European Commission

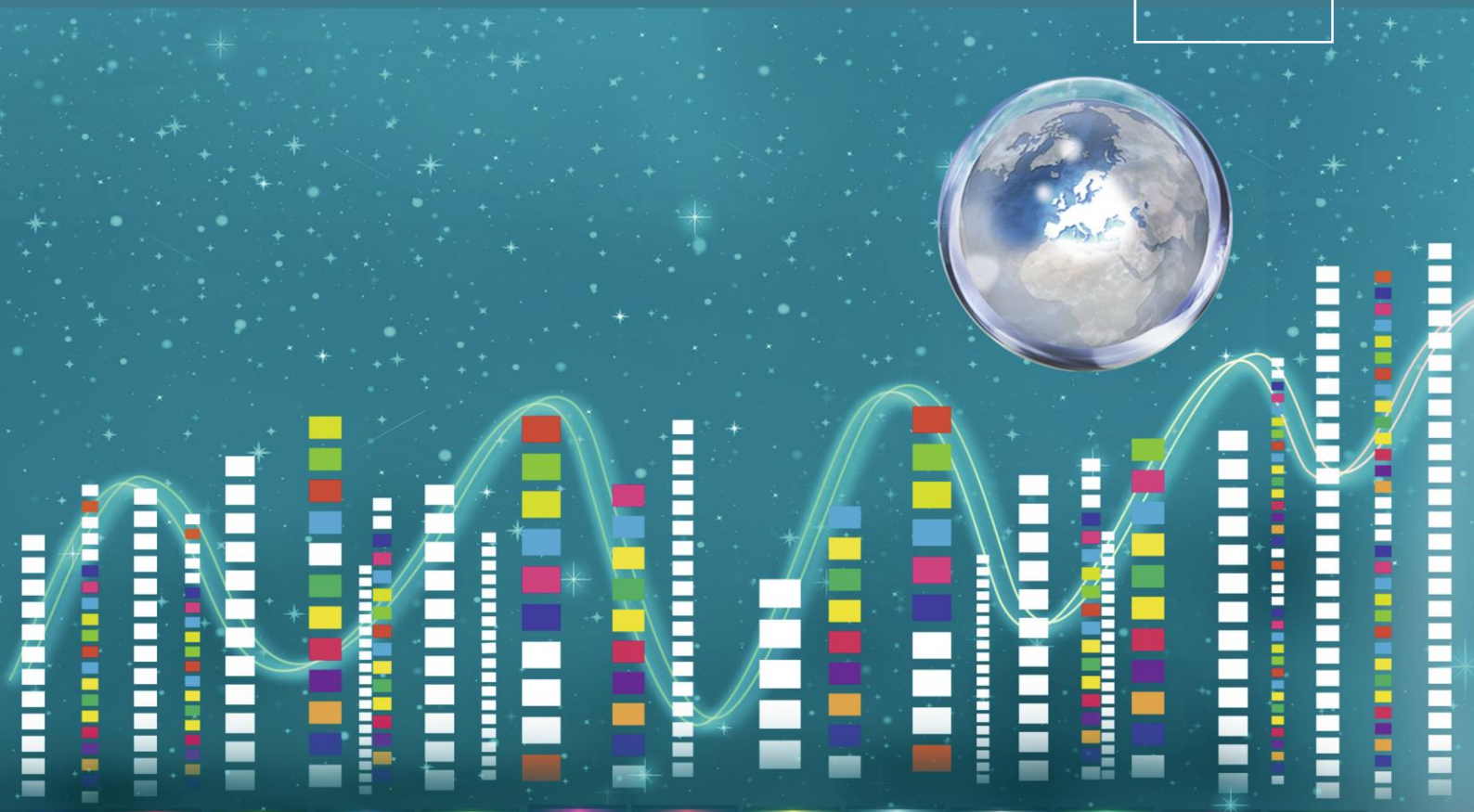
Evaluation study

on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness

Focus on activities related to the Green Transition

Final Report Phase 1 – Horizon 2020

Independent Expert Report



Research and Innovation

Evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness – Focus on activities related to the Green Transition – Final Report Phase 1

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Evaluation study
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Focus on activities related to the Green Transition

Final Report Phase 1 – Horizon 2020

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EXECUTIVE SUMMARY

Evaluation objective and methodology

This report is part of a study combining a back-to-back-approach for the ex-post evaluation of Horizon 2020 and the interim evaluation of Horizon Europe with a thematic focus on Green Transition aspects and the long-term impact of the Framework Programme(s). It constitutes the draft final report for phase 1 (Horizon 2020).

This evaluation study covers all activities of the European Framework Programmes in the impact area Green Transition, i.e., all related activities in Horizon 2020 (2014-2020) and the first phase of Horizon Europe. It notably covers four Societal Challenges under Horizon 2020: SC2, SC3, SC4, and SC5. This evaluation study also assesses European partnerships under the Framework Programme active in Green Transition-related fields with a legal obligation for evaluation (Joint Undertakings, Knowledge and Innovation Communities, Art. 185 or 187 TFEU), as well as the JRC. Other partnerships relevant for the Green Transition (Horizon 2020 contractual public-private partnerships, EJP Co Funds, Joint Programming Initiatives, ERA Nets) are taken into account as part of the evaluation of the thematic areas.

To conduct the evaluation, a specific methodological approach was designed during the inception phase, in agreement with the steering committee. The selected methodological approach mixed various data collection and data analysis tools (e.g. bibliometrics, case study, survey, benchmarking). The different tools mobilised throughout the evaluation enabled the collection of evidence to answer the various evaluative questions considered under this evaluation.

Overview of the Green Transition in Horizon 2020

Research and innovation can play a considerable role in providing the desired directionality for R&I efforts, the foundational technological requirements, technological and social innovations for shaping the transformation process to a green European society, paving the way for the required behavioural change through integration of all stakeholders, including civil society. However, the Green Transition goes far beyond transitions pushed by new technologies. Nature-based, non-technological and socio-economic innovations are also hugely important to advance the transition.

The launch of the European Green Deal, in 2019, can be considered a (r)evolution given its comprehensiveness, consistency and the priority given to the Green Transition. The package sketched many elements for the conceptualisation of a Green Transition in Europe, even if, from an R&I perspective, a clear definition does not currently exist. Green Transition can be considered as the necessary shift for achieving the priority objective of a climate-neutral economy in Europe by 2050, to which R&I constitute one of the fundamental components. It should be noted that the diagnosis leading to the need for Green Transition and related objectives already existed prior to the Green Deal, and were included in many policy and programme developments (including Horizon 2020), albeit in a more siloed manner.

In the design and implementation of Horizon 2020, tackling Societal Challenges and addressing EU policy priorities and global challenges through R&I has already been given an equal footing with fostering scientific excellence and enabling industrial leadership. Thematic priorities in the multi-annual Work Programmes were increasingly geared towards sustainability objectives. An initial conceptualisation of a Green Transition was thus embedded in Horizon 2020, with the following principles:

- R&I should contribute to the development of technologies and innovation so that all technological solutions and the respective innovation systems become net zero.

- In the meantime, while this is a longer-term endeavour, more sustainable alternatives need to be made available now (i.e. more efficient use and effective uptake of existing technologies as well as innovative business models).

- Producers and consumers along the value chains must make more sustainable choices, for which there is a need to provide the networks and capacities for rethinking and redesigning the incentives to deliver the required behavioural change.

- Negative externalities to the environment and to society must be reduced in parallel in order to prevent, minimise, or repair damages and ensure higher levels of resource efficiency.

Based on this overarching definition, sectoral definitions, for each Societal Challenge, were developed in the frame of this study.

Main findings for the four Societal Challenges

For Societal Challenge 2 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy), Horizon 2020 was an enabler of the Green Transition within the R&I scope. It constituted a unique, instrumental and ambitious mechanism to bring forward an R&I agenda, and then support relevant topics. During its timeframe, the design of topics and the selection process shifted towards a more applied and integrated perspective, which can be considered a success in support of the Green Transition. Horizon 2020 appeared to be effective, as many projects are on track to make significant progress. There is however a lack of information on the impacts, which cannot be measured immediately and for which additional monitoring tools to 'traditional' R&I indicators will need to be implemented.

For Societal Challenge 3 (Secure, clean and efficient energy), the framework programme was positively assessed in terms of relevance, coherence and effectiveness. The level of ambition, topical choices and tools mobilised appeared to be highly satisfactory to address and adapt to the challenges and needs of relevant stakeholder groups for the Green Transition. Horizon 2020 was found to be effective in terms of addressing this Societal Challenge, as many projects are on track to make significant progress. The programme support helped developing practice-oriented and usable solutions, as well as flagship initiatives that demonstrate how policy objectives can be operationalised with a holistic perspective. As for SC2, the overall impacts cannot yet be measured and will require appropriate monitoring over time.

For Societal Challenge 4 (Smart, green and integrated transport), the evaluation found that the relevance, coherence and effectiveness were overall positive. The Work Programmes successfully transformed during the course of Horizon 2020 to match the evolving needs in this field, one of the largest in terms of GHG emissions. However, the programme put a strong emphasis on medium-to-long term technological development, at the expense of other types of innovation (e.g., social, economic, organisational), which are immediately needed in order to support the Green Transition. However, and as is the case for other SCs, is is not possible to measure the impacts at this stage.

For Societal Challenge 5 (Climate action, environment, resource efficiency and raw materials), the evaluation found a significant degree of appropriate and timely progress in support of a Green Transition. The intervention area was found to be relevant, with a progressive focus on more systemic approaches and topical focal areas (e.g., adaptation rather than mitigation in WP 2018-2020). In terms of coherence, some room for improvement was identified, whether through an enhancement of inter-DG collaboration/coordination or through a better articulation with other national and EU-level policies. Most projects are on track to achieve their objectives, notably in the area of knowledge/capacity building and scientific and technological development, and are expected to generate significant effects in key areas (e.g., Circular Economy-based approaches, NBS). Nonetheless, it was noted that the level of collaboration across all the necessary stakeholder groups to support the Green Transition could have been enhanced.

Contribution of the Framework Programme to the Green Transition

In order to analyse the extent to which Horizon 2020 has induced the necessary processes for a Green Transition, the evaluation used the concept of the Multi-Level Perspective and the concept of transformative outcomes. Three analytical levels are distinguished: (i) niches, which are protected spaces and the locus for radical innovations; (ii) socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and (iii) exogenous socio-technical landscape developments. To manage and steer transitions, stakeholders can have control over three, general, spatially-bounded macro-mechanisms: (1) building

or nurturing niches; (2) expanding and mainstreaming niches, and (3) opening up and unlocking regimes.

Regarding the first macro-process, Horizon 2020 was successful in providing a visionary approach, and supporting the development of new relevant areas, knowledge and stakeholders for the Green Transition. It contributed to establishing and promoting new fields of innovation, whether through new areas of knowledge, ground-breaking solutions or support to pioneers. It successfully contributed to learning and exchanging in the field of Green Transition, as well as promoting awareness of problems related to the Green Transition and new ways of solving them. It fostered networking between young innovation fields, and it contributed to managing expectations and promoting shared visions among innovators. In many instances, the programme provided a common understanding of the future direction of innovation in the respective areas. Horizon 2020 was recognised as contributing to the expansion of new fields of innovation relevant to the Green Transition, including for non-technological innovations (notably for SC2, SC3, and, to a lesser extent, SC5).

For 'Expanding and mainstreaming niches', Horizon 2020 seemed to play a key role in supporting the implementation of innovative solutions in field of Green Transition, although it could have been stronger in terms of radical innovations. Horizon 2020 was found to support the expansion of new fields of innovation, but also the replication of innovative solutions relevant to the Green Transition in new contexts. It successfully contributed to the dissemination and diffusion of innovative solutions and concepts. However, it was found to have had a lesser impact in terms of the institutionalisation of new strategies and norms relevant to the Green Transition, calling into question the links between R&I and policy making.

Finally, for the last macro-regime, responses have been more mitigated regarding the role of Horizon 2020. The programmes contributed partially to all related items, from breaking up outdated structures and strategies relevant to the Green Transition to abandoning outdated habits and rules to enable the Green Transition, and from exchanging between "old" and "new" areas of knowledge relevant to the Green Transition to flexible response to changing framework conditions to enable the Green Transition.

The role of the partnerships

The analysis performed in relation to the patnerships contributing to the Green Transition showed that these have been of high relevance in relation to the Work Programmes of the Societal Challenges and the Green Transition. Throughout all SC areas, the different types of partnerships managed to gather innovation actors and stakeholder communities aorund topics of strategic mutual interest, with the industrial development-oriented partnerships in particular contributing to increasing coherence. Indeed, relevant regulatory bodies have been effectively involved in the partnership activities that allowed for a better co-development of new technologies, standards and norms, whereas the public-private partnerships managed to activate EU Member State actors around topics of their specific interests and contributed to the alignment of national research programmes. The partnerships proved to be an important tool for close cooperation and exchange with different actors on behalf of the European Commission, other union bodies, and the EU Member States. However, some challenges in aligning activities of the partnerships with national governments and their activities persist, as do challenges in relation the coordination of strategic activities of the partnerships and the work programmes.

Key findings per evaluation criteria

Relevance – Horizon 2020 already partially the Green Transition, even though its conceptualisation was initiated only during its implementation with the emergence of the European Green Deal. An orientation towards facilitating the Green Transition had already been incorporated in the programming of Horizon 2020 with clear references to (and the incorporation of) the strategic policy priorities in the Europe 2020 strategy. However, no specific, measurable and time-bound R&I targets related to the Green Transition in Horizon 2020 had been set up. There is a need to better define and conceptualise the requirements for the Green Transition at the R&I policy level. Specific definitions of the Green Transition, R&I targets and indicators for contributing to the Green Transition should be developed at the thematic level in Horizon Europe.

Horizon 2020 was found to be relevant to tackle the challenges and key EU priorities associated to the Green Transition in each societal domain, and adapted to their evolution over time. Horizon 2020 exhibited a strong capacity to react, and gradually adapt to emerging challenges and new policy developments. However, it has to be noted that Horizon 2020 did not take a proactive approach towards shaping the Green Transition. In some areas, the evaluation identified emerging needs that were not fully captured by the programme, or to the extent the urgency of action is needed. It was also found that, although a gradual shift was operated over time towards more systemic approaches, the programme could have put further emphasisemphasis to address the wider set of challenges related to the Green Transition, including socio-economic issues, and less on supporting 'simple' technological changes.

Overall, Horizon 2020 was effective in reaching out to relevant stakeholders and addressing the needs of the target groups. Across all SC areas, project participants showed high motivation to contribute to relevant aspects related to the Green Transition. Tackling Societal Challenges effectively requires addressing all relevant stakeholders associated with the intervention. The project portfolio analysis showed that, compared to FP7 projects, Horizon 2020 was associated with higher shares of projects involving multiple sectors, indicating a higher degree of trans-disciplinarity. A minority of beneficiaries still considered that Horizon 2020 was only partially successful in addressing all relevant stakeholder groups. In order to ensure the mobilisation of relevant stakeholders, the planning and incorporation of a coherent and continuously updated stakeholder engagement strategy at the project level is a key pre-requisite for reaching out to the required stakeholders. At the programme level, strong emphasis should be put on the elaboration of specific instruments that allow to engage all required stakeholders for enabling the Green Transition. The provision of Coordination and Support Actions and making use of the competences of partnerships to reach out to regional/local stakeholders can further enhance knowledge diffusion and scaling-up of solutions.

Coherence – Horizon 2020 funding related to the Green Transition is in a unique position, with a strong positioning within the European research and innovation landscape. However, Horizon 2020 has lacked some coherence on the issue of mobilisation and coordination of multiple actors across different sectors and at different levels (i.e. EU, national, regional, local), which is increasingly seen to be a requirement for effectively managing the Green Transition. At the R&I programming level, evidence on the coordination between the Framework Programme and the European Partnerships has been mixed and no common approach existed, leading to fragmented results. To further enhance coherence and synergies among the Framework Programme, the European Partnerships and the EU Member States, specific governance mechanisms for the coordination of the strategic planning of activities need to be set up.

Efficiency – Overall, Horizon 2020 was found to be cost-effective. Horizon 2020 allocated more EC funds across all Societal Challenges than the previous framework programme, while the average cost per project remained rather similar. The programme was assessed to be very efficient in terms of administration and management. Perceptions are positive regarding administrative and financial requirements, as well as for contractual conditions. The project application and selection processes were efficient to a large extent. Continued improvements are underlined by beneficiaries in terms of EU requirements, both from FP7 to Horizon 2020, but also from Horizon 2020 to HE. Efforts for the preparation and submission of proposals were deemed appropriate, and projects were carried out in a timely manner or required limited changes. When necessary, the degree of flexibility of Horizon 2020 was mostly appropriate. Nevertheless, the coordination of the Green Transition requires management and governance capacities going beyond the R&I policy level. Significant capacities for steering and managing the coordination between different policy areas, across organisational boundaries are needed both at the programme level and at the project level.

Effectiveness – The main outputs related to the Green Transition in all SC areas comprise: 1) technological outputs; 2) scientific outputs; 3) networks; 4) close-to-market outputs and 5) policy outputs. It appears however that the current monitoring system does not allow to fully capture the extent of the effects in the field of Green Transition, and that additional monitoring tools to 'traditional' R&I indicators will need to be implemented. Horizon 2020 funding in the Green Transition Area enabled researchers to reach top tier status within the subset of their Horizon 2020-funded publications but did not lead to significant results on other dimensions (e.g., cross-disciplinarity, international co-publications, science-industry collaborations). The influence of these dimensions, and notably the R&I quality, on the Green Transition processes should be further investigated.

Horizon 2020 funding in the Green Transition Area did not result in high levels of demonstrators, utility models or trademarks. Comparators for measuring the impact or quality of these outputs are missing. Furthermore, it is too early to assess the effects of Horizon 2020 funding in the Green Transition area related to patenting activities. Beyond publications, patents and demonstrators, there are no project-level output metrics available that provide information on the success of Horizon 2020 research and innovation projects. With a view on the Interim Evaluation of Horizon Europe, it should be assessed to which extent the introduction of project specific Impact Pathways and related documentation of projects results provide better information on the effectiveness of the intervention.

The overall results of the study indicate that the FPs in the Green Transition area have been effective in reaching the desired objectives of the projects. Horizon 2020 contributed to reaching the desired outcomes in terms of knowledge creation and capacity building and scientific and technological development. The contribution to better policy planning, new technical standards and standard setting measures gained in importance. The effects in terms of market and business are less tangible, but are frequently not a core ambition of funded R&I projects in any case. The results, however, do not allow for the establishment of reliable claims regarding longer-term outcomes and impacts. While there is strong evidence for achieving the desired project goals and the contribution to the generation of new knowledge, networks and the development of new technologies is high, there is less evidence to which extent projects provide concrete solutions to deliver on the Societal Challenges. If the intention is to further increase deployment of new technologies and the introduction of marketable results, measures for increasing this type of activities need to be strengthened. However, the study findings also indicate that the Green Transition does not only require new technologies but solutions that go beyond the provision of new technologies. There is an evident need for stronger coordination between R&I policy, sectoral policies, and fiscal policies.

Horizon 2020 contributed to support the EU policy priorities and EU action in relation with achieving the Sustainable Development Goals, although no dedicated monitoring system was set up to measure the real achievements.

EU added-value – Across all Societal Challenges, there is widespread acknowledgement that Horizon 2020 has a significant EU added value in terms of funding geared towards the Green Transition. For the vast majority of R&I projects funded across all Societal Challenges, it became evident that without EU funding the projects would not have been implemented or their scope would have been significantly reduced. In addition, Horizon 2020 projects enabled cooperative partnerships of a pan-European nature that would not have existed otherwise. Furthermore, there are strong indications that in some SCs Horizon 2020 provided funding for various topics, where no or little (or only in very few MS) national funding R&I funding possibilities exist and where European coordination in the provision of R&I support is strongly needed. The European Partnerships played an important role in this regard. Horizon 2020 and its partnerships for R&I contributed to better coordination and alignment of R&I activities at the level of policy makers and at the level of R&I communities.

ACRONYMS

Acronym	Meaning
ACRP	Austrian Climate Research Programme
AWS	Federal development and financing bank (Austria)
BBI	Bio-based Industries
BBI JU	Bio-based Industries Joint Undertaking
BG	Blue Growth
BMBF	Ministry of Education and Research (Germany)
BMK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (Austria)
CAP	Common Agriculture Policy
CBE JU	Circular Bio-based Europe Joint Undertaking
CCCA	Climate Change Centre Austria
CEAP	EU Circular Economy Action Plan
CEF	Connecting European Facility
CEP	EU Circular Economy Package
CFP	Common Fisheries Policy
CINEA	European Climate, Infrastructure and Environment Executive Agency
COP	UNFCCC Conference of the Parties
cPPP	Contractual-Public-Private Partnership
CS	Case study
CSA	Coordination and Support Action
EASA	European Union Aviation Safety Agency
EAFRD	European Agricultural Fund for Rural Development
EDA	European Defence Agency
EeB PPP	Energy-efficient Buildings Public-private partnership
EC	European Commission
EIT	European Institute of Innovation & Technology
EJP	European Joint Programme

Acronym	Meaning
ERA	European Research Area
ERDF	European Regional Development Fund
ESA	European Space Agency
EU	European Union
FAA	US Federal Aviation Administration
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FFG	Austrian Research Promotion Agency
FONA	Research for Sustainability, Federal Ministry of Education and Research (Germany)
FP	European Framework Programme for R&I
FP7	7th European Framework Programme for R&I
FP10	(Upcoming) 10th European Framework Programme for R&I
GEO	Group on Earth Observations
GHG	Greenhouse gases
Horizon 2020	Horizon 2020 (8th European Framework Programme for R&I)
HE	Horizon Europe (9th European Framework Programme for R&I)
IA	Innovation Action
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Right
JPI	Joint Programming Initiative
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
JTI	Joint Technology Initiative
JU	Joint Undertaking
KIC	Knowledge and Innovation Community
KLIEN	Austrian Climate and Energy Funds

Acronym	Meaning
KPI	Key Performance Indicator
LEIT	Leadership in Enabling and Industrial Technologies
MaaS	Mobility as a Service
MoST	Ministry of Tourism and Sustainability (Austria)
MS	Member State
NBS	Nature-based solutions
NGO	Non-Government Organization
OA	Open access
OEM	Original equipment manufacturer
P2P	Public-public partnership
PPP	Public-private partnership
PRC	Private for-profit
RIA	Research and Innovation Action
RUR	Rural Renaissance
R&D	Research and Development
R&D&I	Research and Development and Innovation
R&I	Research and Innovation
SC	Societal Challenge
SDG	Sustainable Development Goal
SERA	Single European Railway Area
SES	Single European Sky initiative
SESAR	Single European Sky ATM Research
SFS	Sustainable Food Security
SME	Small and Medium Enterprise
SRIA	Strategic Research and Innovation Agenda
TFEU	Treaty on the Functioning of the European Union
TOR	Terms of Reference
TRL	Technology Readiness Level
UNDRR	United Nations Office for Disaster Risk Reduction

Acronym	Meaning
UNFCCC	United Nations Framework Convention on Climate Change
WP	Work Programme

1. Introduction

1.1. Objectives and scope of the evaluation

The purpose of this study is to provide the Commission with the specific data and analyses needed to support the ex-post evaluation of Horizon 2020 (phase 1, in 2022, object of this report) and the interim evaluation of Horizon Europe (phase 2, in 2023) in the impact area 'Green Transition'. The study feeds into the back-to-back-approach set for the ex-post evaluation of Horizon 2020 and the interim evaluation of Horizon Europe and thus informs the implementation of Horizon Europe in the current multi-annual financial framework (2021-2027) as well as the design of the next Framework Programme (FP10). The outcome of this study also feeds into the horizontal study on the new approach for European Partnerships.

The overall aim of this study is to identify lessons learned from the implementation of Horizon 2020 (phase 1) and Horizon Europe (phase 2) while also assessing longer-term effects of FP activities towards the Green Transition and providing evidence-based suggestions for the improvement of the Framework Programmes in the light of experience.

While the study has the legal obligation to conduct two different evaluations, one with an ex-post character and the other with an interim character, the key thematic focus of this evaluation is on the Green Transition aspects and the long-term impact of the Framework Programme(s).

This evaluation study covers all activities of the European Framework Programmes in the impact area Green Transition, i.e., all related activities in Horizon 2020 (2014-2020) and the first phase of Horizon Europe. This evaluation study also assesses partnerships active in Green Transition-related fields with a legal obligation for evaluation (Joint Undertakings, Knowledge and Innovation Communities, Art. 185 or 187 TFEU). Other partnerships relevant for the Green Transition (Horizon 2020 contractual public-private partnerships, EJP Co Funds, Joint Programming Initiatives, ERA Nets as listed in ToR on page 77) will be taken into account as part of the evaluation of the thematic areas.

More specifically, this evaluation study covered, in Phase I:

- Horizon 2020 programme parts
  - SC2: Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy
  - SC3: Secure, clean and efficient energy
  - SC4: Smart, green and integrated transport
  - SC5: Climate action, environment, resource efficiency and raw materials
- Partnerships with a legal obligation for an individual evaluation
  - Art. 185: Partnership for Research and Innovation in the Mediterranean Area (PRIMA)
  - Art. 187: Bio-based Industries (BBI); CleanSky 2; Fuel Cells and Hydrogen (FCH 2); Single European Sky ATM Research (SESAR); Shift2Rail
  - EIT Knowledge and Innovation Communities: EIT Urban Mobility, EIT Climate-KIC, EIT Food, EIT InnoEnergy

- Partnerships without a legal obligation for an individual evaluation:
  - Consideration of other partnerships (ERANET Cofund / EJP Cofund / Joint Programming Initiatives) listed in annex VII of the TOR within the overall set of activities relevant for this area.

To conduct the evaluation, a specific methodological approach was designed during the inception phase, in agreement with the steering committee (Annex II).

1.2. Methodological approach

While the study has the legal obligation to conduct two different evaluations, one with an ex-post character in Phase I and the second with an interim character, the key thematic focus of this evaluation is on the green transition aspects of the Framework Programme(s). Therefore, the evaluation elaborated working definitions for a green transition and a methodoligcal framework that allows to consider the specific challenges of a green transition in relation to the instruments and actions set out in Horizon 2020 and Horizon Europe. The evaluation followed the main principles of theory-based evaluation (Chen 1990; Weiss, 1997; Rogers, 2007; Funnell & Rogers, 2011), and developed theories of change that related 1) the general and specific needs/challenges of the green transition, with 2) the interventions of the related parts of the Framework Programmes and the European Partnerships.

For providing answers to the evaluation questions of the study in relation to the interventions set, the selected methodological approach mixed various data collection and data analysis tools. The different tools mobilised throughout the evaluation allowed to collect evidence to answer the various evaluative questions considered under this evaluation. Table 1 provides an overview of the contribution of each tool to the different evaluative criteria.

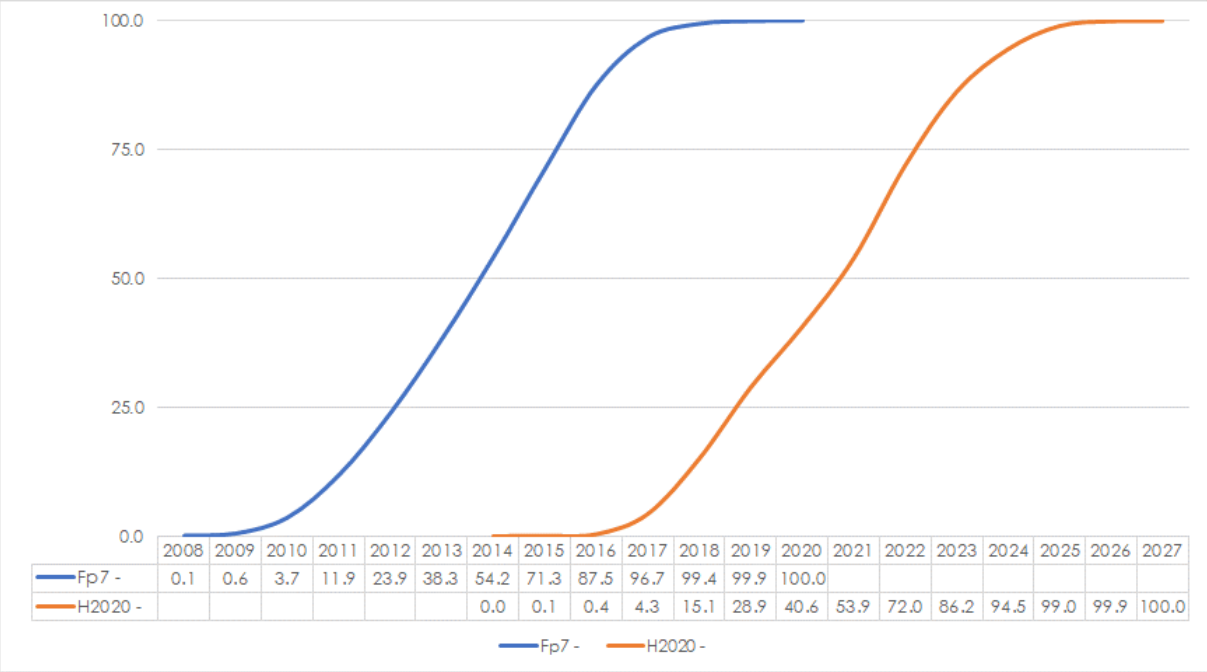
Table 1. Correspondence between the evidence collected through the tools mobilised and the evaluative criteria (the colour the colour intensity reflects the importance of the tool

Table	Relevance	Coherence	Efficiency	Effectiveness	EU added-value	Partnerships specific criteria
Desk research						
Data analysis						
Explorative interview						
International benchmarking						
Case study						
Surveys						
Partnership evaluation						

As a result, several analyses were produced and provided as separate annexes: 1) Quantitative analyses; 2)Topical and benchmark case studies; 3) Survey results. Results from the consultation are provided in the synopsys report.

As regards the quantititative data analysis, in considering outputs and even more so outcomes of H2020 green transition activities, it is crucial to keep in mind when reading this evaluation report that many of these activities are still on-going at the time of evaluation. As shown below in Figure 1, by the

cut-off date of **end of 2021 for project activities used in this study, only 54% of relevant H2020-funded projects had been completed**. The share of completed H2020 projects will reach more than 90% only by the end of 2024. Therefore, all assessments of H2020 outputs and outcomes performed in this study must be considered as preliminary.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Fp7 -	0.1	0.6	3.7	11.9	23.9	38.3	54.2	71.3	87.5	96.7	99.4	99.9	100.0							
H2020 -							0.0	0.1	0.4	4.3	15.1	28.9	40.6	53.9	72.0	86.2	94.5	99.0	99.9	100.0

Figure 1. H2020 and FP7: Percentage share of projects closed by year, in the aggregate of the four Green Transition Societal Challenges

Source: Source-Metrix (Elsevier) processing of eCorda database

Bibliometrics strategies have been deployed to measure the effectiveness of H2020 Green Transition research activities, at scale accross thousands of SC2- to SC5-funded projects. **Biblometrics methods in a program evaluation context are subject to specific limitations.** Comprehensive descriptions of the methods employed in the bibliometrics analyses and of their limitations can be found in Annex II, while full bibliometrics findings are included in Annex V (for the SC) and Annex X (for the partnerships).

Descriptive findings, that provide bibliometric findings for selections of funded projects (in case studies) or partnerships, measure absolute achievements by research area or thematic area relative to selected comparators. These analyses serve to uncover where H2020 support in green transition calls stands out relative to other EU research not funded by the FP. Any outstanding performance under H2020 could relate to the programme having successfully selected for projects/awardees that stand out from the reference populations and/or to the programme having exerted a positive effect on the performance of awardees. To assess the relative contribution of the latter factor in observed difference, a counterfactual analysis was then performed (see below). Indeed, it should be kept in mind that descriptive findings are not able to tell us whether any strong performances recorded by supported researchers were induced by H2020 support itself, or whether the supported researchers would have attained these achievements otherwise, with other funding opportunities. Demonstrations of high-calibre work for any indicator may reflect H2020 support, the peer-reviewed selection process of researchers, or neither or both of these causes.

Counterfactual bibliometrics findings allow for more causal inference-making on the differential impacts of H2020 funding for supported researchers specifically. This approach was employed particularly at the SC level and the in the international benchmarking exercises. Counterfactual findings complement descriptive findings, as the differential changes measured allow Science-Metrix to better answer the question, “did H2020-supported researchers attain the same research achievements on activities without H2020 funding?”. Note that the study only reports statistically robust findings of a meaningful magnitude. For the counterfactual findings, only journal publications by researchers supported by H2020 funding are considered. These authors’ 2014–2021 publications

have been classified as either funded by H2020, or likely funded by parallel, concurrent funding from other sources (so-called “parallel” publications). Parallel publications provide a baseline against which to measure the specific incremental effect of H2020 funding on the scientific performance of supported researchers (by relevant indicator). This comparison controls for several biases, such as performance level, culture, gender, seniority and other author-level variables that might otherwise be distributed differently between the comparative groups typically used (for example when comparing H2020-supported publications against EU Member States).

To analyse to which extent Horizon 2020 has induced processes for a Green Transition, the evaluation uses the concept of the Multi-Level Perspective (MLP) and the embedded concept of transformative outcomes that has been considered as an analytical guidance for the analysis of the interventions and operationalised in the survey design and the case studies[1].

For the European partnerships for R&I under the scope of this evaluation, a specific approach was designed to cover both phases of the study. Indeed, PRIMA was the only partnership for which the evaluation was completed during phase 1. The evaluation of all other partnerships will be completed during the phase 2 of the study. To feed in phase 1 with partnership elements, an approach covering both phases was developed, with collection and analysis of primary and secondary data during phase 1, that will continue in phase 2. An analysis of the results to date are provided in chapter 5.3 of this evalution report, data analyses on the partnership performance are provided in Annex X.

In order to disseminate the findings of the study and validate the conclusions of the study, a policy workshop was conducted based upon evidence collected for the draft final report. The workshop findings have been considered for the final report.

1.3. Content of the final report

The final report presents the analysis of each specific programme part within the scope of the evaluation in phase 1, as well as an overview of a horizontal analysis across the framework programme, based on a triangulation of the findings from the various data collection tools. The report highlights success stories that could be included in the final report to illustrate main findings.

The report is organised as follow:

- An introduction section, to present the objectives, scope and content of the report
- A second section on the Green Transition in Horizon 2020, and its meaning for the four Societal Challenges under scrutiny for this study
- A third section on the evidence of findings for each Societal Challenge
- A fourth section on the findings related to efficiency
- A fifth section on the contribution of the framework programme to a Green Transition
- A last section on the overall conclusions and recommendations

In addition, the report is completed by several annexes:

- Annex I: Procedural information
- Annex II: Methodology and analytical models used

[1] Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research policy, 31(8-9), 1257-1274;
Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research policy, 39(4), 435-448.
Ghosh, B., Kivimaa, P., Ramirez, M., Schot, J., & Torrens, J. (2021). Transformative outcomes: assessing and reorienting experimentation with transformative innovation policy. Science and Public Policy, 48(5), 739-756.

- Annex III: Evaluation matrix
- Annex IV: Intervention logics
- Annex V: Quantitative data analysis
- Annex VI: Synopsis of stakeholder consultation
- Annex VII: Survey results
- Annex VIII: Results from the international benchmarking
- Annex IX: SC and benchmarking case studies
- Annex X: Progress reports to this area of the different types of partnerships under Horizon 2020[2]

[2] Annex X is not publicly available.

2. Green Transition in Horizon 2020

The main aim of the report is to analyse to which extent the interventions within SC2-SC5 are useful tools to contribute to the green transition, without pretending that these activities alone already provide a full and complete picture of the green transition. For example, financial instruments going beyond R&I funding are placed within H2020 but are outside the scope of this study, and other instruments such (e.g. regulatory frameworks, trade policies) are placed outside the scope of H2020 (e.g. regulatory framework, trade) and have been dealt with. Against this background, this section provides a first indication how H2020 considered the notion for the green transition in its conceptualisation.

2.1. The conceptualisation of a Green Transition in Horizon 2020

The European Green Deal[3] is Europe's adapted growth strategy aiming to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases (GHG) in 2050 and where economic growth is decoupled from resource use. In addition, the Green Deal emphasises the need to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. At the same time the European Green Deal aims to make this transition just and inclusive, by putting people first and paying particular attention to regions, industries and workers that will face the greatest challenges. As the new EU policy priority, launched in 2019, the European Green Deal sketches all elements for the conceptualisation of a Green Transition in Europe

The European Green Deal has programmatically influenced the design of the new Framework Programme for R&I, Horizon Europe – most prominently through the development of the directly climate related R&I Missions (Adaptation, Climate-Neutral Cities, Soil, and Oceans Missions), Cluster 4: Digital, Industry and Space, Cluster 5: Climate, Energy, Mobility and Cluster 6: Food, Bioeconomy, Natural Resources, Agriculture and Environment. However, the previous Framework Programme Horizon 2020 was built upon very different lines of thinking, focusing on restoring and safeguarding European competitiveness and growth, scientific excellence, and to promote the policy goals of open innovation, open science and openness to the world (three O's). Nevertheless, Horizon 2020 has put tackling Societal Challenges effectively, and addressing EU policy priorities and global challenges through research and innovation, on an equal footing with fostering scientific excellence and enabling industrial leadership. In addition, thematic priorities in the multi-annual Work Programmes have been increasingly geared towards sustainability objectives.

The first Work Programme[4] of Horizon 2020 recognised the untapped potential for the European economy to be more innovative, productive and competitive while using fewer resources and reducing environmental impact:

- Food security has been recognised as a major global challenge that calls for an increase in production of food in Europe through climate-smart agriculture and resource-efficient farming. Growth opportunities may come from new sources, such as the oceans and seas, smart cities, space applications, high-performance computing and more efficient use and reuse of waste and raw materials, water, biomass and by-products of biomass processing.

- A higher degree of resource and energy efficiency could contribute to growth, jobs and enhanced competitiveness, with reduced costs for business as well as significant benefits for health and the environment.

- Combating climate change has been recognised as a challenge, but also an opportunity to shift to a sustainable, low-carbon economy, and therefore the aim was set that 35 % of the Horizon 2020 funds will be climate-change related. Sustainable development and climate action are distinct crosscutting priorities for the whole programme, specifying that while climate action and resource efficiency are mutually reinforcing objectives for achieving sustainable development, the whole of Horizon 2020 should contribute towards these overarching objectives.

[3]https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF
[4]https://ec.europa.eu/research/participants/portal4/doc/call/h2020/common/1617601-part_1_introduction_v2.0_en.pdf

- Horizon 2020 also aimed to deliver opportunities from new forms of innovation, such as social and public sector innovation, and by integrating perspectives from social sciences and humanities.

The second Work Programme of Horizon 2020 emphasises the following:

- The provision of Sustainable Food Security should address resilience and resource efficiency in the primary sectors (agriculture, forestry, fisheries and aquaculture) and in the related up- and downstream industries. Aims include stability and competitiveness of the agri-food chains, such as the food industry, and safeguarding and making efficient use of natural capital as the basis for primary sectors, while factoring in climate and environmental challenges.

- There is a strong political will for Europe to move towards an energy secure, competitive, climate resilient and low-carbon economy, as well as to become the world number one in renewable energies and lead the global fight against climate change. Developing supply chains that are resilient to global competition, to allow active participation of citizens, and at the same time providing a strong response against global warming and other climatic changes, are core elements of the Work Programme.

- In the transport area, focus is on the provision of long-term solutions to key challenges, notably on enhancing safety and reducing transport's dependency on fossil fuels. Cleaner and smarter means of transport, as well as better inter-modal integration, aim to improve the efficiency and resilience of logistics chains, and allowing greater choice to passengers.

- The approach to climate action and sustainable development has been pursued and strengthened through upfront mainstreaming during strategic programming, and then during the development of the content of the Work Programme as well as in plans for monitoring of project implementation. Climate action and sustainable development are some of the key objectives of a number of calls under Societal Challenges (SCs) and leadership in enabling and industrial technologies (LEITs).

Finally, the Work Programme 2018-2020 provides a clear focus on supporting EU sustainable and inclusive competitiveness through the delivery of ideas, technology and processes, and innovative solutions for society's challenges – not least, related to climate change, inclusiveness and sustainability, creating businesses, building market share and generating employment in the short, medium and long term.

Across Horizon 2020 and the Societal Challenges, high-level priority setting for international cooperation had been set in Article 27 of Regulation (EU) No 1291/2013 to establish Horizon 2020. International cooperation with third countries and international organisations shall be promoted and integrated into Horizon 2020 with targeted actions (i.e. through Work Programme activities) as well as horizontal and cross-cutting activities in order to achieve: 1) strengthening of EU excellence and attractiveness in R&I as well as its economic and industrial competitiveness, 2) an effective approach towards tackling common Societal Challenges, 3) supporting of EU external and development policy objectives, complementing external and development programmes including international commitments and their related goals. Synergies with other EU policies should also be sought.

The implementation of the Sustainable Development Goals (SDG) and cross-cutting calls in support of the European Green Deal have been added to the Work Programme for 2020, responding to the pressing need to confront the climate crisis and provide greater protection for the continent’s unique environment and biodiversity. The Green Deal call’s ambition matches the magnitude of the task: its goal is to use research and innovation to kick-start the environmental, social and economic transformations required to tackle the climate challenge and become climate neutral by 2050. To that end, the call prioritises upscaling of innovative solutions and engaging with communities, for example for sustainable land-use or urban development. The call is formulated as a crosscutting call within the focus area 'Building a low Carbon, Climate-resilient Future' and emphasises the energy transition, sustainable ecosystem management, and citizens’ engagement in innovation and the transition to sustainability.

The scoping interviews indicated that a ‘Green Transition’ includes a broad range of complementary aspects, such as the reduction of greenhouse gas emissions to achieve climate neutrality, a reduction of harmful environmental impacts or biodiversity preservation, competitiveness in a global world, and a

just transition to ensure social acceptability. Green Transition is perceived by many as the necessary shift for achieving the overall objectives of the Commission, i.e. a climate neutral economy in Europe by 2050 and all other associated objectives. Although only clearly framed under the European Green Deal in 2019, which is recognised as a clear (r)evolution in terms of comprehensiveness, consistency and priority, diagnostics leading to the need for Green Transition and related objectives were already existing prior to this strategy. This identification includes the preparatory phase of Horizon 2020, although in a more 'siloed', and less conceptualised, way and with a lower degree of priority.

Interviewees also underline that while R&I is a component of the Green Transition, it constitutes only one out of the many necessary components for a successful transition to occur. Several interviewees note that support to a Green Transition should not only focus on technological development, but also, for instance, on deployment. In Horizon 2020, the prioritisation of support to the Green Transition has evolved over time, and it can be seen in the focus areas of the calls, whereby earlier calls targeted socio-economic impacts and later calls increasingly targeted environmental aspects.

The study team therefore recognises that H2020 included already element of a Green Transition thinking. However, working definitions for the contribution of R&I to a Green Transition have been missing. Therefore, the study reconstructed working definitions for a Green Transition for Horizon 2020 and the SC based upon the analysis of the legal base and the inand notes that R&I for a Green Transition should adhere to the following principles:

- R&I should contribute to the development of technologies and innovation which facilitate that all (technological) solutions and the respective innovation systems become net zero,
- in the meantime, while this is a longer-term endeavour, more sustainable alternatives need to be made available now (i.e. more efficient use and effective uptake of existing technologies as well as innovative business models),
- producers and consumers along the value chains need to make more sustainable choices, for which there is a need to provide the required networks and capacities for rethinking and redesigning the incentives to deliver the required behavioural change,
- negative externalities to the environment and to society need to be reduced at the same time in order to prevent, minimise, or repair damages and ensure higher resource efficiency.

Departing from this overarching definition and findings, the following Green Transition working definitions for each Societal Challenge area under consideration in this study have been developed. Based upon the following definitions, the analysis of the legal base, Work Programmes and scoping interviews, the study conceptualised intervention logics for each of the Societal Challenges (see Annex IV), which outline the pathways to impact for the activities of the Framework Programme to contribute to the Green Transition.

2.2. A Green Transition with respect to Societal Challenge 2 "Agriculture, Food, Water and the bioeconomy"

R&I contributing to a Green Transition requires that:

- Competitive and environmentally advantageous bio-based alternatives for fossil-based products and processes are provided.

Within bio-based systems this should include the following:

1) negative climate impacts (i.e. emissions by agricultural sectors) have to be reduced;
2) ecosystems and biodiversity have to be preserved and restored;
3) a sustainable and efficient use of biological resources (oceans, soils) within planetary boundaries and ecological limits has to be established;

4) a fair, healthy and environmentally-friendly food system, including sustainable food consumption and reduction of food loss and waste has to be created.

The Work Programme analysis and the interviews conducted in Phase I of the ex-post evaluation of Horizon 2020 show that the Green Transition goal is to contribute to transforming conventional agricultural and industrial processes, and food and non-food products, into resilient, sustainable, bio-based resource- and energy-efficient ones. These production systems need to produce more food, fibre and other bio-based products with minimised inputs, environmental impact and greenhouse gas emissions, as well as enhanced ecosystem services, zero waste and adequate societal value. This should be achieved without compromising natural resources on land and in water, while contributing to recovery of biological diversity.

At the same time, it should contribute to improving human health through healthier food and consumption, boosting European innovation and industries and ensuring sustainable rural development. As these objectives indicate, SC2 covers a broad range of themes ranging from the various types of primary production (agriculture, forestry and marine), to processing and production of a wide range of goods, and healthy and sustainable consumption in different geographical areas (land and sea).

2.3. A Green Transition with respect to Societal Challenge 3 "Secure, clean and efficient energy"

R&I contributing to a Green Transition requires the following:

- Improvements in energy efficiency and energy saving are required in order to reduce energy demand.
- All energy sources need to become more sustainable; fossil energy sources need to be replaced with renewable energy sources.
- Technologies need to be made available that make renewable energy secure and economic to use: new renewable energy technologies, grid expansion, energy storage, sector coupling, and an increase in the flexibility of the energy system is required. Digitisation will be an important driver in the energy sector transformation.
- Citizens must support and benefit from a transition towards renewable energies.

The Work Programme analysis and the interviews conducted in the inception phase of the ex-post evaluation of Horizon 2020 show that a successful energy transition towards a decarbonised energy system is critical to reaching climate neutrality. The production and use of energy currently accounts for more than 75 % of the EU's greenhouse gas emissions.

The future energy system is expected to be based on cyber-physical infrastructure, with a shift from end-use considerations to energy services, and from a grid-centric perspective to an increasing focus on energy logistics, as well as a complete shift in energy generation. The necessary transformation processes and pathways will mean changes not only to energy infrastructure and technologies, but more importantly to the broader socio-technical, socio-economic, institutional, and governance systems, i.e. the strategies, practices, actor networks, policies, regulations, and markets and allocation mechanisms constituting the energy system. More specifically, all energy sources need to become more sustainable by replacing fossil energy sources with renewable energy.

In order to achieve this, innovation and technology development and implementation need to be accelerated to make renewable energy secure and economic to use, including through the development of new renewable energy technologies, building interconnected energy systems and integrated grids, modernising infrastructure, promote sector coupling and by increasing the flexibility of the energy system. At the same time, improvements in energy efficiency and energy saving are required for the energy transition. Finally, the two notions of twin and just transitions are of particular importance for the decarbonisation of the energy system: The digital transition could provide opportunities and solutions to drive the transformation of the energy system. While transitioning the energy system from a fossil-fuel-based one towards a decarbonised one based on renewable

energies, policymaking and innovation activities must ensure that all citizens benefit from the transition and that energy remains reliable and affordable.

The Horizon 2020 SC3 interventions already contribute to the Green Transition with objectives addressing the need to make energy systems more sustainable and more efficient while ensuring the security of supply. However, the European Green Deal introduced more ambitious targets and thus the need to accelerate the decarbonisation of the energy system in order to reach climate neutrality by 2050. Therefore, the key question in the analysis of the Green Transition is the extent to which SC3 activities were, or will likely be able, to contribute to the higher sustainability ambitions and the corresponding need for an accelerated transition towards a decarbonised energy system.

2.4. A Green Transition with respect to Societal Challenge 4 "Smart, green and integrated transport"

R&I contributing to a Green Transition in the field of transport and mobility should adhere to the following principles, which were later set out in the Sustainable and Smart Mobility Strategy (2020)5:

- All transport modes need to become more sustainable as all are indispensable for our interconnected transport system.
- Until this objective is reached and as each mode is in the process of decarbonising, more sustainable alternatives need to be made available now (supply-side).
- There is a need to reinforce the incentives for transport users to make more sustainable choices (demand-side). These incentives include carbon pricing, taxation, infrastructure charging and improved information to users.
- Transport activities also produce negative externalities to the environment and society. Therefore we need to reduce negative externalities: e.g. greenhouse gas (GHG) emissions, noise, air and water pollution, energy consumption, biodiversity loss and habitat damage, congestion and degradation of public space, and accidents leading to injuries and loss of life.

The document analysis and interviews show that a successful green transport transition will provide significant economic, social and environmental benefits: cutting climate-warming greenhouse gas emissions, reducing air and noise pollution and their negative impacts on health, and driving innovation. Transport needs to cut emissions by 90 % by 2050.

In Horizon 2020, objectives regarding a contribution to the Green Transition have been present from the beginning, addressing the need to make transport more sustainable and efficient by seamlessly integrating all transport modes. Moving from Work Programme to Work Programme one can see that more and more 'green' topics have been included. However, transport is seen by interviewees as one of the few sectors which has not done enough in terms of transition to green operations, with the more problematic sectors being international transport, namely aviation and waterborne transport.

2.5. A Green Transition with respect to Societal Challenge 5 "Climate action, environment, resource efficiency and raw materials"

The definition of Green Transition within the context of SC5 is not straightforward. The term Climate Action is a broad concept, and it encompasses climate mitigation, as well as adaptation and resilience at Member State (MS), EU, and international/UNFCCC levels. Its definition and implementation within SC5 should be seen as being part of a 'higher' climate action concept. Climate action at an EU/MS level includes the reduction of greenhouse gas emissions (as part of a wider international effort) in order to prevent climate change from reaching dangerous levels, and complementing the broader actions needed to address the unavoidable impacts of a changing climate.

[5] SWD(2020) 331 final: Sustainable and Smart Mobility Strategy – putting European transport on track for the future.

Horizon 2020's development and positioning on climate action was strongly influenced by the Europe 2020 strategy and its "20/20/20" climate/energy targets.[6] The policy framework direction was further developed for climate and energy in the EU 2030 Climate and Energy Framework in 2014,[7] as well as through a Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy in 2015[8], and the Clean energy for all Europeans package in 2016.[9]

It is also useful to recall here that the more recent objective of the European Green Deal in 2019[10] to make Europe climate neutral by 2050 is one of climate action, defined through the European Climate Law, with a GHG reduction target of at least 55 % by 2030 compared to 1990 levels. Furthermore, the recent COP27 UN Climate Change Conference (27th Conference of the Parties of the UNFCCC), includes a climate action agreement on mitigation, whereby it was agreed that limiting global warming to 1.5°C requires rapid, deep and sustained reductions in global GHG emissions, reducing them by 43 % by 2030 relative to 2019 levels and that this requires accelerated climate action during the coming decade.

In addition, adaptation to climate change has been defined by the Intergovernmental Panel on Climate Change (IPCC) as being the process taken to "adjust to the actual or expected climate and its effects". Whereas resilience to climate change can be defined as being the capacity to prepare for, respond to, and recover from the impacts of hazardous climatic events while incurring minimal damage to societal wellbeing, the economy and the environment. This can then be thought of as adaptation to climate change and resilience for climate change and not as one leading to the other or "adaptation for resilience".

R&I contributing to a Green Transition through Horizon 2020 and SC5 is then defined by this study as requiring that:

- Actions are implemented to support the achievement of an overall and broader objective of climate action and through specific activities that relate to an enhanced understanding and implementation of climate neutrality, adaptation, and resilience while equitably producing societal, economic and environmental benefits.

- EU policy problem dimensions and issues are supported, by providing timely and appropriate research and evidence across different disciplines, stakeholders, and priority areas and encompassing environment, energy, transport, infrastructure, agriculture/food, ecosystems, and health domains.

- Needs and priorities are identified and facilitated through alignment and enhancement of governance, collaboration/cooperation between actors, and the development of experience and expertise (e.g. testing innovative approaches for Circular Economy, bringing new/wider stakeholders together, and exploring and developing the concept).

The Work Programme analysis and the interviews conducted in Phase I of the ex-post evaluation of Horizon 2020 show that there has been a progressive and more defined/systematic approach as the Work Programmes have progressed and that the Green Transition goal can be broadly considered as:

- enabling a climate neutral and resilient economy and society;

- protecting and sustainably managing natural resources and ecosystems;

- providing for a sustainable supply and use of raw materials, able to meet changing population needs within the limitations of natural resources and ecosystems.

It should be noted though, that SC5's weighting of focus and prioritisation has clearly been more on the adaptation and resilience component of climate action, together with resource efficiency and raw

[6] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0015
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:80:FIN
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1582103368596&uri=CELEX:52016DC0860
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN

materials (and that mitigation can be considered as being more within the overall focus of other SCs, such as SC3 for energy and SC5 for transport).

A set of specific R&I-based activities are defined under SC5 with the aim of enhancing the transition to a more climate neutral and resilient, resource efficient, and competitive Europe while also contributing to the UN Sustainable Development Goals (SDGs) and to the Paris Agreement. The focal topics include:

- Climate science (e.g., providing support to improved understanding and closing of knowledge gaps in climate science and for IPCC reports, and for developing next generation Earth System Models).
- Earth observation (providing timely and appropriate information/data on climate, energy, natural hazards).
- Mitigation (e.g. providing scientific support to designing mitigation pathways and policies, and supporting climate policies to deliver the Paris Agreement, negative emissions, and land-use based mitigation assessments).
- Adaptation and resilience (where adaptation is considered as distinct but complementary to resilience, and as a broad and overarching concept within SC5, not from a narrower perspective, such as nature-based solutions and the Circular Economy which can be framed as more cross-cutting or transversal).
- Nature-based solutions (providing viable solutions from natural ecosystems, e.g. for carbon-neutral cities and improved air quality).
- Systemic eco-innovation, critical raw materials and the Circular Economy (generating and sharing economic, environmental and societal benefits).
- Social and behavioural science for climate action.

2.6. The Joint Research Centre's contribution to the Green Transition

In addition to the activities of Horizon 2020, the Joint Research Centre (JRC) contributes to the Green Transition through various work strands. The activities of the JRC are being assessed by an independent expert panel in the course of the ex-post evaluation of Horizon 2020. Taking into account the relevance of the JRC activities for the Green Transition, the following paragraphs provide a synthetic overview on the activities of the JRC in 2014-2020 related to the Green Transition, based upon the JRC briefing to the Horizon 2020 ex post evaluation panel[11] which has been informed through independent expert assessments[12].

The JRC's allocated human resources relevant for the 'Green transition' theme amount to 4,300 FTEs over 2014-2020, making up about 31 % of its total research staff. This is the largest segment of the JRC's activities under the Horizon 2020 ex post evaluation themes.

In 2014-2020, almost 3,700 articles authored/co-authored by the JRC and related to the 'Green transition' theme were published, making up nearly 46 % of the JRC's total number of publications in the same period. The publications provided by the JRC demonstrate the high quality of the JRC's research, also in comparison with top organisations with similar characteristics: 39 % of the articles are among the 10 % most-cited in the area, and over 7 % among the 1 % most-cited. The field-weighted citation index is 2.8 and the five most-cited articles – spread over different subthemes – have received a lot of attention among the scientific community, gathering thousands of citations. Almost 60 % have been published in the top 10 % most-cited journals. Overall, on average, the publications related to this theme scored above the JRC average.

[11] Joint Research Center (2022), The JRC in Horizon 2020 and Euratom 2014-2020: Thematic area - The green transition, Report to the ex post evaluation panel, March 2022.
[12] In the context of this evaluation, several JRC representatives were invited for an interview, but all declined.

An independent expert evaluation of 21 activities of the JRC showed that, against 11 criteria for impact on policymaking, impact on scientific and public debate and the long-term societal effects, the JRC has been instrumental to several or all stages of the policymaking cycle.

The intervention of the JRC for each Societal Challenge is presented in the relevant following sections.

2.7. The European Partnerships for Research and Innovation's contribution to the Green Transition

In European R&I policy making, the European Partnerships for Research and Innovation focus around three main rationales, which have developed over time: (1) alignment of the fragmented European Research Area, (2) strengthening the competitiveness of the EU and (3) tackling Societal Challenges and contributing to transformation. In Horizon 2020, two major partnership instruments existed – Public-Public Partnerships (P2Ps) and Public-Private Partnerships (PPPs).

In H2020, the following types of Public-Public-Partnerships exist:

- ERA-NET Cofunds: ERA-NETs aim at (1) facilitating the exchange of good practices, (2) identifying common strategic issues and (3) planning and implementing joint research programmes and activities, in particular joint calls between national R&D programmes. Under Horizon 2020, the ERA-NET instrument and the ERA-NET Plus instrument existing in FP7 were merged into the ERA-NET Cofund instrument to simplify the mix of instruments. The main purpose of the Cofund was to supplement individual calls or programmes funded by entities other than EU funding bodies, managing an international research and innovation programme.

- Article 185 of the Treaty on the Functioning of the European Union (TFEU) provided the opportunity for long-term collaboration between the EU Member States and the EC. The ambition of Article 185 partnerships is to achieve scientific, managerial and financial integration among national research programmes in a given field.

- Joint Programming, launched in 2008 by a Communication of the Commission and following the Conclusions of the Council, is a research and innovation policy concept driven by Societal Challenges. It aims to tackle grand Societal Challenges through more efficient use of resources by aligning funding at the national level and decreasing fragmentation in the European Research Area (ERA).

In H2020, the following types of Public-Private-Partnerships exist:

- Article 187 Joint Undertakings: Strengthening industrial innovation and enabling technological leadership were the key ambition of Public-Private Partnerships (PPPs), which were first launched in FP7. Joint Technology Initiatives (JTIs) based on Article 187 TFEU (ex Article 171 TEC) are long-term PPPs that are managed within dedicated governance structures (Joint Undertakings), whose members include 1) the European Commission, 2) a not-for-profit industry-led association and, 3) EU Member States and Associated States. The core ambition of these partnerships is to boost industrial innovation by providing a clear framework for joint research investment of industry, the Member States and the European Commission.

- The EIT Knowledge and Innovation Communities of the European Institute of Innovation and Technology have been part of the Partnership landscape in Horizon 2020. The European Institute of Innovation & Technology (EIT) is an independent body of the European Union set up in 2008 to deliver innovation across Europe. The EIT brings together leading business, education and research organisations to form dynamic cross-border partnerships. These are called Knowledge and Innovation Communities (KICs), and each is dedicated to finding solutions to a specific global challenge. Since 2010, the EIT has launched eight KICs . EIT Knowledge and Innovation Communities (EIT KICs) are dynamic and creative partnerships that harness European innovation and entrepreneurship to find solutions to major Societal Challenges in areas with high innovation potential – and create quality jobs and growth.

The evaluation of the Framework Programme activities related to the Green Transition provided an analysis of partnerships with a legal obligation for an individual evaluation, i.e. Art. 185 and Art. 187

Initiatives and EIT KICs, for which individual evaluation reports will be provided in the course of the Interim Evaluation of Horizon Europe. For the Art. 185 initiative PRIMA, a full evaluation report was already provided in Phase 1 of the project. Furthermore, this evaluation considered relevant ERA-NETs and Joint Programming Initiatives linked to the Framework Programme. The analysis performed in this evaluation comprised: 1) a quantitative project portfolio analysis for Art. 185 and Art. 187 partnerships based upon eCorda and a portfolio analysis of projects based upon data provided by ERA-LEARN[13], 2) bibliometric analysis on the cPPP and Art. 187 partnerships and EIT-KIC Partnerships, 3) desk research and interviews preparing the individual Art. 187, cPPP and EIT-KIC partnership evaluations, and 4) an analysis of relevant ERA-NETs in the course of the portfolio case studies performed in the SCs.

The table below presents an overview of the partnerships within the scope of the evaluation.

