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Brussels, 31 May 2017
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9787/17
ADD 8

RECH 211
COMPET 454
IND 142
MI 458
EDUC 272
TELECOM 148
ENER 255
ENV 551
REGIO 65
AGRI 289
TRANS 227
SAN 224

COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	29 May 2017
To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2017) 221 final - PART 9/16
Subject:	COMMISSION STAFF WORKING DOCUMENT INTERIM EVALUATION of HORIZON 2020 ANNEX 2

Delegations will find attached document SWD(2017) 221 final - PART 9/16.

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Brussels, 29.5.2017
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PART 9/16

COMMISSION STAFF WORKING DOCUMENT

INTERIM EVALUATION
of
HORIZON 2020

ANNEX 2

{SWD(2017) 220 final}
{SWD(2017) 222 final}

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B. FUTURE AND EMERGING TECHNOLOGIES (FET)

B.1. INTRODUCTION

B.1.1. Context

Throughout previous framework programmes Future and Emerging Technologies (FET)[1] has provided the European ICT communities with the capacity to look far ahead to technologies to come. Successive FET calls have explored new ideas early on, and identified and matured promising areas, both in terms of substance and in terms of building the multi-disciplinary communities engaged with them. Intelligent robotics, Internet of things, bio- and neuro-morphic computing and simulation, soft robotics, complex systems science, cognitive computing, secure quantum communication, neural prosthetics, brain-computer interfaces, nano-optomechanics, spintronics and advanced photonics – these are but some of the areas that are driving innovation today and in which FET has supported pioneering ground work.

During FP7 FET funded 2 500 participations in 320 collaborative projects, for a total of EUR 825 million[2]. It has involved an estimated 8 000 to 10 000 PhD students and postdocs in mind-opening interdisciplinary collaborations across Europe. Interdisciplinarity has become the hallmark of FET, with projects involving not only the ICT science and engineering disciplines but also fields as diverse as biology, medicine, material science, neuroscience, energy, music, economics, finance, and more.

Building on the abovementioned achievements, under Horizon 2020, FET was conceived as one of the key elements in support of the Europe 2020 strategy's goals by helping strengthen the Union's science base as well as its research and innovation system. Important needs in this respect that are to be addressed via FET-funded activities include achieving and maintaining a strong presence of European actors in key sectors as well as the promotion and development of world-class cooperation schemes for research and innovation.

The analysis presented in the present thematic annex draws on the following sources: CORDA data; a report by an ad hoc panel of independent experts; an external study carried out by the CARSA-led consortium for DG CNECT[3]; PPMI's 'Assessment of the Union Added Value and the Economic Impact of the EU Framework Programmes (FP7, Horizon 2020)'; conclusions from the expert panel on FET Flagships and self-assessment by the relevant units at DG CNECT. The primary focus is on DG CNECT activities.

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[1] *http://ec.europa.eu/digital-agenda/en/future-emerging-technologies-fet*
[2] *http://ec.europa.eu/digital-agenda/en/fet-projects-portfolio*
[3] *Prepared in the context of the study SMART 2015/0060 "Support study for the Interim Evaluation of Horizon 2020 – DG CONNECT Activities". The study, which only covers DG CNECT Horizon 2020 activities, will be referred to in the present report as "CARSA study". In the CARSA study survey results refer to FET Open and FET Proactive only. Data from the CARSA study refer, unless otherwise stated, to the period to June 2016.*

B.1.2. Objectives and intervention logic

Objectives

Future and emerging technologies (FET) is one of the components of the Excellent Science pillar of Horizon 2020. It aims at supporting collaborative research in order to extend Europe's capacity for advanced and paradigm-changing innovation, as well as at strengthening the Union's science base and consolidate the ERA to help make the Union's research and innovation system more competitive on a global scale[4]. To do so, it seeks to foster scientific collaboration across disciplines on radically new, high-risk ideas and accelerate development of the most promising emerging areas of science and technology as well as the Union-wide structuring of the corresponding scientific communities. Building on the success of FET in the ICT domain under FP7, in Horizon 2020 FET was lifted to a new level of ambition where it is now called to stimulate new thinking and to nurture European talent for seeking the breakthrough technologies of the future, without the restriction of ICT relevance.[5] It positions itself as a bridge between excellent science and technology innovation, catering for a unique mix of actors from all sciences, engineering and innovation. Furthermore, FET seeks to become a laboratory for new ways of linking science and innovation, e.g. by promoting open and digital science and developing new forms of long-lasting research and innovation partnerships.

Intervention logic

The intervention logic of FET spans from stimulating resolutely bottom-up small scale explorations within the widest possible scope (FET-Open), over the building up of critical mass around promising directions (FET-Proactive), to large scale interventions that require a common European effort over a longer period to pursue grand challenges in science and technology (FET Flagships, two of which were launched at the end of FP7: Graphene[6] and the Human Brain Project[7]). Each in their own way, these three schemes seek to promote science-driven innovation benefiting not only on science and engineering, but also on business, industry, policy making and society.

Enhancing this potential for achieving real impacts had been a major driver at the end of FP7, for attracting a broader range of actors and in particular the scientific and industrial leaders of tomorrow - young researchers and high-tech research-intensive SMEs. FET Flagships bring in a new dimension by focusing efforts over the long term on a targeted objective of a critical size, with returns on innovation, as well as by aligning national and regional efforts with European support. FET Flagships differ from other large scale initiatives as they are science-driven at the outset, while the industrial participation will build up over their ten-year duration.

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

[5] *The ex-Post Evaluation of the Seventh Framework Programme also pointed out that, 'Over the Framework Programmes, FET has contributed to enable Europe to take the lead in such areas as nano-electronics, microsystems, new computing paradigms, dependable embedded systems, photonics, and new materials. It is also pioneering research in promising research fields such as quantum information processing, complex systems and bio-inspired ICT systems.'* https://ec.europa.eu/research/evaluations/pdf/archive/fp7-ex-post_evaluation/staff_working_document_annexes_part_1_en_autre_document_travail_service.pdf#view=fit&pagemode=none

[6] http://graphene-flagship.eu/

[7] https://www.humanbrainproject.eu/discover/the-community/partners;jsessionid=1ty1gff12jdek1x1j9gv4mhzbk

The focus of FET intervention has evolved over time. At the start of Horizon 2020 (FET Work Programme 2014-15)[8] the main objectives were (1) to open up FET to the full range of technologies and interdisciplinary collaborations for science and innovation and the corresponding mix of new participants; (2) to integrate in FET the implementation of part of the European High Performance Computing (HPC) strategy as an enabler for digital science and innovation, in collaboration with the contractual Public Private Partnership (cPPP) and European Technology Platform (ETP) 4HPC; and (3) to firmly establish the FET Flagship approach as a new instrument for large scale European science and innovation. In the second work programme FET WP2016-17[9], the following objectives gained prominence (4) to address the innovation deficit from science and technology research; and (5) to start developing an industrial strategy and leverage extra resources, for instance from industry involvement and from co-funded activities in strategic areas of common interest to Member States.

Almost all funding is implemented through grants for Research and Innovation Actions (RIA), with the occasional use of Coordination and Support Action (CSA) and ERANET Cofund instruments. Further details are provided in section B.6.1.1.

The **FET-Open** call (RIA part) was designed to be fully non-prescriptive in terms of thematic priorities. Several criteria are used to characterise the kind of research that FET is aiming to fund: visionary, breakthrough oriented, novel, foundational, high-risk, and interdisciplinary. These criteria have basically remained the same from one Work Programme (WP) to the next, with some refinement in wording and a better reflection in the evaluation criteria for projects, in light of the experience from the first batches. FET-Open is planned to be essentially always open with regular deadlines (defining its batches).

The design of **FET Proactive** in WP2014-15 was similar to that of FP7, basically aiming at a collection of projects to explore a common theme. This strategy was revised for WP2016-17 in order to avoid the need to select a limited number of topics (3 in WP2014-15). In WP2016-17, 10 topics are put into competition within a single call topic and the aim is to fund larger projects that can serve as reference ('lighthouse') for the rest of the field. Under its current design, FET Proactive is more clearly positioned as the next step after FET Open, with larger projects (EUR 4 million to EUR 10 million) and more attention to impact in terms of community building for kick-starting innovation ecosystems on new topics.

The **FET Flagships** related calls in WP2014-15 and WP 2016-17 have continued to support and to further develop the Graphene and HBP Flagships launched at the end of FP7 with a 2.5 year ramp-up funding. In 2014, for each of the FET Flagships, a stable and structured partnership between the EC and the Flagships organisations was established and set up through a Framework Partnership Agreement (FPA) which will cover the full Horizon 2020. In 2015 the 2 FPA consortia were invited to submit a proposal to implement the first 2 years of their action plan with EUR 89 million EU funding for each Flagship. A similar invitation is planned for 2017 in WP2016-2017 and will cover the period April 2018 to March 2020 with EUR 88 million EU funding for

[8] http://ec.europa.eu/research/participants/portal/doc/call/Horizon 2020/common/1587754-02._fet_wp2014-2015_en.pdf
[9] *http://ec.europa.eu/research/participants/data/ref/Horizon 2020/wp/2016_2017/main/Horizon 2020-wp1617-fet_en.pdf*

each Flagship. In addition, a call for a coordination and support action to develop impact assessment methodology and tools for the Flagships, was included in WP2014-15.

In designing FET WP2016-17, particular attention was paid to tapping into the innovation potential from the respective FET action lines. For example, actions to stimulate the exploitation of early results from FET research are foreseen. The FET Innovation Launchpad is modelled after the ERC Proof-of-Concept scheme and seeks to give innovators and entrepreneurs freedom and flexibility to innovate from results of previous or ongoing FET-funded projects. In order to create a wider and more diverse support base from which to take these innovations forward, the participation of new actors and of young and high-potential researchers and high-tech innovators is further encouraged (already with success in WP2014-15). There are also opportunities for Coordination and Support Actions that relate to measures for increasing impact, take-up and incubation/greenhousing for and from FET research.

Since the beginning of Horizon 2020, FET projects are part of the Open-Access (it was already the case in the FP7 pilot) and Open-Data pilots. This reflects the wider role of FET as a laboratory for open and digital science and innovation, including HPC for scientific computing and simulation (and cloud computing).

In WP2016-17, ERA-NET Cofund actions are used to boost areas of common interest to Member States in a substantial way (*in casu*, Quantum Technologies) and to allow Member States to explore among themselves such new areas of common interest (Chistera ERANET Cofund) in a bottom-up fashion, in preparation of eventual future initiatives. There is also a FET Flagship ERANET Cofund continuing the activities of the FP7 ERA-NET launched in 2013 with the objective of reinforcing the ongoing 2 FET Flagships by funding transnational projects and strengthening the synergies with regional and national programmes.

The intervention logic charts presented in Figures below (one of them including FET Flagships), which follow the approach by Dinges, et al. (2011)[10], shows how the strategic objectives translate into specific and operational objectives and then into expected outputs, outcomes and impacts. The main mechanisms are represented with different coloured lines:

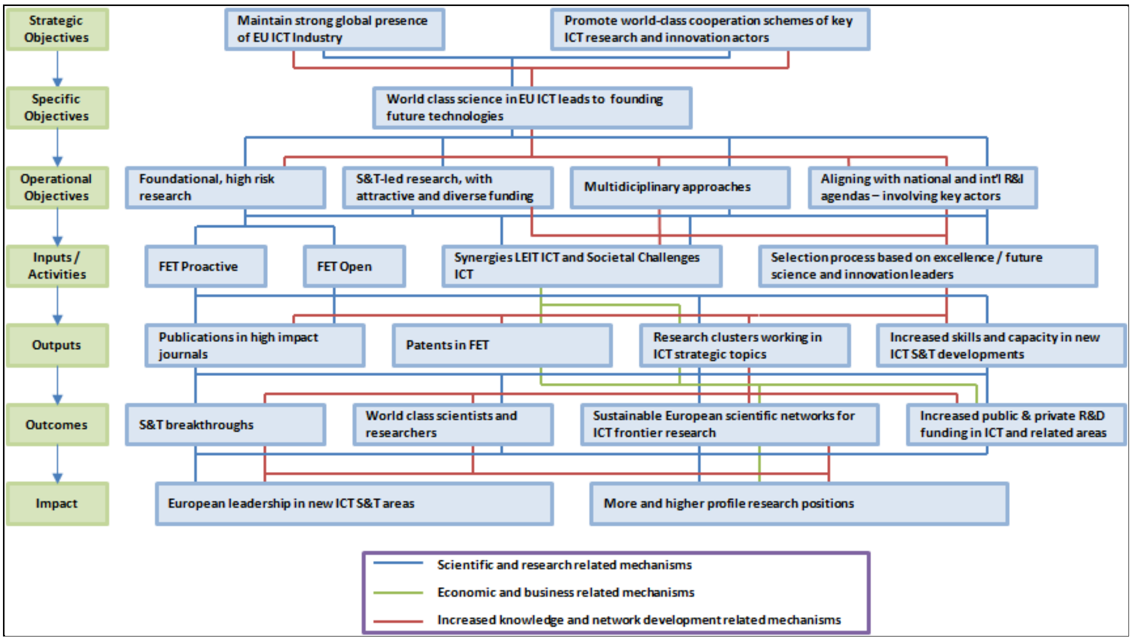
- Blue lines refer to scientific and research related mechanisms
- Green lines refer to economic and business related mechanisms
- Red lines refer to a combination of mechanisms, such as increased knowledge and network development.

As shown in the charts, some of the key expected *outputs* of FET include publications in peer-reviewed high impact journals, patent applications and patents awarded. As to *outcomes* (which are typically observed some time after the end of the projects and whose level of achievement depends on the use and adoption of project outputs by partners and stakeholders involved), these consist primarily of breakthroughs in scientific and technological fields as well as of strengthening and developing sustainable European scientific networks for ICT frontier research. Expected *impacts*, in turn, have to do with

[10] Dinges, M., Poel, M., & Søndergaard-Laugesen, N. (2011). Beyond Patents and Publications: Performance Monitoring Indicators for ICT Research in the EU funded RTD. Deliverable D4 to European Commission, DG Information Society and Media.

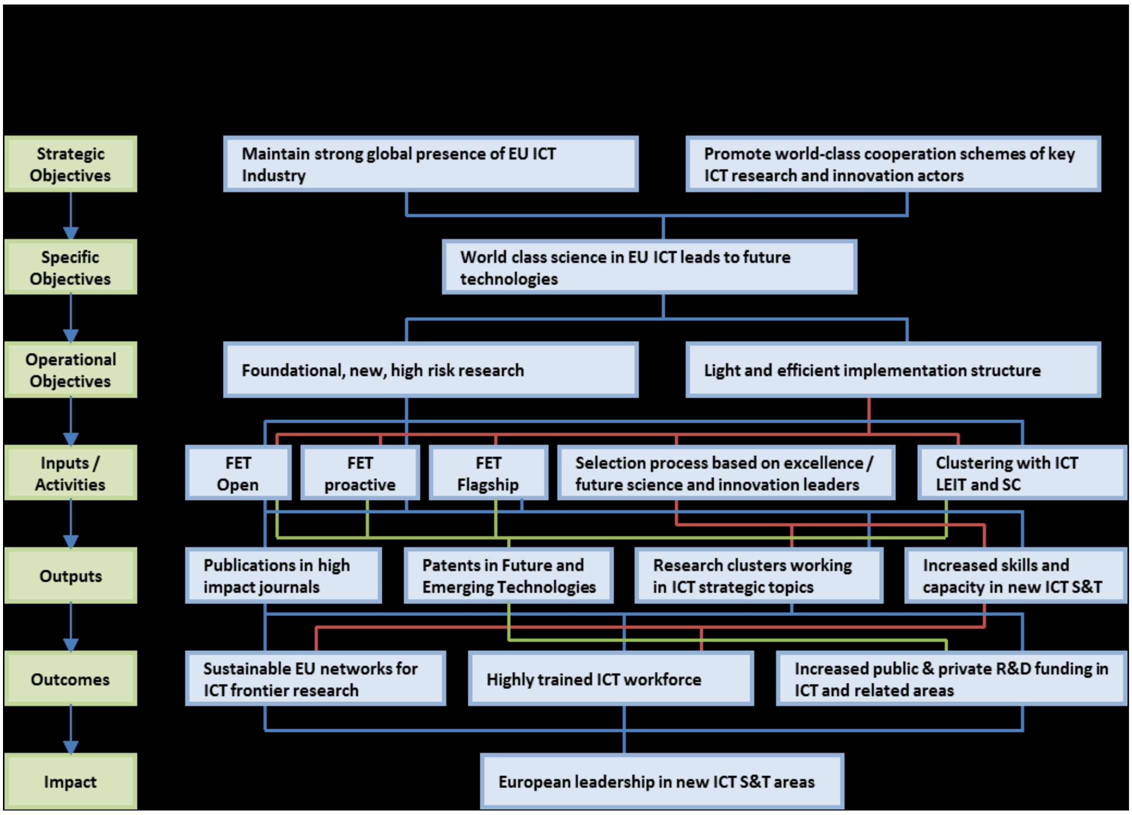
achieving European leadership in new scientific fields and technology areas as well as the creation of more and higher profile research positions.

Figure 36 - FET intervention logic



Source: CARSA.

Figure 37 - FET intervention logic (Flagships)



Source: CARSA/DG CNECT.

B.2. IMPLEMENTATION STATE OF PLAY

B.2.1. Overview of programme inputs and activities

The EC contribution allocated to the implementation of the calls included in Work Programmes 2014-2016 and which had been closed as of October 1st, 2016 has been EUR 575.7 million, or about 21% of total expected budget allocated to FET in Horizon 2020, which amounts to EUR 2.69 billion for the period 2014-2020.[11]

The budget has been allocated through 14 topics included in 9 closed calls for proposals (as of as of 1st October 2016). Through the Horizon 2020 Work Programmes 2014-2017, each line of activity of FET was allocated a share of the overall budget as indicated in the Table 9 below.

Table 9 - Activities and allocated share of budget dedicated to FET for the programming period 2014-2017

Call	Nr of Selected Projects	Share of Horizon 2020 Selected Projects	EC Contribution to Selected Projects (EUR million)	Share of Contribution to Horizon 2020 Selected Projects
FETPROACT-2016	13	0.1%	89.3	0.4%
Horizon 2020-Adhoc-2014-20	2	0.0%	178.0	0.9%
Horizon 2020-FETFLAG-01-2016	2	0.0%	7.1	0.0%
Horizon 2020-FETFLAG-2014	1	0.0%	0.8	0.0%
Horizon 2020-FETHPC-2014	21	0.2%	98.6	0.5%
Horizon 2020-FETOPEN-2014-2015-RIA	46	0.4%	156.8	0.8%
Horizon 2020-FETOPEN-2014-CSA	4	0.0%	2.3	0.0%
Horizon 2020-FETOPEN-2015-CSA	5	0.0%	2.9	0.0%
Horizon 2020-FETPROACT-2014	13	0.1%	39.9	0.2%
TOTAL	**107**	**0.9%**	**575.7**	**2.8%**

Source: CORDA, 1 October 2016.

Summary data on received and retained proposals sorted by type of action are presented in the series of tables below.

[11] http://ec.europa.eu/research/horizon2020/pdf/press/fact_sheet_on_horizon2020_budget.pdf

Table 10 - Key data on proposals per type of action for FET: Number of eligible and retained proposals, EC contribution requested (in million Euros) and success rates (as % of proposals submitted, and as % of budget available)

Type Of Action	Nr of Eligible Proposals	Nr of Retained Proposals	EC Contribution requested by Eligible Proposals (EUR million)	EC Contribution to Retained Proposals (EUR million)	Success Rate Proposals	Success Rate Funding
CSA	76	16	49.6	12.7	21.1%	25.7%
ERA-NET-Cofund	2	2	17.7	17.7	100.0%	100.0%
RIA	3 113	112	10 945.7	626.5	3.6%	5.7%
TOTAL	**3 191**	**130**	**11 013**	**656.9**	**4.1%**	**6.0%**

Source: CORDA data, 1 October 2016, Success Rates by Type of Action (General)

Table 11 - Key data on signed grants per type of action for FET: number, EC contribution, time-to-grant, projects' total costs, % of EC contribution in projects

Type Of Action	Nr of Signed Grants	EC Contribution to Signed Grants (EUR million)	Share of EC Contribution to Horizon 2020 Signed Grants (in programme part)	Nr of Signed Grants per EUR 10 million	Nr of Grants within 8 months	Participant Total Costs in Signed Grants (EUR million)	Share of Signed within Benchmark against all Signed	Average Project Costs in Signed Grants (EUR million)	Average Project E[C] Contributi[on] to Signed Grants (EUR million)
CSA	12	10.1	0.0%	11.9	12	10.1	100.0%	0.4	0
ERA-NET-Cofund									
RIA	80	469.3	1.1%	1.7	75	473.3	93.8%	5.9	5
TOTAL	**92**	**479.3**	**1.2%**	**1.9**	**87**	**483.4**	**94.6%**	**5.3**	**5**

Source: CORDA data, 1 October 2016, Selected Projects and Signed Grants by Type of Action.

As of October 1st, 2016, no projects had been completed yet.[12]

B.2.2. Participation patterns

A total 107 projects had been selected as of October 1st, 2016. Of these, 92 had already been signed.

B.2.2.1. Participation per type of organisation

The selected proposals represent a total of 1 047 participations, mobilising 589 distinct participants. As shown in Table 12 below, most of these were higher education and research organisations, with private commercial organisations and others such as government authorities and private non-profit organisations accounting for a much smaller share of participants. Research organisations and high education institutions typically participate in projects more often than private commercial organisations and other organisations. Shares of funding are roughly in line with participation shares for all

[12] *As per end date in 'raw data' spreadsheet provided by DG RTD.*

organisations, which suggests there are no significant variations in project size depending on the type of organisation.

Table 12 - Key data on participation per type of organisation for FET: number of participants, of project coordinators, of newcomers, of participations, and EC contribution to participations (in million Euros) – all projects included

Participant Type[13]	Nr of Participants in Selected Projects	Nr of NewComers in Selected Projects	Nr of Participations in Selected Projects	% of participations	Average Participations per Participant	EC Contribution to Participations in Selected Projects (EUR million)	% of EC contribution
HES	253		547	52%	2.2	306	53%
OTH	8	1	9	1%	1.1	5.1	1%
PRC	170	42	187	18%	1.1	82.8	14%
PUB	29	2	40	4%	1.4	16.8	3%
REC	129	3	264	25%	2	164.9	29%
TOTAL	**589**	**48**	**1047**	**100%**	**1.8**	**575.7**	**100%**

Source: CORDA data, 1 October 2016, Participants and Participations by Legal Entity.

It must be noted that the Graphene Flagship has a different participation distribution; the Graphene consortium includes 53 companies (29 large and 22 SMEs) representing 34% of the participating organisations.

As shown in Table 13 below, under FET, research and higher education organisations are the applicant categories with the highest success rates, whereas private commercial organisations are those with the lowest one. Public organisations are those with the highest success rate of applications and funding.

Table 13 - Success rates (as % of proposals submitted, and as % of budget available) per country for FET

Legal type of Applicant	Success Rate of Applicants	Success Rate of Applications	Success Rate of Funding (Applicants)
HES	24.6%	5.4%	5.5%
OTH	8.0%	7.7%	10.8%
PRC	8.7%	5.6%	5.8%
PUB	22.8%	21.4%	23.9%
REC	18.7%	6.0%	6.6%
TOTAL	**14.8%**	**5.7%**	**6.0%**

Source: CORDA data, 1st October 2016, Applicants and Applications by Type of Organisation (General).

B.2.2.2. Attractiveness to new participants / newcomers

There are 48 newcomers among participants in selected projects under FET so far (or about 8% of the total, excluding participations via the SME instrument and JU). However, research and education organisations account for a relatively large share of FET participants and these are only differentiated at the very top organisational level (no breakdown by department, etc.). Therefore, this figure has to be interpreted with caution,

[13] *HES= Universities; REC = Research Organisations; PRC= Private sector; PUB= Public bodies; OTH= other.*

as it could be an underestimation. Also, the population of research institutions is limited - and thus so is the scope for new research organisations to participate. Indeed, as can be seen from Table 14 below, which presents funding shares, the majority of newcomers within Horizon 2020 ICT projects are private companies, with only minor differences in composition across pillars.

Table 14 - Funding to newcomers in % of total funding by type of organisation (DG CNECT activities)

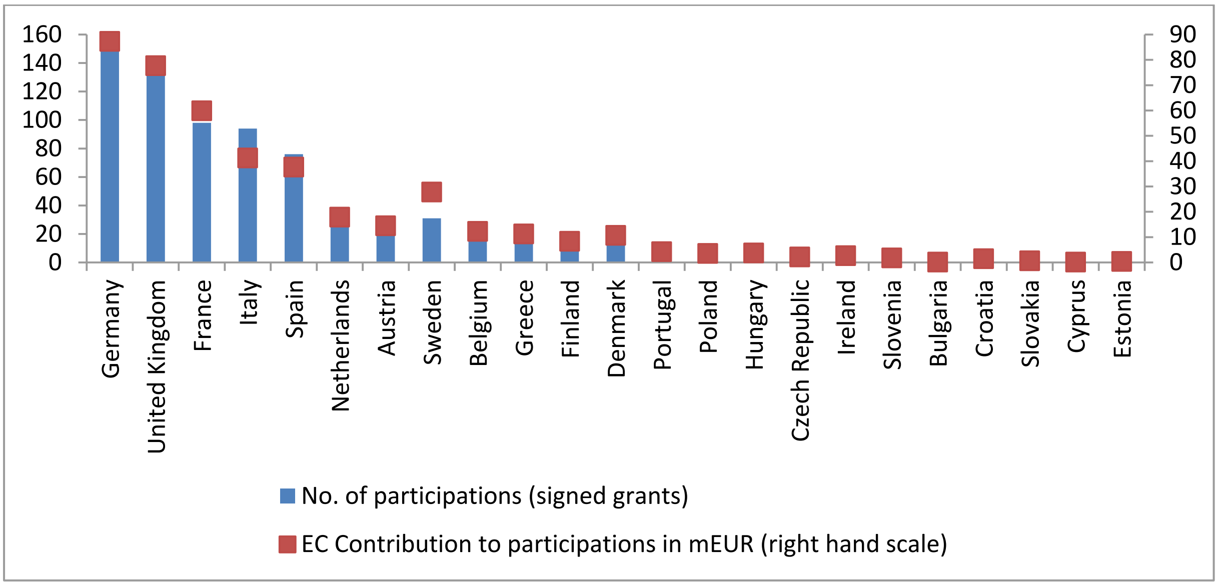
Pillar	LARGE[14]	NIL	REC/HES	SME	Total
Excellent Science	14%	9%	0%	22%	4%
LEIT ICT	23%	36%	1%	44%	17%
Societal Challenges	41%	34%	4%	45%	25%
TOTAL	**26%**	**31%**	**1%**	**43%**	**16%**

Source: CARSA.

B.2.2.3. Geographical participation patterns

As shown in Figure 38 below, participation in FET is dominated by organisations belonging to EU-15 Member States. Among these, shares in total number of participants, participations and funding are broadly correlated with size (although smaller Member States such as the Netherlands, Belgium and Austria account for relatively high shares).

Figure 38 - Number of participations and EC contribution per Member State for FET



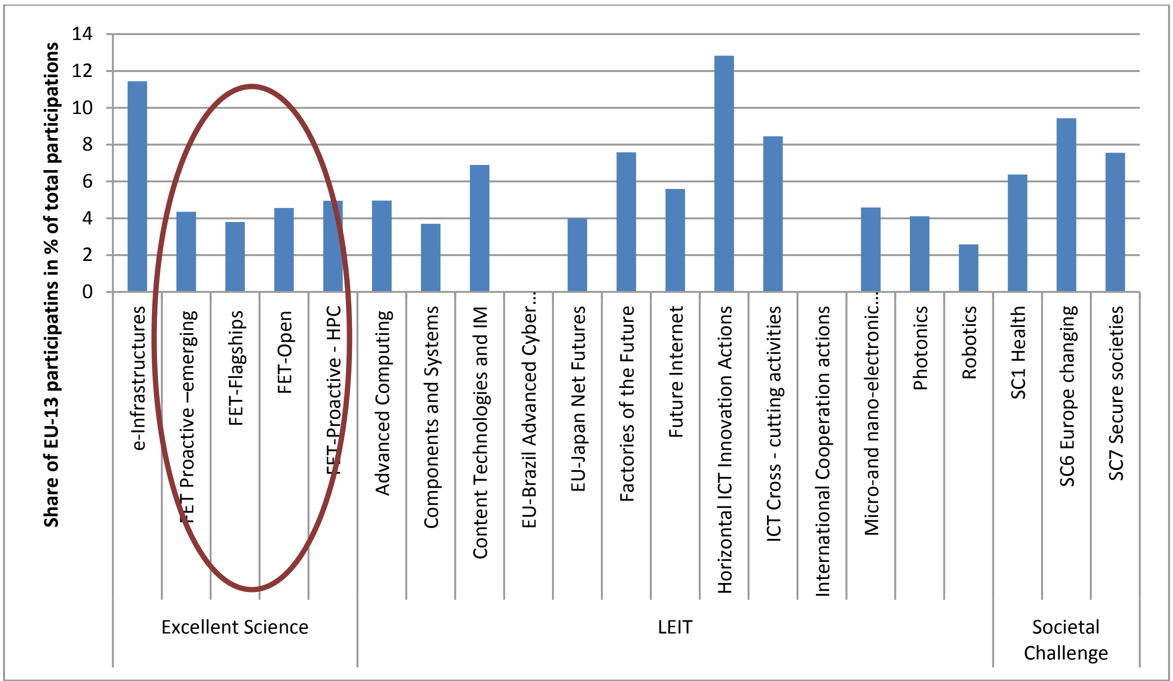
Source: CORDA data, October 1st 2016, Participants and Participations by EU-28 Member State. No participations or no data for MS not plotted on the chart.

[14] *Large companies referred to as LARGE hereinafter.*

As shown in Figure 39Figure 39 - Participations of EU-13 MS in Horizon 2020, by key component (DG CNECT activities)

below, when ICT-related activities are considered, the participation rate of organisations from EU-13 Member States currently stands at lower levels (approximately 4-5% of the total) than the average for Horizon 2020 (6-7%).

Figure 39 - Participations of EU-13 MS in Horizon 2020, by key component (DG CNECT activities)



Source: CARSA.

In addition, as shown in Table 15 below, success rates are comparatively lower (about 50% lower) for organisations participating in FET from EU-13 Member States than for their EU-15 counterparts.

Table 15 - Success rates (as % of proposals submitted, and as % of budget available) per group of countries for FET

GROUP	Success Rate of Applicants	Success Rate of Applications	Success Rate of Funding (Applicants)
AC COUNTRIES	10.1%	5.6%	7.2%
EU-13	9.7%	4.1%	3.3%
EU-15	16.7%	5.9%	6.0%
THIRD_PARTY	3.6%	2.8%	1.6%
TOTAL	**14.8%**	**5.7%**	**6.0%**

Source: CORDA data, October 1st 2016, Applicants and Applications by Country groups (General)

B.2.2.4. International cooperation

89.7% the total requested EC contribution to retained proposals goes to EU Member States and about 9.9% to Associated Countries[15]. Funding for co-operation with third countries (developing countries, emerging economies and advanced economies) is thus residual in terms of funding shares. A total of 166 entities from third countries applied to the programme, within 258 project proposals. Very few of these proposals (0.6%) were retained for funding, involving 6 third country participants.

A number of topics in the FET WP have however an international dimension in that they mention at least one third country or region[16] (data provided by WP drafters during WP preparation). As of October 2016, EC contribution to International Cooperation topics under FET amounted to EUR 94.5m (about 4% of the total for Horizon 2020 and about 19% of the total EC contribution to signed grants under FET).

B.2.3. Cross-cutting issues

Projects funded under the 2014-2016 calls of FET contributed to cross-cutting issues as follows[17]:

- 15.7% (EUR 103 million) of FET's budget[18] has so far been allocated to sustainable development topics, 14.7% (EUR 96.4 million) of the budget to climate related topics and 0.5% (EUR 2.6 million) to biodiversity.
- 73.5% (EUR 369.6 million) of the EC contribution under FET is ICT-related.
- In terms of promotion of socio-economic sciences and humanities (SSH), 9.4% of grants signed so far (EC contribution of EUR 107.5 million) are flagged as SSH-relevant.
- In FET-funded projects, women account for approximately one-quarter of the participants and almost two-thirds of coordinators are women.

B.3. RELEVANCE

B.3.1. Is FET tackling the right issues?

B.3.1.1. The relevance of FET given the challenges to address

The impact assessment of Horizon 2020 notably identified an urgent need for strengthening the EU's science base at a time when non-EU countries[19] are investing massively in science and engaging in strategies to attract the world's top researchers. The impact assessment also pointed out the need to improve the articulation between research and innovation as well as to address deficiencies in trans-national coordination which result in duplication and inefficiencies in the R&I funding of the EU Member States. It notably stated that "Europe's research and innovation system remains constrained by national borders. Research funding is often dispersed, leading to duplication and

[15] For a list of associated countries see: http://ec.europa.eu/research/participants/data/ref/Horizon 2020/grants_manual/hi/3cpart/Horizon 2020-hi-list-ac_en.pdf
[16] Data provided by WP drafters during WP preparation.
[17] Data for sustainable development, climatea action and gender issues, cut off date: 1 January 2017
[18] All figures calculated as share of signed grants as of October 1st, 2016.
[19] The USA, China and Taiwan are mentioned as examples of EU global competitors in science.

inefficiencies. In spite of the benefits of coordination, almost 90% of R&D budgets are spent nationally without coordination across countries".[20]

FET's goals appear to reflect the abovementioned needs, which, in general terms, can be considered to have remained relevant to date. In particular, those of (1) turning Europe's excellent science base into a competitive advantage by uncovering radically new technological possibilities (support for outstanding research, particularly basic and frontier research under FET, has considerably increased, and emphasis is put on its multidisciplinary character as an important driver of ground-breaking discoveries), and (2) make the EU the best place for collaborative research and innovation in future and emerging technologies – including the overall aim to "play an active and catalytic role in stimulating new thinking, new practices and new collaborations"[21]. A dedicated case study prepared as part of the CARSA report found that FET-projects involve high-tech research-intensive SMEs and generate innovation eco-systems by spreading new ideas, methods, approaches or technology in the industrial R&D community.

FET Flagships represent large and strategic efforts on grand interdisciplinary science and technology challenges having the potential to deliver transformational impacts on science and technology and substantial benefits for European competitiveness and society (see Commission Staff Working Document[22]). They bring together the necessary resources and partners to move up promising emerging technologies along the TRL scale during their 10 year duration. They aim at bridging the gap between European excellent science and innovation. They are expected to coordinate efforts at European, national and regional levels contributing thus to address the deficiencies in trans-national coordination of R&I funding in their specific domains. The Flagships Panel confirmed the continuing strategic relevance of the Flagship instrument for Europe's research and innovation as part of Europe's overall Research and Innovation Strategy and strongly endorses the thinking underlying the Flagship.

The expert panel's report offers further insights in relation to relevance. It claims that, at the level of DG CNECT and the related ICT domain, very high priority has been given to the future of digital computing. Europe has called for a knowledge society, which has to be supported by digital infrastructures and functionalities. Therefore, it concludes, 'it is a must for Europe to position itself at the forefront of « beyond Moore » or « beyond silicon » solutions'.

In this respect, the panel of experts, in its report, welcomes the programmes on HPC, Quantum computing and Graphene as well as some aspects of the Human Brain Project, which are related to the future of computing. Furthermore, even some biological material such as Stanford's biological transistors can be of some use as well as photonics or optical based technologies. Based on these new materials and technologies, new types of algorithms (e.g. probabilistic algorithms) are to be explored, which may help reduce the complexity of classic deterministic computing. The same goes for new programming methods related to the new materials (e.g. quantum device programming). The current dispersal of approaches and solutions may however, according to the panel, 'lead to an overabundance of proposals in one domain alongside a lack of proposals in other

[20] http://ec.europa.eu/research/horizon2020/pdf/proposals/horizon_2020_impact_assessment_report.pdf
[21] *Proposal for a COUNCIL DECISION establishing the Specific Programme Implementing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020) /* COM/2011/0811 final - 2011/0402 (CNS)* http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52011PC0811
[22] *SWD(2014) 283 final: http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=6812*

domains while not reinforcing each approach by experience gained in others. Nowadays, nobody knows what will be the future of computing in 10 to 15 years.'

The panel's report adds that the HPC initiative seems to strike the right balance between the development of the technology for future exascale computers and the development of applications. However, new computing methods that are very demanding in terms of computing power, such as Big Data and machine learning, do not appear to be sufficiently linked to the HPC initiative.

B.3.1.2. The relevance of FET to address European objectives

FET responds to the following main political drivers of the Commission:

Disruptive and Open Innovation: As stated in a 2014 study for the European Parliament, 'To remain at the forefront of international developments, it is important to strengthen and revitalise the European industrial base'.[23] Europe thus needs a modernised industrial base supported by cutting-edge key enabling technologies, and more companies that produce breakthrough innovations that are radical, disruptive, capable of rapid scale-up, and ready for expansion in new and global markets. Open innovation and cross-industry innovation can help achieve these goals.

Digital Single Market (DSM) – Digitising European Industry: The European society stands on the brink of a new industrial revolution, driven by technological breakthroughs such as the Internet of Things, cloud computing, artificial intelligence, big data analytics, robotics and 3D printing. The EU's Digital Single Market (DSM) Strategy, which was adopted in May 2015, seeks to bring these technologies to Europe's industry and society.[24] For many years FET has been spearheading the technology research for High-Performance Computing (HPC) and Quantum Technologies, two cornerstones of the DSM strategy[25]. FET seeks to further capitalise on European research excellence to achieve European leadership in both these future and emerging digital technologies, by:

- Achieving European independence and capacity for high-performance computing as a strategic resource for digitising European industry and society.[26][27]

- Capitalising on European Excellence in quantum technologies for a radical future ICT, driven by an emerging European quantum industry with global standing.[28]

The CARSA study justifies the relevance of FET-funded activities by the challenges being faced by the European Union: as President Juncker has recently indicated[29], the aim

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[23] *http://www.europarl.europa.eu/RegData/etudes/STUD/2014/536282/IPOL_STU(2014)536282_EN.pdf*

[24] *See the DSM strategy on digitising the European industry, http://europa.eu/rapid/press-release_IP-16-1407_en.htm*

[25] *European Cloud Initiative - Building a competitive data and knowledge economy in Europe (COM(2016) 178 final) http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=15266*

[26] *Staff working document on Implementation of the Action Plan for the European High-Performance Computing strategy, SWD(2016) 106 accompanying COM(2016) 178 http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=15269*

[27] *The European Council of 28 June 2016 in its conclusions called for "swift and determined progress … to create the right conditions for stimulating new business opportunities by … coordinating EU efforts on high-performance computing. In this context the European Council looks forward to the launch of an important project of common European interest in this field;" (http://www.consilium.europa.eu/en/press/press-releases/2016/06/28-euco-conclusions/)*

[28] *Staff working document on Quantum Technologies, SWD(2016) 107 accompanying COM(2016) 178 http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=15270*

is to modernise Europe and to invest in the EU's digital future in the following years. The current aim to create a Digital Single Market also reinforces this consideration. In addition, the study highlights the relevance of these activities in light of the need to continue creating Pan-European technical solutions, for example with regard to connectivity goals[30]. These efforts can only be achieved at EU level, by further integrating different actors of the value chain (private, public and academia) and benefiting from multidisciplinary cooperation to achieve research excellence, which is not possible at national level. EU level action in this respect is also justified, according to the study, on economic grounds, as ICT are important enabling technologies that, if developed on a European scale, can help stimulate economic and industrial activity across the continent.

Furthermore, it can be argued that FET is in line with the *three O's* Strategy of Commissioner Moedas:

- **Open *Innovation*:** through its collaborative spirit, interdisciplinarity, and stimulation of a broad and diverse mix of stakeholders with particular attention to early innovation steps in FET Open and Proactive, and to further bridging the gap between excellent science and innovation in FET Flagships that mobilise the necessary efforts to do so.
- **Open *Science*:** through its contribution to open-data, digital science and innovation, and the European Science Cloud. Survey results from the CARSA study[31] suggest that, according to project coordinators, open science principles were applied in a majority of projects (all Pillars). The principles most commonly applied were related to open access (of research publications and data). 82% of project coordinators responded that open science principles were being applied in their project, with open science defined as doing science in an open and collaborative way, sharing research results as much as possible.[32]
- **Open *to the world*:** by welcoming participation from across the world, by benchmarking itself against the best, and by the active collaboration with relevant large scale initiatives worldwide, e.g. in the context of the FET Flagships; e.g. the HBP collaboration with the US Brain initiative and the Japanese Brain/Mind project.

B.3.2. Flexibility to adapt to new scientific and socio-economic developments

Throughout previous framework programmes, FET has provided the European ICT communities with the capacity to look far ahead to technologies to come. Successive FET calls had explored new ideas early on, and identified and matured promising ones,

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[29] Speech by President Jean-Claude Juncker to the plenary session of the European Parliament on the result of the referendum in the United Kingdom (Brussels, 28 June 2016)
[30] President Juncker. State of the Union 2016: Commission paves the way for more and better internet connectivity for all citizens and businesses. (Strasbourg, 14 September 2016)
[31] Survey run between March and September 2016. Three separate questionnaires used: one for participants (576 responses out of 1449 surveys sent), one for coordinators (462 responses out of 681) and one for a non-participant 'control group' (471 out of 1750 including returned e-mails). The coordinator and participant surveys were launched 4 July 2016. According to the agreed 3 week schedule, the surveys were closed on 25th July, Regarding the non-participant survey, the contractors provided the Commission with the link and suggested email to send out, as contact details of the unsuccessful applicants could not be shared due to confidentiality reasons. The survey was launched on July 26th 2016 and closed on August 22nd, running for a slightly longer period to take into account the summer break.
[32] 11% (48 projects) reported that the project was not applying these principles; 7% (31 projects) did not know.

both in terms of substance and in terms of building the multi-disciplinary communities engaged with them. Intelligent robotics, Internet of things, bio- and neuro-morphic computing and simulation, soft robotics, complex systems science, cognitive computing, secure quantum communication, neural prosthetics, brain-computer interfaces, nano-optomechanics, spintronics and advanced photonics – these are, according to the relevant units at DG CNECT, but some of the areas that are driving innovation today in Horizon 2020 and in which FET has supported pioneering ground work.

A key dimension of relevance has to do with the ability of FET-funded research and innovation activities to continue to respond to current / evolving economic and societal needs. Thanks to its essentially open and non-prescriptive nature, FET can adapt to the rapidly changing technological and scientific scene as well as to changes in the wider socio-economic or political spheres. Research proposals tend to be less constrained by policy objectives set out in a Work Programme established years earlier, as can be the case in other parts of Horizon 2020, and as such can target topical issues using the latest scientific and technological approaches.

FET Open is explicitly non-topical and non-prescriptive in order to allow for new ideas, whenever they arise and wherever they come from, within the broadest spectrum of themes and disciplines. It actively seeks to promote new future scientific knowledge and technologies.

FET Proactive focuses on the maturing process of novel areas and themes, by working towards structuring emerging communities and supporting the design and development of transformative research themes. The cluster-based structuring process concerns emerging new areas that cannot yet be included in industry research roadmaps. To do so, it notably follows selection criteria that take into account excellence in science-driven research towards future technologies, potential for creating a critical mass and impact on science and technology.[33]

FET Flagships are 10-year endeavours. Their flexibility comes from the periodic (every 2 years) update of their strategic research agendas and technology and innovation roadmaps and the gradual focus on those technology options that have the highest potential to deliver innovation. The relevance of funding R&D on graphene and 2d materials and on the areas addressed by HBP (developing IT tools for a more collaborative approach to brain research, brain inspired computing technologies and new tool for brain medicine) is not questioned by current / evolving economic and societal needs. Their continued relevance has been confirmed by the Flagships panel.

Evidence of the relevance of the Horizon 2020 ICT topics in relation to future technology trends can be found in a recent study on the technologies that are expected to have significant potential to drive economic impact and disruption by 2025.[34] The criteria used to identify such technologies are:

- The technology is rapidly advancing or experiencing breakthroughs,
- The potential scope of impact is broad,

[33] *Proposal for a COUNCIL DECISION establishing the Specific Programme Implementing Horizon 2020 - The Framework Programme for Research and Innovation (2014-2020) /* COM/2011/0811 final - 2011/0402 (CNS) http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52011PC0811*

[34] *McKinsey (2013). Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey & Company, 05.2013.*

- Significant economic value could be affected, and
- Economic impact is potentially disruptive.

Among the 12 technologies identified, a prominent place is given to (a) Mobile Internet, (b) Automation of knowledge work, (c) the Internet of Things, (d) Cloud technology, and, (e) Advanced robotics. Additive transformation, of which 3D printing is one form, is also expected to play a significant part in industrial production systems, with impacts on the costs and localisation of production and the potential for the recycling of raw materials to be systematic. These findings are consistent with those reported by other prospective studies[35] and can thus be considered as proxies for the future trends in ICT. The external study conducted by CARSA on behalf of DG CNECT highlights the important number of FET projects which, according to the results of a keyword-based content analysis of their abstracts, focus on these technologies. The CARSA analysis also identifies a number of gaps, however (see sections 4.3 and 4.4 below for further details on thematic orientation of projects).

B.3.3. Addressing specific stakeholder needs[36]

Specific approaches are foreseen in the context of FET for involving communities of stakeholders, stimulating new thinking, new practices and new collaborations. This is expected to be achieved by bringing together actors from science, technology and innovation, including, where appropriate, users - to the extent possible, from both public and private sectors. Research activities focus on the next generation of science and technology as well as on supporting emerging talent in the EU and worldwide. A key dimension is accessibility of research infrastructure to the research force.

Under FET Open, the focus is on cooperation of research actors with technology providers and other stakeholders – potential users of the new ideas/developments. It crucially seeks participation of new high-potential actors in research and innovation, such as young researchers and high-tech SMEs that have increased prospects of becoming the scientific and industrial leaders of the future.

As to FET Proactive, the emphasis is on moving away from collaborations between a small number of researchers towards clusters of projects that each address aspects of a research theme and facilitate the exchange of results. The FET Proactive call reflects the outcome of two public consultations that aimed at identifying research orientations. Further inputs came from the FET Open portfolio and from ongoing proactive initiatives. All European Technology Platforms were invited to contribute as well. An inter-DG working group within the European Commission and the FET Advisory group took part in the final selection of the topics for the calls (3 for WP2014-15 and 10 for WP2016-17, excluding HPC).

Regarding FET Flagships, the bold investments they represent cannot be carried out alone by the Commission or any single Member State. It requires establishing a close link between related activities at European, national and regional levels and ensuring a mutual reinforcement from the Commission and the Member States and Associated Countries of Horizon 2020, of the research activities that contribute to the Flagships.

