.

4.2. Coherence

This section presents a summary of findings regarding the evaluation criteria on coherence. In this study, coherence is assessed from two perspectives. The first is internal coherence, which focuses on the

11 The European COVID-19 Data Platform , supported by Action 9 of the ERAvsCorona Action Plan, was launched on 20 April 2020 under Horizon 2020. Its objective was to accelerate research and discovery by enabling the collection and sharing of available research data on COVID-19. The platform is hosted by the EOSC and is jointly led by the European Commission, the European Bioinformatics Institute of the European Molecular Biology Laboratory (EMBL-EBI), the Elixir infrastructure and the EOSCLife, ELIXIR-Converge, VEO and RECODID Horizon 2020 projects, as well as the Member States and other partners. See https://www.covid19dataportal.org/

12 See the Relevance study..

13 Ibid.

14 INFRA offered opportunities targeting specific disciplines, often in line with the ESFRI procedures under which RIs are designed bottom-up and the strategic prioritisation among RIs is top-down. Therefore, this programme part is sometimes considered to have followed a top-down approach. However, for the purposes of this analysis, targeting disciplines (input-oriented) is different from targeting challenges (output-oriented): only the latter are considered to follow a top-down approach.

coherence and adequacy of the programme parts under evaluation. The main source of information for this dimension is the relevance study. The second perspective is external coherence, in which the positioning of Horizon 2020 is assessed within the context of the overall European research and innovation landscape, as well as in terms of coherence and/or potential overlaps with other similar European, national/regional or international R&I programmes. The key source of evidence was the 'Evaluation study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system' (hereon referred to as the 'external coherence study'). Whenever relevant, evidence provided by the external coherence study is also complemented by findings from interviews, case studies, desk research, benchmark analysis and the assessment of EU administrative and monitoring data. The synthesis presented below covers all of the evaluation questions (see Annex 2) as per the Tender Specifications, with the findings organised according to the following themes:

- Internal coherence (evaluation questions covered: CH1, CH4).
- External coherence (evaluation questions covered: CH2, CH3).

4.2.1. Internal coherence

Preliminary findings from the relevance study indicate that there is **good internal coherence both between Horizon 2020 actions under Pillar 1, and between Pillar 1 actions and the rest of Horizon 2020**, which has contributed to overall research excellence in the European R&I system. More specifically, the preliminary findings indicate that under Horizon 2020, the MSCA, FET, the ERC and INFRA complement each other to produce excellent science. Research activities funded under the MSCA and ERC were identified as being the most coherent: e.g. the career stage of MSCA fellows is very complementary to ERC grantees, with MSCA actions targeting researchers in earlier career stages. Moreover, it was concluded that MSCA complements other Horizon 2020 activities – in particular FET, the ERC and INFRA – to produce excellent science. Similarly, preliminary evidence also indicates that the ERC funds a broad portfolio of projects with a high degree of complementarity with the themes and challenges covered by the rest of Horizon 2020.

Desk research and interview findings generally confirm the above conclusions from the relevance study. MSCA organisations tended to participate in other parts of Horizon 2020, especially in ERC-funded projects. Insights from the interview programme highlight that the ERC is seen by some as complementary to MSCA, being considered the natural next step in a researcher's career after the MSCA. This is confirmed by the survey of MSCA organisations, in which 45% of the 1,545 MSCA organisations surveyed reported their participation in ERC-funded projects. The organisations surveyed also reported their participation in other parts of Horizon 2020, such as FET (25%) and other European-level programmes or actions (28%). Moreover, according to the results of a survey conducted for the 'Study on mobility flows in the context of the MSCA', 22% of organisations participating in MSCA in widening countries (269 respondents) stated that they had also participated in SEWP actions[15]. On an individual level, 23% of the recipients of MSCA individual fellowships applied for ERC funding after the end of their fellowship, with 12% of applicants being successful[16].

The interviewees also stressed that there is internal coherence between the various MSCA actions, especially Innovative Training Networks and individual fellowships (IF), with IF seen as the next logical step in a researcher's career. Under Horizon 2020, 38% of the 1,533 MSCA host organisations surveyed reported their participation in two or more MSCA actions[17].

In alignment with Spreading Excellence and Widening Participation (SEWP) actions under Horizon 2020, the widening fellowships scheme (WF; rebranded as ERA fellowships under Horizon Europe) contributed to an average increase of 56% in the number of grants to widening countries. This has significantly improved the balance of mobility flows to and from widening countries. Over half of the

15 Survey of MSCA organisations (2022), conducted for the 'Study on mobility flows in the context of the MSCA'.

16 See: 'Case study on the impact of MSCA IF on strengthening human capital in research and innovation'.

17 Survey of MSCA organisations (2022), conducted for the 'Study on mobility flows in the context of the MSCA'. European Commission, Directorate-General for Education, Youth, Sport and Culture, Dėlkutė, R., Nikinmaa, J., Pupinis, M., et al., Study on mobility flows of researchers in the context of the Marie Skłodowska-Curie Actions : analysis and recommendations towards a more balanced brain circulation across the European Research Area : final report, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2766/401134

respondents among widening fellows indicated that the availability of widening fellowships had encouraged them to apply for MSCA[18].

Similarly, although the ERC supports similar groups of researchers to those supported by other parts of Horizon 2020 (e.g. the MSCA), there are complementarities and continuity rather than overlaps between these programme parts. The main reason for this is differences in terms of the types of activities and nature of the projects supported under the ERC and other programme parts: whereas MSCA individual fellowships provide funding for the beneficiary's recruited fellows only, ERC grants support not only the beneficiary principal investigators (PIs) but also the researchers sub-contracted for the project, which helps PIs to build their team. Moreover, there is a trend of continuity in involvement between parts of the programme. For example, former MSCA fellows apply for ERC funding. Similarly, complementarities and continuity exist between the ERC PoC and European Innovation Council (EIC): the PoC supports research into potential innovations at lower TRL, which can later receive funding from EIC Transition Grant scheme for further development and commercialisation.

The relevance study did not identify any overlaps or duplications between different parts of Horizon 2020, and concluded that there is **strong coherence between Excellent Science and other pillars of Horizon 2020, particularly in terms of addressing societal challenges and cross-cutting issues in Europe**. For example, in 2017, 16% of FET's budget was allocated to sustainable development topics, 15% to climate-related topics and 0.5% to biodiversity, 9% to socio-economic sciences, while 74% of the EC contribution under FET was ICT-related. Similarly, strong complementarities were also found to exist between Horizon 2020 research infrastructures and the Societal Challenges pillar, contributing to overall research excellence in addressing key societal challenges in Europe. For example, a number of research infrastructures projects funded under Horizon 2020 were directly related to Societal Challenges 2 (food) and 5 (climate). Furthermore, the MSCA were also found to contribute to the Societal Challenges pillar of Horizon 2020 by enhancing mobility between sectors and encouraging careers outside academia. According to the 'Study on mobility flows in the context of the MSCA'[19], the fellows surveyed indicated the desire to engage in applied and practical research and to work on practical solutions to societal challenges, among the different drivers to leave academia and move into industry.

In terms of the coherence among Horizon 2020 partnerships, **the available evidence shows that partnerships largely complemented each other by contributing to common higher-level goals while using different instruments and attracting different types of stakeholders**. Different Horizon 2020 partnerships such as P2P (public-to-public partnerships), PPPs (public-private partnerships) and EIT KICs (European Institute of Innovation and Technology Knowledge and Innovation Communities) contribute to the overall EU strategic goal of promoting transnational collaboration in research, in order to address economic and societal challenges[20]. Horizon 2020 partnerships also provided a significant level of complementarity with the rest of the programme. A recent analysis showed that in terms of the distribution of funding across different thematic areas, Horizon 2020 partnerships were complementary both with each other and with the rest of Horizon 2020 programme: e.g. P2P funding was mainly concentrated in the areas of health, food security, agriculture and climate action, whereas Contractual Public-Private Partnership (cPPP) funding was mainly allocated to research related to the topics of ICT and Europe in a changing world. In contrast, JU funding was mainly dedicated to transport and ICT, as well as to health-related research, which largely corresponds with the areas that also attracted most funding in other Horizon 2020 instruments[21]. The interim evaluation of Horizon 2020[22] found a clear continuity and complementarity in terms of the TRLs covered between some of the partnerships and the rest of the framework programme: e.g. Horizon 2020 LEIT ICT largely covers TRLs 2-5, whereas ESCEL ICT JTI covers TRLs 6-8. At the same time, previous studies have also called for greater coordination between different partnerships, in order to better exploit the synergies between them, e.g. the need to

18 European Commission, Directorate-General for Education, Youth, Sport and Culture, Dėlkutė, R., Nikinmaa, J., Pupinis, M., et al., Study on mobility flows of researchers in the context of the Marie Skłodowska-Curie actions: final report. Publications Office, 2022.

19 European Commission, Directorate-General for Education, Youth, Sport and Culture, Dėlkutė, R., Nikinmaa, J., Pupinis, M., et al., Study on mobility flows of researchers in the context of the Marie Skłodowska-Curie Actions : analysis and recommendations towards a more balanced brain circulation across the European Research Area : final report, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2766/401134

20 Gøtke, N. et al. (2016). Analysis of ERA-NET Cofund actions under Horizon 2020: Final report of the expert group. https://op.europa.eu/en/publication-detail/-/publication/74c34f43-b147-11e6-871e-01aa75ed71a1

21 European Commission (2022). Performance of European Partnerships: Biennial Monitoring Report 2022 on partnerships in Horizon Europe.

22 European Commission, Directorate-General for Research and Innovation, In-depth Interim evaluation of Horizon 2020: Commission staff working document, Publications Office, 2017.

establish synergies and improve coordination among different ERA-NETs in similar areas, as well as to establish synergies between ERA-NET Cofunds and other ERA instruments and initiatives[23].

4.2.2. External coherence

The external coherence study concluded that in general, the framework programme is highly complementary to other support schemes that exist at EU and national level, and that it plugs important gaps in the overall EU R&I landscape. More specifically, Horizon 2020 was the sole EU programme supporting transnational R&I activities and networks, including through partnerships with Member States, businesses and foundations, based on the key criterion of excellence. Transnational projects accounted for more than 70% of the total funding, while the remaining 30% was dedicated to mono-beneficiary schemes.

The findings of the external coherence study also indicate that the international/pan-European scale of Horizon 2020 complemented existing national/regional schemes by providing international networking, knowledge exchange and cooperation opportunities, contributing to the overall excellence of research projects. The external coherence study concluded that Horizon 2020 allowed the creation of broad project consortia between European and international partners, which helped to boost the quantity and quality of research undertaken. Even in countries where other R&I schemes supported similar types of activities in specific areas (e.g. support for green innovation in Sweden, Denmark and Germany, support for agri-food in Italy), participation in Horizon 2020 was still attractive due to the international context of projects, the networks of excellent players it brings together, and the opportunities to share expertise in such networks. Similarly, interviews with the beneficiaries of projects under the SwafS programme indicated that the work programme complemented existing actions at national level by providing inspiration to develop new policies and programmes, as well as aiding progress. SwafS has also strengthened existing actions at national level by increasing the knowledge and capacities of participating organisations, which has enabled stakeholders to act as advocates for SwafS-like approaches at national level.

Evidence from the interviews and desk research largely supports the above findings of the Horizon 2020 external coherence study. According to interviewees, there is strong coherence between the ERC (which acts to reinforce the more research-intensive actors and to provide a benchmark for others in the European research system) and the European Structural and Investments Funds (which reinforce capacity in less research-intensive regions). Findings from the interviews also confirm that the level and nature of external coherence varies from country to country: while some Member States possess national/regional-level schemes similar to ERC, in some other Member States – where the level of research funding is generally lower – the ERC is one of the few available opportunities to receive support for research on this scale.

Evidence from desk research and interviews also indicates synergies between MSCA COFUND and other EU interventions, particularly the ESIF. The MSCA unit costs study (2020)[24] found that MSCA COFUND actions could be co-funded through the ESIF in the form of sequential funding or parallel cumulative funding. MSCA COFUND beneficiaries managed to secure funding from the ESIF for research, training and networking activities, indicating synergies between Horizon 2020 and other EU R&I funding instruments[25]. In addition, under Horizon 2020, three countries used the ESIF to establish support schemes to fund projects that had been awarded the MSCA Seal of Excellence[26]: Cyprus and Czechia under the European Regional Development Fund (ERDF) in 2017, and Lithuania under the European Social Fund (ESF) in 2018. These synergies between the ESIF and the MSCA present many benefits for funding authorities, allowing them to access a pool of high-quality proposals which they can

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23 Gøtke, N. et al. (2016). Analysis of ERA-NET Cofund actions under Horizon 2020: Final report of the expert group. https://op.europa.eu/en/publication-detail/-/publication/74c34f43-b147-11e6-871e-01aa75ed71a1

24 European Commission, Directorate-General for Education, Youth, Sport and Culture, Pupinis, M., Brožaitis, H., Navikas, V., et al. (2020). Review of Marie Skłodowska-Curie actions unit costs in preparation for Horizon Europe : final report, Publications Office, 2020, https://data.europa.eu/doi/10.2766/36137

25 Synergies and complementarities between the MSCA and national/regional R&D systems have also been identified: e.g. 61% of the 1,359 MSCA host organisations surveyed confirmed the positive impact of regional/national long-term R&D strategies on their capacities to participate in the MSCA, while 59% highlighted the positive impact of the availability of sufficient and stable regional/national R&D funding. Moreover, the importance of the availability of additional funding was reflected in the fact that 17% of 1,255 organisations reported applying for additional funding for their MSCA projects. Source: European Commission, Directorate-General for Education, Youth, Sport and Culture, Dėlkutė, R., Nikinmaa, J., Pupinis, M., et al. (2022). Study on mobility flows of researchers in the context of the Marie Skłodowska-Curie actions: final report. Publications Office, 2022. https://op.europa.eu/en/publication-detail/-/publication/ec662cff-031c-11ed-acce-01aa75ed71a1/language-en

26 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/seal-excellence/funding-opportunities-under-msca_en

fund through a simplified and more streamlined process than if they were to set up their own calls and evaluation process.

4.3. Efficiency

This section evaluates the criterion of the efficiency of Horizon 2020 programme parts covered under this study. Insights are gathered through the literature review, analysis of the administrative data and, to a lesser extent, through interviews. As per the Tender Specifications, all evaluation questions have been covered (see Annex 2 for a list of questions).

The following themes are covered in the analysis of efficiency:
- Budgetary resources (evaluation questions covered: EFF1, EFF2, EFF3)
- The programme's attractiveness and participation patterns (evaluation questions covered: EFF4, EFF5, EFF6, EFF7, EFF8, EFF9)
- Performance of the programme parts (evaluation questions covered: EFF10, EFF11, EFF12, EFF13, EFF14)
- Other (evaluation questions covered: EFF15, EFF16)

4.3.1. Budgetary resources

The management of the Horizon 2020 parts analysed by this study in terms of budgetary resources was **efficient and cost-effective.** To a large extent, the administrative budget under all programme parts did not exceed 5% of the operational budget. More specifically, during the period 2014-2020, the ERCEA[27] proved to be an efficient structure for managing the delegated ERC programme part, as its administrative budget was within the range of 2.5-3.6% of its operational budget, based on payment appropriations. This proportion also decreased over time from 3.6% in 2014 to 2.5% in 2020[28]. MSCA, FET-Open, SEWP and SwafS programme parts were all managed by the Research Executive Agency (REA). Based on the information made available in REA's Annual Activity Reports, REA was efficient in implementing the programmes in terms of the budget spent. For instance, the administrative budget's share of the total operational budgets for the MSCA varied from 1.8% in 2017 to 2.3% in 2020. The administrative budget as a share of operational budget for SEWP and SwafS ranged between 2.9% and 2017 to 2.6% in 2020.

The European Commission allocated over EUR 68 billion to funding research and innovation projects under Horizon 2020. Of Horizon 2020's budget, 39% was allocated to implementing the programme parts associated with excellent science that are analysed by this study, i.e. Pillar 1, SEWP and SwafS. The largest programme parts were the ERC and MSCA; nearly 20% and 10% of total Horizon 2020 funding went to implementing these programme parts, respectively (see Table 7). In descending order, around 3.8% went to the implementation of FET, around 3.6% to INFRA, around 1.5% to SEWP and around 0.7% to SwafS programme part.

Table 7: Number of projects, EU contribution and its share by programme part

	Number of projects	EU contribution (in EUR million)	Share of EU contribution (in %)
European Research Council	7,885	13,536.7	19.8
Future and Emerging Technologies	642	2,608.7	3.8
Marie Skłodowska-Curie Actions	12,168	6,591.3	9.6
Research Infrastructures	351	2,437.6	3.6
Spreading Excellence and Widening Participation	488	1,015.9	1.5
Science with and for Society	262	494.7	0.7
Total Horizon 2020	35,855	68,461.9	100

Source: compiled by the study team using Corda data.

Considering the large number of applications received, the evaluation and grant agreement preparation (GAP) processes were, for the most part, swift. All programme parts achieved their time-to-inform (TTI) targets (9 months for ERC; 5 months for the rest). Average time-to-sign (TTS) was

27 Since 2009, the ERC's dedicated implementation structure has been the ERC Executive Agency (ERCEA).

28 See the ERCEA's Annual Activity Reports (2014-2020).

longer than was set down in the targets for the ERC (target: 121 days), INFRA and SwafS (target: 91 days) programme parts. It is important to note, however, that this part of the process depends not only on the programme management but also on the work of the consortium. Overall, the time-to-grant (TTG) exceeded the target time only under the INFRA programme part.

Table 8: Project application and selection indicators by programme part (days, in red if it exceeds target-time)

	Total number of applications analysed[29]	Average TTI[30]	Average TTS	Average TTG
European Research Council	57,801	170.9	152.2	359.0
Future and Emerging Technologies	7,303	139.2	81.9	214.7
Marie Skłodowska-Curie Actions	79,727	139.3	69.5	208.5
Research Infrastructures	969	132.6	132.4	265.5
Spreading Excellence and Widening Participation	2,943	131.9	86.3	223.5
Science with and for Society	1,971	110.4	124.8	222.1
Total Horizon 2020	295,885	111.7	98.8	231.0

Source: compiled by the study team using Corda data.

Horizon 2020 time-to-inform and time-to-grant indicators were well in line with those of other major funding bodies and programmes worldwide. For example, the UK Research and Innovation (a branch of the EPSRC with a budget of over EUR 800 million) took approximately 5 months to inform its applicants about evaluation decisions, which is comparable to the Horizon 2020 TTI process (legal target of 5 months) [31]. NIH branches (in the US) took between 8 and 20 months from the application submission until they sent a notice of the grant award[32]. The Swedish Research Council took between 3 and 10 months to publish evaluation decisions[33].

The average time it took to make the payments under Horizon 2020 was 27.9 days, and most (91.5%) payments made were within the target time of 90 days. The two programme parts that exceeded the Horizon 2020 average for timely payment were ERC and MSCA – 98.6% and 94.6% (respectively) of payments were within the target. This indicates the high level of efficiency of the implementing agencies ERCEA and REA. On the other hand, payments under programme parts such as INFRA and SwafS were slower on average, with 80% and 78.6% of payments being made within the target, respectively. The share of payments made within the target time for these two programme parts was between 11.5 and 12.9 percentage points lower than that for the whole of Horizon 2020.

Table 9: Average time-to-pay and share of payments within the target time, by programme part (days)

	Total number of projects analysed	Total number of payments made[34]	Average TTP	Share of payments within the target (90 days)
European Research Council	7,620	26,282	17.6	97.6%
Future and Emerging Technologies	632	1,863	34.5	86.8%

29 The total number of applications is based on the data availability for TTI, i.e. if there no data are available for the date of the proposal information letter, then the proposal is not included in this table. In addition, 223 applications were dropped as outliers for calls: EURATOM-Adhoc-2014-20, H2020-Adhoc-2014-20, H2020-IBA-CS2-GAMS-2017, as project implementation started way earlier than the official closure date of these calls.

30 The target for time-to-inform (TTI) is max 5 months (152 days), except for ERC, which is 9 months (273 days). The target for time-to-sign (TTS) is max 3 months (91 days), except for ERC, which is 4 months (121 days). The target for time-to-grant (TTG) is max 8 months (243 days), except for ERC, which is 13 months (395 days). The ERC has different targets due to its proposal evaluation rules. The ERC runs a two-step evaluation, with panel meetings at both steps and interviews at step 2.

31 See: https://www.ukri.org/councils/epsrc/guidance-for-applicants/what-happens-after-you-submit-your-proposal/peer-review-process-faqs/#contents-list.

32 See: https://www.nimh.nih.gov/funding/grant-writing-and-application-process/timeline-for-decisions-about-your-grant-application & https://www.niaid.nih.gov/grants-contracts/due-dates-preparation-time-review-cycles.

33 See: https://www.vr.se/english.html.

34 Negative payments and regularisation are excluded.

	Total number of projects analysed	Total number of payments made[34]	Average TTP	Share of payments within the target (90 days)
Marie Skłodowska-Curie Actions	10,637	28,204	38.5	94.6%
Research Infrastructures	347	1,190	59.5	80%
Spreading Excellence and Widening Participation	453	1,280	32.7	86.2%
Science with and for Society	257	754	42.5	78.6%
Total Horizon 2020	33,621	104,321	27.9	91.5%

Source: compiled by the study team using Corda data.

4.3.2. Programme attractiveness and participation patterns

Horizon 2020 is a unique pan-European programme that funds high-quality research projects. As illustrated by its high oversubscription rates, the framework programme is well-perceived and attractive to applicants. Nevertheless, the main factors that motivate researchers and organisations to apply differ slightly by programme part. Our survey[35] results revealed that for the ERC, MSCA and FET programme parts, the most important motivating factor to apply for Horizon 2020 funding was the freedom and flexibility to pursue one's research agenda. For the ERC and FET, this was followed by the opportunity to conduct basic research and, for the MSCA, the opportunity to improve one's skills and competencies. This is followed by the opportunity to develop research infrastructures under the INFRA programme and interdisciplinary cooperation under SwafS. The possibility of international collaboration with other European and non-European research partners was an important motivation for all programme parts. These survey findings line up with the overall objectives of each programme part.

The high demand for funding and the limited budget of the Horizon 2020 programme has meant that only a small fraction of applicants were funded (see Table 10). Horizon 2020 has faced an oversubscription problem: only 11.5% of proposals submitted received funding. Among the sub-programmes highlighted in this analysis, the FET programme was the most competitive, with only 8.9% of applications being successful. The highest success rate was observed for the INFRA programme; this reached 33.5%. The higher success rate in INFRA programme can be explained by the different logic of the programme part. It directly supports research organisations to strengthen their research infrastructures (not research teams as it is the case in other programme parts, such as for example MSCA, SEWP or FET). Success rates under the ERC, MSCA, SEWP and SwafS programmes were very similar – ranging from 12.9% for the ERC to 15.9% for SEWP. The greatest competition between high-quality proposals was seen for the FET and MSCA programme parts.

To illustrate the magnitude of oversubscription, this study has calculated that **to fund all high-quality[36] proposals submitted to all actions of Horizon 2020, the European Commission would need to increase the Horizon 2020 budget by EUR 183 billion.** For instance, for the ERC part, the Commission would need to at least triple its budget, i.e. it would have needed another EUR 29 billion compared with the current budget of EUR 13.5 billion (see Table 7 for total budgets). In the case of the MSCA, the budget would have to increase almost six-fold, by EUR 38 billion, in addition to the current budget of EUR 6.5 billion.

Applying to Horizon 2020 involves the cost of proposal preparation. The literature shows that proposal preparation imposes an important burden on scientists applying for a grant provided by any of the world's major funders[37]. This is especially salient in the case of unsuccessful proposals, since the

35 Six surveys were run between August and September 2022, one for ERC, one for MSCA – IF, and one for each other programme parts. All surveys were split into beneficiaries and unsuccessful applicants.

36 High-quality proposals are proposals that were scored above the evaluation threshold.

37 Bollen, J., Crandall, D., Junk, D., et al. (2017). An efficient system to fund science: from proposal review to peer-to-peer distributions. Scientometrics 110, 521–528. https://doi.org/10.1007/s11192-016-2110-3; Herbert, D.L., Coveney, J., Clarke, P., Graves, N., & Barnett, A.G. (2014). The impact of funding deadlines on personal workloads, stress and family relationships: A qualitative study of Australian researchers. BMJ Open. doi:10.1136/bmjopen-2013-004462.

effort and costs invested– for the most part – do not pay off. **Our estimates show that up to EUR 9,694.4 million was spent on unsuccessful proposal writing**. The average cost of writing a single proposal was estimated to be between EUR 18,257.1 and EUR 37,169.5. These costs vary according to the programme part (and depend on the requested contribution, as well as the consortium size) (see Table 11)[38]. It should be noted, however, that these numbers are best estimates, given the data availability. Aspects such as resubmissions, efficiency gains due to previous experience, and outsourcing to professional proposal writers (the use of external consultants and their fees are discussed below), are not directly reflected in these estimates.

Table 10: Success rates and additional funding required to fund unsuccessful above-threshold proposals, by programme part

Programme part	Number of eligible proposals	Number of proposals above threshold	Number of successful proposals	Success rate	Success of rate for high-quality proposals	Additional budget needed to fund all unsuccessful high-quality proposals (in million EUR)	Ratio of budget needed to fund all unsuccessful high-quality proposals to existing programme part funding
ERC	57,216	23,701	7,357	12.9%	31.0%	29,564	2.2
FET	7,123	3,344	635	8.9%	19.0%	8,766	3.4
INFRA	947	711	317	33.5%	44.6%	1,760	0.7
MSCA	78,763	63,143	11,381	14.4%	18.0%	38,029	5.8
SEWP	2,925	1,938	464	15.9%	23.9%	1,589	1.6
SwafS	1,933	1,019	256	13.2%	25.1%	1,677	3.4
Total Horizon 2020	299,423	143,301	34,338	11.5%	24.0%	183,463	2.7

Source: compiled by the study team using Corda data.