[13] www.era-learn.eu

Table 2. Summary of Article 185 and 187 Partnerships

Name	Year Established	Societal Challenges	Objective	Approach	Budget[14]	Main Stakeholders (type, number)	Targeted Outcomes
Partnership for Research and Innovation in the Mediterranean Area	2017	SC2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy SC5: Climate Action, Environment, Resource Efficiency & Ra Materials	To build R&I capacities and to develop knowledge and common innovative solutions from agro-food systems To make those systems sustainable, and for integrated water provision and management in the Mediterranean area To make those systems and that provision and management more climate resilient, efficient, cost-effective and environmentally and socially sustainable To contribute to solving water scarcity, food security, nutrition, health, well-being and migration problems upstream	Support the increased coordination of national research and innovation agendas by funding projects, supporting innovation and policy, and monitoring and evaluation of the implementation of the PRIMA programme. Support all types of re-search and innovation activities, including research, development and innovation projects, innovative demonstrators and pilot plants, capacity building, training, awareness-raising and dissemination actions, and researcher mobility, addressing a wide range of Technology Readiness Levels and ensuring an appropriate balance between small and large projects Across three thematic areas: management of water; farming systems; agro-food value chain	494 EUR million (2018-2021)	1571 beneficiaries from education, research, public authorities, business (2018-2021)	Address the Mediterranean region's environmental, sustainability and socio-economic challenges by contributing to the development of its R&I ecosystem and better regional coordination and integration
Bio-based Industries (now Circular Bio-based Europe)	2014	SC2: Food Security, Sustainable Agriculture and Forestry, Marine and Maritime and Inland Water Research and the Bioeconomy	To contribute to a more resource-efficient and sustainable low-carbon economy To increase economic growth and employment, in particular in rural areas, by developing sustainable and competitive bio-based industries in Europe	Demonstrate technologies for enabling new chemical building blocks, new materials, and new consumer products from European biomass Develop business models to integrate economic actors along the value chain Set up flagship biorefinery plants to deploy the technologies and business models, demonstrate cost and performance improvements that are competitive with fossil-based alternatives Across three main areas: feedstock, bio-refineries; market, products and policies	3.7 EUR billion	1880 participants from education, research, businesses, public bodies	Replace 25% of oil-based chemicals by 2030, provide 10 times more bio-based materials Drastically reduce EU's dependency on the import of strategic raw materials, such as protein (by 50%), phosphorus and potassium (by 25%) Cut greenhouse gas (GHG) emissions by 50% Create up to 700,000 green jobs by 2030, especially in rural and coastal areas, diversifying and

[14] For 2014-2020, unless otherwise mentioned

Name	Year Established	Societal Challenges	Objective	Approach	Budget[14]	Main Stakeholders (type, number)	Targeted Outcomes
							growing farmers revenues
Clean Sky 2	2014	SC4: Smart, Green and Integrated Transport	To contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviatio To develop a strong and globally competitive aeronautical industry and supply chain in Europe	Provide grants for research and innovation actions and other innovation measures Bring together the relevant partners to achieve innovative technology and full-scale demonstrators Create operational and marketable solutions Stimulate involvement of SMEs Ensure collaboration and cooperation with related European, national and transnational activities and related Joint Undertakings Engage in information, communication, exploitation and dissemination activities Liase with a broad range of stakeholders	1,755 EUR billion	2317 participants from education, research, businesses, public bodies, lower involvement of public bodies than other partnerships	Integrate, demonstrate and validate technologies capable of: (i) increasing aircraft fuel efficiency, thus reducing CO_2 emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014 (ii) reducing aircraft NOx and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014
Fuel Cells and Hydrogen (now Clean Hydrogen)	2008	SC3: Secure, Clean and Efficient Energy	To make Europea a global leader in FCH and enable market breakthrough	Establish and manage the JTI Design and implement a Multi-Annual Implementation Plan Ensure good operation of the RTfD Transparent and fair competition in particular for SMEs Across three pillars: transport, energy and cross-cutting	665 EUR million	545 participants from businesses, research and education, particularly high participation from SMEs	Mitigate climate change Economic growth and jobs creation Reduce time to market Strengthen the European Research Area
Single European Sky ATM Research[15]	2007 (including prior versions)	SC4: Smart, Green and Integrated Transport	Strengthen and integrate the Union's research and innovation capacity in the ATM sector, making it more resilient and scalable to fluctuations in traffic while enabling the seamless operation of all aircraft Strengthen, through innovation, the competitiveness of manned and unmanned air transport in the Union, and ATM services'	Exploratory research Industrial research and validation Fast-track innovation and uptake Digital sky demonstrators	Approximately 1,600 EUR million	2300 participants from businesses, education, research and public bodies	Strong and integrated R&I capacity in the ATM sector Competitiveness of manned and unmanned air transport and ATM services markets Efficient and environmentally friendly single European sky airspace

[15] The following information is for SESAR 3, unless otherwise mentioned.

Name	Year Established	Societal Challenges	Objective	Approach	Budget[14]	Main Stakeholders (type, number)	Targeted Outcomes
			markets to support economic growth in the Union Develop and accelerate the market uptake of innovative solutions to establish the Single European Sky airspace as the most efficient and environmentally friendly sky to fly in the world				
Shift2Rail	2014	SC4: Smart, Green and Integrated Transport	Achieve the Single European Railway Area (SERA) through the removal of remaining technical obstacles enhance the attractiveness and competitiveness of the European railway system retain and consolidate European rail industry's leadership on the global market	Cost-efficient and reliable trains, including high-capacity trains and high-speed trains Advanced traffic management and control systems Cost Efficient, Sustainable and Reliable High Capacity Infrastructure IT Solutions for attractive railway services Technologies for sustainable and attractive European rail freight	745 EUR million	1464 participants from education, research, businesses and public bodies	Reduced system costs: 50% reduction in lifecycle costs for goods and services in the sector 100% increase of capacity of rail to transport passengers and goods Improved services and customer quality: 50% increase of reliability and punctuality of services Simplified business processes Reduced development and productions costs of innovative technologies Enhanced interoperability and safety: Removal of technical obstacles

Table 3. Summary of EIT Knowledge and Innovation Communities

Name	Year established	Societal Challenges	Objectives	Approach	Budget[16]	Main Stakeholders (type, number)	Targeted Outcomes
EIT Urban Mobility	2019	SC4: Smart, Green and Integrated Transport SC3: Secure, Clean and Efficient Energy (operationalized after Horizon 2020)	Create liveable urban spaces Close the knowledge gap Deploy green, safe, inclusive mobility solutions for people and goods Accelerate market opportunities Promote effective policies and behavioural change	Deliver solutions (business creation) Provide impact (factory) Build capacities (academy) Creatie options (innovation) Enable change (city club)	KAVA: 33.1 EUR million KCA: 87.3 EUR million (2020)	Businesses, research, education and cities 250 partners 414 participations in KAVA	Strengthen a multimodal transport system connecting people to jobs, education, and leisure, and expanding equitable access to mobility Expand clean and efficient city logistics for goods deliveries for business and people, Enhance a mobility system that protects and fosters people's health and wellbeing Support a green and human-friendly urban environment, and inclusive design principles Enable Europe's urban mobility sector to lead sustainable urban mobility transformation
EIT Climate	2010	SC5: Climate Action, Environment, Resource Efficiency & Raw Materials	Help Europe avoid over 500 million tonnes (CO_2eq) of emissions Strengthen the resilience of 10 million people to the impacts of climate change[17]	Knowledge and capacity building, which provides high-quality academic training for post-graduate students for the development of entrepreneurship skills Technology and innovation, which focuses on providing support to close-to-market projects Market and business, focusing on entrepreneurship and providing a range of support and business coaching for start-ups and SMEs	KAVA: 668.5 EUR million KCA: 1,743.7 EUR million (2014-2020)	Businesses, start-ups, scientific institutions and universities, city authorities and other public bodies, and citizens 2,105 participations in KAVA	Help leverage over EUR100 billion to support the scale-up of innovations to tackle climate change Generate 50,000 green jobs Become the strategic partner of choice for over 50 cities, regions, and countries across Europe, and through innovation achieve net-zero emissions and climate resilience aligned to the 2015 Paris Climate Change Agreement

[16] KAVA: KIC Added Value Activitites; KCA: KIC Complementary Activities
[17] As per 2019-2023 Strategy, objectives for 2027

Name	Year established	Societal Challenges	Objectives	Approach	Budget[16]	Main Stakeholders (type, number)	Targeted Outcomes
							Enhance the innovation and entrepreneurial skills of over 200,000 people across Europe, equipping them to be leaders of climate action, including supporting 1260 EIT Label graduates through blended and digital learning and at least 82 Higher Education Institutions.
EIT InnoEnergy	2010	SC3: Secure, Clean and Efficient Energy	Become the leading engine for innovation and entrepreneurship in sustainable energy	Provide services for privileged access to helping corporates with the energy transition Connects ideas and industry, innovators and business partners to increase time to market of innovative products, services, and solutions that have high commercial potential. Aims to boost the success rate of start-ups, power the growth of scale-ups and SMEs and help corporates to de-risk their innovation strategies for new businesses Provide PhD and Master courses that combine engineering and technical knowledge with commercial awareness and entrepreneurial spirit for the workforce that is able to address the sustainable energy revolution and achieve a sustainable European energy industry. Across key themes: energy for circular economy, energy storage, energy efficiency, energy for mobility and transport, renewable energies, smart and efficient buildings and cities, smart electricity grid, nuclear instrumentation	KAVA: 620 EUR million KCA: 1511.1 EUR million (2014-2020)	Innovators, start-ups and scale-ups, and students and learners 430 partners 937 participations in KAVA	Contribute to a faster energy transition Bring a constant pipeline of sustainable energy innovation to the market Enable a European energy innovation ecosystem

3. Evidence of Findings per Societal Challenge

This section presents the findings, organised per evaluative criteria, for each Societal Challenge under the scope of this evaluation. For each societal challenge, a detailed intervention logic is presented in Annex IV.

3.1. Societal Challenge 2 'Food, Agriculture, Water and Bioeconomy'

3.1.1. State of Play

Horizon 2020 moved away from a linear, sectoral, and technology-driven intervention logic with a clear shift towards environmental objectives and impact and cross-sectoral activities. In line with the relevant strategies such as the Farm-to-Fork strategy and the Green Deal[18], developed during the Horizon 2020 implementation period, the last Horizon 2020 Work Programme reflected the growing awareness that the existing approaches cannot be considered sustainable per se. Here, not only the potential to reduce CO_2 is of high relevance, but the simultaneous land intensification and related negative sustainability effects as well as social (food security, health, rural living) issues have to be addressed. It also increasingly aimed to break up sectoral isolation and to foster cross-sectoral activities on land (e.g. different application sectors using biomass, innovation along food value chains) and sea (transport, fisheries, tourism, aquaculture, wind farms).

The state of play on Food, Agriculture, Water and Bioeconomy issues is heterogeneous across the EU:

- the geographical context differs greatly in the EU, with very different importance and characteristics of the different types of primary production (e.g. coastal areas, countries with large forestry, etc.) and related industries; and

- various foci have emerged at different times and are in different stages of maturity. On one hand, the Blue Growth focus area mainly addresses early stage approaches so outputs rather than long-term impacts can be expected. On the other hand, for bio-based products, the flagship projects aim to de-bottleneck upscaling and it can be expected that an increasing number of products is getting very close to market entry.

This Societal Challenge benefits from a total budget of EUR 3.54 billion from 2014 to 2020 across 687 projects (EUR 821.5 million across 142 projects, if including the Art. 187 partnership Bio-based industries). The project portfolio is further defined below.

3.1.2. Relevance

3.1.2.1. Strategic priority setting and response to emerging needs

SC2 addresses a broad range of challenges and thematic areas that are associated with the transition from a fossil-based economy towards the use of biological and renewable resources. It spans from sustainable production of nutritious and healthy foods, and raw materials from land and water sources, to a bio-based economy that provides jobs and green growth both in rural and urban regions. It seeks to find solutions to the major challenges facing Europe (as well as the world). Although no comprehensive EU strategy across those thematic fields or challenges was elaborated, the thematic targets of SC2 are prominent in the EU Flagship Initiatives of Europe 2020 "A Strategy for smart, sustainable and inclusive Growth" (2010)[19] and various major European and national policies and strategies. Very important are the European[20] or national European Bioeconomy strategies, the Blue Growth Strategy or the Common Fisheries Policy (CFP) and the Common Agriculture Policy (CAP) and many more.

[18] Three strategies complement other relevant strategies for primary production with agriculture, forestry and marine/maritime, hence the Common Fisheries Policy (CFP), the Common Agriculture Policy (CAP) and the EU Forest Strategy or further develop former strategies such as the Bieoconomy Strategy first launched in 2012.
[19] EC (2010) COM_2010_092: EUROPE 2020 A strategy for smart, sustainable and inclusive growth
[20] European Commission, Directorate-General for Research and Innovation, Innovating for sustainable growth : a bioeconomy for Europe, Publications Office, 2012, https://data.europa.eu/doi/10.2777/6462

Against this background, the legal basis in SC2 addresses a broad range of challenges that are associated with the transition from a fossil-based economy towards the use of biological and renewable resources and therefore the need for sustainable primary production and processing systems. This includes the addressment of key global challenges including the adaptation to and mitigating of climate change; ensuring food security; safeguarding the natural resource base, promoting alternatives to fossil-based economies and sustainably using marine resources while protecting the oceans. The legal basis defines 5 broad lines of activities that aim to achieve socio-economic, but also environmental goals ("Sustainable agriculture and forestry", "Sustainable and competitive agri-food sector for a safe and healthy diet", "Unlocking the potential of aquatic living resources", "Sustainable and competitive bio-based industries and supporting the development of a European bioeconomy", and "Cross-cutting marine and maritime research".

The analysis of the basic act and Work Programmes (WPs) shows that distinct pathways to impacts can be identified that connect the activities carried out within the WP with identifiable effects (outcomes). The table below provides an overview of the pathways to impact derived from the related documents as well as of their expected outcomes identified in the analysis regarding SC2.

Table 4. Pathways to impact and expected outcomes for SC2

Technology & Innovation	Knowledge & Capacity	Coordination & Collaboration	Market & Business	Policies & Standards
Solutions (including social innovation) in rural areas for inclusive growth Sustainable supply of biomass from agricultural, aquatic, industrial, and municipal origins Circular Bioeconomy Solutions New food, feed, fibre and other bio-based products and processes with minimised inputs Solutions across technology fields and sectors Solutions for sustainable food systems and healthy lifestyles More sustainable agriculture and forestry management Increased TRLs and upscaling of pre-existing solutions	Improved understandings of systems and interactions across sectors Improved knowledge, infrastructure and capacities for upscaling bio-based products Strengthened R&I capacities Strengthened human potential in R&D in business and academia Improve current European marine, land and fauna observing, surveying and monitoring capabilities and resources	Cross-border and cross-sector coordination and integration of R&I efforts Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels Science diplomacy in collaboration with third countries International cooperation and networks to address common challenges and explore synergies Community and networks for improved stakeholder involvement Coherence and synergies within the EU, the regional, and the national R&I landscape(s)	Removal of barriers to market entry Reduced time to market for bio-based products Support for market creation Provision of Competitive bio-based products to substitute fossil-based ones Development of inclusive value chains (primary production, industry, distribution) Better access to finance for SMEs	Harmonised, well-understood indicators for sustainability of food and bio-based value chains Improved understanding of socio-economic trends and prospects related to food and healthy consumption and bio-based products New and improved standards and certification system for bio-based products Support to robust and transparent policy-making Citizens' engagement and participatory governance of the Bioeconomy

The expected outcomes show that the WPs operationalise desired results that are in line with how SC2 is specified in the legal base. Furthermore, the results of the project survey show the addressed needs and challenges in relation to SC2 by the supported projects (see figure below). When beneficiaries were asked to which extend different challenges were addressed by their project, the challenge which was named to a high or a very high degree was “Enable sustainable exploitation of natural resources” (78 %), followed by “Supply sufficient food, feed, biomass and other raw materials” (54 %) and “Foster innovation in rural and coastal areas” (52 %). On the other end, 25 % of the respondents considered their project to address the challenge “Maximise social and economic benefits from Europe’s oceans, seas and inland waters” to a large or very large extent.

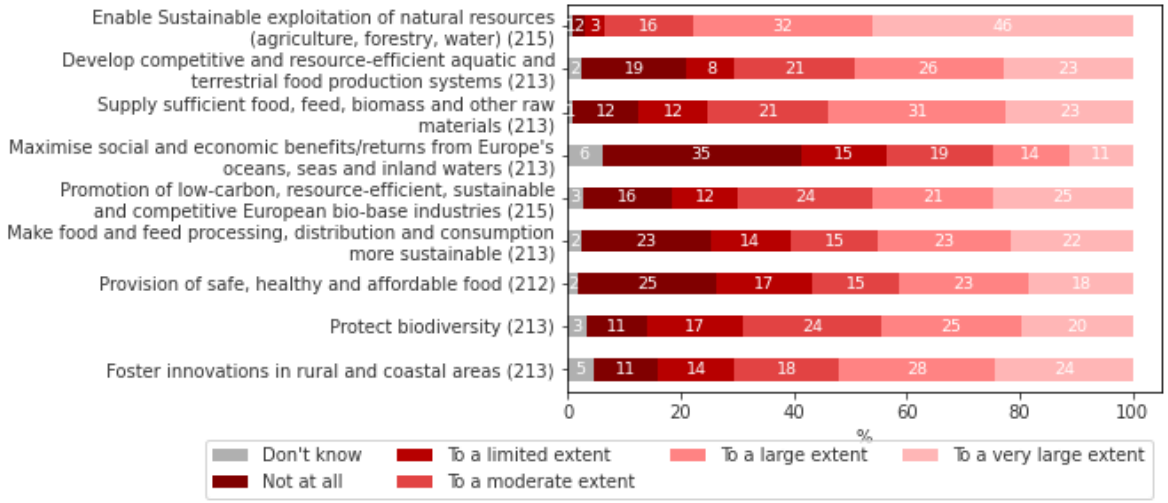


Figure 2 Responses to the question 11: “To what extent does your project address the following needs and challenges?”

Source: Survey analysis, number of respondents between brackets

The figure below shows Horizon 2020’s WPs in SC 2 and how they have progressed thematically through their respective calls during 2014-2020 (with respect to SC2). The WPs are structured within the following four major focus areas with specific goals and objectives:

- **Sustainable Food Security (SFS)**: meeting a growing demand for food worldwide while also providing healthy food, enabling healthy consumption and reducing negative environmental and societal impacts.

- **Blue Growth (BG):** unlocking the potential of aquatic living resources while protecting ocean and inland water environments.

- **Rural Renaissance (RUR):** harnessing opportunities for sustainable growth in rural areas, leading to more and better jobs, a better environment, and better social and territorial cohesion.

- **Bioeconomy:** Strengthening the European bioeconomy.

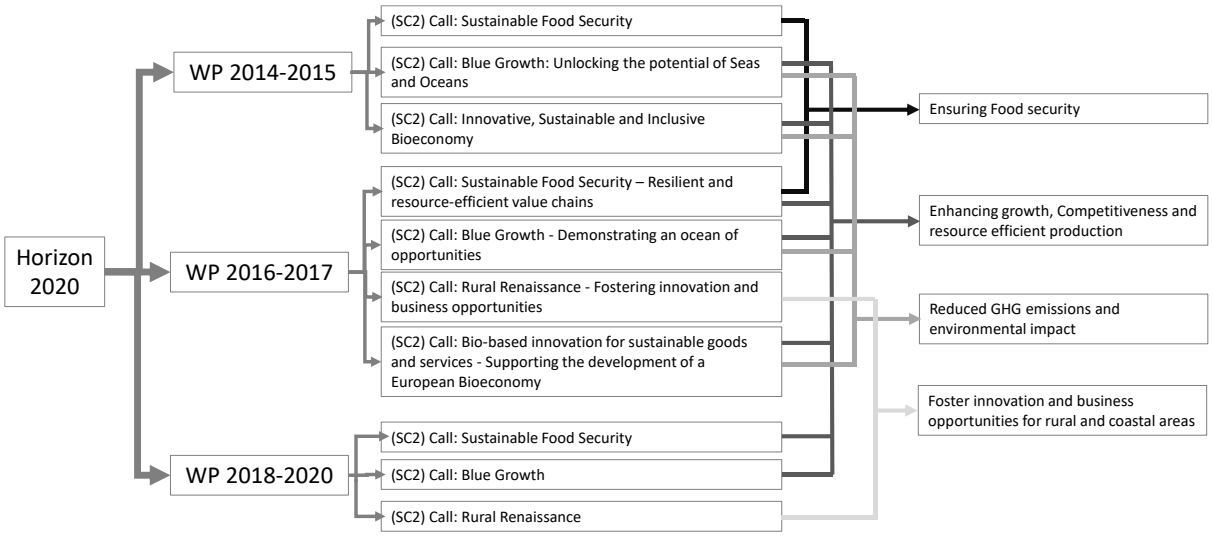


Figure 3 Horizon 2020 SC 2 Calls and their WP focus/ priority areas

Source: Own elaboration

Across these focus areas, the emphasis in the first two WPs was on socio-economic objectives, to strengthen the competitiveness and foster growth for the given sectors whereas the third WP reflects the growing awareness of the need to improve sustainability also for the bio-based sectors themselves. Thus, there were two relevant developments driven by Horizon 2020 (Horizon 2020): First, the aim to break up sectoral isolation and to foster cross-sectoral approaches, and second, the shift towards environmental objectives and impact. Thus, SC2 is well in line with the relevant strategies such as the Farm-to-Fork strategy and the Green Deal, which were developed in parallel to the ongoing Framework Programme (FP).

Originally many of the topics followed a rather linear, sectoral, and technology-driven intervention logic. But with the introduction of Horizon 2020 and over the course of the Framework programme, there has been a clear development towards the interrelatedness of topics, the environmental focus and the systemic approach. This development mirrors the results of the expert interviews, the alteration of WPs and in the contents of related strategy documents (e.g. Food 2030, Updated Bioeconomy Strategy). For example, four out of the ten Food 2030 Pathways for Action explicitly refer to food systems, instead of value chains or the like. Similarly, while earlier WPs in SC 2 focused on exploring new opportunities for exploiting marine biological resources, WP 18-20 saw an expansion in objectives towards also finding sustainable harvesting methods for those resources. Moreover, during Horizon 2020 the orientation to the goals of the Green Transition has increased, although the latter have only been made explicit towards the end of Horizon 2020 – with the update of the Bioeconomy Strategy in 2018[21], which included "healthy conditions of ecosystems" as key priority, and the launch of the European Green Deal, including the Farm-to-Fork Strategy.

More concretely, in the WPs of SC2, the overarching goals did not change significantly. Environmental issues had been prominently flagged already, but the third WP actually promoted those goals more directly whereas purely socio-economic considerations grew less important. Different products and industries (e.g. bio-based products) were no longer considered sustainable per se: Instead, following a more critical approach, it was aimed to make them more sustainable as well. Still, there are challenges how to address potential goal conflicts that arise on a macro level in R&D&I funding (e.g. usage conflicts of renewable resources, higher biomass demand for successful bio-based products, etc.).

[21] European Commission, Directorate-General for Research and Innovation, A sustainable bioeconomy for Europe : strengthening the connection between economy, society and the environment : updated bioeconomy strategy, Publications Office, 2018, https://data.europa.eu/doi/10.2777/792130

3.1.2.2. *Appropriateness of the programme portfolio*

A total budget of EUR 3.54 billion was allocated by the European Commission (EC) to SC2 projects since 2014, resulting in a total of 687 projects. This includes one Art. 187 partnership (Bio-based industries) with EUR 821.5 million, resulting in 142 projects. Among the four focus areas of SC2, SFS line received the highest funding and has shown a very strong increase over the course of Horizon 2020. This reflects that agricultural research had a strong renaissance and the "return" of DG Agri to research and innovation. A thematic portfolio analysis of the 687 SC2 projects revealed that the largest share of EC contribution was attributed to the thematic cluster of bio-based industries (145 projects/ EC contribution of EUR 1,235 million), followed by sustainable food production (109 projects; EUR 620 million) (figure below). However, it should be noted that the activities in the cluster of bio-based industries almost exclusively stem from the Art. 187 Bio-based Industries Joint Undertaking (BBI-JU). This distribution reflects the broad scope of goals and topics lined out in the legal basis of Horizon 2020. Again, there are many thematic overlaps between the clusters (and the underlying Horizon 2020 topics).

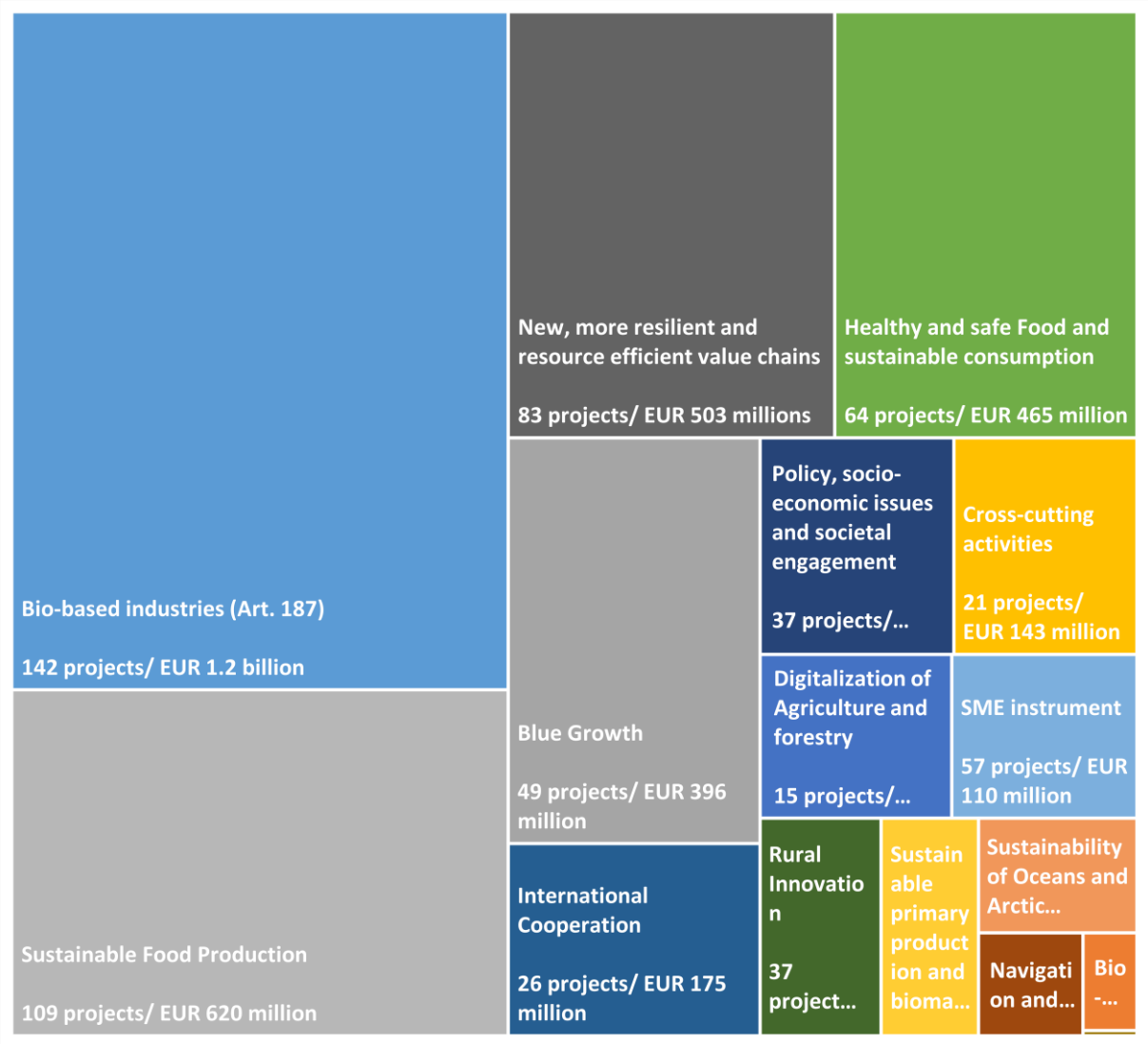


Figure 4 Distribution of EC contributions spent on SC2 projects to clustered sections

Source: eCorda, own elaboration

An analysis of a set of 100 randomly selected SC2 projects revealed a very high fit of project goals with the goals of Horizon 2020. This analysis also revealed a strong thematic overlap between call topics, therefore there are many examples of thematically closely related projects, which are funded under different calls. This was partially due to the fact that topic were continued over the three Work

Programmes. However, there also seems to be a high thematic overlap between Sustainable Food Security (SFS) and Rural Renaissance (RUR). The case study on sustainable soil management in agriculture (Case study 1) also supports this finding as beneficiaries reported that from their perspective there was not difference whether their project was funded under SUS or RUR.

An analysis of the funding instruments in place reveals a high R&I focus: Based on their numbers, RIAs and IAs are the most dominant project types (RIA: 313 projects/ 45.5 % of projects; 41 % of EC contribution; IAs: 166 projects/ 24 % of projects; 56.6 % of EC contribution). 14.7 % of the EC budget was attributed to 126 CSAs (18.3 % of the projects). The SME-II instrument is of minor importance with only 82 projects (11.9 %) accounting for 4.3 % of the EC contribution. This distribution is well in line with the findings from the survey, case studies and interviews that the instrument in SC2 puts a stronger focus on technology and innovation than on market and business development (see also Annex V).

Regarding the type of beneficiaries, businesses show the highest participation rates, with 92 % of projects exhibiting at least one business participation, and with on average six enterprises participating in each project. Entreprises were the recipient of 32% of overall EC contributions to SC2, with slightly half of that amount going to BBI-supported entreprises (15% of overall EC contributions) suggesting that this strong industry focus differs between different programme parts and instruments. This compares to 31% of SC2 overvall budget going to research organisations and 27% to higher or secondary education establishments. Projects involving at least one education (76 %) or research organisations (82 %) are also frequent, whereas public bodies only take part in 37 % of all projects. However, other organisations (NGOs, public sector organisations) participate in 91 % of projects, showing a high involvement of non-research and non-business stakeholders. Furthermore, the share of new participations is highest for the group of private for-profit entities (62.2 %) and other organisations (67.7 %), suggesting that the multi-stakeholder approach enabled the engagement of new stakeholder groups. This data is well in line with the qualitative findings that significant progress was made towards the implementation of the multi-stakeholder approach.

The evolution of the EC contribution per project by year of calls increased from EUR 4.6 million in 2014 to EUR 6.3 million in 2020. Considering the different funding instruments, IAs and RIAs increased in size (the average EC contribution for IAs increased from EUR 5.5 million in 2014 to EUR 8.1 million in 2020, for RIAs the average EC contribution increased from EUR 5.6 million to EUR 6.6 million) whereas the sizes of CSAs and the SME-II instrument projects fluctuated but remained stable overall.

Collaborations of disciplines and across stakeholder groups, also beyond project consortia, are considered highly relevant for the dissemination and implementation of project results, and thus to eventually achieving progress towards the Green Transition. The survey thus asked beneficiaries how intensely their project had collaborated with stakeholders outside the project consortium. The intensity of collaboration was by far the highest for collaborations with research organisations (59 % collaborated or co-led) and Higher Education Institutions (56 %). The lowest level of collaboration intensity was identified with regards to Research Funding Organisations (14 %) and NGOs (19 %).

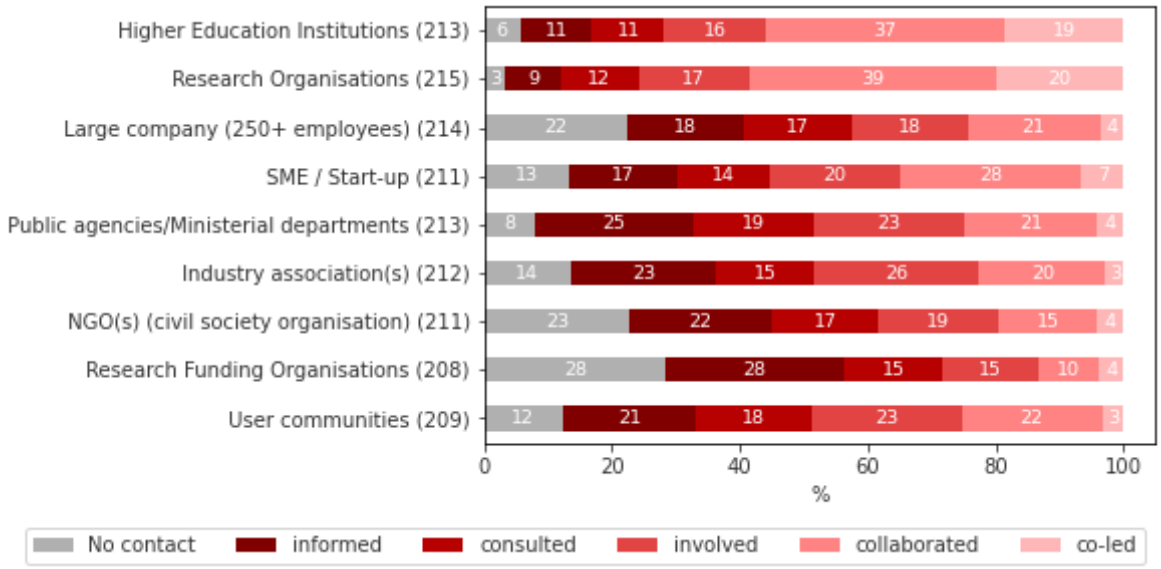


Figure 5 Response to survey question 'How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?' (Q12)

Source: Survey analysis, number of respondents between brackets

All in all, the survey shows that collaboration among different stakeholder groups took place. However, the qualitative analysis (i.e. the case studies) also revealed that projects experienced difficulties to fully meet the requirements for stakeholder engagement (see also section 3.1.4.3).

3.1.3. Coherence of the intervention

One Art. 187 (BBI JU) and one Art. 185 (PRIMA) partnership were mostly financed through SC2 together with other Horizon 2020 instruments. Moreover, the EIT Food is closely related to SC 2. On the EU funding level, links to other programmes exist. The interim evaluation report of the BBI JU[22] states that the development of a sustainable bio-based economy required an integrated approach and an array of instruments addressing various research and innovation needs. The BBI JU focuses rather on high TRL and IAs compared to the SC programme in total. Regarding PRIMA, the evaluation report which was a part of the Green Transition Study, finds no indications of coherence shortcoming between PRIMA and other programmes including SC2 Lastly, the evaluation indicates coherence between EIT Food's activities and the FP in general. Indeed the partnership has been designed expressly to close the gap between applied research and the market, so that complementarity to ongoing initiatives forms one of its key partnership principles. This reflects in its organisational structure, i.e. its Advisory Policy Council, and its close engagement with relevant DGs and in the Food 2030 policy process (see Partnership Analysis).

Various ERA-NET and European Joint Programming Initiatives were of high relevance for SC2, namely the EJP SOIL, JPI FACCE, Oceans, ERA-NET Cofund on Blue Bioeconomy, ERA-Net Cofund on Sustainable Food production and consumption (SUSFOOD2), Maritime and Marine Technologies for a New ERA, and the ERA-NET on Sustainable Animal Production Systems. The Platform of bioeconomy ERA-NET actions was set in place to ensure coherence among many of those initiatives, to increase collaboration among actors, to foster inclusiveness, to increase capacities for efficient and effective ERA-NETs, and to inform research policy making.

Overall, SC2 has a unique position in the R&DI landscape in Europe for the related topics regarding the funding of applied research and innovation support in international consortia (see Annex V). While a few Member States provide significant national funding (e.g. Germany), many Member States do not. Moreover, overall the programmes can be assessed as coherent to other existing funding

[22] Wohlgemuth, R., Gardossi, L., Pursula, T., Cichocka, D., Vandamme, E., & Reid, A. (2017). Interim Evaluation of the Bio-based Industries Joint Undertaking (2014-2016) operating under Horizon 2020.

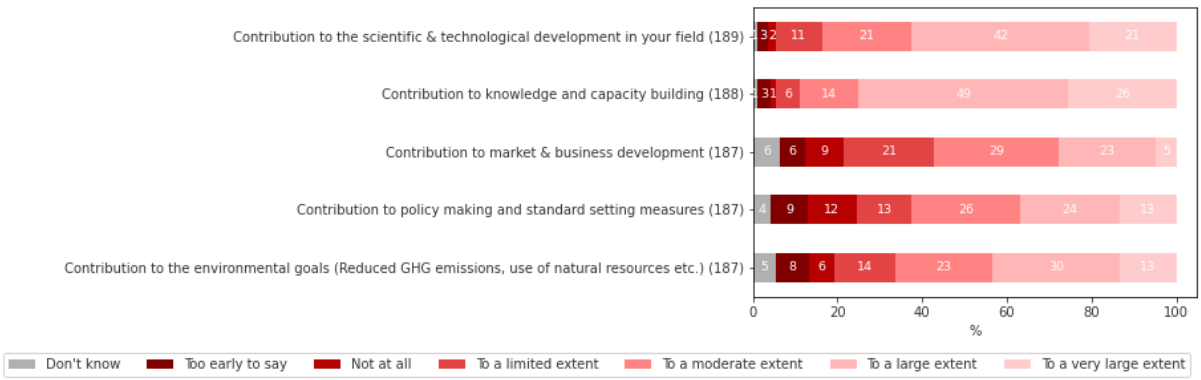
possibilities (e.g. from the EIB for funding for projects in the bioeconomy). This has been confirmed by the experts interviewed on the (i.e. experts with a good overview on the SC as a whole like EC representatives) SC level, as well as by the case studies: For example, for food processing the respective case study (Case study 3) revealed that EU funding is able to provide some sort of coherent R&I activities regarding relevant objectives which are outside the immediate interests of the Member States. Since the EU is responsible for regulating a large part of food production, the Framework Programmes thus allow to conduct R&I from a perspective that matches that of policy making. For bio-based innovations and other specific topics like the exploitation of marine resources, EU funding is of high importance for most Member States because only few of them – those with large R&I budgets – offer dedicated national funding on corresponding projects topics.

Horizon 2020 is complementary to other schemes because it funds fundamental research at the international level, bringing together the best expertise in Europe. While there is no comprehensive data available on the national spending for the "Food, Agriculture, Water and Bioeconomy" area, there are indications from various studies in some of the topics[23], the case study and the evaluations on coherence[24] that Horizon 2020 fills an important gap in the research funding system and has high relevance. Moreover, for the bioeconomy the recent progress report on the 2018 Bioeconomy Strategy Action Plan concludes that substantial progress has been achieved to encourage the adoption, update and coherence of national and regional bioeconomy strategies throughout Europe. There are currently ten EU Member States with dedicated bioeconomy strategies and seven EU Member States that are in the process of developing their respective strategies.

3.1.4. Effectiveness of the intervention

As pointed out in the previous sections, SC2 covers a broad range of topics and goals, therefore also the results are rather diverse. On a project level, the scoping interviews and the case studies provided evidence that many projects are on track to make significant progress. Regarding the outcome pathways indicated in table 1, for relevance, rather all domains are addressed by the interventions, as projects are expected to integrate the different dimensions.

The survey reveals that SC2 has contributed to all innovation dimensions considered (i.e. science and technology, knowledge and capacity building, market and business development, policy and standards, environmental goals) (figure below). Among these, scientific and technological development and knowledge and capacity building ranked highest (84 % and 89 %, respectively, of the respondents report that their project was successful to a moderate, large or very large extent) underpinning the strong research focus of SC2, while the contributions to market and business development ranked lowest (58 %). It has to be noted, that these numbers are based on project counts, while market and business development as well standard-setting is in particular in high focus of certain calls (e.g. Flagship-projects in certain BBI call lines, CSAs largely focusing on sustainability measurement of bio-based products). These projects present only a limited number of all answers,



[23] Wydra, S.; Hüsing, B.; Aichinger, H.; Fischer, P.; Kaufmann, T.; Schmoch, U.; Voglhuber-Slavinsky, A.; Davidis, B.; Spekreijse, J.; Vis, M. (2021): Life and biological sciences and technologies as engines for bio-based innovation; Studies on support to research and innovation policy in the area of bio-based products and services. https://op.europa.eu/en/publication-detail/-/publication/df6b2239-9b3e-11eb-b85c-01aa75ed71a1/language-en/format-PDF/source-199948607

[24] Cf: Draft Final Report: Evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix; Cf: Draft Final Report: Evaluation study on the external coherence of Horizon 2020, p. 31

Figure 6 Responses to the question 'How successful was your project in terms of contributing to the following dimensions in your area of expertise?' (Q29)

Source: Survey analysis, number of respondents between brackets

For two thirds (66 %) of the projects, survey participants reported that contributions to environmental goals were achieved at least to a moderate extent, showing that the majority of projects contributesto a Green Transition (Figureabove). This high rate of (self-reported) achievement is remarkable, given that environmental impacts with respect to a Green Transition 25 (i.e. impacts on soil health or biodiversity) can typically only unfold in a long-term perspective and often depend on further measures like the introduction of a legal framework. With the thematic broadness and high heterogeneity of projects, it is difficult to draw clear-cut conclusions on effectiveness. There are some indications of progress towards demand/societal-challenge-driven R&D (for challenges towards this transition, see below "drivers and barriers"). On both a topic and a Societal Challenge level, key results were:

- to bring agricultural topics back on the agenda.
- to implement an overarching approach for the blue bioeconomy.
- to develop a systemic approach for food sector.
- progress in developing value-chains in the bio-based industry, renewal of the EU Bioeconomy Strategy and successful support of national and regional approaches.
- progress in developing and implementing an inclusive and systemic R&I policy.

3.1.4.1. Technology and Innovation

Within the topics analysed by the case studies, there appears to be a large range of innovative approaches and technologies which are pursued. There is a focus on innovation transfer and the consolidation of existing solutions as well as on the adaptation of technologies towards the various regions and fields of implementation. In line with this, almost 30 % of the survey respondents reported that TRL could not be applied to their project.

Information is limited as to which extent expected outputs – e.g. new foodstuffs, feed, fibre and other bio-based products and processes, solutions across technology fields, etc. – have actually been reached. But the findings that the topics of the legal basis were well addressed and the overall high level of achievement for technology and scientific goals reported by the beneficiaries suggest a good level of outcome. Tentative inference can be made from the partnerships which have elaborated KPIs and released partly impressive numbers – which are mainly related to goals and inputs. However, it is too early to interpret these first numbers for technological and innovation outcomes since these PPPs were founded during Horizon 2020. Moreover, the activities within SC2 also reflect the shift from technology-driven R&I to a more systemic approach as the activities are not restricted to technological innovations and their translation into practice, but also include social innovations and new practices.

However, the survey revealed that more projects addressed early-stage aspects (i.e. expansion of basic knowledge, new tools & techniques) than those aspects associated with higher TRLs (i.e. user-friendliness, increased safety, or cost-reduction) (see figure below). Between 21 % and 58 % of the respondents report that the different technological development results have been fully achieved or achieved to a large extent. These findings are further underpinned by the fact that survey respondents reported that the most projects were at a low TRL at the beginning of the project (see Annex VII, Q22).

"Expansion of basic knowledge for technological development" and "New research tools, models, simulations" stand out as the technological development result which has been achieved to the highest extent (58 % and 57 %). "Increasing the safety of technologies and components" and "Cost

[25] This result somewhat contrasts respondents' claims to contribute little to market development or policy making / standard setting. This, however, may be due to the latter equating technological successes, such as the successful set-up of a new demonstrator, with impact per se.

reduction of technology" are the anticipated technological development result which stand out with a low extent of achievement (full or to a large extent) (21 % and 25 %, respectively). These, rather low, reported output rates within the field of technological goals seem somewhat logic and consistent with the shift towards broadening the scope beyond technological innovation.

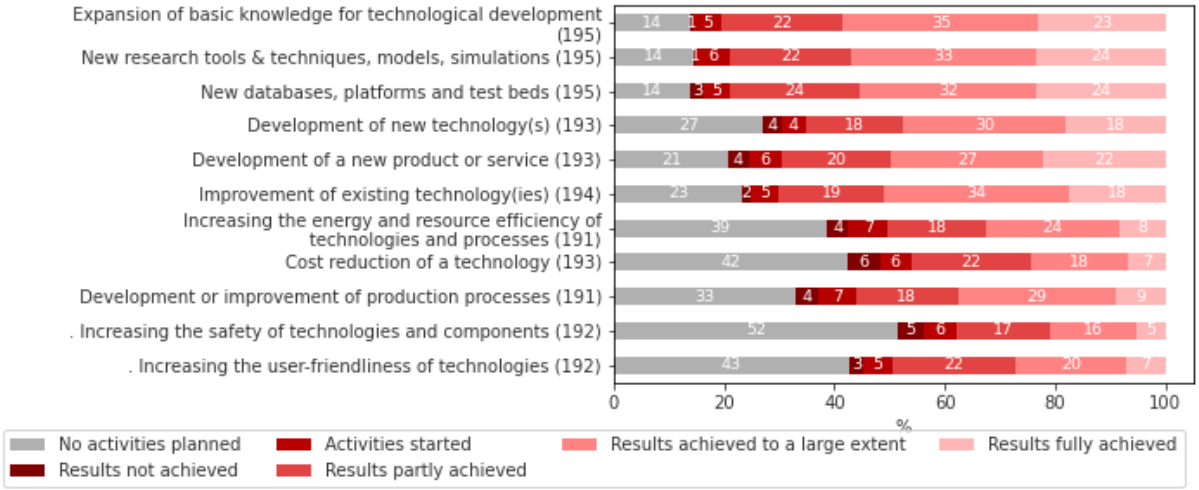


Figure 7: Responses to the question 'In terms of technological development outputs, what are the (anticipated) results of your project?' (Q19)

Source: Survey analysis, number of respondents between brackets

Turning to quantitative findings on technological and innovation outcomes of SC2 projects, 37 SC2 projects (out of 687) reported producing a total of 66 unique contributions to patent families so far. Self-reported trademarks, registered design, and utility models number less than 30 (for trademarks) or less than 10 (for the other two IPR modalities) for all SCs (see Annex V). The safest interpretation of these IPR findings is that it is too early in the Horizon 2020 projects' lifecycle to assess IPR-related technological and innovation outcomes, but it also needs to be taken into account that a large share of the projects did not plan any patent activities (see Annex V and Figure 9 for more detail). More self-reported outcomes are available in the category of demonstrators, pilots, and prototypes. A number of 95 out of 687 SC2 projects report producing such outputs, resulting in 261 unique outputs (see Annex V).

3.1.4.2. Knowledge and Capacity

The case studies as well as the overall analysis of SC2 show various contributions to knowledge and capacity building. The survey also revealed that scientific goals were relevant and pursued by almost all beneficiaries. The Multi-stakeholder approach has been put forward in different initiatives and actions to increase the innovation up-take capacities of the different innovation systems. In line with this, more than half of the survey respondents reported that their projects influenced their organisation to a large or very large extent with respect to an increased focus on interdisciplinary research (see Annex VII, Q26). This self-assessment is underpinned by the quantitative analysis which revealed an increase in the co-participation of non-scientific stakeholder groups compared to FP7 (see Annex V for more detail). Nevertheless, the qualitative analysis also revealed, that there is still a further need for building up more transdisciplinary research networks and for establishing connections between the "classical disciplines" in this field (life sciences, agronomics) and social sciences and economics. For example, in different topics (i.e. marine, soil, see Case studies 1 and 2), experts expressed the need for integrating more social and economic sciences beyond science and technology disciplines. But it was also perceived a challenge to attract social and economic sciences to new topics and, on the other hand, to convince the "classical" research communities (i.e. those providing the technical basis for these topics like life sciences, engineering and agronomics) that they eventually benefit from transdisciplinary research despite the additional efforts that come with it.

The case studies indicate that such integration may have been achieved to a different degree within different topics, also depending on the timeline of funding. E.g. in the case of marine bioresources (see Case study 2) a basic need to promote the inclusion of non-technical aspects into the projects

was articulated, while in the longer standing soil activities, their integration appears more advanced. Therefore concrete challenges of the implementation are in focus there. These findings suggest that Horizon 2020 has been an important driver for increased inter- and trans-disciplinarity in R&I. But they also show that in the future further measures will be needed to drive this transformative process.

Another important aspect is capacity building in a sense to involve stakeholders across the whole innovation value chain. Many cases require the establishment of local networks with users as well as actively engaging with them, in order to enable knowledge transfer to users and training of non-scientific stakeholders. However, - as Case study 1 "Sustainable Soil Management in Agriculture" at least partly reveals - progress is not primarily limited by financial resources but rather by the absorptive capacities of the systems, with all stakeholder groups struggling to respond to the high number of calls. A further relevant aspect is the stock-taking and consolidation of data and methods across the ERA in particular for topics which have mainly been dealt with on national levels in the past, such as the case for soil management (see Case study 1).

The high relevance of knowledge and capacity building is also reflected by the survey results: Gaining knowledge ("Better understanding of the subject") is a goal pursued by all projects with only 1 % of the survey respondents reporting that no activities were planned (figure below). Moreover, for the majority of projects respondents reported that different scientific results have been fully achieved or achieved to a large extent. “Better understanding of the subject” stands out as the scientific result which has been achieved to the highest extent (87 %). It is followed by “Better access to state-of-the-art research” (73 %), and by “Publications in peer-reviewed journals” (63 %). There is no (anticipated) scientific result which stands out with a low extent of achievement, the lowest being “Researchers trained” with 59 %.

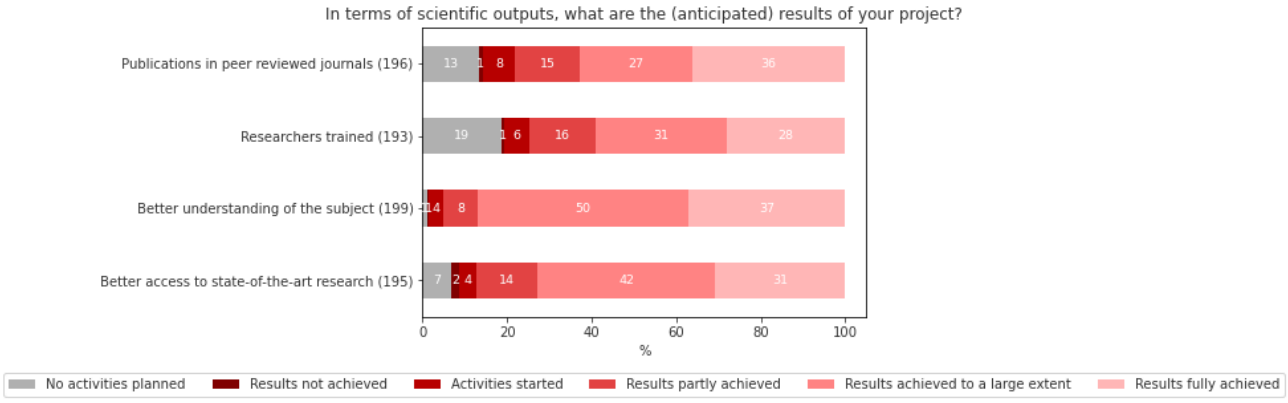


Figure 8: Responses to the question 'In terms of scientific outputs, what are the (anticipated) results of your project?' (Q18)

Source: Survey analysis, number of respondents between brackets

Bibliometric findings show that 5,235 publications have resulted from SC2-funded projects. A share of 68% of Work Programme 2014-2015 and Work Programme 2016-2017 projects reported one or more journal publications, keeping in mind that many H2020 projects have yet to conclude and can be expected to produce additional research publications in the near future (see Annex V for full analysis of H2020 project completion dates by Work Programme).[26] In interpreting the bibliometric findings presented below, it must be remembered that very few SC-level differential outcomes of Horizon 2020-Green-Transition funding have been reported (see the high level analysis in Annex V). That is, the core knowledge and capacity outcomes captured with bibliometrics have been observed in Horizon 2020-Green-Transition journal publications from SC2 through SC5. The findings reported below make clear distinctions between outcomes unique to SC2 and those shared with all other SCs. Figures with the quantitative measurements underpinning the observations below are provided in Annex V.

[26] As a methodological observation, it can be noted that 40 % out of 687 SC2 projects provided at least one publication used in the bibliometric analysis; 2,204 of these publications were used in the counterfactual analyses that provide the core bibliometric findings.

- Like for the other SCs, SC2 funding has enabled researchers with higher-than-EU27-average citation-impact performances to reach even higher citation-impact performances than in their other work.

- As is the case for the other SCs, SC2 funding has been attributed to researchers with a higher-than-EU27-average propensity to publish under open access. SC2 project funding has allowed these researchers to publish even more often under an open access modality than in their other work.

- Uniquely to SC2, funding has supported researchers to see a higher share of their work cited at least once in policy-related documents. These researchers' other work already tended to be more often cited in policy-related documents than expected from the EU27 average.

- As is the case for the other SCs, SC2 funding was awarded to researchers with a moderately stronger pre-existing tendency to engage in academic-private co-publication than at the EU27 average. SC2 funding did not allow a differential increase on this dimension, however.

- Uniquely to SC2, funding has been awarded to researchers with higher tendency to integrate female colleagues as authors, as compared to the EU27 average. SC2 funding has not enabled differential increases itself, however.

- As is the case for the other SCs, SC2 funding has not had meaningful or statistically conclusive effects on cross-disciplinarity of supported publications.

- As is the case for the other SCs, SC2 funding has not had meaningful or statistically conclusive effects on online dissemination of and engagement regarding supported publications (altmetrics achievements)

- As is the case for the other SCs, SC2 funding has not had meaningful or statistically conclusive effects on the share of publications that are international co-publications. The share of authorship by third country-based authors in SC2-funded publications was slightly lower than the EU27 average, however.

3.1.4.3. Coordination and collaboration

FP funding is very important for the community to conduct R&D and to build strong consortia with partners across Europe. The case studies revealed that the pooling of expertise - e.g. based on enzyme libraries and knowledge of several partners around well-defined specific research question - was very productive. Case studies and data analysis also suggest that Horizon 2020 was successful in establishing new collaborations with new stakeholder groups, regional stakeholders, non-scientific stakeholders (e.g. farmers), and that partnerships are effective tools to promote collaboration across the ERA (see below). However, there is a need to strengthen and empower new stakeholders: For example, the dominance of EU-14 countries among the coordinating institutions is striking and there is a risk that this gap between established and new Member States is structurally fuelled and therefore will continue and increase in the future (e.g. promoting large consortia excludes less experienced stakeholders from taking over coordination). As mentioned above, the Multi-stakeholder approach turned out as a highly effective approach and will be continued within the Living labs/missions in Horizon Europe.

Another dimension of interest within the coordination and collaboration effects of H2020 green transition funding concerns linkages enabled across different sectors of activity, possibly fostering inter-organisational knowledge transfer.[27] Looking at inter-sectoral co-participation effects achieved in

[27] For this evaluation, heterophily and homophily have been measured for networks of organisational co-participations within individual H2020-funded projects, with organisations coded by sector of activity. Heterophilic links denote co-participation connections between organisations from different sectors, homophilic links capture co-participation connections between organisations from the same sector. That is, in an hypothetical H2020-funded project with participations from one Higher or Secondary Education Establishments and two Private for-profit entities will contribute two heterophilic (inter-sectoral) connections to the overall network (two distinct PRC – HES connections), and one homophilic (intra-sectoral) connection (PRC-PRC). See Annex II for full methodological details.

SC2 projects (see Annex V for complete findings), as well as SC2-relevant Art. 187 and cPPP partnerships, it can be noted that SC2 projects saw a jump in co-participation by organisations coded as 'other' in eCorda, and that the BBI JU (the sole Art. 187 or cPPP partnership in SC2) projects recorded much higher shares of co-participation amongst private for-profit entities than SC2 projects. The co-participation networks fostered in SC2 projects were slightly more heterophilic (that is made up of inter-sectoral co-participation links) than those of thematically similar FP7 projects (71 % of heterophilic co-participation links, against 64 %, respectively). BBI project networks were less heterophilic than SC2 project networks, with 53 % of heterophilic co-participation links.

Looking more closely at these findings, it can be noted that – compared to FP7 projects in similar thematic areas – SC2 projects saw much more participation by organisations coded as 'other' in eCorda. This category is presumably made up of a diversity of non-governmental organisations or non-public, not-for-profit organisations. A share of 12 % of participants in SC2 projects originated in this category, against 3 % in FP7 projects. A proportion of 6 % of co-participation links in SC2 projects were made up of co-participation between Other Organisations and Research Organisations (against 2 % in FP7 projects), and another 6 % of co-participations by Other Organisations and Private for-profit entities (compared to 2 % in FP7). Co-participations between Other Organisations and Higher or Secondary Education Establishments amounted to 5 %, against 2 % in FP7 projects.

This increase in participation (and co-participation links) is linked to decreases in the participation (and co-participation links) for Higher or Secondary Education Establishments and Research Organisations. Most notably, co-participation links between exactly these two types of organisations have gone down from 20 % to 15 % between FP7 and Horizon 2020-SC2 projects.

BBI JU projects were made of a majority of participation and co-participation links between organisations from the Private for-profit (PRC) entities category. A share of 61 % of participations were provided by PRC organisations, and PRC-PRC co-participations made up 41 % of co-participation links. PRC-ERC co-participation links followed in frequency, making up 21 % of co-participation links.

Turning to country-level coordination and collaboration (see Annex V for full details of findings), the network of country participation to Horizon 2020-Green-Transition projects was dominated by participation from France (1st rank in betweenness centrality,[28] up from 2nd rank in FP7), Italy (2nd rank, up from 6th rank), the United Kingdom (3rd rank, down from 1st in FP7), Germany (4th rank, stable ranking from FP7) and Spain (5th rank, also stable vis-à-vis FP7).

EU-13 countries' betweenness centralities put them between 19th (Hungary) and 61th rank (Slovakia). Out of these 13 countries, 10 have improved their betweenness centrality ranking in this research area between FP7 and Horizon 2020. To take just one example, Romania has moved from 43th to 21th rank on country-level participation between FP7 and Horizon 2020.

3.1.4.4. Markets and business

The relevance of market and business and how the specific goals are pursued varies greatly between the different thematic fields covered by SC2. For certain sub-fields (e.g. bioeconomy) market creation is highly relevant. However, within other fields, in particular agricultural research, the major focus is on how to strengthen and maintain existing – rather traditional – business (farmers) under current circumstances, i.e. sustainable farming. E.g. in the case study "Sustainable Soil Management in Agriculture" (Case study 1), the market pathway is not relevant in a sense that the intervention

[28] Betweenness centrality measures how often a given node in a network lies along the shortest paths between two other nodes that are not directly connected to one another. For example, this indicator would highlight entities who play an important "brokering" role, acting as a connecting link between entities who do not co-publish with one another or cite one another's work directly. In this study, the indicator has been implemented to measure the centrality of a country within co-participation networks analysed from a country-level perspective (country of affiliation of participating organisations). That is, in an hypothetical H2020-funded project with participations from one organisation located in Spain and two organisations located in Portugal will contribute two Spain-Portugal co-participations to the overall network. See Annex II for full methodological details.

contributes to the creation of novel markets, but rather to changing practices within existing businesses – i.e. maintain markets and businesses while pursuing "green goals".

All in all, goals of market development were pursued to a lower degree than scientific or technological goals. This is also reflected by the survey results. A relatively high share of beneficiaries reports no activities contributing to the different goals of this domain were planned in their project[29]: 27 % of the respondents reported that the development of marketable products or services was not planned for their projects. The shares of projects that did not plan any activities towards market launch (36 %), IP creation (49 %), or the creation start-ups or spin-offs (74 %), or jobs (50 %) was even higher (see Figure 9below). As a result, only a minority of survey respondents (between 9 % and 36 %) reported that the different market development results have been fully achieved, or achieved to a large extent, with "Development of marketable products or services" and "Creation of new jobs" being the ones which have been achieved to the highest extent (36 %) and "Creation of a start-up" and "Creation of a spin-off" being the ones which were achieved in the least projects (10 % and 9 % respectively).

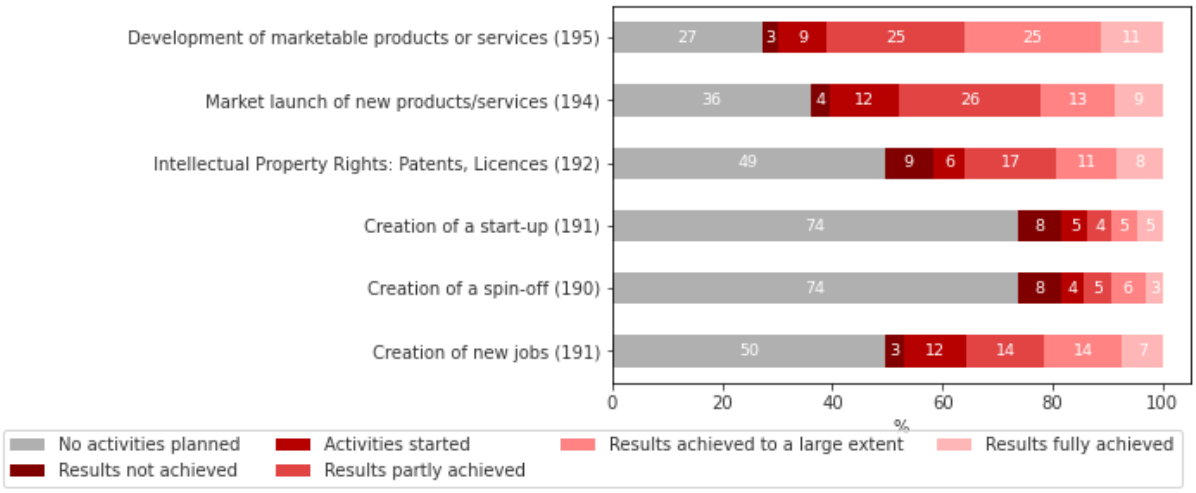


Figure 9: Responses to the question ' In terms of market development, what are the (anticipated) results of your project?' (Q20)

Source: Survey analysis, number of respondents between brackets

It is noteworthy, that a significant share of the survey respondents (28 %) considers the TRL concept not applicable to their project, suggesting that a large share of projects does not pursue the objective of developing a new marketable product or technology. On the whole, low-stage TRLs (TRLs 2, 3 and 4) were reported much more often than higher stage TRLs, suggesting that the aspects or market and business creation are not yet relevant at the current stage for most projects (see Annex VII, Q22 for detail). Nevertheless, for certain topics within SC2 bringing new products and processes to the market are specific goals. For these, usually around TRL 6-7, most R&D results are not directly transferred to the market, but additional efforts are needed. The case study on marine bioresources (Case study 2) revealed that in some cases the industrial partner could already use the project for the valorisation of developments. However, the survey among beneficiaries also indicates that market creation – if pursued at all – not necessarily built on technological innovation as patenting activities were relevant for half of the respondents.

3.1.4.5. Policies and standards

The survey revealed that the majority of projects achieved at least moderate contributions towards policies and standards (Figure 10below).

[29] Not that the categories used for Survey question 20 were identical across all SCs and not specific to SC2.

