D4.1.1: Synthesis report

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Table of contents:

List of Figures

List of Tables

1 Introduction

1.1 SC5 Work Programme 2014-2015

1.1.1 Context

The **Horizon 2020 Framework Programme for Research and Innovation** (2014-2020) was built around three pillars: Scientific Excellence, Industrial Leadership and Societal Challenges.

Focusing on the latter, the societal challenge-based approach was oriented towards "*bringing together resources and knowledge across different fields, technologies and disciplines, including social sciences and the humanities. This covers activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test-beds, and support for public procurement and market uptake.*"[1]

Thus, the incorporation of societal challenges made a significant contribution to the paradigmatic change in research and innovation policy as the objective was now to contribute to **solving important socio-economic challenges** and accelerate, for this purpose, transformative changes, in addition to increasing economic competitiveness for generating economic growth and jobs and improving the functioning of (national) innovation systems.[2]

Fifth of a series of seven, the **Societal Challenge 5 (SC5) Climate action, environment, resource efficiency and raw materials** was designed to boost European competitiveness, raw materials security and improve wellbeing. At the same time, it was expected to contribute to 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.[3]

The Horizon 2020 SC5 was implemented through calls for proposals outlined in three multiannual Work Programmes (2014-2015, 2016-2017 and 2018-2020) oriented to fund research and innovation in the following broad lines of activities:

- Climate Action - Informed decisions for a climate-resilient low-carbon society.
- Cultural Heritage - Engaging a new cultural heritage agenda for economic growth.
- Earth Observations - Crucial information on climate, energy, natural hazards and other societal challenges.
- Nature-Based Solutions - Providing viable solutions of natural ecosystems.

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[1] European Commission (2019): Societal Challenges available at https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges.

[2] Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy, 47(9), 1554–1567.

[3] European Commission (2019) Societal Challenge Climate Action, Environment, Resource Efficiency and Raw Materials available at https://ec.europa.eu/programmes/horizon2020/en/h2020-section/climate-action-environment-resource-efficiency-and-raw-materials.

- Systemic Eco-Innovation - Generating and sharing economic and environmental benefits.

1.1.2 Rationale, objectives and priorities

Within the Work Programme (WP) 2014-2015, the general objectives of SC5[4] were:

i) Achieving a resource efficient and climate change resilient economy and society.
ii) Protecting and managing in a sustainable way the natural resources and ecosystems.
iii) Ensuring a sustainable supply and use of raw materials.

More precisely, it was focused on "*investing in innovation for a green economy* with special emphasis in *social and public sector innovation."*[5] Thus, it was oriented to support projects with two different scopes:

a) Knowledge generation in order to understand changes in the environment, identify the policies, methods and tools that would most effectively tackle the above-mentioned challenges.
b) Innovation deployment oriented to support innovators and businesses to bring green solutions to the market.

Waste and water were selected as particular priorities on the grounds of their potential for business opportunities and job creation while tackling important resource efficiency challenges.

Three different calls were launched in the 2014-2015 Work Programme. These calls are presented in Table 1 below.

Table 1: The main calls of the SC5 Work Programme 2014-2015.

Call	Description
Waste: A Resource to Recycle, Reuse and Recover Raw Materials ***(H2020-WASTE-2014/2015)***	This call on waste aimed at boosting innovative, environmentally friendly and cross-sectoral waste prevention and management solutions along the whole production and consumption cycle, from waste prevention and the design of processes and products for recyclability to reuse and waste management. In order to reach these objectives, the following approaches were advocated: • Participation of citizens in co-developing and co-testing new solutions. • Support to cross-sectoral approaches: Involvement of different actors from different sectors. • Participation of SMEs. • Leveraging funds from alternative sources: European Structural and Investment Fund (ESIF) and European Regional Development Fund (ERDF). • Open access contribution. Under this call, 14 projects in total (nine Innovation Actions (IAs) and five Research and Innovation Actions (RIAs)) were awarded.
Water Innovation: Boosting its value for Europe	The call on water innovation aimed at contributing to several policy objectives including those set out in the Europe 2020 Resource-efficient Europe Roadmap for water:

[4] European Commission (2015) HORIZON 2020 WORK PROGRAMME 2014 – 2015 -12: Climate action, environment, resource efficiency and raw materials.
[5] Idem.

Call	Description
(H2020-WATER-2014/2015)	• Minimise impacts of droughts and floods. • Search for alternative water supply options only when all water saving and water efficiency measures are taken and other options exhausted. • Keep water extraction below 20% of available renewable water resources. The following approaches were advocated: • Seizing new significant market opportunities. • Generation of growth, active SMEs and jobs. • Enhance integrated approaches to water and climate change adaptation and mitigation. • Bringing water innovative solutions to the market. • Boosting innovation actions to offer opportunities to SME, social enterprises and other organisations. • Contributing to open access. • Leveraging other investment funds: European Structural and Investment Fund (ESIF) and European Regional Development Fund (ERDF). Under the water call, 29 projects were awarded (nineteen IAs and ten RIAs).
Growing a Low Carbon, Resource Efficient Economy with a Sustainable Supply of Raw Materials ***(H2020-SC5-2014/2015)***	This thematically most versatile call of the SC5 Work Programme 2014-2015, covered six different lines of activity: 1. Fighting and adapting to climate change. 2. Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems. 3. Ensuring the sustainable supply of non-energy and non-agricultural raw materials. 4. Enabling the transition towards a green economy and society through eco-innovation. 5. Developing comprehensive and sustained global environmental observation and information systems. 6. Cross challenge topics. The general objective of this call was to invest in innovation for a green economy supporting businesses in developing and bringing to the market eco-innovative solutions and to move towards a new era of climate information systems and services that can provide accessible, high quality and ultimately useful data for the public sector, business and society. It also sought to improve the understanding of the complex interactions within across and between ecosystems and the different element driving changes in the environment. In terms of the access to raw materials, it pursued to ensure a significant reduction in resource use and secure a sustainable supply of key raw materials. It considered achieving the above-mentioned objectives considering the following approaches: • Applying a multi-disciplinary research and innovation approach to influence policy, business and society. • Pooling complementary knowledge and resources, including the active involvement of socio-economic disciplines. • Encouraging green public procurement processes. • Contributing to bilateral, trans and international agenda. • Giving opportunities to SMEs. • Contributing to open access.

Call	Description
	• Leveraging other investment funds: European Structural and Investment Fund (ESIF) and European Regional Development Fund (ERDF). • Coordinating research and innovation actions within Europa and beyond. Under this call, 34 projects (thirty RIAs and four IAs) were funded.

In addition to the above-mentioned calls, the SC5 Work Programme 2014-2015 included three cross-societal challenges calls co-financed and co-managed by other Work Programmes.

Aiming at applying a "systemic and cross-sectoral perspective" and ensuring "coordinated research and innovation activities"[6] when referring to climate and environment, the SC5 WP contributed to:

- Blue Growth (formally included in Societal Challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bio economy). Three projects (all of them RIAs) awarded under this call have been included in our analysis.
- Disaster-resilience: safeguarding and securing society, including adapting to climate change (formally included in Societal Challenge 7: Secure societies – Protecting freedom and security of Europe and its citizens). Six projects (four RIAs and two IAs) under this call have been included in our analysis.
- Energy Efficiency (officially included in Societal Challenge 3: Secure, clean and efficient energy). One project (RIA) awarded under this call has been included in our analysis.

1.2 Evaluation approach

1.2.1 Purpose and scope of evaluation

The objective of the IMPACT-SC5[7] project is **to evaluate the progress made and achievements** of the RIA and IA projects funded under the Societal Challenge 5 Work Programme 2014-2015. For that purpose, the evaluation study carried out by the IMPACT-SC5 project has analysed the impact of the eighty-seven SC5 projects[8] resulting from the 2014 and 2015 calls, referring to:

- **Ex-post evaluation** of the progress made and achievements (vs. ex-ante Impact Assessment).
- Exploring the **impact pathways** to trace the different paths on how the project results and outputs have generated (or are expected to generate) wider impacts.
- Cross analysing the (lack of) outputs, outcomes and impacts achieved with **wider societal context**, such as policies or external contextual factors, pursuing a better understanding of why and how certain impacts have or have not been achieved.

[6] European Commission (2013) REGULATION (EU) No 1291/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC.

[7] The project full name: "Assessing the Impact Pathways of IA/RIA SC5 Projects through the Use of Portfolio Analysis."

[8] Data according to European Commission's H2020 Dashboard available at https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard.

- **Project, portfolio, and programme** levels.
- Based on **quantitative and qualitative analysis of data** and information collected from secondary (desk research) and primary (survey, interviews, stakeholder workshop) sources.