Table 11: Estimated writing costs of retained and unsuccessful proposals, by programme part (only eligible proposals)

	Writing costs for retained proposals (in million EUR)		Writing costs for retained proposals as a share of EU contribution (in %)		Writing costs for unsuccessful proposals (in million EUR)		Average writing costs per single proposal (in EUR)	
Horizon 2020	**708.3**	**1,435.0**	**1.0**	**2.1**	**4,758.3**	**9,694.4**	**18,257.1**	**37,169.5**
ERC	155.7*	225.7	1.2*	1.7	968.3*	1,417.6	19,644.5*	28,720.5
FET	27.7	32.0	1.1	1.2	314.9	297.9	48,092.1	46,313.1
MSCA	142.2**	420.7	2.2**	6.4	788.5**	2,381.5	11,817.5**	35,578.0
INFRA	15.2	29.7	0.6	1.2	27.3	39.9	44,868.0	73,444.1
SEWP	8.6	17.2	0.8	1.7	48.3	90.1	19,456.4	36,667.9
SwafS	7.2	14.4	1.4	2.9	53.1	94.9	31,158.8	56,545.5

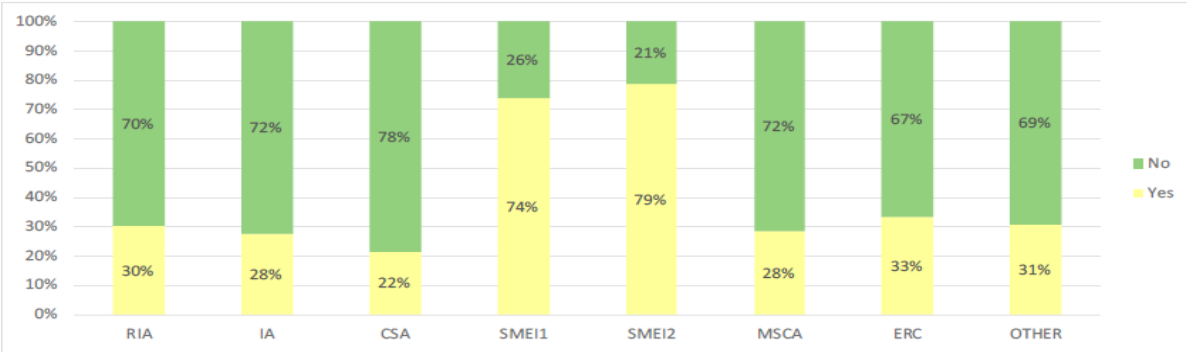
Source: compiled by the study team using Corda data. *Calculations do not include ERC-SyG. **Calculations do not include MSCA-SNLS.

To reduce the risk of potential loss of the resources invested, some consortia choose to hire experienced consultants. Such consultants can assist the consortia at the proposal preparation stage. If the proposal is successful, they may potentially continue to work together and take care of the administrative side of

38 For more details and methodology, please refer to Annex 1, Section 7.6.

the project. In 2018, the European Court of Auditors (ECA) conducted a survey on simplification measures[39]. The survey covered the period from the Horizon 2020 programme's start in 2014 to January 2018, and had a sample of 3,598 respondents. Based on the information provided, around 33% of ERC applicants used the services of external consultants. The corresponding share for MSCA applicants was slightly lower, at 28%.

Figure 4: Use of external consultant to prepare proposals, by type of action



Source: European Court of Auditors on Simplification Measures (2018, p. 47).

In the survey conducted for this study, successful consortia were asked to indicate if they had received help from consulting companies. **The survey found that consortia that had hired consultants to help with proposal preparation in some instances continued to collaborate with them in the administration of the projects**. Between 15% and 26% of respondents (depending on the programme part) made use of external consultants' help during the application stage, and between 11% and 21% employed consultants for project management and administration tasks. In addition, between 9% and 17% of consortia used services of consultants in project reporting, monitoring and finalisation. For example, 26% of FET applicants reported using external consultants to help them prepare their proposals; 21% had used consultants' help in relation to project management and administration, and even fewer – 17% –had used the help of consultants in project reporting, monitoring and finalisation.

The aforementioned European Court of Auditors' study shows that the median value paid to consultants was 5% of the total funding for proposal preparation, and 5% for project implementation. In addition, it is important to note that applicants from different countries are also subject to different taxation rules. Some countries offer tax benefits that may be deducted from the costs of preparing the proposals[40].

With regard to patterns of participation, **countries with the strongest R&I ecosystems dominate the list of Horizon 2020 participants**. Our analysis shows that the largest shares of participants in all programme parts (except for SEWP) came from five countries: Germany, France, the United Kingdom, Spain and Italy. These five countries are home to 44.6% of project participants. This situation is even more prominent within the ERC, MSCA and FET programme parts. Participants from these countries account for 56.7% of all ERC participants, and 45.5% of all MSCA participants. For FET, the figure is 60%. However, the picture changes when these participation numbers are normalised on the basis of the availability of R&I staff in each EU country. Here, the most represented countries in terms of normalised participations in Horizon 2020 are Cyprus, Malta, Estonia, Luxembourg, and Greece (all former or current widening countries).

To address the concentration of EU funding mostly in the EU-14(+UK), Horizon 2020 dedicated its Spreading Excellence and Widening Participation (SEWP) programme part to targeting countries with weaker R&I ecosystems (i.e. widening countries[41]). This is reflected in the participation patterns under SEWP. Whereas Germany, Italy and the UK remained in the top 5 most represented countries, two widening countries – Portugal and Poland – are also among the leading SEWP participants.

39 European Court of Auditors on Simplification Measures (2018, p. 47).

40 For detailed rules on tax benefits for R&I activities in different countries, see the following: https://www.oecd.org/sti/rd-tax-stats-expenditure.pdf

41 Member States that were categorised as widening countries under Horizon 2020 were Bulgaria, Croatia, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia and Slovenia. The following associated countries were also considered widening countries: Albania, Armenia, Bosnia and Herzegovina, the Faroe Islands, the Republic of North Macedonia, Georgia, Moldova, Montenegro, Serbia, Tunisia, Turkey and Ukraine.

While the SEWP programme part was designed to target a previously underrepresented group of participants (widening countries), it attracted a relatively small number of newcomers (only 14% of unique participants). This suggests that the SEWP mostly attracted beneficiaries that were already familiar with EU funding programmes, but either came from a widening country or hosted a researcher from a widening country (e.g. the Widening Fellowships pilot). The programme part that attracted the most newcomers was MSCA, with 53.7% of its participants being newcomers. According to our analysis, the programme parts least open to newcomers were ERC and SEWP programmes, with 17.4% and 14%, respectively.

Further comparison of application and participation patterns (see Annex 1 for details) reveals no great dissimilarities between the shares of applicants and participants in different category types[42]. This means that there are no structural differences between applicant and participant profiles, i.e. the relevant organisations are applying for funding in the various programme parts. Differences, where they exist, can mostly be attributed to the specific focus or objectives of a given programme part e.g. ERC having a larger share of organisations from the Leiden Europe Top 50 ranking among its participants than among its applicants can be attributed to the ERC's focus on excellence. Similarly, higher shares of both applicants and participants in SEWP from EU widening countries can be attributed to the programme's aim to increase participation from this group. In line with SwafS objectives, this programme part was able to attract non-traditional R&I actors – that is, 15.6% of all applicants.

4.3.3. Performance of the programme parts

To measure cost-effectiveness, one needs to identify possible inputs and outputs. Here, the amount of EU funding invested into each programme part is the input, and the number of publications produced by each programme part is the output. If the ratio between the funding invested and the publications produced is adequate, it implies that the programme part was cost-effective. To calculate this, we counted only finalised/closed projects, and retrieved the number of publications per project from the Scopus[43] database.

Our analysis of the output of completed projects shows that most programme parts under the study were cost-effective in terms of the number of publications produced. In line with their objectives to support excellent science, the ERC and MSCA programme parts were the most cost-effective, having produced 90.9 and 85.9 publications per EUR 10 million, respectively. Projects under SEWP produced around 77.1 publications per EUR 10 million of EU funding. Projects under FET produced around 66.9 publications. The objectives of INFRA and SwafS were not centred on the production of publications; hence, it is not surprising to see lower publication counts per EUR 10 million of 35.9 and 6.1, respectively. As a rule, under all programme parts, a handful of projects were exceptional in terms of the number of publications per EUR 10 million. For instance, the project InvisiblesPlus under MSCA produced 375 publications; LASERLAB-EUROPE under INFRA produced 413 publications (see the Annex 1 subsection on cost-effectiveness).

Table 12: Number of publications per EUR 10 million of EU contribution, by programme part (closed projects only)

Programme Part	Number of closed/finalised projects	Number of publications*	EU contribution (in million EUR)	Average EU contribution per publication (million EUR)	Number of publications per EUR 10 million contribution from the EU
European Research Council	1,412	10,825	1,190.4	0.11	90.9
Future and Emerging Technologies	171	4,722	705.4	0.15	66.9
Marie Skłodowska-Curie Actions	6,147	20,235	2,355.5	0.12	85.9
Research Infrastructures	150	2,943	819.6	0.28	35.9

42 We identified the following applicant/participant categories: PRCs , OTHs (this is intended as a proxy for the non-traditional R&I actors, applicants from the EU widening countries), applicants from the non-widening EU Member States, applicants from the associated countries, newcomers (applicant organisations which did not participate in FP7), organisations that were included among the top 50 Universities in Europe according to the CWTS Leiden Ranking, 1% most networked.

43 https://www.scopus.com/

Programme Part	Number of closed/finalised projects	Number of publications*	EU contribution (in million EUR)	Average EU contribution per publication (million EUR)	Number of publications per EUR 10 million contribution from the EU
Spreading Excellence and Widening Participation	167	2,443	316.9	0.13	77.1
Science with and for Society	84	86	140.3	1.63	6.1
Total Horizon 2020	16,609	58,778	18,565.4	0.3	31.7

Source: compiled by the Study Team using Corda data.

The programme parts analysed for this study helped to create new international collaborations that would not have existed otherwise. **The present analysis shows that, compared with a control group of close-peer researchers[44], target group researchers created 1.5 times more new collaborations throughout Horizon 2020**[45]. Similarly, they had 1.6 times more sustained collaborations than their close peers, performed better in terms of sustaining collaborations with their past co-authors, and retained twice as many collaborations as the control group. In addition, all of the programme parts analysed performed above the Horizon 2020 baseline in terms of sustaining cooperation between the different research teams involved in their projects. The absolute majority of projects in which cooperation among the different research teams was sustained at a higher rate than the Horizon 2020 baseline were built on collaboration and co-publication networks that existed prior to the project period. A history of previous cooperation greatly increases the likelihood that cooperation will be sustained and continue in the future.

With regards to **feedback-to-policy**, in a survey carried out for the 'Study supporting the evaluation of the Research Executive Agency (2015-2018)'[46], it was reported that:

- Only 38% of the EC officials surveyed generally agreed that the agency provided them with sufficient policy feedback to inform their policymaking tasks.
- While 74% of the EC officials surveyed thought that REA provided them with relevant inputs for the programme priorities/research topics under their or their unit's responsibilities, less than 60% of the Commission officials surveyed noted that the inputs provided by REA were directly used in the preparation of the work programme or research topics.

To address these shortcomings and improve policy feedback, in 2019, specific Policy Feedback Plans for all REA Horizon 2020 activities were agreed upon between the REA units and their Commission counterparts. In the second half of 2019, REA updated the other members of the R&I family on developments in its policy feedback approach via the Horizon 2020 Dissemination and Exploitation Network. The Internal Audit Service of the European Commission has highlighted the policy feedback activities undertaken so far by REA as good practice.

With regards to ERCEA, the agency evaluation showed that while the requirement to inform policymaking in frontier research is clear in its legal mandate, there is some confusion as to what the extraction of relevant information on policymaking means in practice. In relation to supporting the work of the Scientific Council, the agency's role in policy feedback was found to be clearly understood by the ERCEA, but the needs and expectations of the parent DG appeared to be less clearly understood in terms of what this function means in operational practice.

In terms of good practice examples of external policy feedback activities, ERCEA participated in DG Research & Innovation's Artificial Intelligence (AI) Matrix Task Force, contributing to the inventory of Horizon 2020 projects on AI and providing information about the latest AI-related projects funded in ERC calls. The agency also provided feedback to DG CNECT regarding ongoing ERC projects that could be relevant to future communication on quantum technologies.

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44 The control group was constructed with the aim of being as close as possible to the target group. This was achieved by drawing a random sample of researchers who had collaborated and co-published with the researchers on publications acknowledging the EU funding, but who were not affiliated with the project participant organisations.

45 For more details, please refer to Annex 1 subsection 7.8.

46 See survey C on page 123.

Under Horizon Europe, a new activity delegated to the R&I family executive agencies will be Feedback to Policy (F2P). The Executive Agencies have been closely involved in the development of the F2P framework for HE, and participates in the new Evaluation and Analysis Virtual Entity (EAVE). EAVE will carry out the *ex-post* evaluation of Horizon 2020 and monitor HE against its Key Impact Pathways.

4.4. Effectiveness

The EU support for research and innovation is provided through a variety of instruments that target single and collaborative research and mobility actions. This section presents a summary of the findings of this evaluation regarding the extent to which Horizon 2020 has achieved its objectives in aspects relating to excellent science. This summary presents the main findings of all the evaluation questions relating to the evaluation criterion of effectiveness (see Annex 2) across the following dimensions:

- **Excellent scientific production:** this subsection presents the findings in relation to scientific impacts, research output and excellence (evaluation questions covered: EFC1).
- **Structuring effect of the framework programme:** this subsection analyses the extent to which the framework programme has had a structuring effect in terms of fostering collaboration, as well as its openness towards (excellent) organisations across the EU. (Evaluation questions covered: EFC1, EFC7, EFC16).
- **Horizon 2020 performance targets for specific programme parts:** this subsection shows the extent to which the programme parts under analysis (ERC, MSCA, FET, INFRA, SEWP and SwafS) met their objectives regarding their specific KPIs.
- **Societal impacts:** contribution made to addressing societal challenges. (Evaluation questions covered: EFC4, EFC13*, EFC14*, EFC17, EFC18, EFC19).
- **Innovation and economic impacts:** fostering innovation and competitiveness (evaluation questions covered: EFC8, EFC9).
- **Impact on other policies:** this subsection summarises the main results of the framework programme parts under analysis from the perspective of the cross-cutting issues (evaluation questions covered: EFC11*, EFC13*, EFC15).
- **Strengthening researchers' careers, training and working conditions:** this subsection discusses the main results and impacts of these framework programme parts on these dimensions (evaluation questions covered: EFC10, EFC16).
- Lastly, the **key factors affecting progress and impact** are discussed: this includes findings relating to the role of dissemination, exploitation and communication measures in achieving the expected objectives of the programme (evaluation questions covered: EFC2, EFC3, EFC5*, EFC6*, EFC12).

4.4.1. Excellent scientific production

To measure the quality and impact of the research outputs produced by the framework programme, this study has identified and calculated three indicators measuring excellence of the scientific production. These indicators are presented in Table 13 and focus on the average citation scores, the number of highly cited publications (top 1%) and the contribution to new or emerging research fields. The following sections present the key findings related to these indicators.

Table 13: Indicators of scientific performance: excellent scientific production

Indicator – Horizon 2020	Indicator – Horizon Europe (Key Impact Pathways)
SCI1: field-normalised citation score (MNCS/CNCI/FWCI) – field-normalised citation score; the MNCS / methodology follows the descriptions provided in the study on KIPs.	KIP 1 medium-term indicator: field-weighted citation index (of peer-reviewed publications resulting from the programme) – FWCI score of the framework programme publications.
SCI2: number/share of the top 1% most-cited publications – number/share of FP publications ranked in the top 1% in terms of citations received in their field and year.	KIP 1 long-term indicator: world-class science: number and share of peer-reviewed publications resulting from the projects funded by the programme that are core contributors to scientific fields – share of the top 1% of most cited publications in research funded by the framework programme.

Indicator – Horizon 2020	Indicator – Horizon Europe (Key Impact Pathways)
SCI3: contribution to new/emerging research fields – number/share of FP projects that contributed with seminal research into new and fast-growing research topics (i.e. FP publications were among the Top 1% of publications in a field that was also a new field of research).	Not applicable*

Notes: *there is no comparable indicator in the Key Impact Pathways framework[47].

Horizon 2020 has produced 138,888 peer-reviewed publications[48]. Pillar 1 produced the highest number of publications, primarily thanks to the ERC and MSCA. The most frequent outputs of Horizon 2020 projects were articles (75%), followed by conference papers (17%) and reviews (7%). Of the peer-reviewed publications produced under Horizon 2020, 3.9% were among the 1% most-cited publications (see Table 14 and Annex 14 for an overview of specific programme parts).

Table 14: Main indicators of scientific excellence in Horizon 2020 (SC1 and SC2)

Total number of publications analysed	Publications with at least one citation		Top 1% most cited publications		Average normalised citation score	OA publications	
	Number of publications	% of total	Number of publications	% of total		Number of publications	% of total
138,888	129,245	93.1%	5,406	3.9%	2.03	114,144	82.2%

Source: bibliometric analysis performed by the study team.

Horizon 2020 has strengthened the scientific position of the EU worldwide: in most of the disciplines analysed, the framework programme has achieved higher publication citation scores than any of the other funders selected for benchmarking– both in terms of the share of top 1% most-cited publications and the average normalised citation score of its publications (see Table 15). The impact of Horizon 2020 is especially remarkable in multidisciplinary journals. Engineering Sciences and Natural Sciences show relatively low shares of highly cited publications, both 1.8%, although these are higher for Horizon 2020 than for most of the other international funders analysed.

Table 15: Scientific impact of other national funding programmes, average normalised citation score per discipline

Scientific discipline	ANR	ARC	FCT	FWF	NSERC	NSF	NWO	H2020
Engineering Sciences	1.2%	2.1%	1.4%	1.6%	1.3%	2.2%	1.5%	**1.8%**
Language, Information and Communication	1.5%	1.9%	1.5%	2.3%	1.6%	2.6%	2.2%	**2.4%**
Law, Arts and Humanities	3.0%	2.9%	1.3%	3.5%	2.9%	2.9%	3.8%	**3.1%**
Medical and Life Sciences	1.5%	1.4%	1.4%	1.6%	1.2%	1.7%	1.8%	**2.3%**
Multidisciplinary Journals	1.9%	1.7%	1.5%	1.4%	2.1%	2.5%	1.9%	**3.2%**
Natural Sciences	1.4%	1.7%	1.3%	1.5%	1.4%	1.9%	1.8%	**1.8%**
Social and Behavioural Sciences	1.2%	1.8%	1.4%	1.7%	1.1%	2.2%	1.9%	**2.4%**
Total	1.4%	1.7%	1.3%	1.6%	1.3%	1.9%	1.9%	**2.0%**

Source: bibliometric analysis performed by the study team.

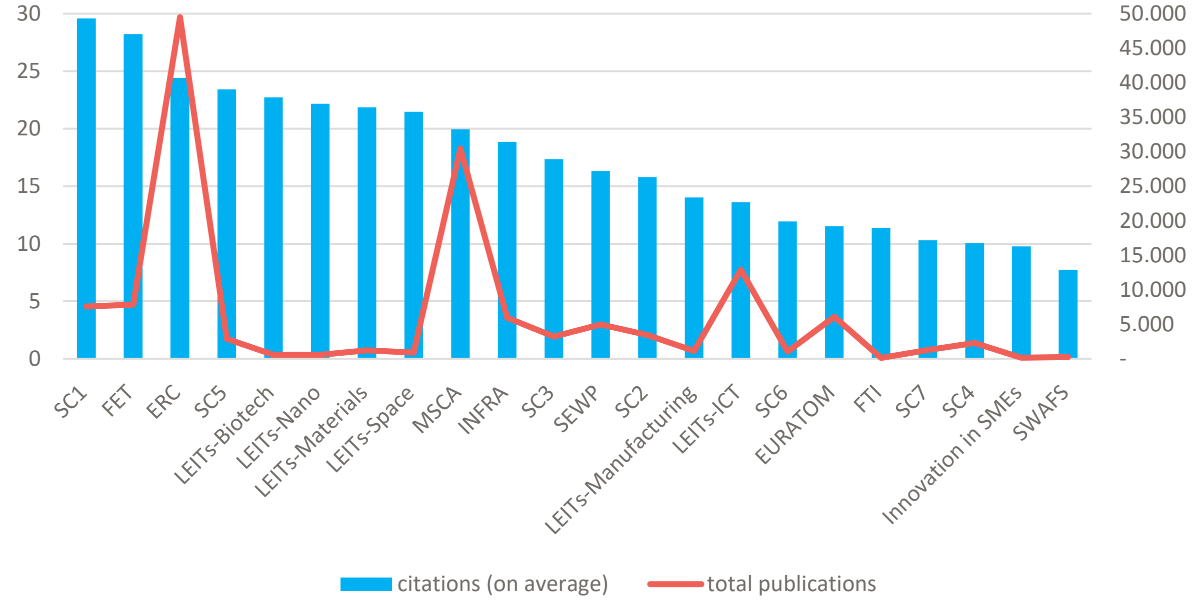
47 European Commission, Directorate-General for Research and Innovation, Nixon, J., Study to support the monitoring and evaluation of the framework programme for research and innovation along key impact pathways : baseline and benchmark report, Nixon, J.(editor), Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/98156

48 After validation of the data carried out by the study team, the validated publications constitute 61% of all reported publications in ongoing and in closed projects. Detailed information on the validation process that was followed is provided in Annex 3.

Scientific excellence in Horizon 2020 was spread across its programme parts, most of them achieving higher citation rates than the world average or comparable international funders. Although analysis by programme part should take into account the policy goals of each part, as well as project level characteristics[49], the analysis across the programme parts reveals the following results:

- ERC and MSCA not only stood out in terms of the large quantity of research outputs produced (see Table 12), but also for their high quality: see, for instance, their average citation scores in Figure 5 and their high shares of publications in the top 1% most-cited publications in Table 38 in Annex 13.
- Societal Challenge 1 (SC1, Health, Demographic Change and Well-being) and Societal Challenge 5 (Climate Action, Environment, Resource Efficiency and Raw Materials), although smaller in terms of EU budget and hence producing fewer research outcomes, also stand out for their very high levels of cited publications (see Figure 5).
- Similarly, publications stemming from the JRC also exhibit very high levels of quality: a third of JRC publications feature in the 90th percentile of the most highly cited publications in their field. Although in the lower end within the Horizon 2020 results, outputs from the EURATOM programme as well as from EIT are above the world average in comparable domains[50]. More details on the performance of the EURATOM programme, and EIT and JRC[51] are provided in Table 16.

Figure 5: Average citation, by programme part under Horizon 2020



Source: bibliometric analysis developed by the study team.

Table 16: Comparison of indicators across organisations: JRC, EURATOM and EIT

Entity	Number of publications	Average citation rate	Average FWCI	Share of top 1%
JRC	7,388	35.64	2.43	5.08%
EURATOM[52]	6,097	11.51	1.28	0.33%
EIT	1,135	19.57	1.73	2.64%

Source: bibliometric analysis developed by the study team.

49 For instance, project duration, funding, the type of beneficiaries (e.g. single beneficiaries vs consortia, size of the consortia, etc.).

50 In addition, when comparing EURATOM and EIT with the UK NPL and France's CEA, respectively, which are similar in terms of disciplines, similar citation metrics are found.

51 The JRC results do not take into account the direct actions of the JRC under the Euratom programme.

52 As the EURATOM publication data can be supplemented with CORDA data, we can further note that EURATOM (with 99 projects) has a publications-per-project" rate of 61.6. This study calculates a rate of 3.2 publications per million euros spent. Compared with the main Horizon 2020 programmes, EURATOM has the highest rate of publications per project, and ranks second only to ERC with respect to the number of publications per million euros spent.

As shown in **Error! Reference source not found.**, Horizon 2020 contributed to the development of **f uture and emerging research and technology fields,** particularly in Pillars 2 (Industrial Leadership) and 3 (Societal Challenges). Worth of note is the strong contribution made by the widening actions (SEWP) in this area, with shares above those obtained in Pillar 1 (Excellent Science), both in terms of the number of publications and the citation impact.

Table 17 Number and share of publications linked to FETs, by Horizon 2020 programme

Programme part	Total number of publications analysed	Number of publications linked to FETs	Number of publications linked to FETS that are also among the 1% cited	Share of publications linked to FETs	Share of publications linked to FETS that are also among the 1% cited
Horizon 2020 Pillar 1: Excellent Science	93,297	22,698	1,453	24.3%	1.6%
H2020-ERC	53,283	12,281	956	23.0%	1.8%
H2020-FET	9,025	3,112	147	34.5%	1.6%
H2020-MSCA	30,721	7,622	397	24.8%	1.3%
H2020-INFRA	6,449	1,378	93	21.4%	1.4%
H2020-SEWP	4,442	1,323	54	29.8%	1.2%
H2020-SWAFS	6,627	356	12	5.4%	0.2%
Horizon 2020 Pillar 2: Industrial Leadership	12,234	4,111	154	33.6%	1.3%
Horizon 2020 Pillar 3: Societal Challenges	18,961	6,555	423	34.6%	2.2%
Horizon 2020 total	**131,786**	**33,663**	**1,971**	**25.5%**	**1.5%**

Source: analysis of EC monitoring, Scopus and MAG/OpenAlex data

This study also examined the performance of the framework programme in specific emerging fields (see Box 1): artificial intelligence (1,971 projects); quantum computing (1,901 projects); and clean energy technologies (2,752 projects).

Box 1 Horizon 2020 performance in specific emerging fields

In the field of **artificial intelligence**, projects under the Industrial Leadership pillar received the largest financial contribution, accounting for more than EUR 3.8 billion. Under the Excellent Science pillar, Marie Skłodowska-Curie Actions contributed the highest number of projects (530) with the participation of 6,316 MSCA fellows involved in projects relating to AI under Horizon 2020. HEIs accounted for more than half (55%) of participating organisations, followed by organisations in the private sector (23%). However, in terms of the geographical distribution of participating organisations, widening countries accounted for just 17%, while third country participation stood at 3%. In terms of research outputs, the most numerous research outputs were publications, accounting for a total of 15,430 publications in the field of AI, 4% of which appeared in the top 1% of most cited journals. Under Horizon 2020, AI-related projects contributed to a total of 106 patents being awarded, with the most patents being awarded as a result of projects funded under the Industrial Leadership pillar.