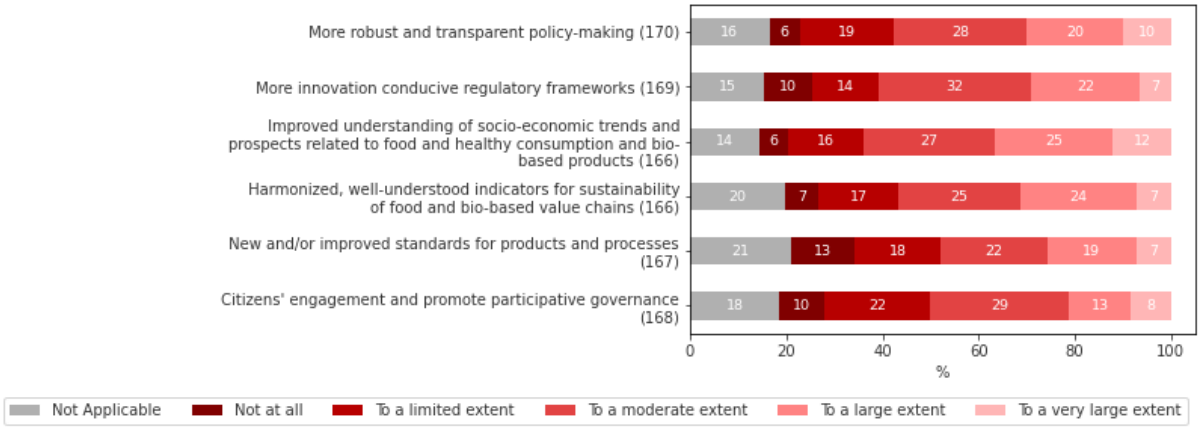


Figure 10: Responses to the question ' To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC2 area? Policies & Standards' (Q34)

Source: Survey analysis, number of respondents between brackets

Similarly, the case studies revealed that across the topics there are significant contributions to policy making. Different CSAs, and some RIAs and IAs, contributed to policy needs (e.g. for regulation) or addressed the improvement of the measurement of sustainability and partly provided roadmaps for future policy-making. The partnerships differ in their focus on policy and standards development, which was very relevant in the BBI JU, while others, such as ERA-NETs or PRIMA had a focus on policy alignment, but less projects that address policy and standardisation issues.

For some specific topics (e.g. marine bioresources) the projects provided important outputs regarding a better understanding of policy makers and the wider public about the potential of marine bioresources, and how to raise awareness (see also case study 2). Standardisation was especially relevant for bio-based products, where in particular dedicated projects (e.g. StarProBio) received high attention. All in all, a good up-take in the process of political decision making can be assumed as SC2 activities resulted in above average citations by policy-related documents (see Annex V). However, according to project beneficiaries it was not always clear if their results actually reached the relevant decision makers.

3.1.4.6. The role of the JRC

In relation to SC2, the activities of the JRC provides support to the implementation of the Common Agricultural Policy (CAP). Under the EU-Africa collaboration, the JRC has collected and provided data, analysis and information systems to support biodiversity and protected areas management and governance at local and regional levels. The JRC's work also contributed to supporting effective climate strategies in forestry and in the use of forest products to replace fossil fuels and other materials. Furthermore, the JRC has been involved in activities supporting the implementation and further development of the bioeconomy strategy since 2012. The JRC has regularly monitored and assessed the progress and impact of the bioeconomy by developing forward-looking and modelling tools. The Bioeconomy Observatory, set up by the JRC in 2013, addressed the previous absence of an integrated monitoring tool that would allow assessing the progress and impact of the bioeconomy, while embracing the bioeconomy, as defined in the 2012 EU Bioeconomy Strategy.

The expert panel appreciated the international aspect of the work and the contribution to EU-Africa policy and implementing relevant funding programmes. They also understood the JRC can be part of the public debate through its partnership with international well-established organisations. The scientific publications were considered favourably. The experts also acknowledge the high policy and societal impacts of the JRC's work, and its large public visibility in implementing sustainable product policies, while the scientific impacts are judged to be somewhat limited. The JRC's work made also an important contribution to the EU policymaking and allowed tracking the bioeconomy progress towards sustainability in the EU and its Member States, raising awareness at EU level.

3.1.5. EU Added Value

All in all, there is diverse evidence that added value has resulted from Horizon 2020: When beneficiaries were asked to what extent they experienced added value from Horizon 2020 projects compared to national or regional funding opportunities for their project, between 45 % and 83 % reported added-value to a large or very large extent for the given aspects (Figure 11 below). In particular, funding opportunities for specific topics, multiculturalism and diversity in consortia composition were valued.

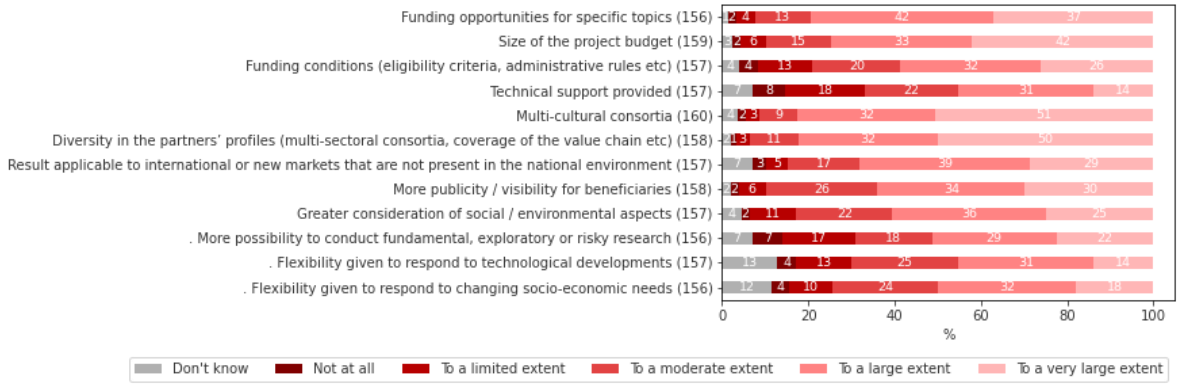


Figure 11: Responses to the question 'To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?' (Q50)

Source: Survey analysis, number of respondents between brackets

The survey results are consistent with the qualitative findings from the scoping interviews, case studies and partnership analyses for SC2: These provided multiple pieces of evidence that for the various topics of SC2, the FP funding provided possibilities to conduct R&D&I where no national funding exists (or only in very few Member States), and that it enabled Europe-wide collaboration for topics with strong links to the Green Transition. E.g. in the food and beverage sector, EU funding somewhat compensates the low private R&D in this sector, and missing public R&D - either in terms of addressed topics or country-wise in the lower income Member States (see e.g. Case study 3). Moreover, the case studies highlight that the FP funding brought together diverse stakeholder groups to pool their expertise, and address issues that are partly beyond the immediate perspectives of the Member States (e.g. systems thinking).

When asked specifically what would have happened to the project without Horizon 2020 funding, 75 % of the respondents answered that the project would not have been implemented, or that its scope would at least have been reduced (73 %). Likewise, 34 % answered that it would have been implemented with fewer partners. Only 21 % consider that it would have been funded on national or regional level (Figure 12 below).

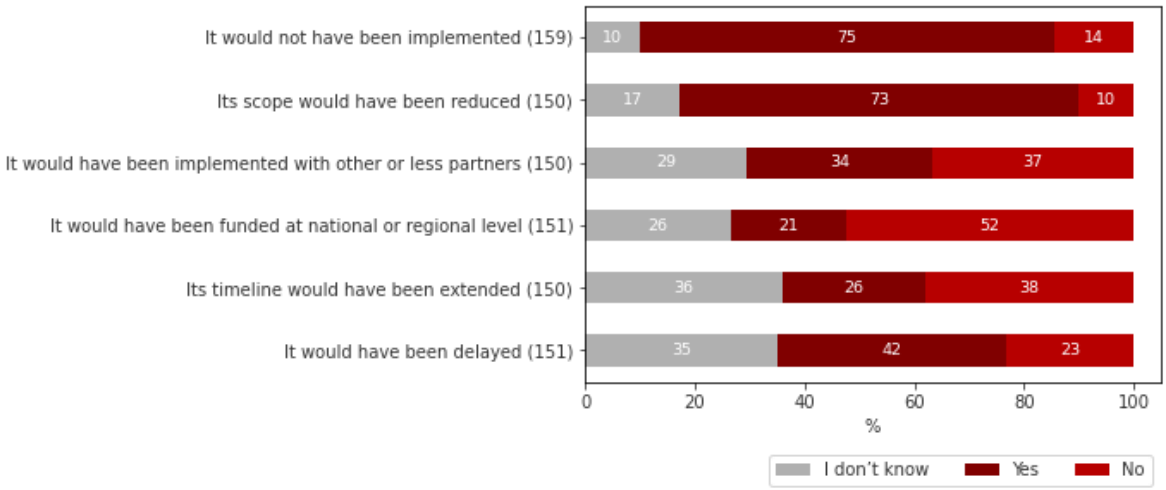


Figure 12: Responses to the question ' Without support from Horizon 2020, what would have happened to your project?' (Q51)

Source: Survey analysis, number of respondents between brackets

Assessing bibliometric output, the main added value of Horizon 2020-Green-Transition funding for traditional research work and outputs has been realised in the dimensions of citation impact and open access (see Annex V for detail). Concerning these two dimensions, the counterfactual analysis shows that Horizon 2020 funding was awarded to researchers with higher-than-EU27-average performances, and that their Horizon 2020-supported research has reached even higher performances than in their other work. This added value of Horizon 2020-Green-Transition support has been observed for all SCs.

SC2 sees unique added value regarding the dimension of policy-related uptake of research publications. Horizon 2020-SC2 awards have supported publications to reach higher levels of policy-related uptake than other publications by the same researchers (see Annex V).

SC2 research did not record added value compared to other publications by supported researchers on the following dimensions: academic private co-publication; gender equity in authorship; cross-disciplinarity; online dissemination and altmetrics achievements. Moreover, SC2 support had slightly negative added value on international co-publication with Third Countries. Yet this was also recorded for the other SCs.

The analysis of partnerships in the thematic context of SC 2[30] revealed that the latter unfold specific EU Added Value in various different ways:

- Partnerships function as instruments to steer and align national research agendas: Through the engagement in partnerships, national R&I communities are strengthened and the implementation of partnerships may influences national R&I agendas. That is, the BBI JU has influenced the implementation/revision of national bioeconomy strategies. However, it is unclear, to what extent other partnerships were similarly effective, and whether the engagement triggered by partnerships will be maintained beyond the lifetime of the partnerships. Especially for large countries, this would be an ambitious goal. By the same token, for small countries with very limited funding capacities it may be difficult to maintain their engagement as well.

- Raising awareness or acceptance for specific topics or thematic aspects: it can be observed that partnerships are generally efficient instruments to promote given themes and topics. For example, the EIT Food is considered an important driver for a more systemic perspective which caters to the complexity of the agro-food sector's challenges. This perspective seems much less pronounced at

[30] The partnerships analysed within the thematic context of SC2 are PRIMA, the BBI JU, and the EIT Food. Additional input was obtained from case studies and scoping interviews.

the national level. Also other partnerships like PRIMA (or CoFund Actions like the EJP Soil) report that through their activities more integrative and participatory approaches became possible.

- Partnerships unfold their strength through collaboration, pooling resources and facilitating knowledge transfer: Partnerships allow for the pooling of resources available in different Member States. As a result, they contribute to integrating the ERA enable a more holistic approach, which could not be achieved via national networks alone. Lower-income countries particularly benefit from this facilitated access and collaboration. So do economic sectors with weak innovation capacities, such as the Agri-Food, which is characterised by the dominance of micro and small companies, and which spends below 1 % of its revenue on R&D. Another key point is that Partnerships enable knowledge transfer in certain geographical areas across borders to address common challenges, such as PRIMA for the Mediterranean area or the ERA-NET for the Blue Bioeconomy for certain seas.

- Leverage of additional resources: According to their self-evaluations, partnerships have positive leverage effects with leverage factors ranging from 1.5 to 6. However, a direct comparison is difficult because the reported figures are not based on a common calculation method. For example, the 2014-2020 EIT Food computed a financial sustainability factor instead of a leverage factor.31

3.1.6. Drivers and Barriers for achieving impact

3.1.6.1. Internal and external factors having an impact on effectiveness and EU Added value

Different drivers and barriers for impact can be identified across the different case studies as well as from the scoping interviews. These range from macro-economic aspects to very practical and operational measures taken.

- **Relevance of macro-economic/political events**: The incisive events and developments of the past years, notably the Covid-19 pandemic and the war in Ukraine, are expected to massively impact the effectiveness of SC2. Interestingly, these appear to be drivers and barriers at the same time. On the one hand, they are drivers for the topics themselves - e.g. increasing the European resilience/reduce the geopolitical dependency on food imports by strengthening the production chains in Europe. On the other hand, there is a tendency to compromise on long-term goals for the sake of short-term effects. This compromises - and partially reverts - what had been achieved with respect to a Green Transition - e.g. by lowering regulatory requirements for sustainable agriculture. Moreover, these developments do not only affect ongoing projects, but also Horizon 2020 projects completed before 2020, as they have a strong influence on the framework conditions and therefore the ability of impacts to unfold.

- **European policy and regulation**: Due to the fact that sustainability efforts are often conflicting with short-term profitability aspects, regulation is a key driver for impact. The introduction of the Green Deal is seen as an important driver for multiple reasons. Even though most of the topics had been pursued well prior and even in previous FPs, with the Green Deal many experts see a gain in momentum. Furthermore, the Green Deal provides a basis and an opportunity for mandatory goals to be included in the legislation. This is an important achievement towards success as the past has shown that without binding legislation, sustainability aspects will fall behind economic goals. Accordingly, in the survey an impeding legal framework ranked second among the barriers that impede a successful uptake of project results (after limited financial resources; see Annex VII, Q35).

- **Multi-stakeholder approach/efforts to engage non-scientific stakeholders**: The multi-stakeholder approach is seen as a highly relevant driver towards achieving impact for various reasons. Most importantly, scientific stakeholders are simply not capable of driving the translation of R&I results into real-world applications where impact can unfold. Moreover, different stakeholder groups (e.g. scholars, administrative bodies, and applicants, public) as well as different scientific disciplines (e.g. life sciences, technology, humanities) can contribute different types of knowledge, which are needed vis-a-vis the increasingly complex topics to be addressed.

[31] This has changed as of 2023 when direct leverage was enshrined in the KPIs.

However, this is impaired by the fact that the multi-stakeholder approach is complex and challenging and requires the re-orientation of the established roles, responsibilities and tasks - including an increased focus and demand side aspects. Moreover, it remains a challenge to integrate stakeholders who are new the European funding landscape. National and regional structures to support these stakeholders (e.g. National Contact Points, cooperation with local administrative bodies) are seen as important instruments to address this challenge.

- **Access to local stakeholders**: An important success factor is the application of instruments that facilitate the access to local stakeholders, for example the provision of material in national languages, the cooperation with local authorities, or the establishment of a network of local hubs. This is particularly important in areas that have a strong regional dimension (i.e. food and agriculture, rural renaissance). Yet it may be of lesser importance for more technology-driven topics (i.e. biotechnology, marine bioresources).

- **Broadness of topics**: A general barrier towards impact can be seen in the broad range of the topics covered by SC2 with a limited budget: With many goals being pursued and the high complexity, the portfolio appears fragmented, there is a risk of losing orientation, or that priorities are watered down instead of unfolding a combined momentum. However, the case study on "Sustainable Soil Management in Agriculture" (Case study 1) shows that momentum can be achieved at a lower level of aggregation for well-defined topics with a clear delineation and well defined common goals.

3.1.6.2. Effectiveness of dissemination and communication measures

All in all, the dissemination of scientific results within the scientific community and towards policy making seems to be high as the bibliometric analysis revealed above average citation rates by other scientific publications as well as by policy-related documents (see Annex V). This suggests that the measures for disseminating the results among these groups are effective. Similarly, a majority of survey respondents reported that dissemination, exploitation and communication activities have been both useful and sufficient (see Annex VII, Q32 for details).

Generally, there was more concern about the disseminating of results among potential end-users and other "real-world" stakeholders. The implementation of the multi-stakeholder approach is considered an important step towards improving dissemination and communication but its implementation remains a challenge. Therefore, the learnings from this process constitute important contributions towards the further improvement of dissemination and transfer of results in the future. In particular, Horizon 2020 has shown that in order to be effective, dissemination and communication measures have to be tailored to the needs of the target groups - e.g. by providing information material in national languages and by making use of local networks for their distribution. Moreover, instruments are needed to connect stakeholder groups, first approaches like stakeholder learning platforms have been implemented in KICs and or the EIP Agri. Interestingly, in some cases the pandemic was seen as a driver for dissemination and communication of results to non-scientific stakeholders and end-users because many more individuals could be reached by virtual means where personal restraints and efforts for access are often lower.

However, beneficiaries were often unsure about the question how effectively policy and end-users could be reached, suggesting there is a need for feed-back as conventional monitoring mechanisms do not allow for this. With a large number of activities taking place in parallel, the synchronisation and coordination of how project results are being disseminated becomes increasingly relevant so that target group remain capable of perceiving and internalising results and react upon them.

3.1.7. International Aspects

While many topics covered by SC2 have a strong local or regional focus, many of the underlying challenges are of global nature and therefore require the development of global solutions in cooperation with international partners. For several topics covered by SC2 their promotion was originally often driven by international stakeholders like the Food and Agriculture Organisation of the United Nations (FAO) due to the fact that only rather recently awareness has risen that aspects like food security or soil degradation are direct threats to European countries. Generally, international cooperation in the context of SC2 serves two distinct goals: Strengthening the European position in global competition but also supporting underdeveloped regions in their efforts for sustainable

development. The H2020 Regulation does not explicitly refer to international aspects in the context of food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy. Despite this lack of direct reference in the legal basis, during the operational implementation of H2020, international aspects are emerging more and more prominently as can be observed across the three WPs.

- WP 2014-2015 refers to the EU strategy for international cooperation in research and innovation and flags out certain topics as particularly for international cooperation within the SFS and the BG call lines. However, while international cooperation is highlighted as a positive criterion during proposal evaluation, no overarching strategy is presented.

- WP 2016-2016 states more clearly that cooperation with third countries is needed in order to address the challenges. Moreover, the WP also clarifies that efforts for international cooperation are either driven by the motivation of European countries to benefit directly from exchange and cooperation with third countries or by the goal to meet international commitments either with respect to environmental protection goals or to sustainable development in non-European regions. Thematically, the focus lies on BG (Arctic and Mediterranean) and SFS (Food, Nutrition and Agriculture; fighting global threats like pests). Geographically, it focusses on establishing and strengthening cooperations with China by the launch of international flagship initiatives and South East Asian regions and Africa.

- Eventually, WP 2018-2020 further strengthens international aspects in particular in the SFS line by introducing dedicated calls for "targeted international cooperations". Moreover, additional international flagship initiatives are launched in the context of ocean and marine research.

Thus, the promotion of international cooperation appears strengthened across the WPs by a higher degree of specificity and the more prominent emphasis on selected third countries and regions as well as thematic prioritizing for international efforts. Beside specific flagships and projects with a dedicated international dimension, also partnerships contribute to international cooperation. While this is more implicit in the case of co-funded partnerships (i.e. the EJP soil), for PRIMA the strengthening of the Mediterranean area including its non-European states was at the core of the partnership and one section there even provided EU funding to non-European states, some of them even not Associated H2020 member states.

The quantitative analysis of the project portfolio (Annex V) observed higher participations by "other countries" (i.e. non-EU27-MS/UK or H2020 associated) for SC2 than for other SCs: This was true with regard to the total number of participations, but also for participations per project. However, while SC2 performed above average with respect to integrating third-country partners this is not reflected by the scientific output: Bibliometric findings on international cooperation (Annex V) for SC2 did not reveal meaningful or statistically conclusive effects on the share of publications that are international co-publications and a slightly lower share of third country authorships projects funded by H2020.

Development of international (Non-EU) collaboration appears to be a relevant motivation for the majority of SC2 beneficiaries. Two thirds of the survey respondents indicated that this factors had encouraged them to either to a moderate, large or very large degree (annex VII, Q10) which is slightly higher than for the other SCs. A similar fraction reported that cooperation with non-European partners contributes either to a moderate, large or very large extent to improving the European position in the global competition (Annex VII, Q17). About half of the beneficiaries from SC2 reported that they had collaborations with non-European partners (Annex VII, Q15). For the beneficiaries development of know-how, additional partnerships and increased visibility was the most often experienced benefits from these cooperations. On the contrary, access to new markets or the reduction of environmental impacts of their activities were experienced much less frequently (Annex VII, Q16). All in all, this indicates that the incentive for international cooperation as set by H2020 was not only adopted by also valued by the beneficiary communities.

Some further insights on the significance of international aspects can be drawn from the analysis of case studies and partnerships in SC2: While the need to collaborate both with European as well as with non-European partners is not questioned in any way, there were some critical voices whether for all topics the European Framework programme is the most suited instrument to enable these cooperation in all cases. For example, with regard to strengthening cooperation with African countries and supporting the development of sustainable food systems in African regions one beneficiary

pointed out that building on existing bilateral relationships between countries might be more efficient way to reach these goals. In the case of the partnership PRIMA, there are clearly positive effects of internationalization for the involved EU countries. For example, projects funded under PRIMA specifically address the needs of the Mediterranean region in terms of ecological, economic and social conditions, which could hardly be investigated otherwise. This leads to valuable solutions for the EU Mediterranean states as well as enables market expansion of technology providers from all EU member countries of PRIMA. In addition, the PRIMA evaluation points out that international cooperation should be done on equal footing. By consequently applying the equal footing principle, the Partnership gained high trust and acceptance by the international partners. Similarly, the Food 2030 strategy dedicates one of its ten action pathways to international cooperation, which is labelled „Food systems Africa“. Under this pathway, the EC lines out the food and nutrition security challenges faced by African countries as well as research and innovation needs and their connection to Framework Programmes.

With regard to effectiveness, it also has to be taken into account that the success of international activities is also largely dependent on the priorities of the international partners. In the case of cooperation with China in the field of agricultural research it was experienced that certain topics were not considered high priority. Therefore, impacts did not always unfold as well as originally anticipated. This aspect may stay important for the future. With the fundamental changes the world has experienced in the past years it therefore seems likely that priority setting in different geographical regions will change further. This should be reflected in strategic priority setting for international cooperation in future Framework Programmes.

3.1.8. Contribution to SDGs

The sustainability goals (SDGs) were introduced as part of the 2030 Agenda for Sustainable Development in 2015[32]. Despite the fact that the SDGs were not in place at the time when Horizon 2020 and its WPs were designed, the calls and activities of SC2 address a broad range of SDGs, with SDG 2 "Zero hunger", SDG 3 "Good Health and Well-being", SDG 6 "Clean water and sanitation", SDG 13 "Climate action", SDG 14 "Life below water", and SDG 15 "Life on land" being at the core of the activities. Beside these, also SDG 9 (fostering innovation), and SDG 13 (reduction of food losses) are addressed by some of the activities in SC2. However, a direct contribution towards a given target can neither be expected nor estimated due to the fact that the activities initiated under Horizon 2020 typically only contribute to the creation of favourable conditions for addressing the SDGs and the elimination of barriers. This can be illustrated by the Zero Hunger target 2.4 (“to ensure sustainable food production systems and implement resilient agricultural practices”): Several projects have yielded evidence for the effectiveness of novel, sustainable farming practices, for example those related to sustainable soil management. However, eventually it will depend on European and international policy making and societal acceptance whether the target of a given proportion of agricultural area under productive and sustainable agriculture (SDG 2 indicator 2.4.1) can be achieved within due time.

3.1.9. Summary of findings

Overall,this study provides ample evidence that for the SC2 the FP has a strong impact in putting relevant topics on the R&D&I agenda, that the mix of instruments is coherent, and that ambitious projects are funded. There are indications that many projects are on track to make significant progress. However, there is a lack of information on the impact. Whereas many projects have just ended, or not ended yet, effects in respect to the goals of the Green Transition will only unfold in the longer-term. In fact, it can be seen as an achievement of Horizon 2020, that the design of topics and the selection process shifted towards a more applied and integrated perspective. This is especially true in terms of contribution to the Green Transition, as societal changes and the transformation of the agricultural and related industrial system are long-term processes. Therefore, the evaluation of impacts can only take place with a certain delay and will require a broader set of tools than scientific and technological innovation indicators alone. Nonetheless, combining the current information about activities and progress, it can be concluded that - within the means and scope of R&I policy - SC2 with its activities provides an important basis for enabling progress towards a Green Transition.

[32] United Nations (2015): Resolution adopted by the General Assembly on 25 September 2015: " Transforming our world: the 2030 Agenda for Sustainable Development". A/RES/70/1.

A case in point is the topic of Sustainable Soil Management which can be considered a successful example for SC2 as Case study 1 clearly demonstrates many of the achievements: This previous niche topic which had suffered from insufficient attention in the past experienced a rapid promotion during the course of Horizon 2020. This development driven by the H2020 activities eventually resulted in the Soil Mission for Horizon Europe, the implementation and learnings from the multi-stakeholder approach, and the application of an increasingly systemic approach for R&D&I. At the same time, it is also an instructive example which illustrates remaining challenges and needs for the further development of the FPs to meet future requirements and to allow for the impacts to unfold.

3.2. Societal Challenge 3 'Secure, clean and efficient energy'

3.2.1. State of Play

Societal Challenge 3 was established to respond to the need to reduce fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs, and climate change.

During the Horizon 2020 implementation period, many significant changes took place. The European Union and its Member States have committed themselves to the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) and play an active role to maximize progress towards the SDGs. With the European Green Deal, the EC adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030.

This Societal Challenge benefits from a total budget of EUR 5.02 billion across 1123 projects (with an additional EUR 63.8 million across 134 projects from the Art. 187 partnership Cells and Hydrogen 2). The project portfolio is further defined below.

3.2.2. Relevance

3.2.2.1. Strategic priority setting and response to emerging needs

The strategic priorities of the "Secure, clean and efficient energy" (SC3)[33] programme part relates directly to the Europe 2020 headline targets[34] and aimed to reduce greenhouse gas emissions by at least 20 % compared to 1990 levels[35], increase the share of renewable energy in our final energy consumption to 20 %, and achieve a 20 % increase in energy efficiency." It pursued the objective "to make the transition to a reliable, affordable, publicly accepted, sustainable and competitive energy system, aiming at reducing fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs and climate change". SC3 aimed to induce significant investments in research, development, demonstration, and market roll-out at affordable prices of efficient, safe, secure, and reliable low-carbon energy technologies and services, including gas, electricity storage, and the roll-out of small and micro-scale energy systems. SC3 priority setting acknowledged that technological solutions need to go hand in hand with non-technological solutions on both, the supply and demand sides and aimed at initiating participation processes and integrating consumers.

The objectives and ambitions of SC3 'Secure, clean and efficient energy' exhibit close links with the key EU energy and climate strategies and provide evidence for the strategic relevance of the research and innovation activities planned in SC3. SC3 aimed to form the technological backbone of European energy and climate policy and contribute to the EC flagship initiatives Resource-efficient Europe[36] and the Innovation Union, which have been put forward as the long-term framework for actions in many Green Transition related policy agendas (climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity, and regional development). To catalyse progress as regards energy efficiency, Resource-efficient Europe aimed to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency.

[33] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1291
[34] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52010DC2020
[35] "or by 30 % if the conditions are right".
[36] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:52011DC0021

The conceptual design of SC3 is closely linked to the Commission Communication on Energy 2020[37], the Communication on Energy Technologies and Innovation[38] as well as the Accelerating Clean Energy Innovation Communication[39]. These documents already acknowledged the important role of R&I in the transformation of the EU's energy system and called for increased actions. Furthermore, SC3 objectives are closely linked to the centrepiece of European energy R&I policy, the Strategy Energy Technology Plan (SET Plan), which serves as a reference point for European, national, regional, and private R&I efforts in the energy field. The SET Plan acted as key reference point for defining SC3 Work Programme priorities as well as those of public-public partnerships (mainly ERA NET Cofunds and JPIs) operating in the energy field[40], ensuring that the overall design of the interventions was highly relevant and considering the scientific, technological, and socio-economic challenges at the time.

Against this background, SC3 had been set out along the following broad lines of activities (see Annex IV for the complete intervention logic of Societal Challenge 3): 1) Reducing energy consumption and carbon footprint by smart and sustainable use, 2) low-cost, low-carbon electricity supply, 3) alternative fuels and mobile energy sources, 4) a single, smart European electricity grid, 4) new knowledge and technologies, 5) robust decision making and public engagement, and 6) market uptake of energy innovation.

The text analysis of the SC3 Work Programmes, instruments, and projects and the scoping interviews performed in the course of this study helped to reconstruct an intervention logic of SC3, that illustrates how SC3 contributes to a Green Transition through pursuing distinct pathways to impact. Within this intervention logic, the following expected outcomes for SC3 have been identified in the analysis.

Table 5. Pathways to impact and targeted Outcomes for SC3.

Technology & Innovation	Knowledge & Capacity	Coordination & Collaboration	Market & Business	Policies & Standards
More competitive, performant and integrated energy generation technologies Smarter, more flexible and resilient energy system More energy-efficient technologies and solutions Increased overall energy efficiency on the demand side Affordable and integrated energy	Innovative energy management solutions and services Enhanced capacity for energy policy implementation and market-uptake World-class research facilities Improved understanding of complex energy system and socio-economic contexts of the energy transition Better understanding of consumer behaviour and uptake of renewable	Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels Cross-border and cross-sector coordination and integration of R&I efforts Increased industrial participation in R&I to enable European production capabilities and supply chains for new, sustainable energy technologies Enabled consumers to actively	Increased market-uptake of innovative, resource efficient solutions Effective removal of non-technological barriers to market uptake of renewable energy and energy efficiency innovations Leveraged demand for sustainable energy solutions More investment in energy efficiency markets	New and/or improved standards for interoperable networks, new technologies, services Accelerated, cost-effective implementation of EU energy policies Improved design, implementation and monitoring of future energy policies More innovation conducive regulatory frameworks More informed, robust and transparent policy-

[37] https://ec.europa.eu/energy/sites/ener/files/documents/2011_energy2020_en_0.pdf
[38] https://ec.europa.eu/energy/sites/ener/files/comm_2013_0253_en.pdf
[39] https://ec.europa.eu/info/research-and-innovation/research-area/energy-research-and-innovation/strategy_en
[40] Evidence from a case study conducted within "Evaluation study on the relevance and internal coherence of H2020"

Technology & Innovation	Knowledge & Capacity	Coordination & Collaboration	Market & Business	Policies & Standards
storage solutions Reducing the cost of renovations targeting improved energy efficiency New and more mature clean, safe and sustainable energy solutions Digitalisation of the energy system More bottom-up, user-centred energy system	energy and energy efficiency solutions Improve knowledge and skills of workforce related to energy efficiency (e.g. through certification)	participate in the energy transition Stronger involvement of civil society in R&I Stronger involvement of Social Sciences and Humanities in Energy R&I	through stronger private capital participation Higher availability of RE and low carbon technologies for different markets and operating environments Reduce time to market for technologies and solutions Strengthened production capabilities and supply chains in Europe More competitive energy system Lower cost of energy derived from renewable generation / making renewable energy economically feasible	making Harmonisation in calculation of energy performance and certification

The expected outcomes show that the Work Programmes operationalise desired results that are specific to the energy Societal Challenge. They target not only technological development issues but pay attention to capacity building, coordination, and collaboration at the level of all required energy system actors, the co-development of policy measures and standards, and an increased focus on innovation and market-uptake. The increased focus on market uptake can be contributed to the integration of the Intelligent Energy for Europe (IEE) programme into H2020 SC3. This line of activity had a specific focus on capacity building and implementing change and had been typically implemented through CSAs, going beyond traditional support studies. even though they were not CSAs in a 'traditional sense' (therefore the high share of CSA in SC3).

The focus on contributing to the reduction of GHG emissions (82 %), addressing grand Societal Challenges related to climate (79 %) and increasing resource efficiency of processes in the area of expertise (65 %) are dominant motivations of project participants[41]. Furthermore, business development and competitiveness has been identified as one of the key motivations for applicants[42].

The results of the participant survey also demonstrate that the strategic orientation of the SC3 project portfolio addresses the challenges outlined in the legal base and the Work Programmes to a large extent. The respondents indicate that the projects are strongly focused on the overall speeding-up of

[41] See Annex: Survey Analysis, Figure 35, Q7.
[42] See Annex: Survey Analysis, Figure 37, Q9.

the market uptake of energy innovations, reducing energy consumption and carbon footprint through smart sustainable use, and the development of low-cost, low-carbon energy technology. Specific technological development challenges, which are part of the broad line of activities to be addressed in SC3, such as alternative fuels and a smart European electricity grid, are considered less frequently in the project portfolio.

Between 14 % and 70 % of the respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent is 'reduce energy consumption and carbon footprint' (70 %), followed by 'develop low-cost, low-carbon energy technologies' (58 %) and 'foster the smart integration of renewable energy' (56 %). The challenges and needs which have been addressed to the lowest extent are 'develop a single smart European electricity grid' (14 %) and 'make alternative fuels and energy sources more competitive' (34 %).

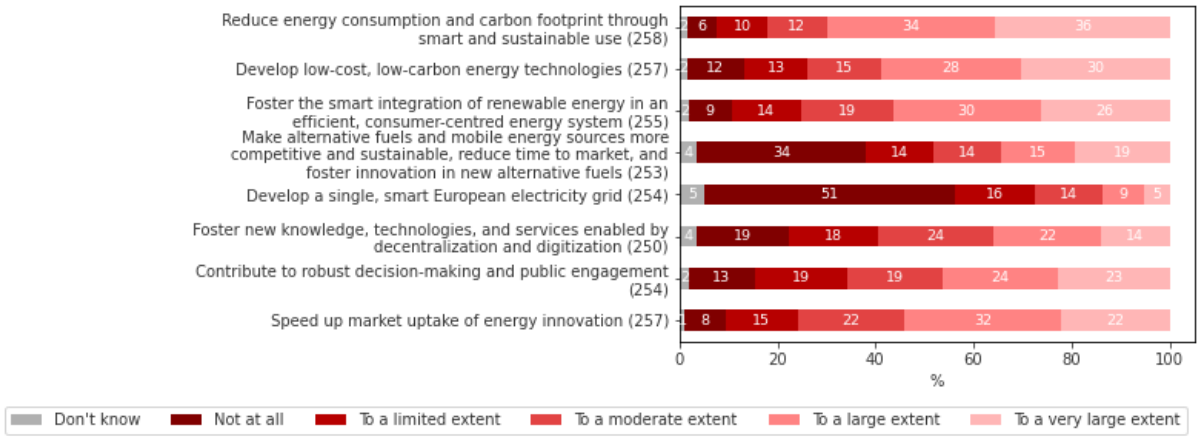


Figure 13 Responses to the question ' To what extent does your project address the following needs and challenges?'

Source: Survey analysis, number of respondents between brackets

SC3 also managed to be flexible to cope with changing circumstances in Europe and in the world: The first Work Programme of the Horizon 2020 Energy Challenge mainly contributed to three focus areas "Energy Efficiency", "Competitive Low-Carbon Energy" and "Smart Cities and Communities". The focus therein evolved from improving specific technologies and their components to their smart integration in an efficient, consumer-centred energy system. A stronger focus on consumer integration and citizen-centred energy systems, as well as system integration, including storage technologies emerged in the Work Programme 2016-2017, while additional themes such as deployment of innovative energy services enabled by decarbonisation, decentralisation, and digitisation were established toward the end of Horizon 2020.

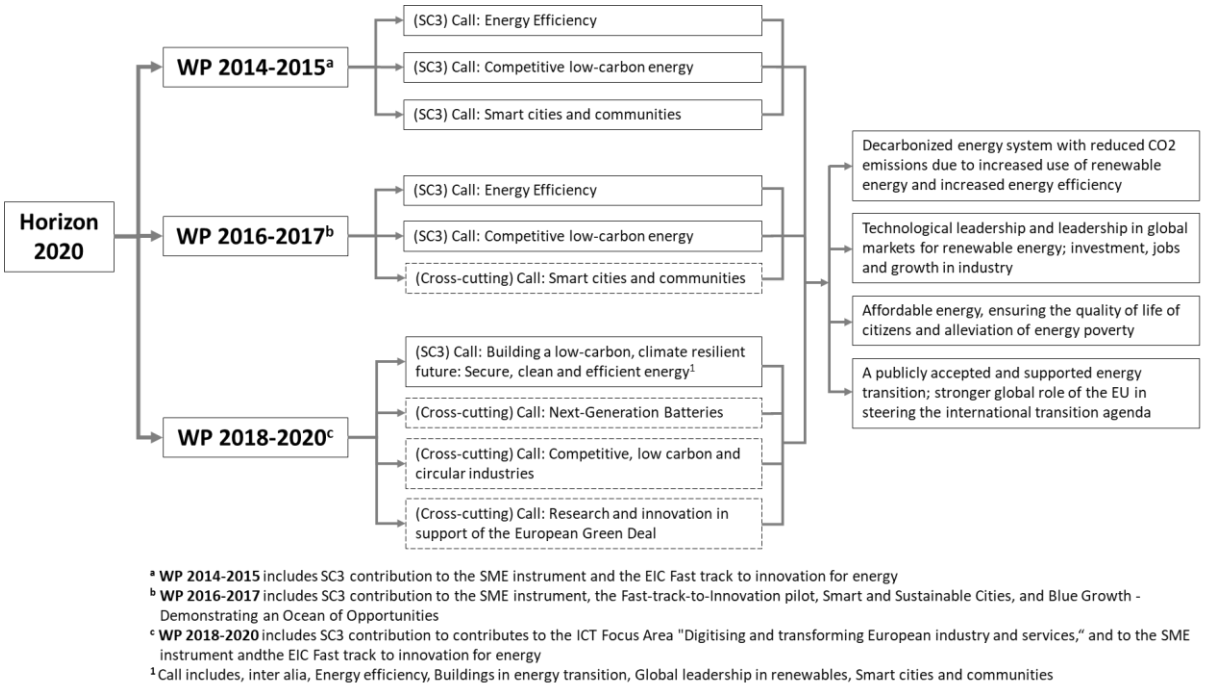


Figure 14 Horizon 2020 SC 3 Calls and their WP focus/ priority areas

Source: Own elaboration

It is noteworthy that, since the conception of the Societal Challenge "Secure, clean and efficient energy" (SC3), a number of international and European strategies and initiatives have emerged that have changed the overarching reference framework for SC3, particularly the Paris Agreement and the European Green Deal. According to the interviews performed in the cities case study and the smart grid case study, the European Green Deal marked a major milestone in the evolution of European and international climate and energy policy progressing from, inter alia, the Rio Conference, the Kyoto Protocol, and COP21. The European Green Deal introduced more ambitious targets for the energy transition and increased the level of ambitions for the energy sector, while simultaneously marking a radical shift within European policymaking as its objectives were enshrined into the European Climate Law. Since Horizon 2020 was conceived, SC3 therefore responded to emerging threats and challenges. The cross-cutting European Green Deal call 2020 addressed SC3 mainly through Area 2, "Clean, affordable and secure energy", Area 3, "Industry for a clean and circular economy", and Area 4, "Energy and resource efficient buildings".

3.2.2.2. Appropriateness of the programme portfolio

A total budget of EUR 5.02 billion was allocated by the EC to SC3 projects since 2014, resulting in a total of 1123 projects. One Art. 187 partnership was partly financed through SC3 (Fuel Cells and Hydrogen 2) comprising 134 projects and an EC contribution of EUR 638.8 million. In addition, public-public partnerships were an important part of SC3 activities including a number of energy related ERA-NET CoFunds[43]. The evolution of the EC contribution per project by year of calls shows for the Energy Sector that average EC contribution per project remained comparatively stable across the years. During 2014-2020 CSAs received on average 1.6-1.8 Million Euros, IA between 8.2 and 16.1 (in 2015 and RIA between 3.7 and 5.1 project funded under a 2014 call received EUR 4.2 million, while a project from 2020 received EUR 5.3 million. Compared to other Societal Challenges, SC3 did not increase as significantly as in the Climate projects.

From a thematic viewpoint, the Horizon 2020 project portfolio in SC3 reflects the integrative, transitional challenges and needs that are required for enabling the energy transition. A text analysis of a set of 100 randomly selected SC3 projects revealed a very high fit of project goals with the

[43] See section 3.2.1.2 on the coherence of the portfolio of instruments

specific programme goal at the thematic level of SC3. As illustrated in the following figure, a clustering of SC3 sections shows that a major focus in the portfolio of projects has been given to the topic of renewable technologies, the integration of energy systems, and human centred design. Furthermore, the SC3 spending covered the main energy consumption sections with highest potential for GHG emission reductions, i.e., climate neutral and cities, and the decarbonisation of GHG intensive industry.[44] Furthermore, R&I activities enabling the replacement of carbon-based fuels (Biofuels, Hydrogen) have been provided by the programme – in the case of Hydrogen almost exclusively by the FCH JU.

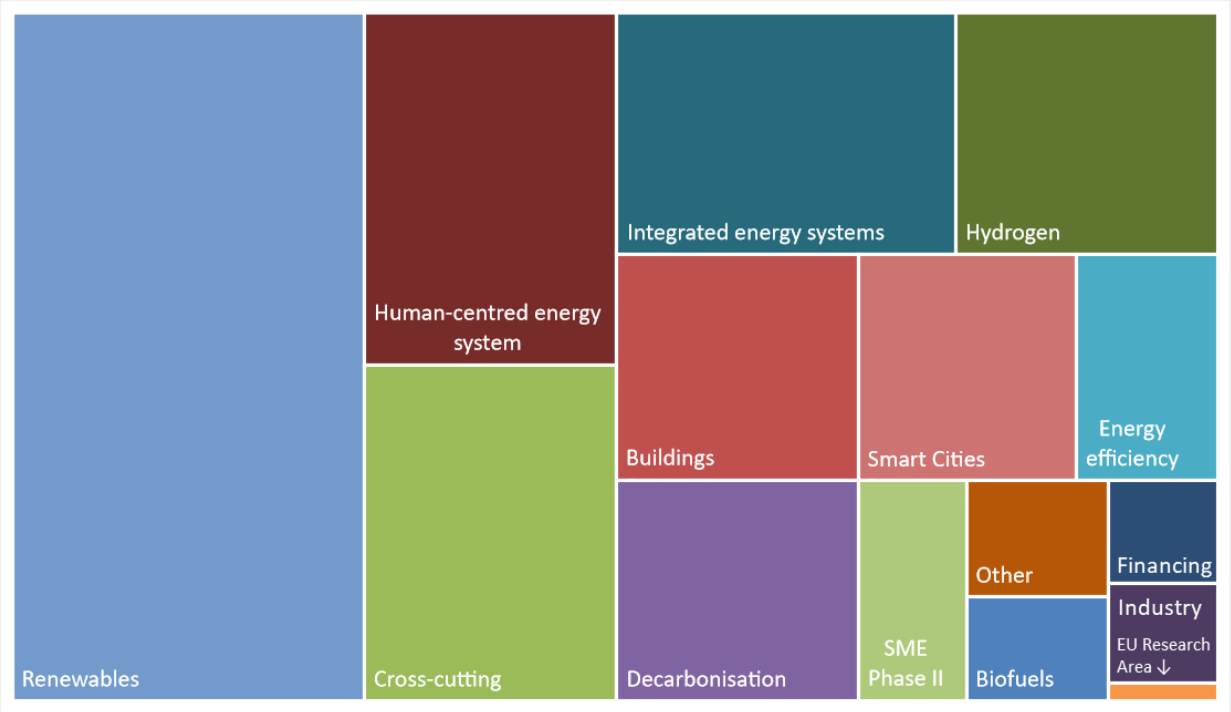


Figure 15 Distribution of EC contributions to clustered sections

Source: eCorda, own elaboration

Regarding the different types of funding instruments used, the energy portfolio has been well suited to address the challenges and different types of stakeholders and enable transformation in the energy system. Indeed, SC3 shows a strong focus on capacity building and supporting stakeholders through CSAs (36 % of number of SC3 projects accounting for 14% of SC3 EC contribution[45]) and engagement activities in projects and Partnerships. Moreover, an adequate mix of Innovation Actions (23 % of projects and 52 % of EC contributions) and Research and Innovation Actions (33 % and 31 % of EC contributions) support strategically oriented technology development on lower TRLs, as well as more market-diffusion oriented measures on higher TRLs. These results are also supported by project coordinators' perceptions in the survey and the case studies. For example, the Cities case study showed that the portfolio of instruments within the Work Programme enabled need-driven knowledge transfer between projects. CSAs and joint capacity building efforts enabled a co-creative and pro-active portfolio development within the Work Programme. Similarly, the partnerships contributed to the mobilisation of public authorities in EU Member States, including additional sources of funding, and the formation of national and regional communities.

Regarding the type of beneficiaries, business enterprises show the highest participation rates, with 92 % of projects exhibiting at least one business participation, and on average six business enterprises participating in each project. Entreprises received 50% of overall SC3 EC contributions

[44] See: European Commission, Directorate-General for Research and Innovation, Borsboom, J., Haindlmaier, G., Dinges, M. (2021). Mission area : climate-neutral and smart cities : foresight on demand brief in support of the Horizon Europe mission board, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/123417

[45] i.e. This can be also accounted to the integration of the Intelligent Energy for Europe (IEE) programme.

through supported projects, much above any other sector (the research organisations sector followed with slightly more than 20% of EC contributions). Projects involving at least one education (69 %) or research organisation (76 %) are also frequent, whereas public bodies only take part in 30 % of all projects. However, other organisations (beneficiaries from NGOs, public sector organisations, local energy providers etc.) participate in 53 % of projects, showing a high involvement of non-research and non-business stakeholders compared to the other SC. The survey analysis supports these findings and confirms that the diverse projects managed to address all relevant stakeholder groups. An overwhelming majority of 71 % of the respondents believed that all relevant stakeholder groups were addressed through the project activities (see Annex VII, Question 9).

Concerning newcomers, SC3 shows similar newcomer rates as SC2 and SC5. While governmental actors, businesses, and other organisation types consist of ca. 60 % or more newcomers compared to the previous funding period, higher education and research organisations consist predominantly of the same organisations. This is little surprising, as R&I activities are among the core activities of higher education and research organisations who collaborate with multiple/different firms on their specific challenges.

Collaboration is a main motivational driver for Horizon 2020 and HEU participants. The following figure shows collaborations with organisations outside the project consortium. The intensity of collaboration was by far the highest with regards to research organisations (48 % collaborated or co-led) followed by High Education Institutions (HEI) (41 %). The lowest level of collaboration intensity was identified with regards to Research Funding Organisations (10 %) and NGOs (19 %).

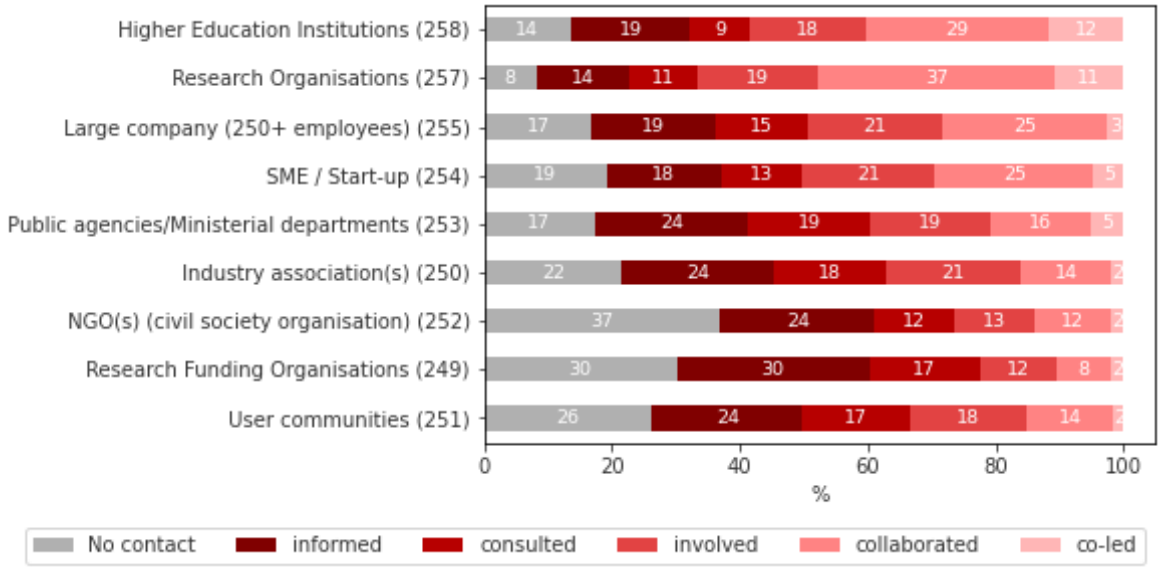


Figure 16 Responses to the question 'How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?' (Q12)
Source: Survey analysis, number of respondents between brackets

3.2.3. Coherence of the intervention

In terms of other funding programmes provided, the portfolio consists of 1) one Art. 187 partnerships partly funded through SC3 (Fuel Cells and Hydrogen), 2) other public-private partnerships with relevance to SC3 objectives, although not directly financed through SC3, included energy-related activities undertaken by the Energy efficient buildings cPPP, SPIRE, and Factories of the Future (FoF) cPPP, and 3) a large number of public-public-partnerships (12 ERA-NET CoFunds, 1 JPI), and 4) the EIT InnoEnergy, which established entrepreneurial activities with relevance to the energy transition.

In terms of instruments provided, there is a clear delineation of priorities covered within SC3 calls and those covered by other programme parts and/or instruments. This includes e.g., the complementarity of SC3 energy efficiency in buildings calls with those of the Energy-efficient Buildings public-private partnership (EeB PPP), where the EeB PPP calls mainly focussed on technology-related topics and SC3 focussed mainly on the removal of existing barriers through market uptake measures in order to

build capacity, provide support for sustainable energy policy implementation, mobilise financing for sustainable energy investments and foster uptake of technologies relevant for energy efficiency in buildings.

As regards the major Public-Private Partnership Fuel Cells and Hydrogen, the JU helped improve technological developments for energy security and contributed to the status of Europe as an international leader in technology. Very importantly, the PPP has stimulated the formation of an FCH community that has become a means for the promotion of FCH technology and helped to provide a strategy to guide collaborative work across a broad variety of applications. Transport and stationary power received the largest shares of funding as they are the main applications. Hydrogen production and distribution which is a prerequisite for both were also well-funded.

Public-Public Partnerships were an important part of SC3 activities. 12 ERA-NET Cofunds were funded by SC3: Accelerating CCS technologies (ACT), Bioenergy Sustaining the Future, European joint programming initiative on smart energy systems for regions & local communities (EN SGplusRegSys), Geothermica, ERA-NET Smart Cities and Communities (ENSCC), ERA-NET Smart Grids Plus (EN SG+), DemoWind – delivering cost reductions in offshore wind, Joint programming actions to foster innovative CSP solutions (CSP), Ocean Energy ERA-NET Cofund, SOLAR ERA-NET Cofund 1 and 2, ERA-NET Digitalisation of Energy Systems and Networks (EnerDigit).

In relation to these Public-Public Partnerships, the energy related case studies performed in SC3 showed that these partnerships managed to support deep knowledge sharing between regional and European initiatives. They managed to build joint accompanying activities, building on the knowledge base, R&D initiatives as well as research and demonstration facilities already in place at regional, national, and European level. The partnerships have proven successful to connect to local and regional actors and contributed to considerable additional leverage of funding. However, the sheer number of Public-Public-Partnerships, which have been organised mainly per type of energy technology and specific topics, increased the fragmentation of the partnership landscape, and clearly called for a rationalisation of public-public Energy partnerships. In the city domain, however, JPI Urban Europe managed to bundle activities of several ERA-NETs under one roof and thereby ensured strategic coherence of activities and coordination processes in relation to cities. However, in line with the finding of the study on Relevance and Internal Coherence of the FP, the Cities case study's findings also indicate that the coordination processes between the Work Programmes of Horizon 2020 and the Public-Public-Public Partnerships have been weak.

In addition to the aforementioned partnerships, the EIT InnoEnergy has been established as a core instrument to foster exchange among all action stakeholders and external experts. The Key Performance Indicators of the KIC InnoEnergy show that this European innovation instrument effectively contributed to the mobilisation of venture funding and support of innovative start-ups and has therefore proven to be highly complementary to the scope of activities of the FP in this area. According to the EIT Annual Activity Report of 2021 EIT InnoEnergy supported 115 startups and investment attracted by start-ups supported by the KIC reached EUR 690 million[46].

Going beyond the framework of Horizon 2020, SC3 is part of a broader European (R&I-) funding landscape aiming at the energy transition:

- EU Innovation Fund, which funds various topics relevant for a Green Transition in energy, notably by supporting activities on the construction and operation of innovative renewable energy installations (amongst others in PV, CSP, on-shore and offshore wind power, ocean energy, geothermal, solar thermal) and energy storage technologies;

- The InnovFin Energy Demonstration Projects (EDP) which provides loans, loan guarantees or equity-type financing typically between EUR 7.5 million and EUR 75 million to innovative demonstration projects in the fields of energy system transformation, including but not limited to renewable energy technologies, smart energy systems, energy storage, and carbon capture utilisation and storage. The product was deployed directly by the European Invesment Bank and supported innovative projects until the end of 2022, partly financed by SC3;

[46] https://eit.europa.eu/sites/default/files/2022-24_20220621_gb72-24_eit_caar_2021.pdf

- ESIF, with the energy union and climate being one investment area;

- IPCEIs, where three European R&I projects focusing on value chain were funded, two on the battery value chain, and one project on the hydrogen technology value chain.

In a worldwide context, the IEA report on World Energy Investments notes that the growth rate for R&D spending on all energy technologies remains stubbornly sluggish, the portion of spending dedicated to low-carbon energy R&D has grown somewhat faster and its share has risen consistently, from around 77 % in 2015 to 83 % in 2020[47]. As regards Energy R&I funding in Europe, the IEA reports 2015-2020 on annual investments in energy R&I funding show that EU funding for Energy R&I remains among the largest compared with national R&I funds provided by EU-Member States. Therein, the SET Plan is the key R&I and technology strategy for the energy area, guiding particularly development of new energy technologies across EU Member States and a forum that ensures that coordination (including cross-DG coordination) and exchange takes place[48]. As regards required coordination processes in this regard, the study on External Coherence has pointed out that more dedicated coordination between the EU and national/regional level is arguably reinforcing synergies in the area of energy innovation, for example through strategic alignment in policies such as the Integrated National Energy-Climate Plans for the year 2030[49].

3.2.4. Effectiveness of the intervention

The case studies and survey find that projects largely succeed in reaching their objectives. Activities also appear to be an important basis for progress along the impact pathways. These results, however, do not allow reliable claims regarding longer-term outcomes and impacts. Based on the survey analysis, there are indications that many projects are on track to make significant progress. 86 % of participants indicated, that their project's results are in line with its objectives (see Annex VII, Q6). Between 29 % and 69 % of the respondents assess that the project contributed to a large or very large extent to the improvement of different aspects of expertise, as shown in the figure below. 'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects of expertise which have been improved to a large or very large extent by the majority of projects (69 % and 58 %), while large or very large contributions to 'policy making and standard setting measures' and 'market & business development' were indicated by much fewer participants (32 % and 29 %).

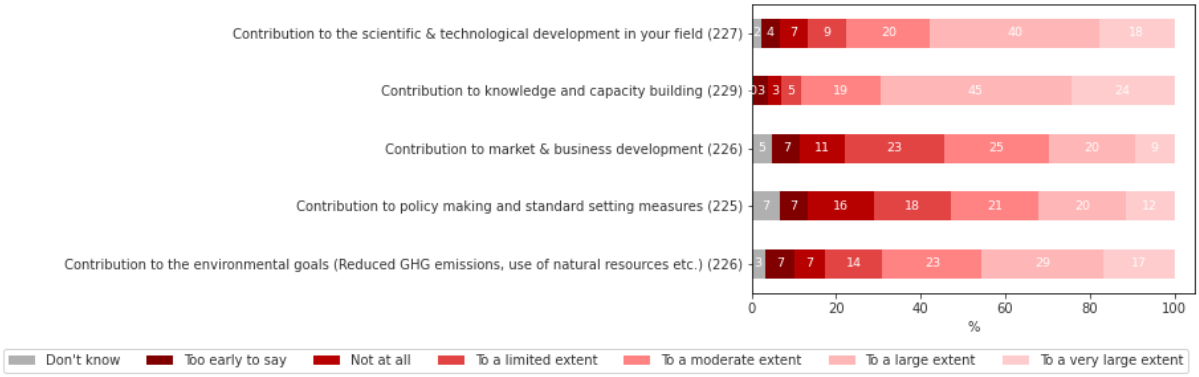


Figure 17 Responses to the question 'How successful was your project in terms of contributing to the following dimensions in your area of expertise?' (Q29)

Source: Survey analysis, number of respondents between brackets

[47] IEA (2021), World Energy Investment 2021, IEA, Paris https://www.iea.org/reports/world-energy-investment-2021, License: CC BY 4.0
[48] Cf: Draft Final Report: Evaluation study on the relevance and internal coherence of Horizon 2020 and its policy mix.
[49] Cf: Draft Final Report: Evaluation study on the external coherence of Horizon 2020, p. 31.

3.2.4.1. *Technology and Innovation*

Case studies show that projects appear to achieve their research objectives. As relevant innovation outcomes, projects developed a portfolio of interventions, including the following: In sectoral services in cities, projects contributed to energy security and reliability, besides other services such as transport and water services. Regarding the case study on a single smart European electricity grid, projects developed software platforms for research use, simulation approaches, and grid operation tools for the industry and power sector and contributed to flexibility in grid solutions and to system integration. Regarding offshore wind, projects conducted feasibility studies, developed designs and demonstrations of larger turbines and solutions or structures for floating offshore wind and bottom fixed offshore wind. In the biofuel context, projects pursued the development of solutions at different points in the value chain, including the supply and processing of biomass, the advancement of intermediate carriers, and the use of biofuels in transport. Many technology and innovation activities focused on application, demonstration, and integration on a higher TRL level, less on basic research and lower TRL levels.

As shown in the figure below, between 22 % and 62 % of the 232 survey respondents assess that the technological development results have been fully achieved or achieved to a large extent. 'Expansion of basic knowledge for technological development' and 'New research tools, models, simulations' stand out as the results which has been achieved to the highest extent (59 % and 62 %). 'Cost reduction of technology'' (26 %) and 'Increasing the safety of technologies and components' (22 %) are the outputs which stand out with a low extent of achievement (full or to a large extent). Moreover, survey results on system development are in line with the results of the case studies, showing that many participants indicated largely or fully achieved contributions to demonstration and piloting of solutions (47 %), integration of technologies (40 %), and system development (34 %) (see Annex VII, Q21).

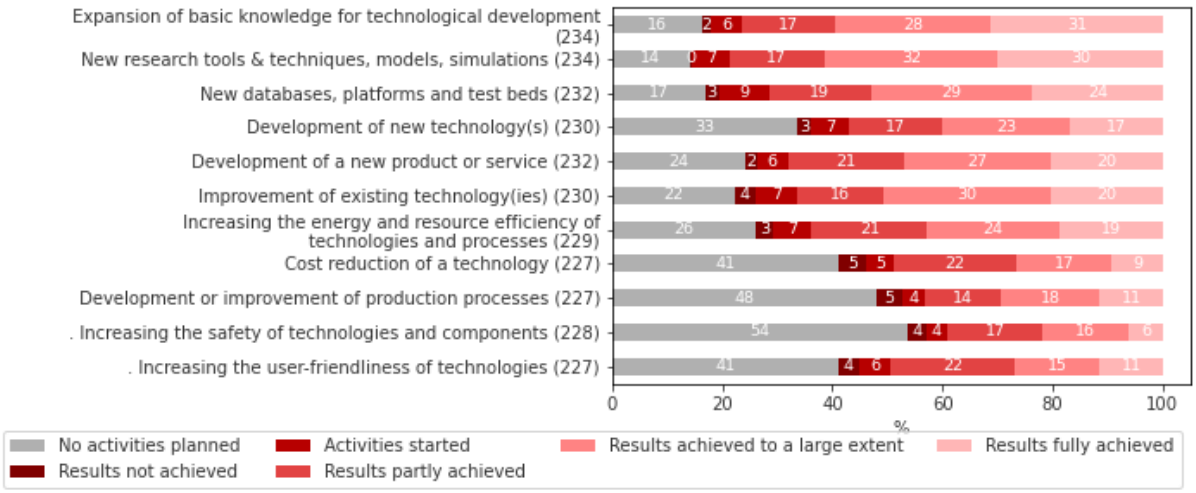


Figure 18 Responses to the question 'In terms of technological development outputs, what are the (anticipated) results of your project?' (Q19)

Source: Survey analysis, number of respondents between brackets

Assessing quantitative findings on technological and innovation outcomes of SC3 projects, 56 SC3 projects (out of 1,100) reported producing a total of 124 unique contributions to patent families so far. Self-reported trademarks, registered design, and utility models number less than 30 (for trademarks) or less than 10 (for the other two IPR modalities) for all SCs (see Annex V). The safest interpretation of these IPR findings is that it is too early in the Horizon 2020 projects' lifecycle to assess IPR-related technological and innovation outcomes. More self-reported outcomes are available in the category of demonstrators, pilots, and prototypes. A number of 168 out of 1,100 SC3 projects report producing such outputs, resulting in 546 unique outputs from this category (see Annex V).

3.2.4.2. *Knowledge and Capacity*

As shown in the figure below, between 49 % and 79 % of the 234 survey respondents assess that different scientific results have been fully achieved or achieved to a large extent. Better understanding of the subject stands out as the scientific result which has been achieved to the highest extent (79 %).

It is followed by ‘Publications in peer-reviewed journals’ (58 %) and 'Better access to state-of-the-art research' (53 %). There is no (anticipated) scientific result which stands out with a low extent of achievement, the lowest being 'Researchers trained' with 49 %.