The above-mentioned 87 projects consist of 53 RIAs and 34 IAs, responding to the above-referenced six calls with 30 specific call topics.

1.2.2 Evaluation framework and criteria

The evaluation conducted in the IMPACT-SC5 project has been mostly guided by the application of the "impact pathway" time-sensitive approach.[9] Therefore, a list of short-, medium- and long-term indicators associated with each impact pathway has been developed aimed at monitoring the performance of the projects towards their objectives.

Addressing the objectives and expected impacts of the SC5 WP 2014-2015, three different impact pathways have been considered in our analysis:

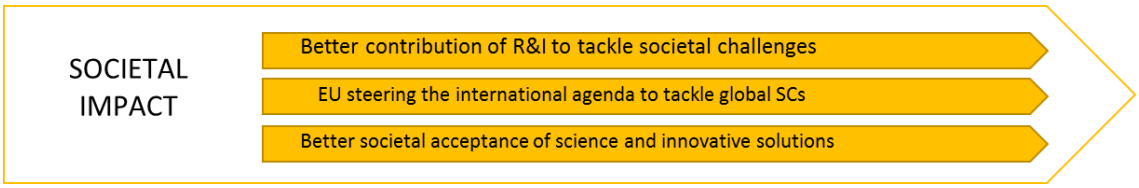
1) Scientific impact pathway

The expected scientific impact of the SC5 WP 2014-2015 is addressed in terms of the following topics:

- Addressing gaps in the knowledge base needed to understand changes in the environment;
- Identifying the policies, methods and tools that would most effectively tackle the challenges related to climate action, environment and resource efficiency;
- Generating world-class excellence in science in areas related to this societal challenge;
- Developing skills, human capital and improved working conditions;
- Delivering and using knowledge and technologies working on an open data basis; and
- Creating international partnerships.

[9] Brussels, 7.6.2018 COM(2018) 435 final ANNEXES 1 to 5 ANNEXES to the Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination {SEC(2018) 291 final} - {SWD(2018) 307 final} - {SWD(2018) 308 final} - {SWD(2018) 309 final}

2) Societal impact pathway



The societal impact of the SC5 WP 2014-2015 is considered in terms of providing evidence-based advice and recommendations to better position EU in the international agenda for the transformation to sustainability, in particular through the implementation of the Sustainable Development Goals (SDGs) and analysing the capacity to develop green innovations and to strengthen the uptake of those by society.

3) Economic impact pathway

The economic impact pathway of the SC5 WP 2014-2015 is addressed in terms of its capacity to:

- Generate innovation-based growth improving the EU's competitiveness and achievement of global leadership;
- Create more and better direct and indirect jobs; and
- Leverage investments in R&I from other funding sources.

In addition, the evaluation framework of the IMPACT-SC5 has employed two different assessment criteria:

- **Performance:** The performance evaluation refers to the assessment of the overall results achieved by the projects granted by the SC5 WP 2014-2015 compared to the expected results. The performance analysis mainly concerns the short-term results of the projects (outputs).
- **Effectiveness:** The analysis of effectiveness focuses on the medium- and long-term results (outcomes and impacts) while measuring to what extent the medium-term results achieved by the individual projects and project portfolios have contributed to the overall objectives of the SC5 WP 2014-2015, as well as identifying the drivers and barriers to this contribution.

1.2.3 Levels of analysis

The IMPACT-SC5 project employs three levels of analysis: the individual project level (micro), project portfolio level (meso) and programme level (macro).

At the project level, the scientific, societal and economic results delivered by each of the eighty-seven projects have been reviewed.

The project portfolio level constitutes the backbone of our evaluation work. We used a project portfolio approach, including the development of project aggregation and analysis of their performance in

comparison to the expected objectives and impacts assigned in the work programme. A project portfolio refers here to a group of projects that are analysed as a functional whole from a systemic perspective, identifying relations, synergies and collaborations found between them.[10]

Five project portfolios have been formed based on their common topics and scientific fields: i) Climate change; ii) Environment, ecosystems and biodiversity; iii) Raw Materials; iv) Waste and v) Water. These portfolios group projects from highly related scientific fields. For the sake of more fine-grained analysis, each portfolio has been divided into two clusters, resulting in five portfolios and ten clusters overall (see Table 2 below).

Table 2: Scientific field-based project portfolios and project clusters.

Portfolio	EC Programmes	Project cluster description	# of projects	Max. EC Contribution (€)
Portfolio 1	**Climate Change**			
Project Cluster 1.1	EU 3.5 EU 3.5.1	Fighting, adapting and mitigating climate change	10	64,327,633
Project Cluster 1.2	EU 3.5.1	Advanced Earth System Models	2	29,306,846
Portfolio 2	**Environment, Ecosystems, Biodiversity**			
Project cluster 2.1	EU 3.5 EU 3.5.2	Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems	7	68,654,214
Project cluster 2.2	EU 3.5 EU 3.5.5	Environment, Ecosystems and Biodiversity: observation and monitoring data	9	60,756,821
Portfolio 3	**Raw Materials**			
Project cluster 3.1	EU 3.5.3	Sustainable production of Raw Materials	12	85,694,642
Project cluster 3.2	EU 3.5.3	Sustainable substitution of Raw Material	4	18,677,201
Portfolio 4	**WASTE**			
Project cluster 4.1	EU 3.5.4	Industrial Waste	7	55,808,020
Project cluster 4.2		Urban Waste	7	49,222,532
Portfolio 5	**WATER**			
Project cluster 5.1	EU 3.5.4	Water resources / resilience	16	78,790,155
Project cluster 5.2		Water treatment (technologies)	13	59,201,331

[10] Cf. Wallace, M.L. & Rafols, I. 2015. Research Portfolio Analysis in Science Policy: Moving from Financial Returns to Societal Benefits. *Minerva,* 53, 89-115.

The programme level of our analysis is presented in this synthesis report. It delivers overarching conclusions on the whole SC5 WP 2014-2015 built upon the aggregated information analysed through the project portfolio assessment.

1.2.4 Methods and data (project/portfolio/programme)

Bearing in mind the relevance of data availability that underpins all assessment exercises, several data collection methods have been used during the project execution. Thus, desk research, surveys, interviews, group interviews and workshops have been conducted with different purposes.

Desk research has been conducted with the aim of compiling and analysing the basic project data (such as the main objectives, timeframe, maximum EC contribution and participant information) and the existing information on the results of the individual projects.

Desk research has been supplemented with an individualised and targeted survey addressed to all the partners involved in the eighty-seven target projects. The survey was conducted with the aim of providing evidence on scientific, societal and economic project outputs, outcomes and impacts. The participants were also asked about the obstacles and good practices in case of impacts, and, their formal and informal relationships with similar projects, among other topics. We received around 250 responses to the survey, including at least one answer from each of eighty-one projects (from project partners or coordinators).

Personal interviews with project coordinators have been conducted to obtain (mostly qualitative) information on the projects and participating organisations under scrutiny. The objective of this data collection was to get a more detailed understanding of the impacts that the coordinators expected the projects to have (determining pathways), including the obstacles, if any, that have hindered the project to make an impact so far. Sixty interviews with project coordinators were conducted, covering almost 70% of the target projects.

Group interviews, with coordinators and partners in four selected projects, have been performed in the context of in-depth case studies. The objective was to collect more focused information on the involvement of the partners of the selected projects in terms of horizontal collaboration activities with other research projects and programmes and to get their views and reflections on the continuity of research activities in follow-up projects, on the role of SC5 funding and on lessons learnt. Twenty-two project partners representing four selected projects participated in the group interviews.

Lastly, several workshops with different objectives have been conducted during the project implementation. For making programme level comparisons between the WPs of the Societal Challenge 5 and Societal Challenge 2, a workshop was organised with stakeholders aiming at discussing how interlinkages between these WPs could help to increase efficiency, reduce redundancies and build synergies in research and applications while also improving governance across sectors. Five policy co-creation workshops (based on the five scientific fields covered by the project portfolios) have been conducted. During these workshops we discussed our findings and conclusions of the results with different stakeholders. During these workshops, co-creation sessions were organised to contribute to the design of future policies that would further enhance the achievement of impacts by the EU-funded projects.

1.2.5 Limitations related to data and ending date of projects

Despite all the effort made to achieve the maximum quantity and quality of data, some limitations regarding data availability and consistency have emerged.

In terms of **data availability**, limitations have been perceived in several ways:

- Due to the General Data Protection Regulation (GDPR) and personal data confidentiality restrictions, the SC5 projects' interim or final reports have not been disclosed to the IMPACT-SC5 consortium. To compensate for this, the EC services shared a number of semi/fully anonymised datasets incorporating some of the outputs achieved by the SC5 projects that partially mitigated the effects of the restrictions.
- There is an overall shortage of indicator data on medium- and long-term impacts for all impact pathways.
- There are limitations related to the project coverage of the surveys and interviews. The participation of SC5 beneficiaries in the data collection activities do not represent the eighty-seven target projects equally.