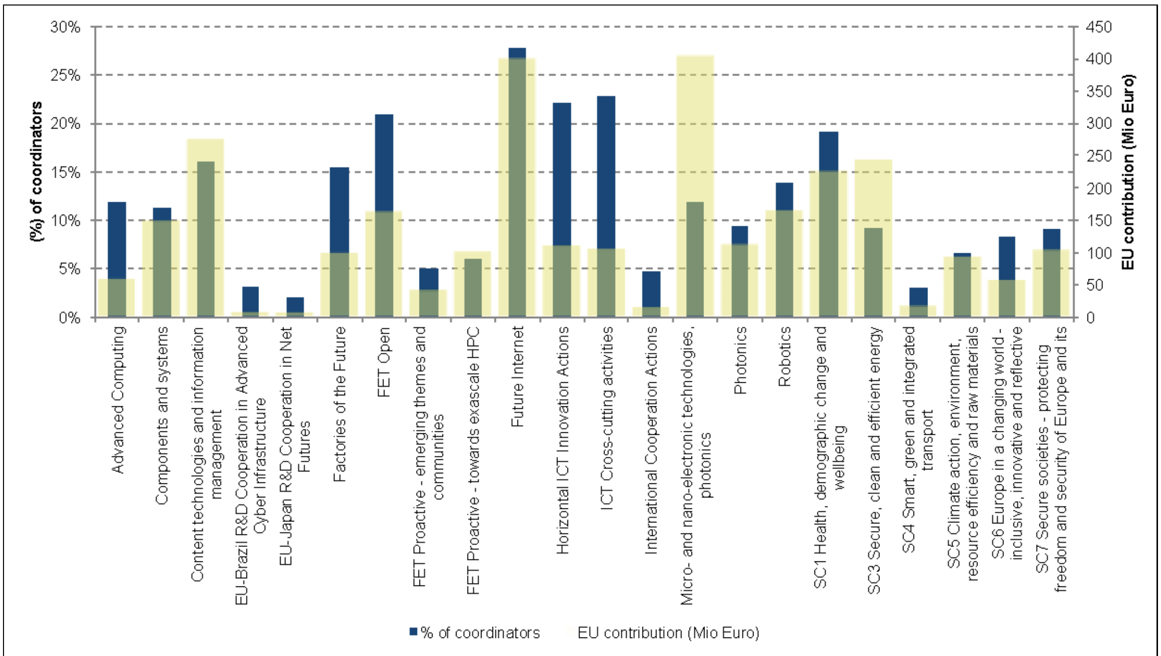
[35] *Iincluding ESPAS (2015) and Gartner Technology Predictions, to be found in:* *http://www.gartner.com/technology/topics/trends.jsp*
[36] *This section draws on: CARSA (unpublished). Support study for the Interim Evaluation of Horizon 2020 - DG CONNECT Activities.*

MS/ACs are therefore specific stakeholders with whom the Commission needs to engage in a continuous dialogue. To address their needs, a dedicated body, the Board of Funders (BoF)[37], has been established in September 2015 and met 3 times in 2016. It brings together the main funders of HBP and Graphene, namely representatives from the MS/ACs and the Commission with the purpose of programming activities in support of the Flagships. The main role of the BoF is to discuss and possibly plan the financial support to the Flagships.

The Flagships panel concluded, however, that there is a need for better balance between investment in research and development in a broad sense, as well as for a better match with industrial needs. There is room for improving alignment in this respect (by deepening the understandings of existing industries as well as of opportunities for new entrants to disrupt existing markets).

The survey carried out by CARSA (not covering FET Flagships) notably sought to gain a better understanding of the extent to which FET is addressing stakeholders' needs. To this end, project coordinators were asked to select the research areas that best correspond to their organisation’s research and innovation needs (maximum 3). Results are shown in Figure 40 below, alongside the EU contribution for each area (in EUR million). They show important differences across programme components. More than one-fifth of project coordinators declared that FET Open was the most relevant area to their organisation’s research and innovation needs. This is to be compared to about 6-7% in the case of FET Proactive. These findings remain largely unchanged for organisations that consider themselves as being EU or national leaders in their respective scientific and technological fields.

Figure 40 - Most relevant research areas (% of coordinators selecting a research area) and EC budget contribution in each research area



Source: CARSA.

[37] *https://www.flagera.eu/about/policy-context/board-of-funders/*

It ought to be noted that nearly one-third of the surveyed coordinators and participants (all pillars) stated that they could identify topics not covered by Horizon 2020. An overview of such topics is provided in Table 16.

Table 16 - Analysis of topics indicated by coordinators and participants not to be included in topics of calls under Horizon 2020 DG CONNECT Activities

Category of topics	**Description**	**Example**	**Total respondents citing items in this category (out of 287 respondents)**	***Total coordinator respondents citing items in this category (out of 144 coordinators)***	***Total participant respondents citing items in this category (out of 143 participants)***
Niche tools and techniques	This category includes field specific hardware and software tools and techniques in areas such as: - Health - Robotics - Biology - Electricity Storage	Computer assisted surgery Robotics in Agriculture	20%	23%	18%
Data-driven projects and concerns over data quality handling	This category includes wishes for more projects on using available data and handling it safely. Such projects were cited in areas such as: - Urban Design - Computing - Internet Security	Quantum cryptography Cross-domain data integration	19%	26%	11%
Basic research and not directly marketable research	In this category respondents expressed their desire to see funding being allocated to more projects that do not have a product that they can directly bring to market. Respondents in this category emphasized how important basic research is to bring real innovation and breakthroughs in Europe. This was particularly emphasized in the context of: - Academic research - Start-up research - SMEs research	Fundamental Physics Preclinical studies in neurodegenera tive diseases	15%	18%	12%
Health, environment and water related projects[38]	In this category, respondents expressed a desire to see more projects being funded on health and environmental issues.	Air pollution Environmental education	14%	8%	20%
Machine-learning, artificial intelligence and language acquisition research	This category includes projects in machine learning and artificial intelligence applicable to: - Robotics - Health¨ - Computing	Bain-computer interface Language Technologies	7%	7%	7%

Source: CARSA

[38] *Water related projects were reported as not appearing in calls in 2015-2016. Examples included energy management in water treatment plants, real time forecast and monitoring systems for integrated management of the whole water cycle and water management by itself, not embedded in agriculture, urban matters, or industry.*

The study conducted by the CARSA consortium also sought to investigate any systematic links between the topics that coordinators perceive as relevant vis-à-vis their organisation's research and innovation needs on the one hand, and the amount of funding allocated on the other hand. To do so, a relevance index was calculated - as the ratio between the number of coordinators selecting a given topic and the level of EC contribution allocated to that topic. The results of this normalisation process are shown in Table 17 - Ratio of most relevant research areas selected by the coordinators to EC budget contribution in each research area

Low values of the index would in principle indicate that a topic is funded in proportion to its relevance with regards to the needs mentioned by potential participants. High index values would indicate that a topic may receive limited funding with respect to its potential attractiveness as measured by coordinators' responses. This line of interpretation would indicate that there is a good match between allocated funding and participants' interests in a number of areas including FET. In contrast, allocated funding to areas such as horizontal ICT innovation actions and international cooperation actions appears to be low compared to the interest coordinators show for them. However, it must be noted that this approach does not necessarily reflect the optimal level of financial support.

Table 17 - Ratio of most relevant research areas selected by the coordinators to EC budget contribution in each research area

Research areas	Relevance Index
FET Proactive - towards exascale high performance computing	**2,6**
FET Proactive - emerging themes and communities	**5,3**
FET Open - novel ideas for radically new technologies	**5,6**
Micro-and nano-electronic technologies	1,3
SC3	1,6
Content Technologies and Information Management	2,5
Future Internet	3,0
SC5	3,1
Components and Systems	3,3
Robotics	3,6
Photonics	3,7
SC1	3,7
SC7	3,8
SC6	6,4
Factories of the Future	6,8
SC4	7,9
Horizontal ICT Innovation Actions	8,7
Advanced Computing	8,9
ICT Cross - cutting activities	9,4
International Cooperation actions	14,2
EU-Japan R&D Cooperation in Net Futures	14,4

EU-Brazil R&D Cooperation in Advanced Cyber Infrastructure	19,9

Source: CARSA.

The report by the panel of experts called upon by DG CNECT highlights two additional issues that ought to be considered when assessing FET's relevance: a) Technology innovation is not always the consequence of a scientific discovery, rather innovation generally originates from the desire to satisfy human, organisational, societal, or economical needs; and b) Industry may observe a need for substitution or enlarged capabilities of current technology and thus stimulate more fundamental research (e.g. the « multicore revolution » of chips in 2005/2006 was introduced by industry while academic research focused on grid computing). Therefore, although FET activities have the potential to keep closing the gap between research and innovation, there is scope for better coordinating the various stakeholders (Industry, Social Sciences, Academic Scientific community) in order to achieve a stronger alignment of basic/fundamental research with future needs.

FET Flagships have a specific role to play in addressing stakeholder needs since they create large collaboration opportunities across the participating organisations and beyond. They also contribute to triggering strategic discussions both with large scientific communities and with industry on new technology development and innovation opportunities for Europe and help recruit, educate and develop research talents in Europe. Furthermore, they create and help spread an innovation mind-set in Europe by implementing ambitious innovation management practices.[39]

B.3.4. Other issues related to relevance

Looking closer at the coverage of FET projects, according to findings from the CARSA study (which excludes FET Flagships) the largest number of FET proposals (67% of the total in 2014 and 59% in 2015) belongs to ICT/engineering/physics disciplines, while Social Sciences and Economics constitute a minor part of the proposals (3% in 2014 and 2% in 2015)[40]. Not surprisingly, the analysis of abstracts of the ICT FET project portfolio reveals that information sciences and information engineering is at the core of almost all projects. Only a limited number of projects can be assigned predominantly to Life Sciences or Physics. For 61% of all ICT-related FET projects it was possible to assign a second scientific discipline (whereof 24% relates to Life Sciences and 13% to Physics).

FET Flagships are in turn highly multidisciplinary; the effort in HBP Flagship is split between ICT and life sciences and the Graphene Flagship involves many disciplines including ICT, physics, chemistry, material science, engineering, life science and many application areas e.g. aeronautics, biomedical, composite materials.

Another interesting finding presented in the CARSA study has to do with the characterisation of projects within each Horizon 2020 pillar. Projects under FET Open and FET Proactive are, according to that study, clearly aimed at creating new knowledge and competences (19.1%, as compared to 8.2% in LEIT ICT and 6.3% in Societal

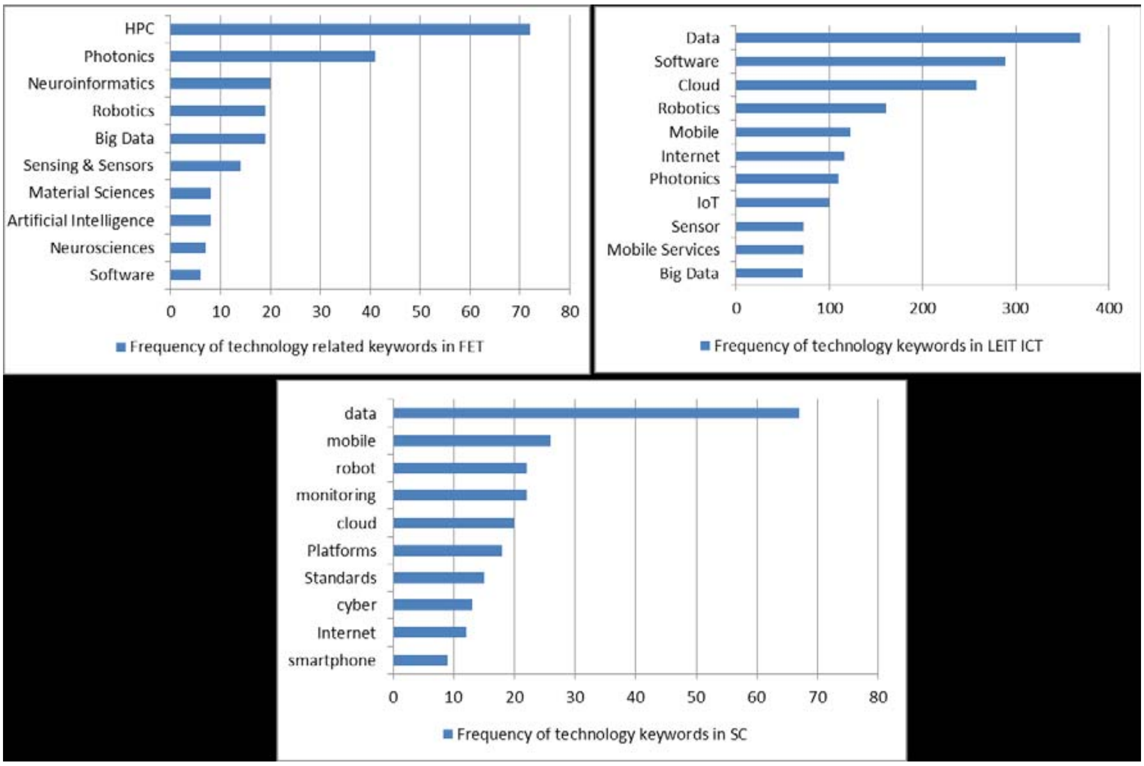
[39] *https://ec.europa.eu/digital-single-market/en/news/fet-flagships-lessons-learnt*
[40] *Quoting figures from REA.*

Challenges[41]). Excellent Science projects are also characterised as having higher technological risk than projects within the other two pillars.

Project objectives and thematic orientation can also provide an indication of relevance and potential results (i.e. also linked to effectiveness).

As shown below, the analysis of abstract shows a strong focus of FET projects (FET Open in particular) on high-performance computing, photonics, neuroinformatics, robotics and big data analytics, whereas e.g. software development ranks comparatively low.

Figure 41 - Technology-related keywords of FET, LEIT ICT and SC



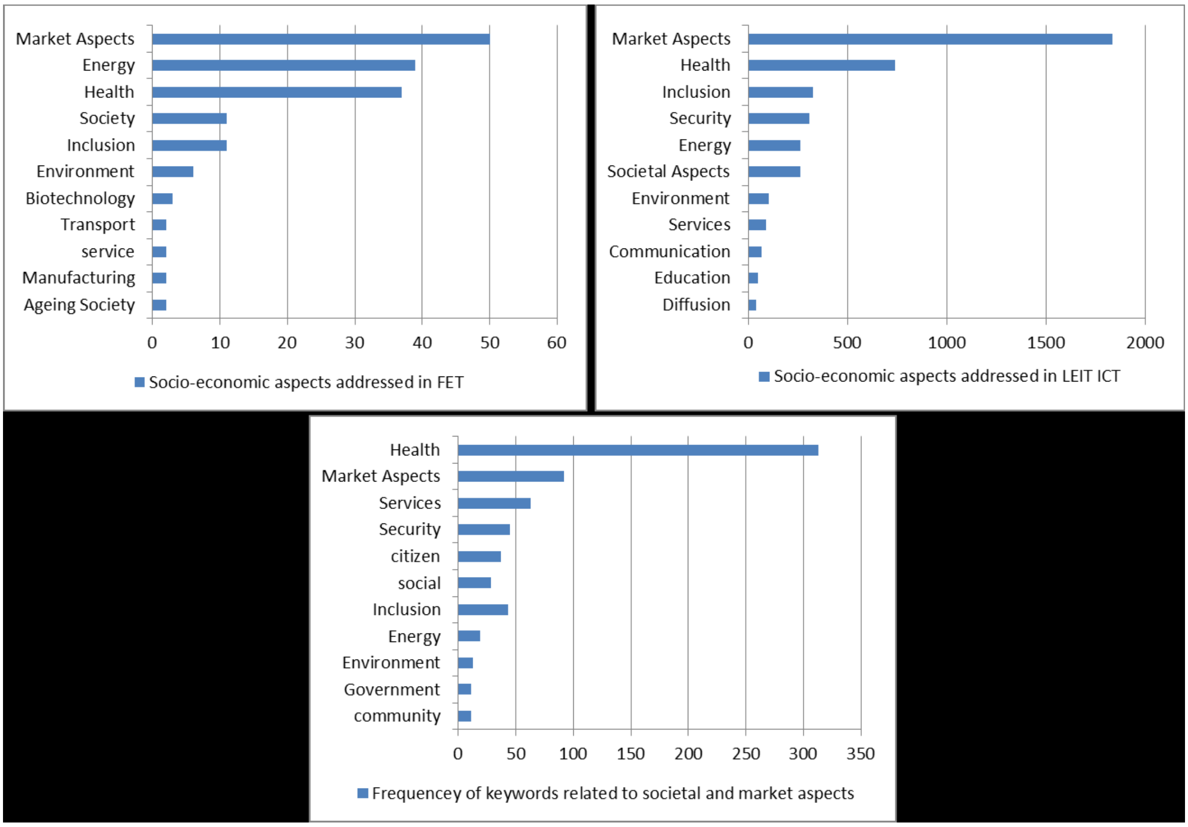
Source: CARSA.

As to socio-economic related keywords, the abstract analysis suggests a clear market orientation of projects in all pillars (including FET, where the development of new tools and an overall relevance for production and roadmaps for commercialisation are important orientations) and also their societal relevance. Energy efficiency, health (diagnostics etc.), and societal aspects also play a role in FET (see figure below for further details).

Overall, the analysis of thematic coverage of FET projects so far (with the possible exception of FET Flagships) suggests that there is room for further nurturing interdisciplinarity.

[41] *ICT-related parts only.*

Figure 42 - Socio-economic related keywords of FET, LEIT ICT and SC



Source: CARSA.

B.3.5. Lessons learnt/Areas for improvement

FET's structure and objectives seem to be in line with the EU's priorities relating to research and innovation, including those from recently adopted strategies such as the Digital Single Market and the three O's Strategy of Commissioner Moedas. Moreover, thanks to its essentially open and non-prescriptive nature, FET can adapt to the rapidly changing technological and scientific scene as well as to changes in the wider socio-economic or political spheres.

In addition, the focus of FET-funded projects seems to reflect many of the developments perceived as determining the future trends in ICT. This is particularly the case of high performance computing (HPC), which can be considered a key enabler, as well as photonics, graphene and 2D-materials, robotics, big data analytics and neuroinformatics.

More than one-fifth of project coordinators surveyed declared that FET Open was the most relevant area to their organisation’s research and innovation needs, compared to about 7% for FET Proactive. Nearly one-third of the surveyed coordinators and participants (all pillars) mentioned topics that, while being of relevance to their needs, were not covered by Horizon 2020; e.g. computer-assisted surgery, cross-domain data integration and fundamental research with no immediate market venues (for instance, in physics and neurodegenerative diseases).

The Flagships Panel also confirmed the continued strategic relevance of the Flagship instrument for Europe’s research and innovation as part of Europe’s overall Research and Innovation Strategy.

Although under its current design FET has the potential to keep closing the gap between research and innovation, there is scope for better coordinating the various stakeholders (industry, social sciences, academic scientific community…) so as to ensure a stronger alignment of basic/fundamental research with future needs. In the same vein, the current dispersal of approaches and solutions may result in imbalances in the number of proposals across topics and fail to promote cross-fertilisation.

B.4. EFFECTIVENESS

As of 1 October 2016, no FET projects had been completed yet. It is thus clear that the measurable output at this stage of the programme implementation is therefore very limited.

Desk research carried out for the CARSA study confirmed that it is still early to reliably assess the potential impacts of successful projects in Horizon 2020, as many of the Horizon 2020 projects are not mature enough yet. However, survey and case studies findings, as well as results from the abstract analysis provide information on the intended and/or foreseeable effects of FET-funded projects.

B.4.1. Short-term outputs from the programme

Below is a summary of the short-term outputs that can be reported based on information provided by project participants (as of 1st October 2016).

Leveraged funding

The maximum rate of reimbursement of eligible costs identified in the Work Programmes 2014-17 is 100% for Research and Innovation Actions (which account for the bulk of those funded under FET). Direct crowding in of funding has therefore been limited so far (EC contribution of EUR 479.3 million compared to total participant costs of EUR 483.4 million).

As to the cPPP on HPC, which is partly funded by FET Proactive, an initial assessment of the leverage on private effort[42] covering the period 2012-2014 points to an overall private investment amount of EUR 390 million p.a. with a leverage factor of ~3.5-4 (counting national as well as EU funding).

Publications

438 publications have been generated by FET projects so far, of which 316 peer-reviewed publications, 63 in conference proceedings/workshops, 5 chapters in books, 2 books/monographs, 6 thesis/dissertations and 46 other publications. As discussed in section 3, in Horizon 2020 the increased attention to scientific and technological excellence, as far as FET is concerned, has translated into specific Key Performance Indicators (KPIs) for high impact publications and public-private co-publications, the former for FET and ICT in Societal Challenges and the latter for LEIT-ICT and ICT in Societal Challenges.

For the two FET Flagships, the first Horizon 2020 projects only started in April 2016. Data for publications relates to the 2.5 year ramp-up phase funding in FP7 with 782 peer-

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[42] *HPC PPP report 2014.*

reviewed scientific publications for Graphene and 272 for HBP. The difference between the two Flagships mainly reflects the fact that a large part of the HBP activities were devoted to the specification and development of the first prototypes of the six ICT platforms HBP publicly released in March 2016.

Responsible Research and Innovation and gender

Moreover, FET has played a positive albeit modest role in the promotion of Responsible Research & Innovation (RRI) across Horizon 2020, as suggested by the fact that, in nearly 8% of projects (7), citizens, civil Society organisations and other societal actors contributed to the co-creation of scientific agendas and scientific contents.

Regarding the gender dimension in research and innovation content, 55% (53) of EC funded projects have so far included a sex and/or gender analysis as part of their research or innovation activities.

Interdisciplinary collaboration and enterprise participation

FET is also an important instrument to support novel, interdisciplinary research with a clear vision of its application potential in mind. FET projects are thereby expected to contribute to the creation of innovation eco-systems by spreading the new idea, method, approach or technology into the industrial R&D community and thus help integrate research and innovation. To do so, FET supports basic science projects which may lead to new technologies with a disruptive socioeconomic potential. A more detailed analysis of FET's interdisciplinarity is provided in section B.6.1.3.

To achieve their ambitious objectives and technology development targets, each of the two FET Flagships seeks to foster synergies and establish collaboration across 100+ partnering organisations. The Flagships Panel recognises that, by bringing together researchers from different scientific disciplines and technology fields, the Flagships started creating an unprecedented level of collaboration and community building in Europe. For example, in March 2016, HBP released its six ICT Platforms, which are the core of the emerging HBP research infrastructure for brain research. This was the result of an extensive multidisciplinary effort involving more than 750 scientific collaborators and engineers from 114 institutions in 24 European countries.

Flagships have so far produced important results: 1,000 top-class scientific publications, 40 prototypes delivered, 2 spin-out companies created and more than 280 concrete collaborations with industry resulting in 10 new products in the marketplace and 48 joint patent applications. See Box 1 and Box 2 below for further insights.

Thanks to their long duration, Flagships enable the participating research groups to build up expertise and create durable links between academia and industry. For example, in the GRAPHENE Flagship, this is key for advancing technology through different Technology Readiness Levels and for completing value chains needed to achieving tangible societal and industrial impact.

Another important indicator of effectiveness is the participation of enterprises in FET-projects. Enterprises involved in FET projects are typically high-tech research intensive SMEs.[43] Enterprise participation in FET (about 14% as per October 2016 CORDA data)

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[43] In the project sample of the FET_TRACES impact assessment project, from which preliminary results can be quoted, there were 105 companies involved in a total of 224 projects or enterprise participation rate of 47%. This figure

tends to be lower compared to other parts of Horizon 2020. This is explained by the nature of FET's advanced research, which is generally undertaken by universities and research organisations.

Box 1 - Highlights from the Graphene Flagship[44]

- A way of producing large quantities of graphene by separating graphite flakes in liquids with a rotating tool that works in much the same way as a kitchen blender[45]. This paves the way to mass production of high quality graphene at a low cost.
- Demonstration that it is possible to interface untreated graphene with neuron cells whilst maintaining the integrity of these vital cells[46]. This result is a significant first step towards using graphene to produce better deep brain implants which can both harness and control the brain.
- Development of a small, robust, highly efficient squeeze film pressure sensor[47]. Pressure sensors are present in most mobile handsets and by replacing current sensor membranes with a graphene membrane they allow the sensor to decrease in size and significantly increase its responsiveness and lifetime.
- In February 2016 the Graphene Flagship presented the inaugural Graphene Pavilion at the Mobile World Congress (MWC), the world's largest gathering for the mobile industry with over 100,000 attendees and 2000 exhibitors in Barcelona, Spain. Over four days of non-stop activity, the Graphene Pavilion featured 12 companies and 12 research centres showcasing graphene-based demos and applications to a continuous stream of visitors, press and companies interested in seeing graphene at work in operational prototypes.
- The Graphene partner Grupo Antolin SA worked in collaboration with Roman Kayaks to develop an innovative kayak that incorporates graphene into its thermoset polymeric matrices. The use of graphene results in a significant increase in both impact strength and stiffness, improving the resistance to breakage in critical areas of the boat.
- Demonstration of high-performance photo detectors for infrared fibre-optic communication systems based on wafer-scale graphene[48]. This can increase the amount of information transferred whilst at the same time make the devises smaller and more cost effective.
- The Graphene partner Italian Institute of Technology (IIT), Italy and Italian luxury design company Momodesign have produced a motorcycle helmet that includes graphene technology.

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comprises the late FP6 period and the FP7 period for projects running until the end of 2014Multiple enterprise participation in projects has not been controlled for yet. The figure is hence preliminary.

[44] *http://graphene-flagship.eu/news/Pages/RampUp_Phase_Highlights_GrapheneFlagship.aspx*

[45] *Paton K.R., et al., Scalable production of large quantities of defect-free few-layer graphene by shear exfoliation in liquids. Nat. Mater. 13, 624 (2014).*

[46] *Fabbro A., et al., Graphene-Based Interfaces do not Alter Target Nerve Cells. ACS Nano, 10 (1), 615 (2016).*

[47] *Dolleman R. J. et al., Graphene Squeeze-Film Pressure Sensors. Nano Lett., 16, 568 (2016)*

[48] *Schall D., et al., 50 GBit/s Photodetectors Based on Wafer-Scale Graphene for Integrated Silicon Photonic Communication Systems. ACS Photonics. 1 (9), 781 (2014)*

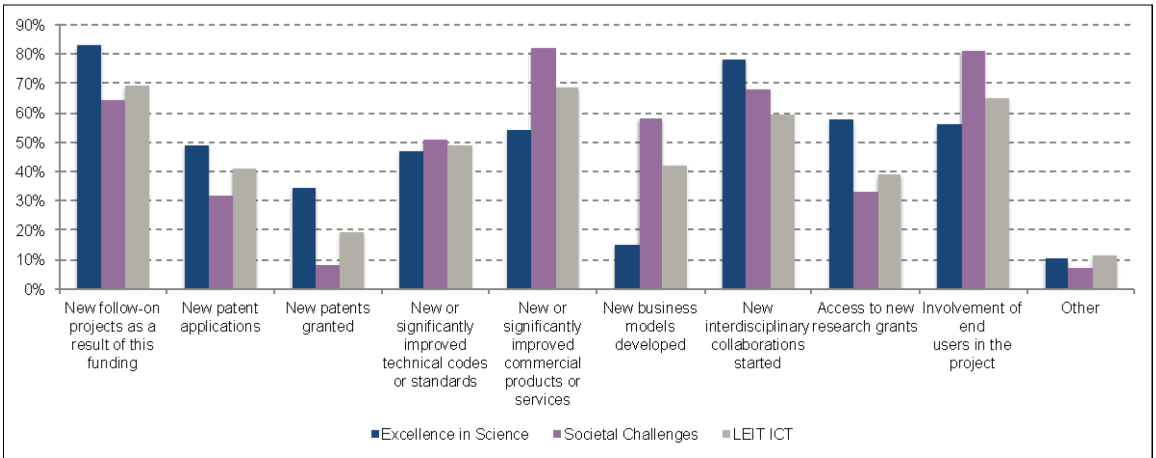
Box 2 - Highlights from the Human Brain Project Flagship

- Digital reconstruction of a crucial part of the rat brain: An international team led by researchers at EPFL produced a draft digital reconstruction of the microcircuitry of the rat neocortex. This is a significant accomplishment because it demonstrates that it is possible to make a successful digital approximation of brain tissue, and is an important first step towards digital reconstruction and simulation of the whole brain (Markram H et al. Cell 2015;163:1-37)
- European Institute for Theoretical Neuroscience (EITN): The EITN was established in 2014 as part of the HBP's theoretical neuroscience activities, and is operated under the Directorship of Alain Destexhe by a unit of the Centre National de la Recherche Scientifique in Paris. The EITN is a prime example of the HBP's openness to the broader scientific community - it creates strong interactions and invites new ideas and theories to the Project.
- On March 2016 HBP announced the release of initial versions of its six Information and Communications Technology (ICT) Platforms to users outside the Project. These Platforms are designed to help the scientific community to accelerate progress in neuroscience, medicine, and computing.

B.4.2. Expected longer-term results from the programme

Project coordinators surveyed gave an indication of the type and number of expected outputs of their Horizon 2020 project. A breakdown per Horizon 2020 pillar is presented in Figure 43 below.

Figure 43 - Expected output from the project by type of output and by pillar (% of coordinators who replied)



Source: CARSA.

Survey results indicate that, as a general rule, most project coordinators expect to have more extensive collaboration and involvement of users in research than in previous FPs. As can be seen from the figure above, the largest expected impact of Horizon 2020 ICT-related projects under the Excellent Science pillar (FET Open and FET Proactive only) relate to access to new follow-on projects as well as to new inter-disciplinary collaborative undertakings. Improved collaboration with the potential beneficiaries of the projects’ results (public bodies, citizens, etc.) is expected to a lesser extent. The development of open platforms and technologies applicable across countries is also part of the key expected results.

In the survey, project participants were also asked about the expected impacts of a specific Horizon 2020 project in which they were participating (from no impact to high impact). A relatively high proportion of project participants perceiving a fair or high impact of the Horizon 2020 project on their ability to access new knowledge and increase staff skills (over 90% of participants –all pillars combined- expected a high or fair impact on these areas). Other areas where a high impact was perceived include access to international technological/scientific networks (over 80 % of participants perceived a high or fair impact in this area). Collaboration with both developers and end-users were important areas where the projects were perceived to have an impact – over 40% of project participants who responded to the question indicated that the project was expected to have a high impact on their collaboration with developers and 43% indicated a high impact on collaboration with end-users. Overall 49% of participants expected a high project impact on their ability to innovate.

The reasons cited by participating organisations in the survey as having encouraged them to apply to Horizon 2020 calls can also be considered a useful proxy for expected results of the programme. Organisations participating in FET Open and FET Proactive projects tend to see access to research funding as the primary motivation (81% rated it as highly important) followed by the opportunity to develop new or improve existing relationships and networks (71%) and by the possibility to address specific scientific or technical challenges (61%).

B.4.3. Progress towards the overall Horizon 2020 objectives

B.4.3.1. Fostering excellent science in scientific and technological research

Strengthening of ERA is one of the high-level objectives of FP7 that is carried over to Horizon 2020. Although it is too early to draw conclusions about their effectiveness, a number of related actions and new initiatives (ERAnets, the pilot ERA Chairs initiative, “Teaming Competition for Excellence”, a more focused international cooperation strategy, etc.) have been introduced in Horizon 2020 to better serve the ERA's objective of promoting scientific and technological excellence of the EU.

Excellence levels of FET research is also underscored by the number of Nobel prize-winners who have been supported by FET[49].

Findings from the CARSA study suggest that open access (which is instrumental in promoting excellence) is reported as being consistently applied across the majority of projects. 88% of project coordinators (from DG CNECT Horizon 2020 activites in FET, LETIC ICT and ICT parts of Societal Challenges) indicated that the project was granting open access to scientific publications (in repositories or via open access publishers). 63% of project coordinators indicated that the project was granting open access to research data and/or re-using openly accessible research data.

[49] *https://ec.europa.eu/digital-single-market/en/news/fet-researcher-joins-list-nobel-prize-winners*

To achieve their objectives, each of the two FET Flagships mobilised synergies and established collaboration across 100+ partnering organisations. By bringing together researchers from different scientific disciplines and technology fields, according to the relevant unit at DG CNECT, the Flagships have started creating an unprecedented level of collaboration and community building in Europe.

The constant renewal of topics and research directions that results from FET allows new groups to emerge and learn from the best in Europe in order to create new nuclei of excellence and opportunities for entrepreneurship and smart specialisation. FET is the European reference for visionary technology and as such plays the inspirational role that actors such as MIT, Caltech or GoogleX play in the US and that are scarce in Europe.

The Flagships Panel view is that the excellent progress in the science related to development of graphene and related materials reported by the Graphene Flagship is underpinned by the engagement of many of the leading researchers and groups in Europe. The large number of very high quality scientific publications (during the FP7 ramp-up phase, i.e. Oct. 2013 to Mar. 2016) and clear progress on technology development illustrate the contribution to fostering excellent science.

It is also worth noting the role of FET Flagships in conveying visibility to EU investments in science and technology. The GRAPHENE Flagship has already held several international collaboration workshops with the USA, Japan and Korea, and has now put in place mobility funding grants for young researchers, in close collaboration with the US-NSF. HBP has also engaged in similar activities and participated in several international workshops. It is now launching concrete collaboration activities notably with the US BRAIN and the Canadian brain initiatives.

The expert panel's report highlights that 'mobilising a critical mass of basic research at the EU level has been the right approach to stimulate significant progress compared to the rest of the world and to remove potential roadblocks'.

Box 3 - Contribution to achievement and functioning of the ERA

- *More effective national research systems*

Member States (MS) support and contribution to the Flagships is essential for their success. They are participating in the Flagship governance structure, notably through the Board of Funders, where they are discussing with the EC the state of progress of the Flagships and programming activities in support of the Flagships. MS are supporting the Flagships either through relevant national programmes and/or through the FLAG-ERA ERANET joint calls. MS have or are planning to have national activities supporting the Flagship roadmaps. The Flagships Panel expects that these coordination activities will contribute to make the overall national research systems more effective in supporting the strategic areas addressed by FET Flagships

- *Optimal transnational co-operation and competition*

The Flagship ERA-NET contributes, through its joint calls and coordination activities, to improve transnational co-operation and competition.

B.4.3.2. Boosting innovation, industrial leadership, growth, competitiveness and job creation

As identified in the case study prepared in the context of the CARSA report, FET projects involve high-tech research intensive SMEs and are thus well suited to generate innovation eco-systems by spreading new ideas, methods, approaches or technologies into the industrial R&D community.

Moreover, survey results suggest that innovation is supported in an adequate manner and is, as a matter of fact, one of the main reasons for participation in Horizon 2020. 70% of project coordinators (all pillars combined – DG CNECT activities only) expected that the project in which they were involved would provide either substantial or radical innovation. In the same vein, when asked about their motivations to participate, more than 60% of surveyed participants in Excellent Science projects indicated that addressing specific scientific or technical challenges was of high importance. This was also the case for the exploration of new scientific fields with multidisciplinary approaches (62%).

The partners in the Graphene Flagship have generated large numbers of high quality scientific publications. These, alongside patent applications filed, provide a platform for innovation and economic impact in Europe. When combined with future collaborations at a European level in areas such as standards, standardised manufacturing and quality control methods, and health and safety, the innovation impact could be significant. The exent of this impact will to a significant extent depend on industrial application and exploitation within Europe as well as on industry participation. The same applies to the Human Brain Project, even though it is still at an earlier stage of development.

Concerning the contribution of FET to the Digital Single Market (DSM) activities of the European Commission, it can be said that, especially the FET projects which are explicitly targeting ICT-topics like software and hardware development, big data analytics, machine learning, artificial intelligence, robotics, etc. are of relevance and support to the aim of the EC to become the leading research area and market for digital technologies. Although ICT-related topics seem to be less present in Horizon 2020 FET projects compared to previous framework programmes due to the thematic opening in Horizon 2020, major breakthroughs in ICT can be expected from the FET programme. The long list of success stories of FET projects supports this assumption[50]. Furthermore, as FET-projects are collaborative and interdisciplinary projects, communication and knowledge exchange using digital infrastructures is vital. The tight link between science and engineering, the policies of openness and the use of digital platforms of communication, massive data processing and simulation characterise FET as well as the DSM.

Based on the limited information available, it can therefore be argued that FET activities have the potential to contribute to the attainment of this programmatic objective.

B.4.3.3. Addressing the major societal challenges

Based on preliminary analysis of intended project objectives and funding allocation, FET-funded activities have the potential to help address most of the Societal Challenges. Close monitoring of implementation and results will however be required in this area.

[50] *See for example the FET newsletter 2016 at: https://ec.europa.eu/digital-single-market/en/news/fet-newsletter-edition-summer-2016.*

The abstract analysis in the CARSA study indicated that Horizon 2020 ICT actions aiming to contribute to several Societal Challenges exist in all three Pillars. For instance, the analysis performed during the study indicated that projects in all Pillars refer to Societal Challenges. This finding is also linked to the findings presented in section 4 of this thematic annex, as it also shows a certain degree of internal coherence between priorities. Section B.6.1.3 also presents relevant information in this respect.

Moreover, addressing problems with a European or international dimension, which is a key aim of the Societal Challenge parts of the work programme, was identified by surveyed organisations as an important motivation for applying to Horizon 2020. 46% of participants in FET Open and FET Proactive projects who replied to the question attached high importance to this reason whereas 36% saw it as fairly important.

In terms of budget allocation, as discussed in section 3.3, sizeable shares of FET funding have been allocated, respectively, to sustainable development topics (EUR 40.5 million), climate related topics (EUR 74.7m) and, to a lesser extent, biodiversity related ones (EUR 2.6 million). This suggests a potential contribution of FET to at least Societal Challenges 2 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy) and 5 (Climate action, environment, resource efficiency and raw materials).

The PPMI study[51], in turn, provides an estimation of the share of projects within the different parts of Horizon 2020 that can be expected to have a wider impact on the Societal Challenges over the next ten years. These estimates are based on responses of project coordinators (a total of 16 in the case of FET) to a survey. Those for FET are presented below (Table 18).

Table 18 - Share of projects in Horizon 2020 sections which are expected to have a wider impact on the societal challenges in the next 10 years

	SC1	SC2	SC3	SC4	SC5	SC6	SC7
FET	33.3%	40%	57.1%	20%	52.4%	30%	25%
Horizon 2020 average	47%	29%	42%	33%	51%	39%	27%

Source: PPMI (2016).

Relevant examples of FET which can contribute to to addressing Societal Challenges are presented in Box 4 below.

Box 4 - Selected projects with potential contribution to addressing Societal Challenges

The **FLORA ROBOTICA**[52] (Project budget EUR 3.64 million) project is to create and explore a plant-robot-human ecology in the form of an architectural ensemble – a technologically enhanced social garden. It aims at elaborating and studying how plants can grow and develop through progressive and symbiotic guidance of a robotic system, and how such plant-robot-human ecosystem can be adaptive to the human environment and applied to architecture to form an entirely novel approach to the design of building

[51] *PPMI, Survey of a sample of project coordinators within the study 'Assessment of the Union Added Value and the Economic Impact of the EU Framework Programmes (FP7, Horizon 2020) (2012/S 144-240132), 2016.*

[52] https://ec.europa.eu/digital-single-market/en/blog/natural-plants-and-robots-are-building-our-future-cities-together; http://cordis.europa.eu/project/rcn/193769_en.html

and public spaces The long-term vision is the development of bio-hybrid plant systems that autonomously grow architectural features, such as a green infrastructure, and adapt to changing needs of humans.

The **A-LEAF** project seeks to respond to the world's challenge of finding new sustainable alternatives to fossil fuels. Our society has been using fossil fuels as a primary source of energy and as raw materials for synthesizing complex organic compounds with added value such as drugs, polymers or agrochemicals. The A-LEAF project aims to design, build and validate a device able to mimic this photosynthetic process as carried out by green plants. The objective is to achieve direct transformation of water and CO_2, through the action of sunlight, into oxygen and organic matter (e.g. methanol, methane). The organic products will then be used as fuels, extracting their stored energy from their recombination with oxygen back to the original feedstock (water and CO_2) in an environmentally neutral closed-cycle.

CResPace[53] (Adaptive Bio-electronics for Chronic Cardiorespiratory Disease – Project budget EUR 4.94 million) will pioneer disruptive technology for bio-electronic medicine to provide much needed therapies for cardiorespiratory and functional neurological disease. The technology implements small neural networks known as central pattern generators (CPG) to deliver fit-and-forget bio-electronic implants that respond to physiological feedback in real time, are safer, simpler, non-invasive, and will last a lifetime. By providing novel therapy for arrhythmias, heart failure and their comorbidities such as sleep apnoea and hypertension, CResPace will extend patients' life and increase quality of life.

B.4.4. Early success stories

In addition to initial achievements of the FET Flaghsips, which are presented earlier in this section, the FET-funded projects presented below were highlighted as promising in the 2014 Horizon 2020 Monitoring Report.

Greenflash[54] (FET-HPC Core Technologies, Programming Environments and Algorithms for Extreme Parallelism and Extreme Data Applications - Project budget: EUR 3.76 million) – *"Green Flash, energy efficient high performance computing for real-time science"* started in October 2015 and has a duration of 3 years The main goal of Green Flash is to design and build a prototype for a Real-Time Controller (RTC) targeting the European Extremely Large Telescope (E-ELT) Adaptive Optics (AO) instrumentation. To build this critical component of the telescope operations, the astronomical community is. Green Flash, will address technical challenges, emerging from the combination of high data transfer bandwidth, low latency and high throughput requirements and propose technical solutions and assess enabling technologies through prototyping and assembling of a full scale demonstrator to be validated with a simulator and tested on sky.

GRACeFUL[55] (FET-ProActive, Global Systems Science – Project budget: EUR 2.4 million) – "*Global systems Rapid Assessment tools through Constraint FUnctional Languages*" started in February 2015 and has a duration of 3 years. The making of policies coping with Global Systems is a process that necessarily involves stakeholders

[53] http://cordis.europa.eu/project/rcn/206180_en.html
[54] CORDIS reference: http://cordis.europa.eu/project/rcn/197543_en.html ; website http://greenflash-Horizon 2020.eu
[55] CORDIS reference: http://cordis.europa.eu/project/rcn/193766_en.html ; website www.graceful-project.eu

from diverse disciplines, each with their own interests, constraints and objectives, where people play a central role and where the quest for solutions to a problem generally intertwines its very specification. This project lays the base for a Domain-specific Languages aimed at building scalable rapid assessment tools for collective policy making in global systems. Results are to be applied and validated for a specific problem case of Climate-Resilient Urban Design in the city of Dordrecht in The Netherlands, but the ambition is providing a general framework and approach applicable to several other Global Systems.

Abiomater[56] (FET-Open research projects – Project budget EUR 2.97 million) – "*Magnetically actuated bio-inspired metamaterials*" started in November 2015 and will be finished by October 2018: The project team, led by The University of Exeter, UK, will explore how magnetically controlled metamaterials – engineered materials with properties not found in nature – could be used to improve medical devices and implants, upgrading treatment options for patients. ABIOMATER will design materials with properties that can be switched remotely with a magnetic field. Pairs of interacting microscopic particles will be incorporated into elastic scaffolds, enabling mechanical and optical characteristics the material to be controlled magnetically. Using the magneto-elastic metamaterials, a suite of prototype devices for lab-on-a-chip systems will be developed, including fluidic micropumps, modifiable filters, tuneable optical devices and bio-compatible substrates with programmable strain fields.

B.4.5. Lessons learnt/Areas for improvement

It is still too early to draw conclusions on effectiveness. Information on the intended and/or foreseeable effects of FET-funded projects is however available.

Based on early data, the number of publications generated by Horizon 2020 projects can be expected to be higher than for FP7. It is also reasonable to assume that potential Horizon 2020 authors will have a stronger focus on high impact journals.

FET-funded projects are characterised by a strong focus on the creation of knowledge and competences as well as by high levels technological risk. They are thus expected to contribute to the creation of innovation eco-systems and thus help integrate research and innovation. Moreover, a number of related actions and new initiatives have been introduced in Horizon 2020 to better serve the ERA's objective of promoting scientific and technological excellence of the EU.

FET is one of the few programmes supporting research-driven high-risk/high-gain work in a context of ever increasing focus on close-to-market undertakings yielding visible results in the short term. Moreover, it promotes cooperation and thus contributes to the creation of new nuclei of excellence and opportunities for entrepreneurship and smart specialisation.

According to FET Flagship coordinators, the flagship's long duration allows to complete value chains and bring technologies to higher readiness levels. Their scale also enables economies of scale benefits in, e.g., dissemination activities and international contacts. It gives the Flagships the critical mass and visibility to approach organisations, public and

[56] *CORDIS reference: http://cordis.europa.eu/project/rcn/196975_en.html ; website http://blogs.exeter.ac.uk/abiomater/*

private, and make contacts that would not happen otherwise. It also enables launching activities that smaller projects would not be able to justify.

Regarding the promotion of Responsible Research & Innovation (RRI) across Horizon 2020, there is room for further enabling contributions by citizens, civil society organisations and other societal actors to defining scientific agendas and scientific contents relating to FET.

Participating organisations have reported that the most significant impacts expected to come out of FET-funded projects have to do with more extensive collaboration and involvement of users as well as access to follow-on projects and new inter-disciplinary collaborative undertakings. Given their stated objectives, FET-funded projects can also be expected to play a significant role in creating new knowledge and helping to develop high-risk innovative projects that can give the EU a competitive edge. Moreover, major breakthroughs in ICT can be expected from the FET programme. However, more information would be required with regard to patent applications as well as the attractiveness of FET-funded activities for non-EU individual researchers in order to assess effectiveness in these areas.

Despite promising initial findings regarding FET Flagships' innovation potential (e.g. regarding prototypes, launch of first commercial products, etc.) the Flagships panel indicates that there is need for further developing a relevant basis for industrial engagement both to leverage the potential inherent in the Flagships' achievements and to develop a shared understanding of market potential and the extent to which this can be realised by European industry.

FET projects, particularly those explicitly targeting ICT-topics have the potential to help achieve the EU's goal of becoming the world's leading research area and market for digital technologies. Indeed, communication and knowledge exchange using digital infrastructures are at the core of many FET projects, which also serve to develop links between science and engineering as well as digital platforms.

Addressing problems with a European or international dimension, which is a key aim of the Societal Challenge parts of Horizon 2020, was identified by most surveyed organisations as highly important in the context of their participation in the programme.

B.5. EFFICIENCY

B.5.1. Budgetary resources

The budget for FET under Horizon 2020 has tripled compared to FP7, to around EUR 2.5 billion (2014-2020). 40% of this was reserved for FET-Open. Since FET-Open's bottom-up and light process is rather labour intensive, it was outsourced to the Research Executive Agency, while management of the other schemes of FET (FET proactive and FET flagships) remains with DG CONNECT.