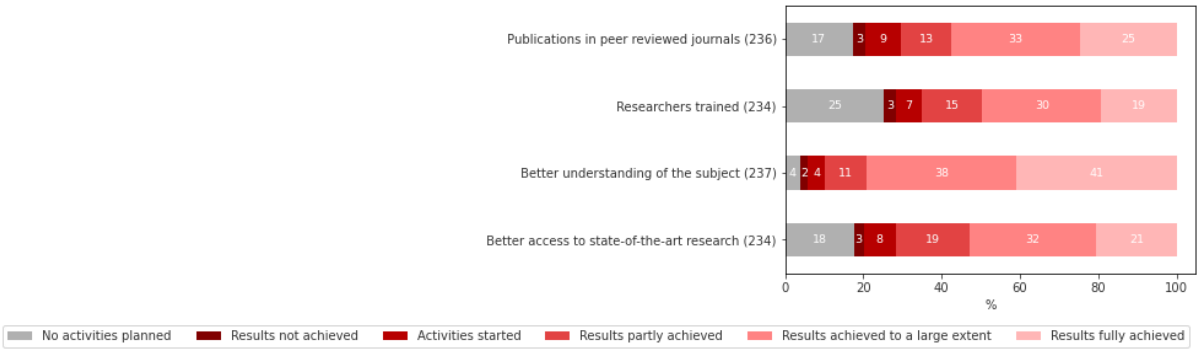


Figure 19 Responses to the question 'In terms of scientific outputs, what are the (anticipated) results of your project?' (Q18)

Source: Survey analysis, number of respondents between brackets

These results are confirmed by the case studies, which found considerable contributions to knowledge and capacity building in their respective areas. Projects generally produced accessible and useful knowledge that was shared through various dissemination and collaboration formats. Communication and diffusion activities included knowledge sharing through liaisons groups (Sustainable and Smart Cities), guidelines for energy consumption interventions and an open-source toolbox for modelling integrated energy systems (Single Smart European Electricity Grid), upskilling in projects where workers move between companies and regulators (Offshore Wind), and targeted dissemination activities for an academic or industry audience and the development of new assessment methodologies (Biofuels). With regards to collaboration and knowledge exchange platforms, the Cities case study illustrates the important role of the AGORA[50] in JPI Urban Europe but finds that joint capacity building was restricted to informal exchange between EC and Urban Europe representatives.

Bibliometrics findings show that 4,761 publications have resulted from SC3-funded projects. A share of 64% of Work Programme 2014-2015 and 2016-2017 projects reported one or more journal publications, keeping in mind that many H2020 projects have yet to conclude and can be expected to produce additional research publications in the near future (see Annex V for full analysis of H2020 project completion dates by Work Programme).[51] Overall, bibliometric evidence suggests that while the performance of publications was very good, cooperation patterns in publications did not fulfil the objectives of the SC regarding crossdisciplinarity, gender balance, or internationalisation. In interpreting the bibliometrics findings, it must be remembered that very few SC-level differential outcomes of Horizon 2020-Green Transition funding have been reported (for the high level analysis, see Annex V, Section 3). That is, the core knowledge and capacity outcomes captured with bibliometrics have been observed in Horizon 2020-Green Transition journal publications from SC2 through SC5. The findings reported below make clear distinctions between outcomes unique to SC3 and those shared with all other SCs. Figures with the quantitative measurements underpinning the observations below are also provided in Annex V, Section 3.

- Like for the other SCs, SC3 funding has enabled researchers with higher-than-EU27-average citation impact performances to reach even higher citation impact performances than in their other work.

- As is the case for the other SCs, SC3 funding has been attributed to researchers with a higher-than-EU27-average propensity to publish under open access. SC5 project funding has allowed these researchers to publish even more often under an open access modality than in their other work.

[50] AGORA is the JPI Urban Europe stakeholder platform. See: https://jpi-urbaneurope.eu/agora/
[51] On a methogological note, a share of 38 % out of 1,110 SC3 projects provided at least one publication used in the bibliometric analysis; 3,521 of these publications were used in the counterfactual analyses that provide the core bibliometric findings.

- Uniquely to SC3, SC3 funding has enabled differential gain in the share of supported publications seeing online dissemination or engagement towards them (altmetrics achievements).

- As is the case for the other SCs, SC3 funding was awarded to researchers with a moderately stronger pre-existing tendency to engage in academic-private co-publication than at the EU27 average. SC3 funding did not allow a differential increase on this dimension, however.

- As is the case for the other SCs, SC3 funding has not had meaningful or statistically conclusive effects on cross-disciplinarity of supported publications.

- SC3 funding has not had meaningful or statistically conclusive effects on the integration of women colleagues in publication authorship.

- SC3 funding has not had meaningful or statistically conclusive effects on the share of supported publications cited at least once in policy-related documents.

- As is the case for the other SCs, SC3 funding has not had meaningful or statistically conclusive effects on the share of publications that are international co-publications. The share of authorship by Third country-based authors in SC3-funded publications was slightly lower than at EU27 average, however.

3.2.4.3. Coordination and collaboration

Based on the results of the case studies, the relevance of coordination and collaboration was generally well-recognised in the programme strategy and projects, and relevant stakeholder groups appear well supported and integrated in the projects.

In the Cities context, projects created learning platforms connecting cities, businesses and research institutions in a double/triple helix that were supported by co-creation tools. Moreover, EC contributions appear well-balanced across public actors, private across, research institutions, and higher education institutions. International cooperation beyond the EU was also an important facet to broaden perspectives and exposing partners to international markets.

In the Grid context, large scale campaigns demonstrated how transmission and distribution systems operators shall coordinate grid services. Cooperation and coordination also took place concerning storage capacity sharing over virtual neighbourhoods of energy ecosystems and operation planning tools through a Pan-European Network. In stakeholder consensus building exercises, European, international, and national stakeholders of the ETIP SNET were able to connect. European level consensus building was supported through a continuous process of interaction with all stakeholders.

In the Offshore Wind context, there appeared to be good collaboration between industry, research centres, and the public sector on defining priorities, in particular through the ETIP Wind platform and the SET Plan implementation. International collaboration played an important role, particularly with the United Kingdom and Norway due to their activities in offshore wind and took place largely through the DemoWind ERA-NET.

In the Biofuels case study, collaboration between stakeholders, particularly with industry partners, was an important part of projects and prerequisite in most calls analysed. Collaboration with partners across the whole value chain was deemed crucial for the projects' success and to bridge the gap between research and implementation. Moreover, industry partners provided financial capacity for the exploitation of project results. International collaboration with non-EU countries was an important factor, with higher participation rates (4.3%) of third countries than the SC3 average.

Survey results (see Annex VII, Q32) confirm the findings from the case studies, showing that participants indicate large or very large contributions particularly to international cooperation and networks (52 %), pan-European, transdisciplinary collaborations (48 %), cross-border, cross-sector coordination and integration (48 %), and communities for stakeholder involvement (46 %). Much lower contributions, however, were seen concerning the involvement of civil society (20 %) and the participation of consumers in the energy transition (28 %).

Concerning inter-sectoral co-participations (see Annexes II and V, much like in the other SCs, SC3 projects saw an increase in participations by Other organisations over thematically similar FP7 projects, from 3 % to 13 %. Co-participations links between Other organisations and Private for-profit entities have increased the most in moving from FP7 to SC3, from 3 % to 8 % of the overall amount of co-participation links.

The increase in the participation and co-participation links of Other organisations comes with decreases in participations by Higher or Secondary Education Establishments (23 % to 17 %) and Research Organisations (23 % to 19 %). The largest decrease in intersectoral collaboration links is for the collaboration share between Higher or Secondary Education Establishments and Private for-profit entities, which went from 20 % in FP7 to 14 % in SC3. On balance (across all sectoral combination pairs), heterophily in SC3 projects is on par with that of thematically similar FP7 projects (59 % and 60 % of co-participation links between heterophilic, respectively).

Considering coordination and collaboration effect in SC3-aligned article 187 and cPPP partnerships, these projects unsurprisingly fostered higher PRC-PRC co-participation links, and co-participation links between PRC organisations and the other organisation types, than found in the SC3 projects themselves. For instance, SC3-art. 187 partnerships fostered a share of 39 % of their co-publication links between PRC organisations, against 26 % in the SC3 projects.

Art. 187 partnerships record 51 % of their co-participation links as heterophilic, while in cPPP partnerships, the proportion of heterophilic links is 63 %.

Considering country-level coordination and collaboration (Annex V, Section 1.5), the network of country participations to Horizon 2020-SC3 projects was dominated by participations from Germany (1st rank as in FP7), Spain (2nd rank, up from 5th rank), France (3rd rank, down from 2nd in FP7), Italy (4th rank, stable ranking from FP7) and the Netherlands (5th rank, up from 8th in FP7).

EU-13 countries' betweenness centralities put them between 15th (Slovenia) and 57th rank (Estonia). Out of these 13 countries, 9 have improved their between centrality ranking in SC3 (or the equivalent FP7 research area) between FP7 and Horizon 2020. To take just one example, Romania has moved from 35th to the aforementioned 15th rank between FPs.

3.2.4.4. Markets and business

As shown in the figure below, between 2 % and 36 % of the respondents assess that the market development results have been fully achieved or achieved to a large extent. 'Development of marketable products or services' and 'Market launch of new products/services' are the market development results which have been achieved to the highest extent (with 36 % and 28 %, respectively, choosing fully or to a large extent achieved). 'Creation of a start-up' and 'Creation of a spin-off' are the anticipated market development results which stand out with a low extent of achievement (2 % and 4 % respectively). The majority of participants (51 %) also indicated a moderate or large contribution of their project to improving the 'time-to-market' of new solutions (see Annex VII, Q25).

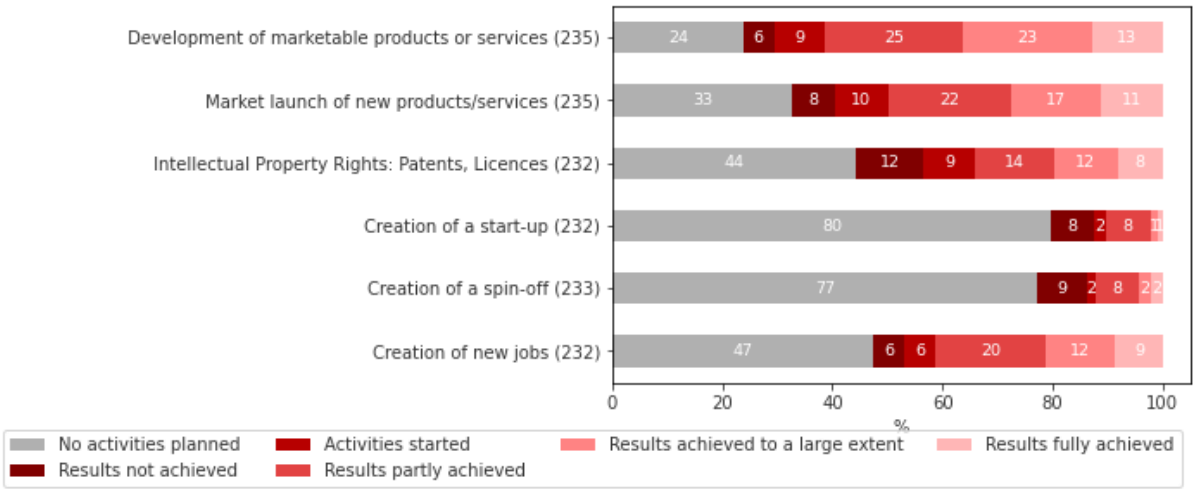


Figure 20 Responses to the question ' In terms of market development, what are the (anticipated) results of your project?' (Q20)

Source: Survey analysis, number of respondents between brackets

Results from the case studies confirm these results and illustrate the market relevance of solutions developed in projects particularly with regards to the development and launch of solutions and services.

In the Cities context, the market-relevance is well reflected in the participation patterns or projects, which generally show strong involvement of public and private actors. As mentioned, funding appears to focus on demonstration and the implementation of real-world solutions and business models. Lighthouse projects contribute to replication and upscaling of integrated solutions. The case study highlights the end of projects as a barrier to market integration. Assessment and follow-up funding may provide incentives to work “on the last mile” and bring solutions to market. In the Grid context, projects include market-driven approaches for operation models, e-trading solutions, demand response tools, and novel business models. In the Offshore Wind context, cost of energy of offshore wind has been reduced significantly compared to the start of Horizon 2020, also due to lower costs of installation and operation. System operators, developers, and governments making commitments to real-life projects allows considerable opportunities for upscaling, with a strengthened role or Europe in the industrial leadership in offshores and floating offshore wind. In the Biofuels context, projects developed sound business models and use cases to demonstrate the financial viability of large scale biofuel production, with pre-commercial testing and production demonstration being important aspects.

3.2.4.5. Policies and standards

SC3 activities provided some contributions towards policy making processes at various levels. The case studies showed that considerable contributions to policies have been present in many projects, for example in the form of strategic guidance and by providing high-level results to policy makers, as well as the standardisation of data and platforms and contributions to regulatory frameworks.

Across all SC3 related projects, between 16 % to 27 % think the projects contributed to certain outcomes in terms of policies and standards. ‘More robust and transparent policy-making products’ comes first with 27 % of the respondents while ‘Harmonisation in calculation of energy performance and certification’ and ‘New and/or improved standards for interoperable networks, new technologies and services’ come last with 16 % and 20 % respectively. Overall, however, survey participants indicated comparatively few contributions to new norms and standards (22 %) compared to more general contributions to system development (see Annex VII, Q21).

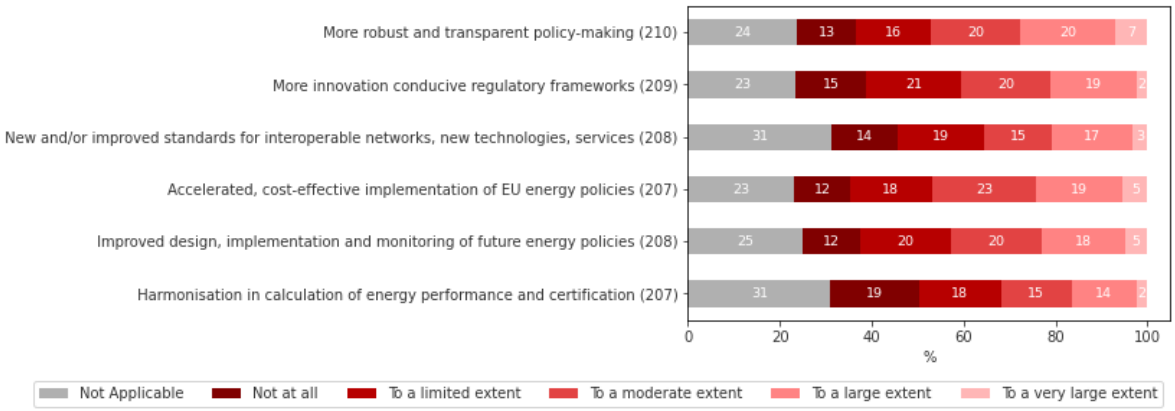


Figure 21 Responses to the question ' To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC3 area? Policies & Standards' (Q34)

Source: Survey analysis, number of respondents between brackets

The Cities case study shows high ambitions to contribute towards institutional and government arrangements and urban and land use. Regarding regulatory frameworks, results were better compliance with EU and national regulations as well as some contributions to existing frameworks and standards. While there was some alignment with ERA-NETs within JPI Urban Europe, there was limited strategic dialogue for the Horizon 2020 Work Programme with the Urban Europe initiative. Standardisation of data and platforms played an important role and funding for these topics was considered crucial as a basis for holistic city development. The Grid case study finds that policy briefs were provided on high-level findings, including typologies for sustainable energy consumption initiatives. Moreover, there were efforts to integrate SSH and European energy policymaking. Similarly, in the Offshore Wind context, policies were informed by the knowledge produced in projects, and evidence from projects provided trust and certainty to the European Commission regarding the feasibility and reliability of the future energy system. EC policy, in turn, provided relevant signals to the market about R&I priorities. In the Biofuels context, activities included seeking improvements to the financial framework conditions, the alignment between policy areas and governance levels, and the harmonisation of national standards and improvements to certification schemes.

3.2.4.6. The role of the JRC

In relation to SC3, the activities of the JRC provides support for the complex matter of energy legislation in the context of the Energy Union Strategy, adopted in 2015. The JRC activities in this area showed that the JRC lends scientific credibility to voluntary initiatives (e.g., Covenant of Mayors) while also providing scientific backing to legislation related to energy efficiency, including on building renovation as well as heating and cooling infrastructure. The JRC also provided dedicated support to legislation on improving the security of gas supply in the EU. This particular activity is part of a number of work streams focused on energy systems and markets that also covers energy digitalisation energy market integration. A large set of activities is additionally involved on the decarbonisation of energy supply, including policy support on batteries, hydrogen power and renewables.

In relation to Energy activities, the experts recognised the role of the JRC supporting other Commission DGs in implementing energy efficiency policies, as in providing guidance to Member States regarding their energy-related national plans. The scientific impact of the JRC's work in this area was particularly noted, based on the highly cited publications in highly-visible journals. The JRC could explore fostering research into energy efficiency with other institutes. It could also further its stakeholder reach by engaging more directly with organisations and associations interested in construction and energy poverty. The experts also considered the JRC to have particular impact in supporting smaller municipalities that may have lacked the resources to develop energy and climate action plans. Similarly for those municipalities in southern Europe where city-level green initiatives may not have pre-existed. However, the experts found it is difficult to trace specific impacts to the JRC's activities given the number of overlapping climate and energy initiatives happening at several levels of governance.

3.2.5. EU Added Value

European R&I related to Energy research and innovation performed in the course of the SC3 Work Programmes and the related public-public and public-private Partnerships exhibit high EU added value. The case studies performed in SC3 show that the portfolios of instruments contributed to the formation of EU wide R&I communities encompassing not only R&I actors, but also relevant national governing bodies, regulation authorities, preparing the field for faster uptake of innovation and alignment of efforts.

Between 34 % and 76 % of the respondents think that Horizon 2020 provided an EU added value in a number of aspects to a large and very large extent. The aspects of 'Multi-cultural consortia' and 'Diversity of partner profiles' come first, both with 76 %. They are followed by 'Funding opportunities for specific topics' (73 %). The lowest value added is on 'Flexibility given to respond to changing socio-economic needs' (34 %) and 'technical support provided' (37 %).

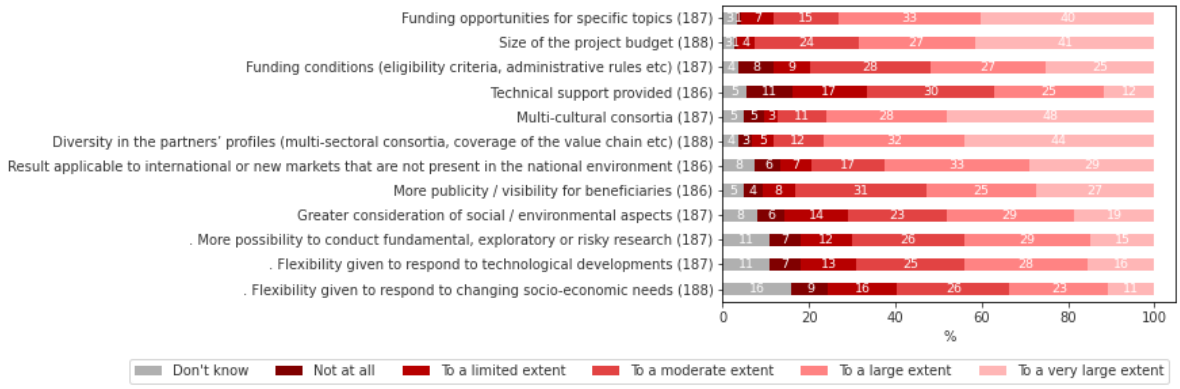


Figure 22 Responses to the question 'To what extent do you see added value from funding Horizon 2020 projects compared to funding on a national or regional level?' (Q50)

Source: Survey analysis, number of respondents between brackets

In the Cities context, the Work Programmes have created highly ambitious flagship initiatives, demonstrating how overarching policy objectives can be operationalised, implemented, and replicated. In the Grid context, Horizon 2020 has increased the participation of the industry compared to earlier funding periods and was able to support the harmonisation between national and EU policy goals, which would have not been possible using only national funding. Offshore Wind has been developed into a "European success story", with almost all coastal countries (and some landlocked countries) exploring or developing solutions in a joint framework. Similarly, in the case of fuel cells and hydrogen, national initiatives (e.g. Italy, Germany) strategically link to overarching EU policy goals. In the area of Biofuels, the FP also provided strong support for the development of expert networks and the establishment of international research teams and streams. Overall, funding and guidance by the EC in SC3 promoted pursuing a European strategy, as opposed to single national efforts by northern and western countries.

At the project level there is evidence for EU added value in SC3 too. Without support of the Framework Programme, 71 % of the respondents answered that the project would not have been implemented at all; 75 % responded that the scope would have been reduced; 44 % that it would have been implemented with other partners. Only 17 % consider that it would have been funded on national or regional level.

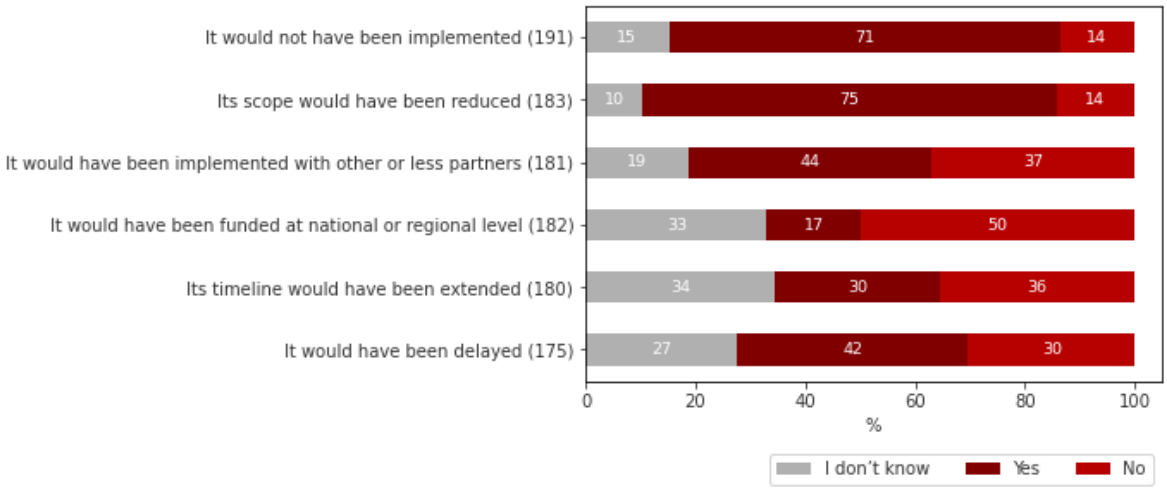


Figure 23 Responses to the question ' Without support from Horizon 2020, what would have happened to your project?' (Q51)

Source: Survey analysis, number of respondents between brackets

Funding provided by SC3 enables 'Multi-cultural consortia' and 'Diversity of partner profiles' (76 %) as well as 'Funding opportunities for specific topics' related to the Energy transition (73 %). The lowest value added is on 'Flexibility given to respond to changing socio-economic needs' (34 %) and 'technical support provided' (37 %).

The main added value of Horizon 2020 Green Transition funding for traditional research work and outputs (captured through the bibliometrics assessment), has been realised in the dimensions of citation impact and open access (see Annex V, Section 3). On these two dimensions, the counterfactual analysis shows that Horizon 2020 funding been awarded to researchers with higher-than-EU27-average performances on these dimensions, and that their Horizon 2020-supported research has reached even higher performances than in their other work. This added value of Horizon 2020 Green Transition support has been observed for all SCs.

SC3 sees unique added value on the dimension of online dissemination and altmetrics achievement. Horizon 2020-SC2 awards have enabled supported publications to reach higher levels on altmetrics dimensions than in other publications by the same researchers.

As is also the case for the other SCs, SC3 research publication did not record added value compared to other publications by supported researchers on the following dimensions: academic private co-publication; gender equity in authorship; cross-disciplinarity; policy-related uptake. SC3 support has had slight negative added value on international co-publication with Third Countries, as was also recorded for the other SCs.

3.2.6. Drivers and Barriers for achieving impact

3.2.6.1. Internal and external factors having an impact on effectiveness and EU added value

The analyses revealed several important factors that impacted effectiveness and EU added value in SC3. While some factors appeared relevant in SC3 overall, some aspects were only found in specific thematic areas as presented in the case studies. In summary, drivers in SC3 comprise a strong focus on higher TRL levels and the demonstration, implementation, and upscaling of solutions through strong EU-wide cooperation with necessary stakeholders, including industry and users. Barriers consist of inconsistent utilisation of EC funding across member states and both programme-related as well as market-specific barriers to the exploitation of project results. The following list is a summary of the drivers and barriers from the synthesis of general analyses and case studies as well as selected factors from the case studies that appear particularly salient. The case studies provide more details on specific drivers and barriers in the respective thematic contexts (see Annex IX).

Drivers:

- **Focus on applied research:** Horizon 2020 appears well structured to move technologies to higher TRL levels, particularly the focus on applied research, replication, and upscaling, if necessary, as well as the involvement of industry and application partners, as evidenced by all SC3 case studies.

- **European cooperation:** Survey results show that multi-cultural consortia were evaluated as the largest added value of Horizon 2020 compared to national or regional funding, with 76 % of participants perceiving a large or very large added value. This factor was noted as particularly important in the Grid and Biofuels case studies, where the internationalisation of research teams and project consortia was deemed crucial for bringing together the specialised expertise along the value chain.

- **Stakeholder involvement:** Cooperation and community building with stakeholders and challenge owners, and particularly with industry partners, have fostered the development of needs-based and practically relevant solutions and facilitated the dissemination and exploitation of results, the planning of future steps. In the biofuels context, for example, industry partners were deemed particularly important due to the increased financial capacity to carry results forward.

- **Implementation and integration focus:** The implementation and integration focus have increased the visibility of solutions and reduced the perceived technological or financial risks and improved learning and capacity building.

- **Replication and upscaling:** The focus on replication and upscaling and strong market integration enabled learnings and exchange on issues of replication and valorisation. Project outcomes appear to have been taken up frequently and utilised after the end of projects. However, the overall exploitation of project results may have suffered due to economic reasons and a lack of follow-up after projects were concluded (see below).

Barriers:

- **Low involvement of some Eastern European Countries:** Overall, some Eastern European Member States saw the lowest EC contributions in SC3, in particular Poland, the Czech Republic, and Romania (see Annex V). Similarly, in the Cities case study, a considerable divide between EU 15 and some EU 13 countries was observed due to low EC contributions in the EU 13 countries stemming from a lack of national public R&I funding provided for EU R&I cooperation in their R&I systems.

- **Low involvement of some large Member States in specific cases:** Although Germany, Spain, and France are the most central countries in the network of SC3 (see Annex V), the case studies 4, and 5 (Cities, Smart Grids) showed comparatively lower participation. Explicitly in the Grid case study, in which joint European approaches have been deemed very important, national activities appear to supersede EC funding in some instances.

- **Lack of last-mile funding and economic risk:** Results of the survey show “limited financial resources for the implementation of the project results” and “economic risk” as the most prevalent barriers as perceived by the participants, with 36 % and 25 %, respectively, describing the factors as large or very large barriers for the successful uptake of project results (see Annex VII, Q35). Moreover, the Grid and Cities case studies specifically identified a lack of project follow-up and “last-mile” funding, which may have incentivised implementing solutions or bringing them to market.

- **Barriers to competitiveness and mainstreaming:** Context-specific barriers prevent or delay large-scale uptake or implementation of solutions. In the Grid context, incumbent players resisting taking up open-source solutions, significant differences in the preparedness across regions, missing regulatory and market frameworks, and lacking inclusions of customers and citizens appear responsible for a delayed implementation of smart technologies particularly in the distribution system. In the biofuel context, second-generation biofuels that do not compete with food crops show low cost-competitiveness, which still prevents their usefulness for the energy transitions.

- **Volatile political framework:** In the Biofuels context, frequent changes in the political framework conditions on a European and national level limited investments, as they created uncertainties for investors. Moreover, biofuels still suffer from a negative public perception that mostly stems from negative associations with first-generation biofuels competing with food crops, influencing the political debate.

- **Lack of flexibility during the project runtime:** The Offshore Wind case study identified a lack of flexibility with regards to updating project targets, which meant that project goals went out of date too quickly as the industry was sometimes moving at a faster pace.

3.2.6.2. Effectiveness of dissemination and communication measures

The case studies find that overall, communication and dissemination measures were effective in capitalising on the investments made by the Work Programmes.

In the Cities context, a variety of activities and effects was identified, ranging from project-specific capacity building to programme level communication and dissemination measures. The study highlights the effectiveness of target-group specific formats and of twinning or leader/follower-approaches.

The Offshore Wind case study found that projects were effective in targeting ETUP Wind, ministries, and regulators to engage decision makers and inform them about project findings. The Offshore Renewable Strategy (albeit not funded under Horizon 2020) was considered an important contribution to the dissemination of offshore wind targets in Europe.

In the Grid context, communication with stakeholders was deemed effective as stakeholders, particularly grid operators, were involved from the beginning using bilateral and multilateral interactions to establish trust and making use of expertise and functionalities for the specific use cases. Regarding the global level, scientific activities were seen as effective in achieving impact. Moreover, the development of open-source solutions was considered crucial for the diffusion of knowledge.

The Biofuels case study found successful communication activities promoting project activities and results, which includes measures by Partnerships. However, a stronger focus on engagement measures with stakeholders and the public was deemed important for the future. Established “brand names” of projects were evaluated as useful and should be kept when they continue activities.

3.2.7. International aspects

Clean energy solutions are worldwide needed for tackling climate change and require heavy public and private investment into clean energy research and innovation. International cooperation in clean energy research contributes to mitigating climate change, reducing emissions and advancing global commitments under the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development. While the SET-Plan provided a strategic approach for advancing the implementation sustainable energy technologies, the priority setting for the international dimension of SC3[52] emphasises that a joint European strategy provides a critical mass to attract interest from other technology leaders and to foster international partnerships to achieve the Union's objectives. It should make it easier for international partners to interact with the Union to build common action where there is mutual benefit and interest.

The survey results (Annex VII) indicate that 27% of the respondents in SC3 have collaborated with non-European partners within the project (Q15). Those who collaborated with non-European partners pointed to several major benefits (Q16) of this collaboration, among which ‘Development of know-how’ is the biggest identified benefit (75% - to a large or very large extent) followed by ‘Development of new, additional partnerships’ (63%). ‘Access to new markets’ and ‘Reduction of the environmental impact of the organisation’ have been the two smallest benefits (17% and 22% respectively). 37% of the respondents consider that cooperation with non-European partners contributes to a large or very

[52] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1291

large extent to improving the European position in the global competition. Another 21% think this advancement is to a moderate extent.

Societal Challenge-level counterfactual bibliometric findings on international collaboration (Annex V) for SC3 show that, SC3 funding did not have a statistically significant effect on international co-operation compared with non-EU FP funded publications but SC3 funded international co-publications exhibit a significant higher share of authorships.

Findings from the case studies in the energy sector show that international collaboration depends largely upon the topic under consideration. The cities case (C4) conducted in SC3 underlined the EU leadership role in tackling global challenges associated with the green transition, and cooperation with third countries was important to broaden research perspectives and explore new approaches and solutions to green transition challenges in the smart and sustainable cities field. Moreover, the investments in international cooperation exposed partners to the demands of international markets and provided first market entry points to them. This aspect of collaboration is reflected in the project participation of partners from third countries. The offshore-wind case (C6) showed that international cooperation played a considerable role in the portfolio with a high project participation from the United Kingdom and Norway due to their activity in the offshore wind sector in the North Sea. On the other side of the spectrum, the case study on smart grids (C5) showed that there was only on Third Country in the network (China) and that H2020-associated countries have been positioned in the periphery with less frequent collaboration links.

3.2.8. Contribution to SDGs

Overall, the case studies show already considerable contributions of SC3 to the SDGs. The programme's objectives in SC3 are generally intrinsically connected to the SDGs, particularly SDG7 ("Ensure access to affordable, reliable, sustainable and modern energy for all"), which is the main reference strategy for energy transition-related activities within the EU. For the most part, projects in SC3 have provided an important basis for progress towards EU policy priorities. The case studies illustrate the importance of SC3 for the SDGs as follows: 1) The case studies Offshore Wind shows strong contributions to and a high relevance for SDGs, particularly SDG7 (Affordable energy) and SDG13 (Climate action). The EUs strengthened focus on renewable energy is strongly reflected in Horizon 2020, and the outlook on the future development in the respective thematic areas is positive. 2) Projects analysed in the Smart Cities case study show strong alignment with several SDGs (particularly 11, 3, 1, 7, and 9) and deems the intervention portfolio an important basis for future Horizon Europe initiatives, such as the Climate Neutral Cities Mission or the Partnership Driving Urban Transitions. 3) The Smart Grid case study also emphasises the topic's relevance for accelerating the provision of digital grid solutions, which are a pre-requisite for universal access to affordable, reliable and modern energy services (7.1), and for increasing substantially the share of renewable energy in the global energy mix (7.2) a well as an improvement in energy efficiency (7.3). Nevertheless, the extent to which smart grids have become a reality does not yet appear satisfactory. Although Horizon 2020 has improved upon the situation, incumbent players still dominate the market and resist taking up open-source solutions. 4) The Biofuels case study found that contribute to more sustainable fuel technologies to decarbonise transport, however, second-generation biofuels still exhibit low cost-competitiveness, which hinders their potential contributions.

3.2.9. Summary of findings

Overall, the findings of the survey and the case studies indicate significant progress towards a Green Transition in SC3 within the Horizon 2020 framework. While the evidence does not allow for reliable claims regarding long-term impacts in the economic, environmental, social and values domain due to their complexity, scope, and time horizon, as well as the limited information supply from monitoring systems, the evidence suggests high relevance and sufficient coherence in addressing the key priorities in energy.

In general, projects in SC3 were found to reliably reach their goals and build an important basis for positive change along the impact pathways, with considerable EU added value both on the project and on the strategic European level. Indeed, Horizon 2020 showed significant EU added value in SC3 that enabled projects with larger scope and more diverse consortia that mostly could not have been implemented otherwise. Added value was also generated in the scientific output, particularly regarding citation impact and open access.

Regarding the strategic orientation and relevance of SC3, the desired results, the thematic portfolio, and the instruments used appeared to be adequate to address the challenges of a Green Transition in energy. In this regard, SC3 took new strategies (such as the Paris Agreement and the Green Deal) into account and responded to emerging threats and challenges over the course of the programme. As a result, the project portfolio appears well-suited, reflecting challenges and needs to achieve the energy transition. Moreover, the funding instruments used appear suitable to implement different project types and address relevant stakeholder groups.

In particular, the evidence shows that the focus on implementation, integration, and demonstration and extensive cooperation with and involvement of relevant stakeholders, such as the industry, cities, or grid operators, have helped developing practice-oriented and usable solutions as well as flagship initiatives that demonstrate how policy objectives can be operationalised with a holistic perspective. In this regard, case studies in SC3 consistently emphasise the added value through collaboration within Europe across stakeholder groups.

Evidence on projects' contributions from the survey and the case studies suggests that SC3 saw significant contributions in scientific and technology development, knowledge and capacity building, and coordination and collaboration. However, regarding contributions to markets and business, survey results and the Cities case study show that a potential lack of "last mile" funding and high economic risk may prevent project results from being implemented in practice or brought to the market. Moreover, area-specific challenges, such as the dominance of incumbent players in grid systems, or the low competitiveness of second-generation biofuels, have hampered the energy transition in these contexts.

The strong focus of SC3 on applied research and the emphasis on demonstration, implementation, and upscaling as well as the European cooperation on complex issues have been important factors driving the effectiveness and EU added value in SC3. However, some large and Eastern European Member States have shown comparatively low participation in SC3, which may have jeopardised the full potential of European cooperation. Regarding the exploitation of project results, the design of the programme may have not used all potential levers to incentivise and support the implementation and market introduction of project r, as financial resources for the implementation of the project results were often perceived as limited, and economic risk was deemed high.

3.3. Societal Challenge 4 'Smart, Green and Integrated Transport'

3.3.1. State of Play

In transport historically, there were three pillars, namely safety, competitiveness, and greening. The objectives in the beginning of H2020 had a stronger focus on growth and wellbeing, and during its implementation focused increasingly on environmental aspects and a move away from the strict division by transport modes. More systemic issues are being addressed and there is also an increase in coverage of socio-economic topics in societal drivers, citizens' needs, mobility drivers and behaviour.

The Societal Challenge benefits from a total budget of EUR 5.7 billion across 1,434 projects (about half dedicated for the Art. 187 Partnerships Shift2Rail, Fuel Cell and Hydrogen, Clean Sky 2, SESAR). The project portfolio is further defined below.

3.3.2. Relevance

3.3.2.1. Strategic priority setting and response to emerging needs

The specific needs identified for Societal Challenge 4 are meeting "the growing mobility needs of its citizens and the changing needs shaped by new demographic and Societal Challenges with the imperatives of economic performance and the requirements of an energy-efficient low-carbon society and climate-resilient economy."[53] To address these needs, the specific objective for the Transport Challenge in 2013 has been "to achieve a European transport system that is resource-efficient, climate and environmentally-friendly, safe and seamless to the benefit of all citizens, the economy and society" (ibid). The aim is to support research and development in the area of green and integrated transport that promises innovation and meets the Societal Challenges. In doing so SC4 aims to keep a balance between the specific research needs for the four modes of transport (road, rail, air and water borne) and the overarching needs for innovation and reduction in pollution, including CO_2 emissions.[54]

Transport is fundamental to economic growth and has local/urban, national and international dimensions. The Interim Evaluation of Horizon 2020 (2017)[55] identified the international dimension as particularly relevant and reflected in a comparatively high proportion of International Cooperation topics (29 % compared to 23.3 % for the entire Horizon 2020 programme) in the programme design. However, at the time of the Interim Evaluation participation from third countries was down from FP7.

Transport is one of the main sources of CO_2 emissions (23 % of all EU Greenhouse gas emissions and 33 % of the final energy use). The continued reliance on fossil fuels, increases in traffic and congestion in European cities caused by increased use of private cars and freight/delivery traffic require a holistic and interdisciplinary approach to R&I.[56] The design of Horizon 2020 recognises the immediacy of the problems and has moved research closer to the market compared to FP7. In addition, it is adaptable to emerging developments.[57]

To achieve the objectives formulated in the legal base, SC4 had been set out along the following four broad lines of activities: 1) Resource efficient transport that respects the environment, 2) Better mobility, less congestion, more safety and security, 3) Global leadership for the European transport industry, 4) Socio-economic and behavioural research and forward looking activities for policy making.

The text analysis of the SC4 Work Programmes, instruments, and projects and the scoping interviews performed in the course of this study helped to reconstruct an intervention logic of SC4, that illustrates

[53] Regulation (EU) No 1291/2013
[54] COMMISSION STAFF WORKING DOCUMENT INTERIM EVALUATION of HORIZON 2020 {SWD(2017) 220 final} {SWD(2017) 222 final}, page 818
[55] COMMISSION STAFF WORKING DOCUMENT INTERIM EVALUATION of HORIZON 2020 {SWD(2017) 220 final} {SWD(2017) 222 final}, page 818
[56] COMMISSION STAFF WORKING DOCUMENT INTERIM EVALUATION of HORIZON 2020 {SWD(2017) 220 final} {SWD(2017) 222 final}, page 827
[57] COMMISSION STAFF WORKING DOCUMENT INTERIM EVALUATION of HORIZON 2020 {SWD(2017) 220 final} {SWD(2017) 222 final}, page 835

how SC4 contributes to a Green Transition through pursuing distinct pathways to impact[58]. Within this intervention logic, the following expected outcomes for SC4 have been identified in the analysis.

Table 6. Pathways to impact and expected outcomes for SC4

Knowledge & Capacity	Technology & Innovation	Coordination & Collaboration	Policies & Standards	Market & Business
Better understanding of local and regional specificities, user behaviour and perceptions New European multimodal transport management systems More service-oriented transport systems Access to new knowledge	Comprehensive, intermodal and appropriate systemic evolution New generation of innovative and environmentally friendly air, waterborne and land transport means Efficient interfaces between long distance and urban mobility networks New European information and payment systems	Stronger pan-European collaboration, across disciplines, sectors, value chains and technology levels Cross-border and cross-sector coordination and integration of R&I efforts	More informed transport policies New transport standards	More competitive and cooperative industry Access to new markets More sustainable manufacturing of innovative systems and equipment

The figure below shows the breadth of the needs and challenges identified to guide the development of Horizon 2020 addressed by the supported projects. Between 34 % and 73 % of the respondents consider that the different needs and challenges have been addressed by the project to a large and very large extent. The challenges and needs which have been addressed to the highest extent are 'making transport more sustainable and respecting the environment' (73 %), followed by 'increase the resource efficiency of the transport system' (69 %) and 'decreasing emissions and other negative side effects of transport' (68 %) (see Annex VII, Q 11). These needs and challenges are closely linked to those identified for a Green Transition as set out in the Sustainable and Smart Mobility Strategy (2020).

[58] See Annex IV: Intervention logics for the complete intervention logic of Societal Challenge 4.

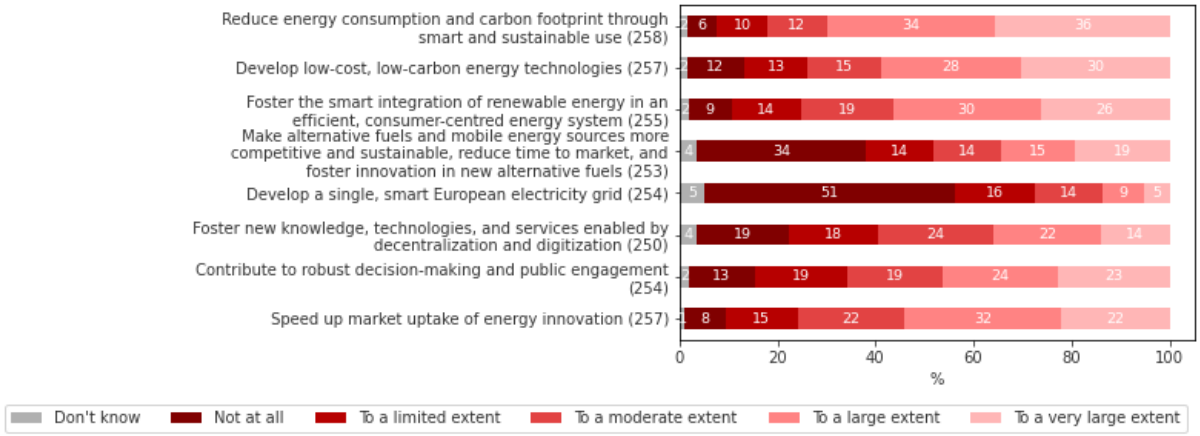
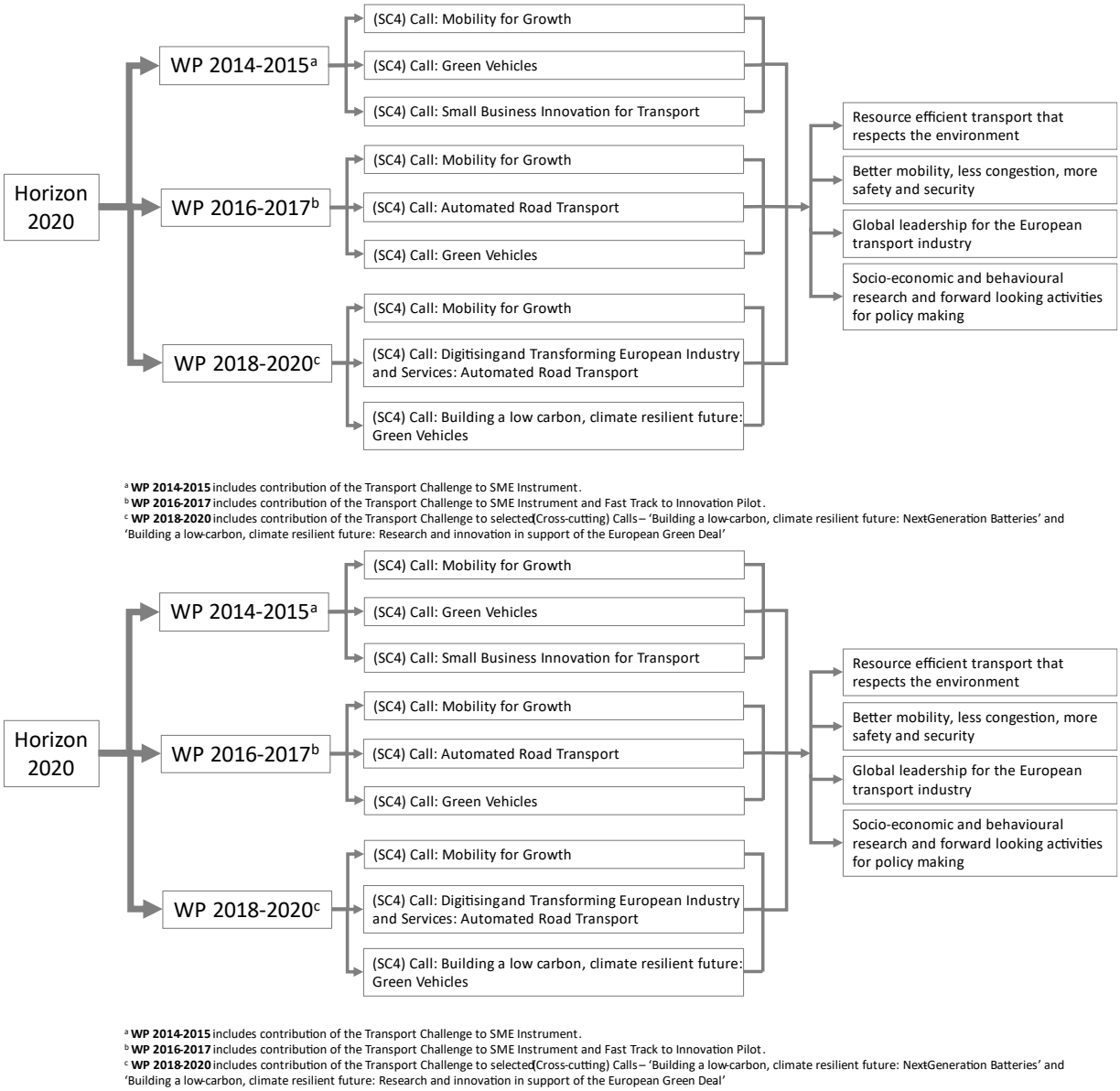


Figure 24 Responses to the question 'To what extent does your project address the following needs and challenges?'

Source: Survey analysis, number of respondents between brackets

The challenges and needs which have been addressed to the lowest extent are 'decreasing traffic congestion' (32 %), 'making transport and transport systems seamless' (34 %) and 'performing socio-economic research and forward-looking activities for policy making' (34 %) (see Annex VII: Survey results, Q 11).

The figure below shows the calls under the Horizon 2020 Work Programmes 2014-2020. The overall objective of achieving a European transport system that is resilient, resource-efficient, climate- and environmentally friendly, safe and seamless for the benefit of all citizens, the economy and society as well as the objectives activities are aiming at and their structure (on the right side) have remained constant over the years. An indication is also provided where SC 4 has made a contribution to other Societal Challenges and their calls within Horizon 2020.



Horizon 2020
WP 2014-2015a
WP 2016-2017b
WP 2018-2020c
(SC4) Call: Mobility for Growth
(SC4) Call: Green Vehicles
(SC4) Call: Small Business Innovation for Transport
(SC4) Call: Mobility for Growth
(SC4) Call: Automated Road Transport
(SC4) Call: Green Vehicles
(SC4) Call: Mobility for Growth
(SC4) Call: Digitising and Transforming European Industry and Services: Automated Road Transport
(SC4) Call: Building a low carbon, climate resilient future: Green Vehicles
Resource efficient transport that respects the environment
Better mobility, less congestion, more safety and security
Global leadership for the European transport industry
Socio-economic and behavioural research and forward looking activities for policy making
a WP 2014-2015 includes contribution of the Transport Challenge to SME Instrument.
b WP 2016-2017 includes contribution of the Transport Challenge to SME Instrument and Fast Track to Innovation Pilot.
c WP 2018-2020 includes contribution of the Transport Challenge to selected (Cross-cutting) Calls – 'Building a low-carbon, climate resilient future: NextGeneration Batteries' and 'Building a low-carbon, climate resilient future: Research and innovation in support of the European Green Deal'

Figure 25 Horizon 2020 SC 4 Calls and their WP focus/ priority areas

Source: Own elaboration

The objectives in the beginning of Horizon 2020 had a stronger focus on growth and wellbeing, but not to the same extent on environmental aspects. The Interim Evaluation[59] makes recommendations related to this, which are taken into consideration in WP 2018-20. The change in the approach of Work Programmes reflects a conceptual shift in research programming and approach to research. This is reflected in the following ways:

There is an increasing focus on green topics. Moving from WP to WP there is a move away from the strict division by transport modes (within Mobility for Growth) towards green technologies. A straight comparison of the topics in WP 14-15 to WP 18-20 demonstrates this shift. The 2014-15 WP starts with a mode-by-mode approach from aviation to waterborne (Mobility for Growth). Additional calls on Urban Mobility and Logistics and other cross cutting topics follow. This is contrasted with a WP 18-20 which starts with cross cutting calls exploring climate resilience, safety, global competitiveness and more.

[59] Horizon 2020 Work Programme 2018-2020, 11. Smart, green and integrated transport, p 6

WP 18-20 highlights the need for disruptive innovations across call themes including in policy making in the urban mobility context, in the design of aircraft, the identification of mobility solutions as a service and more.[60] This change addresses a recommendation by Transport Advisory Group (TAG) regarding the need for more disruptive innovations during the preparation of the WP 18-20.[61]

There is an increase in coverage of socio-economic topics in societal drivers, citizens' needs, mobility drivers and behaviour in WP 18-20 compared to earlier WPs. This addresses the fourth objective for SC4, socio-economic and behavioural research and forward-looking activities for policy making. Case studies 10, 11 and 12 all have examples for this. Case Study 11 for example discusses the challenges of integrating sustainable transport and logistic solutions into planning decisions.

The conceptual shift in Horizon 2020 is continued with a paradigmatic shift in policy from Horizon 2020 to HE to a more environmental and sustainable approach. Avenues in research and innovation already taken under previous FPs were reinforced in new strategies. For example, *Sustainable and Smart Mobility Strategy – putting European transport on track for the future,* the Mobility Strategy 2020, highlights the role of transport and mobility as a service and the need to tackle Climate Change[62]. This can be interpreted as a much more coherent approach with a stronger policy drive.

3.3.2.2. Appropriateness of the programme portfolio

A total budget of EUR 5.7 billion was allocated by the EC to SC4 projects since 2014. About half of the EC contribution is dedicated for the Art. 187 Partnerships (EUR 2.8 billion). Four partnerships have been financed (Shift2Rail, Fuel Cell and Hydrogen[63], Clean Sky 2, SESAR). Projects inside these partnerships account for 48 per cent of all SC 4 projects. The importance of the SME instrument is also significant in SC 4, representing about 26 % of all projects with only 3 % of the budget.

In the transport area two ERA-Net Cofunds on Urban Accessibility and Connectivity (EN-UAC) and Electric Mobility (EMEurope) are financed. In total 48 participations of Member States and Associated Countries have been financed within the framework of the two ERA-Net Cofunds with an EC contribution of EUR 11.3 million and a total investment of EUR 34.2 million. Additionally, two other ERA-Nets have also a small number of transport projects related to waterborne transport (MARTERA – marine technologies as part of SC2) or urban mobility (ENSCC – part of SC 3).

The Art. 187 partnerships in SC 4 vary in size. In terms of number of projects and budget, Clean Sky 2 accounts for two-thirds of all partnership projects in transport and more than half of the EC contribution to the partnerships.

If we look at the types of actions, innovation actions predominate in partnerships, while research and innovation actions predominate outside partnerships in the SC 4 WP. SC 4 has a significantly lower number of CSAs (91 out of 1,434 projects, or 6% in shares, funded with 2% of SC4 EC contributions) compared to the other SCs.

In terms of participations in SC4, larger countries such as Germany, France, Italy, Spain and UK counted most participations. EU-15 countries with well-established R&I systems such as the Netherlands and Belgium were also among the top participating countries.

In terms of EC contribution, the five largest countries France, Germany, Italy, Spain and the UK received largest amount of EC contribution in SC 4. The 'top 5' countries therefore remain the same both in terms of number of participations and EC contribution, albeit France is first in EC contribution and second in participations. EC contributions in SC 4 are highly concentrated in a few member states. More than three quarters are accounted for by the first 6 member states and the UK.

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[60] Horizon 2020 Work Programme 2018-2020, 11. Smart, green and integrated transport, p 6
[61] European Commission, Interim Evaluation of Horizon 2020, Commission Staff Working Document: Annex 2, https://op.europa.eu/en/publication-detail/-/publication/4cedc9a0-d8cc-11e8-afb3-01aa75ed71a1, p 836
[62] Sustainable and Smart Mobility Strategy – putting European transport on track for the future, paragraph 28 and paragraph 36.
[63] SC 4 covers transport projects only. Projects of FCH 2 can also be found in SC 3 and 5.

An analysis of a set of 100 randomly selected SC4 projects from across the Work Programmes and different call areas revealed a very high fit of the project's overall scope with the goals of Horizon 2020 as set out in the specific calls.

A portfolio analysis (illustrated in the figure below) of the 1,434 SC4 projects funded under Horizon 2020 revealed that the largest (42 %) share of EC contribution was attributed to aviation research (775 projects with an EC contribution of EUR 2,437.8 million). It is mainly based on two big Art. 187 partnerships Clean Sky 2 (561 projects with an EC contribution of EUR 1,622.5 million) and SESAR (149 projects with an EC contribution of EUR 545.2 million). This is followed by research related to the road mode of transport (112 projects with EUR 870.3 million). The third largest cluster is made up of research projects that are multimodal in orientation (138 projects with EUR 740.3 million). Other transport modes (rail and waterborne) are less present in Horizon 2020, accounting for only 7.7 % and 3.4 % of EC contribution respectively. The transport sector also benefits from battery research . The share of battery research (7.4 % of EC contribution) is almost as large as research related to rail transport. Socio-economic and behavioural research play only a minor role in SC 4 (35 projects, 1.1 % of EC contribution).

It is apparent from this analysis that research in SC 4 is particularly focused on those modes of transport in which the greatest potential effect of R&I on the reduction of GHG emissions is to be found. Recent analysis by the EEA shows that emissions from aviation are still expected to rise by more than 100% by 2040 compared to 1990 levels. Road transport is on a clear downward trend to below 1990 levels during this time albeit from higher absolute levels.64 Projects dealing with the smooth and intelligent integration of different modes of transport or within public transport also have a considerable share. In this way, a more environmentally friendly choice of transport mode is facilitated.

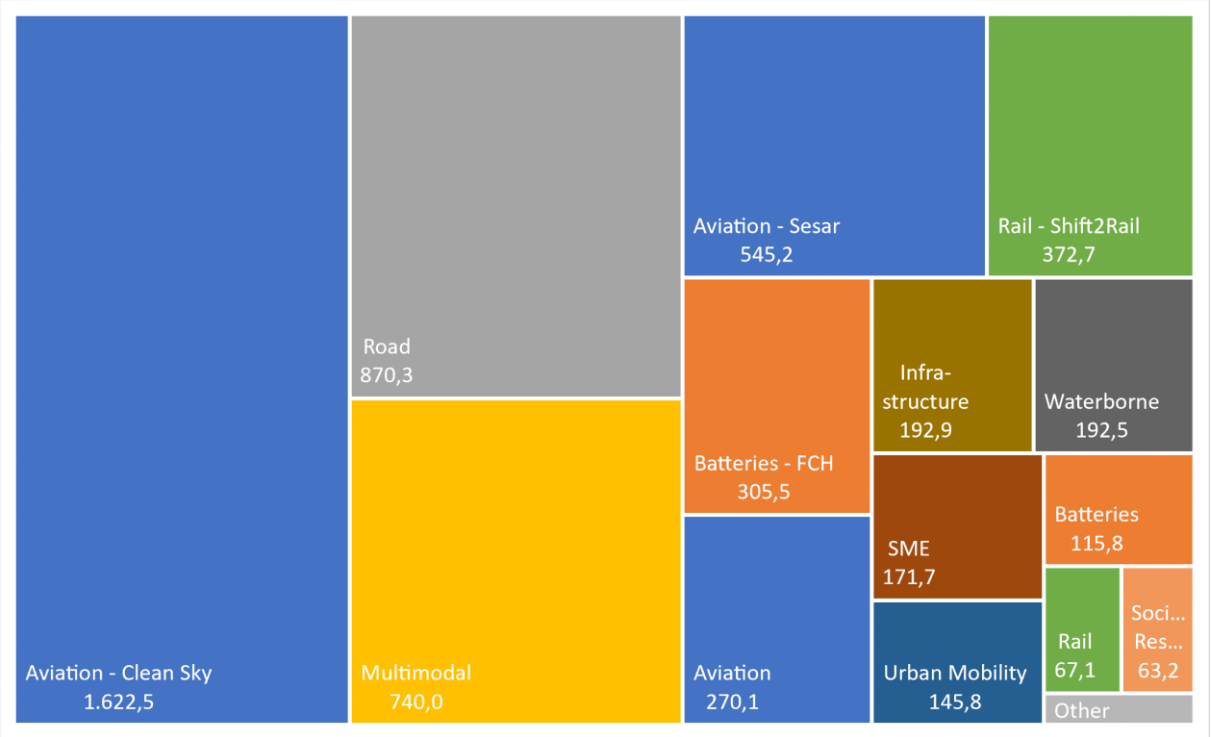


Figure 26 Distribution of EC contributions spent on SC4 projects to clustered sections (WP14-15, WP16-17 and WP18-20; n=1434 projects)

Source: eCorda, own elaboration

[64] European Environment Agency

Regarding the type of beneficiaries, business enterprises show the highest participation rates, with 89 % of projects exhibiting at least one business participation, and on average 6.5 business enterprises participating in each project. About 62% of the EU contribution in SC 4 was granted to enterprises. Projects involving at least one education (64 %) or research organisation (67 %) are also frequent, whereas public bodies only take part in 21 % of all projects. Other organisations (beneficiaries from NGOs, associations etc.) participate in only 25 % of projects. This is considerably less involvement of non-research and non-business stakeholders compared to the other SC.

Concerning newcomers, SC4 shows lower newcomer rates than other SCs. Education and research organisations show a high consistency with a share of only about 5 % newcomers. The share of newcomers among businesses is with 43 % also considerably lower (more than 60 % in other SC).

Coverage of stakeholder groups within the research consortia is good. Some 67 % of the survey respondents believed that all relevant stakeholder groups were completely addressed through the project activities (see Annex VII, Q13+14). Projects with an underlying co-production approach and close collaboration with cluster initiatives were mentioned as successful approaches of stakeholder involvement. By responding 'Partially' the remaining 33 % of the respondents believed that improvements were possible. Especially a lack of time and resources to involve all relevant stakeholders is pointed to. Notably, the involvement of some stakeholders, for example city councils, is more time consuming than that of others, resulting in an imbalance. In some cases, data protection proved to be an obstacle. Commercially sensitive issues and contractual obligations with third parties restricted the exchange of information and hindered stakeholder collaboration.

Collaboration is a main motivational driver for Horizon 2020 participants. The intensity of collaboration with organisations outside the consortium was the highest with regards to research organisations (51 % collaborated or co-led) followed by High Education Institutions (HEI) (44 %). The lowest level of collaboration intensity was identified with regards to NGOs (48 % no contact), Research Funding Organisations (38 %) and user communities (27 %).

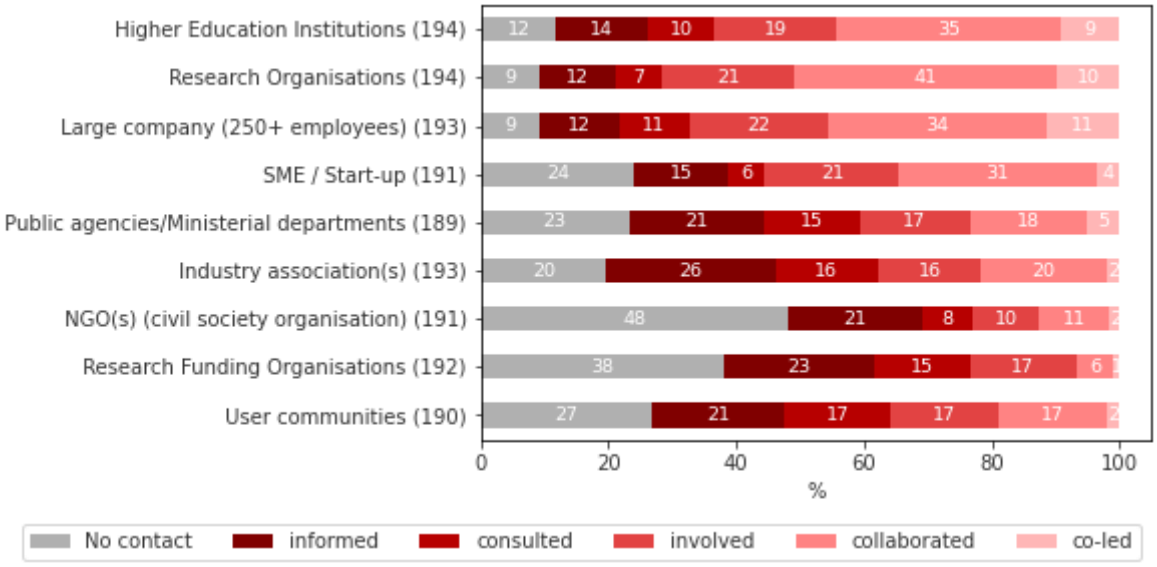


Figure 27 Responses to the question 'How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?'