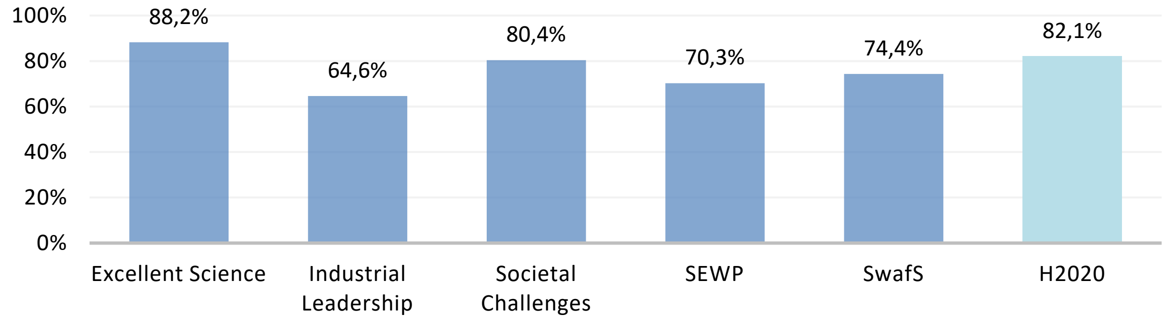
In the area of **quantum computing**, projects under the Excellent Science pillar received the highest financial contribution, accounting for more than EUR 3 billion. Compared with other programmes under the Excellent Science pillar, the Future and Emerging Technologies programme made the largest contribution to quantum computing-related research, with investments of more than EUR 1.1 billion. As with AI, HEIs accounted for more than half of all participating organisations (51%), followed by research organisations (27%) and organisations representing the private sector (18%). Analysis also reveals that most participating organisations are from non-widening countries (79%), with those from widening countries accounting for just 11%. A total of 21,788 publications were produced as a result of the projects funded, out of which 3% appeared in the top 1% of most-cited journals. Lastly, under Horizon 2020, 82 patents were awarded in the area of quantum computing, with 36 patents being awarded under the Excellent Science pillar and 41 under the Industrial Leadership pillar.

In the field of **clean energy technologies**, projects under the Societal Challenges pillar received the greatest financial contribution, accounting for more than EUR 7 billion. Under the Excellent Science pillar, Marie Skłodowska-Curie Actions contributed the most to research into clean energy technologies, with investments of more than EUR 323 million. Across the Excellent Science pillar, SwafS and SEWP programmes, the organisations most widely represented were HEIs (49%), followed by organisations in the private sector (23%). Taking into consideration all three pillars of Horizon 2020 and the SwafS and SEWP programmes, most participant organisations come from non-widening countries (75%), while participation from widening countries accounted for 15%. In projects related to clean energy technologies, only 3% of organisations represented third countries. In addition, 9,439 publications in the field of clean energy were produced as a result of projects funded, out of which only 4% appeared in the top 1% of most cited journals. Under Horizon 2020, 59 patents were awarded in this field, with the largest share of patents falling under the Societal Challenges pillar (47 patents).

Source: case study on the contribution of the framework programme to some emerging areas of science and technology such as artificial intelligence, quantum computing and clean energy technologies (Annex 6.13).

Horizon 2020's open access principles and requirements had a strong positive impact in terms of open access rates (82% across Horizon 2020, see details in Figure 6). These rates are comparable to those obtained at international level by research funders that are more advanced in this domain, such as the National Science Foundation (NSF), the Austrian Science Fund (FWF) and the Netherlands Organisation for Scientific Research (NWO)[53]. The highest open access rates are found in Pillar 1 (88%).

Figure 6: Percentage of open access articles published in peer-reviewed journals in Horizon 2020 per Horizon 2020 thematic priority



Source: bibliometric analysis.

Over time, there was an important increase in the number of open access datasets resulting from Horizon 2020 projects, from 64 open datasets in 2015 to 1,694 open datasets in 2020[54]. However, the data produced did not always comply with FAIR[55] principles, and differences are apparent across disciplines and programme parts. A survey carried out in a previous study found that more than half of

53 European Commission, Directorate-General for Research and Innovation, Monitoring the Open Access Policy of Horizon 2020 : final report, Publications Office, 2021, https://data.europa.eu/doi/10.2777/268348

54 .These numbers stem from the recent MOAP study (p. 50) and "may not capture all datasets produced, but only those that are reported and those harvested by OpenAIRE". European Commission, Directorate-General for Research and Innovation, Monitoring the Open Access Policy of Horizon 2020 : final report, Publications Office, 2021, https://data.europa.eu/doi/10.2777/268348

55 Findability, accessibility, interoperability, and reusability.

respondents believed their Horizon 2020 study was reproducible[56]. However, the MOAP study[57] found that many of the open access datasets were not fully FAIR. For instance, of the deposited datasets, only around 35% were findable (due to the lack of a valid URI) and around 29% were accessible and interoperable (due to the lack of valid URLs). In terms of reusability, roughly 61% of the datasets included a licence allowing text and data mining.

Awards and prizes resulting from Horizon 2020 research: Horizon 2020's advancement of the frontiers of knowledge and support for excellent investigators are also reflected in the many awards and prizes won by Horizon 2020 grantees and beneficiaries. In total, 34.1% of ERC principal investigators who responded to the survey indicated that their work had been recognised through prizes or awards[58]. In total, 12 ERC grantees have been awarded a Nobel Prize after having received an ERC grant[59]. Five of these were awarded in the previous period, 2010-2014, while during the period 2016-2022, seven ERC grantees won a Nobel Prize[60]. Furthermore, after 2014, six ERC grantees have won a Wolf Prize[61] and one has been awarded a Fields Medal[62]. According to survey data from project participants, projects stemming from other programme parts also display positive results in this regard, particularly projects under FET and MSCA[63].

4.4.2. Structuring effect of the framework programme

This study includes an indicator of the structuring effect of the framework programme funding on the creation and sustainability of networks (see Table 18). According to this indicator, **Horizon 2020 has facilitated the emergence of thousands of new collaborations between researchers, and has thus achieved a strong structuring effect on the European research landscape**. The findings of the publication network analysis show that the number of co-author pairs counted after the end of Horizon 2020 projects was higher than those counted before. Any interpretation of these findings should, however, be approached with caution due to the fact that these analyses are based on only a subset of total projects[64].

Table 18: Indicators of the structuring effect of FP funding (SC4) – number/share of projects in which research networks were substantially strengthened and maintained after the end of EU funding, by programme area*

H2020 thematic priority	Total eligible projects for analysis	Total number of author pairs that were built during H2020 projects	Median share of author pairs working 1-2 years before the projects started	Median share of authors working 1-3 years after the end of EU funding
Pillar 1 – Excellent Science	4,648 (70.5%)	280,694 (64.6%)	76,185 (67.7%)	85,855 (62.1%)
Pillar 2 – Industrial Leadership	800 (12.1%)	68,103 (15.7%)	15,425 (13.7%)	21,281 (15.4%)
Pillar 3 – Societal Challenges	989 (15%)	72,807 (16.7%)	15,899 (14.1%)	25,816 (18.7%)
SEWP	81 (1.2%)	10,096 (2.3%)	4,560 (4.1%)	4,395 (3.2%)

56 European Commission, Directorate-General for Research and Innovation, Assessing the Reproducibility of Research Results in EU Framework Programmes for Research : final report, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/186782

57 European Commission, Directorate-General for Research and Innovation, Monitoring the Open Access Policy of Horizon 2020 : final report, Publications Office, 2021, https://data.europa.eu/doi/10.2777/268348

58 Survey of H2020 ERC beneficiaries, conducted on August-September 2022.

59 Source: ERC news webpage.

60 Benjamin List, 2021; Giorgio Parisi, 2021; Peter J. Radcliffe, 2019; Bernard Feringa, 2016.

61 Anne L'Huillier, 2022; Ferenc Krausz, 2022; Giorgio Parisi, 2021; Caroline Dean, 2020; Simon Donaldson, 2020; Jean-François Le Gall, 2019.

62 Alessio Figalli, 2018.

63 Findings based on survey evidence. Survey of H2020 ERC beneficiaries, conducted on August-September 2022: Shares of projects that had received scientific awards and prizes: FET (16%), MSCA (organisations) (14%), SEWP (10%), INFRA (5%) and SwafS (5%).

64 More detailed methodological considerations are presented in Annex 3.

H2020 thematic priority	Total eligible projects for analysis	Total number of author pairs that were built during H2020 projects	Median share of author pairs working 1-2 years before the projects started	Median share of authors working 1-3 years after the end of EU funding
SwafS	29 (0.4%)	858 (0.2%)	30 (0%)	212 (0.2%)
Euratom	16 (0.2%)	1,577 (0.4%)	360 (0.3%)	545 (0.4%)
Total	6,590 (100%)	434,739 (100%)	112,572 (100%)	138,253 (100%)

Notes: *There is no comparable indicator in the Key Impact Pathways framework[65].

Source: analysis of the structuring effect of Horizon 2020 carried out by the study team.

4.4.3. Horizon 2020 performance targets for specific programme parts

Horizon 2020 has achieved even significantly exceeded its targets in the majority of areas/programme parts covered by this evaluation study. The following targets have been met:

- **European Research Council (ERC)**: 5.6% of publications from ERC-funded projects were among the top 1% cited publications in their fields, with an average field-normalised citation score above the global average score of 2.32 (target: 1.0) (KPI1).
- **Future and Emerging Technologies (FET)**: this programme part achieved 66.9 publications per EUR 10 million funding for FET projects, well above the target of 25 publications per EUR 10 million funding (KPI2).
- **Research Infrastructures (INFRA)**: the number of researchers who had access to research infrastructures (20,376) is above the target set of 20,000 (KPI5).
- **Science with and for Society (SwafS)**: this programme part also significantly exceeded the target of 100 institutional change actions promoted by the programme, achieving 841 reported institutional changes (for more details, see the sections below[66]) (KPI21).

For the other programme parts, at the time of evaluation, the indicator values were very close to reaching the set targets:

- **Future and Emerging Technologies:** there were 0.95 patent applications per EUR 10 million funding for FET projects, while the target set for the end of Horizon 2020 was one patent application per EUR 10 million funding. (KPI3)
- **Marie Skłodowska-Curie Actions (MSCA):** so far, under Horizon 2020 the MSCA have supported approximately 49,475 fellows (out of which over 25,676 were early-stage researchers)[67]. Given only 61% of the MSCA projects had been closed, it is safe to assume that the MSCA are on their way to achieving the target of supporting 65,000 researchers (out of which were to be 25,000 PhD candidates) by the time all projects selected under the framework programme come to an end.

65 European Commission, Directorate-General for Research and Innovation, Nixon, J., Study to support the monitoring and evaluation of the framework programme for research and innovation along key impact pathways : baseline and benchmark report, Nixon, J.(editor), Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/98156

66 An internal exercise carried out by the REA in May 2021 identified a total of 734 institutional changes (out of a total of 1,041 items reported by project beneficiaries). This analysis concluded that a large part (29%) of the reported institutional changes did not qualify as such for diverse reasons: lack of attribution to the project (i.e. the activity/outcome was not a result of the project), the activity/output was not intended to last beyond the project's lifetime, or a lack of clarity regarding the reported activity/output.

67 CORDA database. Information retrieved on 19 January 2023. 39% of COFUND, RISE and ITN projects will support more fellows, as they were still ongoing at the time of reporting. IF fellows, where the researcher is known, are accounted for.

Table 19: 2020 indicator framework (and Horizon Europe indicators)

Programme part	Indicator name (Horizon 2020)	Target at the end of Horizon 2020[68]	Achieved value
Excellent Science – ERC (Horizon Europe KPI1)	Percentage of publications from ERC-funded projects that appear among the top 1% most highly cited in their field, and average field-normalised citation score above the global average score of 1.0	1.8% of funded publications rank among the world's top 1% most highly cited publications, and FWCI of 2.46	5.6% of ERC-funded publications appear in the top 1% most highly cited publications, the highest percentage in Pillar 1, with an average field normalized citation score (FWCI) of 2.32
Excellent Science – FET (Horizon Europe KPI2)	Publications in peer-reviewed high-impact journals	25 publications per EUR 10 million funding	66.9 publications per EUR 10 million funding[69]
Excellent Science – FET (Horizon Europe KPI3)	Patent applications and patents awarded in Future and Emerging Technologies	1 patent application per EUR 10 million funding	249 patent applications[70] 0.95 patent application per EUR 10 million funding
Excellent Science – MSCA (Horizon Europe KPI4)	Cross-sectoral and cross-country circulation of researchers, including PhD candidates	65,000 researchers (out of which 25,000 are PhD candidates)	49,475 researchers (out of which 25,676 are ESRs)[71]. Target expected to be reached once all funded projects come to an end
Excellent Science – INFRA (Horizon Europe KPI5)	Number of researchers who have access to research infrastructures as a result of support from Horizon 2020	20,000 additional researchers during Horizon 2020	20,376[72]
SEWP (Horizon Europe KPI20)	Evolution in the share of highly cited publications	-	50 publications (peer-reviewed articles) per EUR 10 million funding, which is the highest rate for all programmes, with an average citation rate of 16.3 citations per publication and a top 1% share of 2.6%.
SwafS (Horizon Europe KPI21)	Number of institutional change actions promoted by the programme part	100 institutional changes in beneficiaries by the end of Horizon 2020	841 institutional changes were reported[73]

(*)Note: SwafS was discontinued in Horizon Europe and there is no comparable indicator in Horizon Europe regarding institutional changes. However, KIP 2 (Strengthening human capital in research and innovation), KIP 3 (Fostering diffusion of knowledge and Open source) and KIP 6 (Strengthening the uptake of research and innovation in society) closely relate to the activities carried out in SwafS.

Source: Horizon 2020 indicators: assessing the results and impact of Horizon (2015).

68 Interim Evaluation of Horizon 2020: https://op.europa.eu/en/publication-detail/-/publication/33dc9472-d8c9-11e8-afb3-01aa75ed71a1/language-en

69 According to the cost-effectiveness calculations (based on closed projects).

70 Horizon Dashboard data, accessed on 21 September 2022.

71 CORDA database. Information retrieved on 19 January 2023. 39% of COFUND, RISE and ITN projects will support more fellows as they were still ongoing at the time of reporting. IF fellows, where the researcher is known, are accounted for.

72 Horizon Dashboard data, accessed on 21 September 2022. Data provided by the European Commission indicate that 16,712 distinct researchers has so far received access to RIs through INFRA - under FP7, this figure reached 21,060.

73 Based on European Commission´s monitoring data. The highest number of institutional changes were reported to target the project itself or the project's host (71%), followed by research performing organisations (61%), researchers (57%) and universities (44%) (See Annex 1 on the effectiveness of SwafS).

4.4.4. Societal impacts: contributing to societal challenges

The intervention logic of Horizon 2020 defines societal impact through the following concepts:

- Better contribution of R&I to tackling societal challenges
- Stronger global role of the EU, steering the international agenda to tackle global societal challenges
- Better societal acceptance of science and innovative solutions

Better contribution of R&I to tackling societal challenges: Horizon 2020 Pillar 1 has been characterised by a strong focus on societal impacts, particularly in the area of health and well-being, as well as industry, innovation and infrastructure[74]: Among the programme parts covered in this evaluation study (ERC, MSCA, INFRA, FET, SwafS, SEWP) for which data were available, the analysis of Societal Development Goals (SDG) shows that the highest shares of projects were associated to SDG 3 Good health and well-being (36% of projects), followed by SDG 9 Industry, innovation and infrastructure (20%) and SDG 13 Climate action (14%). In total, around 26% of all the projects covered in the analysis were not associated with any SDG[75].

Important efforts have been during Horizon 2020 to contribute to improved social outcomes – for instance, by placing a greater emphasis on the principles of responsible research and innovation (RRI). The SwafS MORRI project and its follow-up, SuperMORRI, launched the first large-scale exercise to monitor and evaluate the implementation of RRI, hence contributing to the greater understanding and uptake of these principles across the EU and beyond. Also within SwafS, the Gender-Net PLUS project is an interesting case: national funding agencies collaborated in setting up dedicated calls on integrating the gender dimension into research. Other examples of results contributing to this impact are, for instance, the thinking tool from the NewHoRRIzon project, aimed at ensuring societal readiness in research projects, and the contribution to the Global Code of Conduct for Research in Resource-Poor Settings within the TRUST project. The efforts made by the programme to foster gender equality are also associated with societal impact. These include the need to define the potential gender equality implications of the projects at proposal stage; the support provided by SwafS for the development of Gender Equality Plans; and projects that gathered together national authorities and/or national research funding agencies to promote actions fostering gender equality at national level (e.g. GENDERACTION and GENDERNET PLUS).

Stronger global role of the EU, steering the international agenda to tackle global societal challenges: the Horizon 2020 programme parts covered in this study had an impact on policymaking and agenda setting[76]: At EU level, the analysis carried out in this study shows that 463 publications resulting from 304 projects were cited in EU policy documents. The cited publications came from all of the programme parts under analysis, each showing an impact that appears proportional to the EU budget allocated to it[77].

In addition, the framework programme has addressed grand societal challenges through international collaboration and joint action (Joint Programming Initiatives and other Public-Public-Partnerships). The European Commission introduced Joint Programming in 2008 as one of the priorities for implementing the European Research Area. Member countries participating in Joint Programming are expected to engage in concerted and joint planning, implementation and evaluation of national R&I programmes to define common priorities. Such an approach requires top-down, high-level sustained strategic intergovernmental dialogue. Ten Joint Programming Initiatives (JPIs) stem from the Joint Programming Process, all of which adopted Multiannual Implementation Plans. During Horizon 2020, all JPIs received

74 Findings based on the analysis of indicator SI1: Expected societal impacts of FP projects.

75 Societal Development Goal (SDG) labels were assigned to the projects using the OSDG tool (https://osdg.ai/). Assigning SDG labels was a three-stage process: in the first stage, AI and machine-learning models were used to assign preliminary SDG labels. Expert-curated ontology was then used to double-check and verify the initial labels. In the final step, results were aggregated from the text segment (paragraph) level to the project level, taking into account the size of project corpus, the amount of SDG-related content in the corpus, and the relative distribution of different SDGs. To receive an SDG label, at least 15% of text segments in the corpus has to be SDG-related, and each SDG included in the final label must account for at least 10% of all the SDG-relevant content in the project corpus.

76 Findings associated with the indicator SI4: Impact on policymaking and agenda setting.

77 40% of the publications cited in EU policy documents came from ERC grants, 31% from MSCA, 11% from INFRA, 10% from SEWP, 4% from SwafS and 4% from FET.

financial support for their activities through Collaboration and Support Actions (CSA), and also took advantage of the Horizon ERA-NET Cofund instrument[78] .

Better societal acceptance of science and innovative solutions: Horizon 2020 efforts to promote the social acceptance of science and innovative solutions have grown over time. These can be associated, on the one hand, with the efforts of the European Commission to promote the RRI principles through the framework programme. RRI was presented as a cross-cutting issue in Horizon 2020, with support for six dimensions to achieve them: public engagement, gender equality, science education, open access, ethics, and governance. Horizon 2020, especially through SwafS actions, has played a role in fostering the introduction of RRI into the political agenda across Europe, with national funding programmes aligning with the trends followed in the framework programme. The importance of responsible research and the various dimensions of RRI have been picked up by many Member States. This can be seen, for instance, in the increased uptake observed in recent years of open science principles in funding instruments at national level. Moreover, programmes have been launched in certain Member States to provide funding for RRI, for example through specific calls for citizen science[79].

Horizon 2020 has contributed to expanding the knowledge base and fostering community building around RRI topics, pooling experience and knowledge between countries[80]. The transnational approach taken in these activities is one of the main characteristics of the programme in this regard. This was particularly noticeable in the actions funded by SwafS, such as the RRI-tools project[81], which was frequently mentioned during interviews as a helpful catalogue of information on RRI. Nonetheless, several interviewees mentioned that the knowledge base on RRI is not yet complete, in the sense that the impact of many relevant projects is not yet visible, and long-term impacts are still insufficiently well measured (see Box 2).

Box 2: Barriers to the implementation of responsible research and innovation

Although RRI was especially important within SwafS, the analysis of its implementation has shown certain limitations:

- **Lack of broad visibility and understanding of the term**: stakeholders in the R&I field have fewer difficulties in relating to the specific components of RRI – gender equality, public engagement, ethics, open access, science education and governance – than to RRI as an overarching concept.
- **Limited stakeholder resources** (especially among not-for-profit organisations and SMEs) to work towards RRI. This hinders the creation of new collaborations and the development of effective quadruple helix governance models.
- **Limited knowledge base on the impact achieved by the actions (especially in the long term)**. Efforts to build up the knowledge base on RRI could consider monitoring its impacts among the finished projects to add to the knowledge base, inform good practices and share experiences.

4.4.5. Innovation and economic impacts: fostering innovation and competitiveness

Horizon 2020 science and research activities were also expected to contribute to the performance and competitiveness of the EU´s research and innovation system (e.g. intellectual property, the commercialisation of research results, entrepreneurship, etc.). The innovation/economic impact in the intervention logic of Horizon 2020 is defined according to the following concepts:

- Better innovation capacity of EU firms
- EU tech leadership and strengthening the competitive position of European industry

78 78 ERA-NET Cofund actions were developed, with a total EU contribution of EUR 545,5 million, the largest contributions going to the Societal Challenges of Environment, Health and Food.

79 For example, the Flemish government in Belgium released two citizen science calls in 2017 and 2019. https://www.ewi-vlaanderen.be/oproep-citizen-science

80 For a more detailed overview of RRI under Horizon 2020, please see the Evaluation Study on the implementation of Cross Cutting Issues in Horizon 2020.

81 https://rri-tools.eu/

- Diffusion of innovation into the economy (including jobs, growth and investment)

To assess innovation/economic impact, the study team employed indicators that are universal across the various Horizon 2020 programme parts and which allow for a cross-programme comparison of performance. The main findings of this analysis are presented below:

- **Important patenting activity has been carried out in Pillar 1**. Horizon 2020 Pillar 1 achieved patenting rates similar to other pillars of Horizon 2020. According to the analysis carried out by the study team (see Annex 3 of the study[82]), within Pillar 1, ERC achieved the highest number of foreground patents (82), followed by MSCA (44) and FET (25). ERC and FET displayed similar shares of patents that had at least one citation, with 35% and 36% respectively.
- **A strong focus on the early stages of innovation**. Analysis based on Innovation Radar data for each thematic pillar of Horizon 2020 shows that over the period 2014-2020, the programme's main focus was on innovation in the earlier stages of maturity: 53% of all innovations produced under the programme correspond to the 'Exploring' phase (see Table 20).
- **In terms of the types of innovation, Pillar 1 followed a similar pattern to Horizon 2020 overall**, with a strong focus on early-stage innovation: 65% of the innovations produced within Pillar 1 correspond with the 'exploring' stage, while only 10% were deemed market-ready, below the 17% average share for Horizon 2020 as a whole.

Table 20: Overview of innovations, by maturity stage

H2020 pillar	Exploring	Tech ready	Business ready	Market ready	Total per pillar
Pillar 1: Excellent Science	1,579 (64.9%)	277 (11.4%)	328 (13.5%)	249 (10.2%)	**2,433 (100%)**
Pillar 2: Industrial Leadership	1,784 (46%)	703 (18.1%)	558 (14.4%)	833 (21.5%)	**3,878 (100%)**
Pillar 3: Societal Challenges	811 (51.6%)	267 (17%)	222 (14.1%)	272 (17.3%)	**1,572 (100%)**
Total per stage	**4,174 (52.9%)**	**1,247 (15.8%)**	**1,108 (14%)**	**1,354 (17.2%)**	**7,883 (100%)**

Source: analysis of Innovation Radar data, Annex 3.

Box 3: ERC Proof of Concept

The ERC Proof of Concept was introduced in 2011 to help bridge the so-called 'Valley of Death' between excellent frontier research and innovations that provide societal and economic advantages. A total of 1,125 Proof of Concept projects were supported under Horizon 2020[83]. The results of the Proof of Concept-funded projects, with some exceptions, remain closer to the idea generation phase than to innovation, according to the evaluation carried out for the 2021 ERC Annual Activity Report[84]. Nevertheless, Proof-of-Concept funding has proven to be successful in providing the first commercialisation testing grounds for early-stage fundamental research inventions and concepts, and has been quite effective when it comes to patenting[85]. Proof-of-Concept funding created opportunities for university staff members to move on to a different career path, i.e. towards entrepreneurship[86].

82 Patent data was downloaded from the Cordis databased and matched with patents on the PATSTAT database.

83 Source: Horizon 2020 Dashboard. There is a small discrepancy between data sources. CORDIS data indicates that there were 1,130 projects (see case study on 'Achievement of commercial and/or social innovation potential of ERC projects that received ERC Proof of Concept funding'). In particular, CORDIS data show four projects more in 2016 and one project more in 2020.

84 See Annual report on the ERC activities and achievements in 2021.

85 See the case study on the 'Achievement of commercial and/or social innovation potential of ERC projects that received ERC Proof of Concept funding'.