In terms of **consistency of data**, **the constraints relate to:**

- Inconsistency of indicator data depending on the information source.
- Discrepancies among project partners and lack of a common perception on project results and impacts achieved by a project.
- Discrepancies related to the projects' results delivered after project completion not considered in any official information source.

In addition to the constraints related to data availability and consistency, serious limitations have been encountered due to fact that **most of the projects under scrutiny have been finished very recently**. Indeed, almost 75% of the target projects were finished in 2019, 2020 or in the first months of 2021. The remaining 25% were finished in 2018. Therefore, in case of many projects under scrutiny, the necessary amount of time has not elapsed to make a proper and full assessment of medium- or long-term impacts

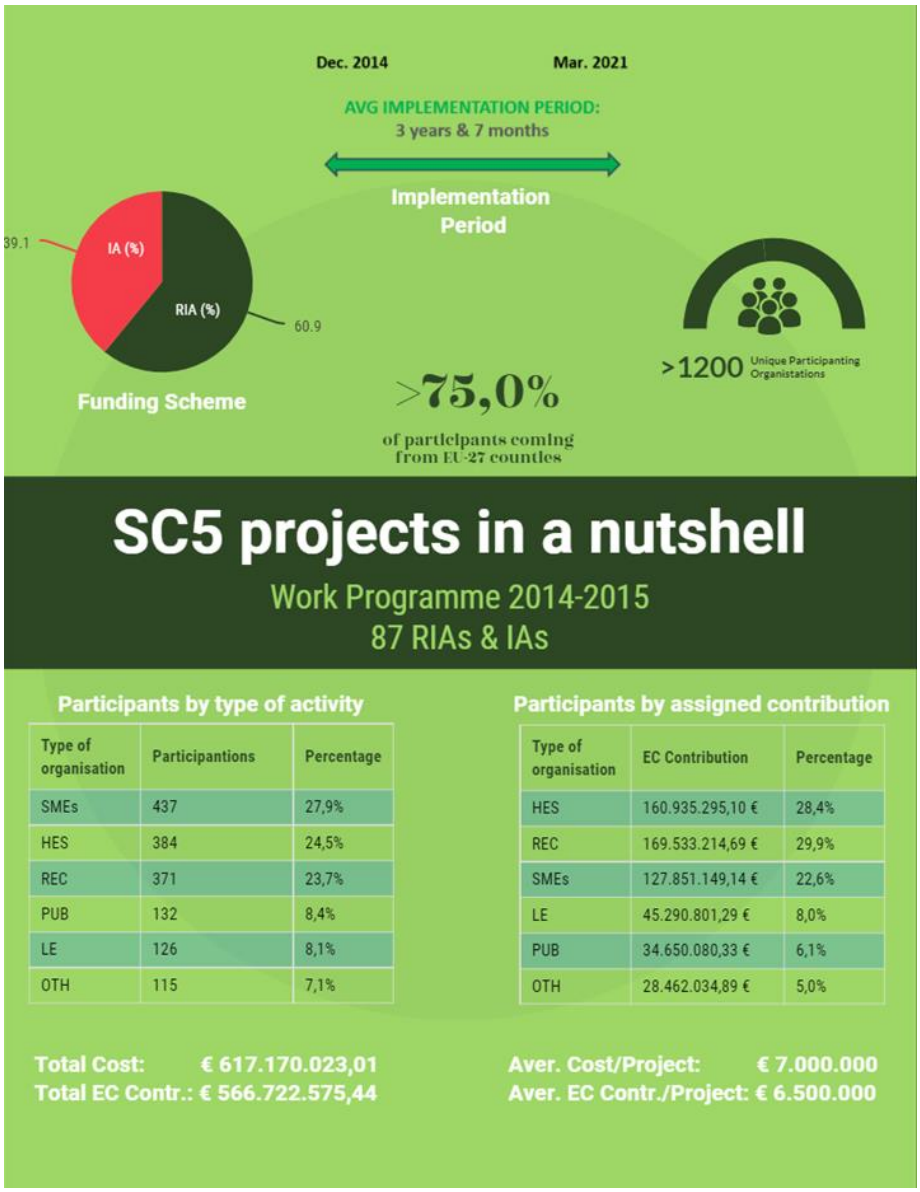
2 Project performance outlook

2.1 Introducing the 87 SC5 projects under investigation

The Societal Challenge 5 Work Programme 2014-2015 (SC5 WP 2014-2015) aimed at investing in innovation for a green economy, addressing the gaps in the knowledge base needed to understand the changes occurring in the environment, identifying policies, methods and tools that would most effectively tackle the abovementioned challenges, and supporting innovators and businesses to bring green solutions to the market. Waste and water were selected as particular priorities for the SC5 WP 2014-2015.

The following infographic presents some key facts and figures for the 87 SC5 projects investigated:

Figure *1*: Facts and figures on the SC5 projects under scrutiny



Funding Scheme and Topic

In total 87 RIA/IA projects were funded from 30 different topics from which 60,9% (53 projects) constitute Research and Innovation Actions (RIAs) while the remaining 39,1% (or 34 projects) were Innovation Actions (IAs).

Implementation Period

In terms of implementation period, the first projects started in December of 2014 (CloseWEEE, INFINITY and OptimOre) while the programme ended with the completion of CRESCENDO project in March 2021. The average implementation period for all the 87 projects is calculated at around 3 years and 7 months.

Participating Organisations

These 87 projects involved more than **1,200 unique participating organisations**, of which approximately **36,0% are Private-for-profit entities**, **24,5% Higher or Secondary Education Establishment and 23,7% Research Organisations**. The remaining **15,7%** of the participation came from **Non-profit Research Organisation** (8,4%) and **Other Establishments** (7,3%). Interesting is the fact that the vast majority of the private for-profit entities that participated are **SMEs** (**77,6% or accounting for the 27,9% of the total participation**) while 22,4% are Large Enterprises (accounting for the 8,1% of the total participation).

Overall, **organisations from around 70 different countries were involved**. The vast majority of the participating organisations came from EU-27 countries (around 75%). UK involvement was considerable, accounting for 11,3% of total participation. Finally, a number of beneficiaries was engaged from all over the world (such as the US, Canada, Australia, Japan, China, different African countries, etc.).

Private-for-profit entities, including SMEs

As could be expected, more than **half of the participation (50,2%) in the IA projects came from Private-for-profit entities**, most of which were **SMEs**. Participation from Higher or Secondary Education Establishment and Research Organisations was calculated at 33,1%. On the other hand, **RIA SC5 projects involved mostly academic partners and research-oriented partners (56,9%)** while the participation of private establishments reached 27,9%.

Cost and Funding

The total cost of all the projects under investigation was EUR 617,170,023 with an **EC maximum contribution of EUR 566,722,575**. In further detail, approximately **two thirds of the EC maximum contribution (65,0%) was allocated to RIAs with the remaining 35% allocated to IAs**.

The cost of projects ranges from EUR 2,361,622 (REMEB project) to EUR 20,652,921 (AltantOS project). The average cost of the projects included in this project cluster is approximately EUR 7,000,000 while the average EC contribution reached around EUR 6,500,000.

Research Organisations (REC) and Higher or Secondary Education Establishments (HES) absorbed more than half of the EC funding (around 58%). This is aligned with the fact that around two-thirds of the projects represent RIAs. **Private for-profit entities absorbed 30,6% of the EC contribution, most of which**

allocated to SMEs. Last but not least, Public Bodies received around EUR 34,000,000 or 6,1% of the total funding, while 5,0% of the money has been absorbed by other organisations types.

When looking only at the **IAs where the funding rate is associated with the type of organisation** (in principle, the rate is 70% for profit-making legal entities and 100% for non-profit legal entities), their total budget was calculated at around EUR 238,000,000 while EUR 199,000,000 were eventually reimbursed from the EC (or 83,5% funding rate).

Private-for-profit entities, including SMEs

Private-for-profit entities participating in IAs received 40,6% of the overall IA funding (**EUR 80,000,000**). The majority of IA funding was allocated to SMEs. When observing the RIAs, the amount of budget dedicated to private-for-profit entities dropped to a quarter of the total RIA awarded budget (**25,2% or around EUR 90,000,000**).

2.2 Key scientific results achieved

Regarding publications, based on the data provided by the European Commission as well as the IMPACT-SC5 survey, altogether projects under investigation generated **3,017 publications** which are further analysed as follows: (i) **1,859 peer reviewed publications**, (ii) **558 conference proceedings**, (iii) **45 articles**, (iv) **43 book chapters**, (v) **19 monographic books** and (vi) **463 other publications**. In addition, 30 thesis dissertations were submitted during the course of the 87 SC5 projects.