Despite this budget increase, the thematic opening of the programme from “ICT and neighbouring fields” to “all of science” seems to have led to a dramatic oversubscription of FET calls, especially of FET Open calls where the success rate in the first half of 2016 was well below 3%. Recent cuts in national research funding may have contributed to the dramatic increase of proposals for FET projects. The oversubscription in FET-Proactive is less dramatic, although some topics under FET WP2014-15 were also heavily oversubscribed.

According to the European Commission's unit in charge of FET, there are enough excellent submissions to absorb at least three times the currently available budget for FET Open.

FET-Open uses short 15-page proposals in a one-stage submission and evaluation procedure. The budget per batch has been gradually increasing (currently to EUR 84 million, up from EUR 39 million for the smallest batches in WP2014-15). This reflects the overall financial profile for FET in Horizon 2020, which is heavily backloaded. In order to address the oversubscription in FET-Open, the number of batches is expected to be reduced as of 2017 (WP update currently underway) to one per year so that more budget can be made available per batch and resubmissions are discouraged. There are also plans to reduce the indicative funding for FET-Open projects to up to EUR 3 million, instead of the current range of between EUR 2 million and EUR 4 million.

NB: Given the FET Flagships implementation based on Framework Partnership Agreements covering the whole of Horizon 2020 within which invitations to submit proposals are periodically addressed to the consortia, the notion of "success rate" is considered not to be applicable.

B.5.2. Programme's attractiveness

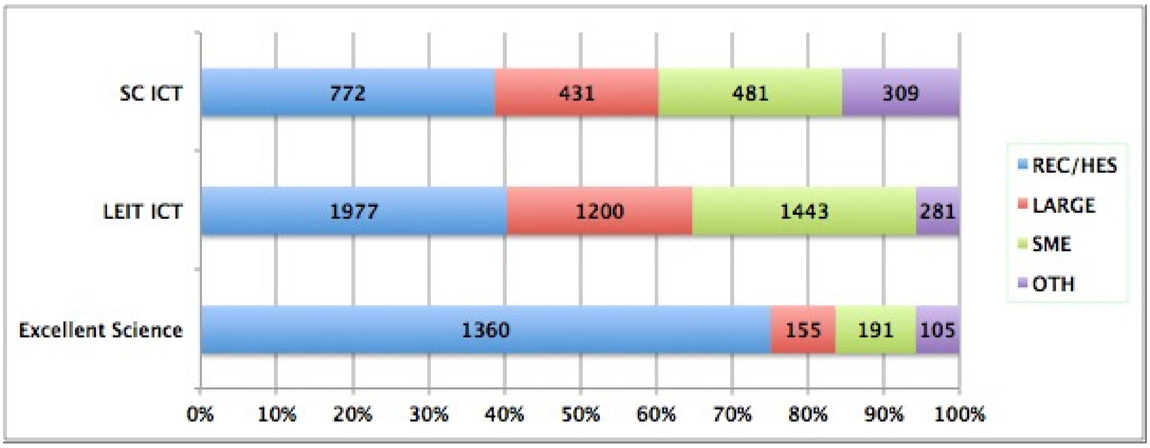
B.5.2.1. Mobilisation of stakeholders

.Within FP7, FET funded 2500 participations in 320 collaborative projects, for a total of EUR 825 million[57]. It has involved an estimated 8,000 to 10,000 thousand PhD students and postdocs in interdisciplinary collaborations across Europe. Interdisciplinary had become the hallmark of FET, with projects involving not only the ICT science and engineering disciplines but also fields as diverse as biology, medicine, material science, neuroscience, energy, music, economics, finance, and more.

A case study on participation patterns under Horizon 2020 has been carried out in the context of the CARSA study. It points out that participation patterns in ICT related fields by organisation vary with the level of emphasis put on innovation by the different types of organisations, as well as on their participation objectives. FET, for example, has a strong focus on basic research and is thus dominated by academic partners, whereas the share of the latter is significantly lower in either LEIT ICT or Societal Challenges (ICT parts). A comparative chart is provided in Figure 44 below.

[57] *http://ec.europa.eu/digital-agenda/en/fet-projects-portfolio*

Figure 44 - Participations per organisation type (DG CNECT Activities)



Source: CARSA.

Regarding newcomers' participation the study concludes, based on the limited number of newcomers from Universities or Research Centres (about 4% of total newcomers), that, for these participant categories, prior experience is an important prerequisite for participation. With respect to FET, it stresses the few opportunities available for newcomers and argues that this may be due to the fact that research networks have been formed through previous FP collaborations and previous FP experience is a prerequisite to be part of these networks. It adds, however, that it could be useful to carry out an assessment at a lower organisational level (e.g. University Departments, Institutes/Laboratories within Research Centres), which would enable to assess if new research teams, including those with non-ICT research focus appear under the traditional academic participant labels.

The HBP and Graphene Flagships, in turn, mobilise respectively 116 and 154 partners. The ERA-NET Co-fund FLAG-ERA coordinating the MS/ACs support to the Flagships counts 39 funding agencies from 26 countries in Europe and beyond (22 full members and 17 associate members). This level of mobilisation corresponds, according to the responsible unit at DG CNECT, to the one expected to fulfil the specific objectives of the Flagships.

Participants (including project coordinators) were asked about their level of satisfaction with various aspects of the administration and management of the programme. The majority of participants and coordinators declared themselves as being very satisfied or somewhat satisfied with most aspects. However, key dissatisfaction was expressed regarding aspects such as application procedures, proposal evaluation and selection and reporting procedures.

Specific areas of focus raised in the qualitative answers from the survey included suggestions related to simplifying the application procedure and proposal preparation. The application procedure was generally regarded as time consuming, especially when considering the relatively low chances of success. There was a net preference for two-stage applications with a shorter and less time consuming first phase, timely and useful feedback from the evaluators and a longer and more detailed second phase of applications for a small number of potentially successful applicants.

Reporting and feedback mechanisms were another key area of focus in the qualitative answers. The reporting process was described as too time consuming and not always aligned with the needs of the project, and the importance of being able to reach out to the project officer and not only the national contact points was also highlighted by respondents. ICT issues related to the online system and Horizon 2020 participant portal were a third area of focus. Examples of suggestions for improvement were included ensuring the information provided in the application was reflected in the online reporting tools, and there was interest in more collaborative online platforms for projects. The table below presents a breakdown of the relevant survey results by Horizon 2020 pillar.

Table 19 - Degree of respondent satisfaction with the administration and management of the programme by programme aspect (% distribution of participants within each pillar category)

Aspect of Horizon 2020		FET (Open and Proactive)	LEIT ICT	Societal Challenges (ICT parts only)
Process to define the work programme	Very dissatisfied	3.1%	3.3%	3.3%
	Somewhat dissatisfied	17.4%	16.7%	10.9%
	Somewhat satisfied	57.4%	51.4%	42.9%
	Very satisfied	10.6%	19.8%	22.8%
	Do not know	11.6%	8.8%	20.2%
Application procedures (call publication, information etc.)	Very dissatisfied	0.0%	1.6%	1.0%
	Somewhat dissatisfied	3.1%	6.6%	9.6%
	Somewhat satisfied	55.6%	48.8%	46.0%
	Very satisfied	36.7%	41.3%	34.8%
	Do not know	4.7%	1.7%	8.5%
Quality of additional information/clarifications on call objectives	Very dissatisfied	0.0%	2.5%	2.8%
	Somewhat dissatisfied	7.0%	12.8%	10.0%
	Somewhat satisfied	72.7%	58.5%	52.1%
	Very satisfied	12.0%	22.4%	19.8%
	Do not know	8.3%	3.8%	15.3%
Proposal evaluation and selection	Very dissatisfied	3.1%	6.2%	4.2%
	Somewhat dissatisfied	26.2%	12.3%	17.5%
	Somewhat satisfied	47.5%	49.2%	40.9%
	Very satisfied	11.6%	28.4%	26.1%
	Do not know	11.6%	3.9%	11.2%
Grant procedures	Very dissatisfied	4.7%	3.0%	1.0%
	Somewhat dissatisfied	6.0%	7.2%	6.2%
	Somewhat satisfied	53.9%	51.4%	42.2%
	Very satisfied	30.8%	34.8%	40.0%
	Do not know	4.7%	3.6%	10.6%
Monitoring procedures	Very dissatisfied	3.9%	2.8%	1.3%
	Somewhat dissatisfied	15.5%	9.3%	6.3%
	Somewhat satisfied	51.3%	54.0%	41.8%
	Very satisfied	10.0%	23.5%	30.6%
	Do not know	19.4%	10.4%	19.9%
Reporting procedures	Very dissatisfied	5.7%	2.6%	1.9%
	Somewhat dissatisfied	11.3%	10.8%	6.8%
	Somewhat satisfied	53.4%	56.8%	42.9%
	Very satisfied	10.0%	21.0%	30.7%
	Do not know	19.6%	8.8%	17.6%

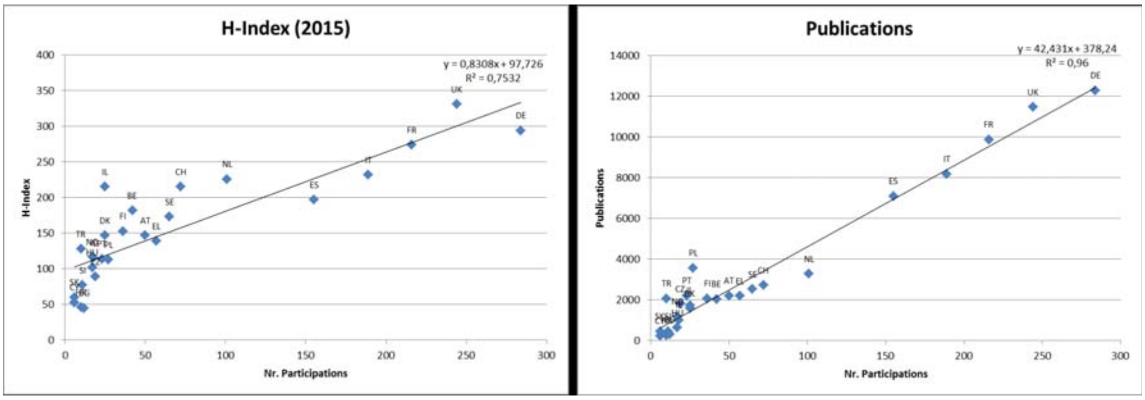
Source: CARSA.

FET Flagship coordinators reported that a very large consortium creates difficulties both for its internal management and with Commission's processes and IT. At the same time, the share of management costs in the Graphene Flagship has been kept at a low level during the ramp-up phase, and was 1.5% below the average management costs for FP7 projects. In addition, they reported that funding of the Flagships' Core Projects over a two-year cycle results in the consortia being involved in a constant bidding process with significant associated management and administrative costs.

B.5.2.2. Geographic dimension

Country participation patterns correspond to a large extent to the level of scientific excellence: Germany, the UK, France, Italy and Spain, which account for the largest share of participations, also exhibit a high H-Index. Among EU-Member States, only the Netherlands and Belgium seem to have a lower participation rate than their H-Index[58] would suggest (see Figure 45 below).[59]

Figure 45 - Excellent Science (DG CNECT activities): Top 25 country participation



Source: CARSA.

As discussed in section 3, participation rates of EU-13 Member States (although with differences within that group) is lower for FET than for the Horizon 2020 average when ICT-related activities are considered. These initial results suggest that no major trend reversal regarding geographic participation is underway. To further promote convergence, the panel of independent experts commended the adoption of the Spreading Excellence and Widening Participation instrument but concluded that it is too early for a fully-fledged assessment thereof.

In addition, the analysis presented in the CARSA study presents interesting findings regarding co-operation activities with major industrial companies from third countries.

When considering the participation of companies from the United States, Japan, China, India and South Korea, the analysis of the Horizon 2020 ICT database reveals that direct participation from the US, Japan, China, Korea and India is marginal. As shown in the table below, total requested EC funding for participants from these countries at the time

[58] The h-index is an author-level metric that captures both the productivity and citation impact of the publications of a scientist or scholar: "A scientist has index h if h of his or her Np papers have at least h citations each and the other (Np − h) papers have ≤ h citations each" (Hirsch, 2005). All papers by a scientist that have at least h citations are called the "Hirsch core" (Rousseau, 2006). An h index of 5 means that a scientist has published five papers that each have at least five citations. An h index of 0 does not inevitably indicate that a scientist has been completely inactive: he or she might have already published a number of papers, but if none of the papers was cited at least once, the h index is 0." For countries, an h index of 5 means that this country has 5 researchers which each have at least published 5 papers that have yielded a minimum of 5 citations.

[59] Draws on CARSA study. The analysis refers to the Excellent Science pillar as a whole.

of writing summed up to EUR 753 155, of which 75% were allocated to Higher Education Institutions and Research Organisations. Large companies did not receive any funding and funding for SMEs was marginal.

Table 20 - Requested EC contribution from China, India, Japan, South Korea and United States, in EUR

	CN	IN	JP	KR	US	Total
LARGE	-		-	-	-	-
OTHER		-		146 500	-	146 500
REC/HES	-		153 750	15 000	389 905	558 655
SME					48 000	48 000
Total	-	-	153 750	161 500	437 905	753 155

Source: CARSA.

However, when looking at the presence of the major ICT companies from the five countries above (all pillars are considered), the following results are obtained:

- From the Top-20 Chinese ICT companies, only Huawei Technologies participated in Horizon 2020 ICT activities. The company participated via a subsidiary located in Germany. The requested EU contribution is 5 million Euros.
- From the Top-60 Japanese ICT companies, 8 (Fujifilm, Fujitsu, Hitachi, Murata, NEC, Sony, Tokyo Electric, Toshiba) participated in Horizon 2020 ICT activities via European subsidiaries. Total requested EU contribution is 14 million Euros.
- From the 5 listed Indian companies, 1 company belonging to TATA industries participated in Horizon 2020 ICT. The requested EU contribution was 280 thousand Euros.
- From the 11 listed South Korean companies, 1 company participated in Horizon 2020 ICT. Samsung Electronics participated via its UK subsidiary. The requested EU contribution is 3.2 million Euros.
- From the 128 listed US based companies, 14 participated in Horizon 2020 ICT via several EU based subsidiaries. The total requested EU contribution of these companies is 45.5 million Euros. IBM (15.9 million Euros) and Intel (9.6 million Euros) are the two most important US owned beneficiaries. Both companies are active in Horizon 2020 ICT via several national subsidiaries.

In total, foreign owned companies located in the five countries mentioned above account for 68 million Euros worth of Horizon 2020 ICT funding. This sum is equal to 10% of total funding requested by large companies in Horizon 2020 ICT activities.

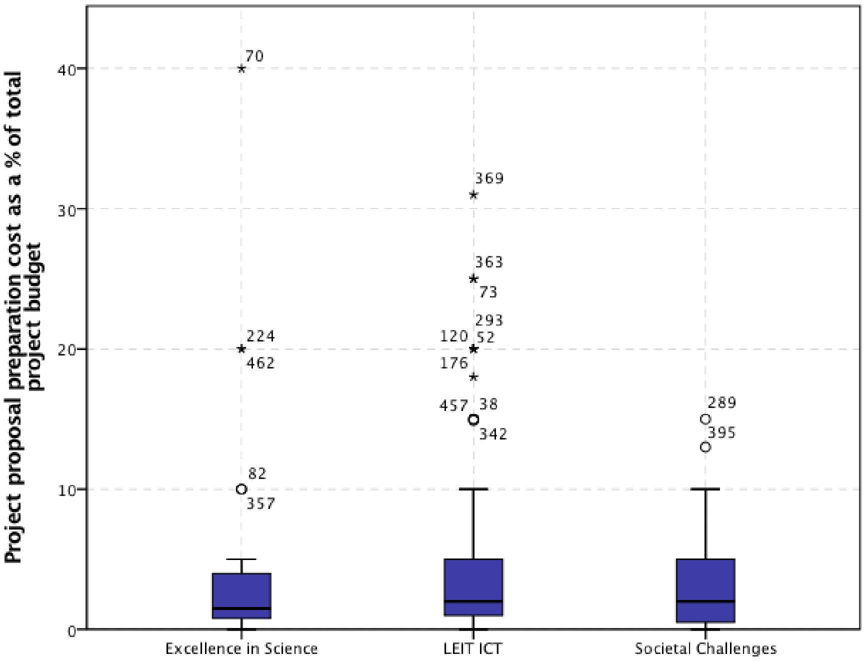
B.5.2.3. Cross-cutting issues

B.5.3. Cost-benefit analysis

In FP7 ICT Cooperation, FET projects resulted in 3,269 publications, of which 2,022 were articles. FET was the FP7 ICT Cooperation's strategic objective with the highest number of journal articles per funding received, with 82 and 50 articles per EUR 10 million funding for FET open and FET proactive, respectively, compared to an average of 16 articles per EUR 10 million funding across all strategic objectives.

In the survey, project participants were asked about the cost of preparing a proposal. The average cost of preparing a proposal was reported to be nearly 4 person months (for a full-time employee) and approximately 2,300 EUR in travel budget per organisation. Project coordinators provided estimates of proposal preparation costs as a share of total project budget. The median share was lowest for higher education institutions at 1% of total project budget and reached 3% for large companies and SMEs. The figure below presents the reported total costs of proposal preparation expressed as share of total project budget. As can be seen in Figure 46, there tends to be less variation in the case of FET. Average preparation costs relative to total budget are also lower in FET than for the LEIT ICT or SC parts.

Figure 46 - Reported total costs of proposal preparation as a share of total project budget by pillar (% of project coordinators)



Source: CARSA.

As for the Flagships, their management costs, which are currently available for the Graphene Flagship, have so far been kept at a low level (4.7% of the overall budget), that is 1.5% below the typical percentage figure for management costs in FP7 projects.[60] Nevertheless this is only one indicator, and the matter needs to be considered in more detail as the Flagships develop, particularly with regard to factors that may affect efficiency in the longer term (e.g financing cycle for the Flagships' Core Projects).

Overall, evidence from the survey suggests that, from an organisational perspective, the benefits of participating in FET-funded DG Connect Horizon 2020 projects exceeded or were at least comparable to the costs associated with preparing and submitting a proposal. 89% of participants in FET Open and FET Proactive projects consider that the benefits of their participation in the project identified by the survey exceeded or were comparable to the overall investment made by their organisation (see table below). This can be considered to be a positive finding, especially given that at this interim stage many of the potential project results have yet to be realised and further organisational benefits are likely to come during the remainder of the programme. It should be noted

[60] *DG CNECT.*

that benefits could stem not only from project participation, but also from the process of preparing and submitting a proposal (e.g. knowledge gained during this period, new partnerships etc.).

Table 21 - Assessment by participants of the benefits of participation compared to investment, by type of organisation (% distribution of participants within each pillar category)

	FET (Open and Proactive only)	LEIT ICT	Societal Challenges (ICT parts only)
Substantially lower than overall investment	0%	2.3%	0.9%
Lower than overall investment	3.1%	6.1%	5.7%
Comparable to overall investment	46.7%	49.5%	47.7%
Exceed overall investment	31.0%	29.4%	39.2%
Largely exceed overall investment	11.3%	5.9%	3.0%
Do not know	7.9%	6.7%	3.4%

Source: CARSA.

B.5.4. Lessons learnt/Areas for improvement

Although the budget for FET under Horizon 2020 has tripled compared to FP7 (to around EUR 2.5 billion for the period 2014-2020), the thematic opening of the programme from “ICT and neighbouring fields” to “all of science”, combined to recent cuts in national research funding, seems to have led to a dramatic oversubscription of FET calls, especially of FET Open calls where the success rate in the first half of 2016 was well below 3%. According to the European Commission's unit in charge of FET, there are however enough excellent submissions to absorb at least three times the current available budget for FET Open.

Evidence from the survey (excl. Flagships) suggests that, from an organisational perspective, the benefits of participating in FET-funded DG Connect Horizon 2020 projects exceeded or were at least comparable to the costs associated with preparing and submitting a proposal for a very large majority of participants. It should be noted, however, that these benefits could stem not only from project participation, but also from the process of preparing and submitting a proposal (e.g. knowledge gained during this period, new partnerships etc.).

The majority of participants and coordinators declared themselves as being very satisfied or somewhat satisfied with most aspects. However, dissatisfaction was expressed regarding aspects such as application procedures (which is generally regarded as time consuming, especially given the relatively low chances of success), proposal evaluation and selection and reporting procedures.

Stakeholder mobilisation patterns so far suggest that there is scope for enhancing participation opportunities for newcomers.

B.6. COHERENCE

B.6.1. Internal coherence

B.6.1.1. Internal coherence of the actions implemented in FET

The role of FET Open and FET Proactive is to incubate the seeds of radical innovations by the creative exploration of early stage, high-risk and visionary technological possibilities. It aims at what is new, untested, surprising, stimulating, high-risk but ultimately promising and rewarding in economic or social terms. FET Flagships, with their 10 year perspective, allow moving promising technologies up the TRL scale to a point where industry can exploit them.

FET does not itself aim to obtain short-term commercial successes. It provides *patient funding* that serves to build up confidence in new ideas, in those having them and the teams collaborating on them. According to the relevant unit at DG CNECT, it thus grows innovation capacity for the future, both in terms of ideas, the possibilities they create and the people taking them forward.

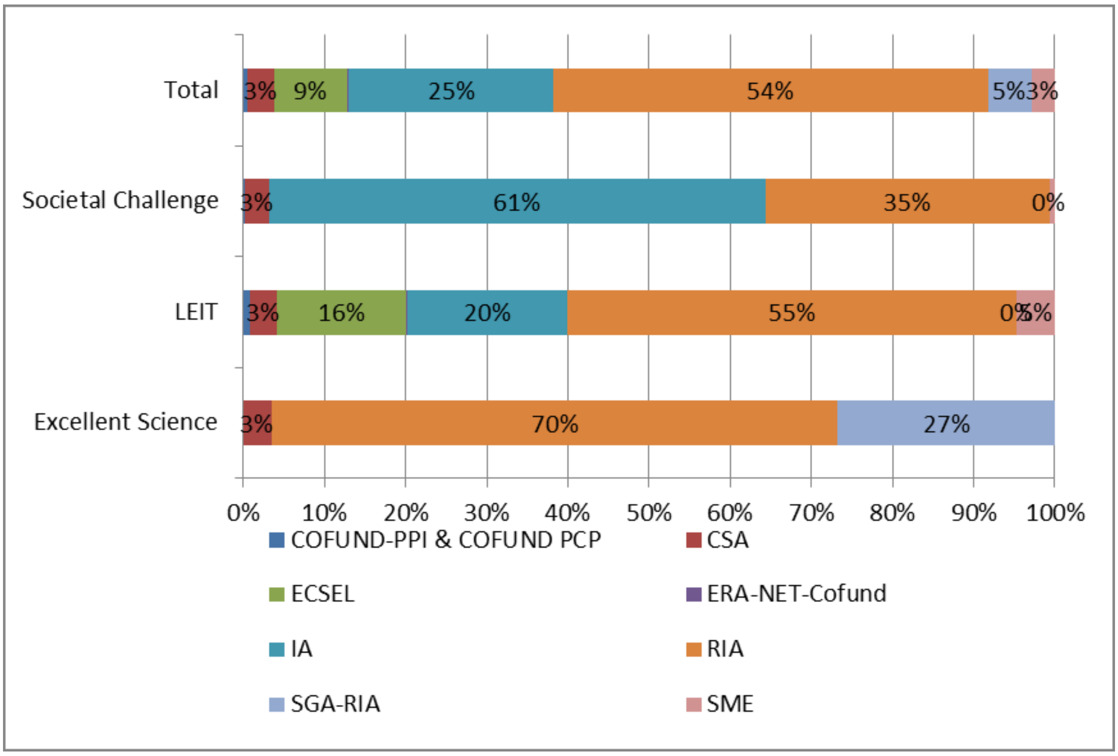
Large FET proactive initiatives (like on HPC) and FET Flagships (like on Graphene or the Human Brain Project) allow the EU to launch large scale initiatives of common interest that go beyond the funding capacity of any single Member State and that are able to compete on a Global scale. The ERANET Cofunds under FET are, according to the relevant unit at DG CNECT, also helping to implement actions in areas of common interest to Member States and to prepare future initiatives in a transparent way.

The figure below shows the distribution of funding by type of action and Horizon 2020 priority, which is distinctly different from the number of projects. Significant differences across WP areas exist: Excellent Science provides predominantly funding in terms of RIA, the majority of funding within the Societal Challenges is provided for Innovation Actions. The CARSA study concludes that, from a research and innovation policy point of view, the different emphasis in the allocation of funds to different instruments seems to be appropriate. Indeed, the higher share of RIA seems to be justifiable. Indeed, a higher share of 'pure' innovation projects might lead to detrimental effects concerning cooperation, as these would be too close to the market and hence subject to competitiveness considerations by individual firms.

In terms of FET's components, FET Open consists primarily of smaller-scale RIAs with a few CSAs to complement them, providing coherence and building communities around specific FET domains. These are also linked to the RIAs in FET Proactive, which are larger in scale to reflect the more mature nature of the technologies being addressed.

The FET Flagships are implemented with Framework Partnership Agreements and related Specific Grant Agreements in the form of RIAs. The coordination of MS/ACs support is implemented through successive ERA_NET co-fund actions.

Figure 47 - Distribution of Horizon 2020 ICT projects by type of action and funding share (FET projects belong under 'Excellent Science')



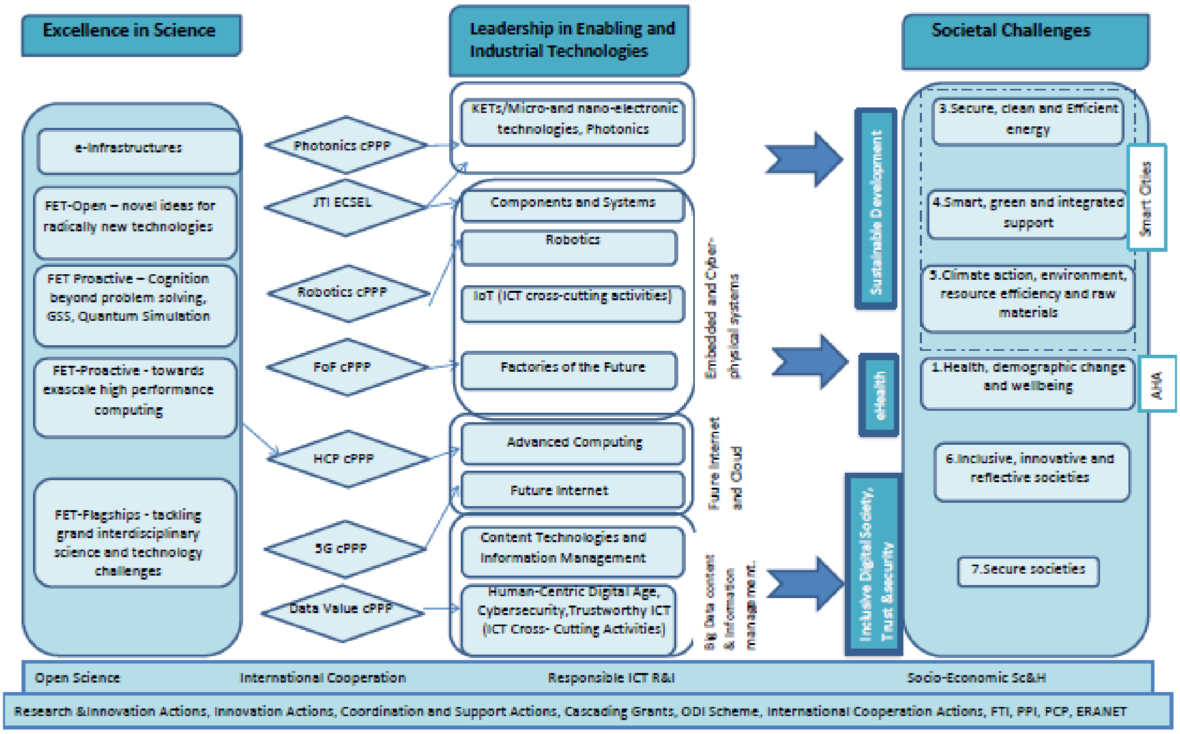
Source: CARSA.

B.6.1.2. Internal coherence with other Horizon 2020 intervention areas

FET-Open and FET-Proactive cater to a wide range of high-potential actors, including young researchers, start-ups, high-tech SMEs and entrepreneurs that are best placed to realise the disruptive potential from FET research. Measures to address the funding gap for promising projects and to foster links with the rest of Horizon 2020 include cross-pillar exposure of projects and stimulating cross-over of participants between different parts of the programme. Coherence with ICT-LEIT and the European Research Council is also ensured through discussions and consultations on the scope and content of the relevant Work Programmes and Calls.

Horizon 2020 ICT activities can be considered to form part of a “holistic” approach within the programme's framework. Complementarity and consistency of Excellence Science (including FET) with LEIT ICT and Societal Challenges are shown in Figure 48 below.

Figure 48 - Structure of the Excellence Science pillar and linkages with and Societal LEIT ICT and Societal Challenges



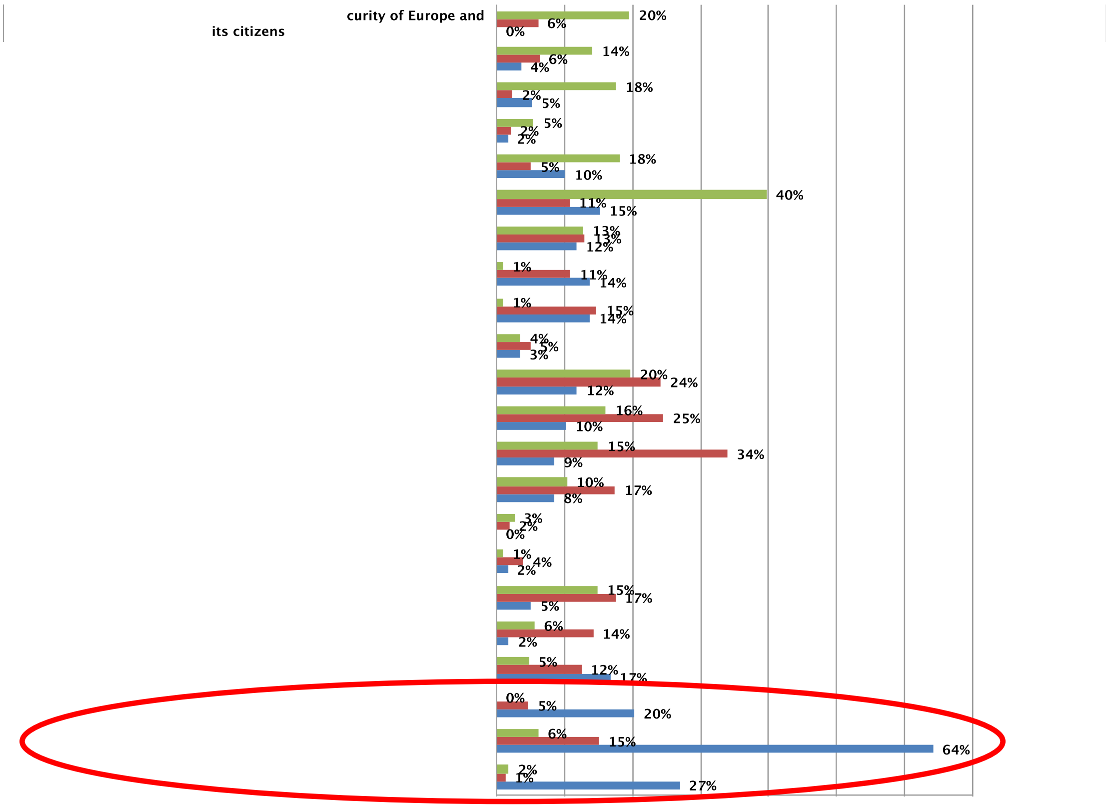
Source: EC Services.

The content analysis of the project abstracts carried out in the CARSA consortium study suggests that FET projects may provide results that can be very relevant to projects in a number of topics under LEIT ICT and Societal Challenges (ICT-related parts). A practical application of this finding would be in guiding future clustering and information sharing activities of projects across different priority Areas.

An important indication of internal coherence is to be found in survey results. As shown in the figure below, organisations already involved in a project in a given priority are also interested in most topics of other priority areas that may correspond to different approaches to research and innovation. Participating organisations therefore consider that such different approaches can be combined to cover their needs. In this respect, there seems to be strong coherence between FET's various components, whereas FET's coherence with other elements of Horizon 2020 other than FET (as measured by responses from the organisations' coordinators) appears to be lower.

The Flagships Panel reports that there is limited evidence that activities in the Flagships are informing support elsewhere in Horizon 2020. The agendas of the current Flagships are particularly relevant to areas such as the 'Nanotechnologies, Advanced Materials, Biotechnology, and Advanced Manufacturing and Processing' (NMBP) and the 'Information and Communications Technology' (ICT) programme areas of Horizon 2020 – with which coherence could be stronger.

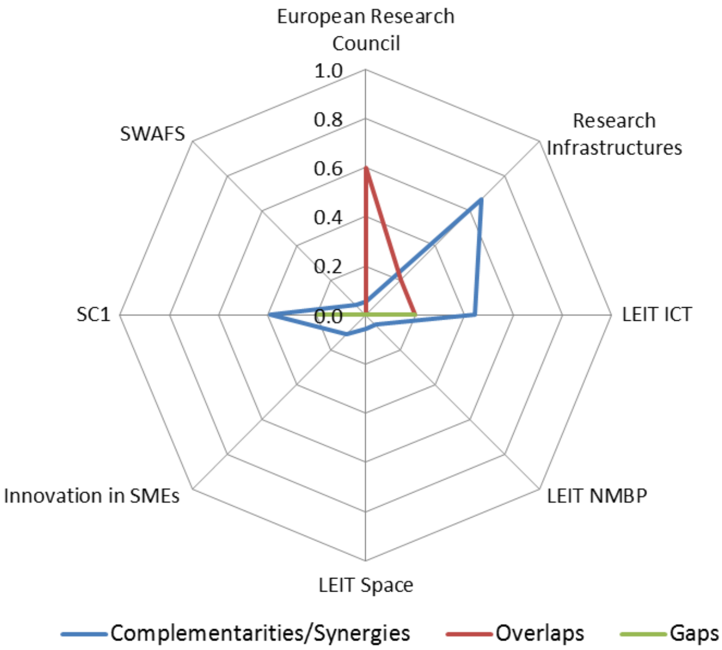
Figure 49 - Relevant topics for coordinators (up to 3 topics per respondent). The results are provided as shares (%) of coordinators within each priority area*



Source: CARSA.
**Excludes FET Flagships.*

As shown in Figure 50 below, results from an internal EC analysis on the internal coherence of FET with other Horizon 2020 specific objectives point to the prevalence of important synergies between FET and Research Infrastructures (e.g. HPC cPPP) and, to a lesser extent, between FET and LEIT ICT and SC1. Gaps are also observed between FET and those three other areas (the last two in particular, especially at implementation level), although they do not seem to be major. In turn, important overlaps seem to exist between FET and ERC activities (at both strategic and implementation levels). These results are largely consistent with those from the scales for LEIT ICT, Research Infrastructures and ERC, but not with those for SC1 (which predominantly show overlaps, not synergies with FET).

Figure 50 - Internal coherence of Future and Emerging Technologies with other Horizon 2020 specific objectives



Source: EC Services.

B.6.1.3. Ensuring that every euro spent counts twice

FET is a home for interdisciplinary research[61], with projects involving not only the ICT science and engineering disciplines but also fields as diverse as biology, medicine, material science, neuroscience, energy, music, economics, finance, and more. The technologies coming from FET can and are exploited in addressing a wide range of applications and domains beyond ICT, including the various Societal Challenges identified by the Commission. In this way, a greater impact can be achieved.

Combined results from the survey and the content analysis of the project abstracts carried out in the CARSA consortium suggest that FET projects have the potential to provide results that are of relevance to projects in a number of topics under LEIT ICT and Societal Challenges ICT. As previously stated, a practical application of this finding would be in guiding future clustering and information sharing activities between projects across the Priority Areas. Table 22 below draws on the findings from both research methods to identify the specific areas of FET for which combined approaches are more likely to occur[62].

[61] *https://ec.europa.eu/programmes/horizon2020/en/news/fet-living-interdisciplinarity*

[62] *The two research methods provide different, but complementary pieces of the links that may exist between a topic X of a current project and another topic Y. The survey gives a measure of the likelihood that the next project of a participant in project X could well be in topic Y that is also relevant for this participant. The abstract analysis informs that the results of a project in topic X can be very relevant for a project in topic Y.*

Table 22 - Links of topics across priorities corresponding to combined interests of project participants

Priority Area chosen for current project	Survey - Relevant Topics from other Priority Areas (indicated by more than 10% of respondents)	Abstract analysis – Relevant key words pointing to topics from other Priority Areas (top 10 frequently cited in each Priority Area)
FET	**LEIT ICT**	
	Micro- and nano-electronics	
	Photonics	Photonics
	Robotics	Artificial intelligence
	ICT cross-cutting activities	Neuroinformatics
	Horizontal ICT innovation actions	
	Advanced Computing	HPC, Big data
	Societal Challenges ICT	
	SC1 Health	Health
	SC3 Energy	Energy
	SC5 Climate action	Environment
	SC6 Europe in a changing world	Inclusion

Source: CARSA.

Examples of FET-funded research that has applications in other domains include the projects below (all ongoing):

IBSEN[63] (Bridging the gap: from Individual Behaviour to the Socio-tEchnical Man) is a FET-open research project that intends to provide a real breakthrough by creating a repertoire of human behaviours in large (more than 1000 people) structured groups using controlled experiments. In particular, the project builds on a novel experimental protocol, software and analytical tools to allow large scale experimentations. To achieve these results, IBSEN requires a high-degree of interdisciplinary which is reflected in its team composition, consisting of physicists, economists, social psychologists, and computer scientists. This variety will allow to create a technology providing a basis for socio-economic simulations that are expected to radically change many fields, from robotics to economics, with technological and societal impacts, including policy-making in socially pressing issues.

CONQUER[64] (Contrast by Quadrupole Enhanced Relaxation) is a highly interdisciplinary project combining expertise in quantum physics, chemical and biomedical engineering, material characterisation as well as nano-toxicology. In particular, the combination of quantum-mechanics and cutting-edge imaging technologies has the potential to create Molecular Imaging solutions with significant impact: the radically new diagnostic and therapeutic treatments developed in the project are key elements to achieve the healthy well-being of European citizens.

The aim of **Lumiblast**[65] (A paradigm shift in cancer therapy – using mitochondria-powered chemiluminescence to non-invasively treat inaccessible tumours) is to establish a breakthrough technology by providing proof-of-concept in extracellular systems, particular cancer cell cultures and animal models, with the vision to advance to a different treatment for cancers of various origins in the next years. To this end, the project relies on a concerted interdisciplinary action involving expertise in various fields:

[63] http://ibsen-Horizon 2020.eu/
[64] http://cordis.europa.eu/project/rcn/196966_en.html
[65] http://cordis.europa.eu/project/rcn/203541_en.html

photo-medicine, synthetic chemistry, photo-chemistry, pharmaceutical formulation, ROS-activated luminescence.

LiRichFCC[66] (A new class of powerful materials for electrochemical energy storage: Lithium-rich oxyfluorides with cubic dense packing) is based on a long-term vision to develop a novel class of materials into practical use, involving foundational aspects in S&T with breakthrough character, high novelty and risk. Indeed, the project intends to explore and optimize possible compositions, synthesis methods, structural properties and dynamics of Li-rich FCC materials through a broad interdisciplinary approach, involving predictive computational work, advanced chemical synthesis and high-end characterization. This will lead to a paradigm change in the design of battery materials and unexpected effective mechanisms: it could revolutionize the use of batteries in applications involving a need for supplying large amounts of energy and power from small spaces.

The FET-Proactive project **ESCAPE**[67] (Energy-efficient SCalable Algorithms for weather Prediction at Exascale) aims to develop world-class, extreme-scale computing capabilities for European operational numerical weather prediction (NWP) and future climate models, based on a holistic understanding of energy-efficiency for extreme-scale applications using heterogeneous architectures, accelerators and special compute units. In this way, the project will provide the necessary means to take a huge step forward in weather and climate modelling, through interdisciplinary research on energy-efficient high-performance computing and the combination of complementary skills of all project partners, including global NWP and high-performance computing centres.

Both FET Flagships are also examples of highly multidisciplinary projects.

A case study carried out by CARSA in its report concludes that the contribution of the interdisciplinary approach to research and innovation actions and results is undeniable, and the novelty produced through this approach encompasses a variety of fields and areas of research that complement each other in considerably revolutionary ways. The added value of interdisciplinary collaboration is to be found both in:

- Its function as approach to solve difficult real world problems that cannot fit within single disciplinary boundaries[68] as well as;
- Its inspiring nature leading to new scientific discoveries, based on the exchange and interaction among different disciplines.

Despite its great potential, interdisciplinary research collaborations are still limited, as confirmed by the findings of the Commission's Portfolio Analysis on FET-OPEN RIA and by the findings of the analysis of abstracts in the CARSA study, one of the main barriers to the full development of interdisciplinary research seems to be that the collaboration with Social Sciences and Humanities in technology projects is often superficial and "pro forma". In this sense, there seems to be room for encouraging research collaborations to go beyond current mainstream configurations with the aim to advance different scientific and technological disciplines together and in synergy towards a common breakthrough.

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[66] *http://cordis.europa.eu/project/rcn/203539_en.html*
[67] *http://cordis.europa.eu/project/rcn/197542_en.html*
[68] *DEA, summary report, Interdisciplinary research Is key to solving society's problems; http://dea.nu/sites/default/files/Resume_interdisciplinary_0.pdf*

B.6.2. External coherence

B.6.2.1. Coherence with other EU funding programmes

CARSA's analysis concludes that measures adopted reforms to foster synergies between Horizon 2020 (including FET) and other EU interventions relating to Research and Innovation (e.g. by cumulating grants or combining funding from different instruments) have increased potential for creating such synergies.

In this context, the study stresses the high degree of coherence between Horizon 2020 DG CONNECT Activities and ESIF. Key priorities for EU Member States that are identified as suitable for being addressed by combining ESIF and Horizon 2020 funding include:

- Increased quality of ICT services and applications for SMEs
- Opening up business opportunities for digital companies in new areas, such as intelligent transport systems, Intelligent Energy Distribution Systems and ICT solutions for healthy active ageing
- New e-government services and applications including e-procurement, e-inclusion, e-accessibility, e-learning and e-education services
- Improved ICT infrastructure and large-scale computer systems

The study adds that, in some cases, European deployment can be achieved or further enhanced through the use of the Connecting Europe Facility (CEF), which offers the means for ESIF investments to be designed to be interoperable or compatible with solutions in other EU countries or at EU level for the case of telecommunication, transport and energy networks.

However, according to CARSA, there is limited evidence that these synergies are effectively being exploited. Moreover, the survey and interviews show that programme participants have limited knowledge of and/or make limited efforts to exploit other funding opportunities.

As previously indicated, survey results (conducted among Horizon 2020 participants in DG CNECT activities in all three Pillars) revealed limited knowledge of, or intention to use other sources of funding (either in a concurrent or alternative manner). In order to obtain more insight on how Horizon 2020 participants approach funding from ESIF, a number of follow-up interviews were conducted with a balanced representation of organisations having or not attempted to combine different sources of R&I support. The main outcomes of these interviews were as follows:

- The interviewees recognised the benefits of the different types of synergies but often made reference to the difficulties of “finding one’s way around the bureaucracy of ESIF”, relating to administrative documentation, reporting and expense verification processes, particularly in the case of SMEs.
- An additional difficulty for academic organisations, more frequently encountered in cases where ESIF funding is used to commercially exploit the outcomes of an FP project, is that the research teams prefer to focus on follow-up scientific work, so other organisational units need to be involved, like Technology Transfer Offices that have a stronger focus on innovation. The success of the operation relies to a large extent on the way such units cooperate with the research teams.

- Finally, a factor that needs to be taken into account for the use of ESIF in R&I actions is enhancing the private companies demand for innovation in a given region. It was stressed by academic and private sector interviewees that particular attention should be given to support actions aiming at demonstrating the benefits associated with commercialising and applying research outcomes and their link to innovativeness and high-growth potential of companies. Such actions would help academic institutions in sharing their expert knowledge and in finding suitable business partners to develop projects with high economic and societal impact for their region.

Box 5 - Research and Innovation in ESIF

As per the CARSA report, support to Research and Innovation is foreseen in four out of the five European Structural and Investment Funds (ESIF): the European Regional Development Fund (ERDF), the European Social Fund (ESF), the European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF). The most relevant Thematic Objectives (TOs) for funding R&I related activities include: Strengthening research, technological development and innovation (TO1); Enhancing access to, and use and quality of, ICT (TO2); Enhancing the competitiveness of SMEs (TO3)[69];Supporting the shift towards a low-carbon economy in all sectors (TO4); and Enhancing institutional capacity of public authorities and stakeholders and efficient public administration (TO11) .The first two these TOs are of particular relevance in terms of potential synergies with FET.

Management Authorities in each Member State are in charge of the design and implementation of ESIF at national and regional level, taking into account the rules specified in the regulations governing each programme. The ESIF regulations contain specific provisions regarding the activities to be supported, especially for the case of R&I actions[70]:

- For ERDF, between 50% and 80% of the funds are dedicated to, at least, two of the above TOs[71]. The use of funds from ERDF in the field of research and innovation is conditional upon the adoption of smart specialisation strategies at national or regional level, termed as RIS3. These strategies define the priority fields for investment and use of the funds, in connection to national/regional strengths and capacities.
- ESF funding can be used for capacity building of researchers and for networking between research institutions.

In the current programming period, the overall spending from ERDF and ESF for R&I actions in the four objectives mentioned above is expected to be around EUR 110 billion, with an estimated EUR 40 billion going to the first Thematic Objective (TO1)[72].