86 Ibid.

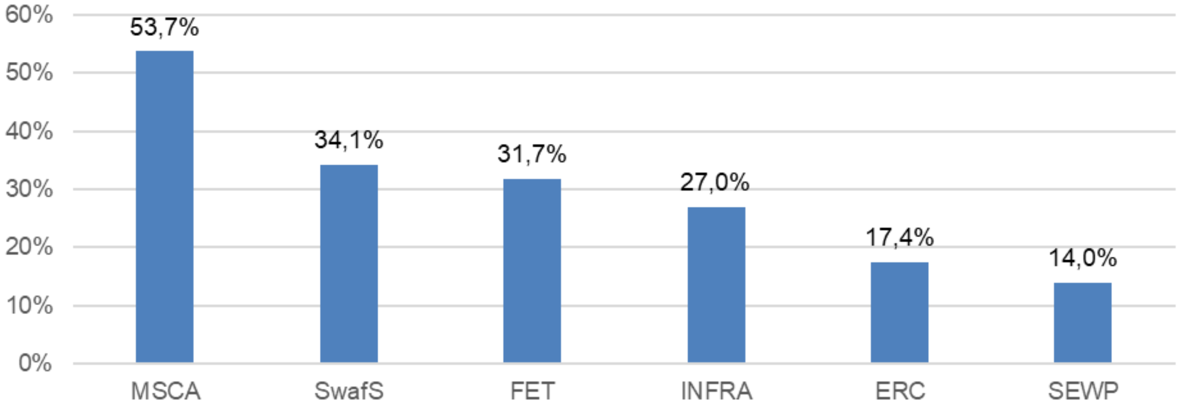
The participation of industry in Pillar 1 and SEWP has remained limited.[87] With some exceptions, interviews with project beneficiaries indicate that connecting with industry often remains a difficult task for projects that offer potential for commercialisation.[88] For instance, many ERC principal investigators interviewed did not see the value of involving industry in their projects, and industry was often not interested in engaging with ERC projects. Despite this, evidence stemming from the survey and interviews with project beneficiaries indicates that Horizon 2020 has played an important role in fostering awareness and confidence among researchers of the commercial potential of their research. thanks to their participation in its projects.

The case of FET is particularly interesting in this regard: According to the FET-TRACES project[89], 83% of FET projects had contacts with industry, 40% had at least one partner from industry; industry participated in one-third of its research papers, and 12% of projects produced at least one spin-off company. In addition, the commercialisation of the research results of the Graphene Flagship was very successful, with the formation of new start-ups and the creation of products as a direct result of the funding.

4.4.6. Impact on other policies

Openness to (excellent) institutions across the EU and beyond: Horizon 2020 was open to (excellent) research organisations and institutions. Analysis of the concentration of funding shows that around 50% of funding in Horizon 2020 was allocated to 376 organisations representing the top 1% most-networked Horizon 2020 participants based on their degree centrality scores[90]. Meanwhile, around 10% of the Horizon 2020 funding went to the 50 highest-performing European universities, based on the Leiden ranking data. Around 20% of Horizon 2020 funding went to newcomer organisations – i.e. those which had not participated in FP7. Pillar 1 stands out for its relatively low degree of openness to newcomers compared with other pillars, MSCA being the programme part that showed a greater openness to new organisations, with 54% of the organisations being new to the programme (see Figure 7).

Figure 7: Share of newcomers* by programme part



Source: compiled by the study team using Corda data.

Widening participation: the participation of widening countries remained challenging during Horizon 2020. When looking specifically at the EU-13 Member States, analysis of Horizon 2020 data indicates that the participation of organisations from these countries represented 14% of all Horizon 2020 participants, receiving 5.25% of net EU contribution.

87 The shares of PRC (private sector) organisations participating in Horizon 2020 were as follows: 1.5% in ERC; 21,6% in MSCA; 23% in FET; 9.9% in INFRA; 4.6% in SEWP; 16.1% in SwafS. In Horizon 2020 overall, the share of participants from the private sector was 33.3%.

88 See the case study on the ‘ERC impact on creating new or pushing existing frontiers of science’.

89 FET-Traces is a Horizon 2020 impact assessment research project for the European Commission, which has analysed and measured the impacts of the research funding scheme “Future and Emerging Technologies Open” (FET Open and FET Proactive).

90 Based on network analysis developed in the context of this evaluation study.

Table 21: EU-13 Member States by pillar in Horizon 2020, participation and funding

Pillar	Share of participation	Share of EU financial contribution
Cross-theme	6%	4%
Euratom Research and Training Programme	18%	8%
Excellent Science	6%	3%
Industrial Leadership	8%	5%
Science with and for Society	16%	12%
Societal Challenges	10%	6%
Spreading excellence and widening participation	32%	40%

Source: Horizon 2020 Dashboard: Cross-cutting issues. Retrieved 8 February 2022.

SEWP therefore constituted a key element in fostering participation rates among widening countries: 42% of participants in these actions come from widening countries (32% from the EU-13; see Table 21). The findings of this study[91] indicate that the widening actions seem to be more effective in retaining participants from widening countries within the framework programme and in enhancing their connections with (excellent) participants, than in attracting newcomers from these countries. Interviews with SEWP beneficiaries from widening countries indicated that these actions fostered their capacity to connect with other relevant research and industry actors, increased their international visibility and reputation, and helped them be better able to prepare successful proposals both at national level and in the EU context.

The widening actions were also particularly important for widening countries in terms of the production of excellent research: nearly one in three of the highly cited publications of Horizon 2020 produced by widening Member States came as a result of SEWP actions. In contrast, around 2% of highly cited publications by non-widening Member States come from the widening actions. However, the widening actions still face challenges with regard to attracting international talent and in the management of complementary funding, particularly from the ERDF.

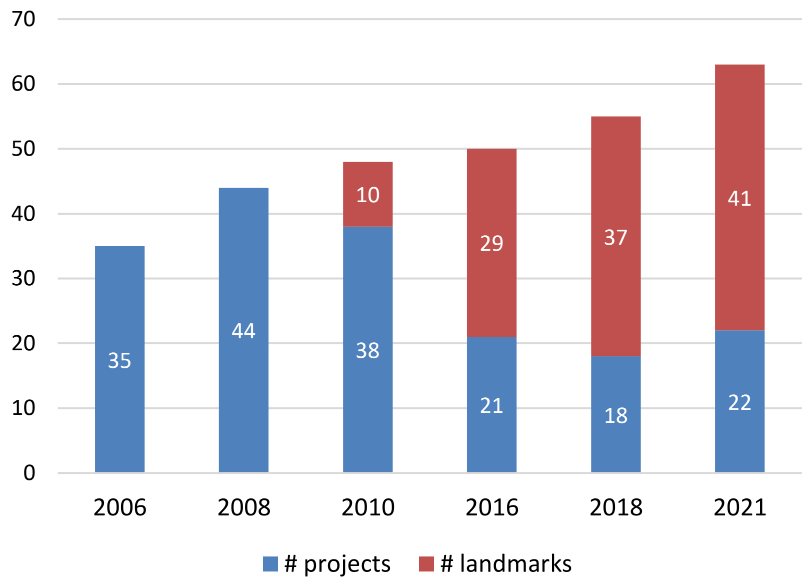
In addition to SEWP, other programme parts also demonstrated relatively strong participation by institutions from widening countries. This was most notable in the case of SwafS, where widening organisations and institutions constituted 21% of all participants (16% from the EU-13 Member States).

Developing and deploying world-class European research infrastructures: Horizon 2020 has played a pivotal role in promoting the development of pan-EU research infrastructures (RIs): research infrastructures (INFRA) work programmes, included those under Pillar 1, reinforced the development of pan-EU infrastructures, providing support for collaboration, joint research and services, as well as the provision of access to these infrastructures. One of the key indicators used to measure the effectiveness of the programme from this perspective is the number of national research infrastructures networked (in the sense of being made accessible to all researchers in Europe and beyond, through Union support). At the time of preparation of this report, the number of networked infrastructures has reached 883 (912 if we include e-infrastructures), hence reaching the target set for the end of Horizon 2020 (900).

Strong support for the ESFRI Roadmap: Horizon 2020 has provided significant support for the development of the pan-EU research infrastructures included in the European roadmaps published by the European Strategy Forum on Research Infrastructures (ESFRI). These roadmaps list the most important RIs in Europe for the next 10-20 years, with the aim of stimulating the implementation and/or upgrading of these RIs. As shown in Figure 8, the number of ESFRI infrastructure landmarks (i.e. more mature RIs) has reached 41. Interviews with stakeholders and beneficiaries indicate that this is in large part thanks to the contribution of INFRADEV and other INFRA calls.

91 Based on data analysis of participant data and interviews. More information is available in Annex 6.11. Contribution of SEWP to integrating research groups from widening countries.

Figure 8: Evolution of ESFRI projects and landmarks in the ESFRI roadmaps



Source: ESFRI roadmap reports[92].

Progress towards open and data-driven R&D&I: fostering the role of research infrastructures towards open and data-driven research and development. Special mention deserves to be given to the launch in Horizon 2020 of the European Open Science Cloud (EOSC). With a budget of EUR 244 million, INFRAEOSC calls constituted the first steps in this initiative, which aims to provide all European researchers and a wider community (industry, public sector, citizen scientists etc.) with seamless access to public and commercial services, including those developed by RIs. Overall, it is too soon to grasp the full impact of INFRAEOSC calls, as these were launched during the later phases of Horizon 2020.

Horizon 2020-funded research under Pillar 1, SEWP and SwafS, had an impact on policymaking and agenda-setting. The analysis carried out in the context of this study provides data on the number of citations of FP projects and/or their publications in EU policy documents. These reveal that programme outputs were taken into consideration in EU policymaking. When considering the citation of FP publications from Horizon 2020 Pillar 1, SwafS and SEWP (with a total of 304 projects cited), the programme parts that are most frequently mentioned in EU policy documents are ERC grants (40%), followed by MSCA projects (31%). From a more qualitative perspective, it is also important to consider the impact of the programme in fostering the alignment of policy priorities between the EU and the national and regional levels, for instance by promoting the alignment of the projects' activities with the Smart Specialisation Strategies: this alignment was, for instance, very visible in actions funded by SEWP.

The framework programme has improved and aligned organisational practices and structures, most notably through the MSCA, SEWP and SwafS. Evidence from interviews and surveys indicates that the MSCA had a positive structuring effect on organisations in improving the quality of training, career development, human resources practices and procedures, and improving working conditions. The MSCA also contributed to the adoption of practices that promote gender balance and inclusiveness. The operating model for the MSCA promoted the adoption of these practices outside Europe as well as within it[93]. The SEWP and SwafS work programmes included the introduction of institutional and structural changes as one of the key expected results of the funded projects. However, there is still potential to improve the monitoring approach adopted during Horizon 2020 in this regard (see more details in Box 4).

Horizon 2020 has promoted the uptake of high-quality standards and approaches. The efforts made to foster the application of open access and FAIR principles, gender equality and ethics have led to many visible changes at the level of participating institutions and researchers. This is particularly

92 All roadmaps are available here: https://www.esfri.eu/library

93 See case study on 'Inclusiveness and gender dimension in the MSCA', Annex 6.

relevant in the case of newcomers (i.e. organisations without previous experience in the framework programme): their participation in the FP often led to an improvement in their gender equality practices, and/or their degree of awareness and uptake of open science principles and ethics. Moreover, the application of the Seal of Excellence (see Box 5) at national level not only produced positive effects in terms of efficiency for both national funding agencies and researchers, but also in terms of promoting and rewarding excellent research.

Box 4: Monitoring institutional and structural changes

The introduction of institutional/structural changes as result of projects was an important expected outcome of the SEWP and SwafS work programmes. The number of institutional changes resulting from the programme was the main KPI for SwafS. This evaluation study shows that, while the notion of institutional or structural change is relevant and it is important to measure the progress and impact of these programme parts, the operationalisation of this concept presented certain limitations. First, the definition of the concept of institutional change – 'a change in terms of how a beneficiary governs or structures itself' – was not always clear to beneficiaries, and was not always understood in the same way. Second, in the case of SwafS, there was a lack of consistency between the response options included in the Horizon 2020 reporting template and the phenomenon that was meant to be measured – the latter referred to project results and outputs, while the former referred to changes in governance at organisational, regional or country level.

Despite these limitations, the number of institutional changes appears to be well above 100, which was the target set for SwafS. This achievement was confirmed by an internal analysis carried out by the Research Executive Agency (REA) in 2021. After screening the institutional changes reported by SwafS projects, REA concluded that 734 institutional changes (out of a total of 1,041 items reported by project beneficiaries) could be considered as such. This analysis indicated that a large portion (29%) of the reported institutional changes did not qualify as such for diverse reasons: e.g. a lack of attribution to the project (i.e. the activity/outcome was not a result of the project); the activity/output was not intended to last beyond the project lifetime; or the lack of clarity as to the reported activity/output.

Box 5: The Seal of Excellence under Horizon 2020

The Seal of Excellence (SoE) initiative was launched by Commissioners Moedas and Cretu in 2015 to maximise synergies between different funds in order to enhance competitiveness, jobs and growth. The initiative aimed to provide alternative funding bodies interested in investing in R&I with information on the readiness and quality of project proposals that had already been evaluated by Horizon 2020. The SoE was granted if a project proposal was evaluated as being excellent, but was not financed due to budgetary constraints. SoE were first applied to SMEs in the SME Instrument, but the number of programme parts in which it could be applied has grown over time. National-level implementation of the SoE, differs according to the different programme parts (MSCA, SME Instrument, and ERC Proof of Concept).

Seal of Excellence in MSCA: in Pillar 1, MSCA is the programme part with the most experience with the use of the SoE. The MSCA news page reports that over 11,900 IF proposals were awarded with an SoE in Horizon 2020[94]. The Horizon Dashboard[95] indicates that 12,944 MSCA IF applicants were awarded an SoE, 9% of whom later received funding[96]. A total of 14 countries have introduced support programmes for MSCA applicants who have received a SoE, including eight widening countries (Bulgaria, Cyprus, Czechia, Lithuania, Poland Slovakia, Romania, and Slovenia).[97] These 14 countries have, in total, 22 different support schemes (either at national, regional or institutional level, with one scheme being privately funded)[98].

94 https://marie-sklodowska-curie-actions.ec.europa.eu/news/msca-seal-excellence-awarded

95 H2020-MSCA-IF-2016 until 2020.

96 Horizon 2020 Dashboard. Horizon 2020 Seal of Excellence – Applicants in proposals awarded with the SEal (filtered by MSCA applicants).

https://webgate.ec.europa.eu/dashboard/sense/app/da74e0f1-2508-4d90-a812-56891175b702/sheet/PbZJnb/state/analysis

97https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/seal-excellence/funding-opportunities-under-msca_en

98 See, for example, the study on mobility flows in the context of the MSCA.

With regard to Horizon 2020 cross-cutting issues, it is important to note that the majority of the associated KPIs have shown a positive evolution when compared with the interim evaluation[99]. These are the indicators relating to gender equality, bridging from discovery to market application, sustainable development, climate change and biodiversity, fostering the ERA, the Digital Agenda and widening participation. This positive evolution has been driven by the increased importance of gender equality in EU policy (e.g. Gender Equality Plans), efforts to promote innovation (e.g. the establishment of the EIC Pilot in 2018), the introduction by Ursula von der Leyen of the Green Deal and the twin transitions (2019) and the stronger integration of widening countries.

Pillar 1 stands out for its contribution to international cooperation (MSCA, INFRA). Sustainable development (MSCA, SwafS), digital agenda (FET, INFRA) and climate change (INFRA) have also received important attention from the programme parts covered in this evaluation. The contribution made by SwafS is especially remarkable in the fields of social sciences and humanities (SSH), responsible research and innovation (RRI) and sustainable development. More detailed figures on this are provided in the later section on EU added value on page 56.

4.4.7. Strengthening researchers´ careers, training and working conditions

Participation in Horizon 2020 is associated with positive effects in terms of career prospects, particularly for those in earlier career stages, such as MSCA fellows, ERC Starting and Consolidator grantees, and the more junior team members of the teams supported by SEWP. Nonetheless, there is a lack of systematic data that would allow the analysis of this impact on collaborative grants, as no information was collected about the researchers involved in these. This has been addressed in Horizon Europe, where information on the individual researchers involved (and their ORCID identifiers) is collected at proposal stage.

Horizon 2020 has largely strengthened researchers' skills and international mobility, and hence contributed to the circulation of talent and knowledge across the ERA. The key results of the programme in this regard are as follows:

- **MSCA is the largest worldwide international researcher mobility programme**: under Horizon 2020, the MSCA have so far supported approximately 49,475 fellows (out of which over were 25, 676 Early-Stage Researchers). The MSCA are expected to reach their target of 65,000 once all funded projects have come to an end.
- **Contributing to the return mobility of fellows**: The MSCA have also helped researchers by bringing them back to their countries of origin. This finding is particularly strong in relation to experienced researchers participating in Individual Fellowships (IF) and COFUND. Moreover, this trend towards return mobility is especially notable for citizens of the widening countries. The reintegration panel (RI) of the European fellowships (IF-EF) supported the return mobility of nationals or long-term residents of Member States or associated countries.
- **Fostering Europe´s capacity to attract world-class talent:** MSCA have supported researchers from 160 nationalities (40% of all researchers involved are nationals of non-EU countries) and participation by organisations from 139 countries worldwide. The MSCA are the most international part of Horizon 2020. High levels of cross-border mobility have also been noted among ERC team members in previous reports: half of Horizon 2020 ERC team members were non-nationals of the country in which the project was based. INFRA contributes to making Europe more attractive to world-class researchers from abroad, mainly through international cooperation set up within INFRASUPP projects[100], but also by funding transnational and virtual access (TNA/VA) of researchers from abroad.
- **Strengthening the diversification and improvement of researchers' skills and knowledge:** examples of this type of impact have been observed, for instance, in MSCA. These show a strong impact on the quality of training and supervision, with high levels of satisfaction across all actions[101]. The contribution to skills made by Horizon 2020 is also visible in INFRA, where training was a frequent component of projects, being especially relevant to the users of research infrastructure.

99 For a more detailed overview of cross-cutting issues under Horizon 2020, please see the Evaluation Study on the implementation of Cross Cutting Issues in Horizon 2020.

100 For example, within the topics "policy and international cooperation measures for RIs" (INFRASUPP-01-2016, INFRASUPP-02-2017 and INFRASUPP-01-2018-2019). Examples of projects are provided in the first question on the achievement of the objectives of INFRA.

101 Around 90% of IF and RISE fellows considered training and supervision to be good or very good, while ca. 80% of COFUND and ITN fellows considered them to be good or very good.

SwafS also contributed to this goal[102]: 81% of SwafS respondents to the survey[103] reported that their projects had improved the research skills, knowledge and competences of researchers to a large extent (50%) or to a moderate extent (31%). Meanwhile, 85%[104] reported that their projects had improved the transferable skills and competences of researchers (such as project management, teamwork, etc.) to a large or moderate extent.

- **Promoting transnational access to pan-EU research infrastructure through INFRA**: data received from the European Commission in October 2022 regarding the amount of transnational or virtual access shows that 16,712 unique researchers[105] had received access to RIs through INFRA at the time of writing this report[106]. With many projects still ongoing, this figure is expected to grow and reach similar levels of transnational access to those seen under FP7 (21,060 unique users[107]). In total, 844 RIs have been accessed, with an average of 1.6 installations accessed per RI. The three most widely used RIs were all synchrotron radiation sources: SOLEIL in France, Diamond in the UK, and MAX IV in Sweden.
- **Strengthening EU labour market for researchers through EURAXESS and support for the RESAVER pan-European pension scheme**: Between 2014 and 2020, a total of 442,752 offers were published on EURAXESS, significantly exceeding the annual target of the third ERA KPI of 60,000 research positions advertised[108]. There is, however, potential for improvement: findings from the MORE Study in 2019[109] indicated that only 19% of the researchers in EU-28 countries knew about EURAXESS, that awareness was particularly low among R1 researchers[110] (11%), and that little progress had been observed over time (awareness in 2016 reached 16%).

4.4.8. Factors influencing progress and impact

Several factors have been found to have had an impact on Horizon 2020's progress and impact. These occur at the level of the R&I framework conditions (uneven levels of R&I performance and research management capabilities), and at the level of the framework programme design and management.

From the perspective of the **R&I framework conditions** within which Horizon 2020 and its funded activities operate, the following factors can be cited:

- **Challenges faced in fostering the participation of widening countries in the framework programme:** Horizon 2020 included several actions to promote the participation of widening countries through the creation of a specific programme part (SEWP) and by encouraging organisations from these countries to participate in proposals. In the programme parts covered by this evaluation study, lower levels of participation were observed in Pillar1 programme parts (ERC, FET, or INFRA) than in the more transversal parts (SEWP and SwafS). Interviews carried out with project coordinators also confirmed the difficulties faced by organisations from widening countries in attracting talent for key positions in their projects (see, for example, ERA Chairs in SEWP), and to ensure sustainability after the end of the projects (e.g. Centres of Excellence under Teaming).

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102 10% of the budget of SwafS was allocated to the activity line 'Science Careers' (EUR 48 million).

103 Survey of Horizon 2020 beneficiary organisations, conducted on August-September 2022 (n=80; see Annex 4.1).

104 Ibid, n=82.

105 Most of these researchers were granted access by projects under INFRAIA calls (99%): 11,169 TNA/VA user projects were funded through INFRAIA in Horizon 2020.

106 This figure is based on data reported by 97 projects. The Horizon Dashboard indicates that the total number of researchers having had access to research infrastructures through support from Horizon 2020 is 20,376 (hence, it is above the target of 20,000 researchers).

107 The figure for FP7 should be approached with caution, as 53 projects were not considered in the calculation of the figures due to the incompatibility of the structure of their reporting data. It is important to note that these figures are very different from the number of unique users reported by the Staff Working Document on sustainable RIs, which reported 25,782 unique researchers benefitting from the TNA/VA scheme.

108 Evaluation Study on the Implementation of the Cross-cutting Issues in Horizon 2020, Annex 8: Fostering the functioning and achievement of European Research Area, version of June 2022.

109 European Commission, Directorate-General for Research and Innovation, MORE4 : Support data collection and analysis concerning mobility patterns and career paths of researchers : survey on researchers in European higher education institutions, Publications Office, 2021, https://data.europa.eu/doi/10.2777/132356

110 R1 refers to first-stage researchers according to the European Commission´s research profiles descriptors: https://euraxess.ec.europa.eu/europe/career-development/training-researchers/research-profiles-descriptors

- The recent evaluation of the Policy Support Facility (PSF)[111] indicated that a large majority of stakeholders were very positive about the initiative. Periodic feedback about the PSF's work showed that its operational recommendations by leading experts and policy practitioners **catalysed changes in implementing national R&I reforms**[112]. However, the Court of Auditors report[113] indicated that the PSF's ability to induce necessary changes in national systems was limited, attributing this to the limited availability of resources for the PSF, the fact that not all widening countries request support, and the freedom of Member States to decide whether or not to implement the reforms identified by the PSF.
- **Interviews with principal investigators, individual fellows and project coordinators indicate that researchers are often insufficiently trained or supported to lead a research team**. In the ERC, some of the junior researchers interviewed expressed a need for the development of a mentoring system to support and prepare them to manage research teams and cope with this responsibility[114]. In SEWP, coordinators from the widening countries often indicate the lack of sufficient administrative and financial support to lead their projects (and their research) efficiently.
- **Organisational strategies to support mobile researchers and help them integrate into new work environments are considered drivers of high-quality science and of the success of these projects**. This has been observed in interviews with beneficiaries of ERC, MSCA, and SEWP grants.

From the perspective of the **framework programme design and management**, the following factors have been identified:

- **Sufficiency of funding**: views were mixed as to whether the funding provided is sufficient to achieve all objectives. Survey evidence shows that ERC grantees consider funding to be sufficient, while MSCA fellows report greater difficulties – in particular, with regard to their participation in conferences or paying the processing fees to publish in peer-reviewed open access journals. SEWP beneficiaries positively perceived the introduction of the reimbursement of a share of research costs incurred during Horizon 2020.
- **Difficulties associated with managing complementary funding**: these often entailed delays to project execution, and constitute important barriers. This has been flagged as particularly relevant for Teaming projects (SEWP), which have often faced challenges in managing and securing the timely arrival of complementary funding from sources other than Horizon 2020, most notably from the ERDF[115]. The lack of experience of national administrations with no prior experience in co-funding was also mentioned by project beneficiaries as a frequent barrier.
- **Flexibility in adapting to unexpected circumstances and issues**: Horizon 2020 offered sufficient flexibility for projects to adapt their activities and approaches during the project's lifetime (e.g. changes in scope, addressing difficulties in hiring talent, the COVID-19 pandemic). This was generally considered an important positive factor in fostering the success of the projects.
- **Multiple factors affect research productivity in Horizon 2020**. First, the number of research areas attributed to the outputs (i.e. knowledge diversity) positively affects research productivity and quality (citations and the share of publications in the top 1%)[116]. Second, open access is associated with a higher impact: having at least one publication with open access boosts the number of citations received (48% more[117]). This confirms the importance of the European Commission's efforts to promote open science.

111 European Commission, Directorate-General for Research and Innovation, Meyer-Krahmer, F., Grech, J., Sánchez, B., et al., Horizon 2020 Commission Expert Group for the evaluation of the Horizon 2020 Policy Support Facility : final report: (report-only version without annexes), Publications Office, 2020, https://data.europa.eu/doi/10.2777/433930

112 European Commission, Directorate-General for Research and Innovation, A new ERA for research and innovation : staff working document, Publications Office, 2020, https://data.europa.eu/doi/10.2777/605834

113 European Court of Auditors. Special Report 15/2022.

114 This point relates to one of the lessons learned that derives from the evaluation of the ERC work programme. More detailed recommendations at the level of the programme parts covered are found in Annex 1.

115 European Court of Auditors. Special Report 15/2022. This issue has been highlighted in the past and is currently being addressed by the European Commission and REA. For instance, the EC has standardised the information on complementary funding that needs to be provided, as well as reporting on the progress of the complementary funding.

116 An increase in the number of research areas increases the number of publications by 21%, citations by 7.5% and the likelihood of ending up in the top 1% by 17%. See the productivity analysis carried out by the study team in Annex 8.

117 More details are provided in Annex 8 (Econometric modelling results).

- **Communication matters**. Communication between the European Commission and the funded projects (and within the projects themselves) was often considered an important factor leading to success. This was the case for the five cluster projects funded under INFRAEOSC-04-2018[118], which unites ESFRI projects and other world-class RIs in five thematic clusters. These projects regularly meet between themselves and with the Commission to discuss various topics. These include future funding schemes and activities, or their possible contribution to the future development of the EOSC. The positive effects of the communication between projects in SwafS have also been highlighted: the *Sister projects*[119], a cross-project initiative on gender equality, was set up to share knowledge and good practices and to carry out joint communication campaigns.
- **Dissemination, exploitation and communication activities** appear to play an important role across all of the programme parts analysed in this study. Analysis of the reporting data indicates that these activities tend to target audiences in line with the objectives of the actions. Compared with other pillars, Pillar 1, SEWP and SwafS were more likely to produce publications, as well as to participate in workshops and conferences. This is consistent with their scientific focus. These programme parts have also produced significant progress in terms of open access publications. However, EC monitoring data has highlighted certain inconsistencies which hinder analysis of the dissemination, exploitation and communication indicators, such as the number of persons reached, or details of specific activities. Information on the number of dissemination and communication activities by type cannot be associated with a particular type of audience nor the number of persons reached.
- **The exploitation and development of research results could be promoted further**: while Horizon 2020 has had a positive effect in terms of promoting researchers´ awareness of the development and commercialisation potential of their research, greater attention could be devoted to this.
- **Horizon 2020 supported the development of networks to support applicants and beneficiaries**. The role of National Contact Points is also said to be key in providing support, information and communication to applicants and beneficiaries. There is, however, a lack of systematic evidence across all programme parts regarding the role and impact of these networks.