Figure ***2***: Key scientific results.

Based on the responses collected from our survey, the vast majority (77,4%) of the beneficiaries reported that their projects (project beneficiaries' perception) have achieved to a **considerable and/or great extent**

the delivery of their outputs through the publication of scientific reports/articles and/or formal publications generation.

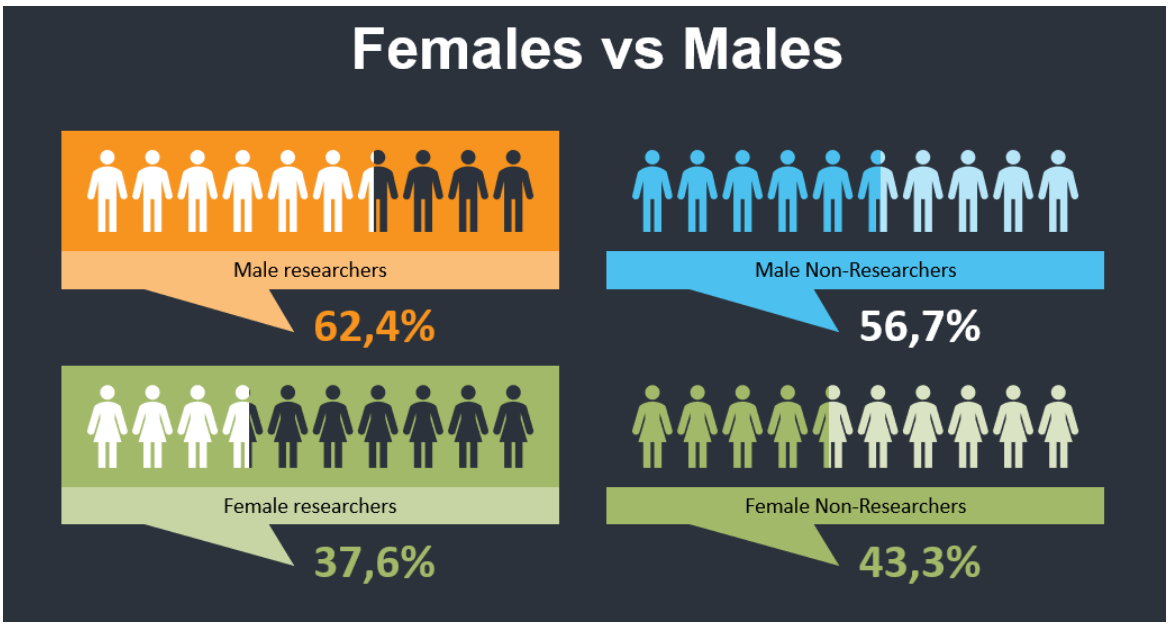
Related to the **gender dimension**, almost half of surveyed SC5 beneficiaries (45,3%) considered that their projects have **considerable and/or great extent contributed** to the generation/incorporation of gender knowledge.

Finally, three quarters (75,1%) of the survey responses indicate that the project participants consider that their work has **addressed gaps in the knowledge base** needed to understand change in the environment, with **175 out of the 233 responders reporting considerable to great advances in addressing knowledge gaps**.

Regarding the contribution of these projects to **strengthening human capital in research and innovation**, no official information is available about the number of early-stage researchers recruited for the projects and retained beyond the life of the project, or about the number of awarded PhD degrees that were supported by the projects. However, two-thirds of the surveyed project beneficiaries (142 out of 214 or 66,4%) pinpointed that their projects **contributed (considerable and/or great extent) to the career development of researchers, and specifically to researchers included within their project teams**.

From a **gender** point of view, the vast majority of the projects have been coordinated by **males**. On top of that, there is an **uneven distribution between female and male researchers** within projects' teams. More specifically, 3,339 females and 5,547 males were engaged or 37,6% and 62,4% accordingly. When looking only at the non-researchers' a **fairer distribution between females and males** is observed (females: 2130 or 43,3% | males: 2793 or 56,7%).

Figure ***3***: Female vs. male participation



As stated above, around 3,000 publications were generated from which **two third (2,049 or 67,9%) have been provided via open and unrestricted access** (**Green or Golden Access).** In further detail, 1,308 peer-reviewed publications, 424 conference proceedings, 30 book chapters, 28 articles, 14 monographic books, 25 thesis dissertations and 220 other publications have been published as **open access outputs**. On top of that, all 87 projects have collectively produced around **400 open access datasets.**

Regarding the partnerships and international openness, according to the survey responses **41 projects have jointly organised activities with other H2020 projects**, including conferences, workshops or joint dissemination activities.

2.3 Key societal/environmental results achieved

When referring to the **number of policy outputs** - addressing specific EU policy priorities, cluster challenges or Sustainable Development Goals (SDGs) - we identified, by juxtaposing the retrieved information from our literature review (Task 2.1) with our survey, **that 54 out of the 87 projects produced policy-related outputs** addressing EU policy priorities and Sustainable Development Goals. It should be noted that for 19 projects no relevant information was found. Moreover, when analysing the survey responses, around **half of the surveyed beneficiaries (46,1%) reported that their project has to a considerable and/or great extent contributed to policy development** (strategy papers, expert groups etc.).

Regarding the **number of policy interactions** promoted, at least **59 of the 87 projects (67,8%) participated in several conferences, discussion forums, or experts or focus groups**, conducted at local/regional, national or European level and that, in most cases, those **contributed considerably to the achievement of the projects' impacts**. Again, for 16 projects no relevant information was found or retrieved.

On top of that, **citizen engagement and co-participatory approaches with civil society organisations were conducted** by almost 45,0% of the SC5 projects (39 out of 87 projects). The projects collaborated with citizens during the project implementation period, mainly through co-creation workshops, open consultations, and surveys. No relevant information was found for 20 projects.

Figure 4: Policy outputs.

2.4 Key economic results achieved

In terms of the economic impacts, based on the data received by the EC services, the following results have been achieved:

- 256 innovations;
- 794 testing activities;
- 278 innovations entering the market from which 188 were introduced by SMEs;
- 41 projects introduced new innovative methods;
- 54 projects produced new innovative products; and
- 49 projects established new innovative processes.

It is interesting here to point out that due to GDPR and confidentiality issues, the European Commission services shared with our team only anonymized and aggregated data with a view to protect individual SC5 projects' personal data and market interests.

Figure 5: Outputs of commercial importance.

On top of the above, and based on our survey findings, 24 out of the 87 projects **reported that they filed for protection of their Intellectual Property Rights (IPR)** (such as patent, copyright, trademarks) or that they are waiting for IPR to be filed in the near future. This finding only reflects the results stemming from our survey and should be treated with caution.

Interesting is the fact that, **almost half of the beneficiaries answering the survey (46,1%) stated that their projects contributed to regulation/standard harmonisation**. This outcome is in line also with the impact of the projects on the policy impact pathway described in the previous section. In further detail, the survey shows that around half of the projects **created or developed new standards** as well as **harmonised standards**. Moreover, a number of projects created new standards committees and contributed to the work of two other existing standards committees.

In terms of **creating more and better jobs**, no official data from the EC was shared. According to the survey results, project coordinators indicated that more than **400 new scientific jobs, 150 technical jobs**

and 80 administrative jobs have been created within the projects. This information cannot be considered as relevant enough for analysis, since it is information coming from only a number of SC5 coordinators during the survey. Moreover, no information about the number of the jobs retained once the projects have come to an end has been made available to the IMPACT-SC5 team.

In terms of additional funding leveraged, the available information does not permit definite conclusions to be drawn since the survey information comes from only two of the ten projects. In any case, it seems that, considering the gathered data, only a limited number of projects (around 10%) of the projects has managed to leverage additional funding from public and /or private sources.

Regarding the change in the **Technology Readiness Levels** (TRLs) achieved, no official data was made available to the team. During the interviews a number of project coordinators stated that their projects succeeded in advancing in this respect (around 30,0% of the SC5 projects). Yet, the data available does not allow for a straight-forward conclusion on this aspect.

Last but not least, **60% of the projects stated in the survey that they have developed collaborative outputs** in the form of joint public-private publications.

3 Portfolio analysis of impact pathways

3.1 Scientific impact pathway

3.1.1 Short-term impacts

In this section, the five project portfolios are reviewed and compared with each other in terms of short-term scientific impact pathway indicators.