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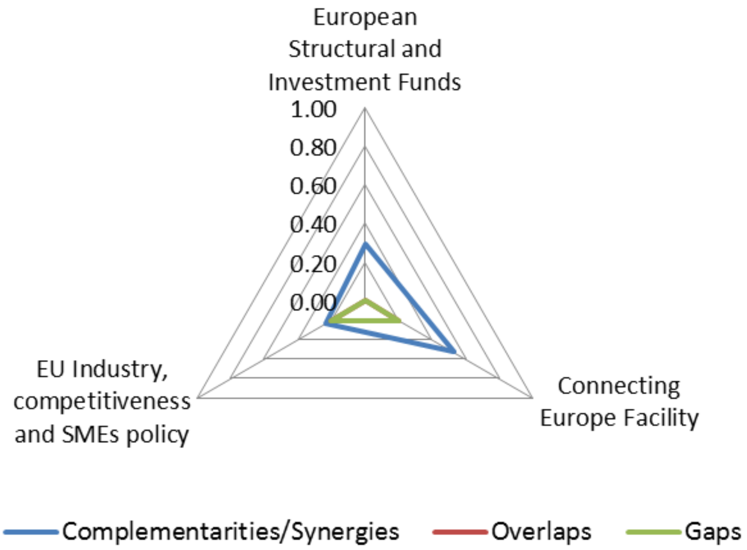
[69] *In EAFRD and EMFF the support is for SMEs in the agricultural and the fishery/aquaculture sector, respectively.*
[70] *Regulation (EU) No 1303/2013 of the European Parliament and of the Council of 17 December 2013.*
[71] *At least 50% in less developed regions, 60% in transition regions and 80% in more developed regions.*
[72] *To be compared to 10 billion Euros spent for the corresponding R&I theme in the period 2000 – 2006. Source: Madureira, A.M., Nilsson, J.E., & Gheorghe, V. (2007). Structural Funds as instrument to promote Innovation - Theories and practices. VINNOVA Report VR 2007:02, February 2007*

As shown in Figure 51 below, results from an internal EC analysis of FET with other EU policies and programmes point to the existence of important synergies or complementarities between FET and Connecting Europe Facility activities and, to a lesser extent, between FET and ESIF and the Union's industry, competitiveness and SME policy. Relatively minor gaps are observed, however, between FET and each of those three other areas.

Figure 51 - External coherence of Future and Emerging Technologies with other with other EU policies and programmes



Source: EC Services.

B.6.2.2. Coherence with other public support initiatives at regional, national and international level

Few countries, if any, can claim to have the best expertise in Europe in any non-trivial range of disciplines. World-class results can hardly be achieved without leveraging upon Europe's most valuable assets. In addition, as pointed out by staff in the relevant unit at DG CNECT, FET is one of the few programmes supporting research-driven high-risk/high-gain work, as most programmes, national and regional ones included, seem to be moving closer to the market for shorter term returns in terms of growth and jobs.

Interviews with participants revealed that there are cases where research in national programmes was a stepping-stone to FP/Horizon 2020, as well as examples of the reverse sequence, where FP/Horizon 2020 projects led to research funded by national programmes. In most such cases the national programme had a clear focus on research through university/private company collaborative schemes. Such funding schemes may relate to ESIF, as is the case of Greece, or come from national/regional sources, as is the case of Finland or Germany.

The survey conducted as part of the CARSA study was used to assess the degree to which participating organisations benefit from opportunities and synergies with other sources of funding. Two key findings emerging from the analysis of survey responses (which encompass participants in all Horizon 2020 Pillars and not only FET, but can be considered an indicative proxy) are the following: (1) for more than 70% of Horizon 2020 participants the availability of national funding opportunities in topics related to their Horizon 2020 project is nil or low[73], and (2) more than 80% of Horizon 2020 participants have not applied to other national or international programmes for the particular topics of their Horizon 2020 projects.

Overall, the findings above suggest that the survey respondents had limited knowledge or experience regarding the synergies that could be developed by combining Horizon 2020 and other sources of funding. It is worth noting that university partners seem to be more active in exploiting other funding opportunities, as a larger share within this category considers availability of funding to be fair/high (40% compared to 28%, the average for all participants). Conversely, research centres have a more pessimistic view as to availability of national funding and show the lowest activity in attempting to obtain competitive funding. This may also be related to a stronger interest in other sources, such as service contracts with the private sector.

It should be pointed out that non-participants were shown to be more active in attempting to obtain funding from other sources than organisations involved in Horizon 2020: the share of non-participants that applied to national and/or international funding programmes is 33%, compared to 18% for Horizon 2020 participating organisations. The more intense involvement of non-participants can be related to a preference for continuing on national or regional programmes that are more adapted to specific needs, or for which a good track record has been already developed. Findings also suggest that Horizon 2020 participation does not seem to offer any competitive advantage for securing funding from other sources.

Member States' support and contribution to the Flagships, via their national or regional programmes and via the ERA-NET transnational calls, is essential for the Flagships success. For the time being, their direct financial contributions are, lower than expected. The Flagship panel recognise that linking research investments made through public funding - and private - across Europe with the two current Flagships is proving to be more difficult than expected. In order to address this issue, the panel proposes a revision of the means of engaging with Member State and Associated County initiatives. This could be achieved through a process of monitoring the model of using Partnering Projects with a view to identifying improvements and simplifications, and by looking beyond this model to find other ways of further engaging public and private initiatives in the Flagships.

B.6.3. Lessons learnt/Areas for improvement

The design and implementation so far of FET appears well suited to guarantee acceptable levels of internal coherence among its components. FET Proactive has the strategic role of maturing promising future and emerging technology areas, detected and continuously challenged by FET-Open, that can find their way into other programmes (including national ones) as well as to innovative industrial applications, some of which by means of the FET Flagships. This interplay between bottom-up and top-down approaches is an important part of the concept of FET.

Coherence between FET and other Horizon 2020 intervention areas is in turn ensured by means on regular discussions and consultations on the scope and content of the relevant

[73] *While responses may considerably vary across Member States, the frequencies for sums made over EU-15 and EU-13 (the "enlargement" Member States) are roughly the same.*

Work Programmes and calls. Articulation between FET-funded activities and those from other parts of the programme could however be improved. One specific area for improvement would be to ensure support for the further development and exploitation of the results of work under FET Open. The findings presented in this section also suggest that, despite strategic alignment, there is still scope for enhancing the complementarity of interventions under FET (and Horizon 2020 as a whole) and ESIF at the implementation level. Moreover, stakeholders have pointed out that combining funding from both sources can sometimes be a cumbersome process. In the same vein, the Flagships panel acknowledges that, while the Flagships do provide a basis for collaboration at EU level, coherence and collaboration with other parts of Horizon 2020, such as LEIT ICT and NMBP or SC1 could be further enhanced.

FET projects have the potential to provide results that are of relevance to projects in a number of topics under LEIT ICT and Societal Challenges (ICT parts). Indeed, technologies developed thanks to FET-funded actions can have a wide range of applications including in areas beyond ICT, thus achieving greater impact. Despite this potential, interdisciplinary research collaborations are still limited. One of the main barriers to the full development of interdisciplinary research seems to be that the collaboration with Social Sciences and Humanities in technology projects is often superficial and "pro forma".

A number of cases have been identified where research activities under national programmes act as stepping stones to Horizon 2020 projects and, conversely, where FP/Horizon 2020 projects have led to research being funded by national or regional sources. However, survey results suggest that respondents had limited knowledge or experience regarding the synergies that could be developed by combining Horizon 2020 and other sources of funding. Survey findings also suggest that participation in Horizon 2020 does not seem to offer any competitive advantage for securing funding from other sources.

MS/ACs direct financial contribution to the Flagships has so far been lower than expected. The Flagship panel recognise that linking research investments made through public funding - and private - across Europe with the two current Flagships is proving to be more difficult than expected. There is thus a need for further engaging with relevant public and private initiatives.

B.7. EU ADDED VALUE

B.7.1. Horizon 2020 projects demonstrating EU Added Value

As all selected projects are, as a pre-condition, required to demonstrate EU added value and increase the effectiveness, efficiency and synergy through collaborative European research, a set of examples are given here to illustrate the diversity in how this happens in practice.

Effectiveness

The ODYCCEUS (Opinion Dynamics and Cultural Conflict in European Spaces – Project budget EUR 5.82 million) project[74] explores how social media and the

[74] http://cordis.europa.eu/project/rcn/206203_en.html

digitisation of news and discussion fora are having far-reaching effects on the way individuals and communities communicate, organize, and express themselves. It will show how the information circulating on these platforms can be tapped to better understand and analyse the enormous problems facing our contemporary society, and help monitor, from an EU-wide perspective, the growing number of social crises due to cultural differences and diverging world-views, with ways to resolve conflicts before they lead to violence.

Efficiency

DOLFINS (Project budget EUR 4.25 million)[75] strives to give scientific evidence and citizens' participation central roles in the policy process concerning finance. DOLFINS will focus on two crucial and interconnected policy areas that will shape the public debate in the coming 5 years: How to achieve financial stability and how to facilitate the long-term investments required by the transition to a more sustainable, more innovative, less unequal and greener EU economy. By pooling resources from across the EU, they will deliver quantitative tools to evaluate policies aiming to tame systemic risk and to foster sustainable investing. They will also investigate how to engage citizens in the early stage of the policy making process and will develop evidence-based narratives in order to better shape policies in the public interest.

Synergies

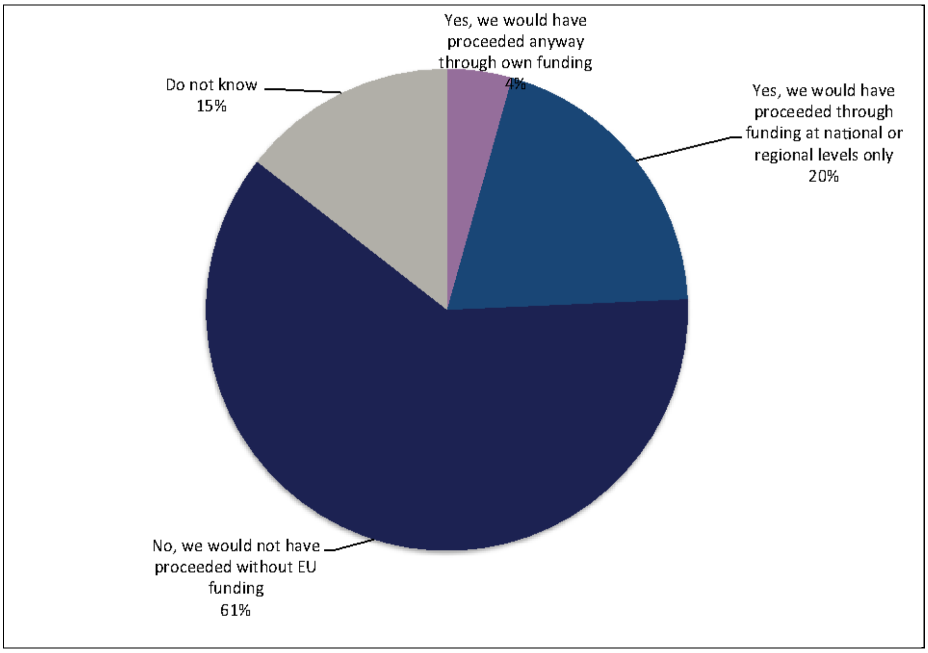
The QuantERA project EUR 40.46 million of which EU contribution EUR 11.51 million)[76] has brought together 32 organisations from 26 countries to support research in Quantum Technologies. It answers the growing need for collaborative endeavours in the field of quantum technology research, which due to its highly interdisciplinary nature, cannot be carried out by an individual institution or state. Through coordination of national and regional research funding programmes, QuantERA avoids the problem of fragmentation of national efforts, encouraging transnational collaborations and leveraging Europe's competitive advantage in the field of quantum technology.

B.7.2. Other issues related to EU added-value

According to survey results from the CARSA study approximately 61% of participants (all Pillars, DG CNECT activities only) indicated that they would not have proceeded with the planned research and development activities without EU funding. 20% of participants would have proceeded through funding at national or regional levels only, and a relatively low proportion (4%) indicated they would have proceeded with their own funding. It shows that the EU funding allows research and development activities to proceed which would not have been funded at national or regional levels.

[75] http://cordis.europa.eu/project/rcn/193749_en.html
[76] http://cordis.europa.eu/project/rcn/207196_en.html

Figure 52 - Had EU funding not been available, would you still have implemented the planned R&D activities in the specific research area*? (% participants)



Source: CARSA.
**All Pillars, DG CNECT activities only.*

The figures above are consistent with those presented in the PPMI study, which, based on survey responses, concludes that two-thirds of FET projects would not have gone ahead in the absence of EU funding. The same study indicates that 50% of FET projects would have taken longer to produce the same or very similar outputs had the beneficiaries received national or regional funds instead of Horizon 2020 funds.

According to the CARSA study, most of the dimensions of European Added Value are expected to be strengthened by the Horizon 2020 DG CONNECT Activities (including FET) thanks to the existing continuity of goals, activities and funding instruments between FP7 and Horizon 2020. The increased importance of frontier research in the programme, combined with the target to more efficiently support exploitation and commercialisation of research is also expected to bring about:

- Strong clusters of EU scientists assuming leading position in frontier research that will shape the ICT technologies of the future;
- Academic-business partnerships that contribute to increasing the competitiveness of the ICT industry;
- An increased number of ICT SMEs that expand their market presence across the EU and at a global level, and
- Adequate ICT solutions developed to address the Societal Challenges, widely used across the EU and supporting the global presence of EU ICT businesses.

Examples have also been provided regarding the enabling effects of the Flagship Instrument, which is by definition aimed at building critical mass and obtaining synergies:

- To achieve their ambitious objectives and technology development targets, each of the two FET Flagships mobilised synergies and established collaboration across 100+ partnering organisations.

- By bringing together researchers from different scientific disciplines and technology fields, the Flagships started creating an unprecedented level of collaboration and community building in Europe. For example, in March 2016, HBP released its six ICT Platforms, which are the core of the emerging HBP research infrastructure for brain research. This was the result of an extensive multidisciplinary effort involving more than 750 scientific collaborators and engineers from 114 institutions in 24 European countries. The Platforms have now been opened to a very large number of users from all over Europe and beyond and will enable new kinds of collaborative research to be performed in brain research, cognitive neuroscience and brain-inspired computing.
- Through their long duration, Flagships enable the participating research groups to build up expertise and create durable links between academia and industry. For example, in the GRAPHENE Flagship, this is key for advancing technology through different Technology Readiness Levels and for completing value chains needed to achieving tangible societal and industrial impact.
- Flagships contribute to create and spread an innovation mind-set in Europe. For example the GRAPHENE Flagship is providing lectures for young researchers in winter schools on how to innovate; innovation support to partners that have valuable technology but lack the experience to exploit it; and is helping industry to become aware of opportunities offered by new technologies. By doing so, the GRAPHENE Flagship becomes a natural hub for bringing together market pull and technology push, up to the point where industry adopts new technologies.
- Flagships help educate, keep and develop research talents in Europe: in their ramp-up phase, each Flagship mobilised ~300-350 young researchers (PhDs or post-doc level) from all over Europe and beyond. For example the GRAPHENE Flagship, with its focus on pushing forward new technologies and innovation, and its internal education activities, not only helps creating a culture of entrepreneurship, but also is serving as a training platform for supplying the skilled researchers European high-tech industry needs. The HBP trains a new generation of neuroscientists capable of harnessing the power of high performance computing and data analytics.
- Flagships open the door for international collaboration by shaping the role Europe has on the global landscape in terms of science, technology and innovation, and forming a natural anchoring point (see above).
- Flagships give high visibility to the EU investments in science and technology, and attract a lot of attention from both public and scientific media.

B.7.3. Lessons learnt/Areas for improvement

Few countries, if any, can claim to have the best expertise in Europe in any non-trivial range of disciplines. World-class results can hardly be achieved without leveraging upon Europe's most valuable assets. Considering also evidence that most projects FET projects would not have gone ahead in the absence of EU funding or would have done so less efficiently, it can therefore be argued that excellence in multidisciplinary R&I collaboration is best achieved at European level.

FET is instrumental in bringing about large scale initiatives of common interest that help build a critical mass by going beyond the funding capacity of any Member State and that are able to compete globally (e.g. FET Flagships). It also enhances coordination and creates synergies by helping to overcome national fragmentation and implement actions in areas of common interest to Member States and to prepare future initiatives in a well-structured and transparent manner (e.g. ERANET Cofund).

The increased importance of frontier research in the programme, combined with the objective of supporting exploitation and commercialisation of research is also expected to bring about higher levels of effectiveness for the EU as a whole, including through the development of Pan-European technical solutions that address the Union's Societal Challenges as well as strategic goals such as developing a genuine Digital Single Market. Furthermore, ICT are important enabling technologies that, if developed on a European scale, can help stimulate economic and industrial activity across the continent. This involves further integrating different actors of the value chain (private, public and academia) so as to benefit from multidisciplinary cooperation to achieve research excellence, which can only be achieved through EU level action.

FET Flagships play an important role in conveying visibility to EU investments in science and technology. The GRAPHENE Flagship has already held several international collaboration workshops with the USA, Japan and Korea, and has now put in place mobility funding grants for young researchers, in close collaboration with the US-NSF. HBP has also engaged in similar activities and participated in several international workshops and is now launching concrete collaboration activities notably with the US BRAIN and the Canadian brain initiatives.

According to the expert panel, there is however room for improvement when it comes to developing scientific, societal or industrial exploitation plans.

B.8. SUCCESS STORIES FROM PREVIOUS FRAMEWORK PROGRAMMES

As outlined in the CARSA study, synergies and economies of scale are at the core of EU Added Value aspects highlighted in previous FP; e.g. addressing Pan-European challenges and building critical mass in specific research/technological domains by bringing together dispersed knowledge and stakeholders not traditionally cooperating; developing strategic agendas in key sectors, allowing participants to cooperate on common challenges and lowering risks; and make research implementation achievable at a scale not possible at national or local level (additional opportunities for research become available at a scale not reachable at national and local level; indeed, a large majority -estimated at 70 to 80%- of ICT projects in FP6 and FP7 would not have been implemented without the level of support provided by EU funding[77]). Specific examples of FP7 ICT EU added value notably include:

- Enhancement of European and international cooperation
- In FET Flagships, critical mass (both in terms of financial support as well as in multi-disciplinary cooperation) was reached on a scale that no Member State alone could have afforded
- In cloud computing, the EU added value has consisted of supporting the competitiveness of the European industry in a key technology revolution that is transforming the way IT is developed and delivered

[77] The survey to FP6 IST project participants showed that only 23% of the organisations would pursue R&D efforts in the specific thematic/business area without EC funding, with responses varying from 32% for large industrial enterprises to 22% for Higher Education Institutions, 21% for Research & Academic Institutes and 20% for SMEs (Cartalos, et al,, 2012). In the interviews conducted during the evaluation of FP7 ICT 79% of respondents identified research results that could not have been achieved without EC funding (Galasso, et al,, 2015).

- In robotics, EU funding has promoted multidisciplinary and large-scale development, involving more industrial actors in a sector traditionally dominated by academia
- In ICT for language technologies, EU-wide collaboration led to breaching the language barriers and in breaking the national fragmentation, as the extreme diversity of the European landscape makes it difficult for any single provider to cope with it.

A sample of some of the FP7 success stories includes the following:

PUFFIN - Strong and reliable authentication is key in our digital society. The existence of Physical Unclonable Functions (PUFs), the technology that implements the electronic fingerprint of devices, has been demonstrated by the PUFFIN FET Open project in standard devices. PUF is a strong security and authentication solution for the connected world. Thanks to PUF, your electronic data is totally secured against attacks. No more identity theft, counterfeiting and cloning of systems, piracy of media content and software apps, financial losses by securing mobile payments. The applications for mobile phones are now implemented by its SME partner Intrinsic-ID who has just won the overall Innovation Radar Prize 2016 and also the prize of the Excellent Science category. With the Innovation Radar Prize, INTRINSIC-ID will get a boost and will hopefully soon be integrated in our mobile devices.

GHOST is designed to tap humans' ability to manipulate physical objects through the interfaces of computers and mobile devices. By developing shape-changing displays you can touch and feel, the technology allows us to handle objects, and even data, in a completely new way. A surgeon, for instance, will be able to work on a virtual brain physically, with the full tactile experience, before performing a real-life operation. Designers and artists using physical proxies such as clay can mould and remould objects and store them in the computer as they work. One of the GHOST partners, the University of Bristol, has spun off a startup, now employing 12 people, called UltraHaptics, to develop technology being studied in GHOST. The levitation technology will be further developed via a new FET-OPEN project called LEVITATE.

Body-on-Chip is coordinated by a Swiss biotech SME, InSphero, and aimed to provide the basis for the company's next wave on innovation. Its current core business is to sell 3-dimensional biological tissues (human or other) that it produces through a propriatory hanging-drop technique and distributes all over the world. Their next step, addressed by this FET-project, is to develop an ICT-controlled microfluidic platform that integrates several of such tissues (heart, liver, brain,…) into a realistic metabolism, like in the human body. This promises to greatly enhance the efficiency and reliability of drug-testing and toxicity research. With this FET technology InSphero is competing with much larger initiatives worldwide (Darpa, NIH), and with success. Today InSphero is already working with 15 out of the top 15 pharmaceutical companies worldwide.

B.9. LESSONS LEARNT/CONCLUSIONS[78]

B.9.1. Relevance

Key findings	Supports excellent science in multidisciplinary research and is line with relevant objectives as well as current and evolving challenges – although a number of shortcomings still need to be addressed. Flagships' relevance in terms of the transformation of science into enabling technologies for disruptive innovation is confirmed.
Strengths	FET is responsive to many key developments likely to determine future trends in ICT. It has a key role in promoting collaborative research as well as in graduate training. FET-projects involve high-tech research-intensive SMEs and generate innovation eco-systems by spreading new ideas, methods, approaches or technology in the industrial R&D community. Flagships' objectives are unique to this particular instrument and highly relevant to Europe's overall Research and Innovation Strategy
Bottlenecks/ weaknesses	Very small success rate due to oversubscription with a limited budget considering the size of the domain where FET actions can be used. There is room for further enabling contributions by citizens, civil society organisations and other societal actors to defining scientific agendas and scientific contents relating to FET. Flagships: balance between investment in research and development in a broad sense, and the need of industrial focus to match industrial needs, must still be found. There is room for improving alignment in this respect (by deepening the understandings of existing industries as well as of opportunities for new entrants to disrupt existing markets).

B.9.2. Effectiveness

Key findings	The programme has so far been a catalyst for ideation. Participants expect positive impacts on interdisciplinary collaborative undertakings as a result of their participation; projects selected so far aim at creating knowledge and develop high-risk innovative projects, which suggests these could be among the key outcomes to be generated. Flagships give high visibility to the EU investments in science and technology.
Strengths	The proposals submitted are of very high quality.

[78] This section draws primarily on the conclusions from the expert panel's report, which refer to the Excellence Science pillar. It also presents selected elements from the CARSA study and key conclusions for the Flagships Panel.

	High levels of collaboration have been achieved; which implies high likelihood that innovation eco-systems will be created. Flagships:10-year horizon allows completing value chains, bringing technologies to higher readiness levels, and creating real impact; critical mass and visibility.
Bottlenecks/ weaknesses	Many excellent proposals are rejected, which is likely to negatively affect effectiveness (as promising projects will not be funded). Flagships: despite clear innovation potential, they are still to fully develop a relevant basis for industrial engagement and impact, increase implementation flexibility and responsiveness. There is also room for improving cooperation between Partnering Projects and Core Projects.

B.9.3. Efficiency

Key findings	The actual economic impact is yet to be demonstrated. The Flagships Panel believes that it is too early for assessing this aspect in detail.
Strengths	Participants perceive benefits from participation as exceeding costs - these benefits could stem not only from project participation, but also from the process of preparing and submitting a proposal (e.g. knowledge gained during this period, new partnerships etc.). The programme promotes multidisciplinary collaboration. Most participants and coordinators surveyed were satisfied with most participation-related aspects. Flagships: For the Graphene coordinator, the budget size allows the flagship to exploit scale benefits in, e.g., dissemination activities and international contacts.
Bottlenecks/ weaknesses	Frustration about success rate. Dissatisfaction was expressed regarding aspects such as application procedures (which was generally regarded as time consuming, especially given the relatively low chances of success), proposal evaluation and selection and reporting procedures. Stakeholder mobilisation patterns so far suggest that there is scope for enhancing participation opportunities for newcomers. In the current state, the programme is not viewed as focusing enough on strategically orientated research (FET Open). Flagships: management and administrative burden could be reduced (including by adapting IT tools, which need to enable handling large consortia).

B.9.4. Coherence

Key findings	The expert panel concluded that, in the framework of a very restricted budget, FET Open is too broad and not strategically oriented enough – so assessing coherence is difficult. CARSA study and Flagships panel offer preliminary insights.
Strengths	Overall, FET's design appears well suited to ensure internal coherence. FET Proactive has the strategic role of maturing promising future and emerging technology areas, detected and continuously challenged by FET-Open, that can find their way into other programmes (including national ones) as well as to innovative industrial applications, some of which by means of the FET Flagships. Flagships: synergies exist with other parts of Horizon 2020, in particular LEIT ICT, some PPPs and Societal Challenge Health.
Bottlenecks/ weaknesses	Further improvements are possible regarding the articulation between FET-funded activities (e.g. exploitation of results) and with ESIF at implementation level. Flagships should in theory provide a framework for coordination of efforts at European, national or regional levels. Linking national initiatives to the Flagships has only happened to a limited extent.

B.9.5. EU Added Value

Key findings	The programme helps build critical mass and obtain synergies by overcoming national fragmentation; it is also instrumental in mobilising excellent research across Member States. Flagships: they bring about critical mass (both in terms of financial support as well as in multi-disciplinary cooperation) reached on a scale that no Member State alone could have afforded.
Strengths	FET helps address EU-level challenges and EU strategic goals, including through the development of Pan-European technical solutions that address the Union's Societal Challenges and help complete the Digital Single Market.
Bottlenecks/ weaknesses	According to the expert panel, there is room for improvement when it comes to developing scientific, societal or industrial exploitation plans.

C. MARIE SKŁODOWSKA-CURIE ACTIONS

C.1. INTRODUCTION

C.1.1. Context

Article 179 of the Treaty on the Functioning of the European Union foresees a European Research Area (ERA) in which researchers, scientific knowledge and technology circulate freely. In this regard, the Marie Skłodowska-Curie actions (MSCA) as a flagship programme for researcher mobility and training are embedded in the European Union's legal basis.

During FP7, MSCA funded over 11 000 projects involving 50 000 researchers with a budget of EUR 4.7 billion. Under Horizon 2020, the MSCA are part of the Excellent Science pillar and will fund 65 000 researchers to the tune of EUR 6.162 billion, 8% of the overall budget. This represents a 30% increase compared to FP7 and is a clear sign of recognition from stakeholders - including the Member States and the European Parliament - of a strong added value of the programme and its proven track record over the past twenty years.

This thematic chapter draws on the following sources: an external evaluation study[79] carried out by ICF International on behalf of DG EAC, analysis carried out internally by the MSCA unit in DG EAC and the relevant units in REA, and the use of proposal and project data from the Commission's CORDA database on Horizon 2020.

C.1.2. Objectives and intervention logic

The main objective of the MSCA is to invest in the people who drive research and innovation in Europe, to enhance the skills and competences of the researchers and to deliver on innovation, growth and competitiveness. Highly-trained researchers are necessary to advance science and business competitiveness, which, in turn, are important factors in attracting and sustaining investment in Europe.

In establishing Horizon 2020, the European Council pointed to the "*critical need to reinforce, widen and extend the excellence of the Union's science base and to ensure a supply of world-class research and talent to secure Europe's long-term competitiveness and well-being."*

The Council foresaw a key role for the MSCA, alongside FET and the ERC, among others, in "*building competence in the long term, focusing strongly on the next generation of science, systems and researchers, and providing support for emerging talent from across the Union and from associated countries. Union activities to support excellent science should help consolidate the ERA and make the science system of the Union more competitive and attractive on a global scale."* [80]

[79] Study carried out by ICF International. Final report forthcoming June 2017
[80] Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020

Beyond the overarching objectives of Horizon 2020, and while also contributing to a number of issues which are cross-cutting throughout the Horizon 2020 programme, MSCA address four specific objectives:

- Fostering new skills by means of excellent initial training of researchers – the goal is to train a new generation of creative and innovative researchers, and enable them to convert knowledge and ideas into products and services for economic and social benefit across Europe.
- Nurturing excellence by means of trans-national and cross-sector mobility – the goal is to enhance the creative and innovative potential of researchers at all career levels by creating opportunities through international and inter-sectoral mobility.
- Stimulating innovation by means of cross-fertilisation of knowledge – the goal of is to reinforce trans-national and cross-sector collaboration in research and innovation through exchange of R&I staff.
- Increasing structural impact by co-funding activities – the goal is to increase the numerical and structural impact of MSCA and to foster excellence at national level in researchers' training, mobility and career development by leveraging additional funds and co-funding activities at the international, national or regional level.

Furthermore, the MSCA provide specific support to initiatives raising awareness on the importance of the research career and disseminating research and innovation results emanating from work supported by the programme.

A comparison with FP7[81] shows a high degree of continuity although the objectives and structure of MSCA have evolved over time to reflect emerging needs and simplify the programme's structure. Under Horizon 2020, MSCA have an increased focus on societal challenges, societal and innovation impacts and inter-sectoral mobility. It is addressing Open Science, Responsible Research and Innovation, as well as placing stronger emphasis on the implementation and adoption of the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers (Charter and Code).[82] It also puts into practice the Principles for Innovative Doctoral Training, as illustrated by the introduction of doctoral training programmes under COFUND.

Overall, the MSCA offer excellent and innovative research training as well as attractive career and knowledge-exchange opportunities through trans-national and cross-sector mobility of researchers, to better prepare them for current and future societal challenges.To address the identified objectives, the programme has adopted the intervention logic presented in Figure 53.

In brief, the MSCA are composed of Innovative Training Networks (ITN) which aim to train a new generation of creative, entrepreneurial and innovative early-stage researchers, raising the excellence of research in Europe. ITN supports competitively selected doctoral(-level) programmes, implemented by partnerships of universities, business and other research performing organisations, across Europe and beyond. Partnerships take the form of collaborative European Training Networks (ETN), European Industrial Doctorates (EID) or European Joint Doctorates (EJD).

[81] *COUNCIL DECISION of 19 December 2006 concerning the specific programme "People" implementing the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007 to 2013) (2006/973/EC).*

[82] *https://euraxess.ec.europa.eu/jobs/charter*

Individual Fellowships (IF) support experienced researchers undertaking mobility between countries, and where appropriate to the non-academic sector[83]. They aim to enhance the creative and innovative potential of experienced researchers by providing opportunities to acquire new knowledge, to work on research in a European context or outside Europe, to reintegrate researchers who return to Europe and to restart the careers of individual researchers.

The Research and Innovation Staff Exchanges (RISE) support international and inter-sectoral collaboration through research and innovation staff exchanges, and sharing of knowledge and ideas from research to market (and vice-versa).

The COFUND scheme aims at stimulating regional, national or international programmes (fellowship or doctoral programmes) to foster excellence in researchers' training, mobility and career development, spreading the best practices of MSCA.

In addition, the European Researchers' Night (EUR 4 million per year) aims to raise the awareness and recognition of the public on research and innovation activities. Through these activities it also has a role in encouraging the public to embark on scientific careers- through specific events, rather than supporting research projects.

The MSCA are open to all domains of research and innovation, addressed under the Treaty on the Functioning of the European Union, from basic research up to market take-up and innovation services. Research and innovation fields as well as sectors of activity are chosen freely by applicants in a fully bottom-up manner.

Mobility is a key requirement in the MSCA, be it international, inter-sectoral or interdisciplinary. Researchers receive funding on the condition that they move from one country to another to broaden or deepen their competences.

The actions are open to researchers and innovation staff at all stages of their career, irrespective of age. They are open to universities, research institutions, research infrastructures, businesses, and other socio-economic actors including civil society organisations from all countries, and third countries[84]. Attention is paid to encouraging the strong participation of business, in particular SMEs.

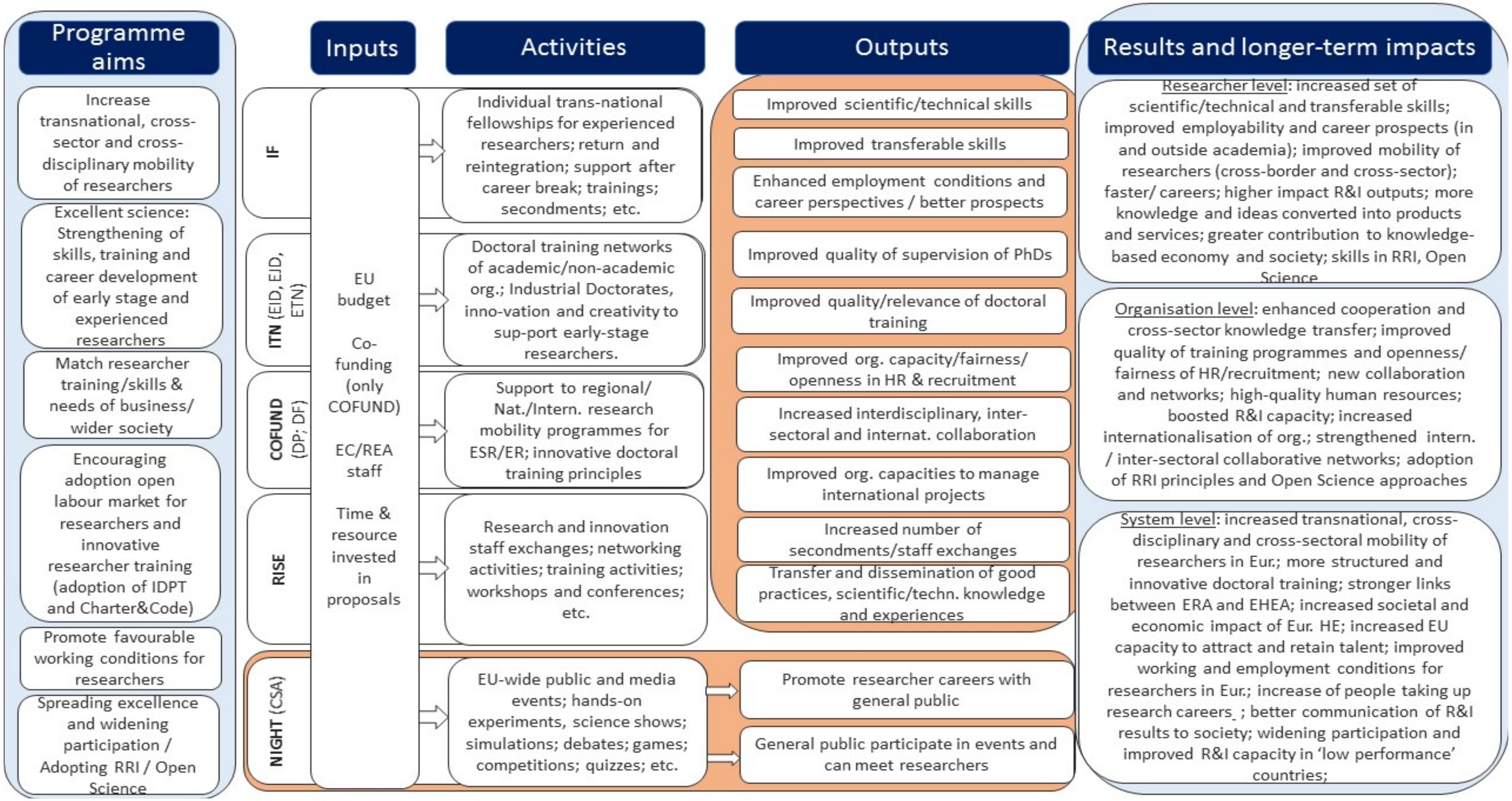
The principles of the Charter and Code promoting open recruitment and attractive working and employment conditions should be applied by all MSCA funded participants. Many of these principles have been translated into legally binding conditions of the MSCA model grant agreements. Furthermore, the European Code of Conduct for Research Integrity is endorsed (c.f. Article 34 of the Model Grant Agreements).

MSCA also endorse the Horizon 2020 cross-cutting issue "Responsible Research and Innovation" (RRI), engaging society, integrating the gender and ethical dimensions, ensuring access to research outcomes and encouraging informal science education. All applicants to the MSCA calls are encouraged to adopt an RRI approach into their proposals. Indeed, around 30% of all the RRI-flagged budget in Horizon 2020 goes to MSCA.

[83] *This includes for example the new Society and Enterprise Panel in the IF Call 2016; https://ec.europa.eu/research/mariecurieactions/news/20160412-if-society-enterprise-panel_en*

[84] *Under the conditions defined in the Horizon 2020 Rules for Participation Regulation No 1290/2013 and in part A of the General Annexes to the Work Programme.*

Figure 53 - Intervention logic of the MSCA (Horizon 2020)



Source: ICF Evaluation Report 2017

C.2. IMPLEMENTATION STATE OF PLAY

C.2.1. Overview of programme inputs and activities

To date, EUR 2.1 billion has been allocated to the implementation of MSCA calls included in the Horizon 2020 Work Programmes 2014-2016. The total budget allocated to MSCA for the period 2014-2020 is EUR 6.1 billion which represents 8% of the overall Horizon 2020 budget. Table 23 provides an overview of the number of projects and funding per action during the first three years.

Table 23 - Number of MSCA projects and funding allocated for the programming period 2014-2016

Type of Action	Nr. of projects	EC funding, in €m
Innovative Training Networks (ITN) 2014-16	389	1 259
Individual Fellowships (IF) 2014-15	2 444	451
Research and Innovation Staff Exchange (RISE) 2014-16	265	223
COFUND 2014-15	55	164
CSA (mainly NIGHT) 2014-16	93	18
All actions in MSCA	3 246	2 115

Source: CORDA data, 1 January 2017. Note that 2016 Calls for IF and COFUND were not completed by this date and therefore the data refer only to 2014 and 2015 for these two actions.

The budgetary allocation of the programme and selection of projects reflects the objectives of the programme. The largest share of funds is devoted to ITN of early-stage researchers. IF are the second largest part of the programme funding experienced researchers. RISE and COFUND each account for around 10% of the budget. In addition, the European Researchers' Night (EUR 4 million per year) aims to raise the awareness and recognition of the public on research and innovation activities.

C.2.2. Participation patterns

A total 11 127 projects were supported under FP7 with around 2 500 still ongoing at the beginning of 2017. Under Horizon 2020, 3 246 projects (signed grants) were ongoing as of 1 January 2017. The programme's oversubscription rate has doubled between FP7 and Horizon 2020, largely due to an ever growing demand for funding of ITN and IF. Overall, around 80% (amounting to over 14 300 proposals) of all high-quality proposals have not been funded. See Table 24.

Table 24 - Number of proposals, oversubscription rate and success rate per type of action

Type of action	Number of eligible proposals	Number of high quality proposals	Number of retained proposals	Oversubscription rate	Success rate (proposals)
MSCA-COFUND	207	158	52	204%	25,1%
MSCA-IF	15 988	13 059	2 493	424%	15,6%
MSCA-ITN	4 282	3 645	335	988%	7,8%
MSCA-RISE	927	588	257	129%	27,7%
Total	21 644	17 592	3 231	444%	14,9%

*Source: CORDA data, 1 January 2017. Notes:i) There may be discrepancies between the number of retained proposals (the 'Main' list) and the number of signed grants in Table 1 which may include proposals from the reserve list. For IF the number of signed grants is actually lower than the number of retained grants due to withdrawals from grant preparation since individual researchers may find other engagements, such as permanent employment. ii) High-quality proposals are those which scored 70% or more in the evaluation. iii) The oversubscription rate corresponds to the number of [high quality proposals/number of retained proposals]-1 *100.*

C.2.2.1. Participation per type of organisation

The funded proposals represent a total of 7 852 participations, mobilising 2 464 distinct beneficiaries.[85] Private for profit organisations account for 43% of all MSCA beneficiaries whereas they make up 16% of all participations, i.e. the number of projects in which they are beneficiaries. This reflects the relatively small number of times (1.2 on average) that a private for profit organisation participates in MSCA compared with an average of 6.5 times per higher education institution. See Table 25 below.

In addition, Table 28 provides information for the top twenty beneficiaries.

In terms of success rate, the differences between the various types of organisation are relatively small: 11.4% for public institutions, 11.8% for the private sector and 13.1% for Higher Education Institutions. One important exception concerns non-academic applicants for the Individual Fellowships. In 2014 their success rate was 9.4%, about half of the success rate for all applicants (18.6%). The Society and Enterprise panel was introduced in 2016 to address this issue.

[85] *IF and COFUND are mono-beneficiary actions while RISE and ITN are multi-beneficiary actions. Furthermore, a beneficiary may participate in more than one project.*

Table 25 - Number of participants, coordinators, newcomers and EC contribution by type of actor for MSCA

Participant legal entity	Number of distinct participants in signed grants	Number of projects coordinators in signed grants	Number of newcomers in signed grants	Number of participations in signed grants	EC contribution to participations in signed grants (EUR million)
Higher education institution	752	2 468	47	4 886	1 407
Public institutions	79	22	21	93	42
Research Centres	446	675	35	1 456	400
Private sector	1 052	55	490	1 263	246
Other institutions	135	26	86	154	20
Total	2 464	3 246	679	7 852	2 115

Source: CORDA data, 1 January 2017. Note: The data include beneficiaries only and therefore exclude the partner organisations who may receive funding from the beneficiary.

C.2.2.2. Attractiveness to newcomers

There are 679 newcomers[86] which represents 21% of participants in signed grants. The majority of newcomers are private for profit organisations.

C.2.2.3. Geographical participation patterns

Table 26 - Geographical distribution of funding, participants and coordinators

Country group	Number of participations	% of all participations	% of coordination roles	EU funding allocated (€ million)	% of EU funding allocated
EU-13	497	6%	3%	97	5%
EU-15	6 843	87%	91%	1 894	90%
Associated countries	505	6%	5%	123	6%
Third countries	7	0.1%	0%	1	0.1%
Grand Total	7 852	100%	100%	2 115	100%
of which widening countries	678	9%	4%	133	6%

Source: CORDA data, 1 January 2017. Note: If MSCA partner organisations are included, partner organisations from third countries represent 11% of all participations, compared to 4% across Horizon 2020 – the largest share of third country participations across all parts of Horizon 2020. The EU funding that beneficiaries may transfer to the third country partner organisations in their consortium is estimated at EUR 78 million.

There are wide discrepancies between European countries in their ability to attract MSCA funding. For example, EU-13 countries account for 20% of the EU population or 12% of the EU researcher population but in 2015 the share of EU-13 accounted for 6% of total participations in MSCA (Table 26 and Table 27). Data show that in general EU-13 countries tend to submit fewer proposals than EU-15 countries and that the quality of submitted proposals is also lower[87]. However, all EU-13 countries have a significant share of high-quality proposals above threshold. See Figure 54 below.

[86] Participants are regarded as newcomers if they did not participate in a project under FP7.
[87] The number of proposals below threshold amounts to 29% on average among EU-13 compared with 16% on average for EU-15 countries.

Table 27 - Participation patterns by country for MSCA

Member States	Number of distinct participants in signed grants	Number of projects coordinators in signed grants	Number of newcomers in signed grants	Number of participations in signed grants	Success rate (applications)	EC contribution to participations in signed grants (EUR million)
Austria	72	59	15	191	15,2%	48,7
Belgium	66	97	13	268	11,4%	87,5
Bulgaria	33	6	8	34	17,1%	3,2
Croatia	11	2	2	16	7,2%	2,6
Cyprus	14	16	3	40	10,5%	8,5
Czech Republic	36	12	5	65	9,1%	16,7
Denmark	48	143	7	261	12,9%	86,6
Estonia	14	11	2	28	13,2%	5
Finland	39	38	11	119	12,8%	34
France	220	294	53	721	11,9%	192,4
Germany	320	278	86	926	11,9%	263,1
Greece	79	46	25	189	11,7%	37,3
Hungary	26	9	4	44	9,5%	8,2
Ireland	47	92	19	167	15,3%	62,7
Italy	231	216	68	625	11,3%	150,6
Latvia	4			6	3,8%	1,3
Lithuania	14	5	2	22	9,5%	3,2
Luxembourg	10	6	2	19	11,1%	4
Malta	8	3	5	13	21,1%	1,6
Netherlands	121	234	36	541	12,7%	178,3
Poland	68	29	16	114	12,3%	28,8
Portugal	81	49	17	165	10,9%	37
Romania	34	7	12	41	11,6%	4,4
Slovakia	24	4	10	32	17,0%	5,5
Slovenia	23	6	8	42	9,2%	8,2
Spain	256	302	68	719	11,4%	182,6
Sweden	64	64	22	240	11,2%	74,4
United Kingdom	280	1045	79	1692	14,6%	455,1
Total EU-28	2243	3073	598	7340	12,4%	1991,2

Source: CORDA data, 1 January 2017.

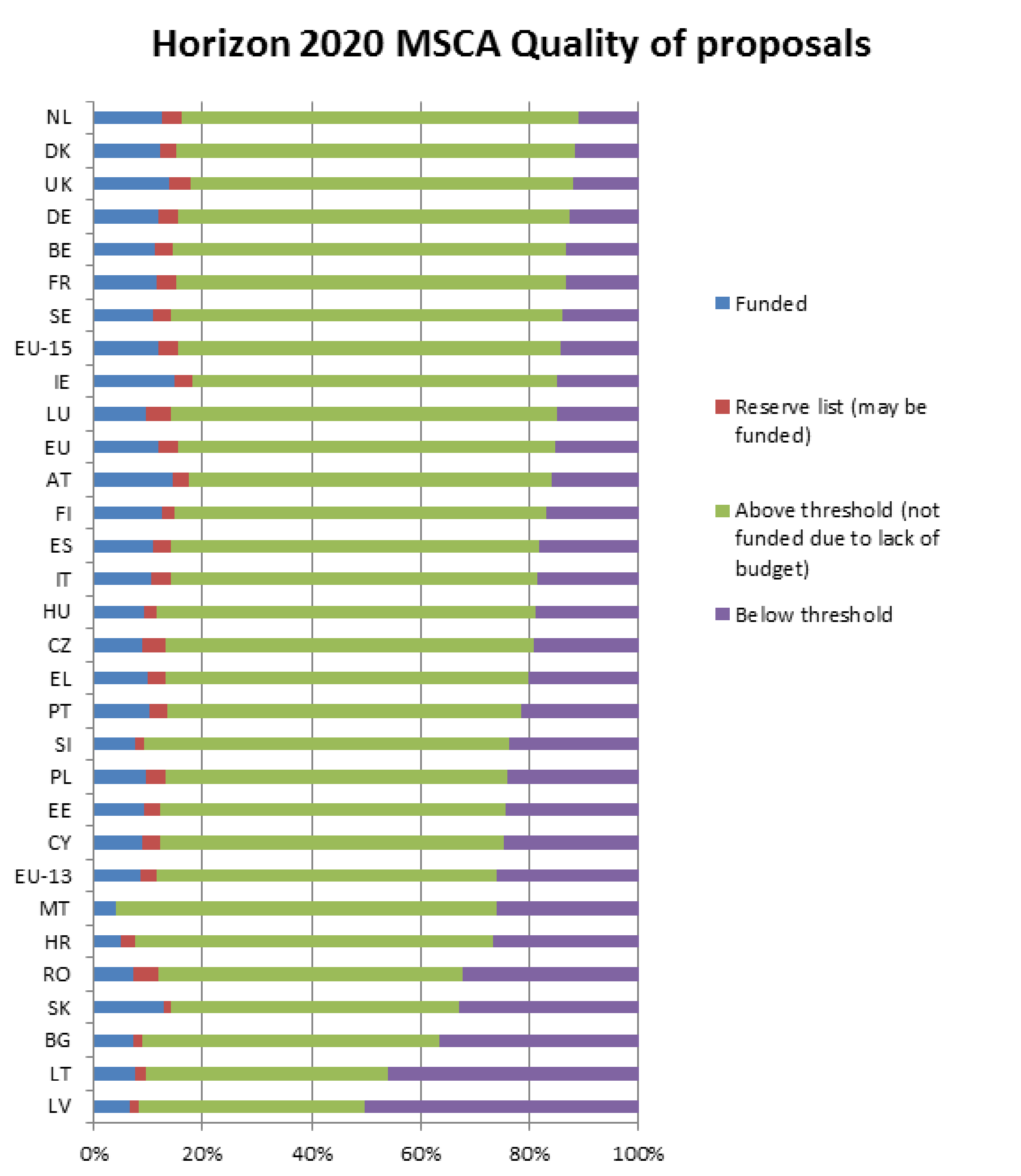
Table 28 provides an overview of the main organisations participating in MSCA in terms of funding received. The top twenty is composed of universities and public research institutions.