4.5. EU added value

European added value refers to the need for Europe to intervene; it describes value that is additional to that created by the actions of individual Member States, and may result from different factors, e.g. coordination gains, legal certainty, greater effectiveness or complementarities. It indicates the European-wide relevance and significance of the action in presenting models and mechanisms that could be applied not only regionally or nationally, but also across the EU[120]. The findings of this report with regard to EU added value are structured according to the following themes:

- EU added value of the interventions and instruments implemented (evaluation questions covered: EAV1)
- EU added value in addressing cross-cutting issues (evaluation questions covered: EAV2)

4.5.1. EU added value of the interventions and instruments implemented

Recent studies and reports confirm that EU investments in research and development generally provide very significant value in addition to what would otherwise have been created by the actions of Member States alone. According to the report of the High-Level Group on Own Resources[121], research and development (along with internal and external security) is one of the areas with the highest potential for EU added value.

The Horizon 2020 programme parts covered in this evaluation provide significant EU added value in terms of providing support for research that would not be possible without the FP funding. Survey data show that a large share of unsuccessful applicants did not implement the projects or activities proposed in their applications after failing to receive Horizon 2020 funding.

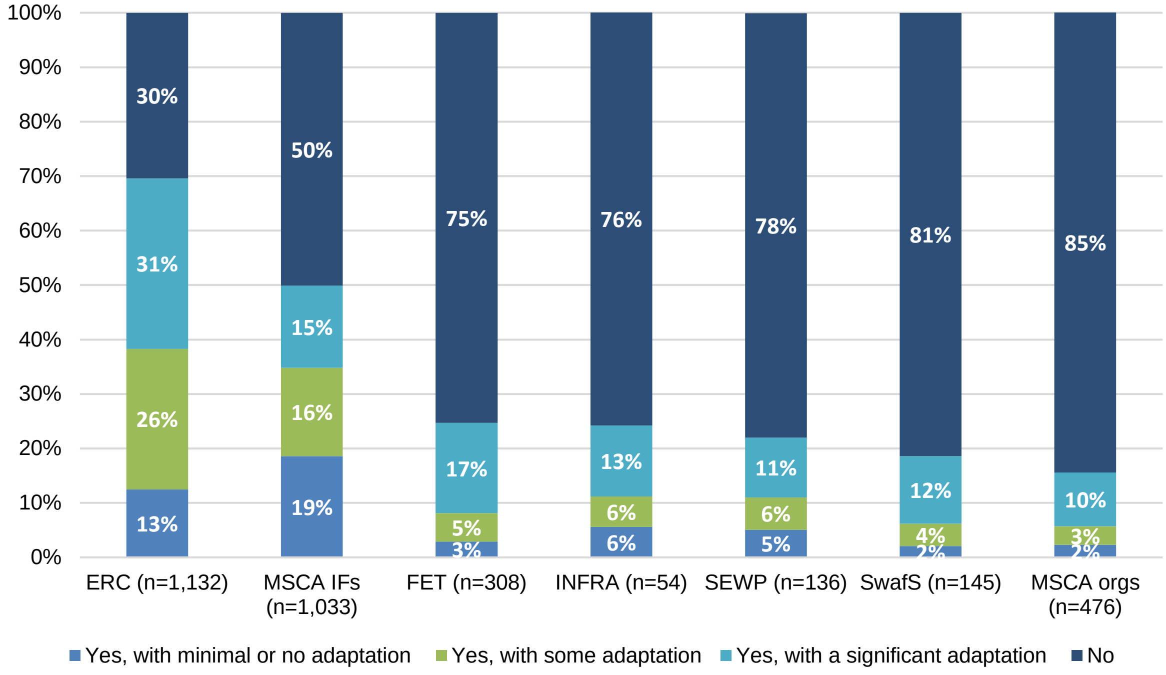
118 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/infraeosc-04-2018

119 https://www.superaproject.eu/sister-projects/

120 European Commission Factsheet: Funding under the 3rd Health Programme 2014-2020. The European Added Value, available at https://ec.europa.eu/chafea/health/programme/documents/factsheets-hp-av_en.pdf

121 Monti, M. et al. (2017) “Future Financing of the EU: Final report and recommendations of the High-Level Group on own resources”, December 2016.

Figure 9: "Did you implement the project or the activities proposed in your application after not being successful in the application to Horizon 2020 funds?" (Survey answers from unsuccessful applicants from organisations to MSCA, FET, INFRA, SEWP and SwafS and unsuccessful applicants to MSCA IF and ERC).



Source: survey of unsuccessful Horizon 2020 applicants, conducted August-September 2022.

A more detailed look at the adaptations made to those projects that were implemented after being rejected for Horizon 2020 funding shows that in the majority of cases, those **projects that were funded by other non-FP sources after introducing some adaptations were usually *smaller in terms of the amount of research outputs and innovations to be produced***. For example, in the case of projects that unsuccessfully applied to the ERC, 89% of all projects that were eventually implemented with some or with significant adaptations in this area were usually smaller in terms of the amount of research outputs and innovations to be produced (compared with the original research proposal submitted for Horizon 2020 funding). The same applies to 70% of unsuccessful applicants to MSCA IF who eventually implemented their projects after being rejected for Horizon 2020 funding. Furthermore, in the majority of cases, compared with the original research proposals submitted for Horizon 2020 funding, the **adapted projects were *less complex/diverse in terms of research methods to be used.*** In the case of unsuccessful ERC applicants, among the projects that were eventually implemented with some or with significant adaptations in this area, 79% were less complex/diverse in terms of the research methods to be used. The same applies to 60% of MSCA IF applicants and 77% of applicants to MSCA collaborative actions. Lastly, survey evidence also shows that the **adapted projects were also usually *smaller in terms of the number of research (sub)areas covered.*** In the case of unsuccessful ERC applicants, 92% of projects that were eventually implemented with some or with significant adaptations in this area, were smaller in terms of the number of research (sub)areas covered (compared with the original research proposal submitted for Horizon 2020 funding). The same applies to 77% of MSCA IF applicants and 90% of MSCA collaborative actions applicants (for more details, see Annex 1)[122].

Study evidence also shows that Horizon 2020 provided **key added value in terms of supporting projects that involved larger teams and employed more researchers** (**compared with what would otherwise have been possible without FP support)**. This was confirmed in interviews with beneficiaries and by the survey results, which show that the average number of staff employed in ERC projects (in addition to the Principal Investigator) was almost twice as high as that for projects that were adapted after applying unsuccessfully for ERC funding: an average of 7 staff members in full-time

122 Please note that the comparison between the Horizon 2020 beneficiary projects and the control group projects (projects that were rejected for Horizon 2020 funding but which continued through the use of alternative non-FP funds) focuses mainly on individual researcher projects (ERC and MSCA IFs). The main reason for this is a very low number of control group projects in collaborative actions (MSCA, FET, INFRA, SwafS and SEWP), which prevents a meaningful comparison. For example, the survey of unsuccessful applicants provided data on 13 unsuccessful applicants to INFRA projects that were continued using alternative, non-FP funds (for more details, see Annex 1).

equivalent (FTE) per ERC project, compared with 3.6 staff in FTE employed in the control group projects. (A more detailed analysis is presented in Section 1.3.1. of Annex 1). Interviews with beneficiaries also confirmed that the EU added value of the ERC stems from funding that allows the recruitment of a significant number of researchers, the longer duration of projects and a higher degree of freedom and research autonomy for PIs and their teams, compared with what would be available without such support under Horizon 2020.

Providing funding for research that could not be supported through other sources was also one of the key areas of Horizon 2020's EU added value. When asked to indicate what prevented them from implementing their project without Horizon 2020 funding, the overwhelming majority of those unsuccessful applicants who did not implement their projects after being rejected for Horizon 2020 funding indicated that *no alternative funding was available for that type of research*. This reason was indicated as either an important or very important factor in discontinuing their project by 78% of unsuccessful ERC applicants, 83% of unsuccessful applicants for MSCA collaborative actions, 69% of unsuccessful MSCA IF applicants, 81% of those for FET, 92% of unsuccessful INFRA applicants, 90% of those for SEWP applicants, and 86% of those for SwafS.

In addition, for many consortium-based projects, **Horizon 2020 helped in pooling together a critical mass of expertise, skills and resources from different countries that would not be possible at the level of Member States**. When asked what prevented them from implementing their project without Horizon 2020 funding, more than three-quarters of unsuccessful applicants to MSCA (ITN, RISE, COFUND), INFRA, FET, SEWP and SwafS indicated that their *project required the involvement of a variety of international partners, and could not be implemented without them* (see Figure 10). Other sources of evidence (interviews, case studies and previous studies) also strongly support the above findings regarding the EU added value of Horizon 2020 in pooling the expertise and **building international research networks**. Interviews indicate that for many beneficiaries, the ERC PoC was the only option to accomplish cross-border cooperation, as many national funding schemes only supported cooperation with organisations within the same country. The case study on the 'Contribution of SEWP to integrating research groups from widening countries' concluded that the SEWP provided significant EU added value in terms of providing a framework for networking and collaboration between research groups from widening countries and top research organisations in Europe. The case study on the Graphene Flagship found that the lasting network and the development of long-lasting relationships between relevant partners across Europe was emphasised by multiple stakeholders involved as one of the most significant aspects of the EU added value.

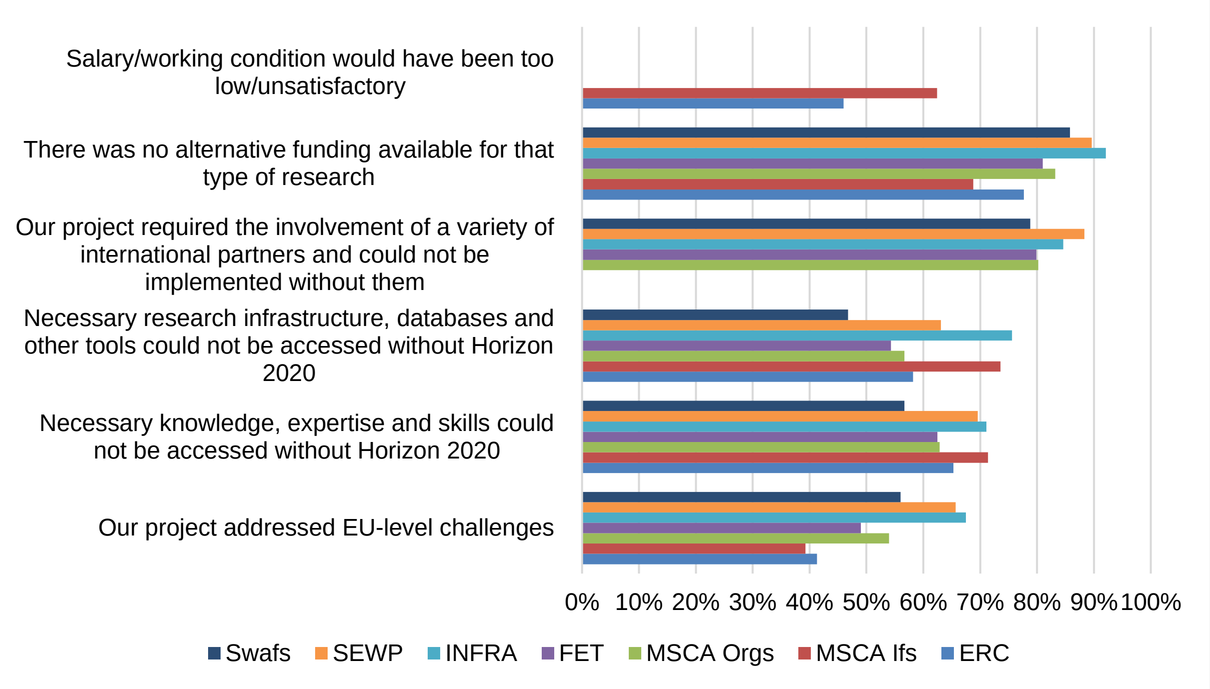
Recent literature also suggests that pooling together resources and expertise allows the achievement **economies of scale**, especially in specific research areas, in addition to what would have been available in the case of Member States' own interventions. According to the report of the High-Level Group on Own Resources[123], EU investments in research and development have particularly high potential for economies of scale, since a multiplicity of small-scale activities may be less economically viable than one or a limited number of bigger projects. Economies of scale that resulted from Horizon 2020 were particularly noticeable in areas such as fuel cells, as well as hydrogen and climate change, where the EU support for the development of large-scale research infrastructures helped to save large amounts of funding (compared with the amount of funding that would have been required to build similar infrastructures across individual Member States)[124].

Study evidence also indicates that Horizon 2020 offered **significant EU added value by providing necessary infrastructures** and **access to necessary knowledge, expertise and skills** that would not have been available without Horizon 2020, and which enabled projects to be implemented. More specifically, 74% of unsuccessful applicants to MSCA IF, 58% of unsuccessful ERC applicants, 76% of unsuccessful INFRA applicants and 57% of unsuccessful MSCA collaborative actions applicants indicated that they had not implemented their projects because, without Horizon 2020 funds, they *could not access necessary infrastructures, databases and other* tools. At the same time, 71% of unsuccessful applicants to MSCA IF, 65% of unsuccessful ERC applicants, 71% of unsuccessful INFRA applicants and 63% of unsuccessful MSCA collaborative actions applicants indicated that without Horizon 2020 funding they could not access necessary knowledge, expertise and skills (see Figure 10; for more details, see Annex 1).

123 Monti, M. et al. (2017) 'Future Financing of the EU: Final report and recommendations of the High-Level Group on own resources', December 2016.

124 Assessment of the Union Added Value and the economic impact of the EU framework programmes (FP7, Horizon 2020), https://op.europa.eu/en/publication-detail/-/publication/af103c38-250d-11e9-8d04-01aa75ed71a1/language-en

Figure 10: "How important were the following reasons that prevented you from implementing the project without Horizon 2020 funding?" (share of respondents indicating 'very important' or 'important', answers from unsuccessful applicants who did not continue their projects after being rejected for Horizon 2020 funding).



Source: survey of unsuccessful Horizon 2020 applicants, conducted August-September 2022.

It is also notable that Horizon 2020's EU added value is significant in terms of **reinforcing European research infrastructure policies and integrating research infrastructures** that are often fragmented and spread across different Member States. More specifically, the INFRA programme played a key role in contributing to the sustainability of research data and services, going beyond what would have been available at the level of individual infrastructures in Member States. In Europe, the majority of research infrastructures are funded nationally, through complex and varied funding sources that involve a wide variety of different rules, leading to the suboptimal use of Member States' resources, the duplication of services, scattered access to data and services, or even a lack of access to infrastructures in certain Member States. The case study on the impact of the framework programme on the creation of new excellent services found that Horizon 2020 INFRA created added value by federating data and services produced by world-class European research infrastructures, and making them easily accessible to European researchers. Similarly, since the construction and operation of research infrastructure are funded from a wide range of European, national and regional sources, support for the priority investments identified in ESFRI roadmaps has played an important role in shaping the overall European research and technology infrastructure landscape[125].

Evidence also shows that Horizon 2020 offered **significant EU added value in terms of providing training for researchers that would not have been available without Horizon 2020 funding**. When asked what type of training they received within the framework of their project, only 5% of MSCA IFs indicated that they did not receive any training. In contrast, among those unsuccessful applicants to MSCA IF who continued with their projects using alternative, non-FP funds, the share of those who did not receive any training was 22%. Moreover, 71% of MSCA IF fellows received training in *new and/or advanced scientific methods* in their research field (compared with 51% among the control group researchers). Moreover, 57% of MSCA IF fellows received training in *proposal and report writing* (compared with 35% among the control group). In general, MSCA beneficiaries received more training than researchers in the control group across various areas. These included training in horizontal skills/cross-cutting issues such as *open access*, foreign languages, research ethics, IPRs, and others (for more details, see Section 2.3.1. in Annex 1). The case study on MSCA ITNs and their structuring

125 European Commission, Directorate-General for Research and Innovation, ECORYS, Evaluation study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system.

effect reveals that collaboration with partner institutions from other countries, the organisation of consortium-level training programmes, and access to top international experts in their respective fields would have been difficult to achieve for most of the beneficiary researchers without being part of the ITN scheme.

Likewise, promoting research excellence in terms of the advancement of researchers' careers, mobility, and talent circulation was also one of the key areas in which Horizon 2020 provided EU added value. Although fellowship schemes exist at national level, as does support for researcher mobility, existing national-level initiatives are often relatively small in scope and scale. Consequently, Horizon 2020 schemes, particularly the MSCA, present an additional opportunity for researchers to pursue their research and skills development regardless of the funding available in their home countries. The study on mobility flows in the context of MSCA (2022)[126] found that the MSCA offered high added value in **retaining excellent European talents in the EU, bringing talents back to the EU, and attracting foreign researchers** to the EU. The findings of the study on mobility flows also confirmed that the MSCA not only contributed to retaining a substantial number of European researchers in Europe, but also helped to attract both European and third-country researchers living abroad. For example, 74% of all IF fellows of any nationality were already residing within the EU-27+UK prior to applying for their MSCA fellowship, whereas 92% of all IF fellows of any nationality ended up being hosted in the EU-27+UK by the end of the fellowship. Similarly, case study evidence also confirms that the MSCA constitute significant added value by attracting and retaining top researchers, as most non-EU MSCA researchers remain in Europe.

Horizon 2020 **provided EU added value across numerous aspects in relation to research excellence/conditions, leading to higher research quality**. These aspects include, for example, more opportunities to conduct fundamental research, better opportunities for interdisciplinary research, greater research autonomy and more international mobility opportunities – in addition to what was available at national/regional level. When asked about the benefits of their project, 97% of ERC PIs strongly agreed/rather agreed that as a result of their project, they had gained more *opportunities to conduct basic/fundamental research* (compared with 65% for the control group). Another 97% stated that they had gained *more flexibility to pursue their specific research agenda* (compared with 67% in the control group). Similarly, 89% of MSCA IF fellows strongly agreed/rather agreed that as a result of their project, they had gained *international mobility opportunities* (compared with 63% in the control group) and gained *interdisciplinary cooperation opportunities* (80% of MSCA IF fellows vs 65% in the control group) (for more details, see Annex 1).

Interviews with stakeholders (grantees and EC officials) suggest that a key aspect of EU added value created by the ERC is **the level and amount of competition stemming from its EU-wide scope**: the need to compete for funding with other top researchers from all over Europe boosts the quality of research proposals and the general level of research excellence achieved by ERC projects. One of the key catalysts boosting the excellence of EU-funded research is the **bottom-up approach** supported by Horizon 2020 programme parts. Horizon 2020 (and in particular, its Excellent Science-related programmes) complement existing R&I schemes in Europe by promoting fundamental and novel research activities, which are often enabled by the bottom-up approach of Horizon 2020. This was especially true in the case of the MSCA and ERC, whose grants did not prioritise any particular research area. The bottom-up approach allows applicants with a bright research idea in any field to apply and potentially obtain funding – an advantage that is not evident in the national scholarship schemes investigated.

As found by the case study on support for frontier research by the Horizon 2020 ERC, EU support provided high added value, particularly by **supporting high-risk/high-return frontier research in Europe in ways that could not be achieved at national/regional level**. The majority of beneficiaries and other stakeholders interviewed indicated that they would not have been able to realise the same research projects without ERC support. While some beneficiaries stated they would still have been able to pursue their frontier research without ERC support, they acknowledged that the project's scope, scale and impact would have been much more limited. The level of complementarity between national-level schemes and EU added value depended on individual Member States. In some countries (e.g. Germany or Sweden), which offer significant national funding opportunities for basic research on health, researchers more often tend to rely on and apply for national funding rather than EU funding (due to the

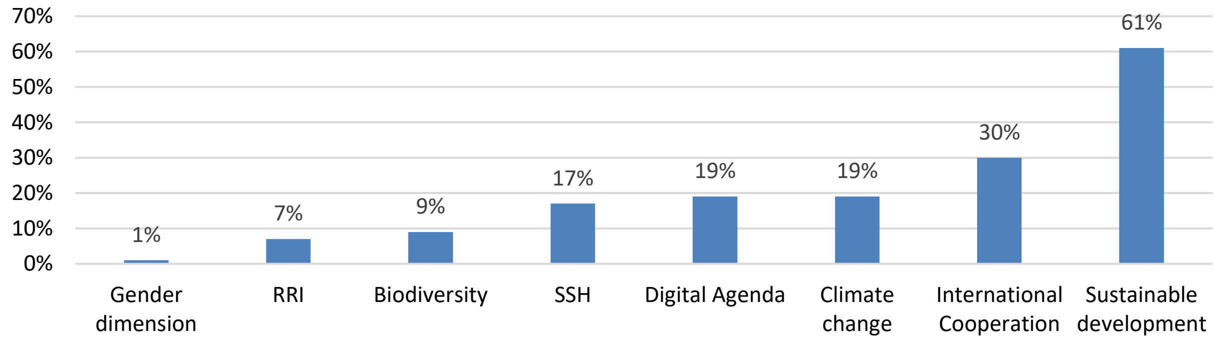
126 European Commission, Directorate-General for Education, Youth, Sport and Culture, Dėlkutė, R., Nikinmaa, J., Pupinis, M., et al., Study on mobility flows of researchers in the context of the Marie Skłodowska-Curie actions: final report. Publications Office, 2022.

simpler, less complex application process and the lower time investment required)[127]. The role played by Horizon 2020 in complementing the fundamental research funding was much more significant in countries where fewer resources were available to support frontier research. For example, the ERC provided particularly high EU added value towards countries that had few bottom-up, researcher-driven funding schemes for frontier research, as well as to countries in which grants were substantially smaller than those offered by the ERC.

4.5.2. EU added value in addressing cross-cutting issues

According to the analysis of administrative data, the programme parts evaluated under Pillar 1 of Horizon 2020 contributed significantly to addressing cross-cutting issues (CCI)[128], although the coverage of these issues was somewhat lower in comparison to other pillars of the programme. More specifically, according to the administrative data, **projects flagged as relating to cross-cutting issues accounted for around 74% of all Horizon 2020 Pillar 1 Excellent Science projects**. This was somewhat below the share of CCI-flagged projects in Pillar 2: Industrial Leadership (95%); Pillar 3: Societal Challenges (99%); SEWP (79% of CCI-flagged projects); and SwafS (90%). In terms of the coverage of specific cross-cutting issues, analysis shows that Sustainable Development was the most widely covered CCI (61% of all projects under the Pillar 1: Excellent Science were flagged with this cross-cutting issue). This was followed by International Cooperation (31% of all projects) and Digital Agenda/Climate Change (19% of projects were flagged with these cross-cutting issues). Overall, the thematic coverage in terms of the various CCIs under Pillar 1 was not significantly different from that of other pillars of Horizon 2020. For example, Sustainable Development was the most widely covered CCI across all pillars of the Horizon 2020 programme.

Figure 11: Share of Horizon 2020 Pillar 1: Excellent Science projects flagged with specific cross-cutting issues



Source: data retrieved from e CORDA, Policy monitoring and ToA datasets.

Within Horizon 2020 Pillar 1: Excellent Science, MSCA had the highest share of CCI-flagged projects (99%), closely followed by FET and Research Infrastructures (98% of all projects flagged with CCI). The share of CCI-flagged projects within ERC was 33%. Within SwafS, 90% of all projects were CCI-flagged, while the corresponding figure for SEWP was 79% (see Figure 11 for more details)[129]. It should be noted that different programmes focused on specific cross-cutting issues, thereby complementing each other in terms of CCI coverage. For example, within the MSCA, the most widely covered cross-cutting issue was Sustainable Development (92% of all projects were flagged with this CCI), followed by International Cooperation (52%). In contrast, FET projects mostly addressed the Digital Agenda (87% of all FET projects were flagged with this CCI), followed by Sustainable Development (32% of all projects). The

127 European Commission, Directorate-General for Research and Innovation, ECORYS, Evaluation study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system.

128 Based on the Evaluation Study on the Implementation of Cross-Cutting Issues in Horizon 2020, cross-cutting issues include: Sustainable Development, Climate change & Biodiversity; International cooperation; Responsible Research and Innovation (RRI); Gender equality; SME involvement; Bridging from discovery to market application; Social Sciences and Humanities (SSH); Digital Agenda; Fostering ERA; Widening participation; Interdisciplinary and cross-sectoral R&I; Flagship initiative "Innovation Union".

129 The 'Evaluation Study on the Implementation of the Cross-cutting Issues in Horizon 2020' concluded that, despite the positive evolution of some cross-cutting issues indicators, the overall implementation of cross-cutting issues was limited due to the lack of an integrated approach towards monitoring and implementation.

CCI most widely covered by ERC projects was Sustainable Development (16% of projects), followed by Climate, and Social Sciences and Humanities (9% of all ERC projects were flagged with these CCIs).