Portfolio 1: CLIMATE CHANGE

The CLIMATE CHANGE portfolio is comprised of 12 projects that are divided into two clusters:

- Project cluster 1.1 Fighting, adapting and mitigating climate change (10 projects), out of which 8 were RIAs and 2 IAs.
- Project cluster 1.2 Advanced Earth System Models (2 RIA projects).

As expected from the objectives and expected impacts of the calls under which portfolio 1 projects have been awarded, this portfolio mainly focused on reinforcing and extending the existing science base and therefore establishing high quality new knowledge and reducing knowledge gaps in the area of climate change.

In line with the objectives and expected impacts of the portfolio 1 topics, this portfolio spanned the range from new research to improve our understanding of the Earth's climate system and the impact of climate change on social infrastructures and assets as well as the development of new or improved standards, products and services to mitigate and adapt to the impact of climate change. As well as delivering high quality new knowledge in the form of publications, this portfolio also performed well in terms of developing prototypes and innovations (albeit limited to projects under Project Cluster 1.1).

Considering the short-term scientific impact pathway indicators, the two clusters of this portfolio are quite different. Although the projects of both clusters aimed towards applied research and production of scientific publications that improve research in the areas of climate changed and Earth system models, they differ in relation to the openness of the scientific data collected or elaborated as well as in relation to the support given towards young researchers. Collectively, the two clusters delivered around 480 peer-reviewed publications, with around 412 (85%) published in open access (OA); 88 via Golden and 324 via Green OA. Of the 229 peer-reviewed publications in project cluster 1.1, 85 publications are provided via Gold open access and 79 via Green open access (in total 164 or 71,6%), whereas among the 251 peer-reviewed publications produced by projects in cluster 1.2, 3 publications are provided via Gold open access and 245 via Green open access (in total 248 or 98,8%)[11].

In relation to gender, male researchers prevailed female researchers by 3 to 2 approximately in both clusters. With respect to non-researchers there are no data available for Project Cluster 1.2. For Project Cluster 1.1 the ratio between female and male participants is more balanced, with 46% of participants being females.

An area where the two clusters had significant differences between them concerned their support given towards strengthening of human capital in research and innovation: Project Cluster 1.1. reported very few PhD theses being supported as part of their projects (seven in accordance to the reports of five projects) whereas Project Cluster 1.2 – as reported by one of the two projects included – achieved to advance the career development of 30 to 40 PhD students and 40 to 60 young postdocs, while the coordinator of the other project stated that many masters, PhD, and post-doc students were started, and the project is expected to positively influence the career path of those young researchers involved in it also beyond the lifespan of the project.

Regarding internationalisation, both projects involved international (non-EU27) partners with differentiating ratios between them: approximately 25% of participating organisations in Project Cluster 1.1 were international organisations (around half though are from the UK) while the percentage of international partners in Project Cluster 1.2 rose to 36.2% (with the vast majority being from the UK).

In comparison to other portfolios, the CLIMATE CHANGE portfolio is among the top performers with respect to strengthening of research careers and the second performer in relation to the production of peer reviewed scientific knowledge, including open access.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY

The ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio is divided into two project clusters:

- Project cluster 2.1 Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems (7 projects), all of which were RIAs.

[11] Here we need to mention that the data regarding the peer-reviewed publications and open access peer-reviewed publications were provided via the European Commission services. These data refer to a certain point of time (time of delivery of data). Currently updated figures may exist on peer-reviewed publications and open access peer-reviewed publications due to projects' advancements.

- Project cluster 2.2 Environment, Ecosystems and Biodiversity: observation and monitoring data (9 projects), of which 5 were RIAs and 4 IAs.

As anticipated from the objectives and expected impacts of the calls under which Portfolio 2 projects have been awarded, this portfolio mainly focused on reinforcing and extending the existing science base and therefore establishing high quality new knowledge and reducing knowledge gaps.

Considering the short-term scientific impact pathway indicators, the two clusters of this portfolio are quite similar. Both clusters – although the first one includes only RIAs and the second is a mix of RIA and IA projects – achieved a rich production of open access, peer-reviewed scientific publications. In further detail, Project cluster 2.1 delivered 465 peer reviewed publications, out of which more than half (252) were open access (Gold or Green). These figures are the highest among all five portfolios. Project cluster 2.2 produced 256 peer reviewed publications, out of which the vast majority (231 or 90,2%) were open access. Overall, the portfolio aimed to contribute to the improvement of knowledge in relation to protection of the environment, sustainably managing natural resources, water, biodiversity and ecosystems as well as towards the collection and provision of data and insights on environment, ecosystems and biodiversity.

In relation to gender, male researchers prevailed female researchers also in this portfolio by 3 to 2 approximately in both clusters. With respect to non-researchers for both project clusters the ratio between female and male participants is reversed, with 59% of participants being females.

Concerning the support given towards strengthening of human capital in research and innovation, only project cluster 2.1. reported information. According to the reports reviewed and the interviews conducted around 50 PhD theses and Master diplomas were supported by all 7 projects in the EU and abroad, e.g. Africa.

Regarding internationalisation, both projects involved international (non-EU27) partners with differentiating ratios between them: approximately 32.5% of the participating organisations in project cluster 2.1 were international organisations (with around half being from the UK) while the percentage of international partners in project cluster 2.2 was lower at about 23.4% (yet, it should be taken into consideration that 24 out of the total 41 international organisations of this cluster are coming from the UK).

In comparison to other portfolios, the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio excelled with respect to creation of high-quality new knowledge and the reduction of knowledge gaps in relation to all other portfolios examined, in strengthening human capital in R&I, in particular in relation to non-researchers, and fostering the diffusion of knowledge and open data.

Portfolio 3: RAW MATERIALS

The RAW MATERIALS portfolio is divided into two projects clusters:

- Project cluster 3.1 Sustainable production of Raw Materials (12 projects), all of which were RIAs.
- Project cluster 3.2 Sustainable substitution of Raw Materials (4 projects), all of which were RIAs.

Projects in this portfolio were driven by industrial interest, reflected in the ratio between private for profit and research/academia participants: Higher Education Institutes and Research Institutes accounted for 44% of all participants and 48% were private-for-profit organisations. This is in line with the objectives of the calls that aimed towards industrial driven research and the creation of new integrated sustainable concepts for mining, the reduction of geological uncertainty through the development of new geo-models.

Considering the short-term scientific impact pathway indicators, the two clusters of this portfolio are quite similar. Both clusters collectively produced 213 peer-reviewed scientific publications, of which 64 (or 30%) were provided via Gold open access. In addition, 46 peer-reviewed publications were provided via Green open access (or 21,6%). These figures are among the lowest among all five portfolios.

In relation to gender, male researchers prevailed female researchers also in this portfolio by 3 to 2 approximately in both clusters. With respect to non-researchers, the ratio between male and female participants was similar (3 to 2) in project Cluster 3.1, but in Cluster 3.2 it improved as the ratio was more balanced in favour to female participants: 58% were females vs 42% males.

Concerning the support given towards strengthening of human capital in research and innovation, very little information was collected for either cluster of projects.

Regarding internationalisation, both projects involved international (non-EU27) partners with differentiating ratios between them: approximately 18.9% of the participating organisations in project cluster 3.1 were international organisations (yet, to be mentioned that 25 out of the total 34 international organisations are from the UK), while the percentage of international partners in project cluster 3.2 was almost double 34.9%, among which two thirds are UK based.

In comparison to other portfolios, the RAW MATERIALS portfolio was one of the low achievers in producing scientific results, despite the fact that all projects funded under these topics were RIAs.

Portfolio 4: WASTE

The WASTE portfolio is divided into two projects clusters:

- Project cluster 4.1 Industrial waste (7 projects), out of which 2 were RIAs and 5 were IAs
- Project cluster 4.2 Urban waste (7 projects), out of which 3 were RIAs and 4 were IAs

Overall, this portfolio is placed in the before-last position in all scientific impact pathways, as its focus was mainly on the innovation and policy development arena.

In relation to the scientific impacts collectively achieved, both industrial and urban waste projects have contributed to the delivery of improved and innovative processes, methodologies, techniques or solutions, related to the fields of knowledge prioritised in the topics under scrutiny. However, some differences have been found; project cluster 4.1 has been industry driven, with higher participation of companies and research organisations leading the implementation of the projects, while the urban waste related projects (cluster 4.2) have adopted a more policy-oriented focus with higher participation of public bodies and other type of organisations, such as regional environmental or development agencies, etc.

Considering the short-term scientific impact pathway indicators, the two clusters of this portfolio are quite similar. Both clusters collectively produced 69 peer-reviewed scientific publications, among which a little less than half (31) were Gold open access while 20 were published as Green open access peer-reviewed publications (or 29%). These figures are the lowest among all five portfolios (in terms of quantity). However, what should also be noted here is the fact that around 26 open access datasets have been produced, mainly under project cluster 4.2, which places the portfolio around the middle of all others.