Table 28 - Top twenty institutions benefitting from MSCA funding

Position	Legal name of the participant	Participant requested EC contribution	Number of participations
1	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	45.502.611,60	168
2	KOBENHAVNS UNIVERSITET	32.023.147,20	111
3	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	29.768.351,12	132
4	KATHOLIEKE UNIVERSITEIT LEUVEN	27.170.210,40	68
5	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD	24.634.683,54	107
6	UNIVERSITY COLLEGE LONDON	24.430.431,44	86
7	IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE	22.192.769,52	81
8	AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS	21.717.249,96	89
9	DANMARKS TEKNISKE UNIVERSITET	21.436.806,48	34
10	TECHNISCHE UNIVERSITEIT DELFT	18.708.269,09	40
11	THE UNIVERSITY OF BIRMINGHAM	17.595.510,24	66
12	TECHNISCHE UNIVERSITEIT EINDHOVEN	15.155.425,03	37
13	UNIVERSITEIT UTRECHT	14.828.574,60	48
14	MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	14.176.813,68	65
15	TRINITY COLLEGE DUBLIN	13.192.716,30	25
16	CONSIGLIO NAZIONALE DELLE RICERCHE	13.188.320,88	44
17	THE UNIVERSITY OF NOTTINGHAM	12.842.782,41	36
18	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	12.558.855,78	35
19	UNIVERSITY COLLEGE DUBLIN, NATIONAL UNIVERSITY OF IRELAND, DUBLIN	11.910.013,50	31
20	EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH	11.706.249,00	18

Source: CORDA data, 1 January 2017.

Figure 54 - MSCA Quality of proposals per country



Source: DG EAC calculations based on MSCA data from the evaluation of proposals.

C.2.2.4. International cooperation[88]

MSCA play a key role in terms of being open to the world, building international collaboration and attracting and retaining researchers in Europe through dedicated actions.

All actions support international cooperation, with in particular, IF and RISE specifically targeting mobility to third countries: RISE through the inter-sectoral/international eligibility criterion and IF through the "Global Fellowships" which allow some of

[88] *By international cooperation we mean cooperation with third countries outside of the EU and Associated Countries.*

Europe's leading researchers to carry out research outside Europe, with an in-built return phase to Europe. RISE, with around 470 third-country participations corresponding to almost 30% of its total participations, is the most international scheme in Horizon 2020. Furthermore, both ITN and COFUND attract international participants at an above-average rate even if they are not specifically targeting third countries.[89]

MSCA account for more than half of all third country participations in Horizon 2020 and around 80% of all US participations. Almost 140 nationalities have received MSCA funding since 2014. Around one in four MSCA fellows are researchers attracted to Europe from countries outside the EU Member States or the Horizon 2020 Associated Countries. Highly developed countries such as the US have been attractive destinations for outgoing MSCA researchers. However, emerging countries such as China, Brazil or India attract only small numbers of European researchers, and cooperation should be reinforced to ensure more effective brain circulation.[90]

Under MSCA, the vast majority of legal entities from third countries do not participate as beneficiaries but as partner organisations and therefore do not receive funding directly from the EU. Researchers and doctoral candidates may apply from any country in the world and receive funding through the MSCA when coming to an EU Member State or AC country; the same is valid for researchers and doctoral candidates from within the EU and AC to do parts of their training in any country in the world.

A total of 1 662 entities from third countries applied to the programme, within 5 342 eligible project proposals. 19% of these proposals were retained for funding, involving 598 third countries participants.

Table 29 - Participations of third countries to MSCA projects

Associated Countries	Participations in MSCA projects			
	2014	**2015**	**H2020**	**FP7**
United States	169	210	381	934
Australia	26	34	60	172
Canada	27	29	56	146
Argentina	25	17	42	92
China	16	24	40	316
Brazil	13	22	35	187
Japan	18	14	32	59
Chile	12	15	27	52
South Africa	15	10	25	77
Russian Federation	7	11	18	170
Third Countries*	409	498	909	2 639

*Source: CORDA data. Note: *FP7 figures are presented for the same countries as for Horizon 2020.*

[89] *Performance Analysis of International Participation in Horizon 2020, EC 2016*
[90] *Issue Paper for the High Level Group "Open to the World"*

C.3. RELEVANCE

C.3.1. Is MSCA tackling the right issues?

C.3.1.1. The relevance of MSCA given the challenges to address

As set out in more detail in Section C.1.2, the Council decision establishing Horizon 2020 pointed to the "*critical need to reinforce, widen and extend the excellence of the Union's science base and to ensure a supply of world-class research and talent to secure Europe's long-term competitiveness and well-being."* More specifically, the Council foresaw a key role for the MSCA, alongside FET and the ERC, among others, in "*building competence in the long term, focusing strongly on the next generation of science, systems and researchers, and providing support for emerging talent from across the Union and from associated countries. Union activities to support excellent science should help consolidate the ERA and make the science system of the Union more competitive and attractive on a global scale."* [91]

These objectives were set in a political context that underlined Europe's research and development performance gaps[92]. While performance in these areas has been improving to varying degrees, the need for further progress persists on issues such as Europe's comparatively low share of researchers employed by enterprises[93], and these political priorities remain firmly on the agenda[94].

In the face of these challenges, MSCA are highly relevant in that they provide high-quality and innovative research training and attractive career opportunities through trans-national and cross-sector mobility of researchers and foster the transfer of knowledge and cooperation between research performing organisations. The Juncker Commission's priorities will benefit from this strong research base, in particular in boosting jobs, growth and investment.[95]

There is a large body of evidence to support MSCA's focus on international mobility: Researchers with international experience tend to exhibit a higher scientific impact (up to 20% higher than the impact of those who opt to stay in their home country), and international co-publications tend to be more often cited (European Commission 2016). OECD data suggest that "with few exceptions, individuals not changing affiliations (stayers) are more likely to publish in journals of lower "prestige" (OECD 2015:104). Mobility is also a key tool to develop international cooperation, which strengthens the excellence and attractiveness of R&I in the EU. It provides access to the state of the art and new resources, it develops, attracts and retains high quality researchers in Europe, and it can lead to connections with research test beds and innovative advances in areas where European countries are less specialised (European Commission 2016[96]).

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[91] *Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020*
[92] *Commission Staff Working Paper: Executive Summary of the Impact Assessment Accompanying the Communication from the Commission "Horizon2020 –the Framework Programme for Research and Innovation". COM (2011) 808 Final.*
[93] *Hollanders, H., Es-Sadki, N. and Kanerva, M. (2016) European Innovation Scorecard 2016. European Commission.*
[94] *European Commission (2016) Science, Research and Innovation Performance in the EU. Brussels, DG Research and Innovation.*
[95] https://ec.europa.eu/commission/priorities_en
[96] *European Commission (2016) 'Performance analysis of international participation in Horizon 2020. A support study for the interim evaluation of Horizon 2020' European Commission, October 2016.*

MSCA have demonstrated improved flexibility under Horizon 2020 by responding to the emerging challenge of migration flows, by refining and highlighting the features aimed at welcoming researchers to Europe. It also actively promoted the results of the research that the EU has funded on topics linked to migration.

MSCA are also very relevant given their bottom-up nature. This provides the space for researchers to come up with their own solutions to major societal challenges, and means that technological or scientific advances can be harnessed by the scientific community.

The MSCA programme supports specific actions to help change public perception of science as well as researcher careers, and strengthen efforts to disseminate research to the broader public. While all MSCA include dissemination activities, the NIGHT action through its funded projects around Europe and beyond specifically addresses these system level objectives of the programme.

C.3.1.2. The relevance of MSCA to address European objectives

The EU political agenda is focussed on strengthening the EU's competitiveness, stimulating public and private investment, promoting growth, and creating new and sustainable jobs[97]. Research and innovation are seen as a crucial driver to stimulate and leverage investment that expands opportunities for highly-skilled individuals, as well as to generate new solutions and knowledge which will help to deliver on the Commission's agenda.[98] Moreover, highly-skilled human resources and international collaborations in research in science and technology result in significant "soft power"[99], linking to the EU priority of being a stronger global actor.

The Juncker Commission's priorities will benefit from a strong research base, in particular in the areas of boosting jobs, growth and investment, and a connected digital single market. The Impact Assessment (IA) of Horizon 2020[100] underlined that a strong research base is a key component for Europe to address EU2020 goals; it is also a key component to meet Sustainable Development Goals. In particular MSCA aim to contribute to making effective use of Europe's investment in research and innovation, which Europe2020 goals aim to raise to 3% of EU GDP, by focussing on equipping – notably the next generation of[101]- scientists with the skills needed to develop their career within and outside academia, in particular, industry, through excellent training and the stimulation of mobility.

Moreover, efforts under Horizon 2020 to increase the participation of businesses in MSCA and equip the next generation of researchers with the skills needed to develop their career outside academia are also in line with the country-specific recommendations of the European Semester 2016, to strengthen inter-sectoral cooperation to turn research results into future products and services.

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97 European Commission (2016) European Economic Forecast Autumn 2016. Institutional Paper 038. Economic and Financial Affairs, November 2016. http://ec.europa.eu/economy_finance/publications/eeip/pdf/ip038_en.pdf

98 Issue paper for the High Level Group "Contribution to Juncker priorities and current challenges"

99 Portland Research (2015) Soft Power 30. A global ranking of soft power.

100 Commission Staff Working Paper: Executive Summary of the Impact Assessment Accompanying the Communication from the Commission "Horizon2020 –the Framework Programme for Research and Innovation" . COM (2011) 808 Final.

101 This is particularly important given Europe's ageing research population. Avramov, D. (2015) 'FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): rationale, implementation and achievements' Final Revision 13 August 2015.

In terms of the three O's strategy, MSCA calls for proposals have promoted new training elements and modules on open science, innovation and entrepreneurship in the training programmes for researchers. MSCA are also renowned for being open to the world, and indeed participation in MSCA accounts for more than half of all third country participations in Horizon 2020. See section C.2.2.4.

C.3.2. Flexibility to adapt to new scientific and socio-economic developments

While no specific foresight exercises have been undertaken, evaluation findings[102] show that the programme is well adapted to a wide range of emerging needs. Furthermore, Horizon 2020 allows for a more flexible approach to respond to new emerging challenges compared to FP7.[103] For example, MSCA have demonstrated a certain level of flexibility by responding to the emerging challenge of migration flows through initiatives aimed at welcoming researchers to Europe.

More generally, given the use of annual calls and the focus on training and skills development, MSCA have the capacity to adapt to technological and scientific advances and changes of the wider socio-economic and political context, through the prioritisation of training programmes and of skills to be developed in its work programme[104].

Moreover, the bottom-up approach provides the space for researchers to come up with their own solutions to major societal challenges and means that technological or scientific advances can be taken up by the scientific community. Analysis suggests that research areas proposed by researchers do address societal challenges and contribute to new and emerging areas of science with potential relevance to these challenges.[105] For example, a relatively high number of MSCA projects (603 or 19% of total signed grants) contribute to ICT. Extensive research towards societal challenges and participants going on to become Nobel laureates (8 in total between 2012 and 2016) are also features of MSCA. Furthermore, MSCA responds in particular to the expectations of young researchers who look for opportunities to pursue new ideas that may lead to breakthrough discoveries.[106]

C.3.3. Addressing specific stakeholder needs[107]

The programme aims to address the needs of a range of stakeholders including individual researchers, higher education institutions, research institutions, businesses, NGOs.

[102] *PPMI (2013) "FP7 Marie Curie Actions Interim evaluation. Implementing Framework contract EAC/50/2009". Final Report.*
[103] *The FP7 ex-post evaluation concluded that even though FP7 responded to the economic crisis it was not flexible enough to respond to new emerging challenges. Horizon 2020 has been designed with sufficient built-in flexibility to tackle new and unexpected challenges, see Article 15 of the Horizon 2020 Regulation.*
[104] *See Horizon2020 Work Programme 2016-17. 3. Marie-Sklodowska-Curie Actions.*
[105] *DG EAC internal analysis on keywords of projects*
[106] *"Measures to support early stage researchers, raise the attractiveness of scientific careers and foster investment in human potential in research and development" - conclusions of Council of Ministers, adopted on 29/11/16 (15013/16)*
[107] *This section draws on: CARSA (unpublished). Support study for the Interim Evaluation of Horizon 2020 - DG CONNECT Activities.*

Stakeholder feedback on the relevance of the programme aims and the forms of support it provides is positive.[108]

The steadily rising number of applications received to MSCA calls is a clear indicator of their relevance and high attractiveness. In 2016, the highest number of proposals ever submitted to a single deadline (8 946) under Horizon 2020 were for the IF call.

Interview data for this evaluation conveyed a clear message that MSCA continue to be relevant within the current context based on its capacity to address skills development, enhancing the internationally visibility of researchers' quality and capacity building/ visibility in both academic and other organisations. Interviewees reported:

"MSCA is an excellent programme that should continue beyond the ages. It is a relevant instrument to address the real needs for research in the EU. (…) When we think about competitiveness with other world regions and about developing research in Europe, all of this starts with people. Hence, the exposure to an international environment through the MSCA/ MCA is precious". –National policy-maker and programme officer.

"The most important aspect of the programme is skills development. The programme aims to contribute to the development of researchers' skills and support their careers through the prestige of the MSCA fellowships. The programme also helps to build capacity within teams and institutions through the mobility of researchers, fostering the internationalisation of teams and research in Europe" –National policy-maker and programme officer.

Firstly - looking at the relevance for individual researchers - the programme objectives were regarded as being highly relevant to early career researchers. Interviewees were first asked to indicate their motives for applying to MSCA. If motives were deemed to be of (very) great importance, interviewees were then asked to what extent their expectations were fulfilled. IF fellows appear to have had their expectations fulfilled to a (very) great about the following aspects: conducting research abroad (89%); working with researchers in academia (87%); and working at an institution or with researchers with excellent reputation (86%). Similar data were reported for these categories by ITN fellows. Around 46% of ITN fellows had their expectations fulfilled to a (very) great extent for enhancing their chances of a career outside academia. Some stakeholders reported that there is less support for senior researchers in the programme than for other types of researchers.

The MSCA Advisory Group expressed support for the enhancements that have been delivered within the MSCA in defining the research positions that can be supported. It also recognised that the issue of diversity and inclusion in research goes beyond gender, and that a greater diversity of excellent researchers makes for better research.[109]

A new study on the IF Career Restart Panel shows the successful outcomes of this type of fellowship, but highlights that career re-starters have particular difficulties in finding a permanent position and often cannot catch up with their peers within only two years.[110]

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[108] *PPMI (2013) 'FP7 Marie Curie Actions Interim Evaluation' Final report. See for example Coimbra Group position paper on Horizon 2020 https://www.coimbra-group.eu/uploads/2013/Coimbra%20Group%20position%20on%20Horizon%202020-Final-22Feb2013.pdf; LERU (2016): LERU's interim evaluation Horizon 2020*

[109] *MSCA Advisory Group report June 2016*

[110] *Study "Research careers in Europe" (2016), recommendation No 15, p.132, http://bookshop.europa.eu/en/research-careers-in-europe-pbNC0614200/ ;ISBN: 978-92-79-44501-9; doi: 10.2766/051369*

Second –looking at the relevance of MSCA to a broader public - there is a recognised gap in public awareness of the MSCA and more generally in understanding of the benefits of publicly-funded research. The European Researchers’ Night and the outreach activities undertaken by the fellows under the various MSCA schemes aim to fill that gap: bringing researchers closer to the general public and increasing awareness of research and innovation activities, with a view to supporting the public recognition of researchers, creating an understanding of the impact of researchers' work on citizen’s daily life, and encouraging young people to embark on research careers. The NIGHT attracts over one million visitors every year.

Third, MSCA are relevant to the needs of a diverse set of organisations, including those outside of the higher education sector. Taking the example of RISE, this action enables the organisation of travel/ meetings/ networking activities within a single project and the pooling of resources instead of having to submit separate proposals for all these activities. These activities can connect industry and academia, and facilitate researcher’s mobility. However, RISE was also reported by some stakeholders as being restrictive in terms of its requirement of a secondment.

“We saw some examples where RISE was used by small SMEs and larger companies to test ideas in collaboration with universities. It allows them to work with new researchers. That time under RISE was seen as a trial period for a possible contract later. As an example, Procter&Gamble in my country collaborated with a university in Italy for a long time. They developed some new products together, and P&G offered some of those researchers a contract afterwards.” Interviewee (Policy-maker and programming officer).

Efforts have also been made to better meet the needs of the non-academic sector, In this regard, a new pilot Society and Enterprise Panel for experienced researchers within the Individual Fellowships was launched in 2016.

C.3.4. Lessons learnt/Areas for improvement

The programme is relevant in addressing many of the issues associated with Europe’s relative lack of competitiveness: the need to attract more highly skilled researchers in the global race for talent; fragmentation of the European public science and research base; lack of high-quality training of and career development for researchers; and insufficient knowledge transfer and mobility of researchers between academia and non-academia.

The objectives of MSCA thus continue to correspond to the needs within the EU. This view is supported by stakeholders such as LERU and Science Europe as well as other evidence – eight Nobel Prize winners between 2012 and 2016 had been actively involved in projects funded by the programme- suggesting that the design of MSCA is relevant to meet those overall objectives.

Increased flexibility of calls and researcher positions (e.g. combined positions, part-time work, secondments) might facilitate more international, interdisciplinary and cross-sector careers. At present, researchers must devote themselves to their project on a full-time basis with part-time allowed for personal or family reasons only. This restriction might limit the possibility of entrepreneurial activity within research training, for example, or formal training to enhance career prospects (e.g. an additional degree in an area such as management or law).

Extending the possibilities for part-time would allow for more tailor-made mobility and allow experienced researchers in their Individual Fellowship action to pursue supplementary professional activities. These might include creating a company, or engaging in advanced studies not related to the MSCA grant.. Flexibility is important in supporting equality of access for all researchers, irrespective of their personal circumstances[111]. In this regard, MSCA could be more relevant by increasing the attractiveness of the IF Career Restart Panel both in terms of funding and duration. In addition, the conditions for benefitting from the family allowance could be made more flexible in order to ensure that researchers with dependent family members are appropriately financed at all stages of their career.

Specific support could also be provided to researchers living with a disability: mobility is often far more difficult and more expensive for them due to special needs when travelling, finding a suitable residence, and working abroad. Disabled researchers should be able to enjoy the same opportunities as their peers to participate in the MSCA. Therefore a distinct disability allowance for such researchers could be envisaged.[112]

C.4. EFFECTIVENESS

No MSCA projects had been completed at the time of writing. It is thus clear that the measurable output at this stage of the programme implementation is somewhat limited. Moreover, the full value and impact of mobility and opportunities opened up by MSCA is often revealed after many years. Nevertheless, a large body of evidence shows that MSCA continue to have a positive impact on individual researchers, organisations, and at the system level. In particular, a series of surveys of MSCA fellows and organisations carried out on behalf of DG EAC by ICF provides some insight into the impact of MSCA funding.

C.4.1. Short-term outputs from the programme

Around 27 000 fellows have been funded under the budget of the MSCA calls for the years 2014-16. All fellows will experience mobility between countries and an estimated 12 000 will benefit from some form of cross-sectoral mobility out of or into an academic setting.

To date under Horizon 2020, there have been 1 114 publications in MSCA projects, of which 740 in peer-reviewed journals. This is the highest number of all areas in the Framework Progamme.

C.4.2. Progress towards the overall Horizon 2020 objectives

C.4.2.1. Fostering excellent science in scientific and technological research

MSCA are characterised by an emphasis on research excellence and on the benefits to be gained through mobility, which can be international, interdisciplinary or inter-sectoral. They are based on the idea that knowledge transfer happens through people and their interactions, and that training in the delivery of excellent research, amplified through mobility, delivers benefits that can last throughout a career. More than 100 000 high-

[111] *MSCA Advisory Group report June 2016*
[112] *Text based on internal gap analysis by the European Commission in preparation for the scoping paper 2018-20.*

quality researchers have benefitted from a mobility experience over the past twenty years.

There is strong evidence of longer-term scientific value and societal impact of the programme. MSCA fellows have a strong reputation for research excellence with several recent European Nobel Prize laureates having benefited from the programme. MSCA researchers have contributed to major scientific discoveries. For example, scientists supported by the MSCA were part of the team which discovered the Higgs boson in 2012. The so-called 'God particle', considered the basis for all matter in the universe, was identified at CERN, the European nuclear research facility in Geneva. Furthermore, in 2016 MSCA fellows were among the researchers who contributed to proving one key prediction in Einstein's theory of relativity: the existence of energy waves capable of distorting space-time (the detection of gravitational waves).

C.4.2.2. Training the next generation of researchers

MSCA aims to support excellent and innovative research training and the development of skills relevant to a researcher career. Over the course of Horizon 2020, up to 25 000 early-stage researchers will be funded through MSCA.

Evidence shows that MSCA have provided researchers with an enhanced set of research-related and transferable skills: around 80% of fellows reported that they were (very) satisfied with the innovative research training and professional development opportunities provided during their MSCA fellowship. The skills which have been acquired include those specific to the research profession, such as interdisciplinary techniques, publishing research, the use of specialised equipment or research data management, and transferable skills such as presentational skills, languages and project management skills.

The doctoral training offered under the ITN ensures a wide promotion and implementation of the EU Principles for Innovative Doctoral Training. An international, inter-sectoral and interdisciplinary environment created by consortia from different countries provides the next generation of researchers with innovative training, transferable skills such as an entrepreneurial mindset, and significant exposure to industry. Figure 55 shows the skills most acquired by ITN fellows during their fellowship. While fellows are largely satisfied with the training received, survey data[113] also reveal that a significant number of ITN fellows would have liked more training in certain areas: 27% in report and proposal writing, followed by around 23% in new or advanced scientific methods, project management and team management/leadership skills.

[113] *Forthcoming study on "Business participation and entrepreneurship in Marie Skłodowska-Curie actions (FP7 and Horizon2020")*

Figure 55 - Share of ITN fellows who reported that they had acquired to a (very) large extent the following skills during their fellowship (%)

Source: Survey of ITN fellows 2016. 2 489 responses.

More than one quarter of ITN and IF fellows reported that the fellowship had exceeded their expectations and a further 55% said that it had met their expectations. [15% said it was too early to say while only 5% felt that it had not met their expectations].

Evidence suggests that the quality of doctoral training programmes has improved as a result of MSCA. Organisations were asked to what extent has/will your participation in the MSCA programme led/lead to improvements in for example the quality of training for researchers. More than 50% responded yes to a (very) large extent, a further 20% to a "moderate" extent and 10% to a small extent. Around 10% reported no effect.

“Participants get skills in project management and the prestige of being involved in the programme which supports their applications for other programmes and funding in the future”. - National policy maker and programming officer, National Research, Development and Innovation Office

“When they finish their fellowships, researchers are much better equipped and capable to set up their own team and build a network around themselves.” - National policy-maker and programming officer and national contact point

“The MSCA fellows also learn about some abilities an “ordinary” scientist usually doesn´t learn. This goes from project management to patent law and registration to intellectual property issues.” - National policy maker and programming officer

There is strong evidence that MSCA fellows are producing excellent research and indeed in many cases are outperforming other established researchers in their field. Bibliometric analysis indicate that MSCA fellows are twice as likely as the average researcher to have publications that belong to the Top 1%, Top 5% and Top 10% of cited publications. While the data do not show a causal relationship, it is reasonable to assume that the training and skills development associated with the fellowship has had a positive impact. Indeed a recent survey carried out as part of the UNIKE project shows that 71% of MSCA fellows felt that the quality of their scientific contribution was improved as a result of mobility to a high or very high extent.[114]

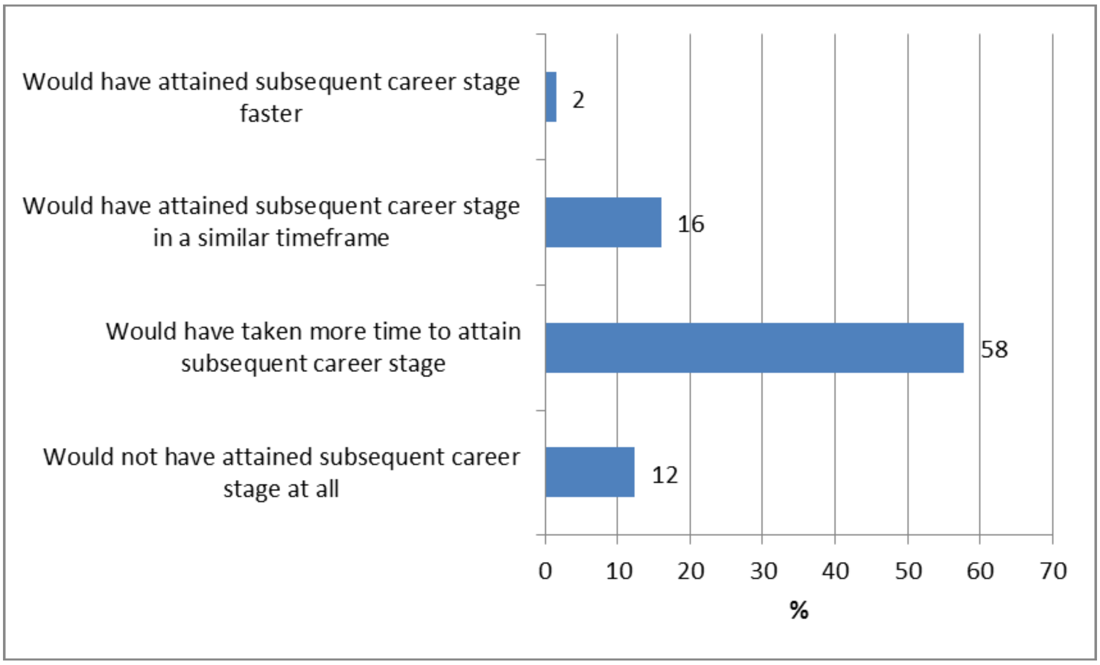
C.4.2.3. Improving researchers' employability and career prospects

A key objective of MSCA is to ensure attractive career opportunities for funded researchers, and to support their career progression. MSCA have focused strongly on developing the next generation of science, systems and researchers and ensuring that they are better equipped with the skills needed to work across all sectors of the economy.

Past IF fellows were asked whether they believe that they would have attained the subsequent career stage at the end of their fellowship without participating in MSCA: 14% believed they would not have attained the subsequent career stage at all, around 60% that it would have taken them more time to attain the next stage and 14% that they would have reached that stage in a similar timeframe. Only 2% of respondents believe they would have attained the next career stage faster. See Figure 56.

Around 38% of respondents indicated that they had moved to a more senior position after their MSCA fellowship. Two thirds of these fellows attribute this career progression to a (very) great extent to participation in MSCA with only 10% perceiving a small or no effect.

Figure 56 - Impact of Individual Fellowship on career development



Source: Survey of IF Fellows 2016. Question 23: Do you believe that you would have attained the subsequent career stage after the end of your fellowship without participating in MSCA? In total 377 past IF fellows replied to this question. A further 12% responded "don't know".

Further evidence shows that, over the longer-term, MSCA have had a very positive impact on the careers of many researchers, improving their employability and career

[114] *"The mobile academic - A survey of mobility among Marie Skłodowska-Curie doctoral fellows", Working Paper by Lisbeth Kristine Walakira and Susan Wright, UNIKE, May 2017.* http://www.e-pages.dk/aarhusuniversitet/1644/

prospects both in and outside academia. There are numerous examples of successful careers following the fellowship, including several recent Nobel Laureates, some of whom are former fellows or had fellows in their research teams, while others were involved in the coordination of projects. Indeed, evidence shows that some excellent researchers would have had real difficulty to pursue a research career without an MSCA fellowship.

"Between spring 1994 and 1997, I presented the concept of STED microscopy around the world. Still most people remained skeptical. In this period, the risk of dropping out was quite high. I managed to get another stipend, an EU Marie-Curie fellowship. I could thus proceed." – 2014 Chemistry Nobel Prize winner Stefan W. Hell who was a Marie Curie Fellow in 1996-97, and then became a MSCA project coordinator.

The MSCA can also be the starting point for a successful career beyond the research field. Such is the case of the current Portuguese Minister of Education, Tiago Brandão Rodrigues. Awarded two different MSCA fellowships related to his cancer research, later he would remain linked to the scheme as an expert evaluator for calls. There is also evidence that former MSCA fellows tend to be more successful when applying for ERC grants.

"The EU funds dozens of initiatives that support scientific research but few have the overall impact of the Marie Sklodowska-Curie Actions. These have literally changed lives, affecting the careers of young scientists across the EU, including Ireland." – Irish Times article[115]

Academic researchers' exposure to private companies and the business environment as part of their MSCA fellowship contribute to their employability outside academia and help them decide on the most suitable career path. Survey data show a positive relationship between the presence of business organisations in a MSCA project and the number of MSCA fellows who would consider a career in the private sector: the share of beneficiary fellows considering such a career choice was 54% within the group of the projects with no business organisation involved, whereas the same share of fellows within the projects with at least one business organisation involved was significantly higher – 84%.

Evidence shows MSCA has had a leverage effect on job creation. More than one in three organisations indicated that participation in MSCA had helped create new jobs in addition to staff directly funded by the project. In total, 23% of organisations had created (or will create) one additional full-time equivalent (FTE) job while 12% of organisations had created two or more FTE posts as a result of participation in MSCA.

Organisations were also asked to what extent has/will your participation in the MSCA programme led/lead to improvements in for example the career development for researchers. Around 50% responded yes, to a (very) large extent, a further 20% to a "moderate" extent and 10% to a small extent. This points to the key role played by MSCA in providing researchers with funding opportunities and working conditions that allow them to develop their research and career.

[115] http://www.irishtimes.com/news/science/marie-curie-fund-helping-to-develop-scientific-leaders-in-ireland-1.2975401

In addition, MSCA have boosted opportunities for 87 leading researchers to return to research after a career break through the IF Career Restart panel.

C.4.2.4. Improving international collaboration and attracting leading researchers to Europe

MSCA play a key role in terms of being open to the world, building international collaboration and attracting and retaining researchers in Europe. MSCA have the highest number of international participations in Horizon 2020 with almost 140 nationalities funded since 2014. Around one in four MSCA fellows are researchers from countries outside the EU Member States or AC and hence have been attracted to Europe.

In terms of outward mobility, Global Fellowships (GF) will be awarded under Horizon 2020 to around one thousand of Europe's leading researchers. This enables them to carry out research at a leading institution outside Europe with a mandatory 12 month return period to a European host. While highly developed countries such as the US have been an attractive destination for outgoing MSCA researchers, emerging countries such as China, Brazil or India attract relatively small numbers. Cooperation should be reinforced to ensure more effective brain circulation[116].

Some stakeholders, including the MSCA Advisory Group, have indicated that the Global Fellowships could be reinforced to enable more researchers to gain new skills and knowledge abroad which they bring back to Europe from leading centres in any country. This would also foster new partnerships between outgoing fellows, their European employers, and their host organisations around the world.

MSCA have improved opportunities for leading researchers to return to Europe. More than 500 leading researchers will benefit during Horizon 2020 through the Reintegration option of the IF Action. Some stakeholders however have called for additional budget efforts to attract back more European researchers working in third countries, who may be reluctant to return given that public R&D expenditure declined in half of the Member States between 2007 and 2014[117].

In terms of increasing the global reputation of their organisation, around 65% of project coordinators responded that MSCA had an impact to a (very) large extent, another 18% to a moderate extent and 6% to a small extent. Similar figures were reported regarding the contribution of MSCA to the internationalisation of their organisation and/or the capacity of its researchers to conduct research abroad. Around 32% of organisations reported that MSCA had helped them retain excellent researchers in Europe who would have left Europe otherwise. Almost 40% felt that it "may have helped but that it is difficult to say", while only 16% said that it had not helped.

C.4.2.5. Building and strengthening partnerships across borders and sectors

A further specific programme objective of the MSCA is to facilitate knowledge exchange and, by implication, support the development of new researcher collaborations. Around 72% of IF fellows and 80% of ITN fellows indicated that they had developed new collaborations during their fellowship. Regarding collaboration partners, IF and ITN

[116] *Issue Paper for the High Level Group "Open to the World"*
[117] *"Science, Research and Innovation performance of the EU 2016", European Commission, p.32.*

fellows with any new organisations involved in their MSCA project (i.e. organisations with which they as individuals have not worked before) were asked to elaborate on the type of these collaboration partners. When asked about the extent to which new collaborations helped fellows in progressing their career, 58% of IF fellows indicated that the impact of new partnerships on career progression was high (for ITN, the figure was 44%).

Around 47% of organisations were "strongly satisfied" and 36% "satisfied" with the partnerships developed as a result of MSCA participation. Enhanced cooperation is also achieved through the EJD programme (around 1 000 doctoral candidates) which promotes international, inter-sectoral and multi/interdisciplinary collaboration in doctoral training in Europe.

In total, 57% of IFs were very satisfied (and a further 26% satisfied) with the partnerships they developed as a result of their MSCA fellowship. This helped them progress with their career as well as acquire/improve technical and scientific skills. Survey data also show that the collaborations between researchers created or strengthened during MSCA fellowships are sustained. Around 90% of fellows who had developed collaborations with academic partners and 70% of those working with non-academic organisations reported that they had either fully developed plans or were currently developing plans for further collaboration.

Further evidence of the sustainability of collaboration built and strengthened during MSCA fellowships comes from new bibliometric analysis. While more than half of the publications of IF fellows between 2007 and 2016 were publications involving international collaboration, this figure was 35% for the control group of researchers similar to IF.

C.4.2.6. Increasing exposure to industry and transferring knowledge across sectors

One of the weaknesses identified in FP7 was the "lack of a significant transfer of knowledge and insufficient two-way mobility of researchers between academia and the non-academic research organisations."[118] Efforts were made to tackle this better under Horizon 2020.

MSCA have increased the opportunities for researchers to gain exposure to industry and other non-academic sectors. Private for profit organisations account for 43% of all MSCA beneficiaries whereas they make up 16% of all participations in projects. This reflects the relatively small number of times (1.2 on average) that a private for profit organisation participates in MSCA compared with an average of 6.5 times per higher education institution.

MSCA feature non-academic sector partners playing a strong role in joint researcher training projects and 25% of its publications are public-private co-publications. Furthermore, around 1000 doctoral candidates will benefit from a European Industrial Doctorate (EID) programme to develop their skills inside and outside academia.

[118] *Avramov, D. (2015) 'FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): rationale, implementation and achievements' Final Revision 13 August 2015.*

Under IF, a Society and Enterprise panel was introduced for the first time in 2016, dedicating EUR 8 million to individual fellowships in companies or other organisations outside of academia. The response has been positive though it is still too early to evaluate this panel but it is expected that its continuation would lead to around 200 experienced researchers receiving funding for fellowships taking place in the non-academic sector by 2020.

Over the first three years of RISE 2014-16, there were almost 23 000 planned secondments with staff exchanges to or from non-academia and to or from third countries. See Table 30. Around half (11 826) are academia to academia exchanges, all involving a third country, with 7 196 outgoing and 4 630 incoming.

The other 11 000 exchanges all involve non-academic partners. Some 6 510 involve staff exchanges from academia to non-academia, of which 1336 were to a third country and 498 were staff coming into the EU/AC from third countries. The two latter categories are new features of Horizon 2020. In addition, some 4 302 involve mobility into academia from another setting.

Table 30 - RISE - planned secondments/staff exchanges 2014-16 by sector and region

	Moving from an EU or Associated country to another EU/AC	Moving from an EU or Associated country to a Third Country	Moving from a Third Country to the EU or Associated country	Total
Academia to Academia	*not permitted*	7196	4630	11826
Academia to non-academia	4676	1336	498	6510
Non-academia to academia	3114	606	582	4302
Non-academia to non-academia	*not permitted*	162	93	255
Total	7790	9300	5803	22893

Source: DG EAC analysis based on CORDA data January 2017.

It is important to note that much of the research output from fellows may be produced after the fellowship and is therefore difficult to monitor. Bibliometric analysis is a useful source in this regard and indeed shows that ITN fellows are performing strongly. Their share of academic-non-academic cross-sector publications (4.3%) is significantly higher than the world average (2.6%) and also higher than that of the control group of researchers similar to ITN (3.8%).

C.4.2.7. Strong support for interdisciplinary research

Strong interdisciplinary research is founded on strong disciplines. The MSCA therefore support excellent research within disciplines as well as interdisciplinary research. Around 30% of MSCA proposals so far are deemed to have included multidisciplinary research[119]. The MSCA programme therefore provides both an example of how multidisciplinary research may be assessed, and directly supports multidisciplinary research. ITN specifically emphasise the need for interdisciplinary/ complementary research programmes, underpinned by corresponding training modules. The programmes therefore are expected to provide a direct contribution to the proportion of

[119] *Based on keyword analysis carried out by REA on the IF Calls 2014 and 2015*

interdisciplinary research in Europe as well as equipping early-stage researchers with the skillset and tools needed to conduct interdisciplinary research in the future. COFUND programmes are often interdisciplinary[120].

Interdisciplinary research is particularly strengthened when fellows have the opportunity to work with business organisations. Survey data shows that 69% of fellows involved in projects with businesses are doing interdisciplinary research compared to 36% of fellows with projects that have no business organisation involved.

The MSCA Advisory Group concluded that major intervention was not necessary in support of interdisciplinarity within the MSCA but suggested that actions could be taken to further enhance the benefits of interdisciplinarity within the programme, for example a recognition that excellent interdisciplinary researchers (whether they are MSCA applicants or proposal evaluators) do not necessarily have the standard academic track record of other excellent researchers.

C.4.2.8. Structuring effect on organisations

As stated in MSCA work programmes, the principles of the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers promoting open recruitment and attractive working and employment conditions should be applied by all the funded participants.

There is evidence that MSCA have a positive structuring effect on organisations in terms of improving the quality of training, career development, human resources practices and procedures, strengthening organisational research capacity and providing fair and attractive working conditions.

Around three in four organisations benefitting from MSCA reported that their expectations had been fulfilled to a (very) large extent in terms of accessing research funding and funding for high-quality training on research skills, increasing international collaboration of the organisation and attracting excellent researchers to their organisation.

Organisations reported that participation in MSCA had a positive impact on the structured doctoral training programmes offered at their organisation: around 23% a (very) large extent, another 35% to moderate or small extent. A further 22% said they already had good measures in place while 9% reported no effect.

Organisations were asked to what extent has/will your participation in the MSCA programme led/lead to improvements in areas specifically related to researcher training, recruitment and career progression. More than half of the respondents reported that there had been improvements to a (very) great extent as regards career development (48%) and quality of training (51%). A further 21-24% reported improvements to a moderate extent in each case. Around 31-37% responded that the MSCA programme had led to improvements, to a (very) large extent in the openness, transparency and degree to which career progression procedures and recruitment procedures are merit based, with a further 15-20% answering to a moderate degree.

[120] Avramov, D. (2015) 'FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): rationale, implementation and achievements' Final Revision 13 August 2015.

MICACT[121] - An Innovative Training Network (ITN) coordinated by Tartu University in Estonia together with ten partners from other Member States

An in-depth case study suggests that the impact of MSCA participation on organisations depends on a number of factors including their research capacity prior to the project:

- For universities such as the Polytechnic University of Cartagena (ES) in countries where national funding is relatively low, MSCA funds ESR positions for which there was no alternative financial support. Accordingly, participation in MSCA considerably improved the organisation's research capacity.

- For Tartu University, the availability of research funding was less relevant than getting access to a vast network of partners. This allowed the university to increase the visibility of the quality of existing research, create new collaborations, sustain existing ones and facilitate applications for new projects.

- For Linkoping University, which already had a large network, the most important impact was the ability to attract excellent researchers and the visibility the MSCA funding brings.

C.4.2.9. Addressing the major societal challenges

The bottom-up approach taken by MSCA has allowed a large majority of institutions to train and upgrade the skills of a new generation of researchers able to tackle a broad range of current or expected societal challenges. Moreover, MSCA funding addresses societal challenges to a significant extent, above the Horizon 2020 average and well ahead of the other areas in the excellence pillar: 62% of the budget in 2014-2015 was awarded to projects related to sustainable development, 23% to climate change and 6% to biodiversity.

There are numerous examples of MSCA projects where the research is addressing major societal challenges including the fight against diseases such as cancer, Alzheimer’s and Multiple Sclerosis, providing safer food, developing solutions for improved road safety, reducing noise pollution, preserving cultural heritage and shaping the development of key policies such as migration, climate change and energy.

C.4.2.10. Cross-cutting issues

(a) Gender

A further cross-cutting objective of MSCA is gender equality in research, particularly the inclusion of more women.

The MSCA have a strong track record in the approach to gender which is continuing under Horizon 2020. To date, 40% of MSCA-supported researchers are women[122]. This has increased in relation to FP7 where it was 37% and is higher than the average percentage of female researchers in Europe[123] and other areas of Horizon 2020. The increase may be a result of both a higher number of women applying for MSCA funding, as well as projects recruiting more women. In contrast, the share of female supervisors in

[121] *http://cordis.europa.eu/project/rcn/193854_en.html*
[122] *If all staff are counted, women in MSCA account for 50% of the total compared with 40% in Horizon 2020 overall.*
[123] *SHE Figures 2015: https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-leaflet-web.pdf*

IF is considerably lower (21%), reflecting the glass ceiling apparent among academic staff and research boards.

Proposals submitted under the MSCA programme are encouraged to take appropriate measures to facilitate mobility and counter-act gender-related barriers to it. MSCA work programmes encourage the implementation of training on gender issues and actions to reduce or remove gender-related barriers. Equal opportunities are to be ensured in the implementation of the actions by a balanced participation of women and men, both at the level of supported researchers and that of decision-making/supervision/management structure. In research activities where human beings are involved as subjects or end-users, gender differences may exist. In these cases the gender dimension in the research content has to be addressed as an integral part of the proposal to ensure the highest level of scientific quality.

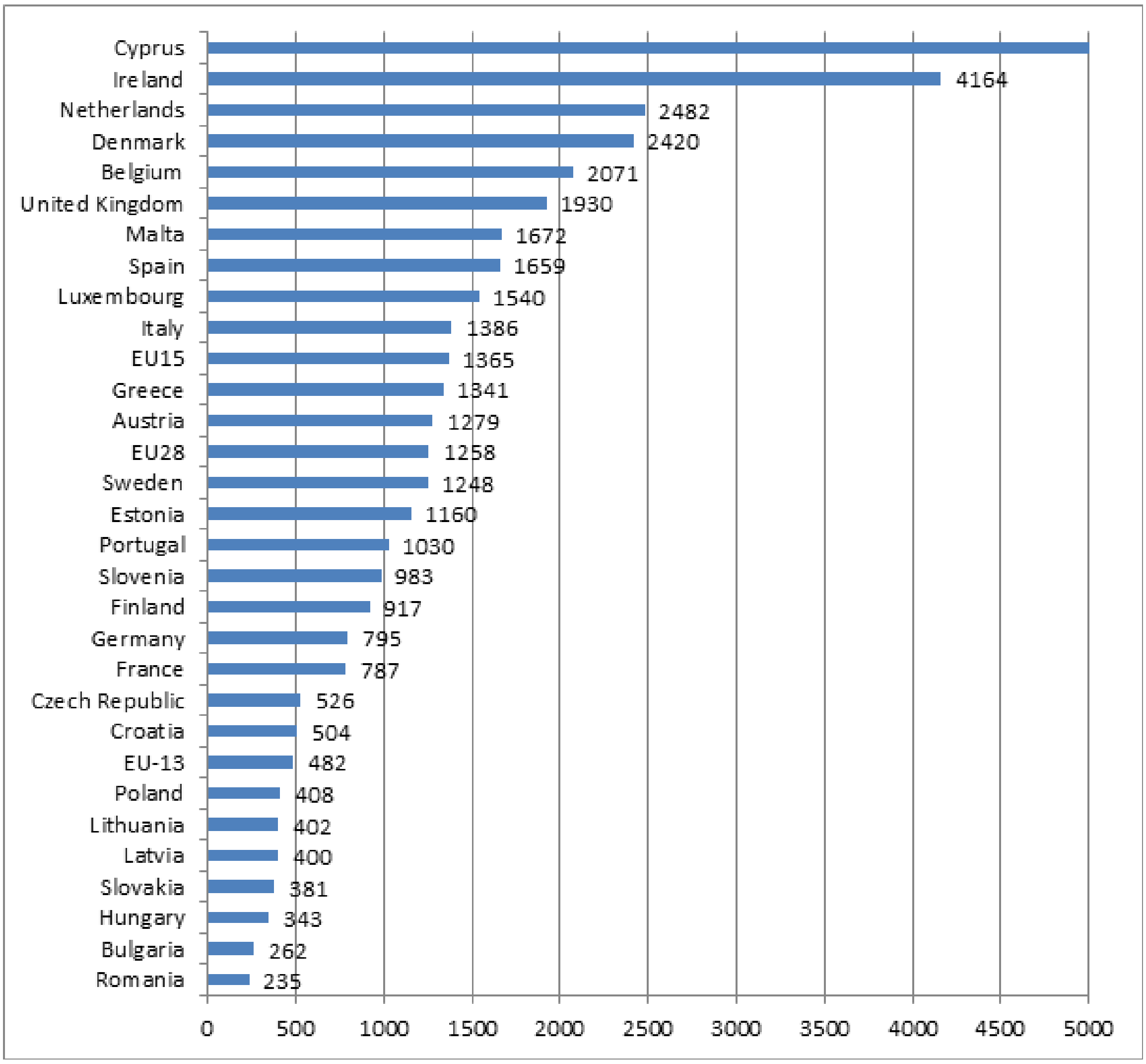
Notably, the proportion of women participating in each individual MSCA scheme has increased between FP7 and Horizon 2020, with the exception of the RISE programme. The share of women is highest for ITN and COFUND. ITN projects are required to present their recruitment strategy in the project proposal, whilst fellows apply for IF funding directly. Therefore higher parity in the ITN scheme shows that organisations pay specific (and increasing attention) to parity in recruiting, whilst gender balance is not part of the evaluation and selection criteria to select individual fellows under IF.