Source: Survey analysis, number of respondents between brackets

The case studies underline these findings. A close cooperation with other EU projects aiming at similar solutions and facing similar challenges proved to be a success factor, building a focussed community of researchers and active stakeholders in a certain field (case studies 8 and 10). These cooperations were sometimes requested for by the calls and were sometimes organised by project teams on their own initiative. A broader multi-stakeholder engagement approach was seen to be more challenging, taking time and resources to involve stakeholders from civil society, local government and end users (case studies 10 and 11). There is a need for a stronger involvement of user communities to integrate the human factor perspective as well as the technology and bringing these together (case study 12).

3.3.3. Coherence of the intervention

Besides collaborative R&D projects, private-public partnerships, especially Joint Undertakings, play an important role in SC4 Smart Green and Integrated Transport. About half of all EC contributions of Horizon 2020 in SC 4 are going into Clean Sky 2, SESAR, Shift2Rail and FCH. Fuel Cells and Hydrogen (FCH) is partly funded through SC4. The EIT Urban Mobility is aimed at putting new *mobility* solutions into practice and the cPPP EGVI is dedicated to delivering green vehicles and mobility. Public-public partnerships are not as prominent in the transport area with two ERA-Net Cofunds being funded within SC4 (EMEurope, ENUAC) and a small number of transport related calls in two other ERA-Net Cofunds in SC2 (MARTERA) and SC3 (ENSCC) respectively.

The Joint Undertakings are primarily funded by resources from Horizon 2020 in combination with resources from their members in the private sector. Thus, they often help to establish the connection between research carried out and the actual deployment of technological solutions and innovations in the sector. Setting up and design of the Strategic Research and Innovation Agendas of the Joint Undertakings have primarily been driven by industry, with limited involvement of representatives outside the membership of the partnerships. The study on Relevance and Internal Coherence of the Framework Programme (ongoing) concludes in its case study on SC4 that coordination and creating synergies between the European Commission and Joint Undertakings as well as among the Joint Undertakings themselves is below a beneficial level with limited information sharing and no strategic exchange and alignment between Work Programmes and Joint Undertakings. However, evidence from interviews and case studies for this study suggest to the contrary that coordination between collaborative research projects in Horizon 2020 and research agendas set by the partnerships is well aligned for some of the transport areas.

Funding for SC4 in Horizon 2020 is complementary to other EU funding mechanisms. According to the External Coherence Study (2022)[65] especially Horizon 2020 and the Connecting Europe Facility for Transport (CEF-Transport)[66] are complementary to each other, with Horizon 2020 mostly contributing to developing and testing new innovative solutions and at the same time mostly covering innovation in terms of vehicles. CEF-Transport is mostly responsible for the full-scale operational deployment of the innovations as well as infrastructure. The study also finds that Horizon 2020 is an important and proven tool to facilitate cross-border R&I collaboration, which is especially relevant in the context of Trans-European Transport Network (*TEN-T*) policy. The authors recommend a shift towards high TRL research focussing on the development of technologies that could serve the specific policy objectives to bridge a currently existing gap between research and the wider objectives in relation to implementation. “There is a need to start analysing the policy priorities and then establishing the pipelines through the different funding programmes from research to large-scale deployment […] The underlining concept is to move towards synergies by design.” (ibid. p.137) As a positive example promoting synergies the Clean Sky 2 Joint Undertaking synergy label complimentary activities’ mechanism is highlighted. This mechanism, which has worked well for the aviation sector, enabled CS2JU beneficiaries to introduce complimentary activities funded or eligible for support through European Structural and Investment Funds.

Public investments in R&D in transport and mobility are large and diverse. A delineation outside of Horizon 2020 is difficult because of the large variety of actors (from the vehicle manufacturer to transport operator) and sectors (e.g. manufacturing, logistics, transport services) involved. Eurostat for example summarises transport, telecommunication and other infrastructures with a government budget allocation for R&D at EUR 2.5bn in 2020.[67] Because there is no comparable breakdown of figures for transport only this is not directly comparable to Horizon 2020 spending in SC4. Private investments in R&D are even larger. For example, as data from the 2020 EU Industrial R&D Investment Scoreboard show Europe’s automobile industry alone spent EUR 58.8 bn in 2020

[65] Evaluation study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system. Case Study Report. Case 9: Coherence in support to the transport, infrastructure and mobility sector.
[66] The Connecting Europe Facility (CEF) for Transport is the funding instrument to realise European transport infrastructure policy. It aims at supporting investments in building new transport infrastructure in Europe or rehabilitating and upgrading the existing one. https://cinea.ec.europa.eu/programmes/connecting-europe-facility/about-connecting-europe-facility_en#cef-transport
[67] DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: gba_nabsfin07)

compared to Japan with EUR 32bn and the US EUR 14.5bn on automobile research. This compares to a budget of Horizon 2020 on SC4 of EUR 6.3bn over the seven years from 2014 to 2020.

The role of EU funding can therefore be to give direction and to support pioneering research in areas that are not (yet) on the agenda of private sector actors by giving political backing and credibility for novel research topics as well as creating networks of like-minded R&D communities.

3.3.4. Effectiveness of the intervention

The survey and case studies find that projects largely succeed in reaching their objectives. Activities also appear to be an important basis for progress along the impact pathways. Project results, however, do not allow reliable claims regarding longer-term impacts.

Based on the results of the survey and presented in the figure below, between 26 % and 66 % of the respondents assess that the projects contributed to a large or very large extent to the different outcome areas. 'Contribution to knowledge and capacity building' and 'Contribution to scientific and technological development' stand out as the aspects which have been improved to a large or very large extent (66 % and 61 %) (see Annex VII, Q29).

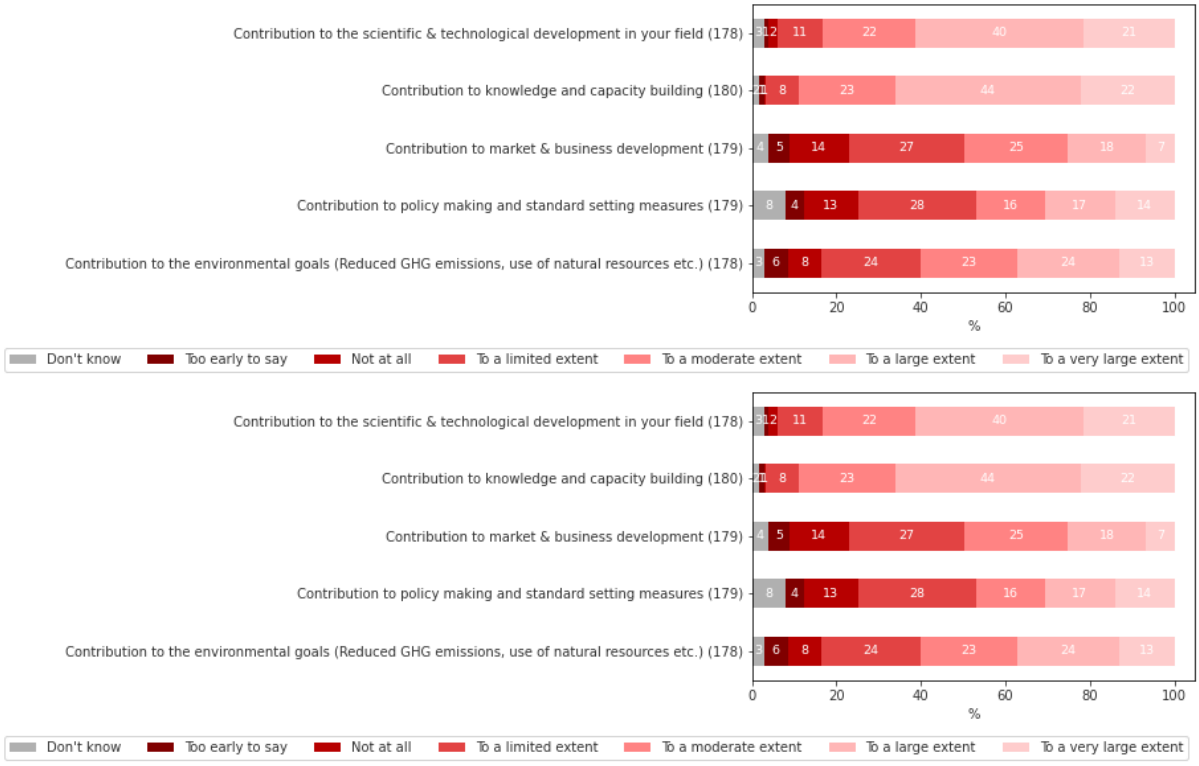


Figure 28 Responses to the question 'How successful was your project in terms of contributing to the following dimensions in your area of expertise?'

Source: Survey analysis, number of respondents between brackets

The dimension "Contribution to market and business development" has the least support from survey respondents. A quarter (25 %) of the 179 respondents confirm a very large or large extent of contribution to Market and Business development (see Annex VII, Q 29). While this is a significant share it is clearly smaller than for the other dimensions. These results make this pathway comparably the least important for Transport and Mobility.

The following sections review the results by impact pathway.

3.3.4.1. Knowledge and Capacity

Survey results show that between 51 % and 85 % of the 184 respondents assess that different scientific results have been fully achieved or achieved to a large extent. Better understanding of the subject stands out as the scientific result which has been achieved to the highest extent (85 %). It is

followed by 'Other publications' (65 %) and 'Better access to state-of-the-art research' (60 %). There is no anticipated scientific result which stands out with a low extent of achievement, the lowest being 'researchers trained'' with 51 % (see Annex VII, Q18).

Bibliometrics findings show that 3,443 publications have resulted from SC4-funded projects. A share of 53% of Work Programme 2014-2015 and 2016-2017 projects reported one or more journal publications, keeping in mind that many H2020 projects have yet to conclude and can be expected to produce additional research publications in the near future (see Annex V for full analysis of H2020 project completion dates by Work Programme).[68] In interpreting the bibliometrics findings presented below, it must be remembered that very few SC-level differential outcomes of Horizon 2020-Green Transition funding have been reported (see the high-level analysis Annex V: Quantitative data analysis). That is, the core knowledge and capacity outcomes captured with bibliometrics have been observed in Horizon 2020-Green Transition journal publications from SC2 through SC5. The findings reported below make clear distinctions between outcomes unique to SC4 and those shared with all other SCs. Figures with the quantitative measurements underpinning the observations below are also provided in Annex V: Quantitative data analysis.

- Like for the other SCs, SC4 funding has enabled researchers with higher-than-EU27-average citation impact performances to reach even higher citation impact performances than in their other work.

- As is the case for the other SCs, SC4 funding has been attributed to researchers with a higher-than-EU27-average propensity to publish under open access. SC4 project funding has allowed these researchers to publish even more often under an open access modality than in their other work.

- As is the case for the other SCs, SC4 funding was awarded to researchers with a moderately stronger pre-existing tendency to engage in academic-private co-publication than at the EU27 average. SC4 funding did not allow a differential increase on this dimension, however.

- As is the case for the other SCs, SC4 funding has not had meaningful or statistically conclusive effects on cross-disciplinarity of supported publications.

- SC4 funding has not had meaningful or statistically conclusive effects on the integration of women in publication authorship.

- SC4 funding has not had meaningful or statistically conclusive effects on the share of supported publications cited at least once in policy-related documents.

- SC4 funding has not had meaningful or statistically conclusive effects on the share of supported publications seeing online dissemination or engagement towards them (altmetrics achievements).

- As is the case for the other SCs, SC4 funding has not had meaningful or statistically conclusive effects on the share of publications that are international co-publications. The share of authorship by Third country-based authors in SC4-funded publications was slightly lower than at EU27 average.

In addition to these results, the case studies reveal how knowledge has been created. For example, SC4 funding has delivered platforms and models which improve the integration of emission free transport and logistics options into busy city centres. This demonstrated by Case Study 11 which includes the example of the FLOW Multimodal Transport Analysis Methodology. Funding has also supported the advancement of knowledge on new materials for efficient aviation like hybrid thermoplastic composite, smart materials and metamaterials to increase aerodynamic efficiency

[68] On a methodological note, 35 % out of 1,434 SC4 projects provided at least one publication used in the bibliometric analysis; 1,079 of these publications were used in the counterfactual analyses that provide the core bibliometric findings.

reducing the use of fuel in aircraft (see Case Study 9) and has contributed to the development of lightweight and composite materials for the maritime industries (see Case Study 8).

The case studies also demonstrate the role of the projects in capacity building and training of researchers and students. Capacity building applies to the users of research results as well as the researchers themselves. For example, transport managers demonstrate need to access knowledge and an ability to make use of it for example in exchange networks. Access to knowledge is all the more important where users are smaller, less well-resourced units (e.g. smaller towns). There is also evidence that the development of new subjects or combination of subjects for further education and training becomes imperative to enable knowledge creation in the areas included in the case studies, e.g. electric aviation or the inclusion of new mobility solutions in transport planning. For example, case study 9 refers to the need to train students and young professionals systematically to enable them to fill the foreseeable demands of new technologies and Case Study 11 demonstrated how projects have supported public authorities in filling knowledge gaps on the impact of sustainable mobility measures and state of the art data collection, interpretation and transport modelling.

Building of and access to research infrastructure across Europe also was an important outcome in several of the case studies (e.g. wind tunnels to test new vehicles) supporting the creation of knowledge.

3.3.4.2. Technology and Innovation

Overall, between 24 % and 70 % of the 185-188 respondents assess that the technological development results have been fully achieved or achieved to a large extent (see Annex VII, Q19). In more detail: 'New research tools, models, simulations' and 'Expansion of basic knowledge for technological development' stand out as the technological development results which have been achieved to the highest extent (66 % and 70 %). 'Cost reduction of technology'' (26 %), 'Development and improvement of production processes' (24 %) are the anticipated technological development results which stand out with a low extent of achievement (full or to a large extent). It has to be noted though, that almost half of the projects did not intend to generate results in this area. 44 % and 48 % respectively had no activities planned in this regard. Thus, developing new technologies rather than making existing technologies more efficient or cost effective is at the core of the projects.

Assessing quantitative findings on technological and innovation outcomes of SC4 projects, 56 SC4 projects (out of 1,434) reported producing a total of 112 unique contributions to patent families so far. Self-reported trademarks, registered design, and utility models number less than 20 (for trademarks) or less than 10 (for the other two IPR modalities) for all SCs (see Annex V). The safest interpretation of these IPR findings is that it is too early in the Horizon 2020 projects' lifecycle to assess IPR-related technological and innovation outcomes. More self-reported outcomes are available in the category of demonstrators, pilots, and prototypes. A number of 165 out of 1,434 SC4 projects report producing such outputs, resulting in 495 unique outputs.

All five case studies demonstrate that most projects achieved their objectives. Outcomes include the demonstration of electric shipping vessels (several demonstrators) and electric aircraft (albeit a very small one), including related certification processes. Examples include the demonstration of aircraft relying solely on electric propulsion or the use of advanced materials (see Case Study 9).

The case studies also identify innovative ways of approaching transport modelling and management in towns and cities to include walking and cycling as well as improvements in safety. Particularly important was the testing of mobility solutions and data collection on site[69]. For example, projects were able to link innovation and research by and for industry into bus and cargo bike systems directly into local governance to enable the creation of solutions to specific locations such as combining public transport and delivery services in space poor inner city areas. The implemented solutions mostly still exist in the cities and regions as demonstrated in Case Study 10 and Case Study 11.

[69] See for example Case Study #10.

3.3.4.3. Coordination and collaboration

More than half of the respondents report contributions to coordination and collaboration to a large or very large extent (see Annex VII, Q32): With 'International cooperation and networks to address common challenges and explore synergies' (56 %), 'Stronger pan-European collaboration across disciplines, sectors, value chains and technology levels' (53 %), 'Cross-border and cross-sector coordination and integration of R&I efforts' (52 %) and 'Community and networks for improved stakeholder involvement' (51 %) cooperation as well as collaboration results are achieved. Only 'Stronger involvement of civil society in R&I' stands out as the outcome to which projects have contributed the least (16 %), with a high share of 22 % finding this not applicable to their project.

Looking at quantitative evidence on co-participation links in SC4 projects shows more subtle changes in the move from FP7 to Horizon 2020 than for the other SCs (see full findings in Annex V: Quantitative data analysis), with small increases found in co-publication links amongst combinations of Public bodies (PUB), Private for-profit entities (PRC), and Other organisations (OTH). The share of homophilic co-publication links (PUB-PUB links, PRC-PRC links, etc) remains at 38 % or 39 % in both cases, indicating a re-shuffling of co-participation links amongst different sectors rather than an outright increase in heterophily of the whole network (keeping in mind that homophilic and heterophilic co-participation links are strictly mutually exclusive and together account for the totally of co-publication links).

The highest absolute shares of co-publication links in SC4 projects are taken up by the PRC-PRC combination (29 %), the PRC-Research Organisations combination (17 %) and the PRC-Higher or Secondary Education Establishments combination (15 %).

Compared to SC4 projects, the networks of SC4-aligned art. 187 and cPPP partnership participants display much higher homophily (58 % and 47 % shares of homophilic sectoral co-participation links, respectively). This homophily is very much driven by co-participation links within the private-for-profit sector, which account for 55 % of co-participation links in art. 187 projects and 42 % of co-participation links in cPPP projects.

In terms of country-level coordination and collaboration (see Annex V: Quantitative data analysis), the network of country participations to Horizon 2020-SC4 projects was dominated by participations from the United Kingdom (1st rank, up from 5th in FP7), the Netherlands (2nd rank, up from 17th rank), France (3rd rank, up from 4th in FP7), Italy (4th rank, up from 6th) and Belgium (5th rank, down from 3rd in FP7).

EU-13 countries' participation-based betweenness centralities put them between 14th (Poland) and 37th rank (Malta). All EU-13 countries have either improved or maintained their betweenness centrality ranking in SC4 (or the equivalent FP7 research area) between FP7 and Horizon 2020.

Evidence from the case studies illustrates how collaboration is an important pathway to impact. Collaboration took place in the form of collaboration with other projects also supported by Horizon 2020. Case Study 8 provides evidence for the successful collaboration between market competitors played a major role in the success of projects in the maritime sector. Case Study 9 demonstrated successful collaboration across sectors which usually do not collaborate (e.g. aviation and automotive) and of researchers from countries usually not involved in these specific areas of research. The latter enables establishing of new research institutions in countries which so far had no related capacity. Case Study 11 includes an example of a project which enabled a university in a member state which so far had no experience in leading EU R&I projects not only to successfully coordinate but also advise other universities to do so thereby enabling the attraction of more R&I funds in the future.

The case studies further provided evidence that successful cooperation between partners from industry, public organisations, certification bodies and researchers can play an important role in successful delivery. Case Study 8 shows this for the maritime sector. This case study also highlighted the role that infrastructure owners (here ports) are likely to play in the future development of technology. The case studies provided some evidence on the role of coordination. For example, Case Study 10 shows that an Horizon 2020 project (CIVITAS) provided a framework to enable coordination between cities and support their efforts to create more sustainable transport systems.

The case studies also showed that some relevant stakeholders, especially smaller organisations, had not been sufficiently active in the collaborations. Case Study 10 provides evidence of this in the

context of urban mobility, where small scale initiatives seen as important at the local level were less active than would have been useful to achieve results on the ground.

3.3.4.4. Policies and standards

Between 26 % and 28 % of respondents think the projects contributed to desired outcomes in terms of policies and standards to a large or very large extent（see Annex VII, Q34). 'New transport standards' comes first (28 %), followed by 'More robust and transparent policy-making' (27 %) and more innovation conducive regulatory frameworks. Inversely, between 30 % and 36 % think the projects contributed not at all or to a limited extent to the outcomes. Between 18 % and 22 % state that the question is not applicable.

Contrary to the survey the case studies included projects contributing to the development of policies and standards, in particular in the form of certification and guidance. Certification processes and guidance to mainly local policy makers were not included in the survey as specific forms of policy and standard setting and therefore not referred to by the respondents.

Certification plays an important role in all forms of transport. Individual parts of vessels and vehicles in all modes have to be certified before they can be used. Guidance can support the many local governments which are aiming to provide the best service for their citizens in complex situations. Both, certification and guidance, have to be seen in conjuncture with the legal geography of transport which differs between modes. International shipping and aviation have global systems, road and rail are impacted by national systems. Local governance plays an important role for transport management in towns and cities. Bearing these geographic constraints in mind, the case studies provided evidence for the following different realisations of this pathway:

- Certification processes are critical for the use of results of research and achievement of objectives: Projects achieved certification and also build capacities in certifying organisations to ease the way for future green transport. Case Study 9 provides an example for the aviation industry and Case Study 12 for the safe use of new technologies in road transport.

- Guidance provided by research projects and implemented by users mainly at local level enabling stakeholders to move to greener transport. One example for this is included in Case Study 11 where guidance related to specific topics of Sustainable Urban Mobility Planning was provided to towns and cities.

- Standardisation nationally using research insights to ensure similar levels of safety or suitable interfaces in the IT architecture (MaaS) across the EU (Case Study 11).

- In achieving certification for green mobility in aviation (Case Study 9) and shipping (Case Study 8) the case studies demonstrate that research can influence policy to push harder for greener transport modes in order to achieve ambitious net zero targets.

3.3.4.5. Markets and business

Compared to the other pathways 'Market and business' is of less importance to the projects in transport and mobility. Detailed survey results show that between 24% and 83% of the 180-185 respondents have no planned activities in terms of market development, among which are creation of a spin-off/start-up, new jobs, intellectual property rights and market launch of new products/services. 'Development of marketable products or services' is the result that stands out with only 24 % having no activities planned and 38 % reporting a high achievement (results to a large extent and fully achieved) (see Figure 87)).

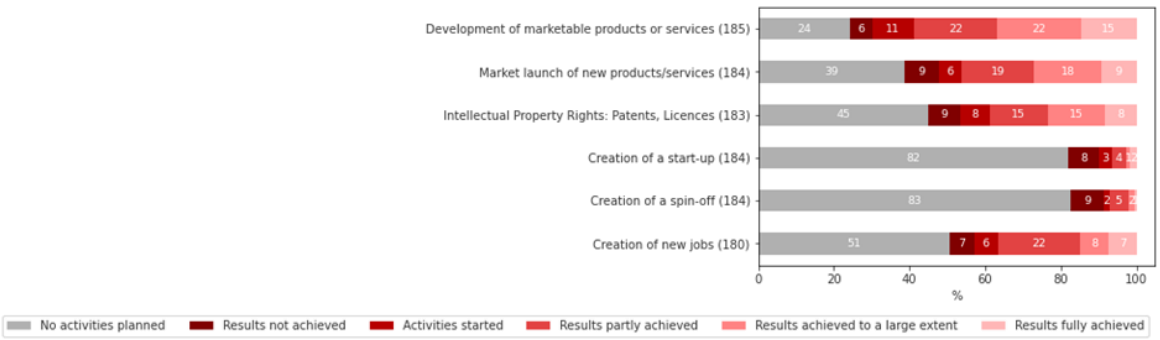


Figure 29 Q20: In terms of market development, what are the (anticipated) results of your project?

In comparison to a share of 8 % of projects targeting TRL8 and 4 % targeting TRL9[70] within the scope of Horizon 2020 (see Annex VII, Q24) this can be assessed as a promising outcome, assuming that development continues and higher TRL will be reached in future. In addition, some 38 % of the respondents think that the project has contributed to a large or very large extent for the improvement of time-to-market of technological solutions (see Annex VII, Q25).

Businesses have been strengthened by their participation especially on a national and European level. The survey shows that the project influenced their competitiveness nationally (39 %), in Europe (39 %) or internationally (25 %) to a large or very large extent. Around 28-32 % think that the increase has been to a moderate extent (see Annex VII, Q28).

Between 14 % and 42 % of the respondents think their project contributed to a large or very large extent to the different desired outcomes of Horizon 2020 in the area of 'Market and business' (see Annex VII, Q33). The share is the highest for the outcome 'More competitive industry' (42 %) followed by 'Reduced time to market' (27 %) The share is the lowest for the outcome 'Higher consumer awareness and acceptance'. It has to be noted that a significant portion of the respondents think the contribution has been moderate.

The case studies demonstrate the importance of the link between solutions identified in the research process and testing them for final use. Being able to test quickly can be important from a business perspective in order to reach the market as it is from a customer perspective to address societal needs. This is for example demonstrated in Case Study 12 with respect to the use of technology for autonomous driving. Several of the projects included in the case study highlighted the need for testing in different settings (e.g. urban versus rural).

The case studies (Case Study 8 and Case Study 9) also identified the need to include infrastructure such as airports and ports that accommodate electric or other low emission means of transport into forward planning to enable market participants to make use of the new technologies and deliver the Green Transition.

Case Study 11 provided an interesting example how start-ups could be integrated into the research process, enabling them to identify market opportunities and provide mobility solutions which would not have come to their attention otherwise. Several social impact start-ups were contributing in project HiReach to address transport poverty and provide services to vulnerable groups. An accelerator supported start-ups in a way to elaborate business models for new and inclusive mobility solutions.

3.3.4.6. The role of the JRC

In relation to SC4, the activities of the JRC have been highly complementary to the activities of the Framework Programme and the activities of the partnerships, as the JRC activities efforts aimed to play a key role in the shaping of standards and policy in the transport sector, including emobility, and

70 Targeted TRL refer to the perception of survey participants, not the requirements set out in the Work Programme which only allows actions up to TRL 8.

in identifying and addressing EU priorities for research and innovation. For example, the JRC performs safety assessments of hydrogen and fuel cells in transport applications, and conducts scientific activities on electric vehicles, smart grids and battery performance. The JRC in particular provides technology and fuel oriented work to support European and international legislation aiming at cleaning and decarbonising transport, with a strong focus on pollutants and CO_2 emissions reduction, the electrification of road transport (including batteries innovation) and alternative fuels in several transport modes (including related infrastructure).

The experts found the JRC to be central to the development of on-road emissions testing, reporting the discrepancies between laboratory and on-road vehicle emissions that led to the outbreak of the Dieselgate scandal, and informing the new legislation on vehicle emissions testing/surveillance that has followed. The impact of the JRC's activities is observed from citizen and city levels (citizen groups and NGOs), all the way to UN committees where it works with other countries to develop international emission regulations.

3.3.5. EU Added Value

The survey clearly finds that Horizon 2020 funding adds value compared to funding on a national or regional level. Between 36 % and 79 % of the respondent agree to a large and very large extent that Horizon 2020 provided an EU added value in a number of aspects. The highest agreement is on the diversity of partners' profiles (79 %), followed by multi-cultural aspects of the consortia and funding opportunities for specific topics (both 77 %). The lowest value added is on 'technical support provided' (33 %), followed by flexibility given to respond to changing socio-economic needs (36 %) (see Annex VII, Q50).

In addition, without Horizon 2020 funding, some 61 % of the 161 respondents answered that the project would not have been implemented; 74 % that the scope would have been reduced; 46 % that it would have been implemented with less or other partners; 20 % that it would have been funded on national or regional level; 39 % that its timeline would have been extended; and 45 % that it would have been delayed (see Annex VII, Q51).

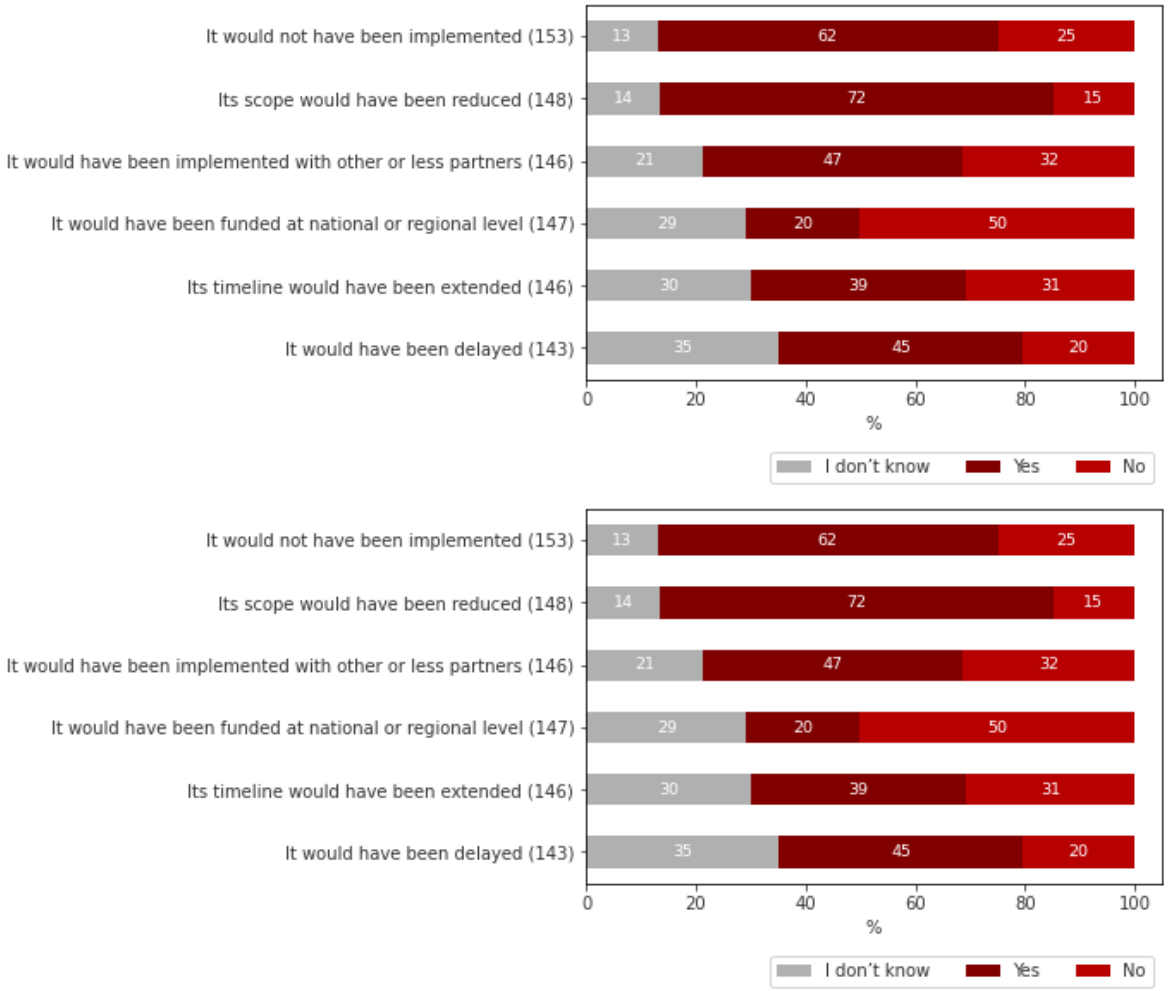


Figure 30 Responses to the question 'Without support from Horizon 2020, what would have happened to your project?'

Source: Survey analysis, number of respondents between brackets

The main added value of Horizon 2020 Green Transition funding for traditional research work and outputs (captured through the bibliometrics assessment – see full results in Annex V: Quantitative data analysis), has been realised in the dimensions of citation impact and open access. On these two dimensions, the counterfactual analysis shows that Horizon 2020 funding has been awarded to researchers with higher-than-EU27-average performances on these dimensions, and that their Horizon 2020-supported research has reached even higher performances than in their other work. This added value of Horizon 2020 Green Transition support has been observed for all SCs.

As is also the case for the other SCs, SC4 research publication did not record added value compared to other publications by supported researchers on the following dimensions: academic private co-publication; gender equity in authorship; cross-disciplinarity; policy-related uptake; and online dissemination and online engagement (altmetrics achievement). SC4 support has had slight negative added value on international co-publication with Third Countries, as was also recorded for the other SCs.

The case studies provide evidence that EU research activity enables building skills and capacity in EU members states who so far have not conducted research in areas around net zero transport, in particular aviation and shipping (case studies 8 and 9). In some case studies EU funding is the only available source as there are no national public funding for the specific research area. Examples of this are included in Case Study 9 and Case Study 11.

The early efforts that the Commission has been making in the field of mobility solutions like shared mobility, cycling and walking as well as Mobility as a Service (MaaS) are much appreciated (see Case Study 11). The EU Commission was the only owner of public R&I funding, that was in 2014 at all

interested in the topics which approached transport and mobility as a service or research questions regarding cycling and walking. The EU gave political backing and credibility to taking those topics seriously, noting the fact that not all problems can be solved completely using only technological means.[71] An example is the need for a shift in the preferred mode of transport for many people, the private car, to public modes of transport, especially rail[72].

EU projects have enabled partnerships and networks between beneficiaries, companies and other organisations such as city governments which would not have come about without EU funding. These create future opportunities for research and the implementation of clean mobility solutions.

As already shown in the portfolio analysis, partnerships are very important in SC 4 in terms of EC contribution, project numbers and participations. The Art. 187 partnerships assessed under this SC demonstrate the unique ability of the EU to bring together large numbers of participants, enabling the building of capacity and spreading of results as well as a dynamic and diverse approach to problem solving.

Activities in the transport pillar of Fuel Cells and Hydrogen (FCH) are designed to accelerate the commercialisation of FCH technologies in transport applications through a programme that includes demonstration and research projects. The FCH JU did not have strong instruments for influencing national policies and technology priorities of Member States and Associated Countries. Most notably, the State Representatives Group did not prove to be a strong and effective entity for facilitating coordination. Nevertheless, since the creation of the JU there has been some perceptible alignment of Member State activities, visible, for example, in the cooperation between municipalities and regions in the implementation of demonstration programmes for hydrogen fuelled buses and in the strategy for hydrogen refuelling stations being implemented through H2Mobility. The existence of the FCH JU has made significant progress in eliminating the fragmentation that previously existed in EU support for FCH technologies that had been dispersed between several support programmes within FP7 and its predecessors. The FCH JU provided a common ground for interaction between beneficiaries of national, regional and European projects, effectively contributing to overcoming the fragmentation of the sector and reinforcing synergies between stakeholders.

The added value of Clean Sky 2 is bringing together the aviation community in Europe behind the objective of reducing the environmental impact of aviation or for Clean Aviation climate neutral aviation by 2050 respectively. Clean Sky 2 was successful in bringing together in their membership all relevant players in aviation in Europe, research institutions, long established big companies as well as SMEs and countries that have not been involved in aviation research before. In this sense the Joint Undertaking integrates the European industry along the value chain and builds a community of practice that opens entry points for following commercial activities as partners have the possibility of getting to know each other before entering long-term contractual commitments as is the case in the aviation industry with very long product development cycles. An economic modelling for the socio-economic impact of Clean Sky 2 suggests that the funded research could deliver economic benefits equivalent to 3.4 times the investment in the programme to Europe by increasing productivity in aerospace and related sectors, and by making European aerospace more attractive to foreign investors.[73]

SESARs role of coordinating all ATM R&D in Europe and the nature of the JU as a public-private partnership induces collaboration of stakeholders across the entire ATM value chain, sets cross-border initiatives and strengthens the link between R&D and the SES policy initiatives through the ATM masterplan. Of note is also the collaboration been industry competitors that SESAR was able to ignite who, without SESAR, would not have a structured framework to collaborate on R&D solutions that are the interest of both industry players and the ATM community at large. As a result, SESAR was able to create additional EU value such as improving technical interoperability between countries and creating a brand representing European leadership in ATM R&D globally.

[71] See Section 4 in EU Regulation No 1291/2013 identifying the benefits of all citizens, economy and society as drivers of R&I activity for Europe.
[72] See for example case study 12.
[73] Towards Towards Climate Neutral Aviation, An Independent Study on the socioeconomic impact of the European Union's Clean Sky 2 programme, 2022

Shift2Rail activities have produced solutions that have shown how to implement overarching policy objectives that are not limited to regional or national contexts. Cross-border solutions and standardisation processes are needed in order to be competitive at the European level. Shift2Rail and the issues it addresses have drawn attention to new and relevant topics in some countries, and thus complementing structures and funding opportunities for railroad issues have been created. Bundling of research activities on rail transport topics under one programme management is seen as a main asset, allowing a strong international exchange during the individual projects and beyond, once they have been completed and bringing together different actors from the rail industry to jointly validate solutions and establish a shared vision for the rail sector. Therefore, the Shift2Rail programme implementation within Horizon 2020 overall demonstrated also a high behavioural additionality within the EU railway system. Long-lasting effects on the conduct of research in the EU R&I railway community have been created. The emphasis set in the programme under Horizon 2020 on openness and collaboration in research and innovation, the value of interoperability beyond systems and national borders, the value of interdisciplinary research, and the importance of attention for the needs of customers and society at large in terms of, e.g., sustainability and user-friendly applications, has led to a change in the R&I agendas of the participating organisations (research & industry). Combined with the well-known influence of EU R&I policymaking and EU R&I agendas on national R&I agendas, these “cultural” changes in the approach to research in the R&I performing organisations themselves set an important basis for the future attainment of the desired transition of the European railway system.

ERA-Net Cofunds pool the necessary financial resources from the participating national and regional research programmes with a view to implementing joint calls for proposals resulting in grants to third parties with EU co-funding in this area. Participants are encouraged to include other joint activities including additional joint calls without EU co-funding. EU provides top-up funding for an integrated programme with distributed implementation by entities managing and/or funding national R&I programmes. In the transport area two ERA-Net Cofunds on Urban Accessibility and Connectivity (EN-UAC) and Electric Mobility (EMEurope) are financed. A narrow understanding of EU added value describes the level of leverage achieved. According to ERALEARN-data in EN-UAC and EMEurope 24 calls have been released. For every euro of EU contribution, 3 euros of national funds were leveraged by these two ERA-Nets.

3.3.6. Drivers and Barriers for achieving impact

The survey results show that between 11 % and 29 % of the respondents consider that different types of barriers impede the successful uptake of their projects to a large or very large extent (see Annex VII, Q35). The two barriers which stand out are ‘Limited financial resources for the implementation of project results’ (29 %) and ‘Impact of COVID19 pandemic’ (20 %). If respondents who chose that the influence is moderate are added to the figures, then ‘Lack of internal organisational support for implementation’ and ‘High economic risk’ are also tangible with 41 % and 44 % respectively.

3.3.6.1. Internal and external factors having an impact on effectiveness and EU added value

All R&I activities are impacted by internal and external factors which can either support of hinder delivery. Below these have been analysed as drivers and barriers.

Drivers:

- **The project consortium, the partners involved and the project coordinator** can be a key driver to the project: Partners should include when relevant certification bodies to enable faster implementation of project results. This finding is supported by all case studies. Case Study 12 highlights in particular the driving force a highly committed coordinator can play, while the role of experienced partners is particularly highlighted in Case Study 11. Examples provided were bringing in third country participants and ensure timely delivery of work during COVID.

- **Cooperation with other EU projects** has positive impacts on outcomes by creating synergies and learning. This is demonstrated in Case Studies 8 and 12 where collaboration with other projects running in parallel or projects of successive calls are linking into each other to create learning across time.

- **Technology and knowledge transfer** from previous EU projects which build into a logical flow of innovation and technology development. This is demonstrated by Case Study 9 where projects were designed to build on each other moving towards higher technology readiness levels.

- **Flexibility** in scheduling, exchanging partners or adapting the subject matter, where demonstrated by the EU has been helpful. This allowed the project partners to reflect on results and pivot the project where results pointed into new directions. Case Study 11 highlights the advantages of a balance between flexibility to drive results and more stringent management to ensure delivery according to plan.

Barriers:

- **Research budgets:** These are in some cases small compared to money spent by large manufacturers or the research needs. This was found by Case Study 9 where research spending on particular projects was identified as low compared to the private sector spending in these areas.

- **Understanding of the Innovation Process**: The different paths of the innovation process may not be fully appreciated by Commission staff and some participants beforehand. Case Study 12 for example suggests that, a process of small steps with intermittent testing in real life scenarios steered by a small and dedicated project team may be more appropriate than a "big leap" approach.

- **The technology focus** of EU Horizon 2020 projects creates a risk for innovation as it leaves out some of the social science domains which are necessary for achieving Green Transition. The analysis of the projects included in Case Study 11 shows instances of a technology focus, which left out the social innovations required to address issues of urban mobility. The EU could nurture strong interdisciplinary research and create additional added value by enabling researchers to look outside their traditional disciplines.

- **The risk appetite of partners**: Risk aversity has been identified as a factor holding up progress. One example emerged from Case Study 9 where OEMs were identified as risk averse, which might lead to holding back on technological development.

- **Complexity of Multi-stakeholder approaches** especially when communities and Governments need to be involved. Case study 10 showed that local actors (e.g. city governments) who have to implement some of the findings on mobility can be hard to reach for researchers. It also requires additional resources to stay in touch with a comparatively large number of smaller stakeholders. In addition, political interests can change during projects. This is demonstrated in case studies 10 and 11 where close collaboration with local authorities played an important role.

- **Reduced implementation resources at the EU level** can impact negatively on projects to deliver. Case studies provide some evidence that the EC has reduced its own subject expertise. This means projects don't have knowledgeable points of contact. See for example Case Study 11 where interviewees felt that a reduction in staff had held work up as there was insufficient capacity to comment or experience to be an "intelligent client" or Case Study 9 where a reduction in numbers of Scientific Officers at the Commission (or not yet sufficient experienced staff in the Agencies) left a resource as well as a competency gap. These observations may have bene caused by the transfer of project management to the Executive Agency as of H2020. During the time of transfer the agency needed to build up staff and expertise levels.

3.3.6.2. Effectiveness of dissemination and communication measures

The survey results show that a significant majority of respondents think that dissemination, exploitation, and communication activities have been both useful (71 % to a large and very large extent) and sufficient (59 %). Less than 8 % don't know or consider that they have been neither useful nor sufficient (see Annex VII, Q36).

The case studies provide some more detailed assessment of dissemination. Projects in the case studies face different audiences ranging from small clearly defined groups around industries such as aviation (Case Study 9) to larger more amorph audiences such as towns and cities, community groups

and residents (case studies 10 and 11). All projects in the case studies have used the "usual" communication tools such as websites and social media. One challenge with these communication methods is that after the closure of the projects these are no longer maintained, and results get lost as highlighted in Case Study 12 where project team members attempt to maintain a website with cost effective safety measures beyond the end of the project but faced resource challenges in doing so.

With marketing agencies apparently specialising on EU research projects there is now a certain homogeneity in the look and feel of these websites with little additional creativity. Case Study 11 refers to an emerging industry developing websites for EU R&I projects. The Cordis site was identified by some as being behind the times and difficult to navigate.

The need for fast messaging on social media reduces the time and scope to think messages through and link them up into coherent, reflected information. Case Study 11 provided some evidence that researchers could feel overwhelmed by this task.

COVID impacted on the use of conferences, particular to close the projects and disseminate final results. However, in some cases online conferences reached a much larger than expected audience in other countries who would have been very unlikely to attend a traditional conference.

3.3.6 International aspects

Transport is an international sector, in vehicle production (incl for rail, road, air and water) as well as service provision. National transport systems are linked to each other, in particular in Europe via roads, rail, waterborne transport and air but also intercontinental, especially via air and waterborne transport links. International supply chains depend on well functioning transport links to enable trade. The resulting environmental challenges such as CO2 emissions are also international challenges.

The H2020 Regulation highlights the role of international cooperation in order to address global problems and strongly encourages the inclusion of third countries into R&I work. However, for transport it is clear that the integrated transport system within the EU needs to become clean and safe for all to use which creates a focus on cooperation within the EU.[74] In addition, many of the problems such as air pollution and lack of safety are localised within regions and cities rather than spilling over into third countries.

Maintaining and increasing the competitiveness of European transport industries globally is clearly spelled out in the H2020 regulation. The Work Programmes operationalise this:

- Work Programme 2014-15 focuses the international cooperation effort on international aviation in three separate calls for cooperative projects with Japan, Canada and China. The focus is on improving the skills and knowledge base available to European researchers.

- Work Programme 2016-17 includes calls for collaboration to address 'global challenges such as CO_2 and polluting emissions, oil dependency, transport safety and security, noise pollution, and standardisation of many services, products and procedures...' because these will benefit from global solutions.[75] The WP highlights in particular road transport automation, green vehicles, safety and infrastructure as areas for potential cooperation with the US, and green vehicles and safety as areas for cooperation with China and Brazil. Transport safety is a topic of considerable interest for cooperation with African countries.

- Work Programme 2018 - 2020 highlights the need for international cooperation again, making the link to the Paris Agreement. This WP also highlights that those sectors which are internationally regulated and have international standards such as aviation and shipping require cooperation. This is important for European competitiveness as well as for addressing international environmental challenges.

[74] Section 4 in EU Regulation No 1291/2013
[75] Work programme 2016 – 2017, smart, Green and Integrated Transport

Bibliometric findings on international cooperation (Annex V) for SC4 show that, as is the case for the other SCs, SC4 funding has not had meaningful or statistically conclusive effects on the share of publications that are international co-publications. The share of authorship by Third country-based authors in SC4-funded publications was slightly lower than at EU27 average, however.

The survey conducted for this evaluation provides insights into the usefulness of international cooperation where it occurred, however only a minority of respondents had cooperated with third country partners: Around two thirds of 198 survey respondents answered the question whether they had collaborated with non-European partners as project partners in their project (Question 15) with 'No', a further 6% didn't know, leaving 27% to respond, yes. Those who collaborated with non-European partners pointed to several major benefits of this collaboration. 'Development of know-how' is the biggest identified benefit (75% - to a large or very large extent) followed by 'Development of new, additional partnerships' (70%). 'Access to new markets' and 'Reduction of the environmental impact of the organisation' have been the two smallest benefits (31% and 34% respectively) (Question 16).

Survey respondents who had collaborated with third country partners (n=52) were further asked whether this cooperation with non-European partners in H2020 contributed to improving the European position in the global competition. Some 46% of the respondents to this question (Question 17) consider that cooperation with non-European partners contributes to a large or very large extent to improving the European position in global competition. Some 23% think this advancement is to a moderate extent. Some 17% think it is either to a very limited extent or not at all while the remaining 14% either don't know or think it is too early to tell.

The case studies do not include many examples of international cooperation. Case Study 12 includes a project (Safer Africa, WP 16-17) which applies learning from EU experience in improving road safety into the African context. It acknowledges the significant differences between European and African safety records and the urgent need to reduce fatalities and injuries.

3.3.7. Contribution to SDGs

R&I conducted under SC4 contributes to SDGs 3 (Ensure healthy lives and promote well-being for all at all ages), 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities) and 12 (Responsible Consumption and Production)[76].

SDG 3 includes target 3.6 "By 2020 halve the number of global deaths and injuries from road traffic accidents".[77] It has to be noted that most of fatal accidents and injuries occur on the roads of less developed countries (see Case Study 12 for detail).

Considering SDG 9, several of the case studies identify the role infrastructure plays for example in enabling the use of non-fossil fuel based propulsion in aircraft and shipping (Case Studies 8 and 9) or the need to adapt infrastructure in towns and cities to enable the use of autonomous driving (Case Study 12) or the combination of non-fossil fuel based forms of public and private transport (Case Study 11).

The provision of safe and sustainable transport systems for all[78] (SDG 11) is also subject of many of the projects analysed under SC4. Case Study 12 for example assesses the safety implications of interactions of transport modes such as rail and road in the European context as well as the context of developing countries in Africa. Here the considerable learning and improvements achieved in Europe contributes towards the SDG globally.

[76] See Inception Report for detail on these.
[77] See United Nations Statistical Office, Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development.
[78] See SDG 11, Target 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

The case studies[79] demonstrated that the strategic objectives, such as zero emission transport (including airborne) relevant for SDG 12[80] are feasible in principle. It is now for policy to start pushing more strongly towards the achievement of ambitious objectives and to take other long-term decisions to enable them (e.g. into infrastructure). Case Studies 10 and 11 demonstrate some of the challenges on the ground when implementing these. For example, local planning needs to address at times conflicting needs of private and public transport while enabling changes to more sustainability through the support for clean transport including walking and cycling.

3.3.8. Summary of findings

Overall, the findings indicate R&I under SC4 within the Horizon 2020 framework has had significant success in moving closer to a Green Transition in transport. This was particularly demonstrated in the transformation of the Work Programmes from 2014 to 2020, taking into account recommendations of the interim evaluation. While the evidence does not allow reliable claims regarding long-term impacts in the economic, environmental, social and values domain due to their complexity, scope, and time horizon as well as the limited information supply from monitoring systems, the evidence suggests a continuing high relevance with transport being one of the main sources of CO_2 emissions. The evidence also supports sufficient complementarity and coherence to facilitate cross-border R&I collaboration, which is especially relevant in the context of transport and mobility.

In general, projects were also found to reliably reach their goals and build an important basis for positive change along the impact pathways. EU added value is significant with the enabling of international R&I networks and drive for cross EU thematic development (e.g. the inclusion of behavioural research, walking and cycling into technology driven R&D) as two examples. In a number of projects (e.g. in case studies 10 and 11), green transport solutions (e.g. better public transport, redesign of transport spaces) have been implemented in cities and municipalities and continue to be implemented and contribute to the Green Transition.

In particular, there is robust evidence on successful contributions for knowledge and capacity building and technology and innovation, where survey responses directly reflect the positive results of the case studies. The case study evidence highlights the strengths of the outcome pathways of Knowledge and Capacity Building within the research community and stakeholders including local authorities (see case studies 10 and 11) and Technology and Innovation, for example in the development of very-low emission and lightweight vessels (case study 8). Drivers for success to be highlighted include the strengths and compatibility of participants and project coordinator as well as a multi-stakeholder approach which brings together all relevant interests.

However, some gaps and weaknesses have to be noted. There are examples, where a strong technology focus of EU Horizon 2020 projects creates a risk for innovation as it leaves out some of the social science domains which are necessary for achieving Green Transition. Multi-stakeholder approaches could be improved, especially when communities and Governments need to be involved. Also, the outcome pathways of Market and Business and Policies and Standards are weaker compared to the other pathways. This could indicate a need to strengthening these pathways as they are clearly necessary for implementation and uptake of Green Transition related research results. For example, a more systematic approach to integrating certification authorities could support moving products more speedily towards the market.

3.4. Societal Challenge 5 ‘Climate action, environment, resource efficiency and raw materials’

3.4.1. State of Play

Horizon 2020’s approach to climate change and sustainable development has arguably had more of a focus on the challenges and solutions for climate action when compared to the objectives of its predecessor, the seventh Framework Programme (FP7) and its cooperation theme on environment (including climate change). During its implementation, its approach has increasingly focused on more

[79] Case Study 8 for shipping, Case Study 9 for aviation.
[80] SDG Target 12.1 Sustainable Consumption and production patterns is the relevant sustainable goal, especially regarding sustainable mobility

systemic approaches. Furthermore, the announcement of the European Green Deal by the Commission resulted in the Horizon 2020 final work programme (2018-2020) being amended through a European Green Deal Call, and the Circular Economy Action Planchanged the Focus Area on Connecting economic and environmental gains – Circular Economy to consolidate R&I initiatives on the topic.

SC 5 benefited from a total budget of EUR 3.04 billion across 524 projects (additionally the Art. 187 partnership Fuel Cells and Hydrogen was financed through SC5 at around EUR 25 million across 8 projects).

3.4.2. Relevance

3.4.2.1. Strategic priority setting and response to emerging needs

Climate action and sustainable development is approached in Horizon 2020 through a series of actions and collaborative opportunities in Societal Challenge 5 (SC5) under "Climate action, environment, resource efficiency and raw materials". The Horizon 2020 Regulation (Point 5 of Part III of Annex I)[81] describes the specific objective for SC5 as being to: *…achieve a resource- and water-efficient and climate change resilient economy and society, the protection and sustainable management of natural resources and ecosystems, and a sustainable supply and use of raw materials, in order to meet the needs of a growing global population within the sustainable limits of the planet's natural resources and ecosystems. Activities will contribute to increasing European competitiveness and raw materials security and to improving well-being, whilst assuring environmental integrity, resilience and sustainability with the aim of keeping average global warming below 2°C and enabling ecosystems and society to adapt to climate change and other environmental changes.*

As described in the previous section of this report, the definition of Green Transition within the context of SC5 is not straightforward. Climate action is a broadly based concept across mitigation, adaptation, and resilience and at MS, EU and international/UNFCCC levels. The definition and implementation of 'climate action' within SC5 should be seen as being part of a 'broader' climate action concept.).

The prioritisation and positioning of climate action (and sustainable development) within Horizon 2020 (and for SC5) were strongly influenced by the Europe 2020 strategy and its “20/20/20” targets and three mutually reinforcing priorities on smart, sustainable, and inclusive growth. It is also notable that while climate action, the environment, resource efficiency, and raw material issues were rated in 2011 as a major Societal Challenge in the Horizon 2020 impact assessment, the 2017 Interim Evaluation for SC5 noted that they were even higher up and at the top of the political agenda in 2016.

In this study’s first interim report, it was noted that Horizon 2020 has recognised the need for and integrated climate action and sustainable development as key priorities to be addressed through its implementation. While these have both been established in a cross-cutting sense within Horizon 2020 (and indeed as a mainstreamed issue), climate action, and sustainable development is approached through a specific Societal Challenge[82].

SC5 set out from the start of Horizon 2020 to support the achievement of a resource/water efficient and climate change resilient economy and society (while protecting and sustainably managing natural resources/ ecosystems and enabling a sustainable supply and use of raw materials). A broad range of R&I focussed needs and priority activities for climate action and sustainable development have also been defined and implemented under SC5. These include topics that focus on: climate science, earth observation, mitigation,[83] adaptation, resilience, nature-based solutions (NBS), and systemic eco-innovation and Circular Economy. SC5 has then aimed through its implementation of the Green Deal objectives (to enhance the transition to a more climate resilient, resource efficient, and competitive Europe) while contributing to the Sustainable Development Goals (SDGs) and to the Paris Agreement. SC5 is also notable as having contributed to a wide range of EC priorities, which include: the Energy

[81] EU Regulation No 1291/2013 (See https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1291)
[82] Horizon 2020’s approach to climate action and sustainable development has had more of a focus on the challenges and solutions when compared to the objectives of the seventh Framework Programme (FP7) cooperation theme on environment and climate change.
[83] As described in Chapter 2 for SC5, mitigation has been more within the overall focus of other SCs, such as SC3 (energy) and SC5 (transport). SC5 has been prioritised environment and efficiency and raw materials and their relevance for climate action.

Union and its forward-looking climate policy; making Europe climate-resilient; an internal market with a strengthened industrial base (and most especially raw materials); and a 'stronger global actor', through the Intergovernmental Panel on Climate Change (IPCC), the Group on Earth Observations (GEO), the Belmont Forum, Transatlantic Ocean Research Alliance, and the SDGs.

Horizon 2020 and its three SC5 Work Programmes have each aimed to contribute to a Green Transition and in a manner based on the needs and priorities at the time of their implementation. An analysis during this study of the Horizon 2020 Regulation (EU Regulation No 1291/2013) and the three SC5 Work Programmes and their respective projects shows that distinct pathways to impact can be identified, which connect the activities carried out with identifiable effects (outcomes). Based upon this analysis and the development of an intervention logic for SC5 the table below provides an overview of the pathways to impact identified for SC5.[84]

Table 7. Pathways to impact and expected outcomes for SC5

Technology & Innovation	Knowledge & Capacity	Coordination & Collaboration	Market & Business	Policies & Standards
New/improved technologies and services accelerating transformation towards climate neutrality (as far as not covered in other SCs). New/improved solutions for sustainable water and forest management. New/improved solutions for preservation and management of cultural heritage at risk from climate change. Digital systems fostering resource efficiency. Innovations enabling increased product durability, interoperability, repair and reuse. Innovations enabling increased recycling of raw	High-quality, policy-relevant evidence on climate change to support mitigation policies and operationalise Paris Agreement goals. Improved capability in assessing impacts of climate change, including mitigation and adaptation costs and co-benefits. Improved understanding of climate change and provision of reliable climate projections. Innovative cost-effective risk prevention and adaptation measures. Improved dissemination of knowledge on	Stronger pan-European and international collaboration, particularly in climate science. Cross-border and cross-sector coordination and integration of R&I efforts across sectors. Collaboration and support with existing research initiatives and networks. Improved participation and financial contributions to multilateral processes[85] and monitoring exercises.	Increased investment in and market uptake of eco-innovation. Increased efficiencies from enhanced supply, use and re-use of secondary raw materials. Improved competitiveness and business/job creation in the field of climate science.	Enhanced alignment and synergy of climate-related R&I and policy. Improved use of existing climate- and water-related Earth Observation data for policymaking. Support to innovative policies and societal change in the context of climate mitigation & adaptation, etc. Improved decision-making on adaptation options, disaster response, and water management. Long-term mitigation and adaptation policy planning. Enhanced implementation of climate and environmental policies.

[84] See Annex IV for the intervention logic that has been developed by this study for SC5.
[85] E.g. Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), intergovernmental Group on Earth Observations (GEO).

Technology & Innovation	Knowledge & Capacity	Coordination & Collaboration	Market & Business	Policies & Standards
materials and higher quality of secondary raw materials. Strengthened eco-innovative technologies, processes, and services. Technologies and data infrastructures enabling comprehensive and sustained Enhanced Operations & Maintenance (EO&M).	climate change to low-and middle-income countries. Increased understanding of ecosystems, their interactions with social systems and their role in sustaining the economy and human well-being. Improved knowledge base on availability of raw materials and skills relating to raw materials. Better systems for measuring and assessing progress towards a green transition.			

Climate change and the environment form key motivational drivers for applicants to Horizon 2020. Survey respondents show the two main motivational factors to be addressing grand Societal Challenges related to the climate (75 %) and increasing resource efficiency of processes in their area. (63 %). The factors that matter the least were found to be the reduction of the environmental impacts of the respondent's organisation (38 %) and contributing to developments that avoid Greenhouse gas (GHG) emissions (63 %). Nevertheless, they remain tangible motivational drivers.

The figure below shows how the needs and challenges of SC5 are considered to have been addressed by projects that have been supported. Between 21 % and 66 % of survey respondents consider that their different needs and challenges have been addressed by the project to a large and very large extent. The challenge and needs which have been addressed to the highest extent are found to be the protection of the environment, sustainably managing natural resources, water, biodiversity and ecosystems (66 %). This is followed by improved climate change mitigation and adaptation policies that build on better evidence on key climate processes and on a more accurate understanding of necessary societal and technological changes (63 %). Eco-innovation enabling a transition towards a green economy and society by generating environmental and economic benefits was also found to a similar extent (54 %). The challenges and needs found to have been addressed to the lowest extent include the development of comprehensive and sustained global environmental observation and information systems (32 %). The analysis undertaken as part of case study 13 on adaptation finds that Horizon 2020 projects have been successful and instrumental towards helping create climate services that provide relevant and high quality information in response to the scientific, technological and/or socio-economic problems and issues identified at the time of the its design and over time (and where it was emphasised by one interview respondent that climate services are critical for adaptation in general and for assessing risks and determining the appropriate strategic response).

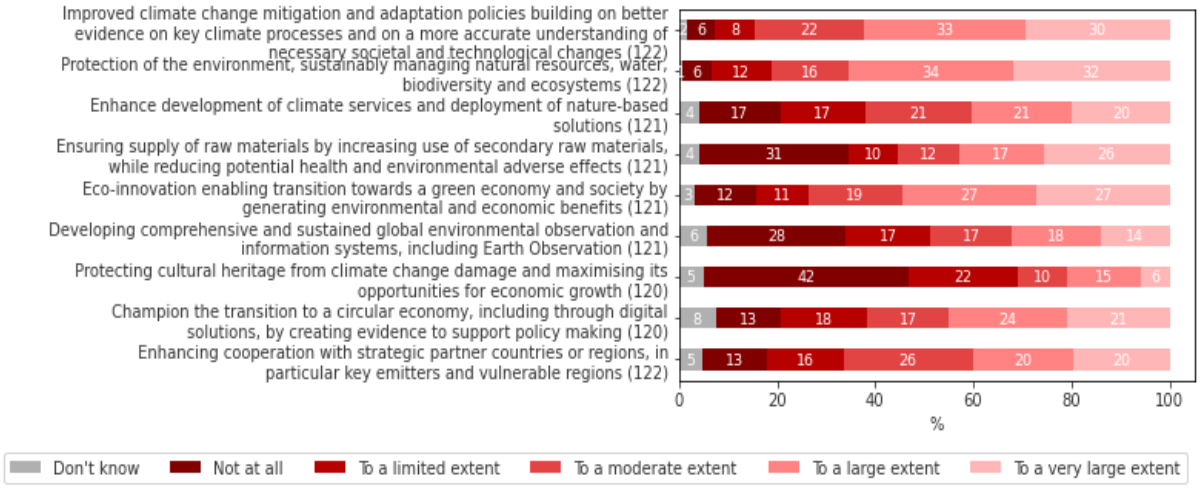


Figure 31 Responses to survey question 'To what extent does your project address the following needs and challenges?'

Source: Survey analysis, number of respondents between brackets

The distinction between adaptation and resilience is an important one and it should be recognised when specifically discussing adaptation (or resilience) within the context of SC5. Adaptation to climate change has been defined by the Intergovernmental Panel on Climate Change (IPCC) as being the process taken to "adjust to the actual or expected climate and its effects". Whereas resilience to climate change can be defined as being the capacity to prepare for, respond to, and recover from the impacts of hazardous climatic events while incurring minimal damage to societal well-being, the economy and the environment. This can then be thought of as adaptation to climate change and resilience for climate change and not as one leading to the other or as e.g., adaptation for resilience (and in this sense, case study 13 for SC5 has focussed on adaptation specifically).