In relation to gender, male researchers prevailed female researchers also in this portfolio by 3 to 2 approximately in both clusters. With respect to *non-researchers* in particular, the ratio between male and female participants was similar (3 to 2) in project cluster 4.1, but in cluster 4.2 - similarly to other portfolios analysed – it improved towards a more balanced representation between female and male participants with 52% being females.

Regarding the support given towards strengthening of human capital in research and innovation, very little information was collected for either project cluster.

Both project clusters involved international (non-EU27) partners to some extent. Around 14.7% of all participating organisations in cluster 4.1 were international ones (with a little less than half being UK based), while the percentage of international partners in project cluster 4.2 was only 1%, the lowest among all portfolios and with no UK participant.

In comparison to other portfolios, the WASTE portfolio was the lowest achiever in producing scientific short-term impacts, and this can be partially attributed to the low number of RIAs funded under the specific calls as well as the objectives set towards applied research.

Portfolio 5: WATER

The WATER portfolio is the largest among all portfolios in terms of projects included. The 29 projects included are divided into two projects clusters:

- Project cluster 5.1 Water resources / resilience that is comprised of 16 projects, out of which 5 were RIAs and 11 were IAs
- Project cluster 5.2 Water treatment [technologies] that is comprised of 13 projects, out of which 5 were RIAs and 8 were IAs

In relation to the short-term scientific impacts of the portfolio, and in accordance with the objectives and expected impacts identified in the calls under which portfolio 5 projects were awarded, the projects contributed to reinforcing and extending the existing science base, establishing high quality new knowledge, and reducing knowledge gaps in the water arena.

With respect to publications, collectively all 29 projects of this portfolio delivered 376 peer-reviewed publications, out of which around a third (138) are available as Gold open access and 113 as Green open access (or 30%). The peer reviewed publications produced between the two clusters are quite similar (200 by cluster 5.1 projects, 176 by cluster 5.2). However, the amounts of open access articles differ quite significantly between the two:

- 158 (out of 200) peer-reviewed publications of cluster 5.1 are open access (≈63% of the total open access peer-reviewed publications).
- 93 (out of 176) peer-reviewed publications of cluster 5.2 are open access (≈37% of the total open access peer-reviewed publications).

The two clusters produced in total 70 open access datasets and software, placing them second in volume across all five portfolios.

In relation to gender, male researchers prevailed female researchers and non-researchers also in this portfolio by 3 to 2 approximately in both clusters. An interesting point comes from projects cluster 5.1 in which 6 out of the 16 projects included had female project coordinators. Concerning contribution towards improvement of gender knowledge the majority of projects in both clusters claimed to have strongly contributed to the generation/incorporation of gender knowledge, but it should be noted that there are different perceptions on this issue among different participants in the same project.

Regarding the support given towards strengthening of human capital in research and innovation, very little information was collected for either cluster of projects.

Regarding internationalisation, both projects involved international (non-EU27) partners: approximately 16.9% of the participating organisations in project cluster 5.1 were international organisations (with around half being UK ones), while the percentage of international partners in project cluster 5.2 was almost double with 29% of participants being from non-EU-27 countries (around a quarter of them coming from UK).

In comparison to other portfolios, the WATER portfolio was around average in producing scientific short-term impacts but scored rather high in relation to making knowledge peer-reviewed accessible via open access publications as well as engaging international partners.

Comparison of portfolios

There are small differences in the ratio of female-male participants among all five clusters (2 female to 3 male participants), which improves a little when observing the ratio of female–male non-researcher participants (more balanced). The involvement of international partners among portfolios is around 22%-27% with the exception of WASTE with 15%.

There are large differences in case of:

- scientific outputs produced, with the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY being the top performer with 721 peer-reviewed publications overall, and the lowest produced under the WASTE portfolio, with only 69 peer-reviewed publications.
- ENVIRONMENT, ECOSYSTEMS, BIODIVERISTY also scored the highest (in terms of quantity) in relation to fostering diffusion of knowledge and open data with around 500 open access (either Gold or Green) peer-reviewed publications. It is to be mentioned here that CLIMATE CHANGE portfolio provided 85,8% of its peer-reviewed publications via

open access, scoring first in terms of the portfolio with the largest share of open access peer-reviewed articles.

- The portfolio with the least scores in this impact pathway was the RAW MATERIALS with only half of its peer-reviewed publications being openly accessible.

Data issues

In general, lack of data is an issue especially in relation to number of publications in the top 10% of impact ranked journals by SC5 subject category (such as: water, waste, resource efficiency, climate action) and the number of recruited early-stage researchers for the project. There is no data available on exact numbers, e.g., joint activities organised with other H2020 projects.

3.1.2 Medium- and long-term impacts

In this section, the five project portfolio are reviewed and compared with each other in terms of medium- and long-term scientific impact pathways.

Portfolio 1: CLIMATE CHANGE

The high level of activity in producing scientific outputs supports the achievement of the medium- and long-term scientific impacts of the CLIMATE CHANGE portfolio. In this respect, the two project clusters of this portfolio, project cluster 1.1 Fighting, adapting and mitigating climate change and project cluster 1.2 Advanced Earth System Models, do not differ in any essential respects.

In case of this portfolio, the expected impacts stated in the SC5 Working Programme 2014-15 were mainly related to the improvement of information availability for decision-makers as well as in relation to the 'Roadmap for moving to a low-carbon economy by 2050', the development of technological and performance standards or assessment methodologies on EU and international level, the improvement of understanding around historic and technological contexts and accordingly of renovation projects, and the increase of international collaboration and cooperation in the area of climate action.

The scientific impact pathway of this portfolio is aligned with the expected impacts, considering the scope of the projects funded, the high number of peer-reviewed publications already delivered and the open access datasets, software, etc. elaborated, as well as the international collaborations in place.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY

As discussed also above, the ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY cluster excelled with respect to the creation of high quality, new knowledge and in strengthening human capital involved in R&I, having a balanced gender ratio when it comes to non-researchers and foster the diffusion of knowledge and open data.

According to the relevant calls, the expected impacts for this portfolio involve – in relation to scientific knowledge – are to provide leadership for Europe in implementing GEOSS, to increase the temporal and geographic coverage of observational data in the Atlantic Ocean, to integrate standardised in-situ key marine observations into models and forecast systems, to contribute to the research requirement for the Copernicus operational services, to improve modelling outputs, to enhance coping with global challenges

associated to climate, natural resources and global scale hazards. To this end, from the analysis of the short-term results and the projects included therein, it was identified that the projects implemented a wide range of science-driven activities with a view to establishing high quality new knowledge. To do so, projects developed comprehensive and sustained global environmental observation and information systems as well as designed technological solutions to address climate change. On top of that, cluster 2.2 projects paid particular attention to providing open and interoperable data and knowledge. Additionally, new innovative research tools, methods and models were developed to strengthen environmental modelling and monitoring capabilities. Moreover, during the implementation of cluster 2.2 projects, a number of advanced technologies were developed and used, such as: power-aware and compact sensor devices for smart applications; crowdsourcing platforms and mobile applications; new remote sensing products for monitoring water utility networks; and user-friendly and innovative authoring tools for parameterisation of various platforms. It should also be mentioned that citizens' science was stimulated through the active promotion of citizens observatories, among other relevant activities.

Regarding collaboration the aims are to improve inter-EU collaboration with respect to Atlantic ecosystem-based research, and international collaboration and cooperation in the areas of biodiversity and ecosystem services. Both clusters paved the way towards the accomplishment of these medium-to-long term objectives through the involvement of relevant consortia and the design of appropriate projects.

Portfolio 3: RAW MATERIALS

As discussed above, the objectives of this portfolio aimed towards industrial driven research and the creation of new integrated sustainable concepts for mining, the reduction of geological uncertain through the development of new geo-models.

The medium- to long-term scientific objectives of this portfolio concern mainly the improvement of efficiency of exploration and exploitation of raw materials' resources, increasing the range and yields of recovered raw materials and the promotion of the EU at the forefront in the areas of sustainable exploration, mining and processing technologies and solutions. As identified via our analyses, the projects funded under both clusters have been driven by real industry needs, and clearly focused on the innovation arena. This portfolio has addressed both the sustainable production and substitution of raw materials, especially critical raw materials which are economically and strategically important for the European economy but have a high-risk associated with their supply. International collaboration was low; however, it was not anticipated to be high at least on work-programme level.

Portfolio 4: WASTE

The medium- to long-term scientific impacts of the WASTE portfolio concerned mainly the enhancement of the innovation capacity and the integration of new knowledge in relation to industrial waste, and the establishment of European research and innovation leadership in urban waste management and prevention on global level as well as the promotion of co-created, gender sensitive solutions in the area of urban waste management.