(b) Spreading excellence and widening participation

Another cross-cutting objective is spreading excellence and widening participation. MSCA fellows select their destination country based on the perceived attractiveness of the research landscape and career opportunities. The most attractive EU destination is the UK, followed at a distance by Germany, France, Spain, Italy and the Netherlands.

In contrast, EU-13 countries receive 4.6% of total MSCA funding although they represent 12% of the EU researcher population and indeed 20% of the total EU population. Figure 57 shows wide discrepancies between Member States in their ability to attract funding, with EU-15 countries out-performing EU-13 countries. Other data show that in general EU-13 countries tend to submit fewer proposals than EU-15 countries and that the quality of submitted proposals is also lower (see Figure 54). However, all EU-13 countries have a significant share of high-quality proposals above threshold.

Figure 57 - MSCA funding under Horizon 2020 in relation to the total researcher population (FTE) in each country



*Source: CORDA data 2017. Note: * The total amount of MSCA funding (EUR) received by projects in a given country divided by the total number (FTE) of researchers in the country, regardless of whether or not they received MSCA funding. The purpose is to take account of the relative size of each country. Cyprus is an outlier with an average of 10 034 per researcher.*

It is also important to note that in its Conclusions on Early Career Researchers of November 2016 the Council of Ministers "*invites the Commission and Member States to foster and adequately reward all types of mobility … while taking into account the need to close the R&I divide across Member States and regions*"[124].

There are currently no specific measures under MSCA to tackle the science divide. Notwithstanding the need for Member States to undertake the reforms necessary to improve their participation and without compromising excellence, consideration should be given to supporting measures to spread excellence across ERA and widen participation in MSCA.

[124] *"Measures to support early stage researchers, raise the attractiveness of scientific careers and foster investment in human potential in research and development" - conclusions of Council of Ministers, adopted on 29/11/16 (15013/16)*

(c) Making research careers more attractive

The European Researchers' Night, attracting more than one million citizens every year, has brought researchers closer to the general public and vice versa, increased awareness of R&I activities and encouraged young people right across the EU and beyond to embark on research careers.

Box 6 - Contribution to the achievement and functioning of the European Research Area (ERA)

The MSCA contribute to the functioning of the ERA[125] in terms of developing more effective national research systems, optimal transnational cooperation and competition, an open labour market for researchers and the international dimension outside ERA.

As regards the creation of a genuine open labour market for researchers, the MSCA continue to have a pronounced structuring impact on ERA and institutional practices by ensuring systematic implementation of the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers (Charter and Code) and in particular by setting standards for quality (doctoral) training, attractive employment conditions and open recruitment for all EU researchers. For example, all funded MSCA participants are required to apply the principles of the Charter and Code.

Furthermore, the MSCA has ensured a wide promotion and implementation of the EU Principles for Innovative Doctoral Training which foster excellence and a critical mind-set and identify the need to provide young researchers with transferable skills and exposure to industry and other employment sectors.

The ERA goal of opening to the world needs European researchers with experience of research and innovation in and with institutions in third countries. The MSCA contribute substantially towards this objective accounting for more than half of all third country participations in Horizon 2020. See C.4.2.4 for further information.

Analysis of objectives and instruments[126] reveals coherence of efforts between the MSCA and EURAXESS, a Commission-funded ERA initiative for researchers. The two initiatives aim at providing European researchers with better mobility, career and personal development opportunities. They differ, however, in terms of the instruments used to achieve this goal: while the MSCA provide actual funding for research mobility, EURAXESS provides practical information for researchers moving from one country to another.

Furthermore, the focus on training of doctoral candidates has also contributed to bridging the European Higher Education Area (EHEA) and the European Research Area (ERA).[127]

[125] http://ec.europa.eu/research/era/pdf/era_progress_report2016/era_progress_report_2016_technical_report.pdf
[126] *PPMI (2013) 'FP7 Marie Curie Actions Interim Evaluation' Final report.*
[127] *FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): Rationale, implementation and achievements, Dr Dragana Avramov, 2015.*

C.4.3. Early success stories

GEAGAM[128]

Geophysical Exploration using Advanced Galerkin Methods (GEAGAM) is a RISE project with high potential. In the first two years of the project alone, GEAGAM published 46 articles in peer-review journals. GEAGAM is a partnership of 12 R&I organisations in six countries, including four from outside the EU and two non-academic R&I organisations from France and the US. In total, 35 researchers will benefit from a mobility experience by the end of 2017. The project is interdisciplinary in nature and will contribute to a variety of applications such as CO2 storage, hydrocarbon extraction, mining and geothermal energy productions. All these science fields required an accurate characterization of the Earth's subsurface. To achieve this goal, complementary areas of mathematics are coupled with efficient, parallel computing and advanced graphics. In this way, GEAGAM will contribute to technology transfer between the most advanced numerical methods and mathematics and the area of applied geophysics.

CropStrengthen[129]

A European Industrial Doctorate (CropStrengthen) coordinated in Germany with partners in Ireland and the Netherlands is providing advanced systems biology training for five Early Stage Researchers. They are investigating novel, non-GMO approaches to increasing stress-resistance in crops. The research could lead to increased yields for farmers and improve Europe's food security. This example illustrates the benefits of cross-sector mobility and the capacity to address societal challenges.

Sharper[130]

As part of the European Researchers' Night, MSCA fund projects throughout the EU. One Italian project (Sharper) which organised a series of events in three cities Perugia, Ancona, L'Aquila attracted over 42 000 visitors in 2016. This was achieved through a relatively small amount of EU funding (EUR 250 000) combined with institutional funding of EUR 90 000.

C.4.4. Lessons learnt/Areas for improvement

The full value and impact of mobility and opportunities opened up by MSCA is often revealed after many years. Nevertheless, evidence shows that MSCA continue to have a positive impact on individual researchers, organisations and at the system level.

MSCA have made a significant contribution to the international, interdisciplinary and inter-sectoral mobility of researchers in Europe and beyond. Over the course of Horizon 2020, some 65 000 researchers will benefit from an international mobility experience funded by MSCA (to date, the budget has covered around 27 000 fellows). For just under half of them, this will also include mobility or exposure to the non-academic sector or vice-versa.

[128] http://cordis.europa.eu/project/rcn/194169_en.html
[129] http://cordis.europa.eu/project/rcn/193962_en.html
[130] http://cordis.europa.eu/project/rcn/193222_en.html

Efforts to increase the participation of businesses in MSCA are in line with the European Semester 2016 recommendations, to strengthen inter-sectoral cooperation. Evidence shows that the majority of fellows are (very) satisfied with the innovative research training and development of skills offered. There is however scope for improvement in encouraging greater participation from firms, public bodies and NGOs as well as equipping the next generation of researchers with a broader set of transferable skills needed to develop their career outside academia.

Evidence shows that an MSCA fellowship has boosted the career opportunities of many fellows and helped them secure a more senior position. Moreover, organisations have indicated that participation in MSCA has helped create new employment in addition to staff directly funded by the project.

MSCA coordinators report a significant structuring effect on organisations in terms of improving the quality of training, career development, human resources practices and procedures, and strengthening organisational research capacity.

MSCA also play a key role in terms of international collaboration and attracting and retaining researchers in Europe. MSCA have the highest number of international participations in Horizon 2020 with 140 nationalities funded since 2014. Around one in four MSCA fellows are researchers from countries outside the EU Member States or Associated Countries. While the US has been an attractive destination for outgoing MSCA researchers, the group of destination countries could be enlarged beyond the traditional highly industrialised ones.

There is also strong evidence of longer-term scientific value and societal impact of the programme. In terms of cross-cutting issues, the MSCA have a strong track record in the approach to gender which is continuing under Horizon 2020. There is clear evidence of wide discrepancies between Member States in their ability to attract MSCA funding, with EU-13 countries tending to lag behind. As there are currently no specific measures under MSCA to tackle the science divide, targeted action may be appropriate.

C.5. EFFICIENCY

C.5.1. Budgetary resources

The budget for MSCA under Horizon 2020 is EUR 6.162 billion, 8% of the overall budget. This represents a 30% increase compared to FP7. In spite of this increase, there is consensus among stakeholders that the budget is insufficient, reflected by high oversubscription leading to low success rates, particularly affecting ITNs. Indeed, the programme's oversubscription rate has doubled between FP7 and Horizon 2020.

As of January 2017[131], there were 14 300 high-quality proposals not funded, corresponding to 80% of all high-quality proposals. Funding all the high-quality proposals would require another EUR 13 billion for the first three years alone. This is more than six times the current level of funding.

[131] *It should be noted that the 2016 Calls for IF and COFUND were not completed by this date and therefore the data refer only to 2014 and 2015 for these two actions.*

There are substantial differences in the success rates and the amount of high quality proposals not being funded. Views by national stakeholders are supported by data showing that ITN have the lowest success rate among the MSCA at 7.8%, and a ten-fold oversubscription rate (Table 24).

Some stakeholders have voiced concern about how the budget is currently spread between different MSCA actions, in particular IF and ITN were perceived to be in need of a budget increase. Consideration should be given to this though it is worth noting however that these two actions combined already consume 80% of the budget.

C.5.2. Programme management

C.5.2.1. Efficiency of programme management

The MSCA underwent significant simplification under Horizon 2020. This included extending the use of simplified forms of grants (unit costs), streamlining the MSCA funding schemes (from 11 to 4) and unifying the rules and framework conditions for mobility. Overall there was broad agreement in 2015 among stakeholders and participants that the simplifications introduced were helpful and effective. [132] About 90% of respondents to a REA online survey in 2015 addressed to participants in on-going Horizon 2020 grants considered the e-signature and the Participant Portal to be "very beneficial" or "fairly beneficial".

A mid-term review of the MSCA unit cost decision concluded that the transition (from FP7 to Horizon 2020) to a reimbursement system entirely based on unit costs has reduced costs and the administrative burden, both on the side of the beneficiaries and the EC.

There are, however, concerns voiced by a number of stakeholders that certain restrictions may deter some potential applicants, e.g., the fact that beneficiaries, many of whom are SMEs, cannot recruit fellows to go on secondments under RISE. Thus, further simplification may be possible.

The MSCA programme is implemented by the Research Executive Agency (REA) whose mandate was extended till 2024, covering the whole grant management lifecycle of Horizon 2020 projects. Analysis indicates that the implementation of the programme is appropriate and efficient. The administrative budget committed by REA to Horizon 2020 MSCA constitutes only a small proportion of the operational MSCA budget, averaging 2.5% between 2009 and 2015, and therefore below the legal objective of 5%.

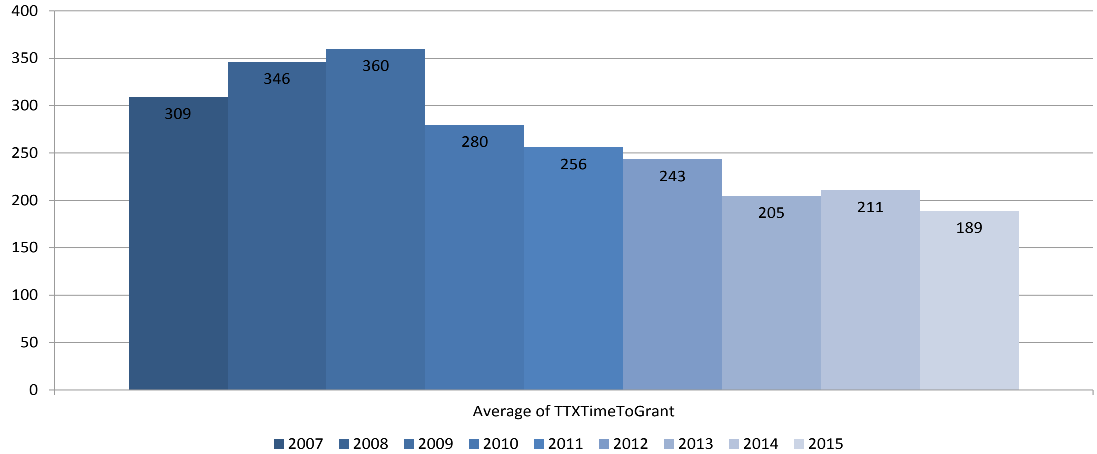
The proportion of the MSCA budget devoted to management is also consistently lower than the average management costs for all aspects of Horizon 2020 managed by REA. REA annual work programmes mandate a target of executing 100% budget for commitment and payment appropriations as key indicators with regards to an efficient management of resources. As of 2010 REA consistently achieved 100% of budget execution on both commitments and payments appropriations, as indicated in the Annual Activity report of each year.

[132] *Science Europe (2016) Science Europe position statement: The Framework Programme that Europe needs. D2016.13.324.10 ; The MSCA Advisory Group.*

C.5.2.2. Time-to-grant

There is evidence of the cost-efficiency of the REA management system. One of the objectives under Horizon 2020 in terms of programme efficiency was to reduce the delay between submitting a proposal and signing the grant agreement. The average time-to-grant for MSCA, if aggregated by year of call deadline, has reduced significantly since 2009 and is now in line or slightly below the average[133] time-to-grant for the overall Framework Programme.[134] See Figure 58.

Figure 58 - Average time-to-grant by year of call deadline, FP7 to Horizon 2020



Sou rce: ICF CORDA analysis.

There also has been improvement in REA overall timely processing and completion of interim and final payments for FP7 which improved from 90% in 2012 to 97% in 2015. As far as Horizon 2020 projects are concerned there have been no interim or final payments during the time period covered by this evaluation.

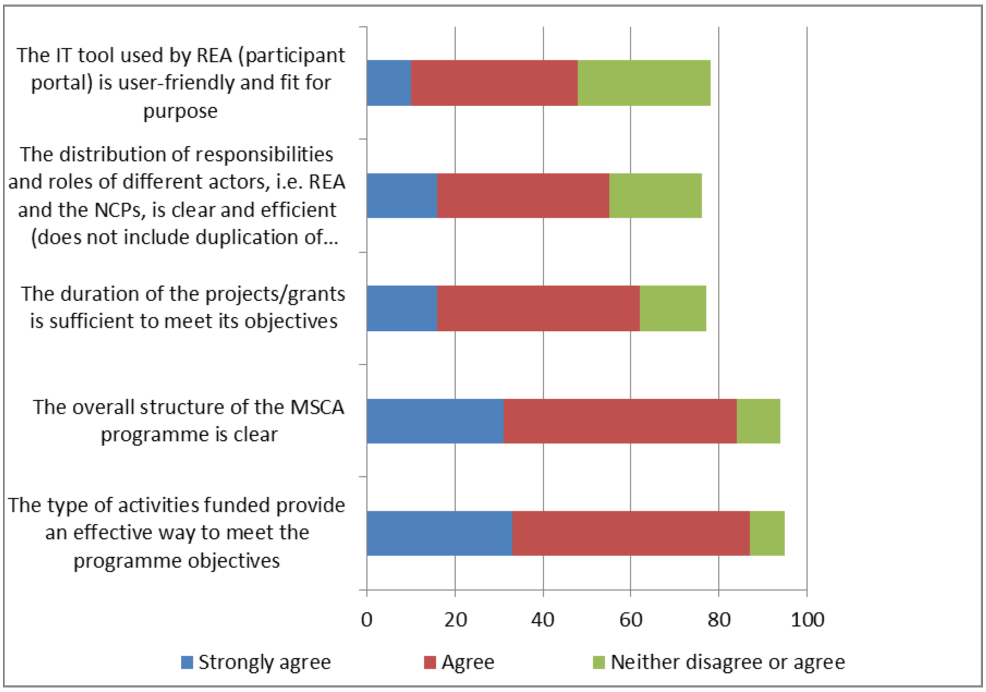
Cost reduction measures have already been taken, notably for high-volume evaluations such as MSCA, which are increasingly conducted remotely without jeopardising the high quality of the exercise. Overall, the evaluation process is viewed by stakeholders as being well organised and managed, given the significant number of proposals. In 2016, the highest number of proposals ever submitted to a single deadline (8 946) under Horizon 2020 were for the MSCA IF call.

C.5.2.3. Effectiveness and appropriateness of administrative and financial rules

National stakeholders generally commended the effectiveness of administrative and financial implementation of the programme. When asked about these aspects, the vast majority of all MSCA participant organisations responding to the online survey indicated that they are satisfied with various aspects of the administrative and financial programme implementation. However, there were also certain aspects where respondents voiced some level of dissatisfaction. 20 per cent of respondents disagreed or disagreed strongly with the statement "The duration of the projects/grants is sufficient to meet its objectives". See Figure 59.

[133] For a limited number of cases,when the TTG was not reached, this was due to a request from the coordinator to extend the GAP procedure or due to extensive ethics issues in the project.
[134] In 2015, average time-to-grant of MSCA was 189 days, compared to 203 on average overall.

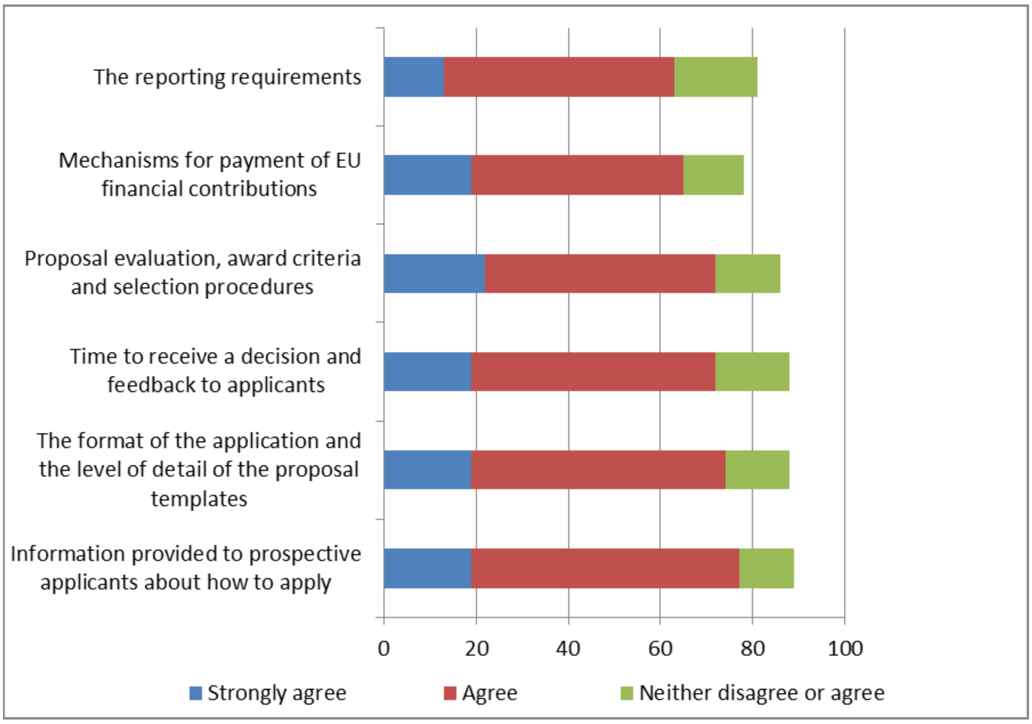
Figure 59 - Effectiveness and appropriateness of administrative and financial rules (views of funded organisations)



Source: MSCA evaluation - IF, ITN, COFUND Organisations – Question 90: "To what extent do you agree or disagree with the following statements?" Around 900 participants responded to this question.

Funded organisations were also asked to what extent they are satisfied with administrative mechanisms and reporting procedures of the MSCA programme. By and large, respondents were satisfied with the aspects listed in Figure 60 below.

Figure 60 - Satisfaction of funded organisations with administrative mechanisms and reporting procedures



Source: MSCA evaluation - IF, ITN, COFUND Organisations – Question 92: "Based on your experience with the MSCA application process and MSCA project participation, please indicate your level of *satisfaction with the following aspects of the administrative mechanisms and reporting procedures of the MSCA programme." The number of participants that responded to this question was 2 115.*

C.5.2.4. Other aspects of cost-effectiveness

For a significant majority of the MSCA beneficiaries, the projects strengthened their ability to do research beyond short-term needs, contributed to establishing R&D as a regular part of their day-to-day activities, and helped to achieve efficiency gains in terms of conducting research.[135]

The NIGHT, with its bi-annual budget of EUR 8 million, can be regarded as highly cost-effective as it manages to reach out to more than one million citizens every year, right across the EU, attracting in particular young people to a possible career in research, including in STE(A)M fields of education.

C.5.3. Lessons learnt/Areas for improvement

Overall the evidence suggests that the programme is significantly underfunded. In spite of the budget increase for MSCA under Horizon 2020, there has been an increase in the oversubscription of MSCA calls, particularly for the ITN where the success rate is 7.8%. This represents a huge loss of talent for Europe as there are enough high-quality proposals to absorb seven times the current available budget for MSCA, and ten times the budget for ITN. It is worth noting that, in the absence of MSCA funding,only 6% of unsuccessful applicants went ahead with the project as planned. See section C.7.

Some stakeholders have voiced concern about how the budget is currently spread between different MSCA actions. In particular IF and ITN were perceived to be in need of a budget increase. Consideration should be given to this though it is worth noting however that these two actions combined already consume 80% of the budget.

The programme underwent significant simplification under Horizon 2020 including extending the use of simplified forms of grants (unit costs) and streamlining the funding schemes. Stakeholders view the simplifications as generally helpful and effective, with for example the unit cost approach reducing the administrative burden.

There is evidence of the cost-efficiency of the REA management system with the time-to-grant indicator having reduced significantly from 2009 to 2015. The evaluation process is regarded as well organised and managed, given the significantly large number of proposals.

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[135] *Avramov, D. (2015) 'FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): rationale, implementation and achievements' Final Revision 13 August 2015.*

C.6. COHERENCE

C.6.1. Internal coherence

C.6.1.1. Internal coherence of the actions implemented in MSCA

According to stakeholders approached for this evaluation and its FP7 equivalent[136], a coherent set of distinct actions is in place within the MSCA programme supporting researchers at different career stages with various forms of mobility (international, inter-sectoral and interdisciplinary).

The ITN provide innovative doctoral-level training leading to a range of skills in order to maximise the employability of PhD candidates (early-stage researchers). ITN absorb more than half the MSCA budget each year. The IF support experienced researchers undertaking mobility between countries, and where possible to the non-academic sector. IF account for around 30% of the MSCA annual budget. RISE supports international and inter-sectoral collaboration through the exchange of research and innovation staff. Co-funding of regional, national and international programmes (COFUND) supports high-quality fellowship or doctoral programmes with transnational mobility. RISE and COFUND each account for around 10% of the total MSCA budget. See Table 24. In addition to the four main actions, the programme also supports the NIGHT with its broader objectives (a CSA).

Another CSA facilitates trans-national co-operation between National Contact Points (NCPs) for the MSCA, with a view to identifying and sharing good practices and raising the general standard of support to applicants, taking into account the diversity of actors.

A series of MSCA-related conferences and events including Presidency conferences, held over the period 2014-2016 brought together a wider range of stakeholders to share good practices, exchange views on the various MSCA actions and put forward recommendations to fine-tune and further improve the programme.

C.6.1.2. Internal coherence with other Horizon 2020 intervention areas

The programme complements other Horizon 2020 activities, in particular FET, ERC and Research Infrastructures to produce excellent science. The closest of these initiatives to MSCA are the ERC grants, but these do not include an explicit requirement for transnational mobility whereas this is a key requirement for MSCA. Moreover, scientific excellence, rather than potential contribution to researcher career development, is the ERC sole criterion for applicant selection.

There is evidence that former MSCA fellows tend to be more successful when applying for ERC grants. An analysis of ERC applicants under Horizon 2020 who were MSCA fellows in FP7 estimates their average success rate at 16%, compared to 12% among all applicants to the same calls.[137] Moreover, there are examples of highly-successful ERC

[136] *FP7 ex-post evaluation PEOPLE Specific Programme (2007-2013): Rationale, implementation and achievements, Dr Dragana Avramov, 2015.*

[137] *For this analysis the study team reviewed ERC applicant data from the following calls for proposals:ERC-2014-ADG, ERC-2014-CoG, ERC-2014-PoC, ERC-2014-STG, ERC-2015-AdG, ERC-2015-CoG, ERC-2015-PoC, ERC-2015-STG, ERC-2016-ADG, ERC-2016-COG, ERC-2016-PoC, ERC-2016-STG, ERC-2017-STG. Out of 22,784 eligible applicants overall, 1,591 (around 7 per cent) were MSCA fellows in FP7. For a previous analysis with similar*

grantees whose earlier career benefitted from MSCA funding. For example, Professor Valeria Nicolosi, an Italian national based in Trinity College Dublin, who has had remarkable success in obtaining ERC funding on four occasions benefitted previously from her experience as an IF in Oxford.

MSCA play a key role in opening up Horizon 2020 to the world, with around one in four fellows coming from countries outside the EU Member States or the Horizon 2020 Associated Countries. MSCA can also be regarded as being complementary to Horizon 2020 investment in research infrastructures, by developing the human resources that can use those infrastructures.

MSCA aim to enhance technological leadership through and entrepreneurship within research, as well as links between universities and industry. This effort is complementary to the existence of an SME instrument in Horizon 2020. This instrument, however, focuses on the development of ideas for products, services or processes that are ready to face global market competition. It is not concerned with basic research, and does not include a similar focus as MSCA on the development of future researchers.

Some stakeholders interviewed reported a degree of overlap between MSCA and the Horizon 2020 SME Innovation Associate Initiative (IAI): Funding PhD recruitment in SMEs.[138] However, this initiative is only accessible to SMEs and start-ups established in the EU Member States and Horizon 2020 associated countries – not to higher education institutions or other types of companies. The initiative aims to facilitate the integration into those entities of researchers who hold a PhD or equivalent and comply with transnational mobility criteria as defined by MSCA. They become post-doctoral research associates for an initial period of 12 months, and the SME receives an individual grant covering salary and related costs to conduct research for their innovation area. The programme will support 90 SMEs in this process. The researchers take part in the business innovation process, learn about industrial innovation and business management skills, and boost their CVs with business experience abroad. It is, thus, a complementary rather than overlapping initiative to MSCA. While IFs can be hosted at or seconded to SMEs, the MSCA IF cater for a larger group of host organisations, give the researcher the freedom to devise their own project, and can have a longer time-span. It would be worth exploring, however, whether the IAI initiative should be incorporated into MSCA due to the commonalities between both.

The EIT is supporting five Knowledge Innovation Communities (KICs[139]), which include higher education, public and private sector research bodies. According to a study by Ecorys[140], the projects operated by KICs may benefit experienced researchers who had already participated in the MSCA. In this way, MSCA help to ensure a supply of experienced researchers to implement projects taken forward under initiatives like KICs, complementing those.

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results, see Economisti Associati, Marie Curie researchers and their long-term career development: a comparative study – Final Report, March 2014. P.110.

[138] *https://ec.europa.eu/easme/en/news/horizon-2020-sme-innovation-associate-funding-phd-recruitment-smes*

[139] *https://eit.europa.eu/activities/innovation-communities*

[140] *ECORYS (2012), Marie Curie Life Long Learning and Career Development Evaluation. http://ec.europa.eu/smart-regulation/evaluation/search/download.do;jsessionid=h1ysTJkS1fMPNDyQyLG8XJ1R2ML1pTc06yxsRQyJNJ1q8rkNLLTY!1601440011?documentId=715857*

C.6.1.3. Ensuring that every euro spent counts twice

The focus of MSCA is to support the development of a new generation of excellent, creative and innovative researchers, and enable them to convert knowledge and ideas into products and services in the future. There are numerous examples of successful (or high potential) projects in which MSCA fellows have produced (or foreseen) close-to-market outputs, covering the full innovation chain. Three examples responding to the various Technology Readiness Levels (TRL)[141] are:

NOLOSS (EID) TRL 3: Applied research[142]

The beneficiary expects that the new knowledge generated in the PhD projects could trigger further research resulting in the technological improvement of one of the company's metrology solutions. This would potentially lead to improvements in some of the company's end-products and consequently the company's overall competitiveness in the market. Similarly, another company indicated that it already sees a very high potential resulting in the development of two new products: a telecom and datacom application in the area of fibre optics and a new application in photolithography that would substantially improve the current technological state-of-the-art in this area.

SAGE-CARE (RISE) TRL 5: Large scale prototype[143]

The aim of this project is to bring together experts from the academic and non-academic sectors to create a holistic informatics platform for rapidly integrating genomic sequences, electronic health records (EHRs) and research repositories to enable personalised medicine strategies for malignant melanoma treatment. A prototype software has already been developed and tested in real life settings. The first feedback from the clinicians was very positive. The interviewees were confident that the project team will manage to develop the fully functional SAGE-CARE informatics platform by the end of November 2017.

MycoTest (IF-EF) TRL 9: Full commercial application[144]

The project aims to develop fast antibody-based screening tests for the detection of harmful mycotoxins in food and feed. The fellow's work has already resulted in innovation, namely four new test kits that will be sold by the host company and are expected to generate a profit. One of the new solutions is already at the production stage and was commercialised in January 2017. The other three will be commercialised in late 2017/early 2018. Potential customers will include analytical laboratories, governmental laboratories and the food industry. One of the new products – the multiplex test for mycotoxins – could be a breakthrough in onsite testing. If the products are all successfully brought to the market, they will be profitable for the host organisation.

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[141] *Technology Readiness Levels are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain: TRL 1 – basic principles observed; TRL 2 – technology concept formulate; TRL 3 – experimental proof of concept; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment; TRL 6 – technology demonstrated in relevant environment; TRL 7 – system prototype demonstration in operational environment; TRL 8 – system complete and qualified; TRL 9 – actual system proven in operational environment*

[142] *http://cordis.europa.eu/project/rcn/202539_en.html*

[143] *http://cordis.europa.eu/project/rcn/194165_en.html*

[144] *http://cordis.europa.eu/project/rcn/195050_en.html*

C.6.2. External coherence

C.6.2.1. Coherence with other EU funding programmes

MSCA are coherent with other EU interventions such as the European Structural and Investment Funds (ESIF) and Erasmus+. The differences between Horizon 2020 (including MSCA) and ESIF are well delimited[145]: MSCA are non-territorial/ transnational and directly managed by the EU, whereas ESIF is co-managed and takes into account geographic specificities in allocating funding. MSCA are project-based and based on excellence whereas ESIF is based on capacity-building in specific eco-systems and prioritises cohesion. It is possible to foresee ESIF investments in support of COFUND, for instance in the form of investment in infrastructures, large equipment (ERDF) or training and networking (mainly ESF)[146].

Erasmus+, funds the mobility of students, early stage researchers (PhD candidates) and staff working in higher education institutions (HEI) for both teaching and training. Training periods can include professional development courses and specific competence-building events abroad (at HEI or other relevant organisations operating outside of education). The sending and host organisations sign a partnership agreement in advance. The duration of the mobility period is shorter (between 3 and 12 months for PhD candidates and between 2 days and 2 months for staff) than under MSCA.

The evolution of MSCA from FP7 to Horizon 2020 has been well received by the stakeholders approached for this evaluation, as some FP7 funding was considered redundant with what was offered by the Erasmus Mundus programme.

Furthermore, implementation of the European Industrial Doctorate under ITN is underpinned by opening up Structural Funds to support universities to take up innovative doctoral training.

C.6.2.2. Coherence with other public support initiatives at regional, national and international level

MSCA are complementary to the situation in most European countries. There is a high degree of synergy between COFUND and national/ regional level initiatives[147]. National initiatives normally do not have an international component similar to that of MSCA and this makes the programme distinct, as does its emphasis on the collaboration with the non-academic sector[148]. National programmes often lack the universality (by focusing for example focus on bilateral exchanges) and flexibility of MSCA[149].

COFUND acts in synergy with the overall R&I strategies of regions/countries, notably by also supporting doctoral or fellowship programmes in the disciplines covered under their smart specialisation strategy, where this exists.

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[145] DG Regional and Urban Policy (2014) Enabling synergies between European Structural and Investment Funds, Horizon2020 and other research, innovation and competitiveness-related Union Programmes. Guidance for policy-makers and implementing bodies. Luxembourg, Publications Office of the European Union.
[146] Example provided in DG Regional and Urban Policy (2014).
[147] ECORYS (2012) FP7 Marie Curie Life-long Training and Career Development Evaluation: Individual Fellowships and Co-Funding Mechanism.
[148] ICF (2017) Marie Skłodowska-Curie actions – FP7 ex post and Horizon 2020 interim evaluation. (in progress)
[149] PPMI (2013) “FP7 Marie Curie Actions Interim evaluation. Implementing Framework contract EAC/50/2009”. Final Report.

SIRCIW[150] - Strengthening International Research Capacity in Wales

Under Horizon 2020, EUR 9.5 million was awarded to the Welsh Government to set up a fellowship programme for 90 experienced, excellent researchers recruited from abroad. The programme is an excellent example of synergies between different funding sources as it is supported by an EU contribution through MSCA-COFUND, the European Regional Development Fund (ERDF), and by various regional financial supports including that of the Welsh government.

The programme also makes sure that researchers from countries that do not have the resources – in particular in the context of economic crisis - to place a priority in international mobility can benefit from mobility experiences[151]. Similarly, research outside of the context of MSCA has found that "collaboration within Europe with some of the smaller European countries in terms of research outputs shows evidence for European capacity building": collaborating with these smaller and lower research-impact countries contributes to improving their research potential and impact[152]. MSCA stimulate collaboration across European countries.

There is, however, some competition between existing programmes for the best research talent. MSCA coexist with schemes that do not stimulate mobility or collaboration with industry, and this is an aspect that requires consideration in order to ensure that mobility and collaboration projects continue to attract outstanding researchers.

Complementarity with national funding programmes has been strengthened through a new initiative launched in November 2016. A Seal of Excellence will be awarded to proposals under IF which score 85% or above but for which there is insufficient funding through the MSCA budget. This provides excellent researchers with recognition of quality and also enables them and the hosting institution with whom they applied to seek alternative sources of funding at regional or national level, including through use of ESIF. Croatia, Cyprus, Czech Republic, Poland and Slovenia have introduced (or have plans to introduce) funding schemes for recipients of the Seal of Excellence, drawing where possible on ESIF.

C.6.3. Lessons learnt/Areas for improvement

MSCA complement other Horizon 2020 activities, in particular ERC, FET and RI to produce excellent science. There is evidence that former MSCA fellows tend to be more successful when applying for ERC grants and indeed there are examples of highly-successful ERC grantees whose earlier career benefitted from MSCA funding.

Evidence exists of complementarity with ESIF and national funding programmes. Member States have combined national and ESIF funding with COFUND which offers additional funding for new or existing regional, national and international programmes to provide an international and inter-sectoral dimension to research training and career development. Nevertheless, the MSCA Advisory Group recommended that best practices

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[150] *http://cordis.europa.eu/project/rcn/198204_en.html*

[151] *ICF (2017) Marie Skłodowska-Curie actions – FP7 ex post and Horizon 2020 interim evaluation. (in progress); PPMI (2013) "FP7 Marie Curie Actions Interim evaluation. Implementing Framework contract EAC/50/2009". Final Report.*

[152] *Science Europe and Elsevier (2013) 'Comparative benchmark of European and USA Research Collaboration and Researcher Mobility' Netherlands.*

in the use of such synergies should be identified and promoted to increase their uptake.[153] Complementarity has been recently strengthened through the newly-introduced Seal of Excellence for individual fellowships.

C.7. EU ADDED VALUE

MSCA continue to help reinforce, widen and extend the excellence of the Union's science base and ensure a supply of world-class research and emerging talent to secure Europe's long-term competitiveness and well-being. Scientific excellence as the main evaluation criterion ensures genuine competition among researchers and research institutions. This enables MSCA to attract among the best scientific talent worldwide and ensures the participation of leading research institutions. There is little or no equivalent to MSCA in the EU Member States as far as their scale, scope, funding, character, generation and transfer of knowledge are concerned.

MSCA are characterised by an emphasis on research excellence and on the benefits to be gained through mobility, which can be international, interdisciplinary or inter-sectoral. They are based on the idea that knowledge transfer happens through people and their interactions, and that training in the delivery of excellent research, amplified through mobility, delivers benefits that can last throughout a career.

Evidence shows that the vast majority of MSCA applications rejected due to budgetary reasons were not subsequently implemented as originally planned: 77% of unsuccessful applicants indicated that they did not proceed with the project while 17% went ahead with significant changes to the project such as fewer partners or activities. Only 6% of unsuccessful applicants went ahead with the project as planned.[154]

Through the MSCA, both individual researchers and institutions build their networks, facilitating collaboration that can be long-term. MCSA have strengthened the resources of those institutions able to attract researchers internationally and thereby encouraged the spread of centres of excellence around the EU.

The doctoral training offered under ITNs ensures a wide promotion and implementation of the EU Principles for Innovative Doctoral Training. An international, inter-sectoral and interdisciplinary environment created by consortia from different countries provides the next generation of researchers with innovative training, transferable skills such as an entrepreneurial mindset and significant exposure to industry.

MSCA continue to have a pronounced structuring impact on ERA by setting standards for attractive working conditions and open recruitment for all EU researchers. For example, all funded MSCA participants are required to apply the principles of the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers. MSCA also contributes substantially to the ERA goal of opening to the world.

The bottom-up approach taken by MSCA has also allowed a large majority of institutions to train and upgrade the skills of a new generation of researchers able to tackle a broad range of current or expected societal challenges. Tackling these challenges solely at national level would be more difficult to achieve. As all selected projects are, as a pre-

[153] *MSCA Advisory Group Report June 2016*
[154] *Respondents who answered "I don't know" are excluded from these percentages.*

condition, required to demonstrate EU added value and increase the effectiveness, efficiency and synergy through collaborative European research, a set of examples are given here to illustrate the diversity in how this happens in practice.

C.7.1. Horizon 2020 projects demonstrating EU Added Value

POLONEZ[155] - Supporting mobility in ERA through an international fellowship programme for development of basic research in Poland

This COFUND project coordinated by NCN Poland (Narodowe Centrum Nauki / National Science Centre) supports international and inter-sectoral mobility by allowing non-resident, postdoctoral researchers to undertake fellowships at Polish research organisations. Case study research suggests that, without COFUND, the programme would not exist due to lack of resources and administrative support. Moreover, the programme is more competitive than other national programmes in terms of researchers' salaries, visibility and brand. These are contributing factors that enable the programme to attract excellent researchers.

ELiTES, SKPLUS and InvisiblesPlus[156]

Thanks to three MSCA RISE projects for research staff exchanges worth more than EUR 2.5 million, the 2015 Physics Nobel co-laureate Prof. Takaaki Kajita of the University of Tokyo investigated together with his European partners new ways of detecting gravitational waves, the interaction of neutrinos as well as their coupling with dark matter. Major breakthroughs are expected soon which may lead inter alia to a New Standard Model of particle physics.

MuseCoP4DT[157] - Design Thinking for Digital Heritage: Developing Communities of Design Practice for Visitor Experience

Two-time MSCA fellow Marco Mason readily acknowledges that neither his research development nor his career success would have been possible without the excellent, bottom-up funding that MSCA provides. An International Outgoing Fellowship (IOF) in 2011 enabled him to go to the MIT in the US. The project consisted of studying the design practice for digital systems for museums. The MSCA funding provided a lifeline which enabled him to carry out cutting edge research. He was then able to bring the knowledge and expertise back to Europe (University of Leicester in the UK) thanks to an IF awarded under the Reintegration Panel in 2015.

C.8. SUCCESS STORIES FROM PREVIOUS FRAMEWORK PROGRAMMES

CLOUD-TRAIN[158] Initial Training Network

The CLOUD-TRAIN ITN project achieved excellent results both from a research point of view, with publications in NATURE, as well as helping the career development of all the doctoral candidates. This was achieved through training in the creation of start-ups and the recruitment of the PhDs by participating businesses at the end of the project.

[155] *http://cordis.europa.eu/project/rcn/196983_en.html*
[156] *http://cordis.europa.eu/project/rcn/102450_en.html; http://cordis.europa.eu/project/rcn/193831_en.html; http://cordis.europa.eu/project/rcn/200226_en.html*
[157] *http://cordis.europa.eu/project/rcn/203459_en.html*
[158] *http://cordis.europa.eu/project/rcn/104657_en.html*

Fellows from 10 institutions were able to conduct experiments on atmospheric aerosol formation at the unique CLOUD aerosol chamber in CERN. Research instruments were developed and improved in close cooperation between non-academic and academic partners.

HERMES[159] - Humboldt in Europe: Researcher Mobility on an Enhanced Scale

In August 2013, the Humboldt Foundation obtained co-funding from the MSCA programme to increase significantly the number of positions for excellent researchers from developing countries and emerging economies. The MSCA co-funded programme is called HERMES - Humboldt in Europe: Researcher Mobility on an Enhanced Scale. All HERMES fellowships are hosted in Germany. The calls for proposals were open only to researchers originally from a developing or transition country. The MSCA co-funding also makes a contribution to improving the situation in the country that the researcher has left. The research carried out by HERMES fellows in Germany must include aspects that are important for the continued development of the researchers' country or region of origin. Moreover, applicants are asked to demonstrate that they will contribute to the exchange of knowledge and methods between Germany and their home country.

IMAGING LYMPHOMA[160] - New imaging methods for detecting treatment response in lymphoma

The MSCA can be the starting point for a successful career beyond the research field. Such is the case of the current Portuguese Minister of Education, Tiago Brandao Rodrigues, appointed in November 2015. Awarded two different MSCA fellowships related to his cancer research, later he would remain linked to the scheme as an expert evaluator for calls.

C.9. LESSONS LEARNT/CONCLUSIONS

C.9.1. Relevance

- The MSCA contribute to Europe's human capital development by supporting the people that drive research and innovation. The actions are relevant in addressing many of the issues associated with Europe's relative lack of competitiveness: the need to attract more highly skilled researchers in the global race for talent; fragmentation of the European public science and research base; lack of high-quality training of and career development for researchers; and insufficient knowledge transfer and mobility of researchers across sectors.

- Efforts to increase the participation of businesses in MSCA are in line with the European Semester 2016 recommendations, to strengthen inter-sectoral cooperation. There is however scope for improvement in encouraging greater participation from firms, public bodies and NGOs as well as equipping the next generation of researchers with a broader set of transferable skills needed to develop their career outside academia.

[159] http://cordis.europa.eu/result/rcn/176883_en.html
[160] http://cordis.europa.eu/project/rcn/94931_en.html

C.9.2. Effectiveness

- MSCA are characterised by an emphasis on research excellence, training, career development and on the benefits to be gained through mobility, which can be international, interdisciplinary or inter-sectoral. Evidence shows that MSCA have a positive impact on individual researchers, organisations and at system level.

- Over the course of Horizon 2020, some 65 000 researchers will benefit from an international mobility experience funded by MSCA (to date, the budget has covered around 27 000 fellows). For just under half of them, this will also include mobility or exposure to the non-academic sector or vice-versa.

- There is also strong evidence of longer-term scientific value and societal impact of the programme. MSCA fellows have a strong reputation for research excellence with several recent European Nobel Prize laureates having benefited from the programme while MSCA researchers have contributed to major breakthrough discoveries including the Higgs Boson at CERN and the detection of gravitational waves.

- MSCA continue to have a pronounced structuring impact on ERA by setting standards for quality training, attractive working conditions and open recruitment for all EU researchers.

- There are wide discrepancies between Member States in their ability to attract funding, Notwithstanding the need for Member States to undertake the reforms necessary to improve their participation and without compromising excellence, consideration could be given to supporting measures to spread excellence across ERA and widen participation in MSCA.

C.9.3. Efficiency

- The programme underwent significant simplification under Horizon 2020 including extending the use of simplified forms of grants and streamlining the funding schemes. Stakeholders view the simplifications as generally helpful and effective, with for example the unit cost approach reducing the administrative burden.

- In spite of the budget increase for MSCA under Horizon 2020, the oversubscription of MSCA calls has doubled since FP7, particularly for the ITN where the success rate is only 8%. This represents a huge loss of talent for Europe with 80% (or 14 300) of all high-quality MSCA proposals not currently funded. Funding all these high-quality proposals would require another EUR 13 billion, around seven times the current level of funding.

- The MSCA programme is implemented by the Research Executive Agency (REA). There is evidence of the cost-efficiency of the REA management system with the average time-to-grant for MSCA having fallen significantly since 2009.

- The European Researchers' Night, with an annual budget of EUR 4 million, is highly cost-effective as it manages to reach out to more than one million citizens every year, right across the EU, attracting in particular young people to a possible career in research.

C.9.4. Coherence

- MSCA complement other Horizon 2020 activities, in particular ERC, FET and Research Infrastructures to produce excellent science. There is evidence that former MSCA fellows tend to be more successful when applying for ERC grants and indeed there are examples of highly-successful ERC grantees whose earlier career benefitted from MSCA funding.

- Complementarity with ESIF and national funding programmes is ensured in particular through COFUND and has been strengthened through the newly-introduced Seal of Excellence for individual fellowships. Nevertheless, there is scope to better identify and promote good practice to increase their uptake.

C.9.5. EU Added Value

- Scientific excellence as the main evaluation criterion ensures genuine competition among researchers and research institutions. This enables MSCA to attract among the best scientific talent worldwide.

- There is no equivalent to MSCA in the EU Member States as far as their scale, scope, funding, character, generation and transfer of knowledge are concerned.

- Evidence shows that the vast majority (94%) of MSCA applications rejected due to budgetary reasons were not subsequently implemented as originally planned.

D. RESEARCH INFRASTRUCTURES

D.1. INTRODUCTION

D.1.1. Context

Horizon 2020[161] (Horizon 2020) is the European Union's research and innovation framework programme for the period 2014-2020.

Horizon 2020 is expected to contribute to the top priority of the Juncker Commission[162] to strengthen Europe's competitiveness and to stimulate investment for the purpose of job creation and growth.
While Horizon 2020 sets out the general objective of that framework programme, the priorities and the broad lines, the specific programme[163] define the objectives and the activities which are specific to each of the different Parts.

Part I "Excellent science" of Horizon 2020[253] reinforces and extends the excellence of the Union's science base and ensures a supply of world class research and talent to secure Europe's long term competitiveness and well-being[164]. It supports the activities of the European Research Council on frontier research, future and emerging technologies, Marie Curie Actions and ***European research infrastructures, including e-infrastructures*** [255]**.**
The main objective of these activities is to build competence in the long term, focusing on the next-generation of science, and providing support for emerging talent from across the Union and from associated countries, hereby also contributing to the European Research Area.

D.1.2. Objectives and intervention logic

The 2015 Expert Advisory Group Implementation Report[165] gave a very good summary for the rationale of Horizon 2020 RI, as follows:

Research infrastructures are facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields. Where relevant, they may be used beyond research, e.g. for education or public services. By offering high quality research services to users from different countries, by attracting young people to science and by facilitating networking, Research infrastructures help structuring the scientific community and play a key role in the construction of an efficient research and innovation environment. Because of their ability to assemble a 'critical mass' of people, knowledge and investment, they contribute to national, regional and European economic development. They are also crucial in helping Europe move towards open, interconnected, data-driven and computer-intensive research.