While climate change adaption ("adaptation") and its R&I-based needs and prioritisation can be considered through a specific perspective (e.g., only within a knowledge-based / eco-system services framing), this study considers that adaptation is broader and holistic in scope within SC5.[86] This study considers this as a topic that includes a wide range of transdisciplinarity, projects and focus (e.g. also across governance, research, collaboration, etc.) In addition to this, adaptation is found to also be present as a topic in other Societal Challenges, such as SC2. The evidence and extent of projects and focus then suggest the importance and relevance of adaptation within SC5 (and across other Societal Challenges) and as a key R&I component for enabling or implementing a broader Green Transition process. As a specific case study topic, adaptation has been found (through this study's case study 13) to be rather different within SC5 in its scope and extent to NBS and the Circular Economy (e.g., there has been a larger number of projects and across different calls for adaptation).[87] Adaptation should be then considered as a broad and overarching concept within SC5 and not from a narrower perspective. Whereas, NBS can be considered as describing a particular set of (technical) responses that are inspired by nature with alternative (engineering) solutions to adapt to climate change. In contrast, Circular Economy describes an ambition/political target which is a pre-condition for climate neutrality and where its achievement depends on 'solutions'.

The figure below shows how Horizon 2020's three Work Programmes have sequenced and progressed through their respective calls for SC5 during 2014-2020. It illustrates how the Work Programmes have pointed towards the economic, environmental, social, and value-based impacts that have been identified within the intervention logic for SC5. An indication is also provided where SC5 has made a contribution to other Societal Challenges and their calls within Horizon 2020.

[86] Through analysis and insight developed for case study 13 with a focus on climate change adaptation within SC5.
[87] Through analysis and insight developed for two 'deep dive' case studies for SC5 with a focus on NBS (case study 14) and the Circular Economy (case study 15).

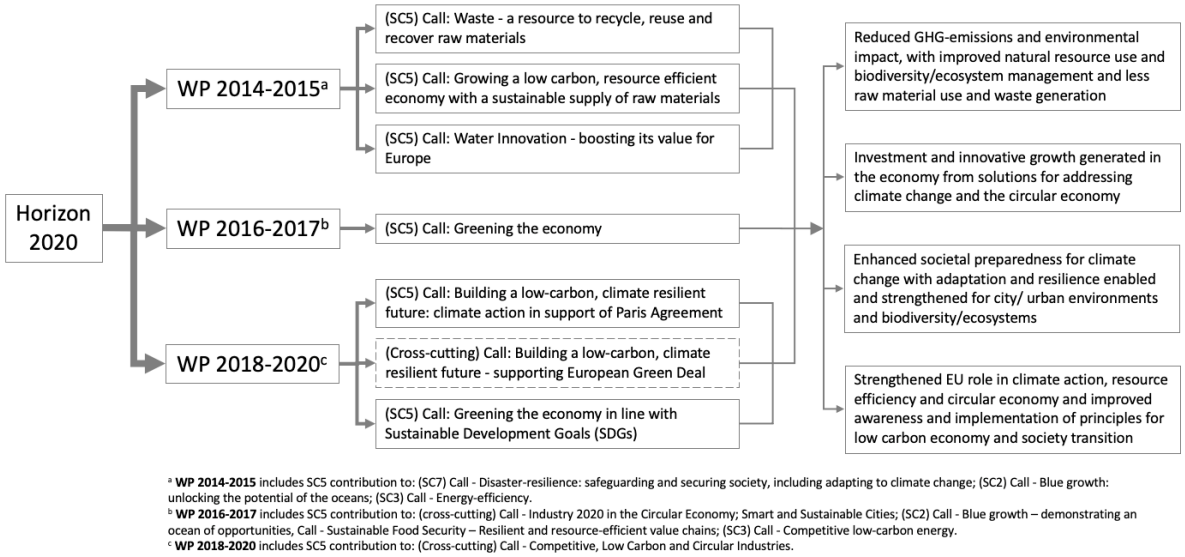


Figure 32 Horizon 2020 SC5 Calls and their WP focus/ priority areas. Source: Own illustration.

During Horizon 2020's implementation period from 2014, the climate change and sustainable development priorities within the objectives of SC5 evolved through the sequence of Work Programmes, progressively focusing on more systemic approaches. Two key areas are highlighted to achieve those objectives. Firstly, climate change mitigation (albeit to a limited extent) and adaptation and resilience and a focus on innovation and investment in climate research and clean/renewable/low-carbon technologies. Secondly, the decoupling of economic growth and social development from resource exploitation and waste and focus on supporting a transition towards a circular economy.

The first two Horizon 2020 Work Programmes for SC5 (during 2014-2017) contribute towards the cross-cutting priorities of climate action and sustainable development. As part of the implementation of the first WP 2014-2015, waste as a resource and water innovation were both seen as key priority areas for focus due to the opportunities for business and job creation as well as the need to address resource efficiency (Note when the first WP was formulated, Circular Economy and its conceptual approach to production and consumption was not yet established. In 2015 the EC adopted the Circular Economy Action Plan (CEAP),[88] with measures to stimulate Europe's transition towards a Circular Economy as well as to boost global competitiveness, foster sustainable economic growth and generate new jobs).

A Focus Area on Building a low-carbon, climate resilient future covers Horizon 2020 actions in the final Work Programme (WP 2018-2020) that contribute to implementation of the goals of the Paris Agreement. SC5 forms a key component of this Focus Area and WP 2018-2020 provides a specific call on: Building low-carbon, climate resilient future - climate action in support of Paris Agreement.

A further Focus Area on Connecting economic and environmental gains is structured in the final Work Programme 2018-2020 to consolidate R&I initiatives towards the achievement of the SDGs, climate action, and industrial competitiveness – and linking to the EC adoption of the 2020 Circular Economy Package (CEP).[89] SC5 also forms a key component of this Focus Area and WP 2018-2020 provides a specific call on: Greening the economy in line with the SDGs. Furthermore, the announcement of the European Green Deal by the EC resulted in WP 2018-2020 being amended through a European Green Deal Call. The Green deal call operates within the building a low-carbon, climate resilient future focus area and through approaches for R&I and the applying science, knowledge and evidence.

[88] https://environment.ec.europa.eu/topics/circular-economy/first-circular-economy-action-plan_en
[89] The CEP is one of the main building blocks of the European Green Deal.

3.4.2.2. Appropriateness of the programme portfolio

A total budget of EUR 3.04 billion was allocated by the EC to SC5 projects since 2014, resulting in a total of 524 projects. At a comparatively lower level to other SCs, one (Art. 187) partnership was partly financed through SC5 (Fuel Cells and Hydrogen) with around EUR 25 million, resulting in a small number (8) of projects.

An analysis of a set of 100 randomly selected SC5 projects from across the three Work Programmes and different call areas revealed a very high fit of the project's overall scope with the goals of Horizon 2020.

A portfolio analysis (illustrated in the figure below) of the 524 SC5 projects funded under Horizon 2020 revealed that the largest (35 %) share of EC contribution was attributed to a broad thematic cluster encompassing raw materials/resource use/circular economy (183 projects with an EC contribution of EUR 1,075 million). This is followed by a cross-cutting thematic cluster (102 projects with EUR 729 million). It is apparent from this analysis that mitigation has a small share of SC5 projects and EC contribution, with just 31 projects and an EC contribution of EUR 159 million (i.e., based on the decarbonisation calls within the final WP 2018-2020 and on the Art. 187 Fuel Cells and Hydrogen (FCH2) partnership). Whereas if the thematic clusters of adaptation/ resilience, biodiversity/ ecosystems, and earth observation are indicatively considered as one broad area, then this would also have a high combined share (29 %) of EC contribution (EUR 892 million) with 143 projects.

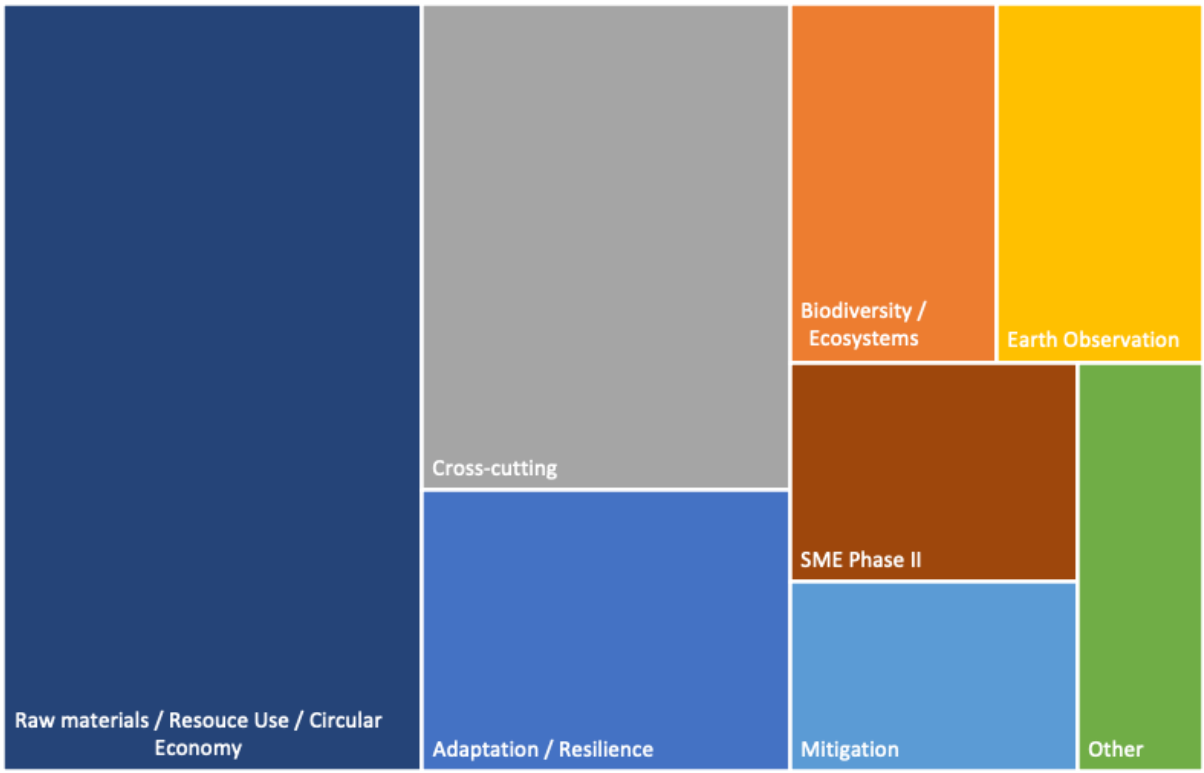


Figure 33 Thematic clustering of SC5 projects (WP14/15, WP16/17, and WP18/20; n=524 projects)

Source: eCordis; own compilation, area represents EC contribution to each project cluster.

An analysis of the funding instruments in place reveals a high R&I focus: Based on the number of projects, RIAs and IAs are the most dominant with 219 projects (41.9 %, 46.2 % of EC contributions) and 153 projects (29.3 %, 45.0% of EC contributions) respectively. Whereas 91 CSAs contributed to 17.4 % of the projects (for 5.7 % of EC contributions). The SME-II instrument is found to be of less importance with only 60 projects (11.5 %, with 2.9 % of the SC5 budget). This distribution of instruments is broadly in line with the findings from the survey, case studies and interviews which highlight the strengths of the outcome pathways of Knowledge and Capacity Building as well as for Technology and Innovation and Collaboration and Coordination to an extent (and while identifying a number of challenges and issues within the Coordination and Collaboration outcome pathway).

With regard to beneficiary involvement, private for-profit entities (excluding higher or secondary education establishments) show the highest participation rates, with 87 % of projects being found to exhibit at least one business participation and with an average of six businesses participating in each project. Entreprises were the recipients of 30% of EC contributions made as part of SC5 projects, on par with the level found for research organisations (also 30%) and close to contributions made to higher or secondary education establishments (26%). Projects involving at least one higher or secondary education establishment (76 %) or a research organisation (82 %) are also both found to have high participation rates and each with an average of 5 institutions participating in each project. The involvement of public bodies (47 %) is found to be lower than for business organisations and education establishments but higher for SC5 than the other SCs (i.e. 37 % for SC2, 30 % for SC3, and 21 % for SC4). Other organisations (such as beneficiaries from NGOs) are found to have a reasonably high participation rate (i.e. 57 % of projects), indicating quite a high involvement of non-research and non-business stakeholders for SC5.

Insight provided from case study 15 on Circular Economy shows that while WP 2014-2015 contained specific waste-related calls as well as a call on Growing a Low Carbon, Resource Efficient Economy with a Sustainable Supply of Raw Materials (which could be considered as a more practical and multidisciplinary approach than the waste calls), WP 2016-2017 was, as compared to the previous Work Programme, more defined and in line with other EU Circular Economy-related policies, plans, strategies as well as with other communities and the SDGs. In addition to this, it was complementary to a specifically targeted circular economy initiative and call on 'Industry 2020 in the Circular Economy'. WP 2018-2020 has then subsequently contributed to implementing the Circular Economy Action Plan (CEAP) and other key high-level EU priorities and with an aim to utilise a multi-disciplinary approach. Similar to the preceding Work Programmes, it has aimed to facilitate bringing together stakeholders and it was found that over time, the focus has shifted from clearly having a goal of supporting SMEs to also considering other actors, including policymakers, the global community (for the respective topic) and industry (and while noting that SMEs have remained an important actor within the calls).

Insight gained through the other two case studies shows that NBS (case study 14) objectives have been present to an extent in each of the Horizon 2020 Work Programmes and mostly within SC5. WP 2014-2015 included sustainability and climate change as transversal issues, focusing broadly on food security and blue growth strategies that built on themes as relevant precursors for NBS and a shift of focus towards nature, biodiversity and economy-positive transformations of urban spaces. Without explicitly using the NBS term, WP 2014-2015 is considered to have pointed to sustainable development of urban areas requiring new, efficient, and user-friendly technologies and services, in particular in the areas of energy, transport and Information and Communications Technology (ICT), delivered through integrated approaches at the level of Research, Development and Demonstration (RD&D). In WP 2016-2017, and as described above, Circular Economy has been a major objective and there was a key focus on biodiversity, food security, and blue growth with smart and sustainable cities including as a crosscutting issue, paving the way forward towards a fully-fledged urban NBS focus in the final WP 2018-2020 (and where as a consequence of this transition, NBS and adaptation have moved steadily and conceptually closer together and with a shift in NBS thematic attention towards NBS predominantly focusing on climate adaptation)[90].

Collaboration needs and activities are an important factor and where coordination between different actors and disciplines is seen as a necessary condition for implementing and accelerating the Green Transition. Survey participants indicate that collaboration is a key motivational driver for Horizon 2020 (and also HEU) participation. The intensity of collaboration was by far the highest with regards to research organisations (61 % collaborated or co-led) followed by High Education Institutions (HEI) (55 %). The lowest level of collaboration intensity was identified with regard to Research Funding Organisations (13 %) and NGOs (13 %).

[90] As described in the section above and while noting it is too early to have conclusive results (i.e. the final WP 2018-2020 projects will complete during 2022/2023), in recent years a more holistic, more policy-coherent view of NBS is found through interviewing undertaken as part of case study 14 to have started to emerge in Horizon 2020 calls. There has been a shift in NBS thematic attention towards NBS predominantly focusing on climate adaptation. This is referred to by Al Sayah, Versini, and Schertzer (2022) as “NBaS” (Nature-based Adaptation Solutions), particularly in urban environments.

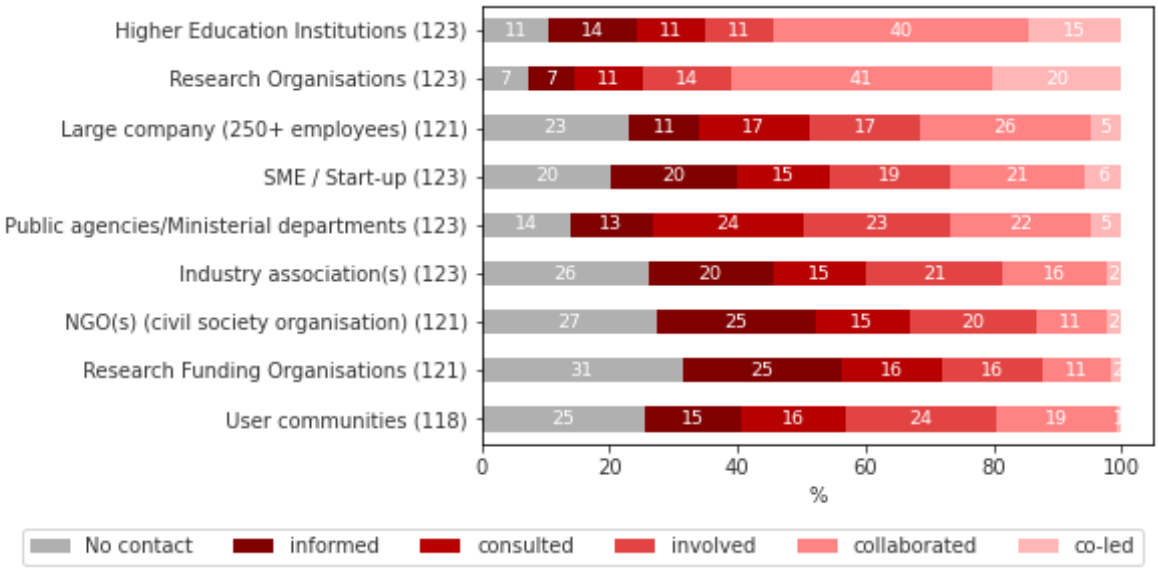


Figure 34 Response to survey question 'How intense was your collaboration with the following stakeholder groups outside the project consortium in the context of your project?'

Source: Survey analysis, number of respondents between brackets

However, the case studies find there to be some issue with regard to the mobilisation and coordination of multiple actors across different sectors and at different levels (i.e. EU, national, regional, local), as has increasingly seen to be a requirement. For example, case study 14 on NBS finds that an internal EC structure has not been specifically established to manage mobilisation/coordination activities. Furthermore, NBS participation has been very low across EU-13 MS and mostly focused on research institutions,[91] which could be seen as evidencing a gap with regard to a policy, legal and business framework for implementation that is able to coherently encompass all MS and their specific contexts. While adaption is found to have increased in relevance throughout the implementation of Horizon 2020 (as have Circular Economy and NBS), more inter-DG collaboration is found to be required to enhance its 'success',[92] through interviewing conducted as part of the case studies. Alongside an integration and alignment of funding programmes (cross-sectoral and bridging all levels of governance) and the mobilisation of business investments to reach a critical transition scale.

3.4.3. Coherence of the intervention

An overview analysis and indication of key strategies / initiatives that have guided and framed SC5's alignment and broader coherence is set out below:

- Europe 2020 Climate & Energy Package: Horizon 2020's development and positioning on climate action (and specifically for SC5) was strongly influenced by the Europe 2020 strategy (COM(2010)2020) and its "20/20/20" targets and three mutually reinforcing priorities on smart, sustainable and inclusive growth.

- Roadmap to a Resource Efficient Europe: Alongside the Europe 2020 strategy, the Roadmap to a Resource Efficient Europe (COM(2011)571) and its vision on structural and technological change to 2050 (and 2020 milestones) and a more resource efficient and low-carbon economy for Europe helped to provide a framework for climate action and sustainable development within Horizon 2020 and SC5 and for the 'Green Transition' in Europe.

[91] Within the EU and across MS there are clearly variations between EU added value, research & innovation and the level/funding of research at MS level (i.e. research expenditure relative to GDP in the post-2004 cohort of MS is lower than for other MS (e.g. The Netherlands and its funding of Circular Economy) which can spend significantly more in relative and absolute terms).

[92] Case study 13 finds that adaptation as a topic has tackled the correct issues through its implementation in Horizon 2020 and particularly with regard to climate services as a tool to address and accelerate climate action.

- EU Adaptation Strategy: The 2013 EU Adaptation Strategy (COM(2013)216) helped frame Horizon 2020 and SC5's latter Work Programmes and aimed to integrate climate-resilience thinking and action in Europe, by enhancing the preparedness and capacity of governance levels to respond to the impacts of climate change. Note: a new EU strategy on adaptation to climate change was adopted in 2021 (COM/2021/820).

- 2030 Climate & Energy Framework: Targets set in the Europe 2020 climate & energy package and subsequent enhanced targets in the 2030 climate & energy framework (COM/2014/015) which built on this provided a basis for further climate-based action and sustainable development within Horizon 2020 and SC5's latter Work Programmes.

- Energy Union: The EC framework strategy for a resilient Energy Union with a forward-looking climate change policy (COM/2015/080) and subsequent Regulation (Regulation (EU) 2018/1999)77) set common rules for planning, reporting, and monitoring to help reach the 2030 climate (and energy) targets and aligned EU planning and reporting to synchronize with the ambition cycles under the Paris Agreement.

- Paris Agreement: COP21 and the 2015 Paris Agreement with its long-term goals to limit dangerous increases in temperature was integrated into the strategic programming of Horizon 2020's Work Programme 2018-2020 under the focus area on building a low-carbon, climate resilient future and alongside a circular economy focus area on connecting economic and environmental gains.

- 2050 long-term strategy: The EC 2050 long-term strategy (COM/2018/773) announced in 2018 sets out a longer-term strategy for Europe to become more prosperous, modern, competitive, and climate-neutral economy by 2050 and vision for the European Union to deliver on the Paris Agreement.

- European Green Deal: The Green Deal (COM/2019/640) announcement by the EC in 2019 resulted in an amendment to Horizon 2020's final Work Programme through a European Green Deal Call operating within the building a low-carbon, climate resilient future focus area and through R&I-based approaches and the application of science, knowledge, and evidence.

- Circular Economy Action Plan: An action plan (COM/2020/98) in support of the European Green Deal was released in 2020, following on from the EC adoption in 2014 of a Circular Economy package (COM(2015)614). The action plan(s) can be considered as a key framing for the scope Circular Economy within SC5 and Horizon 2020.

Partnerships have not been part of SC5's actual project activities to a significant degree. The Public-Private Partnership Fuel Cells and Hydrogen that helped improve technological developments for energy security and contributed to the status of Europe as an international leader in technology, includes 8 projects with an EC contribution of EUR 25 million for SC5 indicated within Art 187 Fuel Cells and Hydrogen FCH 2 (and as such any meaningful insight is somewhat limited). In addition, the EIT Climate-KIC brings together partners from business, academia, and public/non-profit sectors to create networks of expertise, through which innovative products, services and systems can be developed, brought to market and scaled-up for impact.[93] The EIT Climate-KIC can notably be considered to be coherent with the objectives of both the European Green Deal and the Paris Agreement. Furthermore, the EU Adaptation strategy (as adopted post-Horizon 2020 in 2021) highlights the need to accelerate the rollout of adaptation solutions and describes the EIT Climate-KIC as one of today's key player in this space. Also, the EIT Food is the innovation community supporting the activities with a vision to put Europe centrally for a global transformation in how food is innovated, produced and valued by society; as well as the EIT InnoEnergy that has established entrepreneurial activities with relevance to the energy transition.

While Circular Economy and its positioning has been reflected in Horizon 2020 calls since 2014 (and with a Circular Economy Action Plan since 2015), this has not been subject to a particularly increased

[93] The EIT Climate-KIC works closely with the other EIT funded Knowledge Innovation Communities (EIT Digital, EIT Food, EIT Health, EIT InnoEnergy, EIT Manufacturing, EIT Raw Materials and EIT Urban Mobility).

level of importance/presence until the implementation of the WP 2018-2020 (and with new Circular Economy Action Plan being published in 2020).[94] Coherence with other national and EU-level policies is also found through Circular Economy case study 15 to be rather low and particularly for sector-specific policies (e.g., those initiated when the linear economic model was the standard model).

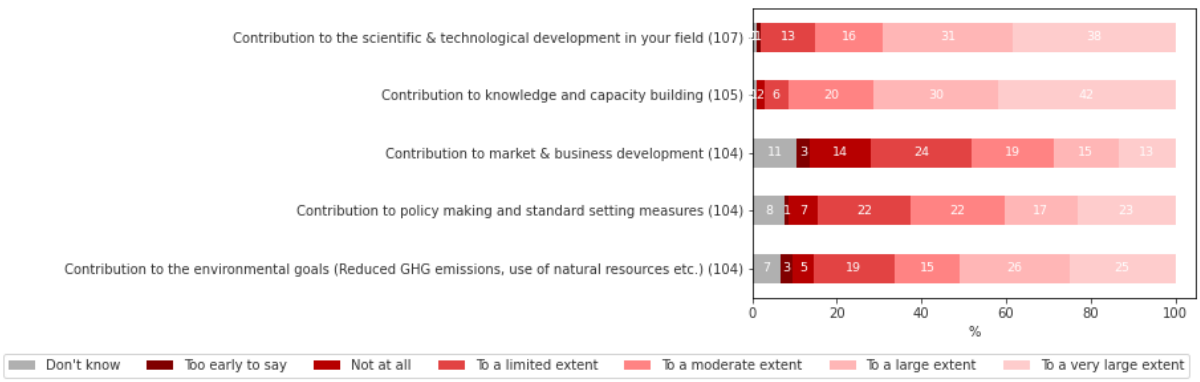
The case studies also find that while the SC5 thematic area is necessarily broad, there are some apparent differences in approaches and implementation and prioritisation of specific topics within and across the EC and MS/AC, in terms of awareness, strategies and actions. Furthermore and while noting it is too early to have conclusive results (i.e. the final WP 2018-2020 projects will complete during 2022/2023), in recent years a more holistic, more policy-coherent view of NBS is found through interviewing undertaken as part of case study 14 to have started to emerge in Horizon 2020 calls. There has been a shift in NBS thematic attention towards NBS predominantly focusing on climate adaptation. This is referred to by Al Sayah, Versini, and Schertzer (2022) as "NBaS" (Nature-based Adaptation Solutions), particularly in urban environments.

With this said, however, it should be acknowledged that both NBS and Circular Economy have developed conceptually and quite considerably since 2012 and that the insight above is perhaps a reflection of that.

3.4.4. Effectiveness of the intervention

Similar to the other Societal Challenges and on the issue of indicating the level of overall effectiveness of the results that have been achieved through SC5, it is not straightforward to illustrate this in a succinct manner. This is due in part to the progressive focus of the SC5 Work Programmes on more systemic approaches and across broad focal areas, e.g. particularly in the final WP 2018-2020 and where the results have focussed on activities across climate change mitigation and adaptation and innovation and investment in climate research and green technologies, as well as the decoupling of economic growth and social development from resource exploitation and waste and focus on supporting a transition towards a circular economy.

At a project level however, there are indications that many SC5 projects provide some degree of progress towards a green transition. The survey (Annex VII) indicates a high level of alignment between the objectives of the projects and their results. Some 84 % of respondents (223) consider that these are fully aligned or aligned to a large extent (and with only 2 % of respondents indicating an alignment to a limited extent). Furthermore, between 28 % and 72 % of survey respondents assess that their projects contributed to a large or very large extent to the improvement of different aspects of expertise. A contribution to knowledge & capacity building and to scientific & technological development stand out as the aspects of expertise that have been improved to a large or very large extent (72 % of 107 and 69 % of 105 respondents respectively). Whereas, contribution to market & business development is the expertise component that has been improved to the lowest extent, with only 28 % of (104) respondents considering that it has been improved to a large or very large extent.



[94] Case study 15 on Circular Economy also notes that the underlying concept has changed from being one of waste management to something that is more 'circular' and in response to the CEAP and policy.

Figure 35 Responses to survey question 'How successful was your project in terms of contributing to the following dimensions in your area of expertise?'

Source: Survey analysis, number of respondents between brackets

The three case studies are also able to provide some illustrative insight here:

- For example, Horizon 2020 is found to have helped to provide important initial steps towards more Circular Economy-based approaches and with the results of the Circular Economy Horizon 2020 projects being found to be generally positive.

- The results of NBS Horizon 2020 projects analysed are also found to be generally positive and as they pave the way towards a global agenda-setting and leadership with regard to NBS and leading to more novel NBS tool platforms with relevance to business and at the level of public urban administration.

- Within the topic of adaptation, a noticeable development has been a move towards the provision of services and the inclusion of organisations led by the private sector and where the project portfolio analysed through case study 13 on this topic includes a positive mix of competent actors and products in climate services. In general though for adaptation, projects are seen to have become bigger than in the past, less specific but more systemic and challenging to manage/coordinate and where it is not yet clear on how they perform as a whole, as there is a risk that they are not well integrated with each other (and as larger, broader standalone activities with scopes and activities that could potentially overlap or function in different directions with an inefficient use of resource and prioritisation).

3.4.4.1. Technology and Innovation

Given that SC5 seeks to support the achievement of climate action and a resource efficient economy and society (requiring new knowledge, expertise, approaches and tools), it is encouraging that the survey finds that the expansion of basic knowledge for technological development together with new databases, platforms and test beds as well as new research tools, models, simulations stand out as the technological development result that has been achieved to the highest extent (and as indicated by 63 %, 64 %, and 72 % of respondents respectively). A cost reduction of technology is an anticipated technological development result that stands out with a lower extent of activity/achievement and as could be expected given the point made above. Overall, between 19 % and 72 % of survey respondents assess that technological development results have been fully achieved or achieved to a large extent (see figure below).

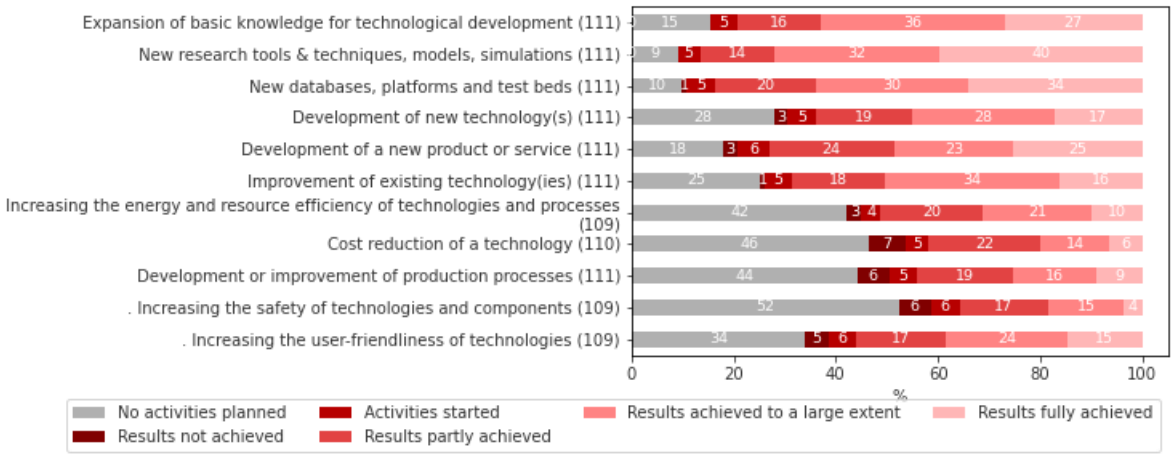


Figure 36 Responses to survey question 'In terms of technological development outputs, what are the (anticipated) results of your project?'

Source: Survey analysis, number of respondents between brackets

In terms of the contribution of Horizon 2020 to anticipated outcomes under Technology and Innovation, survey respondents identified that new or improved technologies and services accelerating

transformation towards climate neutrality and strengthened eco-innovative technologies, processes and services as the biggest achievements (with 52 % and 43 % of 95 respondents respectively indicating that their projects contributed to these outcomes to a very large or large extent). The outcomes achieved to the least extent are found to be new or improved solutions for the preservation and management of cultural heritage at risk from climate change.

An assessment of quantitative findings on Technology and Innovation outcomes for SC5 projects, shows that only 28 SC5 projects (out of 524) report producing a total of 65 unique contributions to patent families so far. Self-reported trademarks, registered design, and utility models are found to number less than 30 (for trademarks) or less than 10 (for the other two IPR modalities) for all Societal Challenges (see Annex V). At this point, the most appropriate interpretation of these IPR findings is considered to be that it is too early in the Horizon 2020 projects' lifecycle to assess IPR-related technological and innovation outcomes. In the category of demonstrators, pilots, and prototypes, 103 out of the 524 SC5 projects report producing such outputs, resulting in 279 unique outputs.

The three case studies undertaken with a focus in SC5-based topics have considered the impact pathway for Technology and Innovation as part of their approach and support the survey finding of a range of positive characteristics specific to the focus/scope of the project portfolios analysed for each of the cases. For example, for Circular Economy it was found that Research and Innovation Actions (RIAs) are less present in the Circular Economy portfolio than on average in the Green Transition portfolio (27 % compared to 42 %). A somewhat similar finding was made for Innovation Actions (IAs), although to a lesser extent (43 % compared to 47 %). This is considered to highlight that the Circular Economy portfolio is characterised by a lower degree of basic research and that it is slightly less application-oriented than the aggregate Transition portfolio as defined for this study. On the other hand, Coordination and Support Actions (CSAs) were more present (30 % compared to an average of 7 %). One possible reason for this is, according to an interviewee, that for Circular Economy, important actions lie in the area of bringing producers and new users of waste together and in anticipation of a new regulatory regime, as well as aligning material use across value chains and sectors. Circular Economy projects were found to have led to more insights into Circular Economy opportunities on a material level, with new insights being discovered for example on the recyclability of materials.

The Technology and Innovation pathway is seen through case study 14 on NBS to emphasise the importance of improving overall services in cities and coastlines (and beyond) by means of developing integrated ecosystem-based solutions with supporting technologies. Overall, this pathway involves the deployment of a portfolio of tools, business models and technological (including social) solutions as part of a new system or their deployment and integration into any system with associated improvements in the services that these sectors provide.

3.4.4.2. Knowledge and Capacity

As would be expected for SC5 and its subject matter, between 60 % and 78 % of survey respondents assess that different scientific results have been fully achieved or achieved to a large extent for SC5. A better understanding of the subject stands out as the scientific result which has been achieved to the highest extent (78 % of 113 respondents). This is followed by improved access to state-of-the-art research (70 % of 112 respondents) and publications in peer-reviewed journals (66 % of 113 respondents).

The contribution of projects with regard to enabling desired outcomes to be achieved is also found through the survey to reflect the broad knowledge and capacity-based focus of SC5, with respondents indicating a strengthening of R&I capacities in their area as well as EU excellence in science & innovation as the two outcomes achieved to the largest extent (66 % and 62 % of 98 and 95 respondents respectively). One of the desired outcomes achieved to the lowest extent is found to be an improved dissemination of knowledge on climate change to low-and middle-income countries (30 % of 94 respondents), which is more of a systemic issue and not just for Horizon 2020.

The bibliometrics findings show that 4,240 publications resulted from 524 SC5-funded projects.[95] A share of 70% of Work Programme 2014-2015 and Work Programme 2016-2017 SC5 projects reported one or more journal publications, keeping in mind that many H2020 projects have yet to conclude and can be expected to produce additional research publications in the near future (see Annex V for full analysis of H2020 project completion dates by Work Programme). In interpreting the bibliometrics findings presented below, it must be remembered that very few Societal Challenge-level differential outcomes of Horizon 2020 Green Transition funding have been reported (see Annex V). That is, the core knowledge and capacity outcomes captured with bibliometrics have been observed in Horizon 2020's Green Transition journal publications from SC2 through SC5. The findings summarised below make clear distinctions between outcomes unique to SC5 and those share with all other SCs (figures with the quantitative measurements underpinning the observations below are provided in Annex V).

- Similar to the other SCs, SC5 funding has enabled researchers with higher-than-EU27-average citation impact performances to reach even higher citation impact performances than in their other work.

- As is the case for the other SCs, SC5 funding has been attributed to researchers with a 'higher than EU-27 average' propensity to publish under open access. SC5 project funding has allowed these researchers to publish even more often under an open access (OA) modality than in their other work.

- As is the case for the other SCs, SC5 funding was awarded to researchers with a moderately stronger pre-existing tendency to engage in academic-private co-publication than at the EU27 average. SC5 funding did not allow a differential increase on this dimension, however.

- As is the case for the other SCs, SC5 funding has not had meaningful or statistically conclusive effects on cross-disciplinarity of supported publications.

- SC5 funding has not had meaningful or statistically conclusive effects on the integration of women colleagues in publication authorship.

- SC5 funding has not had meaningful or statistically conclusive effects on the share of supported publications cited at least once in policy-related documents.

- SC5 funding has not had meaningful or statistically conclusive effects on the share of supported publications seeing online dissemination or engagement towards them (altmetrics achievements).

Focussing on a specific SC5 topic area, case study 14 on NBS highlights that the Knowledge and Capacity (building) pathway for SC5 relates to the need to develop new knowledge, innovations and methods, in particular by including the natural sciences and long-term observations regarding ecosystem interdependencies, as well as frameworks for the systematisation of data and enabling legally binding decision support (and for where the social sciences with a focus on transition governance should be fostered). Monitoring & Evaluation (e.g. for the development of broadly accepted NBS indicators) and establishing learning frameworks for improving decision making support and local governance is seen to play an integral, but as yet less explored, part of this.

The projects analysed as part of case study 14 demonstrate that they have produced actionable and practical knowledge on various facets of urban and coastal environments, particularly with regard to adaptation through innovative circular and ecosystem-based approaches (the effectiveness of NBS, in particular for urban environments, is seen to have successfully been demonstrated; although, it should be noted here that more knowledge is still required on e.g., the monitored interplay and interdependencies of NBS with regard to locally connected ecosystems, including urban spaces). Furthermore, and while Horizon 2020 projects are broadly seen as being successful and instrumental towards creating climate services that provide high quality information, case study 13 emphasises that climate (adaptation) services are indeed critical for adaptation in general and for assessing risks and

[95] On a methodological note, 39 % out of the 524 SC5 projects provided at least one publication used in the bibliometric analysis; 2,261 of these publications were used in the counterfactual analyses that provide the core bibliometric findings.

determining the appropriate strategic response. And instead of pressing those services towards commercialisation, the EC could push for efforts for these to be treated as a public good (i.e. to become open and publicly accessible, such as is the case with meteorological data / weather services).

There are also found to be needs that relate to dedicated capacity building and training activities (and e.g. for different target stakeholder groups). For example, Circular Economy approaches have been noted through one of the case studies as being based on linking waste and input streams in a rather localised manner (at a city or industrial facility level) and with these being linked to the Circular Business Model pathway. A copy-paste approach for these types of Circular Economy approaches when they work for one site specifically is seen as not appropriate, as it might well not work for a different site with its own local context. For these types of Circular Economy approaches, capacity building and knowledge sharing between peers at a local level is crucial and is seen as a potential recommendation that future Framework Programmes could facilitate to an extent. It should also be noted here that this is not limited to 'Circular Economy' but rather to all types of innovation implemented by (local) multi-actor networks. For example, also the approach of the New European Bauhaus or any type of 'lighthouse projects'. All such approaches could benefit from a related stakeholder learning platform (and possibly from horizontal social science activities to analyse what works and under which circumstances).

3.4.4.3. Coordination and collaboration

The Coordination and Collaboration pathway highlights the (increasing) importance of coherently coordinated and well-orchestrated collaboration between different stakeholders, including DGs within the EC, but also within and between MS and the EC, as well as researchers and the private sector.

Between 20 % and 68 % of survey respondents consider that their projects contributed to coordination and collaboration outcomes of Horizon 2020. As can be seen in the figure below, the four outcomes listed at the top have been achieved almost to a similar extent, with around 62-68 % of respondents assessing the contribution to be to a large or very large extent. Which would be expected given that SC5 projects (e.g., adaptation) include a broad range of transdisciplinarity, projects and focus (e.g. across governance, research, collaboration, etc.)

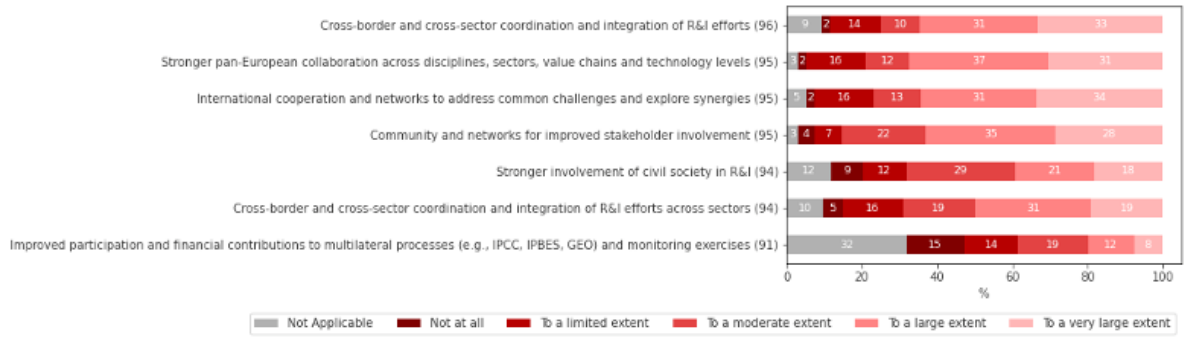


Figure 37 Response to survey question 'To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Coordination & Collaboration'

A quantitative assessment of the sectoral make-up of SC5 projects' co-participation networks (full results are presented in Annex V), shows that inter-sectoral collaboration appears to be rising slightly as compared to (thematically similar) FP7 projects. Within the pool of SC5 projects, 69 % of co-participation links are heterophilic, against 62 % of heterophilic co-participation links in the pool of selected FP7 projects. SC5 projects see a more even distribution of co-participation links along the 10 possible pairs of inter-sectoral co-participation. FP7 projects recorded 18 % of their co-participation links for the pair of Higher or Secondary Education Establishments (HES) and Research Organisations (REC), but this measurement falls to 13 % in SC5 projects. Instead, SC5 projects record more co-participation links involving Other Organisations (OTH) in combination with all the other sectors. Indeed, OTH Organisations make up 11 % of participations in SC5 projects, against 3 % in selected FP7 projects.

The feasibility and strength of a project are seen to be dependent on the diversity of actors within a consortium (and including local stakeholders) and where the quality and concrete input of consortia partners can present a challenge. A project consortium should work closely together and build collaborative relationships to be successful in implementing solutions and at following them up. Furthermore, it has been highlighted (through case study 14 on NBS) that a wider citizen involvement can be essential for successful project development and implementation. Highly participative (e.g., citizen science-based, research and innovation processes) should be boldly fostered and trusted as they are seen as a key component to building legitimacy, confidence, and broad recognition, as well as for developing solutions adapted to the localised need of citizens.

The project portfolio analysed as part of case study 15 provide insights into Circular Economy opportunities at a city level. Horizon 2020 projects are found to support the exchange of best practices and are notably successful in bringing stakeholders together that are on different 'sides' of the value chain. Thus, enabling a greater degree of collaboration. Which is clearly important, as Circular Economy is a topic that is largely about system change. Also, the coordination between various actors within a value chain is supported, making it easier/possible to make agreements on how to increase the recyclability of products (and as seen through the project portfolio analysis, with Circular Economy projects having a higher share of private sector involvement). One recommendation made here specifically is that an enhanced interaction and communication between DG RTD and DG ENV would be of benefit to further implementation of this topic (and as pointed to more broadly in the paragraph above). In addition, the analysis has also found that while Horizon 2020 has been valuable towards making steps to more research on Circular Economy, there is still more that could be done: to take a more holistic view, to focus even more on how Circular Economy thinking can be applied to specific sectors, and to contribute more to the newly created Circular Economy policies.

Also at an urban level, Horizon 2020 projects have been found to support the exchange of best practice for NBS through case study 14. However, shortcomings were highlighted with regard to thematically linking NBS further to key climate resilience and Green Transition areas, such as agriculture (including urban food supply), energy and transport, including the systemic policy frameworks. One recommendation for future Framework Programmes could involve improved coordination/communication between DG RTD, DG CLIMA and DG ENV, on the one hand, and DG REGIO, DG AGRI with DG RTD, on the other (and as pointed to above). And together with setting NBS as a transversal, cross-cutting issue (and potentially involving lighthouse projects) which would support and increase the coordination of further work with existing and coming NBS policies and also beyond.

3.4.4.4. Markets and business

The Market and Business pathway is seen to emphasise a greater and more coherently steered involvement of public and private actors and a focus on pilot and demonstration activities to test solutions in practice and to follow a need and demand driven approach.

As would be expected given that much of SC5's focus is at a relatively early stage with respect to market and business activity (e.g. adaptation solutions, resource efficiency, Circular Economy), between 5 % and 36 % of survey respondents assess that the market development results for SC5 have been fully achieved or achieved to a large extent. The development of marketable products or services as well as the market launch of new products/services are found to be the market development results that has been achieved to the highest extent (36 % and 24 % of 108 and 106 respondents respectively). The creation of a start-up or the creation of a spin-off are the anticipated market development results that stand out with a lower extent of achievement (9 % and 7 % of 105 respondents respectively).

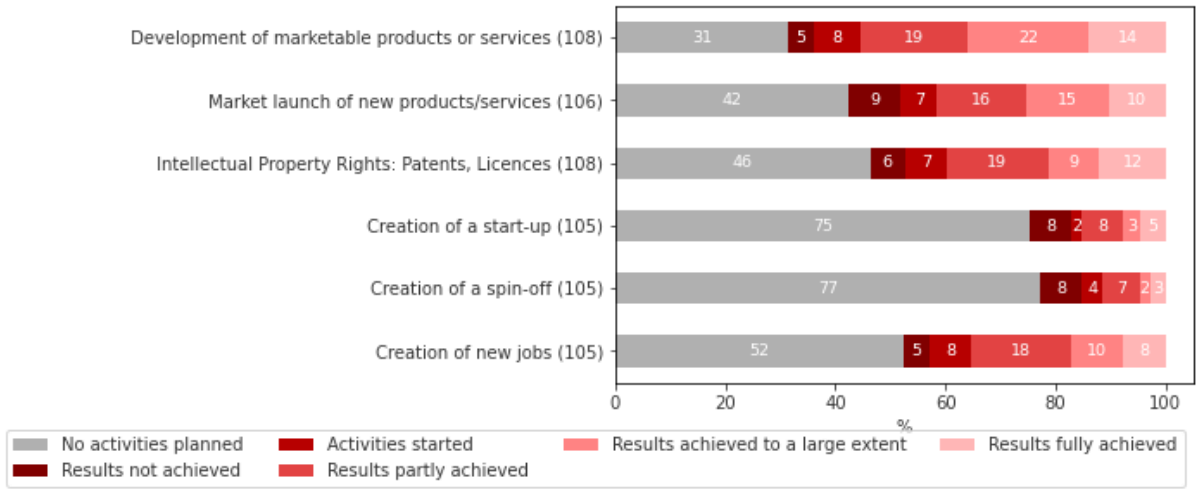


Figure 38 Response to survey question 'In terms of market development, what are the (anticipated) results of your project?'

However, a slightly higher figure of between 34 % and 48 % of respondents assess that their project influenced their competitiveness to a large or very large extent: nationally (48 % of 104 respondents), in Europe (39 % of 103 respondents) or internationally (34 % of 106 respondents). Between 15 % and 26 % of the respondents either don't know or think that the project influenced their competitiveness nationally, in Europe or internationally either not at all or to a very limited extent.

Case study 14 highlights that the markets and business pathway can be considered to emphasise a new mindset towards governance, as well as business and financing models, and that a greater involvement of public and private actors is found to be well reflected in the participation pattern of the NBS projects that have been analysed. Although, it should be noted that the 5 SME projects within NBS-related calls that were analysed do not provide a significant basis for assessing business-driven demands (and even if one notes that 'size matters': only mid to large companies would have the financial means to sustain the implementation of NBS and transformative innovations, making additional funding instruments and coherent implementation strategies for SMEs more relevant).

3.4.4.5. Policies and standards

Between 25 % and 42 % of survey respondents assess that their project contributed to the desired outcomes in terms of policies and standards. A more robust and transparent policymaking is ranked highest with 42 % of respondents indicating this as to a large or very large extent, which is to be expected given the pace at which policymaking has had to develop in a broader sense during the implementation period of SC5's Work Programmes (e.g. Paris Agreement, SDGs, Circular Economy Action Plan and the Green Deal). More specifically and perhaps indicating the challenge associated with tangible progress, an improved use of existing climate- and water- related Earth Observation data for policy- making and an improved decision-making on climate change adaptation options, disaster response and water management are assessed at a lower level by survey participants (25 % and 27 % respectively).

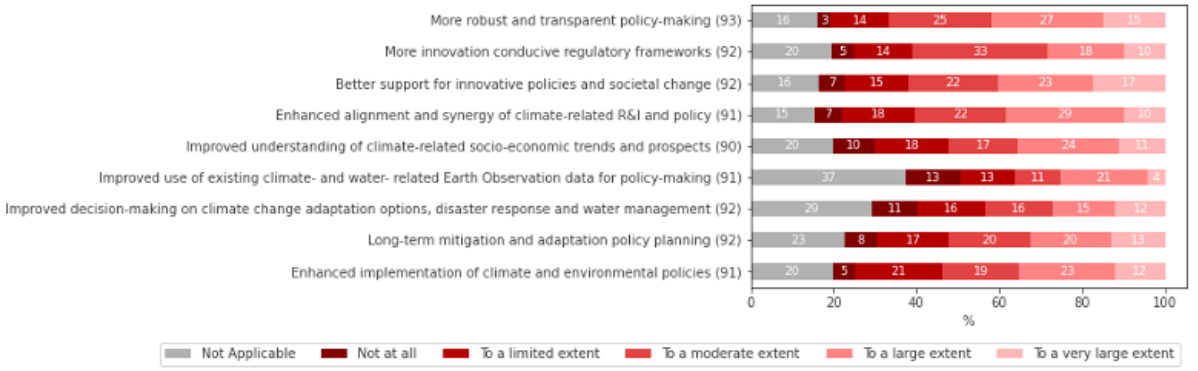


Figure 39 Response to survey question 'To which extent did your project contribute to enable the following desired outcomes of Horizon 2020 in the SC area? Policies & Standards'

The Policy and Standards pathway points to a need to facilitate better adaptation and resilience planning across MS and the EC, through improved understanding, research and implementation. Case study 14 on NBS notes this in particular for DG REGIO, DG AGRI and DG ECFIN with DG RTD and DG ENV, with regard to rural and urban policies and better institutional governance arrangements (e.g. multi-level, cross sectoral, cross system). And where binding frameworks are seen to be necessary at both a European and regional level to take NBS further and where new or enhanced technical standards and standard setting measures developed (e.g., through R&I) are also required for building interoperable technology infrastructure(s) and process frameworks.

The project portfolio analysed as part of case study 13 on adaptation shows work towards and support to improved decision-making on adaptation (especially with regard to R&I policymaking at EU and MS levels) and to more alignment on disaster planning, response, and resilience, as well as increased capacities. The portfolio is also seen to have worked to help improve the alignment of strategies at the MS, national, regional, and local levels. As well as to the mobilisation of actors required for an alignment of sectoral policies improving the use of existing climate research and services.

It is also found that current sector-specific policies for Circular Economy are based in many cases on linear economic systems (and as also highlighted in the above section on relevance and coherence), which can result in Circular Economy approaches being unable to be implemented properly due to the character of the policy regime and even if research through the Horizon 2020 calls has provided results that show a Circular Economy approach is possible. This is seen as particularly the case for sectors where the policy regime was developed some years ago (and when the linear economic model was the standard model), and where the production-phase, the use-phase, and the end-of-life-phase can each have their own specific stakeholders and policies. However, in a circular economic model, these phases should be sufficiently connected, and as such, some policies are potentially at risk of being not being fit for purpose in a circular model. Although, with that said, R&I support can be used within a linear model to create a niche that shows the (technical) viability of circularity. R&I has been observed as being quite effective in creating such niches but without being sufficient to stabilise and 'grow' the niche (although it is noted that the operation of the Inovation Deal could become a relevant and effective instrument here).[96]

3.4.4.6. The role of the JRC

In relation to SC5, the JRC supports the EU's aim of addressing, mitigating, monitoring and adapting to the effects of climate change. It does this by assessing the costs and benefits of various options to reduce climate change hazards, assessing climate change impacts under various mitigation scenarios and forecasts, combining Earth observation data and modelling to better initialise predictions of climate change impacts, and developing climate risk management practices. Furthermore, the JRC conducts a number of activities in support of EU environmental policies. This includes support to policy formulation (modelling of scenarios for impact assessments) as well as implementation (monitoring the state and health of ecosystem services, measuring the levels of pollution in air and water analysing the impacts of droughts and floods in Europe; standards and methods). The JRC performs much of its work in the context of international programmes that operate at the interface of science and policy, such as the Intergovernmental Panel on Climate Change (IPCC), the United Nations Environment Programme (UNEP) and the United Nations Economic Commission for Europe (UNECE).

Overall, the independent experts considered that the JRC has been a key player in EU climate policymaking, particularly in supporting the Commission. Here, it has been crucially central as a direct, inhouse advisory service to policy DGs working on climate and energy issues. The JRC's international activism has enabled it to impact international understanding of actions needed under the Paris Agreement to keep global heating under 2°C. The experts also judged that the activity of quantification of climate impacts and adaptation needs across the EU is favourably, valuing the high scientific quality of the research serving as the main evidence-based for important EU policy developments.

[96] For example, an Innovation Deal "From E-Mobility to recycling: the virtuous loop of the electric Vehicle" was launched in 2018 within the framework of the Circular Economy Action Plan (CEAP).

3.4.5. EU Added Value

Between 50 % and 85 % of survey respondents assess that Horizon 2020 has provided EU added value and to a large and very large extent in several aspects (e.g., especially in terms of value of project budget and funding opportunities for specific topics, with these at 85 % and 83 % of 94 and 93 respondents respectively). The value add for technical support provided and an enhanced possibility to conduct fundamental, exploratory or risky research is seen at a lower level however (with 50 % and 55 % of 92 and 91 respondents respectively). It is encouraging though that 73 % (93 respondents) indicate that their project would not have been implemented without the support of Horizon 2020 and 76% (89 respondents) say the scope of their project would have been reduced.

Positive bibliometric findings for SC5 include (as for the other Societal Challenges) differential increases in citation impact and open access (OA) brought about specifically by Horizon 2020 funding (see Annex V for complete findings). These differential increases capture real added value from Horizon 2020 funding, as the counterfactual publications found for the set of examined researchers can be strongly assumed to have been supported by national or regional funders. On another positive finding such as higher tendency to engage in academic-private co-publications, the positive difference between Horizon 2020-funded publications and the EU27 average is traced solely to the selection effect of Horizon 2020 competition – on this dimension, Horizon 2020 funding has supported already strong researchers on this dimension but has not enabled them to reach even greater achievements.

Added value can be understood economically, politically or as being content-related (e.g. NBS represents a truly European undertaking, which without EU Framework Programme support would most likely have not progressed to a similar extent). Case study 14 on NBS notes that the shift in NBS thematic attention towards NBS predominantly focusing on climate adaptation has owed itself to the Framework Programme's trajectory and bearing. However, NBS research is still highly focused on and undertaken through a specific set of EU countries. Targeted NBS research and R&I would likely also have occurred in R&I-focussed countries (e.g. Germany, France, UK) and also those directly threatened by climate change (e.g. Netherlands, Spain).

Considering that many of the value chains in which Circular Economy approaches are most needed are across MS, or even global, the EU added value of the Framework Programme is considered to be high in this area. For example, case study 15 finds that for the photovoltaics value chain, the fact that the Horizon 2020 projects are EU-wide and even broader, helps to cover the value chains more completely and therefore helps change to come about more holistically. Circular Economy should occur largely on a local / regional level (as well). However, value chains are as wide as the EU, or even bigger. Horizon 2020 has been excellence-based and this should continue. By getting the best universities and experts in the EU to work together on relevant value-add topics, the goal should also be to bring together excellent and 'non-excellent' universities and people from third countries, so the local and regional situations can also be taken into account.

3.4.6. Drivers and Barriers for achieving impact

3.4.6.1. Internal and external factors having an impact on effectiveness and EU added value

Between 14 % and 30 % of survey respondents consider that different types of barriers impede the successful uptake of their projects to a large or very large extent, which is an encouraging finding that reflects a positive positioning of SC5 more broadly. The two barriers that stand out are having limited financial resources for the implementation of project results (30 % of 96 respondents) and an impeding legal framework (25 % of 93 respondents). If respondents who chose that the influence is moderate are added to the figures, then a lack of suitable skilled personnel and lack of internal organisational support for implementation are also tangible barriers (with 41 % and 40 % respectively). It is not clear why this is the case and perhaps this breakdown of the barriers reflects more on the nature of the respondent organisations rather than on Horizon 2020.

Internal and external factors for impact are identified through the case studies. One external factor found as being able to support and help enable success across the case studies (and ultimate impact) is the involvement of the private sector (and while noting of course that this is part of a wider and more fundamental administrative/regulatory enabling piece for social/public good).

- For example, the Circular Economy project portfolio analysis (case study 15) shows a relatively high involvement of private sector organisations in the projects and that this is necessary, given

that many of the value chains that need to make the transition to a more circular model, are already established value chains. Established private sector organisations need to be convinced to change their business models, so their involvement is critical.

- The shift in emphasis in Horizon 2020 (from the previous Framework Programme) has resulted in funding of mostly impact-oriented projects to affect adaptation on the ground (case study 13). This solution orientation can be regarded as a notable achievement, even though it posed a problem for traditionally central players initially, as they had to realise that a paradigm shift was taking place. The key to success was to bring in new players to satisfy the increasing need for stakeholder engagement and co-creation approaches. A noticeable development was then the move towards the provision of services and the inclusion of organisations led by the private sector.

- The project portfolio investigated for adaption (case study 13) includes a positive mix of competent actors and products in climate services and in general, projects under this topic have become bigger than in the past and in general less specific, more systemic and challenging to manage/coordinate. It is not yet clear how they perform as a whole however, as there is a risk that they are not efficiently integrated with each other and through the mix of public and private sector actors.

- It is also emphasised that the nature of public administration is often to manage, but not to create innovative strategies with the potential to replicate in other contexts (case study 14). Moreover, it is often difficult for cities to involve the private sector in developing solutions because of conflict of interest. While a city is interested in finding the right solution(s) for its specific context, the private sector often looks for business cases with high replication potential and positive economies of scale.

On internal factors, the level of analysis on where the needs for more research are as well as the alignment within/across the EC to ensure that there is a coherent, effective policy approach for Circular Economy, have contributed to less progress than there could have been (case study 15). However, with that said, the Work Programmes are found to have established a portfolio of interventions in the NBS field that provide positive foundations for progress towards EU policy priorities and objectives related to the Green Transition (and where the pathways identified for NBS through case study 14 are seen to have contributed to this portfolio through establishing relevant networks/fostering interdisciplinary collaboration, enabling innovative decision support and integrating eco-socio-technical solutions).

3.4.6.2. Effectiveness of dissemination and communication measures

The dissemination of scientific results within the scientific community and towards policy making for SC5 is broadly found to be high and as the bibliometric analysis reveals above average citation rates by publications. Which would suggest that the measures taken to disseminate the results are effective and the standard is high (and for an enhanced understanding of the SC5 subject area itself). Furthermore, SC5 project funding is found to have supported researchers to publish even more often under an open access (OA) modality than in their other work.

A considerable majority of survey respondents (96) indicate that dissemination, exploitation, and communication activities have been both useful (76 % to a large and very large extent) and sufficient (68 %) in the uptake of their project results. Only less than 4 % indicate either ‘don’t know’ or consider that they have been neither useful nor sufficient.

The case studies find that effective mechanisms for dissemination and communication broadly support the investment in and implementation efforts made by the Work Programmes. However, some evidence has been gathered on particular actions, from project to programme level, for improving communication & dissemination measures for impact.

Factors for success seen for Circular Economy (case study 15) are noted as the relatively high involvement of the private sector and that dissemination and communication measures were generally enabled to a greater extent than in other fields. This is particularly visible in the high prevalence of CSA projects as compared to other SC5 focal areas. Within NBS (case study 14), learning and capacity building of project stakeholders is found to have helped improve the effectiveness of individual project communication activities beyond traditional scientific channels and audiences.

Furthermore, at a programme level, communication and dissemination measures are seen to be particularly effective when they have addressed specific needs of stakeholder groups. However, it should be noted that sustained project monitoring at the programme level is key and could not always be ensured.

While end of project events (e.g. with the executive agency REA) are seen to provide a good opportunity to showcase the success of projects, insight provided appears to indicate that EC representation might not be as high as it could perhaps be in some instances and with the potential for specific information points and learnings to be underrepresented. Furthermore (and as highlighted earlier within the relevance and coherence section), one particular recommendation for improvement identified through case study 15 (on Circular Economy) for future Framework Programmes is improved communication between DG RTD and DG ENV (and as this would enhance and increase the relevance and coherence of future calls with existing and coming Circular Economy policies). It should be noted here though that Circular Economy has not been (and is not) the domain of DG ENV alone, but shared with DG GROW (which for example leads on many sectoral policies). Furthermore, DG ENV has not had a specific budget line/'policy agenda'/R&I-focussed staffing for Horizon 2020. The governance and co-creation of topics in Horizon Europe has already substantially changed and notably changed the role (and underpinning resources) in DG ENV.

Another recommendation for improvement could also be the extent to which policymakers in DG RTD and other DGs are updated on the results of the Horizon 2020 projects themselves, which may also be useful to feed into policymaking and to make this more coherent with new, circular business models. Communication actions are also found to be in some need of streamlining and alignment with national stakeholders (e.g. dedicated support through national science funds, research offices at universities, etc.) Further visibility and marketisation could be achieved through agencies and their platforms, actively searching for investors (e.g. issuing calls).