As observed from the analyses conducted and the short term impacts abovementioned, the projects did moderately pave the way towards the accomplishment of these objectives through the production of a rather small number of peer-reviewed publications – and even smaller open access ones – complemented by around 26 open access datasets, software, etc.

Regarding leadership in urban waste management, it is hard to be estimated based on the information collected or made available to our team.

Portfolio 5: WATER

The medium- to long-term scientific impacts of this portfolio stem from both improved knowledge in the area as well as partnerships and international openness. In further detail, in relation to knowledge the aims concern the improvement of understanding the water cycle in relation to climate, the nexus between water management, food and biodiversity, and the contribution towards the Intergovernmental Panel on Climate Change (IPCC).

According to the information made available about the projects and the analyses conducted, it was identified that indeed the projects did elaborate activities related to these objectives through the relatively high production of peer-reviewed publications, which around a third of them are available as open access, and open access datasets, etc.

Comparison of portfolios

The achievement of the medium-and long-term scientific impacts are related to the capacity of the project portfolios to achieve their foreseen short-term scientific results. As observed from the analyses above, the project portfolios and their clusters have succeeded – others more and others to a lesser extent – to deliver scientific results signalling their potential and capacity to produce scientific excellence, improve the knowledge base, engage stakeholders and citizens in the uptake of the knowledge produced and overall contribute to the excellence of science in all fields addressed by the clusters and the portfolios.

The high number of publications produced, with a good percentage of them being open access, their relevant uptake by local/regional, national and international authorities and their inclusion in next work programmes and projects, do provide suggestions that the outcomes produced have been relevant to the research community as well as the end users – industrial, policymaking – foreseen.

Also, the advancement of the research community across Europe, in terms of improvement of skills and experiences through participation in the projects as well as from collaboration with other researchers across Europe and beyond, is anticipated to have multiplying effects in the coming years. The need for synergies and advancement of collaboration among researchers has become even more evident in the current COVID pandemic, which highlighted the need for open-access, across boundaries – whether geographic, thematic or sectoral – across researchers around the globe.

Data issues

Regarding data issues, a primary issue has been the short time between the projects' completion and the performance of the current impact assessment exercise. As identified in our analysis, the first projects started in December of 2014 (CloseWEEE, INFINITY and OptimOre) and the average implementation

period for all the 87 projects is calculated at around 3 years and 7 months. Hence, it has been difficult to measure even medium-term impacts that require at least 3 years to have passed since the conclusion of the projects.

Additionally, as identified through the interviews and the analysis of the database obtained from the EC, it is not evident that the project coordination teams are always capable of monitoring the progress of the scientific indicators that relate to publications, including joint ones between public and private actors, after the completion of their projects. Even more difficult is to monitor the progress made in relation to the people engaged in the projects (researchers and non-researchers), and their scientific and professional progress after their participation in the projects.

The same situation has been faced with the exploration concerning the adoption of innovative solutions elaborated during the projects. The mechanisms that can monitor how and the extent to which SC5 participants have benefitted from innovations deployed in the course of their projects or have achieved to become more resource efficient are not yet in place. This limits the data collection and monitoring of relevant indicators. Additionally, the diffusion of knowledge and open data elaborated during the projects by local, national, European or international stakeholders is not always adequately monitored, and in the cases that it is, it is not collectively or systematically stored and archived within some Commission database. This is an important point, for which relevant mechanisms and processes could be designed and deployed.

Finally, with respect to international partnerships and openness of information collected during the projects, we observed that such kinds of collaborations have been set up and contributed towards the improvement of the scientific base of Europe or the transfer of knowledge from Europe to other parts of the world and the cross-fertilisation of scientific fields. Such collaborations would be interesting to monitor and explore their sustainability, their evolution towards partnerships and their further cultivation into new research projects or scientific areas of collaboration.

3.2 Societal and environmental impact pathway

3.2.1 Short-term impacts

In this section, the five project portfolios are reviewed and compared with each other in terms of short-term environmental and societal impact pathway indicators.

Portfolio 1: CLIMATE CHANGE

The CLIMATE CHANGE portfolio is divided into two project clusters:

- Project cluster 1.1 Fighting, adapting and mitigating climate change (10 projects)
- Project cluster 1.2 Advanced Earth System Models (2 projects)

Considering the short-term environmental and societal impact pathway indicators, the two project clusters of this portfolio are similar. Almost all the projects supported the EU policy priorities on climate change mitigation and adaptation by producing policy outputs, such as policy briefs, promoting policy interactions, such as policy workshops, as well as strengthening the uptake of innovation in society

through engagement of EU citizens and end-users in co-creation of R&I content (note: no data available for 2 projects = c. 17%).

The most widespread means to generate policy outputs were direct dissemination of project results to policy makers and issuing policy recommendations. In terms of policy interaction, most projects participated in conferences, discussion forums or focus groups at regional, national, European or international level. Some projects (4 out of 12) strengthened the uptake of innovation in society by running workshops with citizens and end-users, utilizing online platforms, face-to-face interactions or the voluntary collection of monitoring data. The most common Sustainable Development Goal (SDG) addressed by the projects of this portfolio was Climate action.

In comparison to other portfolios, the CLIMATE CHANGE portfolio is one of the top performers with respect to the generation of policy outputs, while being a medium performer in terms of policy interactions and citizen and end-user contribution.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY

The ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio is divided into two projects clusters:

- Project cluster 2.1 Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems (7 projects)
- Project cluster 2.2 Environment, Ecosystems and Biodiversity: observation and monitoring data (9 projects)

In terms of the short-term environmental and societal impact pathway indicators, the two project clusters of this portfolio are much alike. All but one project supported the EU policy priorities on ecosystem-based management approaches and transfer of environmental knowledge for wider societal use, among others, by generating policy outputs, organising policy interactions and strengthening the uptake of innovation in society (note: no data available for 4 projects = 25%).

Concerning policy outputs, strategy papers were mentioned as one means of impact. Policy interaction took place in the form of expert groups and discussion forums, among others. A considerable number of projects (12 out of 16) supported the uptake of innovation in society via the means of citizen engagement and co-participatory approaches, including co-creation workshops, open consultation and surveys. The most common Sustainable Development Goals (SDGs) addressed by this portfolio were Climate action and Good health and well-being.

When compared to other portfolios, the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio is one of the top performers with respect to all the short-term environmental and societal indicators: policy outputs, policy interactions and citizen and end-user contribution.

Portfolio 3: RAW MATERIALS

The RAW MATERIALS portfolio is divided into two projects clusters:

- Project cluster 3.1 Sustainable production of raw materials (12 projects)
- Project cluster 3.2 Sustainable substitution of raw materials (4 projects)

Regarding the short-term environmental and societal impact pathway indicators, the two project clusters of this portfolio are somewhat different. Project cluster 3.1 addressed the EU policy priorities on reducing import dependency and environmental footprint of raw materials, among others, by taking active measures on producing policy outputs and organising policy interactions (6 out of 8 projects). Project cluster 3.2, on the contrary, did not produce policy outputs according to our results, and only one project reported on organising policy interactions while addressing the same EU policy priorities as the project cluster 3.1. Neither of the project clusters of this portfolio were active in strengthening the uptake of innovation in society through engagement of EU citizens and end-users in co-creation of R&I content. Only one project reported on measures taken with this respect (note: no data available for 6 projects = c. 38%).

Concerning the policy outputs of project cluster 3.1 of this portfolio, policy recommendations and briefs, as well as public consultations, were mentioned as the main means of impact. The policy interactions were organised in the form of conferences, expert focus groups, public consultations and trainings. The most common Sustainable Development Goals (SDGs) addressed by this portfolio were Industry, innovation and infrastructure, Responsible consumption and production, Partnerships for the goals and Climate action.

When compared to other portfolios, the RAW MATERIALS portfolio is one of the low performers with respect to all the short-term environmental and societal indicators: policy outputs, policy interactions and citizen and end-user contribution.

Portfolio 4: WASTE

The WASTE portfolio is divided into two project clusters:

- Project cluster 4.1 Industrial waste (7 projects)
- Project cluster 4.2 Urban waste (7 projects)

In terms of the short-term environmental and societal impact pathway indicators, the two project clusters of this portfolio are quite similar. The majority of the projects addressed the EU policy priorities on reducing the generation of waste and environmental depletion, among others, by producing policy outputs, promoting policy interactions, and strengthening the uptake of innovation in society through engagement of EU citizens and end-users in co-creation of R&I content (note: no data available for 2 projects = c. 14%).