Reflecting this, the objectives of the Research Infrastructure Specific Programme[255] as stated in the Horizon 2020 Regulation are:

- Developing the European research infrastructures for 2020 and beyond
- Fostering the innovation potential of research infrastructures and their human capital

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[161] *http://ec.europa.eu/programmes/horizon2020/en/official-documents*
[162] *http://ec.europa.eu/priorities/docs/pg_en.pdf*
[163] *http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011PC0811&from=EN*
[164] *http://ec.europa.eu/priorities/docs/pg_en.pdf*
[165] *Horizon 2020 RI EAG Implementation report 2015*
http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=22494&no=1

- Reinforcing European research infrastructure policy and international cooperation

The programme objectives are related to the different phases of the research infrastructure life cycle from the preparation, implementation and long-term sustainability to the efficient operation and transnational access and use of research infrastructures. These objectives and related underlined activities are discussed further in the following sections.

While the role of Member States remains central in developing and financing RIs, the Union is playing an important part supporting infrastructures by fostering the emergence of new facilities, opening up broad access to national and European infrastructures, and making sure that regional, national, European and international policies for RIs are consistent and effective. It is not only necessary to avoid duplication of efforts and to coordinate and rationalise the use of the facilities, but also to pool resources so that the Union can also acquire and operate RIs at world level.

Developing the European research infrastructures for 2020 and beyond

Over the past decade and as part of the ERA strategy, the research infrastructure unit works has been working with the European Strategy Forum on Research Infrastructures (ESFRI). Appointed by the ministers of research, the ESFRI was established in 2002.[166] It contributes to the development of a strategic roadmap that identifies vital new European RIs for the next 10-20 years. The ESFRI covers a broad range of scientific macro-domains: Energy (ENE), Environment (ENV), Health & Food (HF), Physical Sciences & Engineering (PSE), and Social & Cultural Innovation (SCI). ESFRI published its first Roadmap in 2006. After its updates is 2008, 2010 and 2016, ESFRI Roadmap 2016 consists of 21 ESFRI project with a high degree of maturity –including 6 entirely new projects and 29 ESFRI landmarks – RIs that reached the implementation phase by the end of 2015. ESFRI projects are long-term projects that take several years to plan, from 2 to 10 years to build and several decades to operate them.

The objectives and the development of a European approach to the joint establishment, implementation and long-term operation of new European research infrastructures, namely ESFRI projects, have evolved over time. Progress was made in recent years with the implementation of the ESFRI roadmap, the integration and opening of national research facilities and the development of e-infrastructures underpinning a digital ERA. Horizon 2020 plays, like its predecessors, a key role in structuring and integrating the European research infrastructure landscape. It provides essential support to ESFRI as a key exercise for the strategic planning and monitoring of European RIs, and for effectively linking science communities. Horizon 2020 supports research infrastructures throughout their lifecycle. In particular, it facilitates the incubation of RIs providing funding for Design Studies and Preparatory Phases. It also helps to integrate existing RIs across Europe through a specially designed instrument – Integrating Activities. Finally, it fosters the implementation and long-term sustainability of RIs through dedicated funding to individual RIs and by supporting clusters of RIs.

Developing new world-class research infrastructures

The specific objective of the Horizon 2020 RI programme is to contribute to the Horizon 2020 general objectives on endowing Europe with world-class research infrastructures that are accessible to all researchers in Europe and fully exploiting their potential for scientific advancement and innovation.

[166] *http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri*

The lines of activities are aiming at developing the European research infrastructures for 2020 and beyond, fostering their innovation potential and human capital and reinforcing European policy. Coordination with the cohesion funding sources is pursued to ensure synergies and a coherent approach for the development of the research infrastructures.
The aim is to facilitate and support the preparation, implementation, long-term sustainability and efficient operation of the research infrastructures identified by the European Strategy Forum on Research Infrastructures (ESFRI) and of other world-class RIs, which will help Europe to respond to grand challenges in science, industry and society. This objective will address specifically those infrastructures that are planning to set up, are setting up or have set up their governance, e.g. on the basis of the European Research Infrastructure Consortium (ERIC)[167] or any equivalent structure at European or international level. The community legal framework for a ERIC is a specific legal form to facilitate the establishment and operation of research infrastructures with European interest.

The Union funding will contribute to, as appropriate:
(a) the preparatory phase of future infrastructures (e.g. detailed construction plans, legal arrangements, multiannual planning);
(b) the implementation phase (e.g. R&D and engineering work jointly with industry and users, development of regional partner facilities aiming at a more balanced development of the European Research Area); and/or
(c) the operation phase (e.g. access, data handling, outreach, training and international cooperation activities).

This activity also supports design studies for new research infrastructures through a bottom-up approach.

<u>Integrating and opening existing national research infrastructures of pan-European interest</u>
The aim is to open up and work in an integrated manner, key national and regional research infrastructures to all European researchers, from both academia and industry, and to ensure the optimal use and joint development of these infrastructures. The Union will support networks that bring together and integrate, on European scale, key national research infrastructures. Funding will be provided to support, in particular, the transnational and virtual access of researchers and the harmonisation and improvement of the services that the infrastructures provide. Horizon 2020 funding under Research Infrastructures through the so called Integrating Activity instrument has been essential in opening-up infrastructure services to best scientists across Europe and to diffuse the Research Infrastructure concept and mode of operation in European laboratories and institutions. Horizon 2020 supported networks of RIs across Europe strengthen its human capital base by providing world-class training for a new generation of researchers and engineers and promoting interdisciplinary collaboration.

<u>Development, deployment and operation of ICT-based e-infrastructures</u>
The aim is to achieve by 2020 a world-leading capability in networking, computing and scientific data in a single and open European space for online research where researchers enjoy leading-edge, ubiquitous and reliable services for networking and computing, and seamless and open access to e-Science environments and global data resources.

To achieve this goal, support will be given to: global research and education networks providing advanced, standardised and scalable inter-domain services on-demand; grid and cloud infrastructures providing virtually unlimited computational and data processing capacity; an ecosystem of supercomputing facilities, advancing towards exascale; a software

[167] http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=eric

and service infrastructure, e.g. for simulation and visualisation; real-time collaborative tools; and an interoperable, open and trusted scientific data infrastructure.

Fostering the innovation potential of research infrastructures and their human capital

Exploiting the innovation potential of research infrastructures

The goal is to stimulate innovation both in the infrastructures themselves and in their supplier and user industry. To this end, support will be provided to:

a) R&D partnerships with industry to develop Union capacities and industrial supply in high-tech areas such as scientific instrumentation or ICT;

b) Pre-commercial procurement by research infrastructure actors to drive forward innovation and act as early adopters or developers of cutting-edge technologies;

c) Stimulate the use of research infrastructures by industry, e.g. as experimental test facilities or knowledge-based centres; and

d) Encourage the integration of research infrastructures into local, regional and global innovation ecosystems.

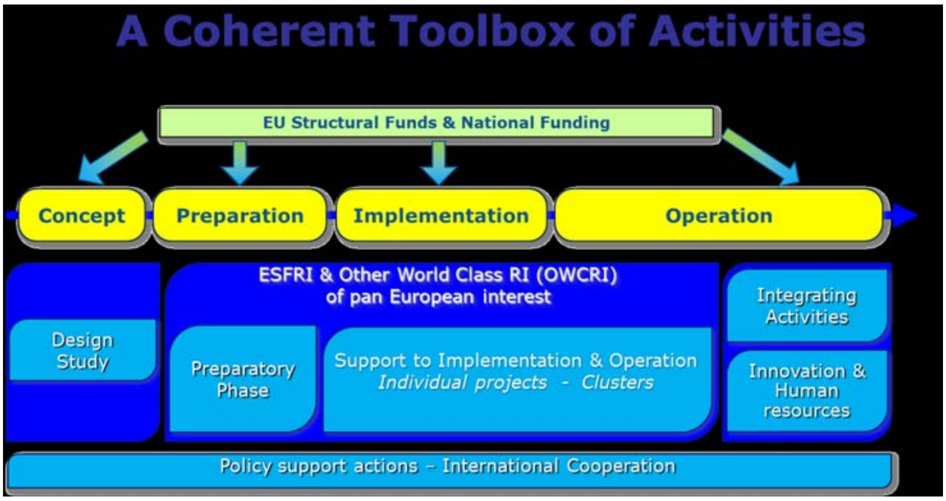
The Union actions will also leverage the use of research infrastructures, in particular e-infrastructures, for public services, social innovation, culture and education.

Strengthening the human capital of research infrastructures

The complexity of research infrastructures and the exploitation of their full potential require adequate skills for their managers, engineers and technicians, as well as users. The Union funding will support the training of staff managing and operating research infrastructures of pan-European interest, the exchange of staff and best practices between facilities, and the adequate supply of human resources in key disciplines, including the emergence of specific education curricula. Synergies with the Marie Skłodowska-Curie actions will be encouraged.

All these interventions are intended to address different stages of research infrastructure lifecycle, from concept design to operation, and are therefore complementary and synergic (Figure 61).

Figure 61 - A coherent toolbox of activities for the life cycle of the research infrastructures. The Horizon 2020 RI actions are in light blue.



Source: internal RTD B.4 data.

Reinforcing European research infrastructure policy and international cooperation

Reinforcing European policy for research infrastructures

The aims are to exploit synergies between national and Union initiatives by setting up partnerships between relevant policy makers, funding bodies or advisory groups (e.g. ESFRI, e-Infrastructure Reflection Group (e-IRG), EIROforum organisations, and national public authorities), to develop complementarities and cooperation between research infrastructures and activities implementing other Union policies (such as regional, cohesion, industrial, health, environment, employment, or development policy), and to ensure coordination between different Union funding sources. Union actions will also support survey, monitoring and assessment of research infrastructures at Union level, as well as relevant policy studies and communication tasks.

Facilitate strategic international cooperation

The aim is to facilitate the development of global research infrastructures i.e. RIs that require funding and agreements on a global scale. The aim is also to facilitate the cooperation of European research infrastructures with their non-European counterparts, ensuring their global interoperability and reach, and to pursue international agreements on the reciprocal use, openness or co-financing of infrastructures. In this respect due account will be taken of the recommendations of the Carnegie Group of Senior Officials on Global Research Infrastructures. Attention will also be given to ensure adequate Union participation in coordination with international bodies such as the UN or the OECD.

Research Infrastructure overall objectives and related intervention logic

The comparison with the objectives of the Specific Programme *Research Infrastructures* in the Seventh Framework Programme for Research and Technological Development (FP7) shows a high degree of continuity forward to Horizon 2020 RIs. The objective of the FP7 programme was:

Optimising the use and development of the best research infrastructures existing in Europe, and helping to create in all fields of science and technology new research infrastructures of pan-European interest needed by the European scientific community to remain at the forefront of the advancement of research, and able to help industry to strengthen its base of knowledge and its technological know-how.

The action areas were:

- *Integrating activities* (with emphasis on the role of ESFRI)
- *e-Infrastructures*
- *Support for new infrastructures/upgrades*
- *Support for policy development and implementation* (which includes innovation)

These broad action areas all continue forward into Horizon 2020 and there are no conspicuous areas of discontinuity.

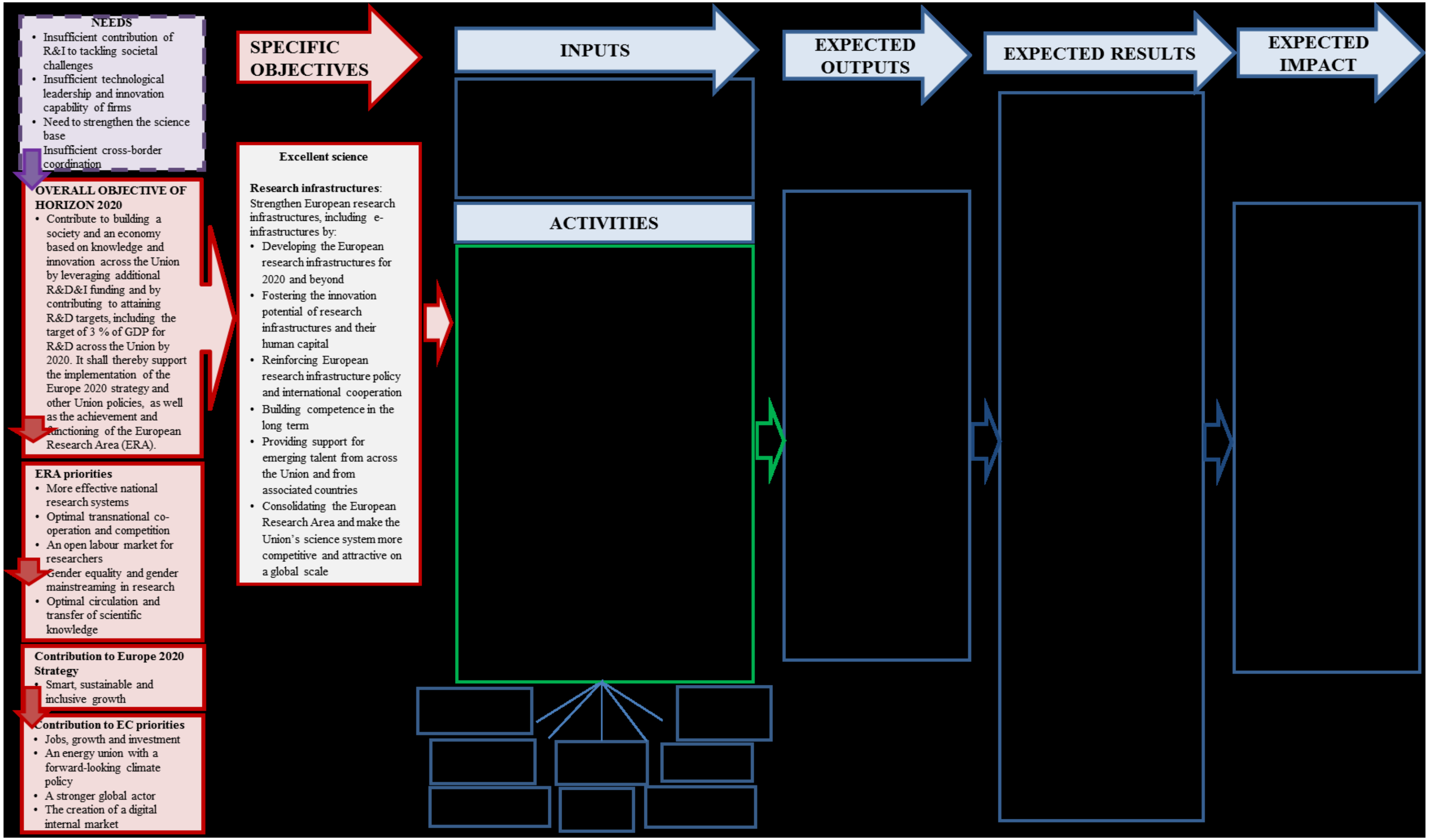
The changes between FP7 and Horizon 2020 RI are reflections of the wider structure of the framework and of the developing policy and scientific context, and only two significant changes can be cited.

The first is that e-Infrastructures have more specific emphasis in Horizon 2020 RI. This was already emerging clearly during FP7 as the emphasis on the “digital economy”, as it is now called, began to increase in successive calls and is a reflection of increasing scientific and technological capability and societal and economic policy drivers.

The second change is the reorientation of Research Infrastructures from the Capacities area to the Excellence Science one. Most of the areas within FP7 Capacities, inasmuch as they relate to research infrastructures, are still addressed within Horizon 2020 RI. However, action to stimulate the establishment and development of research infrastructures or their increased access in “convergence and outermost regions” is not a specific purpose in Horizon 2020 RI, and the coupling of RIs with ERC and MSC in a grouping called Excellent Science is a powerful statement of intent, because it reinforces - in terminology familiar to the scientific community - that this specific programme is science led rather that strategically or end user driven. The envisaged activity is seen as science-driven with a medium- to long-term impact horizon. In the long term these outputs are expected to underpin a wide variety of European and wider scientific, economic, social and other results leading to highly beneficial impacts.

Figure 62 represents the intervention logic for Horizon 2020 indicating the RI specific objectives and related activities, and the expected outputs, results and impact.

Figure 62 - Intervention logic for Horizon 2020 indicating the aspects relevant to Horizon 2020 Research Infrastructures



*Source: EC, DG RTD based on Horizon 2020 Work Programme **2016 – 2017.** 4. European Research Infrastructures (including e-Infrastructures).*

D.2. IMPLEMENTATION STATE OF PLAY

D.2.1. Overview of programme inputs and activities

The data analysed here addresses the situation as of 1st January 2017.

The EC contribution allocated to the implementation of the calls included in Work Programmes 2014-2017 and which have been closed at the date of 1st January 2017 2017 has been EUR 897 billion, about 40% of total expected budget allocated to Horizon 2020 RI in Horizon 2020, which is EUR 2.269 billion for the period 2014-2020. This leaves approximately EUR 1.372 billion for any remaining parts of the 2016-2017 Work Programme and whatever is expected in a 2018-2020 call.

The allocations to each line of activity of Horizon 2020 RI and the numbers of awards made over the period are in Table 31 and Table 32.

The figures include one award (GEANT Connectivity to Latin America) which was funded jointly from the 2014/15 and 2016/17 e-INFRA allocations.

At the time of the interim evaluation, no projects are completed (the earliest having started mid-2015, there are no scheduled ends before 1st January 2017). There are 104 projects ongoing from 2014/15 calls. Further awards have been or will be made from the 2016/17 calls. Of these 45 Grants have been signed and further 16 are under preparation following the 2016 calls.

Table 31 - Activities and allocated share of budget dedicated to European research infrastructures for the programming period 2014-2017

[redacted]						
CALL 1 - H2020-INFRADEV	217.8	34	106	28	323.8	62
[redacted]						
CALL 2 - H2020-INFRAIA	160.6	19	242	29	402.6	48
[redacted]						
CALL 4 - H2020-INFRAINNOV	7.2	3	24	3	31.2	6
[redacted]						
CALL 5 - H2020-INFRASUPP	19.5	11	10.5	5	30	16
[redacted]						
TOTAL RTD	405.1	67	382.5	65	787.6	132
[redacted]						

Source: Corda, calls in 2014, 2015 and 2016, signed Grants cut-off date by 01/01/2017 (including ad hoc calls).

Table 32 - Activities and allocated share of budget dedicated to European research e-infrastructures for the programming period 2014-2017

[redacted]

CALL 3 - H2020-EINFRA	179	29	116.3	15	295.3	44
[redacted]						
CALL 5 - H2020-INSUPP	6.9	5	9.8	7	16.7	12
[redacted]						
GEANT-FPA	30	1.5	64	1.5	94	3
[redacted]						
Human Brain Projects - FPA	0	0	25	1	25	1
[redacted]						
TOTAL CNECT	215.9	35.5	215.1	24.5	431	60
[redacted]						

Source: Corda, calls in 2014, 2015 and 2016, signed Grants cut-off date by 01/01/2017 (including ad hoc calls).

For the following statistics reported in Table 33 and Table 34, 149 grants have been taken into account, which correspond to the ones selected under the 2014-2016 budget.

Table 33 - Share of the funding allocated for each type of action

Type of Action	Nr of Selected Projects	EC Contribution to Selected Projects (EUR million)	Projects Total Costs in Signed Grants (EUR million)
COFUND-PCP	1	4.7	4.7
CSA	50	109.0	115.9
RIA	98	757.3	848.7
SUM:	149	870.9	971.3

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).

Table 34 - Success rate per type of action

Type of Action	Nr of Eligible Proposals	Nr of Retained Proposals	EC Contribution requested by Eligible Proposals (EUR million)	EC Contribution to Retained Proposals (EUR million)	Success Rate Proposals	Success Rate Funding
COFUND-PCP	1	1	4.7	4.7	100.0%	100.0%
CSA	121	47	224.2	110.6	38.8%	49.3%
PPI	1	1	26.0	26.0	100.0%	100.0%
RIA	325	84	2 008.2	626.3	25.5%	31.2%
	448	133	2 263.1	767.5	29.7%	33.9%

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).

The success rate of proposals is 30%. This is rather higher than the Horizon 2020 average (which is about 14%), but a number of components of the programme have, in effect, been targeted at one or a very narrow pool of potential applicants, suggesting that those areas which are intended to be broadly competitive have lower success rates

A two stage call was launched on 2016 for the integrating activities - starting communities. The results of second stage will be available in 2017.

D.2.2. Participation patterns

D.2.2.1. Participation per type of organization

The selected proposals represent a total of 1686 participations, mobilizing 1168 distinct participants.

The academic organisations are 82%, the research organisations 76%, the non profit organisations are 92%, the high education establishments 37 %, the public bodies 67% and the SMEs 6%. Please note that in this classification a participating organization can belong to more than one category, whilst in Table 35 each organization has been classified according to the principal category.

Table 35 - Type of participants in selected proposals

Participant Type	Nr of distinct participants in Signed Grants	% of Participant Type in Selected Projects	Nr of Projects Coordinators in Signed Grants	Nr of Newcomers in Signed Grants
HES	338	33	31	1
OTH	84	8	12	27
PRC	129	12	7	52
PUB	68	7	1	13
REC	412	40	98	39
SUM:	1031	100	149	132

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).Abbreviations: Higher or secondary education (HES),Private for profit (excluding education) (PRC), Public body (excluding research and education) (PUB), Research organisations (REC), Other (OTH).

D.2.2.2. Attraction of new participants/newcomers

The share of newcomers (defined as not having participated in FP7) participations in signed Research Infrastructure grants in 2014 and 2015 is 13% (Table 36 and 37).

The EU-13 participation (EU-13/overall) is 15% in total in 2014 -2016. (Table 37).

D.2.2.3. Geographical participation patterns

A summary of the geographical distribution of participants in Horizon 2020 RI is presented in the Table 36. The EU-13 and third country participation is in total 21%.

Table 36 - Geographical distribution of participants in Horizon 2020

Country Type	Nr of distinct participants in Signed Grants	% of Participation in Selected Projects	Nr of Projects Coordinators in Signed Grants	Nr of NewComers in Signed Grants
ASSOCIATED	96	9	8	14
EU-13	154	15	2	19
EU-15	718	70	137	87
THIRD_COUNTRY	63	6	2	12
SUM:	1031	100	149	132

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).

The distribution of the Member States participation is reported in Table 38, showing a wide participation of all the States, and a particularly high participation of Germany.

Table 37 - Summary of Member States participation

Country	Nr of distinct participants in Signed Grants	% of MS Participants in Selected Projects		Country	Nr of distinct participants in Signed Grants	% of MS Participants in Selected Projects
Austria	22	2.5		Italy	78	8.9
Belgium	39	4.5		Latvia	7	0.8
Bulgaria	11	1.3		Lithuania	3	0.3
Croatia	7	0.8		Luxembourg	2	0.2
Cyprus	5	0.6		Malta	1	0.1
Czech Republic	26	3.0		Netherlands	58	6.7
Denmark	12	1.4		Poland	29	3.3
Estonia	7	0.8		Portugal	31	3.6
Finland	17	1.9		Romania	17	1.9
France	83	9.5		Slovakia	12	1.4
Germany	124	14.2		Slovenia	8	0.
Greece	33	3.8		Spain	77	8.8
Hungary	21	2.4		Sweden	24	2.8
Ireland	18	2.1		United Kingdom	100	11.5
				SUM	**872**	**100**

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).

D.2.2.4. International cooperation

As shown in Table 36, the participation of third countries to Research Infrastructure projects is 6 %

D.2.3. Cross-cutting issues

Research infrastructures are essentially horizontal in nature and therefore covers a wide range of scientific domains. Table 38 shows a rough analysis by broad subject area of the DG RTD awards made in Horizon 2020 RI as of 1st January 2017. The table does not include the e-infrastructure projects.

Table 38 - Scientific classification of Horizon 2020 RI projects funded by DG-RTD

Scientific_Domain	Number of Contracts	EC_Contribution
1. Social sciences and Humanities	12	58.957.050,96
2. Life sciences	22	133.336.281,81
3. Environmental Sciences	21	132.463.359,86
4. Engineering	1	9.979.376,17
5. Energy	5	26.783.487,48
6. Material sciences and Analytical Facilities	10	71.962.039,75
7. Physical Sciences and Astronomy	21	127.308.789,88
8. Information Communication Technologies	3	16.947.712,5
9. Policy development	10	16.032.529,25
TOTAL	105	445.274.738,60

Source: European Commission, internal data base.

Health, Environment and Climate Change raise questions, which require European collaborative research and European collaboration for the joint establishment of research infrastructures.

Table 38 shows that almost half of the financial resources are awarded to Life Sciences and Environment.

This included investments such as:

- ELIXIR: A distributed infrastructure for life-science information
- LifeWatch: e-infrastructure for Biodiversity and Ecosystem research
- GLOBIS-B: global cooperation of infrastructures focused on services to support research predicting the biosphere and measuring the indicators of biodiversity change,
- ECCELS, the European Carbon Dioxide Capture and Storage Laboratory Infrastructure,
- Support for the implementation phase of EPOS, the very large pan-European infrastructure for geo-physical monitoring which will be an essential resource for, *inter alia*, developing more effective earthquake prediction and management for the vulnerable regions of Europe (EUR19M contribution to a EUR31M programme)

A significant number and value of projects funded in the domains of Social Science and Humanities. Examples include:

ESS-ERIC: European Social Survey

SHARE-ERIC: A panel Survey for Health, Ageing and retairement in Europe.

CLARIN-ERIC: Common Language Resources and Technology Infrastructure

As regards the promotion of social sciences and humanities (SSH), in the period 2014-2017 there were 30.4% of the signed grants which have been classified as being relevant for SSH researchers.

What is less evident is the level of involvement of SSH researchers in the Horizon 2020 RI projects, in particular the e-Infra ones, and what any claims of consideration of SSH issues within funded projects actually involve. This is a significant issue because of the relevance of a wider involvement in both the increasing digital economy and the Three “O”s agenda, as well as for the opportunities these developments offer to inform policy in novel ways

Responsible Research and Innovation

The grants flagged as RRI relevant, i.e. where citizens, Civil Society Organisations (CSOs) and other societal actors contribute to the co-creation of scientific agendas and scientific contents represent 25.5 % of the signed grants.

Gender issues

The cross disciplinary nature of the programme, and the fact that gender balances are known to vary very widely across different subject disciplines means that conclusions that specifically relate to the Horizon 2020 RI programme will be fairly meaningless.

However, to date data shows that 87.6 % of Horizon 2020 RI project coordinators are women, and that the overall participation of women in RI projects is 34.2 %.

SMEs and Innovation

The SME participation rate in the programme to 1 October 2016 is 6 % - this refers to the proportion of partners in grants awarded that were from SMEs.

There have been a number of innovation-related call topics, clustered under INFRAINNOV within the DG RTD component, and within EINFRA, which will have engaged SMEs. There is also SME engagement in the large partnerships around HPC and networking (PRACE and GÉANT).

There is a significant network of HPC competence centres for SMEs that has been developed as a result of components of several EINFRA calls.

In addition to the above, there is a very major contribution, both existing and anticipated, catalysed by the delivery of open data agenda.

D.3. RELEVANCE

D.3.1. Is the Horizon 2020 Research Infrastructure programme tackling the right issues?

The background to Horizon 2020 was set very much in the context of general budgetary constraint following the world financial crisis and subsequent economic downturn 2008-2012. Although negotiations reflected this, Horizon 2020 still represents the largest - and longest - EC Research and Innovation programme thus far, and the extent of commitment from Member States reflects the view that investment into the research base is seen as a major means to underpin future economic growth and societal development. To this extent the expectations of impact and benefit from the whole Horizon 2020 programme, including Horizon 2020 RI, are considerable.

D.3.1.1. The relevance of Horizon 2020 RI given the challenges to address

World-class European R&D bodies, be it universities, research organisations or industrial departments, need world-class European research infrastructures. Before Horizon 2020, EU interventions in research infrastructures had usually focused on coordinating national investments in infrastructures and/or bringing them to the European level with the objective of making them better available for researchers, reducing fragmentation and achieving "critical mass" and economies of scale.

The conclusions of the Interim Evaluation of FP7 [168] on research infrastructures stated that the above must continue but express the concern that not enough is done in to exploit fully the European-wide investments in these infrastructures. The expert group concludes "that research infrastructures are a good example of added value at European level, but that they are not yet having as great an impact on ERA as they could." They also suggest that more emphasis should be given in Horizon 2020 to the creation and exploitation of RIs, not least to foster Innovation Union and Digital Agenda goals.

EU funding is indeed able to promote the pooling of resources between Member States to realise pan-European research infrastructures at a level that states on their own are not able to achieve. This type of funding is the only one that is capable of sustaining at least on the medium term the mobility of researchers via the transnational access scheme. National policies are either unable, because of limited funding, or unwilling to dedicate resources of their own to access by foreign users to the research facilities they have funded.

Reflecting this, the objectives of the Research Infrastructure Specific Programme[255] as stated in the Horizon 2020 Regulation, are:

- Developing the European research infrastructures for 2020 and beyond
- Fostering the innovation potential of research infrastructures and their human capital
- Reinforcing European research infrastructure policy and international cooperation

[168] *https://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp7_interim_evaluation_expert_group_report.pdf*

The five components of Horizon 2020 RI work programme closely map to these main objectives:

- **INFRADEV** addresses the development of new pan-European infrastructures, and is significantly (but not entirely) focused on supporting the implementation of the strategic recommendations of ESFRI, the European Strategy Forum on Research Infrastructures. Also under this scheme Cluster projects are supported aiming to develop and deploy common underpinning technologies and services, and to implement common and efficient solutions on issues such as, for example, data sharing and provision, architecture of distributed infrastructures, distributed and virtual access management, and development of common critical physical and virtual components.
- **INFRAIA** is about increasing and improving European-wide access to infrastructures at the national or regional level of wide EU interest. It also explores the setting-up at EU level of new research infrastructure services based on the integration and improvement of national infrastructure services ("starting communities").
- **EINFRA** addresses e-Infrastructures, and is in various ways distinctive. The infrastructure it addresses - for computing and data services - is not always solely, or in some cases even primarily, intended for the scientific research community in the narrow sense. In some ways it has more in common with the common utilities - water, electricity, the telephone etc. Research directly underpins the development and delivery of effective services in the field, but the services themselves are much closer to, and address a much wider potential user base than, those being developed in most other parts of the RIs programme. This broad impact landscape is described as the digital single market. This gives this part of Horizon 2020 RI a considerably wider stakeholder community and a very different innovation perceptive and expectation.
- **INFRASUPP** addresses support to innovation, human resources, policy and international cooperation and comprises several different types of activity.
- **INFRAINNOV**: this component has been added in the 2016/17 work programme and follows the innovation area of 2014-2015 INFRASUPP component.

In their general structure these areas and the objectives they address are in most ways a furtherance of those in FP7, the ex-post evaluation of which was broadly very positive. All together they should provide Europe with an integrated landscape of world class research infrastructures and e-infrastructures to support and boost research and innovation. The growing emphasis on Innovation is a significant development, as is the greater pervasiveness of the virtual/distributed infrastructures and the e-science aspects, and is very consistent with the Juncker vision for EU priorities set out in the document *A New Start for Europe*[169] in 2014. This stressed the role of research and innovation in underpinning a boost for jobs, growth and investment, and also the critical importance of the realisation of the digital single market.

It is possible to refer also to the Expert Advisory Group report on the proposed Horizon 2020 RI work programme for 2018-2020[170] for additional data.

D.3.1.2. The relevance of Horizon 2020 RI to address European objectives

The objective of the RI actions appears to be still relevant and flexible enough to adapt to an evolving political context. While at the beginning the main focus was the contribution to the building of the ERA and the fulfilment of the Innovation Union flagship commitments, in the

[169] *http://europa.eu/rapid/press-release_SPEECH-14-546_en.htm*
[170] *http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=25270&no=1*

latest work programmes emphasis of the Research Infrastructures (RI) Part of Horizon 2020 was on the contribution to the Juncker priorities including the Digital Single Market (DSM) and the Moedas 3O's Strategy.

The Innovation Union Flagship initiative (2010) and the Communication "A reinforced European Research Area partnership for Excellence and Growth" (2012)[171], made commitments on the implementation of the 60 % of the ESFRI roadmap projects[172] to be fulfilled by 2015. This 60% target was reached.

The development of a coherent landscape of leading edge RI in Europe will also help to strengthen innovation further, develop new activities and boost the productivity and competitiveness of our economy. While the majority of RI enable curiosity-driven research and push knowledge frontiers in their respective fields, they have a direct socio-economic impact especially in relation to their links with industry and contribute towards the objective of Jobs and Growth as described in [264].

International cooperation on RI is often the only way forward, as stated at several International for a such as Organization for Economic Cooperation and Development (OECD) and International Conference on Research Infrastructures (ICRI), both when pooling of resources is necessary due to the scale of the investment needed for construction and operation of the RI and when the scientific dimension addressed by the RI has a clear global connotation, but is also an opportunity to support or complement the EU external policy and contribute to Science Diplomacy and to the Open to the World strategy, as demonstrated in the case of SESAME.

The cooperation with strategic international partners on global cooperation was strengthened with the adoption by the G8 Science Ministers in 2013 of a Framework for Global Research Infrastructures[173] prepared by the Group of Senior Officials on Global Research Infrastructures (GSO).

Similarly the implementation of the recommendations of the Communication on the ERA led to the preparation of a Charter of Access to Research Infrastructures[174], as well as to the publication of dedicated actions in Horizon 2020 to support the training of RI managers and the access to RI.

E-infrastructures developments for the establishment by 2020 of a single and open European space for online research, including ubiquitous and reliable services for networking and computing, and seamless and open access to e-Science environments and global data resources, will help to free the potential of Big Data for the benefit of researchers, innovators and business, and to advance research and innovation, therefore contributing to the objectives of the Priority 2 of the Juncker Commission: A Connected Digital Single Market.

The RI action is integrating other emerging trends of relevance for RI, for instance the exploitation of possibilities offered by the widespread usage of connected devices to collect large amounts of data in domains such as social sciences and environment, or the diversification of funding and investment schemes in Research with a possible move towards greater private investment.

The e-infrastructures field is probably the fastest-developing and most economically and socially significant part of the global technology infrastructures landscape at the present time. It is the focus of intense political and commercial interest, with which the EC is deeply

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[171] *https://ec.europa.eu/digital-single-market/en/news/reinforced-european-research-area-partnership-excellence-and-growth*
[172] *http://www.esfri.eu/sites/default/files/20160309_ROADMAP_browsable.pdf*
[173] *https://ec.europa.eu/research/infrastructures/pdf/gso_framework_for_global_ris.pdf*
[174] *https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=access_ri*

involved. As an example, in just two months April-May 2016 the EC produced five significant policy outputs relating to research in the area:

- The European Science Cloud Initiative[175]
- Digitising European Industry Communication[176]
- ICT Standardisation Prioritisation for the Digital Single Market[177]
- Communication on EU e-Government Action Plan 2016-2020[178]
- Competitiveness Council Conclusions on the transition towards an Open Science system[179]

In addition, the "Three O's" which describes a global innovation landscape underpinned by an open science agenda fundamentally predicated on open sharing of research and other data. This is entirely dependent on the types of information and computing infrastructure which are primarily, but not exclusively, the focus of EINFRA. The development of thematic data infrastructures is also supported under INFRADEV and INFRAIA.

The component of Horizon 2020 RI that is delivered through DG CNECT uses the concept of Technology Readiness Levels (TRL), with EINFRA concentrating funding on TRL6 or above.

D.3.2. Flexibility to adapt to new scientific and socio-economic developments

The Interim evaluation Expert report states that the period since Horizon 2020 was conceived has seen some exceptionally rapid developments in science with major consequences for infrastructure needs and development. In particular, technological developments dramatically increasing the capacity of research infrastructures to collect and produce data and the developments in distributed computing, overall computer power and high-volume data transmission have combined to produce an explosion of data-driven science, giving scientists in many disciplines inter-operable access to research data of a hitherto-unimagined scale and diversity.https://ec.europa.eu/digital-single-market/en/news/communication-digitising-european-industry-reaping-full-benefits-digital-single-market

From this has come a great number of platform needs around the data sharing/data access area and the associated requirements for standardisation, tool development etc. In life sciences this has coincided with the development and availability of high-throughput and automated 'omics and imaging technologies giving extensive insights into the function and diversity of genetic and molecular processes and of phenotypes. In the social and environmental sciences, healthcare, the humanities and many other fields, digitisation techniques of all kinds have enabled broad access to previously inaccessible information, a wealth of time-series data, and to all manner documents and images, in some cases dating back millennia, that were hitherto accessible only to very few.[180]

The Research Infrastructures Horizon 2020 and FP7 specific programmes (and earlier) have substantially underpinned the ability of the EU to face up to these issues. The first significant international vision on the open data agenda was an EC High Level Expert Group Report, *Riding the Wave* (2010)[272].

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[175] http://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud
[176] https://ec.europa.eu/digital-single-market/en/news/communication-digitising-european-industry-reaping-full-benefits-digital-single-market
[177] https://ec.europa.eu/digital-single-market/en/news/communication-ict-standardisation-priorities-digital-single-market
[178] https://ec.europa.eu/digital-single-market/en/news/communication-eu-egovernment-action-plan-2016-2020-accelerating-digital-transformation
[179] http://data.consilium.europa.eu/doc/document/ST-9526-2016-INIT/en/pdf
[180] Riding the wave. How Europe can gain from the rising tide of scientific data. 2010

This EU leadership at a global level would not have been possible without the combined efforts of the European scientific community, the EC and the expert advisors - particularly in ESFRI and EIRG - working together over many years. They identified future scientific and technological potential and framed, funded and delivered a series of European interventions which have established the basis for open data and open science in Europe, supported by a growing research infrastructure capability and more people to enable it.[181]

All these developments bring with them issues of ownership, commercial and personal privacy and freedom, or ethical concerns of many kinds. The Horizon 2020 RI programme has had to recognise and respond to these issues as they have arisen.

As reported in the Interim Evaluation report from the experts, one aspect that has been important in realising this vision has been the way the budgetary framework has enabled flexibility and agility. The 2016/7 work plan for INFRADEV included the European Open Science Cloud pilot, thus enhancing the flexibility inherent in the model of a longish funding framework with successive work programmes - this major policy opportunity underpinning the "three O's" was included rapidly and effectively and has delivered a further leg to the European structure to deliver the open data and research agenda and underpin the digital single market. It was also notable how EOSC integrated effectively into the forward vision for EINFRA and the action for clustering the ESFRI infrastructures reflecting the effective level of strategic planning that is maintained within the programme.

In what concerns the e-Infrastructures, as reported in the interim evaluation report, four main European research infrastructures are needed for building the European Data House: Microelectronics, 5G technologies, Cloud infrastructure and High Performance Computing (HPC).

D.3.3. Addressing specific stakeholder needs

In order to address the specific stakeholders needs, in 2012 the European Commission launched a consultation for preparing EU activities for integrating and opening national research infrastructures.

The consultation was advertised on the European Commission website and by emailing to a large public including Programme Committee Members, National Contact Points, European Strategy Forum for Research Infrastructures (ESFRI) delegates, coordinators of proposals and projects of the Seventh Framework Programme (FP7), Research Infrastructures.

The consultation addressed stakeholders, i.e. operators of research infrastructures and user communities, in a bottom-up manner, in order to map possible future topics of Integrating Activities.

The report "Consultation on possible topics for future activities for integrating and opening existing national research infrastructures",[182] summarizes the outcome of this consultation and was the basis of the first Work Programme in Horizon 2020. It identified the thematic research infrastructure areas which were regarded as important to be supported.

Member state delegations to the Programme Committee have regarded INFRAIA together with INFRADEV as the most appreciated parts of the overall programme.[253] INFRAIA is particularly well regarded because the nature of its calls is such that delegations and the scientific community can have input to the process and prioritisation. It is also the part of Horizon 2020 RI that most frequently elicited comments from project participants (and unsuccessful applicants).

[181] https://ec.europa.eu/digital-single-market/en/news/data-harvest-report
[182] https://ec.europa.eu/research/infrastructures/pdf/final-report-CEI-2013.pdf

The list of topic areas in INFRAIA-01, and the result of the above mentioned consultation, was very specific, some based around opportunities to integrate related infrastructures, in order to underpinning the realisation of particular policy goals etc (eg vaccine research, earthquake research, poverty and living conditions) or improving integration of activities around existing and developing large infrastructures (eg neutron beams, synchrotrons, lasers, HPC centers, etc).

The way that topics in INFRAIA-01 had been chosen was the result of a consultative exercise that - *inter alia* - engaged with other DGs in the EC and the MS reps on the Programme Committee, alongside other inputs.

INFRAIA-02 aims to give the opportunity for new research infrastructure communities to explore the improvement and the integration of their services and the provision of access at EU level based on scientific merit.

D.3.4. Lessons learnt/Areas for improvement

The areas covered and objectives addressed by the five components of the H220 RI Work Programme have demonstrated to be highly relevant with respect to the EU priorities and the reinforcement of the European Research Area.
The alignment of the actions developed under the RI part of Horizon 2020 for the development of pan European RI and the ESFRI road-mapping process has proved relevant and allowed for a timely implementation of the ESFRI projects.
The introduction of clusters of research infrastructures addressed the opportunities of the open data agenda and the need for more interoperability between diverse data sets.
The integrating activities have been relevant to address the needs of very diverse communities in transnational access, networking and joint research activities to improve the provided infrastructures services and for what concerns good practice and pan-European scientific integration and outreach.
The emphasis put on Innovation is in line with the Juncker vision for EU priorities.

D.4. EFFECTIVENESS

D.4.1. Short-term outputs from the programme

INFRADEV has raised awareness of the burgeoning potential and stimulated scientific communities across the EU. In close conjunction with ESFRI, it has enabled the EU to be effective in conceiving and delivering large research infrastructure projects at the European and global scale. These would not otherwise have been realised because of their large size, cost and complexity, which has required an EU-wide common vision and the combined efforts of several Member States to initiate them.

The *ESFRI Strategy Report on Research Infrastructures/Roadmap 2016* lists 29 such infrastructures that have reached the landmark (implementation) phase, and another 21 in development. These include world-leading infrastructures across all the disciplines of science. All are potentially open to all EU Member States, and many are attracting participative interest more globally.

Recently ESFRI has developed closer working with e-IRG and has also begun to acquire greater representation of computational and data-led science expertise in its membership.

Horizon 2020 RI plays a major role in promoting research mobility, within the EU and more globally. This is not just a consequence of the movement of scientists to work at different sites - although this is itself very considerable. The synergistic development of common standards, research protocols, tools and platforms means that they are engendering a greater portability of skills, data and knowledge across the European scientific community, and disseminating these both through face-to-face training and e-learning.

The networked provision of computing infrastructure and the development of major data-driven research infrastructures is realizing the reality of a laboratory without walls in which not just scientists but policy-makers, businesses and society generally can access and integrate data and access research knowledge across the EU, wherever they are.

The single greatest benefit from Horizon 2020 RI - and from Horizon 2020 overall - is from opening as much of the data from EC-funded research to the wider scientific community as possible, thereby potentially e.g. maximizing access and usage and reducing unnecessary replication. Various elements are key to realising these benefits. In the Open Data Pilot award holders are encouraged to include proposals to release data as part of their Horizon 2020 project. EOSC will be developed in order to provide the best framework for EU scientists to share, access, manage and interoperate data. The cluster projects aggregate data-led research infrastructures into appropriate umbrella organisations. Effective guidelines for private sector usage and public/private partnerships will be developed.

The main short-term outputs of the Horizon 2020 RI programme are the following: the users supported by the EU in their access to research infrastructure, the set of research infrastructure networked and opened at EU level, the establishment, upgrade and consolidation of new pan-European research infrastructure and e-Infrastructure. As none of the Horizon 2020 RI projects has been concluded to date, it is not yet possible to provide information on the users supported under Horizon 2020. However, the number of researchers who had access to research infrastructures through FP7 support until 2015 is more than 33.000 [183]

Concerning the direct establishment of new RIs, so far 8 Design studies and 13 Preparatory and early phase support grants have been funded, whose outputs will be visible only in the years to come. However, the support provided under FP7 to the preparatory phase of the ESFRI projects in the first Roadmaps, together with the support provided under Horizon 2020 to the acceleration of their implementation, brought 29 of them to be recognised by ESFRI as Landmarks, i.e. implemented and/or providing services. Thirteen new Pan-European research facilities are based already on the new EU Regulation the European Research Infrastructure Consortium, ERIC, which entered into force in 2009 and at least four more ERICs are expected to be launched in 2017.

Concerning the RI networks, so far 37 networks have been established including 8 clusters of ESFRI projects. In parallel 35 e-Infrastructure grants have integrated, federated and/or consolidated e-infrastructure services.

Regarding gender, it is not always possible to integrate a gender dimension in the research to develop or improve research infrastructures. Therefore the main focus has been to remove gender barrier to access to research infrastructures. Data on supported users are however not yet available to verify the effectiveness of these efforts. To date, data shows that 87.6 % of Horizon 2020 RI project coordinators are women, and that the overall participation of women in RI projects is 34.2 %.

The total number of publications from RI projects is 297 of which 188 are in peer reviewed journals and 155 (82.4%) are provided in Open Access. (Data source: Corda, November 2016)

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[183] *http://ec.europa.eu/research/evaluations/pdf/archive/Horizon 2020_monitoring_reports/second_Horizon 2020_annual_monitoring_report.pdf*

D.4.2. Expected longer-term results from the programme

Expected direct longer-term results related to Open Science.

- The creation of the European Open Science Cloud (EOSC) is under way. This will lead to a cross-disciplinarity and interoperable research data space per science and innovation.
- The ESFRI Roadmap has identified and continued to update the landscape of first-class sustainable research infrastructures open to researchers, industry, and other stakeholders, which help addressing challenges in science, industry and society. This process is ongoing and is foreseen to improve the sustainability of research infrastructures.
- The development of a world-class pan-European High Performance Computing (HPC) infrastructure is ongoing and will contribute to excellent research.
- The transnational access scheme supported in the frame of the Integrating activities, foster the mobility of researchers and contribute to the good practice. In the longer term it will contribute even further to the pan-European scientific integration and outreach.
- Work in International fora such as OECD and ICRI, aims at the development and adoption of relevant international open standards based on the best practices of a large spectrum of research communities.

Expected results from the research infrastructure programme related to Open Innovation:

- The involvement of industry (including SMEs) in the development of research infrastructures will increase, thereby raising the technological level and competitiveness of European companies and generating new market opportunities.
- The awareness of industry (including SMEs) regarding opportunities offered by research infrastructure to improve their products will be raised, for example as experimental test facilities, innovation hubs, knowledge-based centres

Expected results from the research infrastructure programme related to Open to the World:

- Global research infrastructures will be further developed enabling researchers to address societal challenges with a global dimension
- The cooperation with key International partners will increase the International outreach of the research infrastructures.