3.4.7. International aspects

Climate change and the environment clearly have a transnational and global nature and scale. The priority setting for the international dimension of SC5 is therefore set out in the Horizon 2020 Regulation (Point 5 of Part III of Annex I)[97] within a broader framing of international targets and ambition for GHG emissions and climate change impacts and a wider global policy framework. The multi-disciplinary nature of the required R&I activities is defined with a requirement to coordinate and pool complementary knowledge and resources in order to 'effectively tackle this challenge in a sustainable way'. The Regulation further notes the international dimension of resource use and the raw materials supply chain and where activities are not just carried out at an EU level but also a global level. As well as the international collaboration dimension for understanding and forecasting climate and environmental change in a systemic and cross-sectoral perspective and where actions should support relevant international efforts and initiatives, including the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Group on Earth Observations (GEO).

Furthermore and in line with the objectives of the 2012 EU strategy for international cooperation in R&I,[98] proposals within each of the three Work Programmes for SC5 have been encouraged to engage with international cooperation and collaborate with third country participants:

- WP 2014-2015 has specific activities with an international collaboration and cooperation focus in its resource/raw materials and water-focussed calls. These include activities to: strengthen international R&I cooperation in the field of water, and to consolidate global knowledge on the green economy in support of sustainable development objectives in the EU and internationally.

- WP 2016-2017 includes international cooperation and collaboration across it calls. For example within the call on Greening the economy, there are specific activities to widen international cooperation activities on climate adaptation and mitigation for climate services, as well as to support international cooperation activities on water and on raw materials. In

[97] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1291
[98] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:52012DC0497

addition, WP 2016-2017 highlights the broader international sustainability and climate change agenda and how SC5's activities are expected to have an impact on the implementation of the UN SDGs, as well as on that of the 2015 Paris Agreement.

- WP 2018-2020 includes international cooperation and collaboration across it calls and for example, within the call on Greening the economy in line with the SDGs, it includes specific activities on strengthening international cooperation on innovation for sustainable urbanisation.

As described earlier, there has not been a significant extent of partnership focussed activity as part of SC5's project activities and therefore insight and findings for international aspects are very limited and indirect in this sense.

Bibliometric findings on international cooperation (Annex V) for SC5 show that, as is the case for the other SCs, SC5 funding has not had meaningful or statistically conclusive effects on the share of publications that are international co-publications. The share of authorship by Third country-based authors in SC5-funded publications was slightly lower than at EU27 average, however.

Results from the survey (Annex VII) on collaboration and with regard to stakeholder involvement indicate, unsurprisingly, that time/resources can limit the amount and types of stakeholders that can be involved. While 65% of survey respondents (124) consider all relevant stakeholder groups as sufficiently addressed through the project activities, reaching out equally to international, EU, national, local and community levels is noted as a challenge and some respondents believe that improvements were possible and that this resulted in an imbalance between the types of stakeholders involved in some cases. Although, it is notable that around half of the respondents (52%) indicate that they have collaborated with non-European partners during their project. Furthermore, collaborations with non-European partners are highlighted as provided specific key benefits, which include development of 'know-how' (and as the most beneficial), followed by the creation of new and additional partnerships, as well as access to new markets. It is also notable that almost half of respondents (44%) consider that cooperation with non-European partners contributes to a large or very large extent towards improving the European position in the global competition (and with 33% thinking this advancement is to a moderate extent).

The case study developed for SC5 with a focus on adaptation (Annex IX, case study 13) identified six main enabling factors for the effectiveness of the portfolio,[99] and where one of these was fostering an international community in adaptation research. Coordination and collaboration among stakeholders was found to have become considerably more important during Horizon 2020 (and as compared to FP7) and more so for adaptation, as a multitude of actors are involved in undertaking the necessary research activity for society to adapt to climate change and for substantially contributing to improved resilience and the green transition. This is also seen to involve a vertical dimension, with policymakers, research funders, public administrations, etc. at different levels (EU, national, regional, and local). There is a coordination and collaboration between these levels, as well as the horizontal dimension, in the sense that these actors coordinate and collaborate on an international, interregional, and inter-community level. Academia and research-performing organisations, businesses, and civil society organisations are seen to be involved in both kinds of dimensions.

NBS is described through case study 14 as building on a long-standing EU policy trajectory.[100] The project portfolio assessed as part of this case for Horizon 2020 is found to directly align with these policy frameworks and where the EU NBS 'ambition' has substantively contributed towards setting the pace at an international level in the field. While clearly strengthening its leading role in this regard, the development and enhancement of the policy framework for NBS at an EU level is still seen very much as a work in progress. Furthermore, case study 14 also shows that pursuing strategic partnerships

[99] 1) focus on a systemic approach, 2) creating services that are relevant for a multitude of actors, 3) using showcases or demonstrators to make adaptation solutions known, 4) fostering the collaboration with non-academic actors through participatory and co-creation approaches, 5) fostering an international community in CCA research.
[100] See: EU Strategy on adaptation to climate change (2013); EU Green Infrastructure Strategy (2013); EU Biodiversity Strategy for 2020 (2011); EU “Blueprint to Safeguard Europe’s Water Resources”; and, EU Action Plan on the Sendai Framework for Disaster Risk Reduction and EU Policy on international ocean governance (2016).

with multiplier organisations that have established thematic networks at the international level,[101] is seen to be beneficial towards enabling and improving outreach. Partnerships in this sense are also seen as important with regard to national R&I stakeholders who would be most effective in communicating through appropriate national channels further improving outreach

For the circular economy (case study) it is found that as many of the value chains in which circular approaches are most needed are EU-wide, or even global, a MS-wide or broader international approach is necessary to make a difference in achieving the objectives of the Framework Programme. Although, the analysis did not show that association with third countries is crucial (i.e., the steps towards Circular Economy approaches in the calls were mainly focused within-EU value chains). An external factor identified as necessary for 'success' is the involvement of the private sector and as many of the value chains that are needed to make the transition to a more circular model are already established value chains. These established private sector organisations and their value chains need to be convinced to change their business models, so their involvement is seen as critical.

3.4.8. Contribution to SDGs

Sustainable development forms a central component of SC5 alongside climate change and the final Work Programme 2018-2020 contains a specific on Call on Greening the economy in line with the SDGs. The activity within this call broadly focuses on moving to a greener, more resource efficient and climate-resilient economy in sync with the natural environment and demonstrating a strong commitment to supporting the SDGs. More specifically, the call actions contribute to implementation of the Circular Economy Action Plan as well as supporting EU support to the SDGs, particularly: SDG 12 'Responsible consumption and production', SDG 6 'Ensure availability and sustainable management of water and sanitation for all', SDG 11 'Sustainable cities and communities' and SDG 13 'Take urgent action to combat climate change and its impacts'. The call also contributes the goals of the Paris Agreement on and the Habitat III New Urban Agenda.[102]

An analysis of the project activities and EC contributions within the Call on Greening the economy in line with the SDGs shows that the raw materials and Circular Economy actions in combination have the highest EC contribution (70 %) within the call and by a considerable margin, with EUR 275.3 million (34 projects) and EUR 200.5 million (28 projects) respectively.[103] Three actions focussed on protecting and leveraging the value of natural and cultural assets (namely NBS/DRR/natural capital accounting, Earth observation, and Heritage) have a combined and somewhat lower EC contribution of EUR 88.5 million (18 projects). Analysis of the funding instruments in place reveals an R&I focus: based on the number of projects, RIAs and IAs are the most dominant with 41 projects (40.2 %) and 47 projects (46 %) respectively. 14 CSAs contributed to 13.7 % of the projects. While this differs from the Circular Economy finding of case study 15 and as described above under Technology & Innovation,[104] it is seen as due to the analysis here also covering raw materials and also that the case study portfolio analysis covers a broader time horizon and over each of the Work Programmes during 2014-2020. It could be argued though that the instrument focus has apparently refined itself to more of an R&I focus in the SDG-focussed call in the final WP 2018-2020.

While recognising that the SDGs are an important part of the overall agenda, it is understood that monitoring of the SDGs has not been specifically established and therefore achievements in this regard are unclear through the case studies undertaken for SC5. The three case studies for SC5 are limited in their scope and as such do not provide specific findings to highlight which SDGs have been contributed to and the extent to which this might have occurred. However, the adaptation case study 13 provides a general view from interviewing that monitoring should be in place in relation to SDGs and case study 15 highlights the importance and direction of the Circular Economy Action Plan.

[101] E.g. International Union for Conservation of Nature (IUCN), UNEP, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the Sendai Framework for Disaster Risk Reduction.
[102] https://habitat3.org/the-new-urban-agenda/
[103] The total EC contribution for the Call on Greening economy in line with SDGs is EUR 676.2 million (102 projects)
[104] Which saw RIAs (and IAs to an extent) as being less present in the Circular Economy portfolio than on average in the Green Transition portfolio and CSAs being somewhat more present.

3.4.9. Summary of findings

Overall, it is shown that there has been a significant degree of appropriate and timely progress in support of a Green Transition through the scope and implementation of SC5 and its Work Programmes.

The analysis supports a broadly relevant response to **relevance** and the needs and prioritisation of climate action and sustainable development through SC5 and including for the topics of adaption, NBS, and Circular Economy that are the focus of the case studies. This is due in part to the progressive focus of the SC5 Work Programmes on more systemic approaches and for topical focal areas that can be considered as particular to the scope of SC5 (i.e. the Work Programmes have focussed to a limited extent on mitigation and mostly on adaptation, resilience and the decoupling of economic growth and social development from resource exploitation and waste and focus on supporting a transition towards a circular economy. Mitigation prioritisation and activities have been focussed through other SCs, such as SC3 (energy) and SC4 (transport)).

A number of **coherence** aspects of SC5 and its implementation are shown to have not operated as well as they could have. There is scope for an enhancement of inter-DG collaboration/coordination, for example with regard to a policy, legal and business framework for implementation that is able to coherently encompass all MS and their specific contexts (e.g., for coordination, research and implementation of NBS and as participation has been very low across EU-13 MS). There is also found to be a need for a greater degree of coherence with respect to circular economy and in relation to other national and EU-level policies. An apparent thematic shift from NBS to NBS focusing on climate adaptation is also notable and as this is something of a cross-cutting issue and with different DGs either using or not using the term NBS still.

On **effectiveness**, a high level of alignment between project objectives and results is identified through the survey (and particularly for knowledge/capacity building and scientific and technological development, such as new research tools, models, simulation and new databases, platforms and test beds). The case study evidence also highlights the strengths of the outcome pathways of Knowledge and Capacity Building as well as the Technology and Innovation pathway to a degree. However, it also identifies a number of challenges and issues within the outcome pathways of Coordination and Collaboration and Policies and Standards. Furthermore, while collaboration within Horizon 2020 is found through the survey to be key for Higher Education Institutions and Research Organisations, it is not established to the same extent for NGOs and Research Funding Organisations (and for non-EU partners it only occurred for a minority of survey respondents).

The evidence indicates the additionality and extent of **EU added value** for SC5 and with a majority of survey respondents considering it to have been to a large and very large extent for budgetary and funding opportunity considerations in particular (almost 75 % indicated that their project would not have been implemented without Horizon 2020 support). It also shows there are more specific indications SC5 projects are on track to provide meaningful results and effective contributions. For example, insight provided through the case studies shows that Horizon 2020 has helped to provide important initial steps towards more Circular Economy-based approaches (and with a relatively high involvement of private sector organisations in projects). Horizon 2020's NBS-based projects have also paved the way towards a global agenda-setting/leadership and to more novel NBS tool platforms. Furthermore, a move towards more impact-oriented activities in the area of adaptation to climate change (or for climate action), including more emphasis on climate services and inclusion of the private sector is seen to have led to a positive mix of competent actors and products in climate (adaptation) services.

4. Efficiency of Programme Implementation

The findings below originate from the survey, scoping interviews, case studies, the benchmarking and the quantitative analysis. Full survey results are presented in Annex VII.

4.1. Project application and selection processes

Overall, 73 % of respondents (all successful applicants) have been satisfied to a large or very large extent with the application process, and only 8 % do not know, have been satisfied to a limited extent or not at all, as detailed in the following figure.

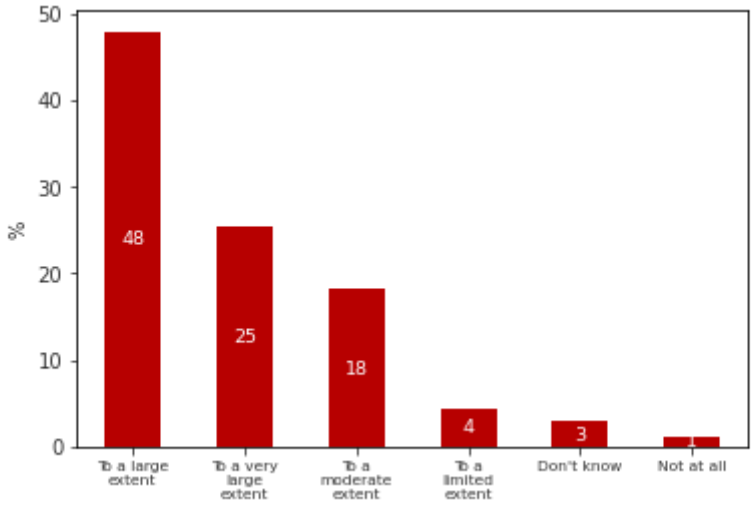


Figure 40 Responses to the question 'How satisfied are you with Horizon 2020 application process for you project?'

Source: Survey analysis, 616 respondents

Regarding the level of effort for the preparation and signature of the proposal, 47 % of the 588 respondents invested less than 10 person/days, while 37 % invested between 10-20 person/days and 15 % invested more than 20 days.

Moreover, between 60 % and 88 % of the respondents agree or strongly agree that the efforts were adequate with regard to all aspects associated with the preparation and submission of the proposal. The rate is the lowest with regard to the probability for a successful application (60 %). The four remaining aspects – volume of funding requested (73 %), complexity of the proposed projects (77 %), number of partners involved (78 %) and strategic relevance/interest in the research (78 %) – were all between 70 % and 80 %. The following figure details the results.

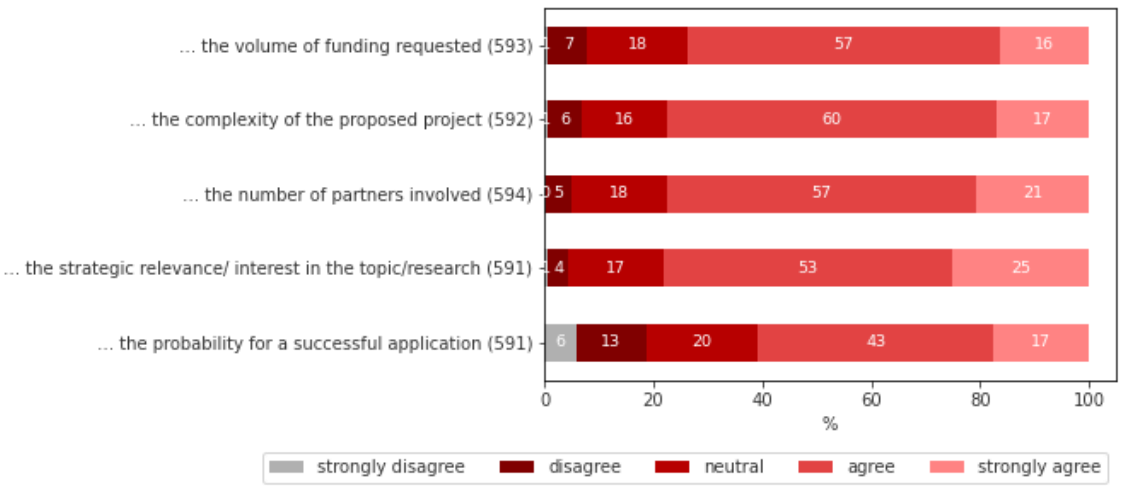


Figure 41 Responses to the question 'To what extent do you agree with the following statements in relation to the efforts needed for a proposal submission?'

Source: Survey analysis, number of respondents between brackets

Case Study 3 showed that the application process could benefit from allowing unsuccessful applicants to improve by learning from successful proposals. The latter may be achieved by providing a list of proposal good practices in a detailed manner based on the experience of successful projects. Complementary, including the possibility to reply to the comments of the evaluators may reduce the risk of misunderstandings. Additionally, the international benchmarking revealed that in the Austrian Climate Research Programme (ACRP) model proposals are reviewed externally by three international reviewers and can be invited to make improvements and resubmit, which has been particularly appreciated by researchers, steering board members and policy makers.

4.2. Administration and management

Overall, 75 % of the 602 survey respondents were satisfied to a large or very large extent with the EC's administration and management during the runtime of the projects. Only 9 % do not know or have been satisfied to a limited extent or not at all (see Q60 in Annex VII).

Moreover, around 50 % of respondents agree (at least to a moderate extent) that administrative and financial requirements should be further simplified. The following figure presents the results of the survey for different requirements:

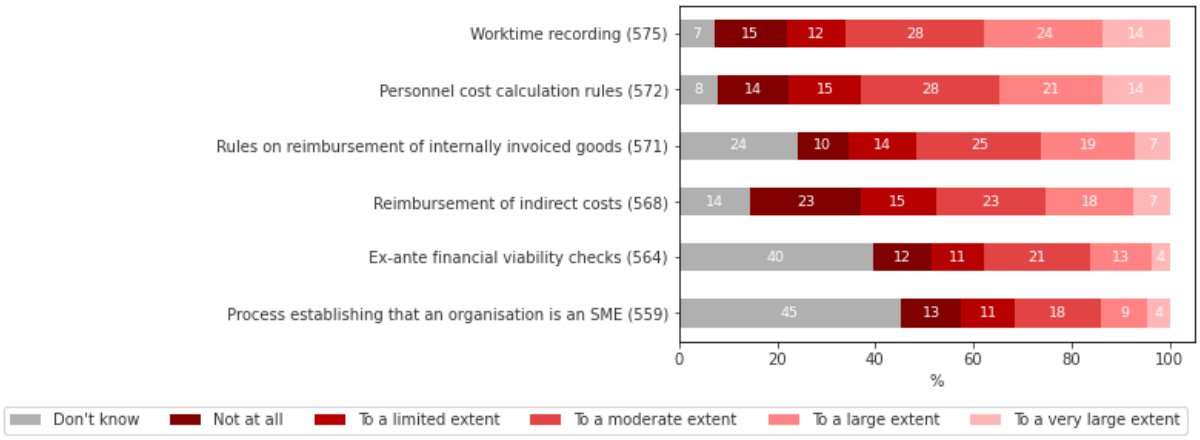


Figure 42 Responses to the question 'to what extent do you agree with the viewpoint that the EC should further simplify its administrative and financial requirements for the following aspects?'

Source: Survey analysis, number of respondents between brackets

Moreover, the respondents were rather positive (agree and strongly agree) with regards to the clarity of the funding scheme (82 %) and the adequacy of the funding schemes for their organisation (76 %). Only between 3 % and 7 % of the respondents disagree or strongly disagree.

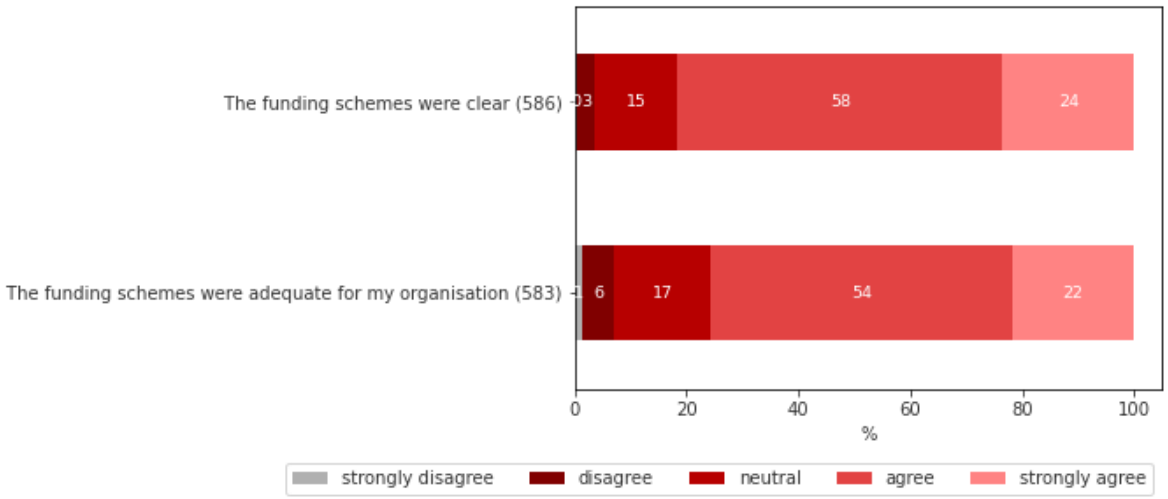


Figure 43 Responses to the question 'to what extent do you agree with the following statements related to the contractual conditions of the Horizon 2020 project? Contractual conditions of the funding schemes (overheads, fixed sum etc.)'

Source: Survey analysis, number of respondents between brackets

Based on the international benchmarking, Horizon 2020's administration and management was deemed very efficient considering that achieving the Green Transition requires the steering and management of different policy areas and stakeholders. Similarly, the NSF programme management was found to have optimised and standardised processes and well-developed IT systems. Also, FONA's project administration and proposal management was found to be highly transparent, professional and efficient. Annex VIII provides the detailed results from the international benchmarking.

4.3. Funding allocation

Overall, the use of funding allocated under Horizon 2020 shows that the shares of EC contribution increased considerably across all Societal Challenges compared to FP7. In fact, the higher shares of EC contributions observed for Horizon 2020, in relation to FP7, is a result of the higher increases observed in EC contributions per project, in relation to the total cost per project. The use of demand-side instrument, such as Pre-Commercial Procurement (PCP) and Public Procurement of Innovation (PPI), remained limited[105].

In total, EC contributions per project amounted to EUR 5.5 million in Horizon 2020, equivalent to a share of 87 %, compared to EUR 4 million in FP7. "Energy" was the SC with the lowest increase in EC contributions per project (EUR 4.3 million to EUR 4.7 million). Despite the increased shares of EC contributions, the analysis per Societal Challenge revealed that there is a disparity in the involvement of Member States. In fact, it was found that some Eastern European Member States saw the lowest EC contributions in SC3, hindering their involvement. Certain large Member States do not make use of Horizon 2020 funding due to their strong and well-established national funding sources.

Moreover, Horizon 2020's increased funding allocation can also be perceived through the total cost per project, which was not remarkably higher than FP7, especially considering the increase in general prices between both programmes. More precisely, the cost per project across SCs (after filtering out the partnerships) ranged from EUR 5.4 million ("Food") to EUR 6.4 million ("Climate"). Annex V provides a more detailed overview of EC contributions and costs per Societal Challenge.

The budget allocation within the SC matches the policy needs identified by Horizon 2020 in the field of Green Transition. As such, SC2 is the Societal Challenge with the highest share of EC contribution,

[105] Although not comprehensive, as there is no direct identification in the monitoring system, only 3 out of 49 PCP and PPI projects were classified in the 4 societal challenges within the evaluation scope.

relating to its unique position in the R&I landscape in Europe for the targeted topics, since only few Member States provide resources. However, there is still a limited resource allocation for the broad range of topics covered by SC2. This risks losing orientation or a watering down of priorities, since the project portfolio appears fragmented with several complex goals.

Based on the scoping interviews, it was found that large amounts of funds are being invested that will accelerate the changes significantly for Societal Challenges, although not covering all their needs. Overall, a general barrier that stood out from the survey among the different Societal Challenges was the "Limited financial resources for the implementation of project results". As such, 36 % of 212 respondents consider that such a barrier impedes the successful uptake of the project in SC3, 30 % of 96 in SC5, 29 % of 172 in SC4, and 27 % of 169 in SC2. Finally, Case Study 9 revealed that funding allocation was small compared to research budgets from the private sector.

In addition, based on Case Study 3, while the competition for funding ensures excellence on the one hand, the rather short project runtimes do not provide enough room to adequately address societal needs in every case. Hence, sometimes whole streams of research cease to exist, when follow-up project opportunities are missed.

Nevertheless, the ACRP benchmark showed that funding is prioritized among researchers for smaller, more flexible, and policy-relevant projects with shorter lifespans. Also, through the NSF benchmark, it was found that creative, innovative or underrepresented communities' projects do not get funding, leading to self-reinforcing loops where only traditional topics are selected. Moreover, there is flexibility regarding the timeline for allocating funding and the project's needs.

Finally, it was found from the KLIMAFORSK benchmark that some projects require that a certain percentage come from other sources (e.g. private sector companies). Hence, it is important to balance perspectives between policy needs and research "end users", which was perceived as difficult to achieve.

4.4. Implementation

On the one hand, Horizon 2020 projects were carried out as planned in a timely manner. Among 918 respondents, almost three-quarters answered that their projects were on time compared to the initial schedule. On the other hand, the implementation of the Framework Programme appeared to be rather flexible. In fact, respondents were positive about the degree of Executive Agencies' flexibility regarding the redefinition of project objectives (64 % of 255 respondents considered it to be the case to a large and very large extent) and changes in project consortium (58 % out of 243 respondents). Only 7 % and 5 % respectively experienced lack of flexibility on behalf of the executing agencies. Case Study 6 identified a lack of flexibility with regards to updating targets, causing project goals to be out of date rapidly. In addition, among 941 observations, almost half of the projects (46 %) only required limited changes, around one fourth of the projects (23 %) required a moderate task redefinition, only 5 % required task redefinition to a large or very large extent, and, finally, one-fifth of the projects (20 %) did not require task redefinitions.

50 % of 584 respondents previously participated in an FP7 project. Overall, respondents perceive a general improvement between FP7 and Horizon 2020. The figure below presents a comparison between both Framework Programmes regarding the experience in different aspects. It was found that 66 % of the respondents agree and strongly agree that budget calculation and financial rules in Horizon 2020 are simpler compared to FP7. Also, 60 % of the respondents agree and strongly agree that the grant preparation IT tool was better in Horizon 2020 compared to FP7. On the contrary, 35 % of the respondents agree and strongly agree that the no-negotiation approach made the project preparation more stressful and time-consuming in Horizon 2020 compared to FP7. However, 50 % remain neutral on the subject and only 15 % disagree or strongly disagree. Also, 31 % of the respondents agree and strongly agree that this approach merely substituted the negotiation with early contract amendments.

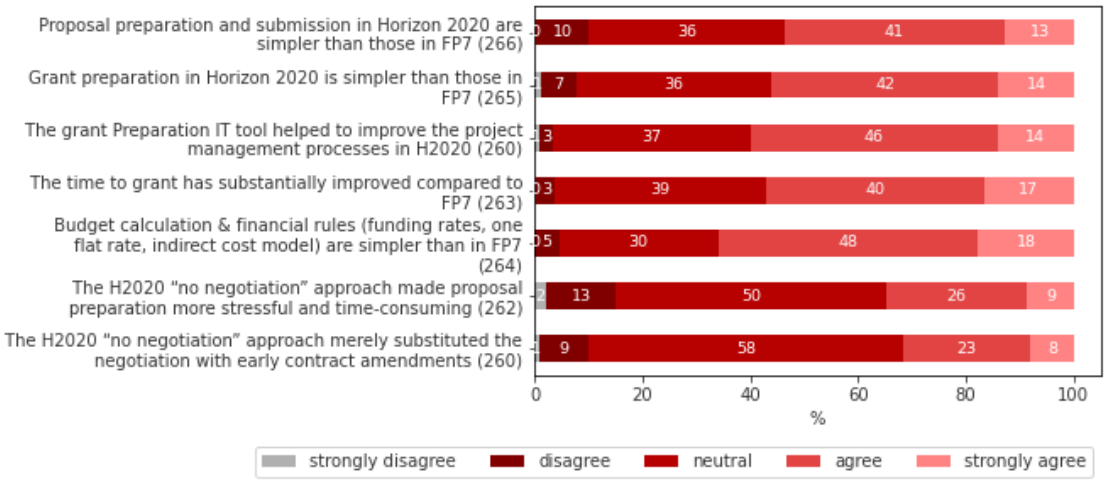


Figure 44 Responses to the question 'Based on your overall FP experience, to what extent do you agree with the following statements on the Horizon 2020 processes compared to FP7?'

Source: Survey analysis, number of respondents between brackets

Similarly, 53 % of 584 respondents currently participate in a Horizon Europe project. From these, 24 % consider that within the current Framework Programme, the administrative and financial requirements have been improved to a large (18 %) and very large extent (6 %). On the contrary, 15% consider the situation has improved to a limited extent. Hence, continuing the positive trend in the perception of improvement between Framework Programmes.

Moreover, more than half of 307 respondents (53 %) answered that the project coordinator was in charge of the project's administrative, financial and legal aspects. Also, 19 % pointed out that a special project management office within the project coordinator organisation was in charge. There were two main reasons for choosing a project management organisation: the increasing size and complexity of the projects (72 % think this to be the case to a large and very large extent); and the improved efficiency of dealing with the administrative and financial issues (73 %).

CS3 found that the interviewed beneficiaries judged the implementation process "well settled". Nevertheless, there seems to be room for improvement: it is important to consider that preparing proposals for voluminous projects consumes a lot of resources. Also, the call topics that were seen as rather wide or generic attracted more applicants, while obfuscating what was actually wanted by the EC. Similarly, stakeholders from Case Study 1 revealed that there was not enough capacity to respond to the large amount of calls in the short timeframe due to the calls' timing in both EJP and Horizon 2020. Hence, it would have been more effective to sequentially publish calls in order for the actors to have more time to build up absorption capacities.

5. Contribution of the Framework Programme to the Green Transition

5.1. Analysis of transition processes induced by the intervention

To analyse to which extent Horizon 2020 has induced processes for a Green Transition, the evaluation uses the concept of the Multi-Level Perspective[106] (MLP), and the concept of transformative outcomes[107] (Ghosh et al. 2021).Three analytical levels need to be distinguished: (i) niches, which are protected spaces and the locus for radical innovations; (ii) socio-technical regimes, which represent the institutional structuring of existing systems leading to path dependence and incremental change; and (iii) exogenous socio-technical landscape developments. The literature identifies three general spatially bounded macro mechanisms that actors can have control over to manage and steer transitions: (1) building or nurturing niches; (2) expanding and mainstreaming niches, and (3) opening up and unlocking regimes.

Research and innovation (R&I) can play a considerable role in providing the desired directionality for R&I efforts, the foundational technological requirements, technological and social innovations for shaping the transformation process to a green European society, paving the way for the required behavioural change through integration of all stakeholders including civil society. However, the Green Transition goes far beyond simply transitions pushed by a given technology. Nature-based, non-technological and social innovations are also hugely important to advance the transition.

We present below the findings from the survey for each of the three macro-processes, based on more than 600 respondents, as well as illustrations from findings from the 15 case studies.

5.1.1. Building and Nurturing Niches

Regarding the macro-process 'Building and Nurturing Niches', Horizon 2020 seems successful to provide a visionary approach, supporting the development of new relevant areas, knowledge and stakeholders in the field of Green Transition:

- For the subtopic "**establishing and promoting new fields of innovation**", almost one third of the respondents consider that Horizon 2020 responded completely to the needs of 'establishing new fields of knowledge' and of 'developing new, groundbreaking solutions', and an additional 44 % that this support was somewhat sufficient. A majority of respondents also considered that Horizon 2020 is partially or completely succeeding in supporting pioneers. Results are however mixed regarding the contribution to the protection of new fields of innovation, whether from dominant interests or market influences.

  The importance of establishing new fields of innovation has been demonstrated in various instances throughout the SC and different types of instruments. In line with the importance of establishing new fields of innovation, survey respondents throughout the SC indicate the relevance of the FP for creating new basic knowledge (Annex V, Q19) and the focus on integration of new technologies (Q21). Prominent examples for establishing and promoting new fields of innovation are the Partnership on Fuel Cells and Hydrogens, which explicitly focuses on the creation of enabling conditions for innovations in this domain, and the research activities on alternative fuels and aviations. The strategic orientation of these domains and some projects therein have been considered pioneers and demonstrated the potential of, for instance, electric aviation and hydrogen in aviation. Projects have also contributed greatly to the development of new materials.

  Furthermore, Horizon 2020 support is praised in terms of "**learning and exchanging in the field of Green Transition**", with, for instance, close to 80 % of the respondents considering that the exchange of experience on innovative solutions was completely sufficient or sufficient.

[106] See: Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274;
Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

[107] Ghosh, B., Kivimaa, P., Ramirez, M., Schot, J., & Torrens, J. (2021). Transformative outcomes: assessing and reorienting experimentation with transformative innovation policy. *Science and Public Policy*, *48*(5), 739-756.

These results are confirmed by SC2 case studies that found considerable contributions to knowledge and capacity building in their respective areas. Projects generally produced accessible and useful knowledge that was shared through various dissemination and collaboration formats. In addition, the case study on Low Emission and Light-weight vessels found that building knowledge and especially expanding the knowledge base played a significant role in all of the projects analysed. The Bio Fuels Case study further shows that the FP had a strong added value in establishing a network of biofuels research and innovation experts, which is reflected in the institutionalisation of networks like the European Technology and Innovation Platform (ETIP) Bioenergy or the European Energy Research Alliance (EERA) Bioenergy which did not only support knowledge transfer and exchange between researchers and practitioners but also pursued trans-national policy support activities (e.g. ETIP Bioenergy on policy support for market integration of biofuels) for improving the alignment between the funding and political framework conditions at EU and national level. Similarly in the Smart Cities case study, knowledge sharing was enabled through dedicated liaisons groups set up to enable peer to peer exchange and the liaison with city representatives or other project partners from the academic or private sectors. These groups were often formed around specific topics of interest or shared challenges and led to the formation of community of practices in the smart and sustainable cities and communities' field.

- Horizon 2020 is also deemed successful in "**promoting awareness of problems related to the Green Transition and new ways of solving them**", with, for instance, 'awareness raising on new ways of solving problems' being partially or completely sufficient for more than two thirds of the respondents. Overall, all aspects were considered to be completely sufficient or sufficient by respondents by over half of the participants (critical questioning of established basic assumptions, awareness of new ways of solving problems, questioning conventional ways of solving problems, breaking down established way of working). This is notably observed in the field of soil management, where the scope of one Work Programme was widened beyond agricultural soils and put additional focus on non-agricultural ecosystems. Soils received additional attention as an important resource, and the role of soils as a carbon sequestration reservoir and the potential of soil-mediated ecosystem services like fertility and productivity.

- The Framework Programme also allows for successful "**networking between relevant young innovation fields for the Green Transition"**, especially between new innovation actors (58 % of respondents state that support is partially or completely sufficient), but also between young innovation fields (52 % of respondents consider this support to be partially or completely sufficient). Indeed, the Zero emission aircraft case study argues that EU projects are being praised for bringing together researchers and young scientists across Europe forming a network of researchers in neighbouring fields to tap into for arising questions or to form new research ideas and projects. These networks also allow for an exchange between companies and research institutions making research more receptive for practical needs and challenges.

- According to survey respondents, Horizon 2020 contributes to "**manage expectations and promote shared visions**", with for instance, 67 % agreeing on a complete or partial Horizon 2020 contribution to a common understanding of the future direction of innovation fields, 65 % to a legitimation of innovative solutions as alternative for the future, and 56 % to an anticipation of future trends and shocks.

- Finally, Horizon has also responded somewhat or completely sufficiently to the different aspects relating to the "**expansion of new fields of innovation relevant to the Green Transition**". Among others, next to technological innovations advances in protection and restoration of land and water ecosystem has received higher attention in related strategies and SC Work Programmes. In addition, the role of social innovations is very important. A large fraction of projects could not apply the TRL concept, suggesting that there are many activities beyond technological innovation (notably SC2, SC3 and SC5, see Annex VII). Broad acceptance of novel approaches comes first with 60 % followed by large-scale use of innovations (57 %); accelerated implementation of innovations (54 %) and lastly by recognition of new 'rules of the game' associated with innovation (52 %). Slightly more than 20 % think the response to these needs is too little or far too little and between 15 % and 20 % do not have an opinion about that.

5.1.2. Expanding and mainstreaming niches

Regarding the macro-process 'Expanding and mainstreaming niches', Horizon 2020 seems to play a key role in supporting the implementation of innovative solutions in field of Green Transition, although it could be stronger in terms of radical innovations:

- Horizon 2020 is found to be a contributor to the "**expansion of new fields of innovation**": 59 % of the respondents considered a complete or somewhat sufficient role of Horizon 2020 to the broad acceptance of novel approaches, 58 % agreed that Horizon 2020 supports large-scale use of innovation completely or sufficiently, and 56 % that it accelerated the implementation of innovations (with 28 % considering Horizon 2020 support to be too little or far too little). The programme supported varied stages of research: large scale use of innovations, broad acceptance of novel approaches and accelerated the implementation of innovations. The Zero Emission Aircraft case study notably mentioned that significant improvements in performance as well as increasing the maturity of the technologies were attributed to the projects. The Smart Cities case study illustrated that the FP supported incremental innovation and the development of specific digitalisation solutions which are necessary for smart grid development activities. Whilst higher TRL levels were prominent in the work program and the projects analyzed, technological openness in the exploration of solutions was an equally important facet. Similarly, the Offshore Wind case study showed that technical innovations enabling future cost reduction and upscaling were financed as part of the FP, with new designs for offshore wind substructures, new systems for monitoring operations and identifying component failure, etc. In the Low Emission and Lightweight vessels case study, the analysed project portfolio consisted of Innovation Actions (IAs) that showed through demonstrator projects that the implementation of new technological solutions or the introduction of advanced materials in ships is possible.

  The Smart Cities case study illustrated that the FP supported incremental innovation and the development of specific digitalisation solutions which are necessary for smart grid development activities. Whilst higher TRL levels were prominent in the work program and the projects analyzed, technological openness in the exploration of solutions was an equally important facet. Similarly, the Offshore Wind case study showed that technical innovations enabling future cost reduction and upscaling were financed as part of the FP, with new designs for offshore wind substructures, new systems for monitoring operations and identifying component failure, etc. In the Low Emission and Lightweight vessels case study, the analysed project portfolio consisted of Innovation Actions (IAs) that showed through demonstrator projects that the implementation of new technological solutions or the introduction of advanced materials in ships is possible.

- Horizon 2020 enables the "**replication of innovative solutions relevant to the Green Transition in new contexts**", may it be through geographical transfer (54 % of fully or partial agreement), re-interpretation and adaptation in other contexts (53 %) or transfer in other application areas (50 %). It's important to note that for each question, about one fourth of the respondents did not express an opinion. The case studies showed evidence of a focus being placed on the replication, upscaling and market integration of projects. For instance, the Low-Emission Vessels case study showed that results of the market surveys and business plans can be capitalized and used in terms of technologies to be funded and markets to be targeted. Similarly, the Smart Grid case study underlines that a strong focus is laid on innovation and roll-out – prototyping, testing, demonstrating, piloting, to large-scale product validation and market replication. The "Smart Cities Marketplace" presented in the Smart Cities case study aimed to promote solutions and business models that can be scaled up and replicated across Europe and aims to lead to measurable outcomes such as new jobs and energy savings.

- The Framework Programme contributes to "**disseminate and diffuse innovative solutions and concepts**": 74 % of the respondents considered that Horizon 2020 fosters, partially or fully, open communication of novel solutions, 72 % that it supports the widespread dissemination of new ideas and 63 % the transfer of knowledge of one's own field of knowledge. The Sustainable and Healthy Transport case study showed that the Park4SUMP project initiated a capacity-building process about the strategies to develop national government laws and regulations to use innovative and effective parking management systems including 14 national governments, increasing their knowledge about parking management greatly. Similarly, the Soil case study demonstrates that the national hubs and facilitators were important factors to success.

- Looking at the "**Institutionalisation of new strategies and norms relevant to the Green Transition**", between 36 % and 44 % of the respondents consider that Horizon 2020 projects respond somewhat or completely sufficiently to the different aspects. Establishing of new, common conditions or norms comes first with 44 % followed by institutionalisation of new solutions (43 %); establishing new rules of conduct (41 %) and lastly by establishing of new legal and regulatory foundations (36 %). Between 25 % and 31 % think the response to these needs is too little or far too little and between 29 % and 33 % of the respondents do not have an opinion about that. It can be overall noted that R&I policy only has very limited influence on the relevant legislative processes, i.e. agricultural policy is very much dominated by subsidies. Typically, it is rather old knowledge (that has long been accepted by the scientific community) that is eventually been taken up by the policy processes. I.e. in the case of soil (but also global warming in general) the knowledge has been there for decades, but only now they have gained sufficient policital attention to be taken up in the policy documents.

The establishment of new standards and legal framework conditions can be observed in the Lightweight vessels case study. All the projects analysed helped to pave the way for new standards and policy measures to encourage ship operators to adopt the new materials and propulsion technologies. In addition, the Smart Cities case study also highlighted that the standardisation of data and platforms has played a considerable role in Horizon 2020. The ambition to contribute to improved policy making involved activities geared towards the provision of better urban and land use planning policies as well as new or better institutional and governance arrangements. Addressing regulatory Frameworks involved better compliance with EU and national regulation (e.g. EU Air Quality), contributions to improvements of existing regulatory frameworks as well as new standards and norms. Similarly, the Zero-Emission Aircraft case study found that working groups with EASA and the American FAA to work on easier and more digital certification procedures have been established. For example, the EASA is working on a virtual protocol for certification; this is referred to as new, unchartered territory. Results of the research projects help preparing the evidence for standardization bodies. In addition, evidence from the Zero emission aircraft case study highlighted that the involvement of the regulatory authority EASA was beneficial to help for future certification of products. Nevertheless, the certification process will take a long time.

5.1.3. Opening up and unlocking regimes

- Results are quite mitigated regarding the potential of Horizon 2020 in "**breaking up outdated structures and strategies relevant to the Green Transition**". Indeed, while 60 % of the respondents considered that Horizon 2020 contributes to **opening the system to new strategies** and 59 % that it supports open-mindedness of established actors for new ideas, the contribution of Horizon 2020 to breaking up the established system through radical innovation is subject to discussion: 42 % of the respondents were fully or partially in agreement, and 39 % in partial or total disagreement. Elements of the literature partially corroborate these findings, underlining a further need to move, in an agile way, from risk avoidance to risk embracing and experimentations to better support the ongoing transitions, the necessary industrial and social transformations and the high-level of policy ambitions[108].

It is interesting to note that within the Improving Food processing and industrial value chains case study, interviewees lauded how Horizon 2020 has contributed to two changes in dominant R&I project paradigms. First, FP has helped putting food system thinking higher on the agenda. By allowing this change away from linear value chain it has paved the way towards embracing the complexity of the food sector. Second, Horizon 2020 has aided raising awareness for the value of involving a variety of stakeholders in R&I activities via multi-actor approaches. It has thereby contributed to making research more transdsciplinarity, and to thus increasing its value for end users.

[108] See for instance, DG RTD 2021, Mobilising innovation for people, planet and prosperity, ESIR Policy Brief no. 2 , https://op.europa.eu/en/publication-detail/-/publication/6dabb3da-8c55-11eb-b85c-01aa75ed71a1/language-en/format-PDF/source-196325752 or OECD 2022 Reviews of Innovation Policy: Germany https://www.oecd.org/publications/oecd-reviews-of-innovation-policy-germany-2022-50b32331-en.htm

The Adaptation for climate action case study underlined that the shift from FP7 to H2020 meant funding mainly impact-oriented projects to affect adaptation on the ground. It posed a problem for traditionally central players initially, as they had to realise that a paradigm shift was taking place. The key to success was to bring in new players to satisfy the increasing need for stakeholder engagement and co-creation approaches. A noticeable development was the move towards the provision of climate services and the inclusion of organisations led by the private sector.

- With regards to "**Abandoning outdated habits and rules to enable the Green Transition**", between 40 % and 56 % of the respondents consider that Horizon 2020 projects respond somewhat or completely sufficiently to the different aspects. Willingness of established actors to engage in new ways of solving problems comes first with 56 % followed by questioning the usefulness of accepted solutions (54 %); acceptance of risks that innovations entail (53 %) and lastly by 'unlearning of old rules and habits' (40 %). Between 25 % and 34 % think the response to these needs is too little or far too little and between 18 % and 26 % of the respondents do not have an opinion about that. In this respect, the Soil case study demonstrates that the topic of soil management has gone from being a neglected issue to a core topic of the Horizon Europe mission. What is more, the traditional separation between agricultural and environmental research has eventually been overcome, thus providing an important basis to integrate also environmental goals in agricultural policy making.

- With regards to "**Exchange between "old" and "new" areas of knowledge relevant to the Green Transition**", between 46 % and 59 % of the respondents consider that Horizon 2020 projects respond somewhat or completely sufficiently to the different aspects. Exchange between "old" and "new" areas of knowledge comes first with 59 % followed by networking between pioneers and established players (50 %); opening up rigid patterns of cooperation to new actors (47 %) and lastly by opportunities for (46 %). Between 25 % and 34 % think the response to these needs is too little or far too little and between 18 % and 26 % of the respondents do not have an opinion about that.

- Regarding **'Flexible response to changing framework conditions to enable the Green Transition'**, between 43% and 60% of the respondents answered that Horizon 2020 projects responded somewhat or completely sufficiently to all four needs. 'The recognition of the need for action due to new developments comes first with 60% followed by the remaining three needs with 47%-43% ('Flexible reaction to trends and shocks', 'Critical (re)interpretation of framework conditions' and 'Rapid raction to changing framework conditions').

5.2. Evidence from international benchmarking analysis

The international benchmarking methodology envisaged a predominantly qualitative comparative analysis of the international benchmarking study case with Horizon 2020, carried out first across benchmarking cases – and eventually with the overall Horizon 2020 evaluation of the present study. Accordingly, the synthesis of results of thecomparison are based on the overall results of the Green Transition evaluation that has become presently available.

In addition to this case study-based qualitative assessment (drawing from desk studies, previous evaluation reports and additional interviews), the internal quantitative assessment included the bibliometric analysis, carried out by Science Metrix. The evaluation of efficiency, effectivity, relevance and coherence with regard to the Green Transition and the Green Deal (in the broad sense outlined in the SC5 synthesis in chapter 3.4.) has also been used for this quantitative assessment. It compared the Horizon 2020 SC5 publications109 to a similar set of publications by the same authors not supported through Horizon 2020, and clearly indicated that Horizon 2020 has an important added value, particularly on the two indicators "Citation Impact" as well as on "Open Access". With regard to academic-private co-publications, the assessment shows that Horizon 2020, as well as the non-Horizon 2020 baseline, score well on this indicator. Overall, and notwithstanding certain methodological constraints, which limit the factual significance of the statistical assessment and

[109] Climate, adaptation, sustainability and resilience research and R&I - these fields, corresponding roughly to SC5, have been the main fields of funding in all benchmarked cases.

therefore should rather treated as indications, the comparative view in the table below shows that Horizon 2020 either scores equal or significantly better than FONA, KLIMAFORSK and the NSF.

5.2.1. Quantitative comparison of the analysed funding programmes

The table below presents a visual comparison of the different research programmes. The column Horizon 2020 SC5 represents an internal comparison. This means that the bibliometric analysis draws on a counterfactual analysis composed of comparing the results of Horizon 2020-funded publications to a Horizon 2020 baseline made up of publications from the same authors as those found on Horizon 2020 papers. The other columns represent a comparison between publications from authors that are funded by Horizon 2020 and publications by the same authors but when they are funded through the other research programmes.

Table 8 Comparison of the research programmes based on the quantitative analysis

	Horizon 2020 SC5	ACRP	FONA	KLIMAFORSK	NSF
International collaboration	-	++	++	o	+
Cross-disciplinarity	o	-	-	o	-
Academic-private co-publication	+	+	++	++	++
Gender-equity	o	+	+	+	-
Citation impact	++	++	++	o	++
Open access	++	++	+	++	++
Policy-related outcomes	o	+	o	++	O
Online dissemination	o	O	o	++	O

The combination of the cell colour and the sign within a cell represents how well Horizon 2020 scores against the other research programmes or against the own internal baseline. The light red and "-" indicate that on one of the indicators the counterpart lead with a statistically significant difference. This does not mean that the counterpart lead on all indicator within that category. The grey cells and "o" mean that there was no statistically significant difference between Horizon 2020 and the counterpart. The light brown and "+" indicate that there was a significant lead for Horizon 2020 on at least one of the indicators within the category in favour of Horizon 2020. The dark brown and "++" indicate that there was a significant lead on all indicators within a category for Horizon 2020.

In the following, we present the overall qualitative assessment as an aggregated view on the case studies. For this, we applied the same transversal evaluation criteria that were used for the benchmarking cases, and which had emerged out of them as highly relevant for the Green Transition to effectively gain track in Europe:

1. **Strategic Development** – refers to the responsiveness and flexibility of the programme to adapt to new challenges, needs, risks and hazards given the global context, as well as the capacity for strategically anticipating these changes in the future.

2. **Uptake of R&I Results** – refers to horizontal and vertical policy (and further societal) stakeholder uptake (economic, social, political, media, etc.) of funded actions and research. In particular, it tries to capture the programme characteristics and provisions for facilitating such uptake, rather than assessing its rate of success or impact.

3. **Networks and Infrastructures** – refers to relevant stakeholder and/or scientific community networks that the programme through its institutional set-up and/or portfolio has enabled or contributed to establish. In the same vein, this includes research infrastructures (institutions, higher education programmes, research labs, equipment, devices, technology, etc.) it helped to put into place. Again, the focus here is not on the actual extent of such changes, but on the facilitation of these through the programme characteristics.

4. **Transdisciplinarity** – refers to the cross-sectorial engagement beyond scientific communities and private/public sectors with the wider civil society, e.g., media, citizens, NGOs, health and social sectors, etc. In addition, it ideally involves all scales of multi-level governance in an aligned and coherent manner. This is a truly transversal category, regarded as key for the Green Deal and Green Transition.

5.2.2. Qualitative comparison along selected dimensions

The qualitative comparison of the analysed programmes is executed along the outcome dimensions defined by the international benchmarking methodology, i.e. they comprise *strategic development* (of the funding programme under scrutiny), *uptake of achieved R&I results*, *networking and infrastructure*, and, as a cross-cutting dimensions, *transdisciplinarity*. In addition, the qualitative comparison also includes the evaluation criteria that *Phase I* of the *Green Transition Evaluation* focuses on, i.e. effectiveness, efficiency, and, to a lesser degree, relevance. The table below aggregates the findings succinctly, the detailed results can be found in the synthesis report of the benchmarking exercise (Annex VIII).

Table 9 Horizon 2020 benchmarking with international benchmarking cases along outcome dimensions (++/+/o/-/--)

	Horizon 2020 (EU)	ACRP (AT)	FONA (DE)	KLIMAFORSK (NO)	NSF (USA)
Strategic development	++ Tight strategic alignment with climate-related political developments and objectives (globally and EU-wide); however, effective uptake and policy impact of strategies taken depends on horizontal policy alignment (e.g. inter-DG/MS cooperation, and the activation and mobilisation of the private/public sectors.	++ Unique institutional set- up, changing annual calls (steering board includes representative from research community and policy making, incl. international experts) Flexible, e.g. new programme initiated to improve policy uptake - good strategic flexibility.	++ Focused on community establishment and institutional capacity, later strategically open and essentially tethered to the private sector (SMEs and large industries) Weakness: civil society, NGOs, and citizens have less been the focus of activities.	++ Rotating themes (climate modelling, impacts, adaptation); combined funding and priority setting by Climate Ministry and Education Ministry. Clear transition-related focus and interdisciplinary, applied focus instead of merely scientific excellence Weakness: few funds for truly transdisciplinary calls.	o NSF objectives mirror national priorities; Operationalises its objectives through ongoing but thematically shifting programmes; good monitoring system in place, most results publicly available; progress halted due to the political landscape, therefore full potential was not reached.
Uptake of R&I results	+ Uptake of results form a strategic goal in parts of the FP and are well integrated in policy-area, at least at EU level; on MS level mixed results (see SC5): while potential benefit is there, most new member-states lag behind; mixed within Commission (depends on DGs and their alignment)	- Rather weak and virtually only by the funding ministry (for other programme pillars), the concerned research community, less by horizontal policy-making and broader society; especially at the local level and private sector.	+ Uptake by policy (Ministry for Climate Action), less by other relevant ministries. Successful at the regional and local municipal level, SMEs and some larger companies; also, very successful with regard to non-academic R&I institutions.	+ Focus on fundamental research, less on R&I and technology development. Good in terms of citation impact and policy uptake, as well as media coverage and altmetrics.	+ High uptake scores in terms of citations in policy-related literature and altmetrics; higher number of co-publications with the private sector.

	Horizon 2020 (EU)	ACRP (AT)	FONA (DE)	KLIMAFORSK (NO)	NSF (USA)
Networking & infrastructure	++ Largely successful in fostering collaboration between different stakeholder groups and within thematic clusters; while some partnerships may be costly and not entirely efficient, they created unique EU added value, confirmed by our survey results.	+ Great at establishing and networking an interdisciplinary research community; infrastructure provision rather weak, especially with regard to for explorative research, dissemination, and outreach. However, it has unique programme and research-related links to IIASTA and IPCC.	++ Effective framework programme with key focus in enhancing large-scale infrastructure, transforming institutions, and financing certain sectors. Networks have been established and fostered. Transitions were achieved; Internationally, good leadership example	+ Managed well linking the scientific communities and networks, especially excellent with regarding international networks. Specific calls for dissemination and outreach, successful in science promotion Weakness: provision of knowledge and know- how transfer to non-academic stakeholders	+ Infrastructure and services reach international, national, state, and local levels (e.g. with regard to droughts, floods, and ecosystems), not specifically geared towards a Green Transition yet, but to climate change adaption (although not transversally or horizontally).
Transdisciplinarity	+ Despite some room to improvement (e.g. governance-focused R&I), it can be regarded as current gold standard in enabling and fostering transdisciplinary research and related action compared to the benchmarked cases; combines a boost in uptake, which could have a huge potential impact if alignment and policy coherence were improved.	- Excellent at supporting interdisciplinarity, built great competencies in this regard over the years; However, not such much with regard to transdisciplinarity (due to reduced policy, private sector and societal uptake).	+ Inter and multi- disciplinarity are supported well, transdisciplinarity well tackled and addressed but structural barriers remain in place; Civil society and citizens remain a bit outside the focus of FONA	- Relatively small budgets for inter- and transdisciplinary research; While being a priority for KLIMAFORSK, strategies have not yet been very successful.	o Successful in fostering science-industry collaboration, non- academic actors involved in agenda- setting; indirectly through USGCRP1.

Relevance	++ Overall, the Framework Programmes are considered to be highly relevant (although the degree of relevance varies across each Societal Challenge).	o From a Green Transition perspective, ACRP's relevance is regarded as average.	++ Good (but not consistently throughout whole F1 to F4 period). Programme is not open to everyone (most of funding goes to a few major non-academic research organizations).	++ Highly relevant to both Norwegian society as well as the research community on a regional, national and global level.	+ Highly relevant, but not specifically geared towards a Green Transition.
	Horizon 2020 (EU)	**ACRP (AT)**	**FONA (DE)**	**KLIMAFORSK (NO)**	**NSF (USA)**
Effectiveness	++ FP is convincingly effective. This is the case across all Societal Challenges, with projects largely succeeding in achieving their objectives. Funded actions and research appear to provide an important basis towards progress along the impact pathways (although to diverging degrees).	++ Performs well in terms of the scholarly output that is generated, enabled by its funding and set-up. In terms of achieving its goals, and given its structural constraints, the programme shows a fairly high rating.	++ Programme is highly effective. Especially sustainability transformation research funding (FONA 2 and 3) was effective in reaching the goals that FONA strived to accomplish. Long-term sustainability of funded infrastructure and networks (including expert careers and absorption of transdisciplinary profiles) is still unclear.	++ An effective research programme. Managed to create coherence within the climate research landscape in Norway. The research outputs by the Norwegian researchers are internationally well-regarded (confirmed by bibliometric analysis).	+ Programme is effective and has impact on multiple levels: internationally (including contributions to IPPC), nationally (contribution to NCAs), regionally, and locally (research on extreme events) However, efficiency was negatively impacted by changing political priorities (and following cuts in funding).
Efficiency	++ Very efficient with regard to management and administration. Coordination of the Green Transition requires steering and managing between different policy areas and along multi-governance dimensions. Serious building of capacities beyond the R&I policy realm is needed.	+ Fares well given its constraints, which are substantial. Manages to process a rather large number of projects quite efficiently and managed to grow and expand (launching the new ACRP Impact funding mechanism)	++ Project administration and proposal management of FONA is highly transparent, professional and efficient. Programme monitoring and transparency could be improved.	++ An efficient research programme. With moderate resources, KLIMAFORSK managed to produce excellent scientific output supporting a wide range of stakeholders.	++ The NSF project/programme management is highly efficient. Optimised and standardised processes, the supporting IT systems are well- developed. Downside: lack of engagement with PIs in case of doubts about the project process.

5.2.3. Lessons learnt for Horizon Europe instruments and portfolio development

Several lessons learnt based on the results of the international benchmarking exercise can be drawn. KLIMAFORKS (NO) and the NSF (US) programme offer distinct lessons, while ACRP (AT) and FONA (DE), despite being entirely different funding programmes, yield similar lessons learnt.

5.2.3.1. Lessons learnt from KLIMAFORSK (NO)

Some projects require that a certain percentage come from other sources than KLIMAFORSK. Funding will mostly come from private sector companies. Important to balance perspectives between policy needs and research "end users", something perceived to be difficult. KF project staff feel that they tend to prioritize the user perspective, linked to the fact that the Norwegian industry is a world leader in the Green Transition. National commercial interests are relevant; Horizon 2020 R&I provides well-received complementary funds. Stability of the calls, every seven years there are new instruments, is seen as a value-added for KF and enables predictability for the proposers and potential applicants. FP might be better in integrating other stakeholders, focusing e.g. on financing projects that will push the Green Transition quickly forward.

5.2.3.2. Lessons learnt from NSF (US)

Currently, the federal government is committed to support climate research and science in general. There are many relevant funding agencies for the Green Transition, for instance much research funded by the Department of Energy, as well as the NSF, NASA, EPA etc. In addition, the military sector is concerned with climate change (from a security perspective) and therefore funds a lot of climate-related research. There are also additional funding streams typical for the US R&I system (e.g. philanthropists, corporates/industry/states/state universities, etc.). This has been different in previous years. Nowadays, under the Biden administration, there is an uptick for NSF funding, especially concerning huge research centres: large teams; +/- 20 million over 5 years. Another example: NSF TIP: aimed at entrepreneurship, e.g. regional innovation engines REI. A single team could get 160 million over ten years. Team up with a lot of (local) partners. NASA: huge funding earth observations.

5.2.3.3. Lessons learnt from ACRP (AT) and FONA (DE)

According to all interviewees, all currently existing instruments would benefit from much better integration with Horizon FP instruments – several share doubts about the trend to centralise and expand projects through the mission approach and consortium criteria. Climate related research (as all R&I research and actions in the SC5) requires often smaller budgets, targeted projects and quick results – especially relevant for local contexts, which would make necessary to better align bigger European funding schemes with MS funding schemes.

Transdisciplinarity is the big elephant in the room, according to several interviewees: On one hand, it is urgently required, especially in a synthetic, governance-focused and social science-led/oriented way (bringing actors together, effectively enabling social innovation and changing social patterns, behaviours and acceptability, etc.). On the other hand, there is an unresolved conundrum: the more non-academic stakeholders are involved, the more project time and funds are required, complicating quick results needed for policy-making and adaptation.

5.3. Partnerships` contribution to the Green Transition in Horizon 2020

5.3.1. Relevance of the partnerships related to the Green Transition

5.3.1.1. Societal challenge 2 'Food, Agriculture, Water and Bioeconomy'

The portfolio of partnerships in SC2 comprised on Art. 187 initiative (Bio-based industries) and one Art.185 partnership (PRIMA) funded in this area. Moreover, the EIT Food and various ERA-NET and co-founded partnerships were highly relevant for SC2.

Concerning the Art. 187 BBI JU, the study found that the BBI JU was predestined to contribute to the Green transition before even the political agenda pointed clearly in this direction - that is to say, before the Green Deal. BBI JU and, later on, Circular Bio-based Europe Joint Undertaking have been very flexible and responsive in adapting their strategies, which is reflected by the two updates of the SIRA in 2017 and now for the new CBE JU in 2022. The relevance of the BBI JU has been underpinned by its high economic relevance, as the sector accounts for 3,6 million jobs and around €700 billion

turnover. Against this background, BBI JU is a key instrument to reduce the dependency on raw material imports, contributing to sustainable growth and revitalising rural and coastal areas.

Concerning the Art. 185 partnership PRIMA, the study findings show that the general and specific objectives of PRIMA have been and remain relevant for the Participating States and the Mediterranean R&I ecosystem. PRIMA is highly relevant for tackling the Mediterranean countries' climate-change-related challenges. The approach by which PRIMA aims to reach its objectives is also important, rigorously following the values of co-ownership, mutual interest, shared benefit and the principle of equal footing.

For the various P2Ps in this area, the case studies showed that these have been highly relevant for SC2, as these provided platforms for R&I communities and national policymakers on topics of mutual interest. The Platform of bioeconomy-ERA-NET actions was established to ensure coherence among many of those initiatives.

Furthermore, EIT Food has put itself in place as an enabler of applied research to cater to the needs of the agro-food sector and thus make it a relevant tool to complement the FPs. While there have been no changes in its Strategic Agenda in 2017-2020, the analysis showed that the partnership has proven flexible in constantly improving its organization, e.g. in terms of effectiveness or financial sustainability. Most notably, the partnership introduced its objectives to facilitate more targeted actions – and narrowed down its calls accordingly, allowing it to better tailor them to the identified needs and objectives.

5.3.1.2. Societal challenge 3 'Secure, clean and efficient energy'

In SC3, the portfolio of partnership instruments comprised the (partly SC3 funded) Fuel Cells and Hydrogen Joint Undertaking, a large number of public-public-partnerships (12 ERA-NET CoFunds; 1 JPI without SC3 funding), and the EIT InnoEnergy (again without direct SC3 funding), which established entrepreneurial activities with relevance to the energy transition.