Evidence from desk research, interviews and case studies confirms that Horizon 2020 provided EU added value in terms of addressing cross-cutting issues such as gender equality, RRI, climate change and others – over and above what could have been achieved at Member State level. The evaluation found, for example, that the MSCA encouraged participating organisations to adhere to the European Charter for Researchers and Code of Conduct, providing equal and inclusive opportunities for researchers.[130]

According to the case study on 'Inclusiveness and the gender dimension in the MSCA (see Annex 6), the MSCA have been successful in removing barriers to the mobility of female researchers: 42% of MSCA fellows under Horizon 2020 were women, ranging from 39% in RISE to 44% in ITN. This is considerably higher than the average percentage of female researchers across the EU, which in 2018 was 34%. Meanwhile, the interviews and literature review carried out for the case study on building the territorial dimension of SwafS partnerships found that SwafS has contributed to raising the profile of responsible research and innovation (RRI) on the political agenda across Europe. This was evidenced by national funding programmes aligning with trends followed within the framework programme, including various dimensions of RRI (research ethics, public engagement, governance, gender equality, science education, open access). The case study on frontier research in the ERC concluded that ERC researchers have often delivered insights that contribute to addressing a number of cross-cutting issues: e.g. 14% of projects funded under Horizon 2020 ERC contributed to policies for the green transition; 10% contributed to the digital transition; and 34% contributed to health policies. This aforementioned case study also identified specific examples of ERC projects that contributed to addressing societal issues such as climate change. For example, researchers from Utrecht University who were involved in an ERC Starting Grant won the Blue-Cloud Hackathon for their innovation to address plastic pollution from aquaculture farming.

Horizon 2020 (in particular the SwafS programme) also provided EU added value by enhancing various aspects of interactions between science and society, including science education, science communication, citizen science and citizen engagement in science. For example, the SwafS programme resulted in EU-wide platforms such as the EU-Citizen.Science[131] platform, which provides a framework for sharing knowledge, tools, training and resources for citizen science beyond individual Member States. However, the available evidence reveals a need to further develop those indicators and targets that could help to better measure the impact of FP projects focusing on citizen science and science communication[132].

Likewise, study evidence indicates that Horizon 2020 also provided EU added value in terms of addressing cross-cutting issues within research institutions that have little or no prior experience with EU framework programmes, particularly institutions from widening countries. For instance, several institutional changes relating to cross-cutting issues were reported by SEWP beneficiary institutions that were new to European research funding programmes[133]. Some respondents indicated that they had developed university-wide ethical guidelines and gender equality plans as a result of their involvement in EU-level projects.

5. Conclusions and lessons learned

This section presents a draft summary of the key findings and lessons learned in relation to the Horizon 2020 programme parts evaluated, and with regard to excellent science under Horizon 2020 overall.

130 Case study on 'Inclusiveness and gender dimension in the MSCA', Annex 6. The MSCA organisations survey conducted as part of the 'Study of mobility flows in the context of MSCA' found a strong commitment to the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers. Out of 1,644 organisations surveyed, 50% indicated they were committed, and 44% that they were somewhat committed, to the Charter for Researchers. Meanwhile, 55% indicated that they were committed, and 39% that they are somewhat committed, to the Code of Conduct.

131 https://eu-citizen.science/

132 Delaney, N. (2020). Science with and for Society in Horizon 2020: Achievements and Recommendations for Horizon Europe. https://op.europa.eu/en/publication-detail/-/publication/770d9270-cbc7-11ea-adf7-01aa75ed71a1.

133 Case study on the impact of SEWP in improving quality (and coverage) of research in widening countries.

Conclusions

Was the intervention relevant?[134]

- Horizon 2020 brought about shifts in topic orientations and a greater focus on impact.
- Horizon 2020 publications outperformed other non-EC funding programme in terms of citations. The impact of Horizon 2020 publications in multidisciplinary journals was remarkably strong.
- Horizon 2020 was successful in mobilising newcomers (understood as organisations that had not participated in FP7), with 27% of all participations coming from newcomers. Pillar 1, SEWP and SwafS were somewhat less open than other framework programme parts, but this is consistent with the smaller size of the population targeted by these programme parts.
- Overall, the participation of third countries in the Excellence Science programme parts – Pillar 1 and SEWP – remained limited, focusing mostly on participations from countries that are well advanced in terms of R&I. The MSCA, however, stand out for the strong level of participation by third countries.

Was the intervention coherent?[135]

- There is a strong internal coherence both between the Horizon 2020 actions under Pillar 1 and between Pillar 1 actions and the rest of Horizon 2020, particularly in terms of addressing societal challenges and cross-cutting issues in Europe. There is no evidence of overlaps or duplications between different parts of Horizon 2020.

- In terms of external coherence, the available evidence shows that Horizon 2020 has complemented other existing R&I support schemes in Europe in multiple ways, including by providing opportunities for international networking, knowledge exchange and cooperation.

- Horizon 2020 partnerships largely complemented each other and other parts of the programme by contributing to common higher-level goals while using different instruments, covering different technology readiness levels (TRLs) and attracting different types of stakeholders. At the same time, there is a need for more coordination mechanisms in order to better exploit synergies.

Was the intervention efficient?

- The management of all programme parts analysed in the study in terms of budgetary resources was **efficient and cost-effective**. The administrative budget under all programme parts did not exceed 5% of the operational budget.
- The European Commission allocated 39% of the Horizon 2020 budget to the implementation of the programme parts analysed under the study: namely Pillar 1, SEWP and SwafS
- Given the large number of applications received, especially under the largest programme parts such as MSCA and ERC, the evaluation and Grant Agreement Preparation (GAP) processes were, for the most part, swift.
- Most payments under the programme parts evaluated were made within the target time of 90 days. The shares of payments made within the target time ranged from 97.6% under ERC to 78.6% under SwafS.
- The results of the surveys carried out for this study reveal that applicants' motivations to participate in Horizon 2020 were largely in line with the objectives of each programme part studied.
- **The main challenge for Horizon 2020 was oversubscription.** This arose from the programme's high level of attractiveness and its limited budget. Analysis shows that for the European Commission, this constitutes a lost opportunity to finance high-quality R&I. Among applicants, this led to a deadweight loss in the case of unsuccessful applications. The challenge of oversubscription had become even more prominent since the previous framework programme. When looking at the programme parts in question, the lowest success rate for applications was under the FET programme, at 8.9%. The highest was under the INFRA programme, at 33.5%. To fully address the magnitude of oversubscription, the EC would have required an additional amount of EUR 183 billion (compared with the actual budget of EUR 80 billion) to fund all high-quality proposals.

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134 Other conclusions relating to the evaluation questions on relevance are included in the 'Evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix'.

135 Other conclusions relating to the evaluation questions on coherence are included in the 'Evaluation study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system'.

- **Applications to Horizon 2020 entails costs in terms of proposal preparation**. This is especially salient in the case of unsuccessful proposals, since the effort and costs invested are, for the most part, misdirected. Our estimates show that up to EUR 9,694.4 million was spent on unsuccessful proposal writing.
- The **simplification measures introduced within the Horizon 2020 framework reduced the burden on applicants** through simpler and faster procedures (as evidenced by the increased timeliness of the evaluation process). Nevertheless, only 20% of applicants surveyed reported a lower workload when preparing their Horizon 2020 application. From the perspective of beneficiaries, one mitigation measure was to involve experienced external consultants.
- The high costs involved in applications, as well as the excellence-based approach to selecting applications, mean that countries with the strongest R&I ecosystems received the highest concentration of Horizon 2020 funding. Analysis carried out for this study shows that most participants under all programme parts (except for SEWP) came from just five countries: Germany, France, the United Kingdom, Spain and Italy. This concentration of funding is, on the one hand, a negative phenomenon that was addressed through the Specific Objective 'Spreading Excellence & Widening Participation'. On the other hand, given the excellence-based funding approach, such a concentration of funding is merely a signal of the uneven research and innovation capacities in the Member States.
- Analysis shows that most of the programme parts studied were **cost-effective in terms of publications produced.** In line with their excellent science-based objectives, the ERC and MSCA programme parts were the most cost-effective, each producing 90.9 and 85.9 publications per EUR 10 million funding, respectively.
- **Horizon 2020 has helped researchers to sustain their existing networks and to significantly expand them** by attracting new co-authors. In addition, this study shows that Horizon 2020, including the programmes specifically addressed in the study, has helped to create new international collaborations that would otherwise not have existed.
- One study, based on a review of REA and ERCEA evaluations (2019), identified some **inefficiencies in relation to the provision of policy feedback from Executive Agencies to the Parent DGs**. To address these shortcomings and improve policy feedback, in 2019, specific Policy Feedback Plans for all REA Horizon 2020 activities were agreed upon between the REA units and their Commission counterparts. Nevertheless, this topic is the subject of ongoing Executive Agency evaluations covering the period from 2018 until the end of Horizon 2020.

Was the intervention effective?

- Horizon 2020 achieved or even significantly exceeded its targets in the majority of areas and programme parts covered in this evaluation study. It has strengthened the scientific position of the EU worldwide, achieving higher publication citation rate scores than any of the other funders selected for benchmarking in most of the disciplines analysed.
- **Under Horizon 2020, scientific excellence was well spread across its programme parts**: the ERC and MSCA stand out for their high levels of research produced and its high impact (highly cited publications), followed by Societal Challenge 1[136], FET, Societal Challenge 5[137], and the Joint Research Centre[138] .
- Horizon 2020´s open access principles and requirements had a **strong positive impact on the number of open access publications** produced under the framework programme, which constituted a share of 82% across Horizon 2020 as a whole. The highest open access rates were found in Pillar 1 (Excellent Science), at 88%. Over time, there was an important **increase in the number of open access datasets** resulting from Horizon 2020 projects, but the data produced did not always comply with the FAIR[139] principles, and differences existed across disciplines and programme parts.
- Horizon 2020 has attracted world-class research institutions and researchers both from within and beyond Europe, with a stronger representation of institutions from more advanced R&I systems.
- Horizon 2020 has facilitated the **emergence of thousands of new collaborations** between researchers, having a strong structuring effect on the European research landscape[140].

136 Health, Demographic Change and Well-being.

137 Climate Action, Environment, Resource Efficiency and Raw Materials.

138 Findings based on the analysis of the indicators SCI1: field-normalised citation score (MNCS/CNCI/FWCI) and SCI2: number/share of top 1% most cited publications.

139 FAIR data are data that meet the principles of findability, accessibility, interoperability, and reusability.

140 Findings based on the analysis of indicator SC4: Structuring effect of FP funding.

- Horizon 2020 has promoted the **uptake of high-quality standards and approaches**, most notably with regard to open access and the FAIR principles, gender equality, and ethics. It has had a positive effect in terms of improving and aligning organisational practices and structures, improving the quality of training, career development, human resources practices and working conditions.
- The **participation of widening countries has remained a challenge** during Horizon 2020. SEWP was therefore particularly important for widening countries, especially in terms of the production of excellent research.
- Horizon 2020 has played a pivotal role in promoting the **development of pan-EU research infrastructures,** contributing in particular to the realisation of the ESFRI roadmaps.
- **Dissemination and communication activities under Horizon 2020** projects target the key audience groups in accordance with the objectives and intervention logic of the specific programme parts. Limitations do, however, exist with regard to the monitoring approach. These hinder analysis of the dissemination, exploitation and communication indicators, such as the number of persons reached, or details of specific activities.
- Pillar 1 (Excellent Science) activities show a **strong focus on societal impacts**, particularly in the areas of health and well-being (SDG 3), as well as industry, innovation and infrastructure (SDG 9).
- The Horizon 2020 programme parts covered in this study had an **impact on policymaking and agenda setting**. The participation of national authorities and agencies was associated with a greater impact of projects in this regard.
- Pillar 1, in line with Horizon 2020 overall, had a strong focus on the **early stages of innovation**. The participation of industry in the work programmes analysed remained limited, and there is still room to improve the exploitation, development and commercialisation potential of research results.
- The majority of the **KPIs on cross-cutting issues demonstrate a positive development over the course of Horizon 2020**. Pillar 1 stands out for its contribution to International cooperation (MSCA, INFRA); Sustainable development (MSCA, SwafS); the Digital Agenda (FET, INFRA); and Climate change (INFRA).
- Participation in Horizon 2020 was associated with positive effects in **terms of researchers' career prospects**, although data gathering limitations prevent a systematic analysis of this across programme parts[141] .
- Horizon 2020 has provided significant support to **researchers' international mobility**, contributing to the circulation of talent and knowledge across the ERA and to the return mobility of researchers, fostering the attractiveness of Europe to international world-class talent and strengthening researchers' skills.

What was the EU added value of the intervention?

- The programme parts assessed in this evaluation provided significant EU added value in terms of funding research that could not be supported through other means (including national/regional funding). With the exception of applicants to the ERC, the majority of unsuccessful applicants across all of the evaluated programme parts did not implement their projects after being rejected for Horizon 2020 funding.
- The available evidence indicates that Horizon 2020's EU added value consisted of supporting **larger scale, more complex and more ambitious research** than would have been possible without the programme's support. Horizon 2020 projects were larger in terms of the number of research staff involved, and more complex in terms of the research methods used and the number of research areas covered. Moreover, compared with projects funded from other sources, Horizon 2020 projects were more ambitious in terms of their research outputs and the innovations to be produced.
- Study evidence also shows that Horizon 2020 provided significant EU added value in terms of **EU-level research network building, pooling together a critical mass of resources, skills and expertise from different countries, yielding economies of scale, as well as providing necessary infrastructure and access to necessary knowledge, and providing mobility and training opportunities for researchers** – all of which were in addition to what would have been available without Horizon 2020. Other key areas of Horizon 2020's EU added value include enhancing the level and amount of competition. This stems from Horizon 2020's EU-wide scope and the bottom-up approach of funding supported by parts of Horizon 2020, which facilitates high-risk, fundamental and novel research activities.

141 This has been addressed in Horizon Europe with the identification of researchers (and ORCID identifiers) in proposal stage.

- The Horizon 2020 programme parts assessed in the present study contributed significantly to addressing cross-cutting issues (CCI), although the coverage of these issues was somewhat lower compared with other pillars of the programme.

Lessons learned

Relevance

Bottom-up and top-down approaches within Horizon 2020 were aligned with both excellent research and societal challenges. The mix of approaches applied was complementary, and allowed a better coverage of research needs and policy priorities. It is important, however, to bear in mind that Horizon 2020's various pillars, as well as its bottom-up and top-down approaches, each had a different focus. When considering EU contribution and the number of projects, there was a greater focus on health and well-being (SDG3) under Pillar 1; industry, innovation and infrastructure (SDG9) under Pillar 2; and climate action (SDG13) under Pillar 3. These differing areas of focus need to be considered when designing future instruments. The framework programme, as the main instrument fostering the development of the European Research Area, needs to encompass actions that focus on specific policy priorities and challenges (top-down), while ensuring that the EU science base is sufficiently interconnected (bottom-up) and able to continue providing the research results on which innovation and responses to future challenges will be based[142].

Coherence

- Currently, a variety of EU-level instruments support R&I. Despite existing complementarities, **this large number of instruments was complex to navigate**, particularly for entities without previous experience of EU framework programmes. This problem of navigability is further aggravated by insufficient and non-centralised information regarding support opportunities and project results. Coherence between Horizon 2020 and other EU-level instruments could be improved by strengthening and institutionalising communication and coordination between those bodies at EU level involved in the management and implementation of different EU R&I support initiatives.
- Similarly, despite the existing complementarities, **more coordination is needed among different Horizon 2020 partnerships** in order to better exploit synergies between them. Examples of this include the need to establish synergies and to improve coordination between different ERA-NETs in similar areas, as well as to establish synergies between ERA-NET Cofunds and other ERA initiatives.

Efficiency

- **The major challenge under Horizon 2020 and all of the programme parts studied was oversubscription,** which has resulted from the programme's high level of attractiveness and its limited budget. For the European Commission, this constitutes a lost opportunity to finance high-quality R&I; for applicants, it leads to misdirection of the efforts and costs in the case of unsuccessful applications. Compared with the previous funding programme, competition has increased, making this issue even more prominent. Further simplification measures alone would be unlikely to successfully tackle inefficiencies relating to oversubscription, for the following reasons:
    - The burden involved in making applications, while unwelcome, discourages consortia that are likely to produce lower-quality proposals from applying for Horizon 2020 funding. In other words, less effort being required for applications might lead to a greater number of unsuccessful proposals, and hence drive up the evaluation burden for the EC.
    - Also, given that a substantial part of the work involved in application preparation goes into developing a high-quality idea and setting up a consortium, further simplification efforts would only have a marginal effect[143].
- There is still room to strengthen the **Seal of Excellence (SoE) initiative**. It is understandable that SoE cannot fully address the issue of oversubscription in Horizon 2020, due to limited national and regional budgets. Differing policy priorities at regional and national levels also explain the difficulties faced in expanding the uptake of the SoE at these levels. Nevertheless, with the cooperation of national funding bodies as well as support from the European Commission, the initiative could be

142 More information on other lessons learned in relation to the evaluation questions on relevance is included in the 'Evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix'.

143 ECA survey shows that only 20% of surveyed applicants reported a lower workload when preparing a Horizon 2020 application as compared to FP7.

strengthened through the wider use of other funding sources, such as the Cohesion Funds and the Recovery and Resilience Funds.

- In addition to the Seal of Excellence initiative, the European Commission could further consider new **ways to address the low success rates** and ensure that unsuccessful high-quality proposals do not result in a loss of effort and resources.

Effectiveness

- **Fostering and spreading excellence:** Horizon 2020's focus on excellence as a key element produced very positive results. These should be maintained in future framework programmes in order to continue consolidating the EU's worldwide position in scientific production and innovation. At the same time, efforts are still required to ensure that progress across the EU is visible. This need is shown by the persistence of low participation figures among organisations from the widening countries. Specific actions targeting such organisations (i.e. widening actions) are considered positive and necessary, although further efforts would be needed to better integrate the widening dimension into other pillars. This could be expected to avoid the concentration of widening applicants in calls that are specifically directed to them, and could be accompanied by incentives to collaborate in other pillars. Consideration should be given to the application of specific budgetary lines to fund excellent applications from widening countries that are not funded due to budgetary constraints.
- **In terms of strengthening researchers' careers,** potential exists to increase the impact of to EURAXESS by increasing the number of research-performing organisations publishing vacancies via the platform and, especially, by increasing the number of non-academic institutions advertising research vacancies using this tool. With regard to skills, Horizon 2020 produced many examples of projects that contributed to the skills of researchers, particularly under SwafS, such as the Chameleons project[144] and the DocEnhance project[145]. However, its contribution to researchers' skills could be developed through a strategy that establishes clearer objectives, operationalisation options and targets. The recently published EU Competence Framework for Researchers[146] could contribute to the development of a common vision on skills development across sectors and countries and in terms of monitoring approaches.
- **Efforts to continue fostering the application of open science need to be continued**. This could encompass better communication of the mission, objectives and specific activities of the EOSC, broader support for the provision of training on open science principles and skills (including train-the-trainer approaches), as well as fostering the convergence of practices through joint actions around a common vision conducted with the MS and national research funding organisations.
- **An improved approach for monitoring the impact of the programme in terms of inducing change at organisational, regional or national level** (e.g. institutional or structural changes) would be welcome. The elaboration of such a monitoring approach could consider the following elements: 1) a clear definition of the output to be measured; 2) attribution – i.e. that a given output is the result of the project; 3) scope – i.e. the level at which the output operates is visible (e.g. organisation, ecosystem, region, etc); 4) timing – i.e. whether the output is finalised or ongoing; and 5) sustainability – i.e. whether the output will last beyond the project's lifetime.
- **Responsible research and innovation was strongly promoted during Horizon 2020**, especially as part of SwafS. However, limited understanding of this concept hindered its more widespread applicability. Its implementation can be expected to be facilitated by focusing on individual components and introducing clear and measurable targets, as well as developing knowledge hubs focusing on specific components (following the example of the EIGE in relation to the GEP).
- **There is potential for improvement in the exploitation, development and commercialisation of research results.** This could be achieved by increasing the attention paid to the development of regional/local ecosystems and the connectedness of research-related organisations within their broader ecosystem. Strengthening collaboration between actors over the innovation cycle and across pillars might contribute to fostering the exploitation of research results. Alignment with Smart Specialisation Strategies is positive, but further action could be taken to foster this connection at local level.
- **With regard to the communication and dissemination of the results of actions funded by the programme,** improvements could be made to the way in which information about this is gathered

144 https://www.chameleonsproject.eu/

145 https://docenhance.eu/

146 European Commission, Directorate-General for Research and Innovation, Knowledge ecosystem : defining a European competence framework for R&I talents, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/1117

(e.g. a reporting template). This would allow more detailed analysis of the main channels used by projects and the sizes of the audiences reached through these. This could help to identify gaps and avenues to provide further support to beneficiaries.

EU added value

- The available evidence indicates that **the additional value provided by Horizon 2020 support was particularly significant in the case of consortium-based actions** (such as those under the MSCA, ITN and RISE) that involved multiple organisations from different countries. Survey evidence shows that the overwhelming majority of unsuccessful applicants to these Horizon 2020 actions were not able to implement their projects without Horizon 2020 funding.
- In contrast, among those Horizon 2020 actions driven by individual researchers/principal investigators (MSCA IFs, ERC), the share of unsuccessful applicants who continued with their projects using other funds was much larger. At the same time, the evidence strongly suggests that even among these types of actions, **Horizon 2020 funding still allows beneficiaries to conduct larger-scale research that is more complex (in terms of the number of scientific fields covered and methods used) and involving larger teams of researchers – in addition to what would have been available without Horizon 2020 funding**.
- **It is important to further develop the capacities of the MSCA to elicit structuring impacts on participating organisations.** The MSCA bring significant added value through structuring effects and the harmonisation of practices. The MSCA have enormous potential to elicit structural impacts on participating organisations, especially since they promote the diffusion of best practices and processes, gender equality, and contribute to the harmonisation and standardisation of specific programmes. This structuring effect is not only felt within Europe, but has an impact on institutions outside Europe as well. Emphasis should be placed on identifying, maintaining and amplifying the aspects of each action that can contribute to this goal.
- Horizon 2020 provided EU added value by raising the profile of responsible research and innovation (RRI) on the political agenda across Europe. Moreover, the programme also contributed to the development of EU-wide initiatives aimed at enhancing interactions between science and society, including science education, science communication, citizen science and citizen engagement in science. Future framework programmes would benefit from the further development of indicators and targets to systemically measure the impacts of FP projects focusing on citizen science, science communication and related themes.

Annexes

Annex 1: Explicit answers to evaluation questions

Please see the separate Microsoft Word file entitled ‘Annex 1 – explicit answers to evaluation questions’.

Annex 2: Methodologies used

Table 22 presents an overview of the main methodologies used in this study, as well as their scope and limitations. Further details on each of these methodologies are provided below.

Table 22: Overview of methodologies used

Method	Scope	Limitations
Desk research	EC publications 2005-2022 (e.g. previous evaluations, reports, Work Programmes, Annual Reports, data sources), mainly covering the periods of FP7, Horizon 2020 (and to some extent already, Horizon Europe). Other relevant (academic) documents, reports, studies and websites relating to, among other aspects, the framework programmes, the programme parts under being studied, the methods used in this study, the cross-cutting topics examined in this study, the projects funded under Horizon 2020, etc.	Information uncovered by the desk research is not always fully comparable with evidence produced by this study when different methodologies have been applied.
Interviews with EC officials, beneficiaries and other stakeholders	Interviews with EC officials and other stakeholders of the specific programme parts covered (i.e. Pillar 1, SEWP and SwafS)	The EC officials and other stakeholders interviewed have not always been engaged with the specific programme part for the whole of the Horizon 2020 period covered by this study. Social desirability might have an impact on the responses expressed in interviews, with a potential bias towards positive aspects. This is compensated for by the large number of interviews, as well as by triangulation with other methods.
Case studies	Twelve case studies focusing on the specific programme parts of Horizon 2020 under study (i.e. the ERC, MSCA, FET, INFRA, SEWP and SwafS). Three case studies focusing on Horizon 2020-wide topics. In the selection of the subset of projects to study in these case studies, the study team aimed to ensure a balance in terms of countries, starting years, areas etc. where relevant. The case studies relied, among other evidence, on interviews with project beneficiaries (e.g. project coordinators).	Case studies inherently delve into specific aspects of a case. As such, case studies elucidate specific topics and focus on a subset of actions and/or projects within a particular programme part. For those Horizon 2020 projects that finished a few years ago, there may be a potential recall bias (interviewees not remembering everything accurately). This is compensated for by the large number of interviews carried out, by targeting beneficiaries from different cohorts, and by triangulating evidence stemming from different methods.
Benchmarking	Four international benchmark exercises were carried out. Analysis of the benchmark programmes briefly presents the history of the programmes, but focuses mainly on the last 8-10 years. Benchmarking mainly relied on desk research and interviews with managers, governors and/or the	The benchmark cases are not fully comparable with the Horizon 2020 programme (parts) under analysis, and are embedded within their own specific contexts. Interviewees may be inclined not to share information that might spur research and innovation in Europe.