D.4.3. Progress towards attaining the specific objectives

The objectives of the Research Infrastructure Specific Programme[184] as stated in the Horizon 2020 Regulation are:

- Developing the European research infrastructures for 2020 and beyond.

The portfolio of projects in INFRAIA and INFRADEV are well under way and do suggest that this objective will be fulfilled. However, due to budget limitations, the full potential of these instruments will only be developed in the longer term.

- Fostering the innovation potential of research infrastructures and their human capital

Concerning this specific objective, support has been provided in the INNODEV scheme to the partnership between RIs and industry (including SMEs) to develop high –tech areas such as scientific instrumentations or ICT. However, the projects have only started and no tangible results have so far been produced.

- Reinforcing European research infrastructure policy and international cooperation

The involvement of third countries in INFRAIA and INFRASUPP is high and contributes to the international outreach and cooperation. For instance SESAME [185] is high profile project contributing to science diplomacy and scientific development in Jordan.

[184] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011PC0811&from=EN
[185] http://www.sesame.org.jo/sesame/

Finally, the data reported in section D.4.1 are in line with the specific objectives and with the intervention logic in Figure 62, in particular for what concerns the development of European research infrastructures for 2020 and beyond, the reinforcement of the international cooperation, and the building of competences in the long term also through the support of emerging talents.

D.4.4. Progress towards the overall Horizon 2020 objectives

D.4.4.1. Fostering excellent science in scientific and technological research

The key factors demonstrating the role of Horizon 2020 RI to the realisation of the ERA are summarised in Section D.7.

Box 7 - Contribution to the achievement and functioning of the ERA

The objective of the INFRAIA is to support the ERA by pooling national resources together thereby creating a more effective use of European research infrastructure.

Substantial effort in Horizon 2020 RI is devoted (mainly in INFRAIA and EINFRA) to widening access to existing national and regional research infrastructures thereby promoting mobility and the open labour market. In addition, these instruments aims at improving their interoperability and integration and encouraging coordinated development of further capability to address problems at the Europe-wide level.

Furthermore the support to the EOSC will ensure optimal circulation and transfer of scientific knowledge.
Finally the ESFRI projects and the creation of the ERICs will in a more sustainable way pool national resources together by creating a single European research infrastructure.

These interventions improve **effectiveness** by opening resources to wider European access and application, and enable **synergy** by enabling the articulation of common standards, cooperation on training etc. They also represent the major contribution to the key indicator for the achievement of the ERA (number of RIs opened up to Europe) referred to in Box 7.

D.4.5. Early success stories

The following projects illustrate some of the wide diversity of added value benefits from Horizon 2020 RI interventions.

ELIXIR-EXCELERATE[186]

Project Type: INFRADEV; budget: EUR 19 million; duration: September 2015/August 2019

The project is aiming at accelerating the implementation and early operation of ELIXIR, the European life science Infrastructure for Biological Information, identified by ESFRI and the European Council as one of the three Europe's priority research infrastructures. With 41 partners in 17 countries this grant coordinates and enhances existing resources into a world-leading data service for academia and industry, grow bioinformatics capacity and competence across Europe, and complete the management processes needed for a large distributed

[186] https://www.elixir-europe.org/news/elixir-accelerates-major-horizon-2020-funding

infrastructure. Four use cases: rare diseases, human data, plant genotype-phenotype and marine metagenomics, will help best tuning the services.

EARTHSERVER[187]

Project Type: EINFRA; budget: EUR 2,8 million; duration: May 2015/April 2018

The project demonstrated successfully at the occasion of the European Geosciences Union (EGU) 2016 General Assembly, the potential of new analytics for multi-dimensional geo-data in the Earth sciences domain, based on the 'rasdaman' array database system technology. They enable ad-hoc analysis of data that can be downloaded on the web from any terminal device, utilising the geodata provider's server capacity, by relying solely on open standards. Such advances can facilitate the provision of scalable services for multi-dimensional data in all Earth sciences fields.

ELI[188]

Project Type INFRADEV; budget: EUR 3,4million; duration: September 2015/August 2018

Implemented as a distributed infrastructure in the Czech Republic, Hungary and Romania, ELI, the Extreme-Light-Infrastructure, will be the first infrastructure identified by the European Strategy Forum on Research Infrastructures (ESFRI) to be located in new Member States. With an implementation budget of over EUR845 million largely co-financed by European Development Fund the project represents an unprecedented example of how research infrastructures can bridge the objectives of scientific excellence, regional development and European cohesion. The challenge is now to make the ERDF investments deliver not only on scientific excellence, but also on socio-economic European cohesion, i.e. to integrate ELI in the national and regional economic landscape for more business innovation.

D.4.6. Lessons learnt/Areas for improvement

The ESFRI Roadmapping process, coupled with the use of the INFRADEV part of the programme to catalyse the design, development and prioritisation of RI proposals, and the partnership this represents between the scientific community, Member State ministers and funders, and the Commission, is one of the major achievements of international science policy in recent years and must be maintained.
However an addition effort is needed for easing the long term sustainability of pan European research infrastructures through a life cycle approach. To this extent specific actions will be foreseen in the last Horizon 2020 work programme.

The pioneering development of distributed European infrastructures and networked infrastructures based around the shared distribution and access to data, materials and tools has been transformative, stimulated scientific communities across Europe into cooperation and created a solid basis for EU-level research.
The support to the interoperability and the European Open Science Cloud has just become and will need further support. An effort for more integration between RI and the e-infrastructures and with other parts of Horizon 2020 would help in this sense to exploit synergies and complementarities.
There is the need of an additional support for innovation and better clarification of purpose, scope and overall strategy for this objective.

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[187] http://earthserver.eu
[188] https://eli-laser.eu/

The two roles of the INFRAIA element of the programme to develop starter communities and to enable advanced ones to address major issues are both valuable, even if the balance between the two is too much in favour of the second. There should be something similar to attract and explore new ideas from the community in EINFRA.
The European Union as a whole is able to conceive and deliver large infrastructure projects at the European scale and develop and lead those at a global scale, of a type, size and number that would not otherwise be possible.
The use of these infrastructures is a major vehicle to promote scientific mobility across the European Union.
The networked provision of computing infrastructure and the development of major data-driven research infrastructures is realising the reality of a laboratory without walls in which not just scientists but policy-makers, businesses and society generally can access and integrate data and access research knowledge across the EU, wherever they are.
The processes of developing and initiating pan-European research infrastructures and particularly the e-science and data sharing aspects, has placed the EC at the global forefront of thinking and policy in the Open Science and Open Data area.

D.5. EFFICIENCY

D.5.1. Budgetary resources

The scientific community is particularly sensitive to success rates. Excessive oversubscription wastes a great deal of effort, whilst under-subscription may indicate a lack of the competitive pressure needed to sustain excellence. These issues are modulated in Horizon 2020 RI because much of the investment is to develop things already in train and consequently some calls may be very focussed and not expected to produce multiple applications.

The bottom-up topics, including design studies, integrating activities for starting communities and virtual research environment, have however been heavily oversubscribed.

The oversubscription of the Virtual Research Environments (VRE) call EINFRA-9 14/15 created some disappointment in the scientific community, as reported by the experts, and concern from some members of the Programme Committee. It was decided not to react to this e.g. by finding more funds or holding another call. The issue perhaps arose because the call drifted away from seeking to add European value to existing and developing Member State infrastructure and associated competencies towards something that looked to many researchers like a call for research projects, because of its emphasis on real-use cases etc. Some of the issues were addressed in the 2016-17 Work Programme and there will be further relevant opportunity in the 2018-20 Work Programme in the context of EOSC.

So far in Horizon 2020 RI an effective programme which meets the objectives is being delivered broadly within the budget. There are clear signs that without major increase the budget will be unable to sustain an ongoing programme to address future infrastructure needs unless there is greater uptake of responsibility for the operating costs of mature new infrastructures, including support for trans-national access, by Member States and member-state funded international bodies.

The existing financial instruments appear to work adequately for most purposes that the Horizon 2020 RI specific programme seeks to fund. There is little use of the provisions that exist for e.g. loans, and it is possible that this might prove a more useful tool in addressing the sustainable funding of operating costs by MS than it currently is.

For infrastructure development, and the stimulation of innovation from it, more could be done to facilitate the role of TTOs (Technology Transfer Offices) which sit at the interface between university and national labs and the private sector.

Complaints made by stakeholders (at meetings, infodays, etc.) that the standard funding model is difficult for small and unusual proposals (studies, workshop programmes etc) have been noted. No evidence has been seen to support this claim and INFRASUPP is currently supporting a sufficient number of policy related activities and international linkage development.

D.5.2. Programme's attractiveness

D.5.2.1. Mobilisation of stakeholders

The core participants of the RI action are RI owners, usually public national research organizations, international organizations or universities. The statitics available so far confirm this pattern (please refer to Section 3.2.1). As shown in Table 9, where the participation per type of actor in FP7 and Horizon 2020 has been compared, the actors have not changed consistently. However, given the particular emphasis of Horizon 2020 on innovation, a larger participation of industry (PRC) has been registered in Horizon 2020 compared to FP7.

The participation of newcomers in all projects of Horizon 2020 so far is 13 % (see Section D.2.2.2, Tables 36 and 37). However, it must be considered that a substantial mobilization of many diverse stakeholders is supported in the INFRAIA projects, through the transnational access actions (TNA), which support the medium term the mobility of researchers. The number of researchers who had access to research infrastructures through FP7 support until 2015 is more than 33.000[275].

Table 39 - Participation by type of actor in Horizon 2020 and FP7
Abbreviations: Higher or secondary education (HES), Other (OTH), Private for profit (excluding education) (PRC), Public body (excluding research and education) (PUB), Research organisations (REC).

Participant Type	% of Participant Type in Selected Projects Horizon 2020	% of Participant Type in Selected Projects FP7
HES	33	37
OTH	8	4
PRC	12	8
PUB	7	7
REC	40	44
SUM:	100	100

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls)

Info days organized by national contact points were held at the beginning of Horizon 2020. Additional info days for various stakeholders have been organized.

D.5.2.2. Geographical dimension

The participation pattern reported in section D.2.2.3 reflects the fact that the majority of research infrastructure of European interest are located in the larger countries. The participation of the various types of countries in FP7 and Horizon 2020 is comparable (Table 40). However, an analysis on the users supported under FP7 shows that smaller countries have, in percentage, a larger share of users supported by EU for the transnational access to research infrastructures (source: internal data).

Table 40 - Participation by group of countries in FP7

Country Type	% of Participation in Selected Projects FP7	% of Participation in Selected Projects Horizon 2020
ASSOCIATED	11	8
MEMBER STATES	78	85
THIRD_COUNTRY	11	6
	100	100

Source: Corda, calls in 2014, 2015 and 2016, signed grants cut-off date by 01/01/2017 (including ad hoc calls).

Relative to the investments in infrastructure development, access and deployment the funding for policy activity and international outreach in Horizon 2020 RI, mostly in INFRASUPP, are relatively small but add considerable value.

Horizon 2020 RI is the only major international collaboration addressing research infrastructure on a broad scale. As such it is increasingly attractive to third countries, and there have been interventions of many different kinds intended to explore and develop infrastructure links with different countries - the G7, BRIC, the developing world etc.

Reciprocal arrangements with third countries have been enabled to give the EU access to expensive facilities elsewhere, and collaborative links developed to achieve global approaches to global problems such as climate change a food security.

Policy development for internationalisation of research infrastructure has of necessity been an area where the EC has developed an international lead, and the ESFRI process for developing and delivering collective priorities is internationally admired. The Horizon 2020 RI programme has also played a major role in the development of the Open Science and Open Data agenda worldwide, largely through its sponsorship of the Research Data Alliance and the role played in taking its message to the G8

D.5.2.3. Cross-cutting issues

Research infrastructures are essentially horizontal in nature and therefore covers a wide range of scientific domains (see section 3.3 Cross-cutting issues). The current coverage of cross-cutting issues corresponds to what expected.

D.5.3. Cost-benefit analysis

The allocated resources are adequate to deliver on the objectives of the RI action, but further optimisation could be possible, which is evident considering the oversubscription of INFRAIA (where topics are defined) and notably INFRADEV (sourse: internal documentation).

Most of the RI grants are large programmes of different types of activities. While the value of some of these projects is undeniable, as reflected in the appreciation of the evaluation experts, not all the activities can result crucial to the expected general objectives of the RI actions. Some more flexibility with respect to the non-negotiation approach of Horizon 2020, would allow an optimization of the implementation of the budget and of the deliverables of grants.

The programme is managed internally by the two implementing DGs (RTD and CNECT). However, the units in charge of this Horizon 2020 part have had significant staff reduction.

This resulted in increased workload for the remaining staff which could in the long term hinder the capacities to develop a coherent RI policy and its implementation in Europe.

The ex-post review of FP7[189] lamented that a target set by the Innovation Union of launching or beginning the construction of 60% of the 2010 ESFRI roadmap by 2015 was proving slow to realise. The ESFRI Roadmap 2016 [190] demonstrates that this target was met. However, the issue highlighted by the FP7 review was of considerable significance, drawing attention to a need to gain more engagement from MS and to show more selectivity and structure in the process of identifying and taking forward European Infrastructure proposals from initial concepts to launch. These issues have been reviewed by ESFRI and are reflected in the structure of the INFRADEV part of the programme.

In particular, there is a specific type of action for each of the design, preparatory and implementation phases, with clear and different criteria appropriate to these levels, no expectation of an automatic ascent up a ladder of successive support and an overriding rule that an infrastructure can only remain on the Roadmap for 10 years. ESFRI has thus moved from a phase of growing the roadmap to maintaining a more steady state situation in which a realistic number of the best cases can be brought through to maturity.

Figure 1 - ELIXIR Infographic

From various analyses carried out by individual research infrastructure, it comes out that investments in their development can have a much higher return. For example, from the recent infographic produced by ELIXIR, the return in investments is in the order of 20 times.

The efficiency gain from the ESFRI process is not just in the provision for better and larger scale scientific activity that makes better use of European-wide resource and expertise. The ESFRI-led prioritization process itself provides a framework that obviates the need for complex international discussions to begin afresh for every new concept. Models for international agreements, particularly the ERIC, developed by the EC, provide the structure to better progress those discussions towards implementation. Several of the newer pan-European RIs on the roadmap are "distributed" - that is to say, they operate through the integration of components at many different sites through the use of e-infrastructure, bringing access to data, tools and facilities to European scientists wherever they are. Key pan-European e-infrastructures in computer networks and high-performance computing and - in the near future - the European Open Science Cloud (EOSC) are key enablers of this process.

[189] https://ec.europa.eu/research/evaluations/index_en.cfm
[190] http://www.esfri.eu/roadmap-2016

D.5.4. Other issues related to efficiency

Sustainability

Sustainability is an important notion for research infrastructures. In brief it implies that when working effectively, a research infrastructure should be able to perform the relevant science, satisfy user demand for its services, and make reasonable provision for maintenance and development, within an income that meets or exceeds its expenditure and is sufficiently stable to allow for staffing continuity and forward planning [191].

Member States have stated that the long-term sustainability is a role for them, and that the role of the EC is to catalyse and enable the necessary route ways to this. Much effort has been invested in FP7 and Horizon 2020 RI to develop infrastructures towards sustainability, both by developing policy tools, (e.g. the ERIC - European Research Infrastructure Consortium [192]- model to help frame the necessary cooperation and funding agreements), and through individual projects addressing the issue as part of their objectives notably through INFRADEV.

There is no one-size-fits-all recipe for achieving sustainability, given the hugely varying nature of infrastructures, the differing financial practices in host organisations and Member States and the fact that the economic situation - global or local - appears to change at a faster rate than the time taken to design and implement the average large infrastructure.

As has been discussed in ESFRI and several ICRI conferences large centralised experimental facilities have huge capital construction budgets, often found from completely different public sources to the recurrent costs. Virtual and distributed infrastructures have no final size, scope or lifetime, developing and changing within a general framework of purpose. E-science and data-based infrastructures draw on diverse technologies being developed by others at sometimes alarming rates, and for these robustness and flexibility is as important as stable budgets.

Requirements for the development of new infrastructures are now getting so large in some areas that the assumption that pan-European aims can be met through the federation and development of existing national and regional resources are not necessarily valid.

Concerning computer-based research data management infrastructure, a Science Europe report: *Funding research data management and related infrastructures (June 2016)*[193] shows that funding agencies and infrastructure providers have little idea how to effectively fund the development and operation of such infrastructure.

International and national models for funding operational costs of research infrastructures that currently exist mainly address centralised facilities (large machines) and are of limited relevance. Although user-pay models exist for some databases and possibly for compute access they are relatively rare and usually relate to a single relatively well-defined specific offering. A fully developed data-led distributed infrastructure is likely to be offering e.g. thousands of heterogeneous databases and analytical and management tools from a very large number of sources to tens of thousands of users on a continuous basis. This renders any form of resource-specific recharge model to individual users very difficult.

The EC has been at the forefront of discussion and innovation in many areas impacting on this general issue through being an early funder of developing distributed infrastructures and leading international consideration of the Open Data agenda. It has the opportunity - and a

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[191] https://ec.europa.eu/research/infrastructures/pdf/lts_report_062016_final.pdf#view=fit&pagemode=none
[192] https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=eric
[193] http://www.scienceeurope.org/wp-content/uploads/2016/05/SE-KE_Briefing_Paper_Funding_RDM.pdf

responsibility - to catalyse effective discussion to try and clarify the routes to ensuring early solutions to the funding issue. It also needs to do this without appearing to relieve MS organisations of the prime responsibility for addressing it.

D.5.5. Lessons learnt/Areas for improvement

The expert group for the interim evaluation have concluded that the Horizon 2020 RI programme is appropriately managed by Commission officials and the two teams in DG RTD and DG CNECT have achieved a good level of overall coherence. The Programme Committee performs an effective and appropriate oversight of the programme.
The consideration of routes to sustainability for virtual and distributed infrastructures is very important because there are no established models. Some of the communities have no familiarity of working with, or tradition of resourcing, such infrastructures and such concepts as recharging are little understood for intangibles such as data access.
Relatively little use has been made of the potential that the financial instruments offer for loans, etc.

The Horizon 2020 RI programme represents greater value for money because of the minimisation of duplication and improved means of access. Reciprocal arrangements with third countries give the EU access to expensive facilities elsewhere.

D.6. COHERENCE

D.6.1. Internal coherence

D.6.1.1. Internal coherence of the actions implemented under RI

The component parts of Horizon 2020 RI together comprise a complementary set of intervention areas which have been developed over a long time: new pan-European research infrastructure conceived and developed through INFRADEV, networking of and access to existing national and regional infrastructures via INFRAIA, the core underpinning e-infrastructure through EINFRA and measures to support training, international outreach policy development and other supplementary measures, the whole forming a comprehensive and interlocking package.

All these interventions are aiming to address different stages of research infrastructure lifecycle, from concept design to operation, and are therefore complementary and synergic (Figure 62).

As shown in Table , the e-Infrastructure work programmes were implemented mainly through Research and Innovation Actions (35) and coordination and support actions (12). Additionally, a Framework Partnership Agreement (FPA) was established between the EC and GÉANT offering a longer perspective for the support to the networking activities of the education and research communities in the EU. The FPA has been implemented though specific grant agreements for research and innovation actions (2). Also, the WP 2016-2017 included a Public Procurement of Innovative Solutions action. The call launched in 2016 aims at supporting the procurement and deployment of innovative HPC systems in Europe and reinforcing access to European leading-edge supercomputing infrastructure.

The CSAs are instrumental in reaching a coherent approach for the e-Infrastructure programme, tackling a variety of policy actions from international cooperation, skills, standardisation, dissemination etc. They complement effectively the research and innovation actions.

In what concerns the RIA actions, the programme has been broken into numerous areas many of which seek to solicit a single proposal or address a very specific requirement.

This was needed in order to cover the whole spectrum of areas and e-infrastructure services, namely: networking, distributed computing, high performance computing, data, open access, centres of excellence, virtual research environments. However, even following this approach it is extremely challenging to cover all services the scientific community needs while avoiding duplication of services, and ensuring an optimal funding model and long term sustainability.

Table 41 - Types of actions for the research e-infrastructures programming period 2014-2016

Type of action	No of actions	Budget EUR	Specific objectives
CSA	12	17 195 680.25	Focus on policy support (standardisation, skills, dissemination, development of small-size foresight roadmaps for research and education communities and operators of e-Infrastructures), international cooperation, support to e-Infrastructure programme, support to the implementation of the Open Research Data Pilot.
RIA	35	206 315 138.50	Focus on networking activities, service activities and joint research activities in various e-infrastructure areas.
SCA-RIA	2	94 000 000.00	Implement the FPA with GÉANT
Total	**50**	**317 510 818.75**	

Source: EC internal monitoring table, cut-off date November 2016.

D.6.1.2. Internal coherence with other Horizon 2020 intervention areas

Within Horizon 2020, the RI interventions are in general coherent with the other programmes,

Figure 64 (based on the Likert scale assessment of an internal EC questionnaire) shows that there are no identified overlaps or gaps with the different actions under Horizon 2020.

The Horizon 2020 RI programme resonates generally well with other Horizon 2020 programmes, in that it provides large numbers of scientists in a whole range of disciplines with tools and resources to enable their research.

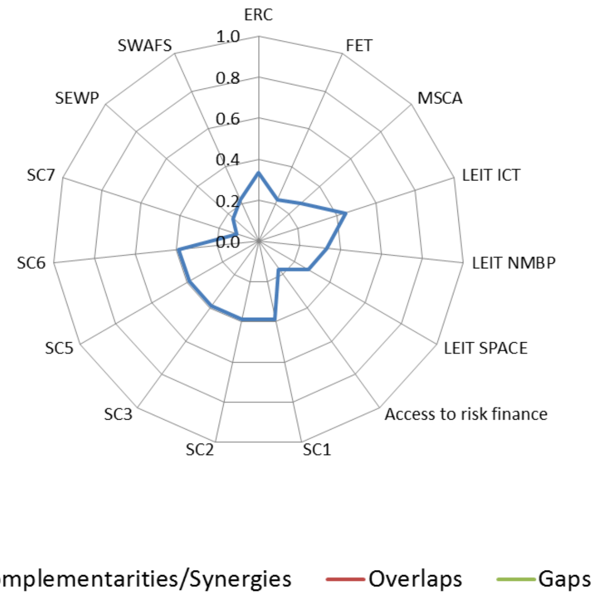
Research infrastructures spread over many domains, and their horizontal nature facilitates the linkages across Horizon 2020.

A demonstration of the linkages with other actions is given by the number of other Horizon 2020 projects where the participants to Horizon 2020 RI actions are involved.

For example, EMBL, the European Molecular Biology Laboratory, is partner of 246 Horizon 2020 projects, but only 52 of these are RI projects in Horizon 2020, whereas among the others there are 32 ERCs, 72 MSCA and 15 FET-OPEN actions. CERN, the European Organization For Nuclear Research, is partner in 179 Horizon 2020 project, 39 of these are RIs, 39 ERC, 15 FET-OPEN and 82 MSCA (Source: Corda).

However, this approach has not been comprehensive in all areas. Specifically, the EINFRA programme is not addressing significant aspects of the infrastructure requirement for the European Digital Open Market, e.i. Microelectronics, 5G technologies, Cloud infrastructure and High Performance Computing. Indeed, a global and comprehensive vision which is not focused on research specifics is required to realize and sustain the DSM.

Figure 64 - Internal coherence of RI with other EU policy programmes



Source: Analysis by EC services.

D.6.1.3. Ensuring that every euro spent counts twice

The limited number of reports and deliverables received up to now from the Horizon 2020 RI projects does not allow to still measure their effective contribution to innovation and to tackle societal challenges.

However, the research infrastructure programme supports a wide range of areas. For instance, in the environment al field, data is produced supporting EU policy for the arctic, global earth observation, COPERNICUS [194], etc.[195]

D.6.2. External coherence

D.6.2.1. Coherence with other EU funding programmes

The research infrastructure part of Horizon 2020 facilitates the setting up in Europe of a landscape of advanced research infrastructures to support leading-edge research and innovation. In doing so, it coordinates with Member States, still the main actors in the fields, and with other EU interventions, in particular Structural Funds but also with different thematic policies.

Structural Funds represent a genuine opportunity for synergistic benefit to both European research infrastructure and regional development. In 2013 DG RTD and DG REGIO collaborated to promote the use of Structural Funds for investment into local infrastructure related to RIs on the ESFRI Roadmap, in the context of Regional Smart Specialisation Strategies, i.e. on the basis that the relevant infrastructure was an investment consistent with

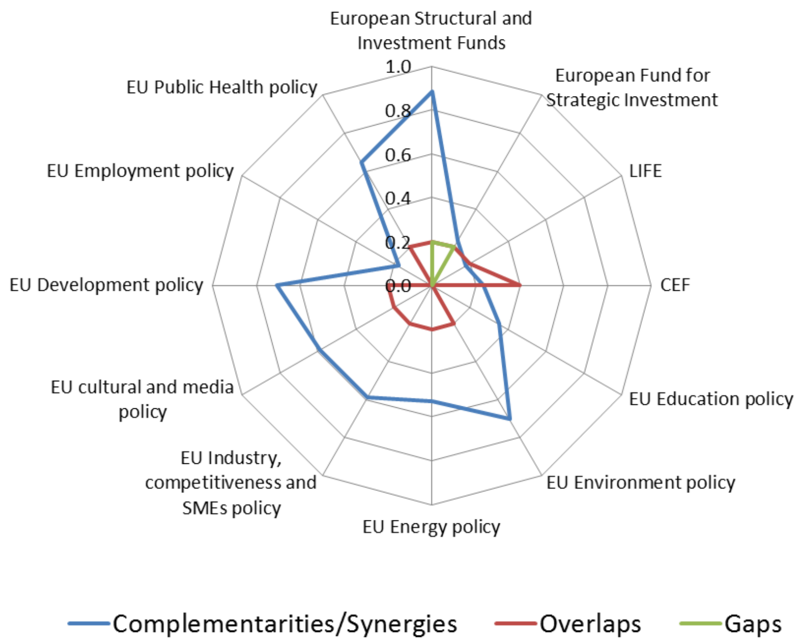
[194] http://ncp-space.net/space-research/copernicus-new/
[195] https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=home

the strategy to develop particular capabilities for the region concerned[196] (See for example the case of ELI, described in Section 5.5).

Synergies with the InnovFin instrument for the construction and major upgrades of pan-European RI have been established. An example is the EU-backed loan agreement signed by the European Investment Bank (EIB) and the European Organization for Nuclear Research (CERN) to finance the High Luminosity Large Hadron Collider (HL-LHC) project, the world's largest and most powerful particle accelerator[197]. Another is the loan for ESRF, the European Synchrotron Radiation Facility-Extremely Brilliant Source (ESRF-EBS) project[198]. Both these infrastructures are Landmarks in the current ESFRI Roadmap[264]. InnovFin has also been used for the construction of major pan-European RIs such as the European Spallation source ESS[199].

The definition of research infrastructures under Horizon 2020 explicitly mentions their use beyond research. Therefore a horizontal effort has been to ensure the availability of RI services to society at large and their coherence with existing public infrastructures. Examples are the starting collaborations between EUROPEANA[200]and DARIAH[201] in the cultural field following a specific Council conclusion and the one between COPERNICUS[286] and the e-infrastructures in the environmental field. These collaborations fostered through meetings and planned future support through Horizon 2020, aim at defining specific remits of the different initiatives to ensure complementarities and better exploit the existing synergies.
Figure 65 depicts to what extent Horizon 2020 RI intervention is coherent with many of other EU interventions. As can be seen, Horizon 2020 RI is coherent with ESIF, giving evidence of the contracture collaboration between DG RTD (Research Infrastructures) and DG REGIO. The lack of complementarity with LIFE and CEF can easily be explained by the different stakeholders involved.

Figure 65 - External coherence of RI with other EU policy/programmes



Source: Analysis by EC services.

[196] http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/smart_specialisation_en.pdf
[197] https://eeas.europa.eu/delegations/council-europe/10037/eib-and-cern-sign-eu-backed-loan-worth-250-million-chf-_fr
[198] http://www.esrf.eu/home/news/general/content-news/general/the-eib-finances-the-esrf-for-65-m.html
[199] http://ec.europa.eu/research/index.cfm?pg=newsalert&year=2016&na=na-291116
[200] https://ec.europa.eu/digital-single-market/en/europeana-european-digital-library-all
[201] http://www.dariah.eu/

D.6.2.2. Coherence with other public support initiatives at regional, national and international level

As mentioned above, the setting up of new research infrastructures can only be made in coordination with national initiatives. The preparatory phase grants facilitate the dialogue with Member States and national initiatives to finalize the memoranda of understanding for the construction of research infrastructures. In addition the support to access to research infrastructures targets what is not supported at national level: the transnational access, i.e. provision of access to users coming from a country different from the one where the infrastructure is located.

The ESFRI roadmap has in fact triggered all Member states to reflect on their own research infrastructures policy, which has resulted in that today all Member states regularly produce their own National roadmap.

Interoperability at global level of data and services provided by the pan-European research infrastructures has been fostered through specific grants and the support to a framework for the international development of data standards: the RDA (Research Data Alliance).[202]

D.6.3. Lessons learnt/Areas for improvement

The component parts of Horizon 2020 RI together comprise a well-figured and complementary set of intervention areas which have been developed over a long time and work together very well. It has a major role in furnishing the excellent science base that underpins the bulk of Horizon 2020. There are good examples of infrastructures that directly resonate with the aims of other Horizon 2020 programme areas, such as Societal Challenges 2 and 5. See also section D.6.1.2.

Few issues still need to be properly addressed:

- E-INFRA is not addressing all aspects needed for the European Digital Single Market (DSM). The mid-term reviewers think that the e-infrastrcutures should be more focussed, directly to the main infrastructures enabling data driven services. Also, given that the process of integration and consolidation of pan-European e-Infrastructure services will intensify and it is likely to result in a governance structure for the EOSC, the current project based funding will become obsolete and require definition of a new funding model.
- Gaps exist on the complementarities and synergies with ESIF and EFSI funds. With respect to the gaps with ESIF and EFSI, scientific communities were not used to work with public authorities traditionally managing structural funds. Anecdotally, results appear to have varied greatly between countries, with some successes in the sense that funds have been used in some places to contribute to important scientific infrastructure, e.g. ELI (see section D.4.5) but not in a way that suggested any particularly systematic approach. Nevertheless, the Structural Funds do represent a genuine opportunity for synergistic benefit to both European research infrastructure and regional development.

D.7. EU ADDED VALUE

This section addresses value that has arisen from the investments through the programme that are over and above those that would arise from interventions at national or regional level.

[202] https://www.rd-alliance.org/

The overall focus of Horizon 2020 RI and the nature of its major interventions are such that the whole programme is seeking to deliver added value of this kind, and much of this is described in the preceding chapters. Here the major added value of Horizon 2020 RI, their importance are summarized.

D.7.1. Horizon 2020 projects demonstrating EU Added Value

The projects already described in Section D.4.5. illustrate some of the wide diversity of added value benefits from Horizon 2020 RI interventions.

Effectiveness

The INFRADEV programme, in close conjunction with ESFRI, has enabled the EU to be **effective** in conceiving and delivering large research infrastructure projects at the European and global scale. These would not otherwise have been realized because of their large size, cost and complexity, which has required an EU-wide common vision and the combined efforts of several Member States to initiate them.

The *ESFRI Strategy Report on Research Infrastructures/Roadmap 2016* lists 29 such infrastructures that have reached the landmark (implementation) phase, and another 21 in development. These include world-leading infrastructures across all the disciplines of science. All are potentially open to all EU Member States, and many are attracting participative interest more globally.

One of these projects, where EU action is the only way to get results to create missing links, avoid fragmentation, and realise the potential of a border-free Europe, is the **European Plate Observing System** (EPOS). EPOS aims at creating a pan-European infrastructure for solid Earth science and will enable innovative multidisciplinary research for a better understanding of the Earth's physical and chemical processes that control earthquakes, volcanic eruptions, ground instability, tsunami, and all those processes driving tectonics and Earth's surface dynamics. Through the integration of a number of existing European research infrastructures and their data, EPOS will allow scientists to make a step change in developing new geo-hazards and geo-resources concepts and Earth science applications to help address key societal challenges[203]..

Efficiency

In the INFRAIA programme, EU offers better value for money, because resources or expertise can be pooled and the action can be better coordinated. European research infrastructures are encouraged to integrate and work together in offering the research community access to their facilities, whilst, at the same time, work on improving the services to the researchers.

One typical example of these projects is **INTERACT**, an a circum-arctic network of currently 77 terrestrial field bases in northern Europe, Russia, US, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. The project has main objectives to build capacity for identifying, understanding, predicting and responding to diverse environmental changes throughout the wide environmental and land-use envelopes of the Arctic, and providing Access to researchers to all terrestrial field stations. Because of the costs connected with research in this hostile environment, the project

[203] *Start date 1/10/2016, end date 30/09/2019, Max EU Grant EUR 18million, 46 Partners : https://www.epos-ip.org/*

allows the managers to pool their resources and knowledge together. In addition, common problems can be addressed and solved through the Grant.[204]

Synergy

Substantial effort in Horizon 2020 RI is devoted (mainly in INFRAIA and EINFRA) to widening access to existing national and regional research infrastructures, improving their interoperability and integration and encouraging coordinated development of further capability to address problems at the Europe-wide level.
These interventions improve **effectiveness** by opening resources to wider European access and application, and enable **synergy** by enabling the articulation of common standards, cooperation on training etc.

Thus the INFRAIA programme is also an EU action answering to the necessary to complement, stimulate, and leverage action to reduce disparities, raise standards, and create synergies.

This is most evident in the field of Atmospheric research, where a subsequent number of projects have been supported, and in particular the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS). ACTRIS is composed of observing stations, exploratory platforms, instruments calibration centers, and a data center from all over Europe. ACTRIS serves a vast community working on climate and weather models and forecast systems and offers high quality data for atmospheric gases, clouds, and trace gases. A substantial part of the project is devoted to standardize procedures and calibrations, ensure consistent data quality, and support the work on climate change. [205]

D.7.2. Lessons learnt/Areas for improvement

The European added value of the Horizon 2020 RI programme appears in several ways and throughout the programme.

The European Union as a whole is able to conceive and deliver large infrastructure projects at the European scale and develop and lead those at a global scale, of a type, size and number that would not otherwise be possible.

The use of these infrastructures is a major vehicle to promote scientific mobility across the European Union.

The networked provision of computing infrastructure and the development of major data-driven research infrastructures is realising the reality of a laboratory without walls in which not just scientists but policy-makers, businesses and society generally can access and integrate data and access research knowledge across the EU, wherever they are.

The processes of developing and initiating pan-European research infrastructures and particularly the e-science and data sharing aspects, has placed the EC at the global forefront of thinking and policy in the Open Science and Open Data area.

[204] *start date 1/10/2016, end date 30/09/2020, Max EU Grant 10 M€, 46 Partners, http://www.eu-interact.org/*
[205] *start date 1/05/2015, end date 30/04/2019, Max EU Grant 9.5 M€, 31 partners, http://actris2.nilu.no/*

All of this represents greater value for money because of the minimisation of duplication and improved means of access. Reciprocal arrangements with third countries give the EU access to expensive facilities elsewhere.

The establishment and maintenance of comprehensive access to word class research infrastructures and enabling e-infrastructure across the EU is a large, long-term project with many challenges, particularly in securing the prioritisation of pan-European approaches when national resources are very constrained. So far the EC and research ministers in MS have shown remarkable tenacity and consistency of vision in pursuing this goal, and it is crucial that this is maintained and that short term economic and other national pressures do not undermine it.

The single greatest effectiveness, efficiency and synergy gain from Horizon 2020 RI - and from Horizon 2020 overall - is from opening as much of the data from EC-funded research to the wider scientific community as possible, thereby potentially maximizing access and usage and reducing unnecessary replication.

Several of the newer pan-European RIs on the roadmap are “distributed” - that is to say, they operate through the integration of components at many different sites through the use of e-infrastructure, bringing access to data, tools and facilities to European scientists wherever they are. Key pan-European e-infrastructures in computer networks and high-performance computing and - in the near future - the European Open Science Cloud (EOSC) are key enablers of this

D.8. SUCCESS STORIES FROM PREVIOUS FRAMEWORK PROGRAMMES

Among the many success stories from FP7 finished projects, the following three have been selected as illustrations of success in developing European added value from national or individual capabilities and outputs and having potential to deliver major social, economic, policy and scientific benefits.

BBMRI[206]

FP7-INFRASTRUCTURES; budget: EUR 10,5 million; duration: February 2013/January 2017

The scope of the FP7-RI BBMRI (Biobanking and biomolecular resources research infrastructure) project was to organise and define the structures needed to bring existing biobanks and resources across Europe into a pan-European infrastructure. The Austrian-coordinated consortium comprised 54 participants and 224 associated organisations from 33 countries. The project successfully provided comprehensive information, standard operational procedures and codes of conduct for European biobanks.

One of the major challenges was the generation of an IT-infrastructure capable of linking the existing biobank data with patient registries and clinical information. Partners established a publicly accessible, common web-based portal as a centralised information site for European technology resources and platforms serving the major biobanks. The portal is functional and available at the BBMRI website. A major aspect of this was developing systems to prevent the personal information of patents associated with the samples flowing inappropriately.

QUALITYNANO[207]

FP7-INFRASTRUCTURES; budget: EUR 9 million; duration: February 2011/July 2015

[206] http://bbmri-eric.eu/
[207] http://www.qualitynano.eu/

QUALITYNANO has networked researchers to develop testing procedures and a European framework to assess the safety of nanomaterials and set up a transnational access programme to experts and equipment across 15 European sites. The work focuses on nanomaterial synthesis, labelling protocols, presentation to living systems and characterisation of the properties of nanomaterials in contact with biological systems. It has included training young researchers to test nanosafety in standard and comparable ways across different labs, enabling the spread of spread of competencies and excellence and quality in nanosafety testing across Europe. This should help ensure that the benefits and innovations to be gained from the use of nanotechnologies in Europe can be realised more safely, with better attention to likely damage to human health and the environment.

OpenAIREplus[208]- making reality of the Open Access vision for science

Project Type: FP7-INFRASTRUCTURES; budget: EUR 5,1 million; duration: December 2011/December 2014

OpenAIREplus is the 2nd generation of Open Access Infrastructure for Research in Europe. The project capitalised on the successful efforts of the OpenAIRE project which moved rapidly from implementing the EU Open Access Pilot project into a service phase, enabling researchers to deposit their FP7 and ERA funded research publications into Open Access repositories. Work in tandem this OpenAIREplus extended the mission further to facilitate access to the entire Open Access scientific production of the European Research Area, providing cross-links from publications to data and funding schemes. This brought together 41 pan-European partners, including three cross-disciplinary research communities. The publication repository networks were expanded to attract data providers from domain specific scientific areas. Innovative underlying technical structures was deployed to support the management of and inter-linking between associated scientific data.

D.9. LESSONS LEARNT/CONCLUSIONS

The principal support components of the Horizon 2020 Research Infrastructures Thematic Programme have been developed and refined, but been essentially constant, over several European Research Framework Programmes. It would not otherwise be possible to support the very long-term process of catalysing the development of international research infrastructures, which can take 10 years or more to the point of implementation and to lead those at a global scale. The use of these infrastructures is a major vehicle to promote scientific mobility across the European Union.

The five components of the Horizon 2020 RI Work Programme have shown to be relevant with respect to the EU priorities and the reinforcement of the European Research Area, and the alignment of the actions for the development of pan European RI and the ESFRI road-mapping has allowed for a timely implementation of the ESFRI projects. In addition the ESFRI Roadmap process, coupled with the use of the INFRADEV part of the programme is a successful example of international science policy in recent years.

The introduction of clusters of research infrastructures addressed the opportunities of the open data agenda and the need for more interoperability between diverse data sets.

The integrating activities have shown to be relevant to address the needs of very diverse communities in transnational access, networking and joint research activities to improve the provided infrastructures services and for what concerns good practice and pan-European scientific integration and outreach.

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[208] https://www.openaire.eu/

The Horizon 2020 RI programme represents greater value for money because of the minimisation of duplication and improved means of access. Reciprocal arrangements with third countries give the EU access to expensive facilities elsewhere.

The emphasis put on innovation is in line with the Juncker vision for EU priorities, but there is the need of an additional support for innovation and better clarification of purpose, scope and overall strategy for this objective.

The support to the interoperability and the European Open Science Cloud has just started. An effort for more integration between RI and the e-infrastructures and with other parts of Horizon 2020 would help to exploit synergies and complementarities.

The processes of developing and initiating pan-European research infrastructures and particularly the e-science and data sharing aspects, has placed the EC at the global forefront of thinking and policy in the Open Science and Open Data area.

The networked provision of computing infrastructure and the development of major data-driven research infrastructures is realising the reality of a laboratory without walls in which not just scientists but policy-makers, businesses and society generally can access and integrate data and access research knowledge across the EU, wherever they are. However, E-INFRA is not addressing all aspects needed for the European Digital Single Market (DSM), and the e-infrastructures could be more focussed, directly to the main infrastructures enabling data driven services.

Gaps exist on the complementarities and synergies with ESIF and EFSI funds.

D.9.1. Relevance

Key findings:
The five sub-programmes of Horizon 2020 RI present a cohesive set of interventions that address the objectives of the programme comprehensively and are highly relevant with respect to the EU priorities and the reinforcement of the European Research Area.

The alignment of the actions developed under the RI part of Horizon 2020 for the development of pan European RI and the ESFRI road-mapping process has proved relevant and allowed for a timely implementation of the ESFRI roadmap.

They are the result of a continuous refinement of successive programmes under previous Frameworks and work together well. This continuity and long-term vision must be retained.

The strengths are:
The integrating activities address the needs of very diverse communities, improving the provided infrastructures services through the spreading of good practice, pan-European scientific integration and outreach.

The EU has developed global leadership in Open Data policy because of policy work developed in FP7 and Horizon 2020 RI since 2010. The infrastructures and resource being developed are critical to the success of the Juncker Commission's *New Vision for Europe*[209]

[209] *10 political priorities of the Juncker Commission* http://ec.europa.eu/avservices/photo/photoByPriorities.cfm?sitelang=en

and the *Open Innovation/Open Science/Open to the World Moedas* vision[210], because they are delivering platforms, tools and skills that will enable it to happen.

The bottlenecks are:
The part to promote innovation is relatively new and needs further development.

The programme has been delivered in a period of unprecedentedly rapid change in science and technology, particularly as it relates to IT and data.

D.9.2. Effectiveness

Key findings:
The outputs collected to date from the ongoing projects are in line with the specific objectives and with the 'Open Science' and 'Open to the World' priorities.

The ESFRI Roadmapping process, coupled with the use of the INFRADEV part of the programme to catalyse the design, development and prioritisation of RI proposals, and the partnership this represents between the scientific community, Member State ministers and funders, and the Commission, is one of the major achievements of international science policy in recent years and must be maintained.

The strengths are:
The pioneering development of distributed European infrastructures and networked infrastructures based around the shared distribution and access to data, materials and tools has been transformative, stimulated scientific communities across Europe into cooperation and created a solid basis for EU-level research.

The bottlenecks are:
Long term sustainability of pan European research infrastructures is difficult to ensure.

The ICT environment is extremely challenging and fast changing.

The support to the interoperability and the European Open Science Cloud could be more structured.

The two roles of the INFRAIA element of the programme to develop starter communities and to enable advanced ones to address major issues are both valuable, but the balance between the two is too much in favour of the second. There could be something similar to attract and explore new ideas from the community in EINFRA.

D.9.3. Efficiency

Key findings:
The Horizon 2020 RI programme is well managed by Commission officials and the two teams in DG RTD and DG CNECT achieve a good level of overall coherence despite the considerable challenges involved. The Programme Committee performs an effective and appropriate oversight of the programme.

The strengths are:

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[210] *Open innovation, open science, open to the world: A vision for Europe* [*http://bookshop.europa.eu/en/open-innovation-open-science-open-to-the-world-pbKI0416263/*](http://bookshop.europa.eu/en/open-innovation-open-science-open-to-the-world-pbKI0416263/)

The consideration of routes to sustainability for virtual and distributed infrastructures is very important because there are no established models. Some of the communities have no familiarity of working with, or tradition of resourcing, such infrastructures and such concepts as recharging are little understood for intangibles such as data access.

The bottlenecks are:
There is particular concern that a sustainable settlement must be agreed between Member States to support PRACE (the HPC infrastructure) and GÉANT (networking), because of the increasing sums being contributed, seemingly haphazardly, from Horizon 2020 RI and the possibility that this will seriously restrict funds for other objectives.

Relatively little use has been made of the potential that the financial instruments offer for loans, etc.

D.9.4. Coherence

Key findings:
The Horizon 2020 RI programme provides a major role in furnishing the excellent science base that underpins the bulk of Horizon 2020. There are good examples of infrastructures that directly resonate with the aims of other Horizon 2020 programme areas, such as food, agriculture, health, materials science etc.

The strengths are:
The Horizon 2020 RI programme resonates generally well with other Horizon 2020 programmes, in that it provides large numbers of scientists in a whole range of disciplines with tools and resources to enable their research.

For competitiveness and security reasons there is a major need to develop a more comprehensive approach to underpinning the success of the European Digital Open Market, with a clearer focus on the key areas of the Cloud and HPC. This is an undertaking which involves not just the current EINFRA programme and DG CNECT but many aspects of the wider Horizon 2020 programme.

The bottlenecks are:
The sharing of data, tools and materials is now becoming a substantial feature of scientific infrastructure, and can entail very serious issues of security, personal privacy and ethics.

D.9.5. EU Added Value

Key findings:
The European added value of the Horizon 2020 RI programme is evident in several ways and throughout the programme.

The strengths are:
The European Union as a whole is able to conceive and deliver large infrastructure projects at the European scale and develop and lead those at a global scale, of a type, size and number that would not otherwise be possible.

The use of these infrastructures is a major vehicle to promote scientific mobility across the European Union.

The networked provision of computing infrastructure and the development of major data-driven research infrastructures is realising the reality of a laboratory without walls in which not just scientists but policy-makers, businesses and society generally can access and integrate data and access research knowledge across the EU, wherever they are.

The processes of developing and initiating pan-European research infrastructures and particularly the e-science and data sharing aspects, has placed the EC at the global forefront of thinking and policy in the Open Science and Open Data area.

All of this represents greater value for money because of the minimisation of duplication and improved means of access. Reciprocal arrangements with third countries give the EU access to expensive facilities elsewhere.

Bottlenecks and weaknesses:

The establishment and maintenance of comprehensive access to word class research infrastructures and enabling e-infrastructure across the EU is a large, long-term project with many challenges, particularly in securing the prioritisation of pan-European approaches when national resources are very constrained. So far the EC and research ministers in Member States have shown remarkable tenacity and consistency of vision in pursuing this goal, and it is crucial that this is maintained and that short term economic and other national pressures do not undermine it.

The second great challenge is to put the third “O” - Open Innovation - alongside the open science and open data capability and capacity which Horizon 2020 RI is helping to realise.