The analysis performed in SC3 showed that the different types of partnerships have been highly relevant to, and complementary to the funding provided by the FP. The Fuel Cells and Hydrogen JU has become the main means for promoting fuel cells and hydrogen technology and helped to provide a strategy to guide collaborative work across various applications. The ERA-NET CoFunds funded by the Framework Programme were important in connecting to local and regional actors and EU Member States. Regarding topics and challenges addressed, they have been considered highly complementary to the FP activities. However, the landscape of ERA-NET CoFunds in the Energy Sector was very fragmented, calling for a rationalisation of public-public Energy partnerships in Horizon Europe.

Furthermore, EIT InnoEnergy has proven to be highly relevant for the EU and its key objective to achieving a Green Transition in Europe. Funded actions of the EIT InnoEnergy significantly contribute to the Green Deal objectives and the UN SDGs. EIT InnoEnergy assessed that 95% of innovations supported by EIT InnoErgy contribute to SDGs 7,8,9,11, 12 and 13. The focus and type of activities of EIT InnoEnergy can be clearly distinguished from activities performed by other parts of the Framework Programme as they focus on the creation of start-up and scale-up funding for innovative Energy solutions.

5.3.1.3. Societal challenge 4 'Smart, Green and Integrated Transport'

SC4 is the Societal Challenge area with the highest share of partnership activities. The four Joint Undertakings Clean Sky 2, SESAR, Fuel Cell and Hydrogen and Shift2Rail account for 48 per cent of all SC4 projects. The Art. 187 partnerships in SC 4 vary in size. In terms of the number of projects and budget, Clean Sky 2 accounts for two-thirds of all partnership projects in transport and more than half of the EC contribution to the partnerships. In addition, two ERA-Net Cofunds on Urban Accessibility and Connectivity (EN-UAC) and Electric Mobility (EMEurope) have been financed. Furthermore, several transport projects related to waterborne transport (MARTERA, marine technologies as part of SC2) or urban mobility (ENSCC – part of SC 3) have been funded in the transport area.

The study found that the mission of SESAR "to accelerate through research and innovation the delivery of an inclusive, resilient and sustainable Digital European Sky" was highly relevant. The JU supports several important policy initiatives of the EU, particularly the Single European Sky initiative (SES) by the European Commission. An external evaluation of SESAR conducted in 2017 confirmed

that SESAR shows significant matches with EU strategic goals and initiatives, acting as a key enabler for the Single European Sky policy and that the JU is delivering solutions for the modernisation of the ATM in Europe. Clean Sky 2 was established with the objective “to contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe. The study findings indicate that the objectives of the partnership are relevant for the Green Transition. The analysis of Clean Sky 2 showed that environmental considerations gained importance, and noise impacts have been taken into account throughout its delivery as a consequence of the evaluation of Clean Sky 2. Over time, the emphasis on emission reductions, including via electric propulsion and hydrogen, increased, and topics of fuel efficiency have been replaced by topics focusing more on enabling emission-free aviation. Clean Sky 2 contributes to the ambition to make the transport system sustainable and seamless for all to use. However, the calls had a clear focus on Large Passenger Aircraft over regional aircraft in an attempt to increase the efficiency of large aircraft. For example, 25 % of the budget in Call 2 was allocated to Large Passenger Aircraft and just under 6 % to regional, a pattern repeated in other calls analysed. Overall, around 50 % of the funds were spent on large aircraft.

For Shift2Rail, the study found that the JU is in line with the 2011 Transport White Paper's goals and contributes to achieving the climate targets by providing an efficient and attractive rail service for passengers, thus ensuring environmentally friendly mobility. Furthermore, the goal of creating a Single European Railway Area (SERA), as outlined in the 2011 Transport Whitepaper and then in S2R's Master Plan, is as relevant today as it was then to achieve a modal shift from road to more sustainable modes of transport such as rail. Thus, the strategic goals of S2R remain relevant in the context of the new European Sustainable and Smart Mobility Strategy launched in 2020. Based upon the S2R Multi-Annual Action Plan, annual activity plans were set-up to define calls and proposals and the launch of tenders. While the objectives of the programme have not changed, also priorities of Shift2Rail have shifted. A common vision for the functional system architecture of the railroad and a conceptual data model have been provided and the activities go beyond the planned technology applications of the technology demonstrators. Thereby, S2R responded to emerging disruptive innovations such as blockchain and artificial intelligence.

Also as regards the Fuel Cells and Clean Hydrogen Undertaking (FCH), the study showed that the objectives and activities continue to be relevant to the grand challenges facing Europe. FCH supported the climate change challenge, helps to improve energy security and contributes to the status of Europe as an international leader in technology. The objectives were in line with the Lisbon Strategy and the launch of the Joint Technology Initiatives was coherent with it. The JU structured its functioning around a long-term research strategy known as the Multi-Annual Implementation Plan, which outlined the research activities for the period 2008–2017 and the pathway towards completion of the objectives set in the regulation. The design of the Annual Implementation Plans was assessed to be relatively open and transparent and has shown some capacity to adapt the contents to unpredicted events and the highest priorities at the given moment.

Finally, the EIT Urban Mobility has already been conceptualised in line with the European Green Deal Priority stipulated in the Political Guidelines for the European Commission 2019-2024. It is committed to contributing to the EC’s Sustainable and Smart Mobility Strategy (2021), which references the proposed European Commission targets for reducing the CO_2 emissions of new cars and vans by 55 %, respectively 50 % by 2030 and zero emissions from new cars by 2035. Although the focus of EIT Urban Mobility is more specific on urban mobility including a strong consideration of urban planning, much of its strategic orientation dates back to SC4 of Horizon 2020. This includes the notion of a resource-efficient, climate and environmentally friendly, safe and seamless European transport system for the benefit of all citizens, the economy and society.

5.3.1.4. Societal challenge 5 ‘Climate action, environment, resource efficiency and raw materials’

As noted earlier, partnerships have not been part of the portfolio of SC5 to a significant degree. FCH has been financed partly through SC5. The EIT Climate-KIC has brought together partners from business, academia, and public/non-profit sectors to create networks of expertise, through which innovative products, services and systems can be developed, brought to market and scaled-up for

impact.[110] The EIT Climate-KIC has built an impressive portfolio of activities and ensured synergies with other initiatives, also in cooperation with international partners that have been highly relevant for contributing to the objectives of SC5 and can notably be considered to be relevant and coherent with the objectives of both the European Green Deal and the Paris Agreement. As pointed out before, as adopted post-Horizon 2020 in 2021, the EU adaptation strategy pointed out that EIT Climate-KIC is one of today's key player in this space.

5.3.2. Coherence of partnerships contributing to the Green Transition

Throughout all SC areas, the JUs managed to gather relevant industry actors and create community of actors along the value chains. In particular in SC3 and SC4, the partnerships contributed to increasing coherence as relevant regulatory bodies have been effectively involved in the partnership activities that allowed for a better co-development of new technologies, standards and norms. In SC2, the creation of cross-sectoral bio-based value chains has been reached through the cooperation of many sectors and industrial clusters.

The P2Ps managed to activate EU Member States actors around topics of their specific interests and contributed to the alignment of national research programmes. A relevant example in this regard has been demonstrated in SC3, in which JPI Urban Europe enabled the creation of transformation-oriented communities of challenge owners at the city level and the R&I community. Despite shortcomings in leveraging additional EU-Member States' funding for R&I[111], the provision and adaptation of common strategic research and innovation agendas and the elaboration of joint activities beyond joint calls enabled the creation of viable communities around topics with high relevance for the Green Transition. Furthermore, some JPIs contributed to a more coherent positioning of ERA-NETs and strategic intelligence processes under one roof (e.g. FACCE-JPI, JPI Urban Europe, JPI Oceans, JPI Climate). This seemed to be missing in other areas (e.g. SC3 -Energy), in which the SET-Plan exerted some top-down influence which became most apparent in the energy-related ETPs but multiple ERA-NETs in certain technologies (e.g. solar power had been set up)[112].

The partnerships have been an important tool for close cooperation and exchange with different actors on behalf of the EU Commission, other union bodies, and the EU Member States. The Joint Undertakings in SC4 have been a very prominent example in this regard. Shift2Rail managed to enable close cooperation and exchange with the European Commission's Directorate-General for Mobility and Transport, as well as with the Directorate-General for Research and Innovation, the European GNSS Agency, and other Union bodies and agencies, to carry out the task of managing "all research and innovation activities co-financed by the European Union, with a focus on rail transport" (S2R Annual Work Plan 2018). Furthermore, SESAR has developed relationships with all other agencies and organisation relevant in this policy area namely, the European Aviation Safety Agency (EASA), European Defence Agency (EDA), the European Space Agency (ESA), EUROCAE – the European Organisation for Aviation Standards. Additionally, SESAR is a priority area within the Connecting European Facility (CEF) which, together with CINEA, manages the Digital Sky Demonstrators activities of the SESAR innovation pipeline.

Also concerning the achievement of synergies and coherence with other partnerships, there are some indications of success. Shift2Rail sought to create synergies and coherence through collaboration with other initiatives and JUs at EU level. An example outlined in the investigation of Shift2Rail was the exploration of a concrete R&I project (FCH2Rail) to demonstrate the feasibility of using fuel cells and hydrogen in the railway environment with FCH. Likewise, SESAR and Shift2Rail collaborated (Linx4Rail) intending to apply knowledge from the aviation sector for innovative traffic management and functional system architecture to the rail sector. SESAR and the Clean Sky partnership both aim to reduce the environmental foot-print of aviation. Whereas the Clean Sky partnership focused on clean aviation technologies (e.g. more sustainable fuels and engines, lighter parts and better wings), SESAR focused on the efficiency of ATM procedures and the improvement of flight paths with corresponding environmental benefits.

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[110] The EIT Climate-KIC works closely with the other EIT funded Knowledge Innovation Communities (EIT Digital, EIT Food, EIT Health, EIT InnoEnergy, EIT Manufacturing, EIT Raw Materials and EIT Urban Mobility).

[111] See European Commission, Directorate-General for Research and Innovation, Giry, C., Hernani, J., Antoniou, L. (2016). Evaluation of joint programming to address grand Societal Challenges : final report of the expert group, Publications Office. https://data.europa.eu/doi/10.2777/19834

[112] See: ERA-LEARN (2020), H2020 Partnership Landscape and its relevance for Horizon Europe – Cluster 'Climate, Energy and Mobility', https://www.era-learn.eu/documents/thematic_analysis_climate_energy_mobility.pdf

The analysis performed in this study concerning the EIT KICs showed that their activities have been highly complementary to the activities of the Framework Programme concerning the Green Transition. The specific focus on entrepreneurship education, supporting of start-ups, and leveraging investments clearly distinguished activities of the EIT with the scope of activities from Horizon 2020. With a view on exploring future synergies, several opportunities could be seized by the KICs. For example, EIT Urban Mobility also promotes activities related to market, regulatory and societal update and aims to strengthen synergies with other relevant initiatives. For EIT InnoEnergy, the alignment of InnoEnergy with other EU policies has been deemed extremely strong, especially with research and innovation policy, energy policy, and decarbonisation policies. InnoEnergy also supports EU´s industrial policy, taking industries of strategic importance for Europe into its focus.

However, previous evaluations of the partnerships and the analysis performed in this study show that challenges in aligning activities of the partnerships with national governments and their activities persist to some extent. One challenge is the inclusion of EU Member States, as indicated in the Fuel Cell and Hydrogen Joint undertaking. The findings reported a lack of effectiveness of the State Representative Group as an important reason behind this situation. The JU compensated for this shortage in doing a very good job of successfully engaging regions. In addition, the Shift2Rail Undertaking reported challenges of engaging EU Member States in the activities of its operation. Still, a more open and pro-active approach towards EU Member States and Associated Countries has been reported in recent years, following the interim evaluation results.

Furthermore, several case studies concerning the P2Ps and the evaluation study on relevance and internal coherence reported some lack of coordination between the activities of the partnerships and the programming of the Work Programmes in Horizon 2020. Limited information sharing and limited strategic exchange on the prioritisation of topics, the alignment between the Work Programmes, and the strategic programming of the partnerships have been criticised, despite the inclusion of the EC in the relevant decision-making bodies of the EU partnerships. The study finding about SC5 and SC4 indicated that the number of EC staff at DG R&I and the Executive Agencies is potentially too small to act on a level playing field with representatives of partnerships with significant resources for planning their activities.

5.3.3. Effectiveness of the partnerships intervention

The analysis of the JU partnerships, the relevant EIT KICs and the findings on the public-public-partnerships conducted in the case studies have shown that these have contributed to the achievement of their objectives and the objectives of the Framework Programme in the area of the Green Transition to a large extent.

The PRIMA evaluation study showed that PRIMA pursued a successful approach to achieve its multiple objectives. The study concludes that PRIMA can be seen as a useful and successful means of European science diplomacy and paves the way for future value added for a potential extension of PRIMA. Some practical challenges persist. One is the realisation of exploitation and market uptake of PRIMA solutions: an increasingly relevant issue in the coming years will be the further exploitation of results achieved by PRIMA projects. In particular, in pilot/demo plants, new practicable solutions are put forward. The maintenance of plants may be relevant for future technology transfer also. Whereas this will already be an issue in the next years, no clear pathways of future financing possibilities for finishing projects exist.

Already in 2014, the activities of BBI JU have been geared towards creating impacts that today could be seen as a direct contribution to the goals of the European Green Deal. The intermediate findings indicate that the BBI JU was a key instrument for realising the EU's objective of a sustainable and competitive Europe and the transition towards a society independent of fossil-based resources[113]. In terms of effectiveness, the intermediate findings of the partnership evaluation indicate that BBI JU exerted a structuring effect in organising the value chain across sectors and effectively mobilised key stakeholders across sectors and geographical areas. Unique instruments, such as flagships and pilot plants, had considerable transformative impacts and made the success story of BBI JU visible. By implementing these types of actions, the BBI JU was effective in its activities towards reaching its objectives. The Teknologisk Institut's assessment shows that most projects under the funding of the

[113] Johnson, Chloe; Ruiz Sierra, Ana; Dettmer, Jan; Sidiropoulou, Kleopatra; Zicmana, Elina; Canalis, Antonella et al. (2021): The Bio-Based Industries Joint Undertaking as a catalyst for a Green Transition in Europe under the European Green Deal. In *EFB Bioeconomy Journal* (100014), pp. 1–8.

partnership have reached their key project objectives[114]. The objectives of developing new products and technologies with great commercial potential, and environmental and socio-economic benefits could be addressed by the BBI JU projects.

Related to SC3 and SC4, the intermediate findings of the Fuel Cells and Hydrogen Joint Undertaking, the JU was effective in performing its operations, managing calls, attracting proposals etc. The partnership's main achievement in Horizon 2020 was to consolidate and organise a previously scattered and fragmented hydrogen ecosystem, attracting some of the biggest industrial players in the field. The JU not only enabled an increase of private R&D funding but also provided anticipation and vision to the hydrogen sector in Europe, becoming a key source of knowledge in Europe for FCH technology. The Hydrogen Valleys have been identified as the most promising activity regarding market and business outcomes. While increasing the TRL of hydrogen technology would potentially lead to economic benefits, the development of a complete ecosystem including the necessary infrastructure for hydrogen remains the key challenge to be tackled in the future.

Clean Sky 2 pursued a Strategic Research and Innovation Agenda with a role for clean aviation in reducing environmental impact, in a sector that is notoriously difficult to decarbonise. A recent independent study on the socio-economic impact of Clean Sky 2 indicated an estimated economic benefit of € 8.5bn of the programme.[115] This includes benefits to the aviation industry and related industries such as airports, tourism, etc., estimated as the direct contribution of funding, R&D activity within the supply chain, and worker spending impacts. In scientific terms, the bibliometric analysis performed in this study showed that Clean Sky 2 stands out for several strengths, among which are: 1) a higher share of 22% of publications were written as academic-private co-publications, against 17% in SC4 and 13% at the EU27 overall level, 2) Clean Sky 2 publications were three times more often amongst highly cited publications at the 5% threshold within their subfield and year than world level, compared to almost two times the world level in SC4 and in EU27 more generally, and 3) a proportion of 67% of CS2 publications were available under an OA modality (open access), against 62% at the SC4 level and 44% at the EU27 overall level. Furthermore, CS2 publications included a 23% share of authorships by Associated Countries , against 17% at the SC4 level and 3% at the EU27 overall level (with UK-based researchers driving the signal and making up 20% of CS2 authorships, much above what is observed in authorship of publications from other Transport cPPP and 187 partnerships).

The analysis of the SESAR 2020 JU indicates that the partnership has been effective in organising R&D activities, developing deployable solutions and building international connections. These have contributed to achieving the objectives of the Framework Programme and the ATM Masterplan. While the independent midterm evaluation of SESAR 2020[116] indicated that the involvement of academia in the overall SESAR programme is the weakest link, the results of the bibliometric analyses performed in this study showed that SESAR publications recorded higher shares of highly cited publications than baseline publications. For example, three times (3.1) more SESAR publications are amongst the top decile of most cited publications in their subfield and year than expected from the world level (i.e. the global average of 10% of publications falling within the top decile of most cited publications – see Annex II for full methodological details). In comparison, this share was twice the expected level in the counterfactual baseline (2.1), or 50% above the expected level at the EU27 average level (1.6).

For Shift2Rail the analysis shows that the innovation programme was very ambitious and has systematically covered the current and future relevant challenges and R&D topics of the railway community. Cross-cutting issues were integrated in a targeted manner. The implementation of the developed solutions has been well on track through technology demonstrators and integrated technology demonstrators, as well as efforts for overall systemic integration. Key challenges and success factors for a sustainable transformation of the railway system have been identified and addressed with stakeholders outside the JU. However, the importance of multimodal interfaces to other modes of transportation requires further attention. However, there are indications that the partnership has not sufficiently succeeded in systematically transferring the valuable research results

[114] Teknologisk Institut (2021): Study on BBI JU project portfolio and KPIs validation. Exectutive Summary. Prepared for Bio-Based Industries Joint Undertaking. Edited by Danish Technological Institute / Food & Bio Cluster Denmark.
[115] Roland Berger and Oxford Economics for Clean Sky 2, Towards Climate Neutral Aviation. An independent study on the socioeconomic impact of the European Union's Clean Sky 2 Programme, 2021, https://www.clean-aviation.eu/media/publications/socioeconomic-impact-of-the-clean-sky-2-programme-0
[116] European Commission, Directorate-General for Mobility and Transport, Ravenhill, P., Bolic, T., Interim evaluation of the SESAR Joint Undertaking (2014-2016) operating under Horizon 2020 : final report, Publications Office, 2017, https://data.europa.eu/doi/10.2832/69327

to the breadth of European industrial and railway companies or to have them transferred by third parties. The bibliometric findings of Shift2Rail recorded more average authorship by Regional Innovation Scheme (RIS) country researchers (43% of authorships on average) than the SC4 baseline (35%), indicating potentially greater equity between zones of differential GDP and income within the EU27 aggregate. However, citation impact indicators for Shift2Rail publications were below the figures found in the baseline but remained above the EU27 average. Furthermore, the share of Shift2Rail publications that are amongst the top cited publications of their subfield are below the baseline (2.1), below the EU27 level (1.6), and below the expected level (1.0) at 0.6.

For the EIT KICs, the Key Performance Indicators and the intermediate results of the analysis of the EIT KICs demonstrate that these effectively deliver visible benefits for EU-wide market development, entrepreneurial education and entrepreneurial activities. In particular, EIT InnoEnergy supported large numbers of start-ups with investments, successfully attracted off-takers, and created firms. Also, EIT Climate-KIC's outreach to 32 countries, over 400 members, 6,000 active alumni and more than 27,000 participants in educational activities speaks to their effectiveness in terms of geographical coverage, variety of activities, and synergies with other partners and EU initiatives. However, as the end of EIT funding for the EIT Climate-KIC is approaching in 2024, the ability to be effective after the end of 2024 is highly questionable, as a considerable downgrading and refocus of activities is to be expected.

5.3.4. Transparency and Openness

The inclusion of a wide range of stakeholders, either in the governance structures or submitted proposals, has been pointed out as a persistent challenge in the study on relevance and internal coherence to apply a more challenge-driven approach that better acknowledges the needs of stakeholder groups and society at large. For example, the study showed that the design of some strategic roadmaps of the Joint Undertakings in Horizon 2020 had been driven predominantly by industry, with limited involvement of representatives outside the consortium. However, some consultation with external stakeholder groups has been implemented. While this ensured the representation of main industrial players at the EU level and an alignment of R&I activities with the technological development needs of industry, this bears major risks of silo-thinking with limited potential to facilitate required transformation processes.

On the other hand, the analysis performed in relation to transparency and openness in this study has shown that improvements in this matter can also be reported. In the case of Fuel Cells and Hydrogen, most stakeholders showed a high level of satisfaction with the level of transparency, and the stakeholders' General Assembly was an important communication channel intended to ensure transparency and openness of the FCH JU activities with its stakeholders. BBI JU has made efforts to close the gaps in geographical coverage. However, the SRIA of CBE JU states also that there could still be an improvement in the outreach and mobilisation of SMEs and other stakeholders, especially in rural, coastal and less advanced regions. SESAR has established procedures that support transparency and openness (e.g. an accessible web page where the decisions of the Admin Board are published). Still, the partnership has high membership costs, prohibiting SMEs and universities from participating.

Similarly, the work program development is done with the members of SESAR, but this process includes the wider aviation community through consultations. In Shift2Rail, the regulation stated that one-third of the budget should go to non-members of the JU. Since only a limited number of SMEs, universities or research centers were members of the partnership, the topics open to non-members were aimed particularly at SMEs and universities or research centres. The strict limitations on membership in S2R were not conducive to inclusiveness in the calls and created some blockage. The S2R interim evaluation already indicated that there were challenges in this regard. Some consortia, e.g., several universities, would have been better suited for some open calls but could not participate due to the restriction. This restricted accessibility of calls for non-members and calls for members also hindered cooperation between the key actors and other stakeholders. However, also Shift2Rail increased activities in opening up and expanding the partnership. In particular, efforts have been made to increase the participation of European Member States and Associated Countries representatives.

5.3.5. EU Added Value & Additionality

Across all analysed partnerships, including the EIT-KICs and ERA-NET CoFunds, there has been a very high relevance of the partnerships in facilitating long-lasting European R&I networks. PRIMA plays a unique role in the Mediterranean R&I ecosystem and serves objectives not covered by other

initiatives and stakeholders, indicating significant impact and sizable additionality. Within BBI, most of the projects and collaborations could not have taken place without EU funding, and the calls triggered cross-sectoral and cross-country cooperations and private investments that would not have been imaginable otherwise. The framework of the BBI JU forced the participants to contribute to the entire value chain (networks) and construct relationships with other European partners. According to BBI, the BBI JU Flagship projects have led to private investment of approximately EUR 1.5 billion with EC funds of 250 million Euros. Also, FCH JU has made significant progress in eliminating the fragmentation that previously existed in EU support for FCH technologies. It provided a common ground for interaction between different stakeholders from the ecosystem. This was also true for SESAR, which was able to initiate cross border collaboration of stakeholders across the entire ATM value chain. SESAR enabled collaboration between industry competitors that would not have been possible before. It also created additional EU value such as improving technical interoperability between countries. This also holds very much true for the activities of Shift2Rail. These have produced solutions that have shown how to implement overarching policy objectives that are not limited to regional or national contexts. The stronger emphasis on openness and collaboration, the value of interoperability beyond systems and national borders, and the importance of attention for the needs of customers and society at large in terms of, e.g., sustainability and user-friendly applications, has led to a change in the R&I agendas of the participating organisations in Shift2Rail.

Regarding the ability to leverage funding from its members, the JUs displayed varying degrees of achievement concerning the contribution targets set by their respective founding regulations for H2020 activities (MFF 2014-2020), reaching 62 % of their members' contribution targets (including IKAA). With 158% of contribution targets reached, FCH outperformed contribution targets set, followed by 84% for Clean Sky 2 and Shift2Rail. SESAR reached 56% of contribution targets by its Members. As regards BBI JU, however, the ECA noted that the JU only achieved around half of the minimum target amount established in the JU's founding regulation and in 2020, no additional cash contributions to the JU's operational costs had been provided. According to ECA, this indicates that the JU encounters significant obstacles in obtaining such contributions from the private members and that the minimum target will not be achieved by the end of the Horizon 2020 programme and DG RTD reduced its cash contributions to the JU by €140 million, which presents a risk to the achievement of the JU's research and innovation agenda for the H2020 programme. However, regarding the leverage effect, the annual report of BBI JU 2020 mentions that the expected leverage effect of BBI in 2021 was above the expected level at EUR 2.6 billion and is on track to reach the program's overall target of EUR 2.8 billion.

The results of the EIT KICs are significantly different from the other parts of the Framework Programme and provide room for network creation with a specific focus on much-needed activities for new entrepreneurial activities in the context of the Green Transition. Furthermore, the EIT-KICs provided EU added value not only through the provision of European Master and PhD programmes but also through its activities in leveraging significant start-up and scale-up investment. Through the strong involvement of EU Member States and national funding agencies, the P2Ps enabled alignment and structuring effects on a European scale, particularly in national programming. While investments have not been as tremendous as in the case of the Joint Undertakings, they enabled the creation of long-lasting national and regional communities of practice in fields of interest for the Green Transition, with significant involvement of policy makers and national funding agencies.

6. Key findings and conclusions per evaluation dimension

The following section provides a synthesis of main findings of this "Evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the Green Transition", along with a set of suggestions for improvement.

6.1. Relevance

Horizon 2020 was already addressing the Green Transition, but did not yet fully operationalise Green Transition targets

Horizon 2020 has been highly relevant to tackle the specific challenges of each societal domain. The programme considered the links between the Societal Challenge and key EU strategies in the related domains, and their evolution over time, as reflected in the different calls. SC2 addresses a broad range of challenges that are associated with the transition from a fossil-based economy towards the use of biological and renewable resources and therefore the need for sustainable primary production and processing systems. SC3 is closely linked to the objectives of the EU energy and climate targets for 2020, the EC Communication on Energy 2020, the Communication on Energy Technologies and Innovation, as well as the Accelerating Clean Energy Innovation Communication. SC4 has close links with the strategic priorities outlined in the 2011 Transport White Paper[117] and recently in the Sustainable and Smart Mobility Strategy 2020, and SC5 was strongly influenced by the Europe 2020 strategy and its "20/20/20" targets.

Since the agreement on Horizon 2020, the urgency of environmental challenges and climate change has substantially increased, and policy has responded. The 2015 Paris Agreement and the Sustainable Development Goals constituted landmark shifts for EU policy making that influenced Europe's new growth strategy – the European Green Deal (2019), aiming to transform the EU into a resource-efficient and competitive economy where there are no net emissions of greenhouse gases (GHG) in 2050 and where economic growth is decoupled from resource use.

The study details that the Green Transition is perceived by many as the necessary shift for achieving the European Commission's overall objectives, i.e. a climate neutral economy in Europe by 2050 and all other associated objectives. Although only clearly framed under the European Green Deal – which is recognised as a clear (r)evolution in terms of comprehensiveness, consistency and priority – diagnostics leading to the need for the Green Transition and related objectives were already existing prior to this strategy, albeit without a clear definition of what a Green Transition meant overall and in particular for each SC.

Against this background, the study findings indicate that an orientation towards facilitating the Green Transition had already been incorporated in the programming of Horizon 2020, with clear references to and incorporation of the strategic policy priorities in the Europe 2020 strategy (specifically the flagship initiatives Resource Efficient Europe and Innovation Union). However, no specific, measurable and time-bound R&I targets related to the Green Transition in Horizon 2020 had been set. The conceptualisation of the programme did not provide a framework on the role and performance of R&I within the Framework Programme to induce the required socio-economic changes in the Societal Challenges addressed.

The Green Transition is not just a technology transition but foremost a system transition. In this respect Horizon 2020 already started to take into account the role and needs of citizens, user communities and related policy domains, going beyond R&I and technological development. This was in particular true for SC2, SC3 and SC5, which had a more balanced approach of different types of instruments and actors. In the transport area, this was more limited due to a lower number of Coordination and Support Actions (CSAs) and a lower representation of different stakeholders and newcomers compared to the other SCs.

Overall, Horizon 2020 still incorporated a strong technological development focus, which prevailed with respect to the question on 'how research and innovation in all forms can induce the required

[117] Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144 final

transformational changes for the Green Transition'. Working definitions related to Green Transition in the Societal Challenges of Horizon 2020, and expected contributions of Horizon 2020 interventions to the Green Transition, had to be developed by the study team and were not part of strategic programming considerations.

Conclusion 1: There is a need to better define and conceptualise the requirements for the Green Transition at the R&I policy level. Specific definitions of the Green Transition, R&I targets and indicators for contributing to the Green Transition should be developed at the thematic level in Horizon Europe.

Horizon 2020 effectively responded to new emerging challenges and policy developments in the world

Horizon 2020 has been highly relevant to addressing the needs and challenges outlined in the key EU strategies relevant at the time of its initial design. It also stayed relevant over time, as it adapted to the evolving policy context. Tackling Societal Challenges effectively and addressing EU policy priorities and global challenges through research and innovation has already been on an equal footing in Horizon 2020, which had focused on fostering scientific excellence and enabling industrial leadership. Departing from this position, which was well embedded in the policy priorities at the time of its creation, Horizon 2020 gradually developed and swiftly responded to subsequent changes in policy priorities and the increased climate emergency.

Horizon 2020 increased its directionality geared towards the Green Transition in the following ways:

- In SC2 "Food, Agriculture, Water and Bioeconomy" there has been a clear development geared towards a higher degree of integration of topics, a more specific environmental focus, and a more systemic approach. Not only the development of bio-based products, but a stronger emphasis on making whole sectors/industries sustainable, gained importance.

- Similarly, in SC3 "Secure, clean and efficient energy", increasing emphasis on the transformation of the whole Energy System had been put at the centre of the programme. This meant targeting technological development issues as well as capacity building and transdisciplinary coordination and collaboration across all required energy system actors.

- In SC4 "Smart Green and Integrated Transport", an increasing focus on green topics in terms of technological developments and a stronger consideration of intermodal transport have been observed. However, the realisation of a sustainable transport and mobility system, which gives a Green Transition a clear priority over other considerations, such as competitiveness of industry or supporting growth via transport and mobility, was not at the core of Horizon 2020.

- In SC5 "Climate action, environment, resource efficiency and raw materials", priorities and objectives have changed throughout the implementation and sequencing of the Work Programme. A progressive tendency towards more systemic approaches, with a focus on innovation and investment in climate research and green technologies, and the decoupling of economic growth and social development from resource exploitation and waste, as well as a focus on supporting a transition towards a circular economy, have all been observed.

Given the large societal impacts of the Green Transition, it is instrumental that policymakers , and not private interest,keep the high-end in the definition of R&I aagenda.The higher mobilisation of Joint Undertakings in the Framework Programmes, while beneficial on some aspects (e.g. leverage on private funding), may provide influence to industrial stakeholders to shape the agenda to their benefit rather than that of society as a whole (risk of silo thinking).

In some areas, however, the evaluation identified emerging needs that were not fully captured by the programme (e.g. transport, energy, nature-based adaptation solutions), or the extent of the required urgency of action. It was found that the programme could have put further emphasis to address the socio-economic challenges related to the Green Transition, including acceptance, contribution and burden sharing, fairness and inclusiveness.

Conclusion 2: Horizon 2020 exhibited a strong capacity to react and gradually adapt to emerging challenges and new policy developments. However, it must be noted that Horizon 2020 did not take a proactive approach towards shaping the Green Transition and Horizon 2020 did not take up enough 'low signal' topics, even if they have emerged in the policy landscape in the period. To further shape

the Green Transition, there is an immediate need to focus on research and innovation activities that not only provide opportunities but effectively enable a transformation of whole sectors and industries concerning production and consumption systems. As the European Environmental Agency pointed out in January 2021, societies need to rethink what is meant by growth and progress and their meaning for global sustainability, and the European Green Deal and other political initiatives for a sustainable future require not only technological change but also changes in consumption and social practices[118].

Horizon 2020 was generally effective in reaching out to relevant stakeholders and addressing the needs of the target groups

Across all SC areas, project participants showed high motivation to contribute to relevant aspects related to the Green Transition. Key motivations to apply for Horizon 2020 funding were mainly related to 1) addressing grand Societal Challenges related to the climate, 2) increasing resource efficiency in processes, and 3) contributing to developments that avoid GHG emissions. To avoid GHG emissions was the key motivation in SC3 and SC4. Increasing resource efficiency was most pronounced in SC2, whereas addressing grand Societal Challenges related to climate was the key motivational driver in SC5.

Tackling Societal Challenges effectively requires addressing all relevant stakeholders associated with the intervention. The project portfolio analysis showed that, compared to FP7 projects, Horizon 2020 was associated with higher shares of projects involving multiple sectors, indicating a higher degree of trans-disciplinarity. Compared to other stakeholder groups, the involvement of public bodies, user communities and, to a lesser extent, other actors (NGOs, associations etc.) has reached high levels in SC2 and SC5 (and lower levels in SC3 and SC4). These stakeholders are particularly relevant for aspects of policy implementation, assuring acceptance, and reinforcing innovation diffusion. The vast majority of projects across all SCs also reported that they have been able to address all relevant stakeholder groups. However, about a third of the survey respondents (ranging from 27 % for SC3 to 40 % for SC2) considered it has only been achieved partially. Identified reasons for this are diverse, ranging from the effects of Covid-19, to lacking time and resources or disinterest on the stakeholder side. It should however be noted that the survey was targeted towards beneficiaries.

For reaching out to the desired stakeholder, the ex-ante consideration on the required instrumental setting of the project portfolio is key. In particular in SC2 “Food, Agriculture, Water and Bioeconomy” and SC3 “Secure, clean and efficient energy” the project portfolio incorporated higher levels of CSAs compared with the other SC areas[119]. Furthermore, an effective mix of Public-Public and Public-Private Partnerships engaged, contributed to reaching out and engaging the required stakeholders. Public-Public Partnerships contributed to a more effective consideration of local stakeholder groups and EU Member State authorities. The Public-Private Partnerships bundled strategic industries and enabled a co-programming of R&I and standard setting-measures, whereas the consideration of EU Member States and reaching out to stakeholders beyond the core actors can be seen as a challenge that still needs to be resolved.

For those engaged in the Societal Challenge areas of Horizon 2020, the study results indicate that Horizon 2020 was very effective in addressing the major needs of target groups related to the Green Transition. Horizon 2020 was effective in providing a visionary approach, supporting the development of new relevant areas, knowledge and stakeholders in the field of Green Transition. It effectively 1) established and promoted new fields of innovation, 2) was praised for enabling learning and exchange in the field of the Green Transition, 3) promoted awareness of problems related to the Green Transition and new ways of solving them, and 4) provided opportunities for networking between relevant young innovation fields for the Green Transition. Furthermore, Horizon 2020 contributed to 5) manage expectations and promote shared visions.

Conclusion 3: At the project level, the planning and incorporation of a coherent and continuously updated stakeholder engagement strategy is a key prerequisite for reaching out to the required stakeholders. At the programme level strong emphasis should be put on the elaboration of specific instruments that engage all required stakeholders to enable the Green Transition. The provision of Coordination and Support Actions, and making use of the competences of partnerships to reach out to regional/local stakeholders, can further enhance knowledge diffusion and scaling-up of solutions.

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[118] https://www.eea.europa.eu/publications/growth-without-economic-growth

[119] For SC3, this higher number can be explained by the legacy of the previous Intelligent Energy Europe Programme (2007-2013, €730m available), relying mainly on CSAs, whose function was thus slightly different from ‘traditional’ CSAs

6.2. Coherence

Horizon 2020 funding related to the Green Transition is in a unique position, with a strong positioning within the European research and innovation landscape.

The study shows that Horizon 2020 is in a unique position in relation to tackling Societal Challenges with a focus on the Green Transition in Europe:

- SC2 “Food, Agriculture, Water and Bioeconomy” is the major funding source for applied research and innovation support in international consortia and fills an important gap in the research funding system in topic areas of high relevance, where only limited funding in EU Member States exists.

- SC3 “Secure, clean and efficient energy” Horizon 2020 funding is part of a broader European R&I funding landscape aiming at the Energy transition. Therein, the SET Plan, as the key R&I and technology strategy for the energy area, guided the development of new energy technologies across EU Member States and provided a forum that ensured that coordination (including cross-DG coordination) took place. In terms of funding, Horizon 2020 remained the major funder for international R&I in the energy context, although IEA reports on energy technologies note that growth rates of public R&I spending remains stubbornly sluggish.

- In SC4 ”Smart Green and Integrated Transport” about half of EC contribution is dedicated for the Art. 187 Partnerships Shift2Rail, Fuel Cell and Hydrogen, Clean Sky 2, and SESAR, which ensured joint technological development avenues for the major transport sectors for whole Europe.

- In SC5 “Climate” the study found strong coherence in terms of overall key strategies and initiatives that have guided and framed SC5’s alignment and broader coherence, whereas partnerships in this SC did not play a major role, except for the EIT Climate-KIC which was not only considered to be coherent with the objectives of both the European Green Deal and the Paris Agreement, but for which also the EU Adaptation strategy (as adopted post-Horizon 2020 in 2021) highlights the need to accelerate the rollout of adaptation solutions and describes the EIT Climate-KIC as one of today’s key player in this space.

However, Horizon 2020 has lacked some coherence on the issue of mobilisation and coordination of multiple actors across different sectors and at different levels (i.e. EU, national, regional, local), which is increasingly seen to be a requirement for effectively managing the Green Transition. At the R&I programming level, evidence on the coordination between the Framework Programme and the European Partnerships has been mixed and no common approach exists. While in some areas a clear division of responsibilities and strong coordination of tasks between the FP, the Partnerships and stakeholder groups has been indicated, other areas expressed the need for stronger coordination between the European Partnerships, the Framework Programme, and the EU Member States. Overall, the Partnerships contributed to the coherence of European R&I programming through providing a joint vision for many areas. This has been particularly true for the Joint Undertakings, although with a strong tendency towards focusing on the key topics of relevance for the industrial players. Also the Joint Programming Initiatives provided a strategic framework for coordination, which inter alia allowed to bundle activities of the diverse to fragmented landscape of ERA-NETs. Furthermore, the partnerships provided a forum for the function of national policy coordination, which is essential for better aligning European and national R&I policies and stimulating joint investments.

Conclusion 4: To further enhance coherence and synergies among the Framework Programme, the European Partnerships and the EU Member States, specific governance mechanisms for the coordination of the strategic planning of activities need to be set up. The governance mechanisms should specifically focus on 1) the cooperation with responsible EC units and executive agencies to detail the multi-annual strategic programming, 2) the coordination and alignment with national and regional activities to provide an interface between national authorities and relevant partnerships and Framework Programme activities, and 3) stakeholder engagement - aiming at increasing the overall impact of the programme by considering the necessary range of needs and collecting a diverse range of perspectives from researchers, practitioners, consumers, public bodies etc.), with the clear focus on enabling and accelerating the Green Transition.

6.3. Efficiency

Horizon 2020 was very efficient in terms of administration and management

Horizon 2020 allocated more EC funds across all Societal Challenges than the previous Framework Programme, while the average cost per project remained rather similar. In addition, the budget allocation within the SC corresponds to the policy needs identified by Horizon 2020 in the field of Green Transition and complementary to the R&I funding ecosystem. The mobilisation of the Joint Undertakings was beneficial in terms of leveraging private funding.

Overall, Horizon 2020 was largely efficient in terms of the administration and management of the projects during their runtime. There was a positive perception regarding administrative and financial requirements, as well as the contractual conditions of the programme. The project application and selection processes were efficient to a large extent. It is to be noted that continued improvements are underlined by beneficiaries in terms of EU requirements, both from FP7 to Horizon 2020, but also from Horizon 2020 to HE.

In fact, the level of satisfaction of project participants was found to be rather high with adequate efforts required for the preparation and submission of proposals. Nonetheless, the application process could benefit from improvement to allow unsuccessful applicants to learn from successful proposals or allowing feedback from evaluators.

To a large extent, projects were carried out in a timely manner or required limited changes. When this was the case, the degree of flexibility of Horizon 2020 was mostly appropriate. Despite the implementation process being deemed well settled by some beneficiaries, improvements could be made regarding the necessary allocation of resources for proposal preparation.

The combination of the results achieved, for instance in terms of bibliometrics (e.g. positive effects in citation impact), and the efficiency of its administration makes the programme cost effective.

In terms of communication and dissemination, measures were generally found appropriate. To be effective, dissemination and communication measures need to be tailored to the needs of the audience, and this seems to have been the case in Horizon 2020. In some Societal Challenges, the higher number of CSAs, including outreach and communication, can explain these results.

Several challenges were identified, however:

- reaching out to policymakers and end-users appears more difficult than reaching out to ‘counterparts’;
- resources/skills needed might not be fully considered by scientists;
- continued knowledge management after the end of a project is not always ensured;
- further coordination is required in a context of increasing parallel activities.

While COVID-19 impacted the possibility of physical meetings, it also allowed a wider audience to be reached.

Horizon 2020 was very effective in delivering the programme related to the Green Transition in an efficient manner. However, the interviews, case studies and benchmarking results indicated that the Green Transition requires significant capacities for its governance – which are at present not being sufficiently provided – In order to improve coherence across DGs, with EU Member States, and at the local/regional level. For the partnerships, mobilising a wide range of relevant stakeholders remains a challenge.

Conclusion 5: The coordination of the Green Transition requires management and governance capacities going beyond the R&I policy level. Significant capacities for steering and managing the coordination between different policy areas and across organisational boundaries are needed both at the programme level and at the project level.

6.4. Effectiveness

Horizon 2020 funding in the Green Transition area enabled researchers to reach top tier status within the subset of their Horizon 2020-funded publications but failed to reach higher levels of cross-disciplinary outputs, science-industry collaborations and dissemination and outreach efforts. An update of the monitoring system would be needed to fully capture the effect of R&I on the Green Transition.

The analysis of Horizon 2020 showed that the main outputs related to the Green Transition in all SC areas comprised:

1) Technological outputs: New technologies, components, systems, innovative processes, improved cost-resource efficiency of technologies etc.;

2) Scientific outputs: scientific publications, project reports, research tools and methods, joint databases, conferences/workshop presentations etc., trained researchers;

3) Networks: research and innovation networks and community building across sectors and disciplines;

4) Close to market outputs: Intellectual property rights, innovative business models, new solutions, start-ups, spin-offs, and

5) Policy outputs: New or improved standards, reference models, inputs to policy making processes and regulations.

It appears, however, that the current monitoring system does not fully capture the extent of the effects in the field of Green Transition, and that additional monitoring tools to 'traditional' R&I indicators will need to be implemented.

Among all types of outputs identified through the investigation in the evaluation study, only scientific outputs (publications) could be subject to a comparative, quantifiable analysis. The comparative analysis showed that for all SCs, Horizon 2020 funding has led to large differential increases in citation impact for 2014-2021 publications, considered against the baseline of parallel publications by the same Horizon 2020 (directly or indirectly) supported researchers. Horizon 2020 support has enabled European and other supported researchers to reach top tier status within the subset of their Horizon 2020-funded publications. Furthermore, Horizon 2020 publications in all SCs exhibited a higher calibre and differential increases in terms of Open Access.

On many other dimensions of bibliometric performance, Horizon 2020 funding related to Green Transition funding did not offer any added value over other sources of funding. These dimensions are: 1) international co-publications, 2) cross-disciplinarity, 3) share of academic-private co-publications, 4) gender equity in research publication authorship, 5) policy-related uptake of support research and its findings, and 6) levels of online dissemination and outreach efforts (Altmetrics dimensions).

It can however be said that Horizon 2020 did successfully select researchers with a stronger tendency for academic-private collaboration than the EU27 average. Furthermore, SC2 saw the selection of researchers with strong overall achievements on gender equity in research publication authorship as compared to the EU27 average. Finally, SC3 supported research which fostered differential gains on the Altmetrics dimension and in terms of Open Access (OA), SC3 enabled a particularly statistically robust lead amongst SCs against SC4 and SC5. Here, Horizon 2020 support enabled a differential gain of 20 percentage points in the share of publications made available by their authors under an OA modality.

Conclusion 5: Against the background of exhibiting a very high impact on R&I quality but limited/no differential gains in many other bibliometric performance dimensions, the role of the specific publication patterns needed to spur the Green Transition should be further investigated. In some Societal Challenge areas, the research supported has led to better results concerning the dimensions of Altmetrics, Open Access, and Gender equity in research publications. Against these findings, it may therefore be interesting to search for best practices in Horizon Europe research calls and instruments that further enable these practices conducive to the Green Transition.

Horizon 2020 funding in the Green Transition Area did not result in high levels of demonstrators, utility models or trademarks. Comparators for measuring the impact or quality of these outputs are missing. Furthermore, it is too early to assess the effect of Horizon 2020 funding in the Green Transition Area related to patenting activities. Finally, due to different methodologies in the attribution of patents to Societal Challenges, a comparison between Horizon 2020 and FP7 needs to be considered with caution.

The number of utility models, registered designs, and trademarks reported in eCorda for these Societal Challenges is very low, with only 2 % of all projects reporting at least one output in one of these categories. 14 % of all projects resulted in demonstrators, with SC4 "Transport" (11 %) exhibiting the lowest share of projects delivering this type of output, and SC5 "Climate" (19 %) the highest share. For demonstrator/pilot prototype, and open research data, the number of outputs per reporting project is very similar across the four Societal Challenges in each of these outputs. For the aggregate of the Societal Challenges, on average, each reporting project reported three demonstrators/pilot prototypes and 1.2 open research datasets. Unfortunately, the lack of comparators in the similar research domains and the absence of any measurement of impact or quality of these outputs prevent further analysis of these outputs.

In terms of patenting activities, it is too premature as of 2022 to formally assess the patenting activity of Horizon 2020-funded projects related to the Green Transition. The time lag between the launch of fundamental research projects and patenting outcomes commonly ranges from 6 to 10 years. It may be considerably reduced when a project is specifically oriented towards applied research and technology development, although still requiring some preparation time. Many patent applications may be done rather late in FP-funded projects' lifecycles, as illustrated by the fact that 54 % of patent applications from FP7-supported projects were made after the closing of FP7 calls (between 2014 and 2021). Against this background, Horizon 2020 funding related to the Green Transition resulted in 306 patents during the runtime of Horizon 2020. In FP7, 400 patents with an equivalent thematic alignment were filed during the runtime of FP7.

Conclusion 6: Beyond publications, patents and demonstrators, there are no project-level output metrics available that provide information on the success of Horizon 2020 research and innovation projects. With a view on the Interim Evaluation of Horizon Europe, it should be assessed to which extent the introduction of project specific Impact Pathways and related documentation of projects' results provide better information on the effectiveness of the intervention.

Horizon 2020 contributed to reaching the desired outcomes in terms of knowledge creation and capacity building and scientific and technological development. The contribution to better policy planning, new technical standards and standard-setting measures gained in importance.

The empirical analysis of the interventions provided by Horizon 2020 in the Green Transition showed that the programme has funded activities that contribute to the following different types of outcomes:

- **Knowledge creation and capacity building:** On the one hand, this outcome relates to the need to develop new knowledge and methods as well as frameworks for the systematisation of data and enabling decision support, while on the other hand, there is a need for dedicated capacity-building and training activities among different target stakeholder groups to prepare the capacity to take up and circulate solutions.

- **Coordination and collaboration:** This outcome relates to the increasing importance of collaboration between different stakeholders (from researchers to relevant public authorities responsible for policy making, the business enterprise sector as major provider of solutions, and representatives from civil society), different research disciplines and geographical extent.

- **Technology and innovation:** This outcome relates to the importance of providing systemic technological solutions and integrated sectoral services for the Green Transition. It concerns the deployment of a portfolio of solutions as part of a new system or their deployment and integration into an existing system.

- **Market and business:** This outcome relates to improving marketability and feasibility of solutions. It emphasises the requirement to follow a needs- and demand-driven approach for the area under consideration. Pilot and demonstration activities should enable the testing of solutions in practice and facilitate replication, upscaling, and new business models.

- **Policies and standards:** This outcome relates to the need to facilitate better policy planning and better institutional governance arrangements (e.g multi-level, cross-sectoral, cross-system). Furthermore, new technical standards and standard-setting measures as well as adapted regulations are needed to drive the Green Transition.

The overall results of the study indicate that the support provided by the relevant Work Programmes in the Green Transition areas havs been effective in reaching the projects' desired objectives. This is the case across all Societal Challenges, with projects largely succeeding in achieving their objectives. Activities also appear to be an important basis towards progress along the impact pathways. Results, however, do not allow reliable claims regarding longer-term outcomes and impacts, and the support was insufficiently underpinned by policies that allow impact.

Across all SCs, the same trends can be observed in the contribution of projects to the different types of outcomes. The key contribution of Horizon 2020 in the area of the Green Transition relates to **knowledge and capacity building** (a vast majority of survey respondents state that their project contributes to a large or very large extent to this dimension). This is followed by the contribution to **scientific and technological development** (a large majority of respondents). Contributions to **policy making and standard-setting** measures have been deemed to be successful to a large or very large extent by about a third of survey respondents. Contributions to **market and business development** have been least successful, with about a quarter of survey respondents across Societal Challenges indicating a large or very large contribution to this dimension.

In terms of **knowledge creation and capacity building**, the study results show that intensified collaboration on R&D with new organisations and an increased focus on interdisciplinary research are the most prominent organisational impacts that have been observed by the project participants. An increased attention to the needs of society (sustainability, societal applications) played an important role in SC2 and SC5, whereas this was less pronounced in SC3 and SC4.

Collaboration and coordination as a desired outcome played a major role across all SCs. For the majority of projects Horizon 2020 contributed to an intensification of cross-border and cross-sector coordination and integration of R&I efforts, stronger pan-European collaboration across disciplines, sectors and value chain, and international cooperation and networks to address common challenges and exploration of synergies. A stronger involvement of civil society in R&I became evident in SC2 and SC3, whereas this was less pronounced in SC4 and SC5.

Results related to the provision of new **technology and innovation** show that the activities provided within the Green Transition area reflect to some extent a shift from purely technology-driven R&I to a more systemic approach. Activities have not been restricted to technological innovations and their translation into practice but also include social innovations and the development of new practices at the actor level.

However, at the same time, the major technological development results of the funded R&I projects have been:

1) the expansion of basic knowledge for technological development

2) the development of new research tools & techniques, models and simulations,

3) the development of new databases, platforms and test beds.

Results associated with higher TRL levels (cost reductions of technologies, improvement of production processes, user friendliness of technologies, increasing energy and resource efficiency) did not play a major role in many of the R&I projects across all SCs.

In terms of the **development of market and business results**, the following study findings stand out: Across all SCs between 44 % and 49 % of projects did not plan activities related to intellectual property rights (patents, licences). Furthermore, between 33 % and 42 % of projects in the SCs did not foresee any activities to launch new products or services (including Art.187 partnerships with less than 15% of the respondents). A quarter to a third of the projects funded did not plan any activities of developing new marketable products or services. At the same time about 36 % of survey respondents across all SCs indicated that results for market development have been achieved to a large or very large extent.

Business development and competitiveness was one of the key motivations for applicants: between half and two-thirds of the respondents indicated that increased visibilty and increased productivity and competitveness were to a large (and very large) extent a factor for applying. But only a fraction considered that their project influenced their competitiveness to a large or very large extent, nationnally (38-48%), in Europe (39-43%) or internationnaly (25-39%).

An improvement of time-to-market of technological solutions has been the major effect of the funding activities provided by Horizon 2020 in the Green Transition area. Across all SCs, the participation in the Horizon 2020 projects did not exert a major impact (no change or less than 10 % increase) in terms of turnover, employment or profit. Only one-quarter to one-third of the respondents reported a contribution to 1-10% increase, while between half to two-thirds of the respondents reporting either not knowing if there had been an increase or no change. In the same vein, also the provision of new start-ups and spin-offs is not a key desired result of the majority of projects, with only 3-10% of the respondents reporting such as creation. In this area, the provisions of the EIT KICs in the Green Transition area provided significant impact due to its specific activities geared towards the direction of fostering entrepreneurial activities.

Contributions to more robust and transparent policy making and more innovation-conducive regulatory frameworks have been major results related to **policy making and the development of standards** that have been reported as major contributions by about half of the project participants, whereas for about one-third of projects this type of contribution was not applicable or not achieved at all. The case study analyses showed that in the different areas of intervention the project portfolios and the partnership activities helped to improve the alignment of strategies at the Member State, national, regional and local levels. In particular in SC4, the project portfolios and the activities of the partnerships contributed to the development of policies and standards in the form of certification and guidance in innovation systems, in which international, national and local governance play an important role for the future development of the related sectors. The co-development of certification and standard-setting measures contributes to speed up market uptake and may also push key market actors to reach ambitious net zero targets.

In terms of participation of international partners, the benefits are similar for all four Societal Challenges: development of know-how and development of partnerships. The effects are less important in terms of access to new markets and the reduction of environmental impacts. Cooperation with non-European partners contributes to strengthening the European position with respect to global competition, and was more strongly reported for SC4 and SC5. Participation in Horizon 2020 did not have any particular effect in terms of international co-publications.

Conclusion 7: While there is strong evidence for achieving the desired project goals – and the contribution to the generation of new knowledge, networks and technologies is high – there is less evidence as to what extent projects provide concrete solutions to deliver on the Societal Challenges. The development of marketable results and market impact are frequently not a core ambition of the funded R&I projects. If the intention is to further increase deployment of new technologies and the introduction of marketable results, measures for increasing this type of activities need to be strengthened. However, the study findings also indicate that the Green Transition does not only require new technologies but solutions that go beyond the provision of new technologies. There is an evident need for stronger coordination between R&I policy, sectoral policies, and fiscal policies. While the bundle of R&I projects in the Framework Programme and the European R&I partnerships allow the provision of joint visions for sectoral developments, the scope of policy making and governance for the Green Transition goes beyond the scope of single projects and R&I partnerships. For Horizon Europe, there is a need to further enhance policy coordination between the Framework Programme and other levels of policy making with the aim of jointly designing the Green Transition.

Horizon 2020 contributed to supporting EU policy priorities and actions in relation to achieving the Sustainable Development Goals, although no dedicated monitoring system was set up to measure the real achievements

In terms of the contribution of Horizon 2020 to the SDGs, it is important to note that the SDGs were introduced in 2015 as part of the 2030 Agenda for Sustainable Development, and thus were not in place at the time of Horizon 2020 design. While SDGs are high on the EU agenda and in line with the EU policy priorities, a dedicated monitoring has not been set up in the framework of Horizon 2020. It is thus impossible to identify the extent of the (indirect) contributions and achievements of Horizon 2020, as illustrated in various case studies. Nonetheless, the focus on the Societal Challenges within the scope of this evaluation allows to clearly state a contribution to EU actions for addressing various

SDGs (table below). Indeed, more that 84% of current H2020 investments were identified as contributing to at least one SDG (82% for societal challenges)[120].

It should be noted that many topics contribute to multiple SDGs, which does not allow for the accounting of the exact budgetary share allocated to each SDG (on average, 3 SGDs are targeted by a H2020 project). Several SDGs, such as 6 'clean water and sanitation', 11 'sustainable cities and communities' and 13 'climate action' received contributions from calls in more than one Societal Challenge. Particularly, under SC5's Work Programme 2018-2020, a dedicated call on 'Greening the economy in line with the SDGs' was launched, showcasing the EU R&I commitment to the SDGs.

Table 10. Contribution of the various Societal Challenges to the SDGs

SC	SDG 1 No poverty	SDG 2 Zero hunder	SDG 3 Good health and well-being	SDG 4 Quality education	SDG 5 Gender equality	SDG 6 Clean water and sanitation	SDG 7 Affordable and clean energy	SDG 8 Descent work and economic growth	SDG 9 Industry, innovation and infrastructure	SDG 10 Reduced inequalities	SDG11 Sustainable cities and communities	SDG 12 Responsible consumption and production	SDG 13 Climate action	SDG 14 Life below water	SDG 15 Life on land	SDG 16 Peace, justice and strong institutions	SDG 17 Partnerships for the goals
2		X	X			X			x			x	X	X	X		
3	X		X				X		X		X		X				
4			X						X		X	X					
5						X					X	X	X				

Overall, the largest share of investment from Horizon 2020 was in SDG 13 Climate Action and SDG 03 Good Health and Well Being, while the EU distance to SDG target is greater for SDG 12 Responsibe Consumption and Production and SDG 13 Climate Action[121].

[120] DG RTD 2022, Sustainable development goals: From Horizon 2020 to Horizon Europe, https://op.europa.eu/en/publication-detail/-/publication/e0faa6d3-4dd1-11ed-92ed-01aa75ed71a1

[121] DG RTD 2022, Sustainable development goals: From Horizon 2020 to Horizon Europe, https://op.europa.eu/en/publication-detail/-/publication/e0faa6d3-4dd1-11ed-92ed-01aa75ed71a1

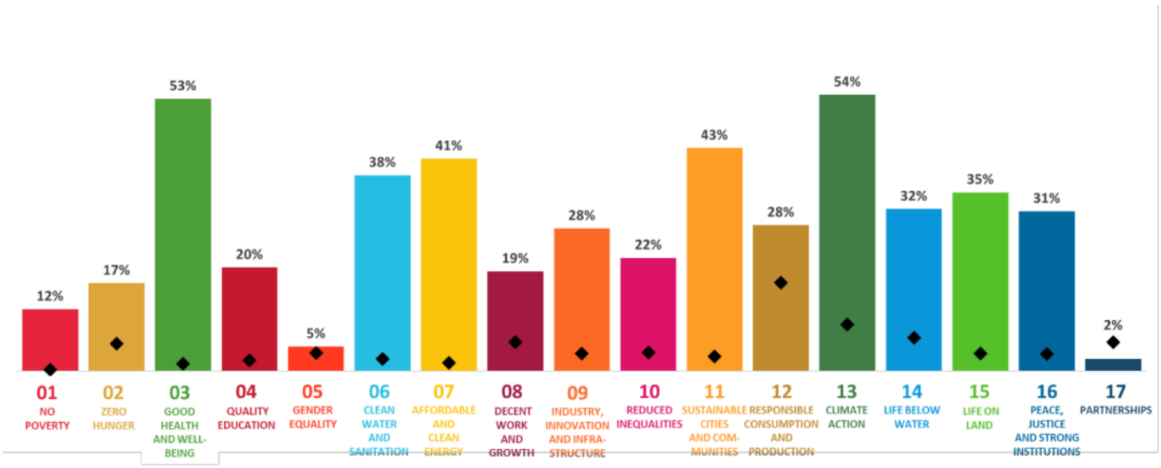

Figure 45 Share of Potential Horizon 2020 Investment by SDG and distance to EU target,

Source: Sustainable Development Goals: DG RTD 2022 From Horizon 2020 to Horizon Europe

6.5. EU added-value

Horizon 2020 funding provided strong EU added-value as it enabled relevant R&I activities at European and global scale that would not have been possible otherwise. Horizon 2020 and its partnerships for R&I contributed to better coordination and alignment of R&I activities at the level of policy makers and at the level of R&I communities.

Across all Societal Challenges, there is widespread acknowledgement that there is a significant EU added value of Horizon 2020 funding geared towards the Green Transition. For the vast majority of R&I projects funded across all Societal Challenges, it became evident that without EU funding the projects would not have been implemented or their scope would have been significantly reduced.

Horizon 2020 projects enabled pan-European cooperation that would not have existed otherwise. The case studies highlight that the FP funding brought together diverse stakeholder groups to pool their expertise and address issues that go beyond the immediate perspectives of the Member States through a systems-thinking approach. Through this approach, Horizon 2020 enabled European-wide collaborations for topics with strong linkages to the Green Transition (e.g. in the food and beverage sector in SC2, and net-zero transport in aviation and shipping in SC4), which otherwise would not have been possible.

Furthermore, there are strong indications that in some SCs Horizon 2020 provided funding for various topics where no (or only in very few MS) national funding R&I funding possibilities exist and where European coordination in the provision of R&I support is strongly needed. The European Partnerships played an important role in this regard. On the one hand, they enabled a focus on building the knowledge base and European network structures for future technologies and the elaboration of joint technological visions and roadmaps relevant for the Green Transition (e.g. in the case of Fuel Cells and Hydrogen, the Joint Programming Initiatives and related ERA-NETs). On the other hand, they provided scope for a stronger integration of technological development, national certification, and European standard-setting processes through the inclusion of key industrial stakeholders. However, in this regard, the risk of remaining open and transparent vis-à-vis new actors and ideas was raised in some instances because the dominance of key industrial players poses a risk that outdated pathways with limited impact on industry transition are being perpetuated.

Conclusion 8: To succeed, the Green Transition requires both individual and collective actions at all levels. It thus needs the design and implementation of support mechanisms to assist in steering stakeholder actions in the right direction. In this regard, Horizon 2020 provided clear added value through the provision of funding in the Work Programmes and European Partnerships. It contributed to support collaborative, ambitious and pan-European projects that would not have been implemented otherwise (or with a lower ambition and a different timeline). Furthermore, in some topics, it addressed funding gaps at the national level. Overall, it also contributed to a better coordination and alignment of

R&I activities in Europe, which is continuously needed to ensure the development of currently non-existing technological solutions to address key challenges, the development of non-technological innovations and the support for their deployment. From a R&I perspective, the Framework Programme is a key tool to support the achievement of major policy objectives such as the EU Green Deal, for which future actions should pay increasing attention to upscaling and repication off all types of innovations

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This report presents the findings and conclusion of the first phase, on Horizon 2020, of the evaluation study on the European Framework Programmes for Research and Innovation for addressing Global Challenges and Industrial Competitiveness - Focus on activities related to the Green Transition.

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