Method	Scope	Limitations
	beneficiaries of each of the benchmark cases.	Social desirability may play a role in the sense that interviewees might mainly emphasise the positive points of their programme. This is addressed through triangulation of evidence from other sources.
Policy workshops	The first policy workshop (October 11-12, 2022) aimed to discuss the preliminary findings per Horizon 2020 programme part with the EC officials and stakeholders. The second policy workshop (January 12, 2023) aimed to discuss the main findings, conclusions and lessons learned at Horizon 2020 level, in terms of the criteria of effectiveness, EU added value and efficiency.	The workshops focused on the presentation and discussion of a selection of key points.
Bibliometric analysis	The starting point for the bibliometric analysis was the reported research output for EC-funded projects under Horizon 2020 (data received from the European Commission). These data were cleaned, validated and enriched by the study team.	Data on Horizon 2020's bibliometric output is subject to omissions and potential errors (due to the voluntary reporting process) . The high number of ongoing (i.e. not closed) projects means that many outputs are still yet to be produced and reported.
Surveys	Six online surveys were launched within the framework of this study. These surveys targeted Horizon 2020 MSCA, SEWP, INFRA and SwafS beneficiary organisations and unsuccessful applicant organisations; Horizon 2020 MSCA IF fellows and unsuccessful applicants, and Horizon 2020 ERC principal investigators and unsuccessful applicants. In general, the survey sample covered the call years 2016-2019 for the survey of beneficiary organisations and researchers, and the call years 2016-2018 for unsuccessful applicants.	The response rates among the beneficiaries of collaborative actions (MSCA organisations, FET, INFRA, SwafS and SEWP) and particularly among unsuccessful applicants to collaborative Horizon 2020 actions were rather low, especially for some programme parts (e.g. for SEWP), meaning that the results should be interpreted with caution. A very low number of control group projects (i.e. projects that applied unsuccessfully for Horizon 2020 funding but were implemented using other, non-FP funding sources) among the unsuccessful applicants for collaborative Horizon 2020 actions, limits comparability between the beneficiary and control group projects for this group. For example, the survey of unsuccessful applicants yielded data on 13 unsuccessful applicants to INFRA projects that nevertheless implemented their projects using alternative, non-FP funds (for more details, see Annex 1). This largely prevents a meaningful comparison between Horizon 2020 collaborative actions and the control group projects. As a result, comparisons between the Horizon 2020 beneficiary projects and control group projects focuses mainly on individual researcher-based projects (ERC and MSCA Ifs).
Patent analysis	Patent analysis was performed for all the Horizon 2020 programme parts (for both closed and ongoing projects). This analysis builds on patent data as recorded in the Cordis database, and	The patent data in Cordis is subject to omissions. Further Horizon 2020 IPR

Method	Scope	Limitations
	was matched with the PATSTAT database by the study team. Furthermore, only patents with priority dates exceeding the start date of the projects were considered.	output is still yet to be produced and reported.
SDG classification	SDG classification was carried out for all the Horizon 2020 projects that were closed at the time of the analysis.	The analysis cannot take into consideration those outputs that are yet to be produced.
Network analysis	The starting point for the network analysis was the reported research outputs for the EC-funded projects under Horizon 2020 (data received from the EC). This set has been expanded with all publications by all of the authors in this set.	Data on Horizon 2020 research output is subject to omissions and potential errors (due to the voluntary reporting process). Many outputs are still to be produced (i.e. ongoing projects) and reported.
Innovation Radar analysis	The Innovation Radar data cover 7,883 unique innovations assigned to 2,203 unique projects and 4,166 beneficiaries.	The Innovation Radar data did not include data on projects under Pillar 4 and Pillar 5 of Horizon 2020, nor for ERC projects under Pillar 1.

Source: compiled by the study team.

Desk research

Desk research was a key source of evidence used in the study to answer a number of evaluation questions. This consisted of a review of relevant literature and analysis of the administrative and monitoring data provided by the European Commission. See Annex 9 for a full list of literature and information sources used to inform the desk research.

Interview programme

The evidence gathered from interviews was a primary source of information in identifying and reviewing the key drivers in relation to specific criteria of relevance, coherence, efficiency, effectiveness, EU added value and partnerships under the programme. Interviews were an integral part of the case studies and the benchmarking exercises.

All interviews were semi-structured. However, certain parts of the questionnaires were fully structured in order to gather survey-like information from the beneficiaries and stakeholders.

An overview of interview results can be found in Annex 4.

Case studies

The following 15 case studies were completed as part of Phase 1 of this study:

Table 23: Case studies

Out of the 15 case studies, nine fed into the analysis of programme parts under Pillar 1 of Horizon 2020; three into the analysis of specific Horizon 2020 objectives (i.e. SEWP and SwafS); while the three remaining case studies covered topics relevant across multiple programme parts.

Table 24: Case studies per programme part

No.	Case study title
CS1	ERC impact on creating new or pushing existing frontiers of science
CS2	Achievement of commercial and/or social innovation potential of ERC projects that received ERC Proof of Concept funding
CS3	Impact of the MSCA IF on strengthening human capital in research and innovation

CS4	Inclusiveness and gender dimension in the MSCA
CS5	Structuring impact of MSCA ITN on doctoral programmes
CS6	FET Graphene Flagship
CS7	FET Human Brain Flagship
CS8	Impact of the framework programme on the creation of new excellent services
CS9	Fostering knowledge creation through transnational access
CS10	Building the territorial dimension of SwafS partnerships
CS11	Contribution of framework programme in integrating research groups from widening countries
CS12	Impact of framework programme in improving quality (and coverage) of research in widening countries
CS13	Contribution of the framework programme to some emerging areas of science and technology such as artificial intelligence, quantum computing, clean energy technologies
CS14	Impact of the framework programme on fostering diffusion of knowledge and open science
CS15	Impact of the framework programme in spreading excellence across the Union

International benchmarks

The **benchmarking** approach followed in this study focused on a cross-case analysis; that is, the benchmark cases were not selected for comparison with a specific programme part, but rather to identify best practices and lessons learned from these programmes that could feed into the analysis of various aspects of Excellence Science within the framework programme. This approach entailed the selection of well-defined aspects for in-depth analysis. These include support for excellent science; spreading research excellence across territories; and building capacity to produce excellent research. The choice of this approach was based on the diverse scope and size of the international initiatives, which makes them unsuitable for a classical, one-to-one benchmarking approach. Following this methodology allowed the identification of common challenges present in both Horizon 2020 and the international initiatives analysed, as well as on the mechanisms set up by other initiatives to address these challenges. This exercise yielded avenues for further reflection and inspiration regarding various aspects relating to excellence science within the framework programme.

Table 25: International benchmarks

No	Benchmark title	Relevance
Benchmark 1	National Science Foundation (NSF): Established Program to Stimulate Competitive Research (EPSCoR) and the Broadening Participation Portfolio (US)	MSCA, INFRA, SEWP, SwafS
Benchmark 2	Canada Excellence Research Chairs Programme (CERC)	ERC
Benchmark 3	Max Planck Centres and Dioscuri Centres of Scientific Excellence	MSCA, ERC, SEWP
Benchmark 4	National Natural Science Foundation of China (NSFC)	ERC, other programme parts

Bibliometric analysis

The bibliometric analysis (explained in further detail in Annex 3) involved matching Horizon 2020 publications to Scopus (and WoS during the early stages of this project as a cross-validation). For the external benchmark, publications resulting from other national/international funders were matched to Scopus (and WoS). An important aspect of the bibliometric analysis was the calculation of key bibliometric metrics using SciVal (and Incites during the early stages of this project) for Horizon 2020 publications and other funders (e.g. NSERC, NSF, NWO).

Econometric modelling/counterfactual analysis

A detailed description of the econometric modelling applied in this study (and its preliminary results) is provided in Annex 8.

Survey programme

The programme of surveys carried out as part of this study consisted of **six online questionnaires** designed to address the full spectrum of respondents whose opinions and perceptions would be crucial to answering certain evaluation questions and/or performing some of the intended analyses. The following surveys were conducted:

- Survey of Horizon 2020 beneficiary organisations (including beneficiary organisations that participated in MSCA, SEWP, INFRA and SwafS).
- Survey of unsuccessful Horizon 2020 applicant organisations (organisations that applied unsuccessfully for MSCA, SEWP, INFRA and SwafS).
- Survey of Horizon 2020 MSCA IF fellows
- Survey of unsuccessful Horizon 2020 MSCA IF applicants
- Survey of Horizon 2020 ERC principal investigators
- Survey of unsuccessful Horizon 2020 ERC applicants

Invitations were disseminated to most of the relevant target groups around mid-August 2022, with some additional invitations (for those programme parts that suffered from a low response rate) were sent out on September 6. A detailed survey schedule, along with additional information on the target groups included in our survey sample, is presented below in **Table 26**.

Table 26: Survey schedule

Survey programme	Call year(s) covered	Number contacted	Launch date	Reminder 1	Reminder 2	Reminder 3	Closure date
Successful applicants, organisations (batches 1 and 2)	2016-2019	4,325	11 August	18 August	25 August	9 September	16 September
Successful applicants, organisations (batch 3)	2016-2019	2,217	16 August	25 August	–	9 September	16 September
Successful applicants, organisations (batch 4) (FET, INFRA, SEWP and SwafS only)	2014-2015	768	9 September	–	–	–	16 September
Unsuccessful applicants, organisations (batches 1 and 2)	2016-2018	13,227	11 August	18 August	25 August	9 September	16 September
Unsuccessful applicants, organisations (batch 3)	2016-2018	6,626	16 August	25 August	–	9 September	16 September
Unsuccessful applicants, organisations (batch 4) (FET, INFRA, SEWP and SwafS only)	2014-2015	5,902	9 September	–	–	–	September 16
Successful MSCA IF applicants	2016-2019	4,022	11 August	18 August	25 August	–	26 August
Unsuccessful MSCA IF applicants	2016-2018	7,929	11 August	18 August	25 August	–	26 August
Successful ERC PIs	2016-2019	2,787	11 August	18 August	25 August	–	16 September

Survey programme	Call year(s) covered	Number contacted	Launch date	Reminder 1	Reminder 2	Reminder 3	Closure date
Unsuccessful ERC PIs	2016-2018	7,910	11 August	18 August	25 August	–	2 September

Source: compiled by the study team.

In total, 5,417 complete and 449 partial responses were received. The highest response rate was among successful MSCA IF applicants (around 25.7% of all invitations sent, including the partial responses), whereas the lowest response rate was recorded among unsuccessful applicant organisations (4.7%) (for more details see Table 27).

Table 27: Number of survey responses and response rates

	Completed responses	Partial responses*	Total number of responses (completed and partial)	Invites sent (valid)**	Response rate / completed	Total response rate (including partials)
Successful applicants, organisations	**767**	**78**	**845**	***7,310***	**10.49%**	**11.56%**
FET	*129*	*17*	146	*1,246*	10.35%	11.72%
INFRA	*162*	*12*	174	*1,755*	9.23%	9.91%
MSCA	*327*	*28*	355	*3,476*	9.41%	10.21%
SEWP	*76*	*9*	85	*541*	14.05%	15.71%
SwafS	*73*	*12*	85	*538*	13.57%	15.80%
Unsuccessful applicants, organisations	**1,154**	**58**	**1212**	***25,755***	**4.48%**	**4.71%**
FET	*304*	*19*	323	*5,859*	5.19%	5.51%
INFRA	*58*	*7*	65	*1,782*	3.25%	3.65%
MSCA	*513*	*16*	529	*13,120*	3.91%	4.03%
SEWP	*135*	*10*	145	*2,084*	6.48%	6.96%
SwafS	*144*	*6*	150	*3,346*	4.30%	4.48%
Successful MSCA IF applicants	**987**	**46**	**1,033**	***4,022***	**24.54%**	**25.68%**
Unsuccessful MSCA IF applicants	**1,020**	**72**	**1,092**	***7,929***	**12.86%**	**13.77%**
Successful ERC PIs	**458**	**24**	**482**	***2,787***	**16.43%**	**17.29%**
Unsuccessful ERC PIs	**1,031**	**171**	**1,202**	***7,910***	**13.03%**	**15.20%**
Total	**5,417**	**449**	**5,866**	**55,713**	**9.72%**	**10.53%**

* Partial responses include only cleaned data, i.e. with irrelevant partial responses removed (respondents who opened the survey, filled out one or two questions and left).

** Invites specific to programme parts for successful and unsuccessful organisations do not account for unsubscribed respondents. Please note that the table only shows invites that were sent to valid email addresses. The contact list was cleaned of duplicates before sending out survey invites.

Data integration and analysis

This exercise involved the matching and integration of Corda, PATSTAT, Scopus, Orbis, Dealroom, Technote, Innovation Radar, OSDG, and other data sources. In addition, master datasets were prepared for data analysis (projects, participation data and Horizon 2020 entities).

Patent analysis

Patent analysis involved matching Horizon 2020 IPR outputs to PATSTAT, identifying foreground patent analysis and calculating key patent value metrics.

Analysis of unstructured data

The analysis of unstructured data mainly involved text mining activities and entity matching activities, as well as adapting the research topic analysis.

Network analysis

Network analysis involved the analysis of the structuring effect of framework programme funding, which was based on author networks. It also included the analysis of funding concentration in Horizon 2020. Network analysis is explained in further detail in Annex 3.

Analysis of SDG data

Analysis of SDG data in relation to Horizon 2020 projects was conducted using monitoring and publication data. This analysis included comparison/benchmarking against other selected funders, via publication data.

Analysis of Innovation Radar data

Analysis was carried out on the dataset and the Innovation Radar data received by the team.

Analysis of key efficiency indicators

Analyses of key efficiency indicators involved the calculation of selected indicators, i.e. Time-To-Inform (TTI), Time-To-Sign (TTS), Time-To-Grant (TTG), budget absorption, application success rates, etc.

Cost-effectiveness analysis

Analysis of Horizon 2020's cost-effectiveness included the calculation of the relative cost-effectiveness of the programme parts under evaluation, focusing on the cost/EU contribution per publication.

Evaluation questions

Table 28: Evaluation questions.

Main evaluation questions	Sub-questions per evaluation criteria
How relevant was Horizon 2020?	**RV1*:** How relevant have the framework programme activities, including partnerships, been in delivering excellent science, given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time? **RV2*:** To what extent have the supported activities, including partnerships, taken into account the latest technological, scientific and/or socio-economic developments at national, European and international levels? What are the emerging needs that the framework programme has not covered? **RV3*:** Has the framework programme tackled the right issues, given the scientific positioning of the European Union, since the programme started and over time? **RV4*:** To what extent have the framework programme activities to deliver excellent science addressed the needs of groups targeted for application/participation in terms of the tools and thematic areas covered? Are the activities as they exist today appropriate to address the scientific needs? What is missing? **RV5***: To what extent have the framework programme activities to deliver excellent science demonstrated being flexible enough to cope with changing circumstances in Europe and in the world? **RV6***: In which areas is the participation of international partners and Associated Countries the most relevant to the delivery of excellent science? How does this participation fit into the objectives of the framework programme, including to reinforce Europe's relative positioning?

Main evaluation questions	Sub-questions per evaluation criteria
	RV7: To what extent does the framework programme provide the right balance between bottom-up and top-down approaches to funding, and between support for basic and applied research, given its place in the European research and innovation landscape?
How coherent was Horizon 2020?	**CH1*:** How coherent has the framework programme been in delivering excellent science, in particular: (i) between the framework programme parts covered by this study; (ii) with other parts of the framework programme not covered by this study; (iii) with other EU programmes serving similar objectives (e.g. Structural Funds, European Fund for strategic investments (smart specialisation strategies), Erasmus+ (notably European Universities, (iv) with relevant national, regional or international initiatives. **CH2*:** What is the position of the framework programme in supporting excellent science within the overall European research and innovation landscape (incl. R&I funds at national, regional and European level) and beyond (at international level)? **CH3*:** What could be done to improve the coherence of the framework programme's interventions in this area with other initiatives to better deliver on the European Union's policy objectives? **CH4:** How is the level of coherence among partnerships, and between partnerships and the framework programme activities in this area? Are partnerships more effective in achieving synergies for scientific impact, compared with other modalities of the programme?
How efficient was Horizon 2020?	**EFF1:** How efficient have the implementation processes been in terms of: (i) administration and management, (ii) project application and selection processes, (iii) funding allocation, (iv) forms of implementation (e.g. partnerships, collaborative research, blending; bottom-up/top-down actions)? **EFF2:** How did these processes cater to needs for flexibility in implementation? What have been the barriers or drivers? How could they be improved, or what else could be done to maximise the benefits of the implementation of the framework programme in delivering excellent science? To what extent have the programme's implementation processes in this area influenced the types of projects selected? **EFF3:** What can be learned in terms of implementation processes from the experience of applicants and participants? What were the key barriers to and drivers of progress they experienced at application stage and during the implementation of the projects, and their consequences for the researchers and organisations involved? **EFF4:** To what extent are project application, management and reporting being performed by organisations other than those performing the research and innovation activities? What are the underlying reasons and implications (e.g. in terms of costs, quality of applications, R&I activities) for the beneficiaries and for the Commission? **EFF5:** To what extent is the whole framework programme attracting relevant applicants, given its overall and specific scientific, economic and societal objectives? What is the distribution of applicants and participants? Are there overrepresented and underrepresented categories? What are the likely consequences of over- and underrepresentation of certain categories (given the programme's general and specific objectives) on the programme's ability to deliver on its expected impacts? Have there been any improvements regarding participation patterns compared with the previous framework programmes? How these categories be best identified during programme implementation? What actions could correct the imbalance (also based on experiences in other programmes)? **EFF6:** To what extent has the framework programme (overall, and in the different areas supported) reached newcomers, non-traditional R&I actors such as citizens, different organisation types including civil society organisations, and beneficiaries from across Europe and internationally, and what lessons can be learned in terms of openness and engagement? **EFF7:** What are the main factors/key determinants that drive or impede researchers and organisations in applying, participating and cooperating in the framework programme? What are the specific factors affecting the application and participation of each under- or overrepresented category? **EFF8:** How proportionate were the costs of application and participation borne by different stakeholders groups, taking into account the associated benefits? Are the administrative costs borne by applicants and participants lower, higher or constant compared with the previous framework programme? Please quantify these to the extent

Main evaluation questions	Sub-questions per evaluation criteria
	possible. How do the costs and benefits of applying to the framework programme balance out from the applicants' perspective? **EFF9:** How can the costs associated with applications be lowered, and benefits of participation be increased for applicants (i.e. the cost of writing proposals), and Commission services (i.e. cost of administrating and running the programme)? **EFF10:** To what extent does the programme support industry-academia, cross-sectoral, cross disciplinary cooperation? Are the networking effects of the programme lasting? What are the determinants for success/failure, in terms of cooperation patterns? **EFF11:** Has the programme led to international collaborations that might not have come into existence otherwise? To what extent are these persistent? What could be done in to improve R&I policy and programme design in this respect? **EFF12**: What could be done in the future to improve the attractiveness and outreach of the framework programme to key targeted groups, given its objectives and core principles, in particular its focus on excellence? **EFF13**: To what extent have the framework programme's activities to support excellent science in this area been cost-effective? **EFF14**: To what extent have the framework programme monitoring and evaluation systems and feedback into policy processes been efficient to ensure evidence-based policymaking? Were adequate systems put in place to share lessons learned from implementation and the results achieved between framework programme interventions supporting excellent science? To what extent does the programme communication/valorisation strategy allow good research practices and scientific results to be identified, capitalised upon and (possibly) transferred? **EFF15:** To what extent are the implementation activities, procedures for peer review and proposal evaluation, and grant schemes established by the Scientific Council of the ERC distinguishable [in terms of efficiency] from those in other programme parts? **EFF16:** How efficient are the modalities to define and report the provision of transnational and virtual access to research infrastructures and the related costs under EU grants?
How effective was Horizon 2020?	**EFC1:** What are the main results and (expected and unexpected) outcomes and impacts from the projects whose core focus is the delivery of excellent science? Does the delivery of the projects' results lead overall to the achievement of the programme's scientific objective(s)? What more is needed to be able to achieve its excellent science objectives and in what timeframe? **EFC2:** What internal or external factors have influenced the progress (or lack of progress) made by the framework programme's interventions in this area towards their impact? What could be done to address these in the short and longer term? Are there any factors that are more or less effective than others, and, if so what lessons can be drawn from them? **EFC3:** To what extent have dissemination, exploitation and communication measures enabled the targeted outcomes and impacts to be achieved? What further actions are needed to maximise the impact of the framework programme's interventions in this area? **EFC4:** To what extent has the framework programme in this area contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)? **EFC5*:** How effective in reinforcing the integration and coherence of the European R&I system is the association of third countries with the framework programme, compared with that of Associated Countries, in terms of both performance and the convergence of values and principles? **EFC6*:** To what extent has international cooperation and, more specifically, the association of third countries with the EU framework programme, made a difference in achieving the scientific objectives of the framework programme? Has international cooperation, and specifically association, increased the EU's scientific performance? **EFC7:** To what extent have the partnerships funded under the framework programme contributed to deliver on its excellent science objectives? **EFC8:** What has been the contribution of the framework programme as a whole, and of the core programme parts covered in this procurement in particular to: • reinforcing and extending the excellence of the Union's science base? • improving the skills of Europe's researchers and facilitating the emergence of new

Main evaluation questions	Sub-questions per evaluation criteria
	talented researchers and cross-border and cross-sectoral mobility? • supporting world class physical and knowledge infrastructures and facilities? • supporting scientific breakthroughs, higher-risk research and research into emerging areas of science and technology? • making Europe more attractive for world-class researchers from abroad? **EFC9:** What has been the contribution of the core programme parts covered in procuring this, particularly in relation to: • consolidating the European Research Area. Does it have a structuring effect on national research systems, in terms of changes to national and institutional policies and practices? • improving the performance of the Union's research and innovation system and making it more competitive on a global scale (inclusing The creation of spin-offs/start-ups, jobs maintained and created, intellectual property activity deriving from scientific results, knowledge valorisation and market uptake)? • ensuring the successful implementation and results of EU missions (applies only to Horizon Europe)? **EFC10:** Long-term impact on researchers' careers; institutional and systemic impact on doctoral and postdoctoral training programmes, and working / employment conditions. **EFC11*:** Take-up and impact of the Seal of Excellence in the Member States and Associated countries, and its link with the Structural and Investment Funds (ESIFs) **EFC12:** How have different types of results (e.g. software, knowledge, data) been made available to the research community, innovation and policy actors, and the general public? How can this be improved? **EFC13*:** To what extent have the projects selected contributed to: • the improvement of the 'ethics by design' approach to the research ethics and integrity appraisal process and guidance (including at national, regional and institutional level)? • the development of inclusive gender equality policies at national level, and opening up to intersectionality, in line with the new ERA Communication? How could effectiveness be increased in this regard? • the promotion of research integrity (procedures, training, education) and catalysing relevant frameworks and approaches at national, regional and institutional level? **EFC14*:** What is the impact of framework programme actions supporting open science, citizen science, gender equality, international cooperation, ethics and integrity, and scientific input to other EU policies? **EFC15:** Level of participation of the ERIC legal entities (European Research Infrastructure Consortium) and the efficiency of the participation process. **EFC16:** To what extent has the framework programme contributed to: • facilitating the work of ESFRI (the European Strategy Forum on Research Infrastructures) and fostering the implementation by Member States and Associated countries of the ESFRI roadmaps? • Increasing access to research infrastructures? • the career evolution of researchers, thanks to access to research infrastructures ('TNA generation')? **EFC17:** To what extent has the general bottom-up approach to providing access to research infrastructures influenced research that addresses global challenges and EU policy priorities? How effective is the new challenge-driven approach in this regard? **EFC18:** To what extent have actions implemented under the framework programme to strengthen the European Research Area at national and institutional level (in open science, RRI, citizen science, gender equality, international cooperation, ethics and integrity) contributed to the attainment of key EU values and principles (as laid down by the EU Charter of Fundamental Rights and EU treaty)? **EFC19:** To what extent have ERA-Nets contributed to strengthening the European Research Area?
What was the EU added value of Horizon 2020?	**EAV1:** What is the EU added value of the framework programme interventions, including that of the different instruments mobilised (such as partnerships), to deliver excellent science? What would have happened if the framework programme had not existed? Could the stakeholders have implemented their activities in another way, including through other national or regional support?

Main evaluation questions	Sub-questions per evaluation criteria
	EAV2: What is the added value of the EU framework programme in addressing cross-cutting or transversal issues such as RRI, co-design and co-creation, gender equality, Social Sciences and Humanities, international cooperation?

Annex 3: Quantitative research track results

Please see a separate MS Word file titled “Annex 3. Quantitative research track results”.

Annex 4: Interview programme results and synopsis report

The primary purpose of the interviews was to contribute to findings linked to case studies, international benchmarks, and findings per each programme part. To that end, in Phase 1 of the study we conducted 224 interviews, covering a wide variety of stakeholders. As shown in Table 29, the first round of interviews took place in the inception stage and was used to explore the expectations and needs of the European Commission and how these could be addressed in the study. All remaining interviews were organised during the interim phase, feeding into case studies, benchmarks and the programme efficiency analysis.

Table 29: Interview programme per stage

Stage of the study	Purpose	Approximate number of interviews	Interviews held to date*
Inception stage	Explanatory interviews with EC officials	25-30	22
Interim stage	Case study & benchmarking interviews with stakeholders	177-184	198
	Interviews for the Efficiency analysis	–	4
Total			224

Source: compiled by the study team. *As of 30 November 2022.

A more detailed overview of interview distribution is presented in Table 30. This is divided into three parts – the first two being interviews regarding the specific programme parts (ERC, MSCA, FET, INFRA, SEWP and SwafS); and interviews regarding the case studies and interviews for international benchmarks. The third column reflects their status, and indicates whether the interview programme in question is already completed.

Table 30: Interview distribution

Purpose	Distribution	Status
Interviews for specific programme parts		
ERC	EC officials – 5	Programme completed: 26 interviews in total
MSCA	EC officials – 4	
FET	EC officials – 1	
INFRA	EC officials – 3	
SEWP	EC officials – 7	
SwafS	EC officials – 3	
Transversal	EC officials – 3	

Purpose	Distribution	Status
	Interviews for case studies	
Case study 1: ERC impact on creating new or pushing existing frontiers of science	Beneficiaries – 8	Interview programme completed: 8 interviews in total
Case study 2: Achievement of commercial and/or social innovation potential of ERC projects that received ERC Proof of Concept funding	Beneficiaries – 12 EC officials – 2 Stakeholders – 1	Interview programme completed: 15 interviews in total
Case study 3: Impact of the MSCA IF on strengthening human capital in research and innovation	Beneficiaries – 13	Interview programme completed: 13 interviews in total
Case study 4: Inclusiveness and gender dimension in the MSCA	Beneficiaries – 8 Stakeholders – 1	Interview programme completed: 9 interviews in total
Case study 5: Structuring impact of MSCA ITN on doctoral programmes	Beneficiaries – 11	Interview programme completed: 11 interviews in total
Case study 6: FET Graphene Flagship	Beneficiaries – 6 EC officials – 1 Stakeholders – 4	Interview programme completed: 11 interviews in total
Case study 7: FET Human Brain Flagship	EC officials – 2 Beneficiaries – 13	Interview programme completed: 15 interviews in total
Case study 8: Impact of the framework programme on the creation of new excellent services	Beneficiaries – 6 Stakeholders – 4	Interview programme completed: 10 interviews in total
Case study 9: Fostering knowledge creation through transnational access	Beneficiaries – 9 Stakeholders – 3	Interview programme completed: 12 interviews in total
Case study 10: Building the territorial dimension of SwafS partnerships	Beneficiaries – 9 EC officials – 1 Stakeholders – 1	Interview programme completed: 11 interviews in total
Case study 11: Contribution of framework programme in integrating research groups from widening countries	Beneficiaries – 16	Interview programme completed: 16 interviews in total
Case study 12: Impact of framework programme in improving quality (and coverage) of research in widening countries	Beneficiaries – 16	Interview programme completed: 16 interviews in total
Case study 13: Contribution of the framework programme to some emerging areas of science and technology such as artificial	Beneficiaries – 10 Stakeholders – 1	Interview programme completed: 11 interviews in total

Purpose	Distribution	Status
intelligence, quantum computing, clean energy technologies		
Case study 14: Impact of the framework programme on fostering diffusion of knowledge and open science	Beneficiaries – 6 Stakeholders – 5	Interview programme completed: 11 interviews in total
Case Study 15: Impact of the framework programme in spreading excellence across the Union	N/A	N/A
Interviews for international benchmarks		
Benchmark No 1: National Science Foundation (NSF): Established Program to Stimulate Competitive Research (EPSCoR) and the Broadening Participation Portfolio (US)	Stakeholders – 2 Beneficiaries – 3	Interview programme completed: 5 interviews in total
Benchmark No 2: Canada Excellence Research Chairs Programme (CERC)	Beneficiaries – 4 Stakeholders – 2	Interview programme completed: 6 interviews in total
Benchmark No 3: Max Planck Centres and Dioscuri Centres of Scientific Excellence	Beneficiaries - 6 Stakeholders - 4	Interview programme completed: 10 interviews in total
Benchmark No 4: National Natural Science Foundation of China (NSFC)	Stakeholders – 8	Interview programme completed: 8 interviews in total

Source: compiled by the study team.

In terms of EC officials, staff from three different Directorates-General were interviewed. Interviews with DG CNECT focused primarily on issues concerning FET and INFRA; questions addressed to DG EAC related to MSCA; while questions for DG RTD essentially all programme parts under evaluation in this study. Interviews with ERCEA, REA and EISMEA mainly covered the questions regarding efficiency.

The interview programme also involved various beneficiaries, including SMEs, universities, private for-profit organisations, research organisations and public bodies.

Annex 5: Survey results

Please see the separate Microsoft Word and Excel files entitled ‘Annex 5.1. Survey Questionnaires’, ‘Annex 5.2. Survey Results’, and Annex 5.3 ‘Synopsis of the Survey Programme’.

Annex 6: Case studies

Please see the separate Microsoft Word file entitled ‘Case studies’.

Annex 7: International benchmarks

Please see the separate Microsoft Word file entitled ‘International benchmarks’.

Annex 8: Updated econometric modelling results

Please see the separate Microsoft Word file entitled ‘Econometric modelling results’.

Annex 9: Literature sources

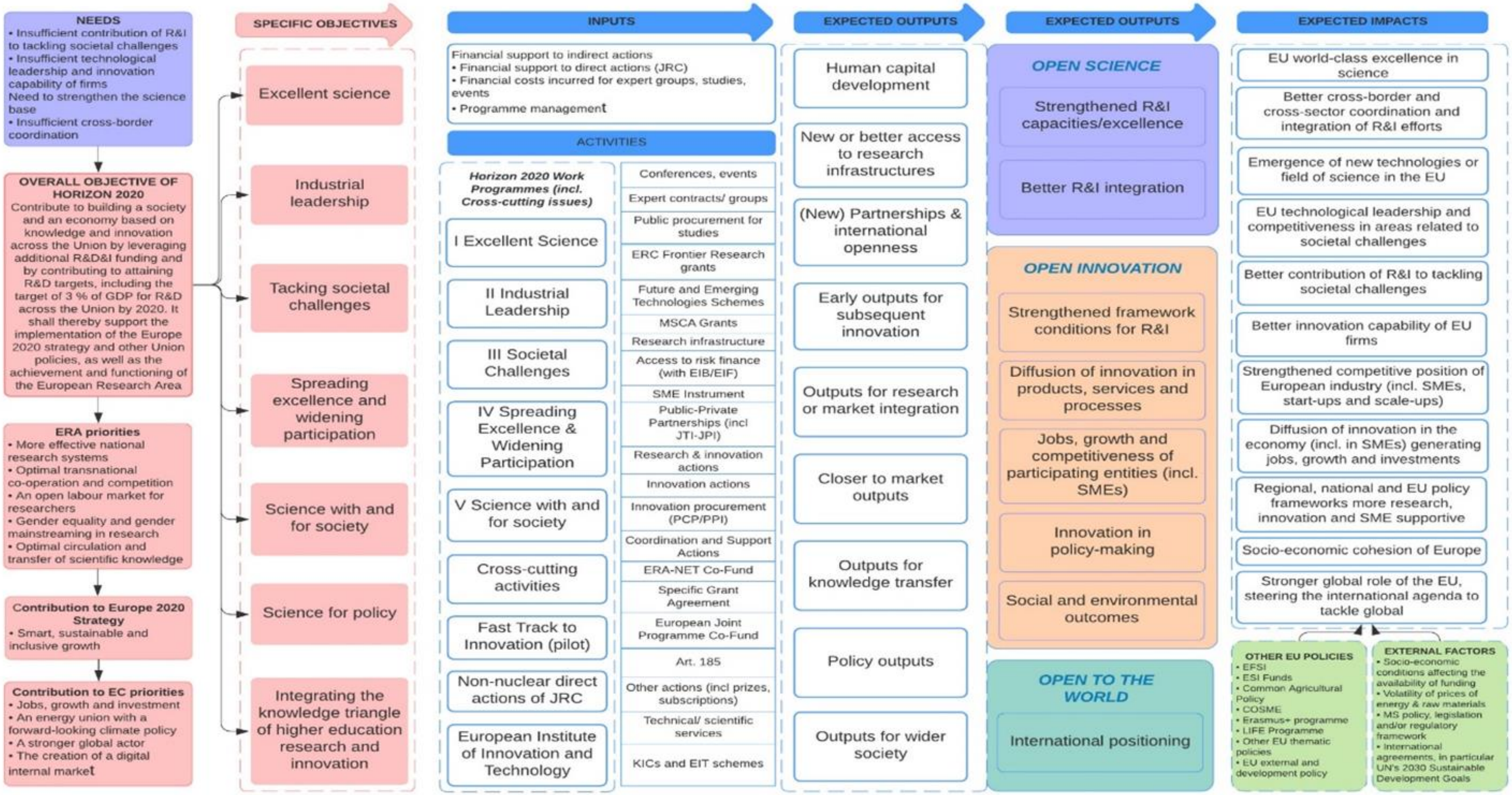
Please see the separate Microsoft Word file entitled ‘Literature sources’.

Annex 10: Intervention logic

The intervention logic of Horizon 2020 reconstructs the links between the problems to be tackled; the objectives to be achieved; as well as the activities and their expected impacts, which are categorised into three main categories: scientific impact, innovation/economic impact, and societal impact. In addition, detailed intervention logics were developed for each specific objective of Horizon 2020 to support the in-depth thematic assessments of each programme part.

Below, we present the overall intervention logic for Horizon 2020. For detailed intervention logics concerning different programme parts, please see Annex 1.

Figure 12. Horizon 2020 intervention logic



Source: based on the Interim evaluation of Horizon 2020, Annex II.

Annex 11: Additional figures on Horizon 2020 projects and proposals

This Annex presents additional figures on the distribution of projects, participations and EU contribution across the programme parts analysed in this study.

Table 31 and Table 32 below provide a breakdown of EU funding data for ERC and MSCA by grant type. As mentioned above, the majority of funding (92%) within ERC was allocated to Starting Grants, Consolidator Grants and Advanced Grants; Individual Fellowships attracted 82% of all MSCA grants, and 30% of MSCA funding. With a contribution of almost EUR 3.5 billion, MSCA ITN actions received the largest amount of EU funding.

Table 31: ERC: Number of projects, participations and EU contribution by type of action (EU contr. in million EUR)

	Number of projects	Number of participations	EU contribution
Starting Grant (ERC-STG)	2,783 (35.3%)	3,419 (33.8%)	4,170.6 (30.8%)
Consolidator Grant (ERC-COG)	2,264 (28.7%)	2,861 (28.3%)	4,409.3 (32.6%)
Advanced Grant (ERC-ADG)	1,592 (20.2%)	2,120 (20.9%)	3,800.7 (28.1%)
Proof of Concept Grant (ERC-POC)	1,130 (14.3%)	1,314 (13.0%)	169.0 (1.2%)
Synergy Grant (ERC-SyG)	99 (1.3%)	377 (3.7%)	981.2 (7.2%)
Coordination and Support Action	12 (0.2%)	25 (0.2%)	5.8 (0.0%)
Low Value Grant (ERC-LVG)	5 (0.1%)	5 (0.0%)	0.3 (0.0%)
Total	7,885 (100.0%)	10,121 (100.0%)	13,536.7 (100.0%)

Source: compiled by the study team with eCorda data.

Table 32: Number of MSCA projects and participations, plus EU contribution, by type of action (EU contribution in million EUR)

	Number of projects	Number of participations	EU contribution
Coordination and Support Action	251 (2.1%)	1,298 (3.9%)	49.8 (0.8%)
COFUND*	218 (1.8%)	966 (2.9%)	601.4 (9.1%)
Doctoral programmes	100 (45.9%)	589 (61.0%)	224.0 (37.2%)
Fellowship programmes	118 (54.1%)	377 (39.0%)	377.4 (62.8%)
IF	10,034 (82.5%)	11,515 (34.5%)	1,918.3 (29.1%)
Career Restart panel	446 (4.4%)	460 (4.0%)	101.2 (5.3%)
Reintegration panel	726 (7.2%)	749 (6.5%)	129.7 (6.8%)
Society and Enterprise panel	288 (2.9%)	293 (2.5%)	51.3 (2.7%)
Standard European Fellowships	7,372 (73.5%)	7,551 (65.6%)	1,345.6 (70.1%)
Global Fellowships	1,202 (12.0%)	2,462 (21.4%)	290.5 (15.1%)
ITN	1,037 (8.5%)	13,069 (39.2%)	3,469.3 (52.6%)
European Industrial Doctorates	157 (15.1%)	988 (7.6%)	242.4 (7.0%)
European Joint Doctorates	76 (7.3%)	912 (7.0%)	262.9 (7.6%)
European Training Networks	804 (77.5%)	11,169 (85.5%)	2,964.0 (85.4%)

	Number of projects	Number of participations	EU contribution
RISE	589 (4.8%)	6,445 (19.3%)	551.6 (8.4%)
Grant to identified beneficiary - Coordination and support actions (MSCA-Special Needs lump sum)	39 (0.3%)	39 (0.1%)	0.9 (0.0%)
Total	12,168 (100.0%)	33,332 (100.0%)	6 ,591.3 (100.0%)

Source: compiled by the study team using eCorda data.*For COFUND, not all participants are included in the analysis due to data limitations. For more information, see Annex 1.

Table 33 provides a breakdown of EU contribution by action type for FET, INFRA, SEWP and SwafS. The RIA instrument was most widely used in FET and INFRA, where up to 70% of the funding was allocated via this instrument. CSA was most widely used in SEWP, and to some extent in FET and INFRA. The analysed programme parts employed a wide range of additional/niche instruments such as fellowships (in SEWP), Specific Grant Agreements, COFUND and others.

Table 33: EU contribution (in million EUR) to the analysed programme parts, by action type

Action type	FET		INFRA		SEWP		SwafS	
	Projects	**EU Contribution**	**Projects**	**EU Contribution**	**Projects**	**EU Contribution**	**Projects**	**EU Contribution**
Research and Innovation Action (RIA)	482	1,840.7	264	1,970.0	0	0	63	125.3
Coordination and support action (CSA)	111	40.6	78	184.9	324	569.0	198	365.6
CSA – Lump Sum	36	3.6	0	0	0	0	0	0
Specific Grant Agreement (SGA-RIA)	7	674.0	7	252.0	44	428.9	0	0
COFUND – Pre-Commercial Procurement (PCP)	0	0	1	4.7	0	0	0	0
Public Procurement of Innovative solutions (PPI)	0	0	1	26.0	0	0	0	0
ERA-NET-Cofund	6	49.7	0	0	0	0	1	3.8
Standard European Fellowships (MSCA)	0	0	0	0	104	15.5	0	0
Reintegration Panel (MSCA)	0	0	0	0	15	2.3	0	0
Career Restart Panel (MSCA)	0	0	0	0	1	0.2	0	0
Total	**642**	**2,608.7**	**351**	**2,437.6**	**488**	**1,015.9**	**262**	**494.7**

Source: compiled by the study team using Corda data.

Overall, programme parts under Pillar 1 received just over 150,000 proposals, with MSCA and the ERC receiving more than 90% of all applications. The share of ineligible proposals was 1.2% for Pillar 1 programmes, 0.9% for SEWP, and 0.6% for SwafS. These shares are similar to the Horizon 2020 average (1.1%).

During the period 2014-2020, the success rate for applications to the ERC programme was 13%; for MSCA it was 14%. Both rates were above the average success rate of 11% for Horizon 2020 as a whole. Within the ERC, Advanced Grants were most competitive (success rate of 8-10%), followed by Starting Grants (10-12%) and Consolidator Grants (12-15%). The success rate for Proof of Concept grants reached 35-45% during the final years of Horizon 2020. The success rate for applications to FET was only 4-6% during the period 2014-2016, making it one of the most oversubscribed programme parts during the early years of Horizon 2020. The rate increased to 13% in 2018, however, followed by 32% in 2019, before the programme transitioned to the EIC Pathfinder. INFRA, on the other hand, with an overall success rate of 33%, had some of the highest success rates observed in Horizon 2020.

Table 34: Number of eligible proposals received and proposal success rates, by programme and call year (in %)

Call Year	ERC	FET	MSCA	INFRA	SEWP	SwafS
2014	8,383 (12%)	2,424 (4%)	8,979 (18%)	338 (25%)	248 (17%)	632 (8%)
2015	7,135 (14%)	0 (N/A)	10,420 (13%)	0 (N/A)	546 (12%)	0 (N/A)
2016	7,933 (13%)	1754 (8%)	10,989 (13%)	267 (32%)	811 (10%)	354 (13%)
2017	8,165 (13%)	0 (N/A)	11,119 (14%)	4 (75%)	0 (N/A)	0 (N/A)
2018	8,218 (12%)	2,804 (13%)	11,853 (14%)	317 (41%)	1,316 (20%)	894 (12%)
2019	8,100 (13%)	139 (32%)	11,728 (15%)	7 (86%)	0 (N/A)	0 (N/A)
2020	9,278 (13%)	0 (N/A)	13,675 (15%)	13 (31%)	0 (N/A)	46 (N/A)

Source: compiled by the study team using Corda data.

Annex 12: Additional data on Horizon 2020 participants

Table 35 shows the distribution of the EU contribution (in million EUR) in the 10 countries that received the highest financial contributions from the programme.

Table 36 presents the number and share of newcomers since FP7, by organisation type, in each of the programme parts covered by this study. For almost 7,000 entities, Horizon 2020 was their first time participating in a framework programme, i.e. they had not received any funding under the same PIC number in FP7. As per the table below, roughly two-thirds of newcomers were SMEs, followed by HEIs (10.8%) and other types of organisations (OTH, 10.9%). The MSCA attracted 4,601 newcomers, representing 71% of all newcomers to the programme parts analysed. More than 70% of newcomers (3,273 out of 4,601) were private for-profit enterprises, highlighting the strong presence of inter-sectoral collaboration in the programme.

The ERC attracted only 195 newcomers. This low number is to be expected, due to the fact that a large majority of ERC funding goes to principal investigators affiliated to universities and research institutes that are frequent participants in EU FPs.

Table 35: EU contribution (in million EUR) to the top 10 beneficiary countries, by programme part

		United Kingdom	Germany	France	Netherlands	Italy	Spain	Belgium	Greece	Other countries	Total
ERC	Number of participations	1,868	1,588	1,267	847	632	610	328	49	2,846	10,035
	EU contrib.	2,418.5	2,360.2	1,558.5	1,181.8	679.2	759.2	461.4	46.6	4,072	13,537.3
	Share of EU contribution received	17.9%	17.4%	11.5%	8.7%	5.0%	5.6%	3.4%	0.3%	30.1%	100.0%
FET	Number of participations	607	896	783	289	676	618	181	128	1,566	5,744
	EU contrib.	307.7	456.3	288.2	136.2	274.8	246.2	91.7	58.2	749.3	2,608.7
	Share of EU contribution received	11.8%	17.5%	11.0%	5.2%	10.5%	9.4%	3.5%	2.2%	28.7%	100.0%

		United Kingdom	Germany	France	Netherlands	Italy	Spain	Belgium	Greece	Other countries	Total
MSCA*	Number of participations	5,177	3,400	2,766	2,135	2,654	2,944	1,149	582	12,217	33,027
	EU contrib.	1,176.8	751	636.8	532	534.3	638.4	284.2	106.1	1,932	6,591.6
	Share of EU contribution received	17.9%	11.4%	9.7%	8.1%	8.1%	9.7%	4.3%	1.6%	29.3%	100.0%
INFRA	Number of participations	708	918	883	547	732	557	252	264	2,875	7,737
	EU contrib.	251.1	374.3	300	327.6	214.1	134.7	84	73	677.1	2 436.1
	Share of EU contribution received	10.3%	15.4%	12.3%	13.4%	8.8%	5.5%	3.4%	3.0%	27.8%	100.0%
SEWP	Number of participations	101	171	81	61	95	51	42	21	979	1,602
	EU contrib.	35.3	44.1	16.4	11.6	14.9	8.8	266.8	5.7	612.3	1,015.9
	Share of EU contribution received	3.5%	4.3%	1.6%	1.1%	1.5%	0.9%	26.3%	0.6%	60.3%	100.0%
SwafS	Number of participations	149	213	169	149	190	273	129	107	1,213	2,592
	EU contrib.	33.2	53	33.9	36.2	40.9	51.2	34	17.8	194.5	494.8
	Share of EU contribution received	6.7%	10.7%	6.9%	7.3%	8.3%	10.3%	6.9%	3.6%	39.3%	100.0%

Source: compiled by the study team using Corda data. *For MSCA-COFUND, not all participants are included in the analysis due to data limitations. For more information, see Annex 1.

Table 36: Number of newcomers since FP7, by organisation type (in %)

	ERC	FET	MSCA*	INFRA	SEWP	SwafS	**Total**
Higher or secondary education (HES)	55 (28.2%)	26 (4.7%)	497 (10.8%)	34 (6.1%)	22 (20.6%)	69 (14.3%)	**703 (10.8%)**
Others (OTH)	19 (9.7%)	20 (3.6%)	397 (8.6%)	95 (17.1%)	15 (14.0%)	160 (33.1%)	**706 (10.9%)**
Private for profit (excl. education) (PRC)	68 (34.9%)	454 (82.2%)	3,273 (71.1%)	245 (44.1%)	27 (25.2%)	131 (27.1%)	**4,198 (64.6%)**
Public body (excl. research and education) (PUB)	7 (3.6%)	9 (1.6%)	161 (3.5%)	49 (8.8%)	17 (15.9%)	56 (11.6%)	**299 (4.6%)**
Research organisations (REC)	46 (23.6%)	43 (7.8%)	273 (5.9%)	133 (23.9%)	26 (24.3%)	67 (13.9%)	**588 (9.1%)**
Total	**195 (100.0%)**	**552 (100.0%)**	**4601 (100.0%)**	**556 (100.0%)**	**107 (100.0%)**	**483 (100.0%)**	**6,494 (100.0%)**

Source: compiled by the study team using Corda data. *For MSCA-COFUND, not all participants are included in the analysis due to data limitations. For more information, see Annex 1.

Annex 13: Programme-specific baseline indicators

Table 37 Horizon 2020 indicator framework[147], related FP7 baseline and link with Horizon Europe indicators

Programme part; indicator ID	Indicator name (H2020)	FP7 baseline
Excellent Science 1 *(KIP 1)*	**European Research Council** – percentage of publications from ERC-funded projects that are among the top 1% highly cited, and average field-normalised citation score above the global average score of 1.0.	According to the interim evaluation of Horizon 2020[148], 7% of ERC publications from FP7 projects were among the top 1% highly-cited publications. An Elsevier study indicated that the FWCI of the ERC in FP7 was close to 3.[149] The *ex-post* evaluation of FP7 'Ideas' also showed that the average productivity of that programme part was 6.7 papers per grant.[150]
Excellent Science 2 *(KIP 1)*	**Future and Emerging Technologies** – publications in peer-reviewed high impact journals	No comparable baseline figures are available. Previous studies provide related information on the number of publications, patent applications and awards under FP7. The *ex-post* evaluation of FP7 on ICT[151] indicated that FET Open, FET Proactive and FET Young Explorers produced 2,024 publications, and that FET Open projects produced 10 patents.
Excellent Science 3 *(KIP 7)*	**Future and Emerging Technologies** – Patent applications and patents awarded in Future and Emerging Technologies	
Excellent Science 4 *(KIP 2)*	**Marie Skłodowska-Curie actions** – cross-sectoral and cross-country circulation of researchers, including PhD candidates	In FP7, MCAs supported some 50,000 mobile researchers.[152] These MSCA fellows were drawn from 140 different nationalities, and 37% were women.[153] Target for Horizon 2020: 50,000 researchers, out of which 20% PhD
Excellent Science 5 *(KIP 3)*	**Research Infrastructures** – number of researchers who have access to research infrastructures through support from Horizon 2020	21,060 unique users[154]
SEWP 20[155] *(KIP 1)*	**Spreading Excellence and Widening Participation** – evolution of the share of highly cited publications	New programme part under Horizon 2020.
SwafS 21 *(*)*	**Science with and for Society** – number of institutional change actions promoted by the programme part	New programme part under Horizon 2020; its predecessor in FP7 was 'Science in Society' (SiS), with a budget of EUR 330 million across FP7. The *ex-post* evaluation of the FP7 SiS[156] reported that 66% of projects fully achieved their objectives, and 34% mostly.

(*)Note: SwafS was discontinued in Horizon Europe, and there is no comparable indicator in Horizon Europe regarding institutional changes. However, KIPs 2 (Strengthening human capital in research and innovation), KIP 3 (Fostering diffusion of knowledge and Open source), and 6 (Strengthening the uptake of research and innovation in society) closely relate to the activities carried out in SwafS.

Source: compiled by the authors on the basis of European Commission, Directorate-General for Research and Innovation, Horizon 2020 indicators: assessing the results and impact of Horizon, Publications Office, 2015.

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147 Source: compiled by the authors on the basis of the European Commission, Directorate-General for Research and Innovation (2015). Horizon 2020 indicators: assessing the results and impact of Horizon, Publications Office, https://data.europa.eu/doi/10.2777/71098

148 European Commission, Directorate-General for the Information Society and Media, Arnold, E., Hammerschmidt, R., Mahieu, B., et al. (2014). Evaluation of pertinence and impact of research infrastructure activity in FP7 – EPIRIA : final report, Publications Office, https://data.europa.eu/doi/10.2759/62665

149 European Commission, Directorate-General for Research and Innovation (2019). Overall output of select geographical group comparators and related FP7- and H2020-funded publication output : final report, Publications Office, https://data.europa.eu/doi/10.2777/63581

150 Bonaccorsi, A., (2015). Ex-post Evaluation of the Seventh Framework Programme. Support paper to the High Level Expert Group. IDEAS Specific Programme Analytical Evaluation.

151 European Commission, Directorate-General for Communications Networks, Content and Technology, Notten, A., Jacob, J., Sasso, S., et al. (2016). Analysis of publications and patents of ICT research in FP7: final study report, Publications Office, https://data.europa.eu/doi/10.2759/78487

152 Avramov, D. (2015). FP7 Ex-post Evaluation PEOPLE Specific Programme (2007-2013): Rationale, implementation and achievements.

153 European Commission, Directorate-General for the Information Society and Media, Arnold, E., Hammerschmidt, R., Mahieu, B., et al. (2014). Evaluation of pertinence and impact of research infrastructure activity in FP7 – EPIRIA : final report, Publications Office, https://data.europa.eu/doi/10.2759/62665

154 Source: European Commission, DG RTD. The figure for INFRA should be considered with caution, as 53 projects were not considered in the calculation of the figures due to the incompatibility of the structure of their reporting data. The Staff Working Document on sustainable RIs reported 25,782 unique researchers had benefitted from the TNA/VA scheme.

155 The ex-post evaluation of FP7 indicated that 85% of the FP7 funding was allocated to organisations located in the EU15, and 4% was dedicated to organisations in the EU13 (this country grouping overlaps to a great extent with the Horizon2020 widening countries.

156 Halme, K. (2015). Summary Report of the Capacities Specific Programme of FP7 for the High Level Expert Group.

Annex 14: Overview of publication performance by programme part

Table 38: Overview of publication performance, by programme part

Programme	Number of publications	Average citation rate	Average FWCI	Share in the top 1%	Publications per million EUR
ERC	49,496	24.4	2.32	5.6%	3.7
FET	7,859	28.2	2.12	5.4%	2.9
FTI	119	11.4	1.69	0.8%	0.2
INFRA	5,925	18.9	1.86	2.9%	2.4
Inn. In SMEs	160	9.8	2.08	5.0%	0.1
LEITs-Biotech	584	22.7	2.01	5.5%	1.0
LEITs-ICT	12,887	13.6	2.03	1.3%	1.2
LEITs-Manufacturing	1,111	14.0	1.99	2.1%	0.6
LEITs-Materials	1,213	21.9	1.83	4.5%	0.9
LEITs-Nano	580	22.2	1.73	4.1%	0.9
LEITs-Space	869	21.5	2.06	3.1%	0.8
MSCA	30,451	20.0	1.92	3.6%	4.2
SC1	7,549	29.6	2.86	7.4%	0.9
SC2	3,458	15.8	1.94	3.3%	0.8
SC3	3,212	17.3	1.98	3.4%	0.5
SC4	2,268	10.0	1.92	1.1%	0.3
SC5	2,862	23.4	2.61	5.9%	0.8
SC6	1,032	11.9	2.25	2.3%	0.9
SC7	1,252	10.3	2.07	1.3%	0.7
SEWP	4,965	16.3	1.54	2.6%	5.0
SWAFS	242	7.7	1.70	0.4%	0.6

Source: bibliometric analysis, developed by the study team.

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