The most common means to generate policy outputs was issuing policy recommendations and briefs, as well as organising public consultations and direct dissemination of project results to policy makers. Policy interactions were promoted by participating in conferences, discussion forums or experts or focus groups. Half of the projects (7) reported on strengthening the uptake of innovation in society by surveys, workshops, online platforms and face-to-face interactions with citizens. The most common Sustainable Development Goals (SDGs) addressed by this portfolio were Responsible production and consumption, Industry, Innovation and infrastructures and Partnerships for the goals and Sustainable cities and communities.

In comparison to other portfolios, the WASTE portfolio is one of the top performers with respect to policy interactions promoted and citizen and end-user contribution, while being a medium performer in terms of policy outputs.

Portfolio 5: WATER

The WATER portfolio is divided into two project clusters:

- Project cluster 5.1 Water resources and resilience (16 projects)
- Project cluster 5.2 Water treatment (13 projects)

With regard to the short-term environmental and societal impact pathway indicators, the two project clusters of this portfolio are much alike. The majority of the projects addressed the EU policy priorities on reducing water use, achieving more efficient water management and minimising the impacts of droughts and floods, among others, by producing policy outputs, promoting policy interactions, and strengthening the uptake of innovation in society through engagement of EU citizens and end-users in co-creation of R&I content (note: no data available for 4 projects = c. 14%).

The most common means to generate policy outputs were direct dissemination of project results to policy makers and issuing policy recommendations and briefs. Policy interactions were advanced by participating in conferences, discussion forums, expert consultations and training sessions. Almost half of the projects (13) reported on strengthening the uptake of innovation in society by citizens' participation in workshops and training sessions via online platforms or face-to-face interactions. The most common Sustainable Development Goals (SDGs) addressed by this portfolio were Clean water and sanitation, Climate action, Responsible production and consumption, Industry, Innovation and infrastructure, Partnerships to the goals and Sustainable cities and communities.

In comparison to other portfolios, the WATER portfolio is one of the low performers with respect to policy outputs generated, policy interactions promoted and citizen and end-user contribution.

Comparison of portfolios

Overall, three portfolios stand out as high or medium performers in terms of short-term environmental and societal impact pathway indicators:

- The ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio
- The CLIMATE CHANGE portfolio
- The WASTE portfolio

All three portfolios listed above are coherent in a sense that their project clusters do not differ from each other in any significant way. Especially, the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio excels with respect to all the short-term environmental and societal indicators examined: policy outputs, policy interactions and citizen and end-user contribution. Moreover, it is the only project portfolio where the majority of the projects reported on supporting the uptake of innovation in society via the means of citizen engagement and co-participatory approaches.

The RAW MATERIALS and WATER portfolios are low performers in terms of all the short-term environmental and societal impact pathway indicators addressed. The RAW MATERIALS portfolio is not

coherent in this respect, however, as the two project clusters of this cluster diverge considerably: project cluster 3.1 Sustainable production of raw materials was more active in policy-related activities and outputs than project cluster 3.2 Sustainable substitution of raw materials. The WATER portfolio, in turn, was coherent in a sense that its two project clusters were much alike while low performing.

Data issues

In general, lack of data was not an issue when short-term environmental and societal impact pathway indicators were addressed in this study, except for the RAW MATERIAL portfolio, where almost half of the data was missing. The projects of this portfolio did not take actively part in the survey and interviews organised by this study. The data in general is limited in a sense that exact numbers of policy outputs and interactions are missing, thus preventing a more detailed comparison of the portfolios with respect to the volume of policy activities and outputs.

3.2.2 Medium- and long-term impacts

In this section, the five project portfolios are reviewed and compared with each other in terms of medium- and long-term environmental and societal impact pathways.

Portfolio 1: CLIMATE CHANGE

The high level of activities in terms of producing policy outputs, running policy interactions and involving citizens and end-users in co-creation of R&I content supports the achievement of medium- and long-term environmental and societal impacts in case of the CLIMATE CHANGE portfolio. In this respect, the two project clusters of this portfolio do not differ significantly.

This portfolio contributed to raising awareness of the need to act to fight climate change through mitigation or adaptation measures. Practical tools, methods and techniques developed for monitoring, planning and decision-support were an important part of these awareness-raising efforts. The projects responding to the Disaster Resilience and Climate Change topics showed a high level of end-user and citizen engagement. Overall, the projects in this portfolio were active and devoted to carrying out policy activities at multiple levels.

The projects' long-term environmental and societal impacts are expected in the following areas:

a) assuring environmental integrity, resilience, and sustainability
b) enabling ecosystems and society to adapt to climate change and other environmental changes
c) protecting and sustainably managing the natural resources and ecosystems
d) improving the understanding of climate processes and on that basis provide the science base for political and business decision-making

In terms of geographical scope, the projects of this portfolio can be divided into internationally oriented projects (e.g. research on carbon transition pathways, coastal flood risk management and climate modelling), on the one hand, and local projects (e.g. conservation of historic buildings and cultural heritage sites), on the other hand. The projects on Advanced Earth System Models were essentially global in their scope.

Many projects of this portfolio reported that their outputs have directly influenced policy, such as development of a new mission on climate. They also reported that the soft policy tools developed by the projects, such as planning tools and assessment frameworks, are already in use. The projects on Advanced Earth System Models reported on close and continuous interaction with the global initiatives, such as the Intergovernmental Panel on Climate Change (IPCC).

Considering this portfolio as a whole, the expected policy-driven impacts stated in the SC5 Working Programme 2014-15 were mainly related to the advancement of the EU policy priorities in the field of climate change mitigation and adaptation measures at various levels. Global scope and cooperation were expected from the Advanced Earth System Models projects in particular. The environmental and societal impact pathway of this portfolio is well on its way towards these medium- and long-term impacts considering the quality and scope of policy efforts carried out by these projects and expectations they have set so far for the policy development in the near future.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY

The ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio is a high performer with respect to all the short-term environmental and societal indicators examined: policy outputs, policy interactions and, especially, citizen and end-user contribution. The two project clusters of this portfolio are not significantly different in this respect.

The projects of this portfolio contributed to the objectives of developing ecosystem-based management approaches, improving evidence-based environmental policy making, and engaging extensively stakeholder groups in transfer and exchange of environmental knowledge, among others. Based on the information gathered in the survey and interviews of this study, the projects were active in their efforts in the policy domain, including development of new databases for guiding the decision process of policymakers and promotion of policy interactions.

Especially, participatory and citizen science approaches were employed to a large extent. For instance, tailored mobile apps were designed for citizens to ease the data collection processes, in addition to employment of more traditional data collection techniques, such as surveys. Besides citizens, the projects engaged with a wide range of stakeholder groups, including business, academia and public administration.

The projects of this portfolio associated long-term expectations for environmental and societal impacts in the following areas, among others:

a) assuring environmental integrity, resilience and sustainability
b) enabling ecosystems and society to adapt to climate change and other environmental changes
c) protecting and sustainably managing the natural resources and ecosystems

Considering the geographical scope, the policy interactions of this portfolio took place at multiple levels, including local, national, European and international collaboration via forums, conferences, trainings and public consultations.

Over half of the survey respondents of this portfolio reported that their project has contributed to a considerable or great extent to policy development. In some cases, the projects report that their recommendations have been adopted by local policymakers into real-life interventions.

Regarding this portfolio as a whole, the expected policy-driven impacts stated in the SC5 Working Programme 2014-15 mainly addressed the development of ecosystem-based management approaches, improvement of evidence-based environmental policy making, and engagement of various stakeholder groups in the transfer and exchange of environmental knowledge. Given the considerable amount of policy outputs produced and wide participation in the projects' stakeholder events as reported by the projects, the environmental and societal impact pathway of this portfolio is well on its way towards these medium- and long-term impacts in the policy domain.

Portfolio 3: RAW MATERIALS

The RAW MATERIALS portfolio is a low performer with respect to all the short-term environmental and societal indicators addressed: policy outputs, policy interactions and citizen and end-user contribution. The two project clusters of this portfolio are somewhat different in this respect. However, lack of data (no data available for 6 projects = c. 38%) makes a closer analysis of the differences difficult.

The projects of this portfolio contributed to the objectives of reducing import dependency and environmental footprint of (critical) raw materials, among others. Based on the information gathered in the survey and interviews of this study, the projects were not active in their policy activities, except for few exceptions. The reported policy interactions took place mainly in the form of dissemination activities, in which policy makers have participated. Employment of participatory or collaborative approaches with citizens or civil society organisations were not reported in case of this portfolio.

The projects of this portfolio associated long-term expectations for environmental and societal impacts in the following areas, among others:

a) recovering of materials previously considered as waste
b) using less material in the processing phase as an input resulting in less environmental impact
c) strengthening the EU in the area of sustainable raw materials substitution

In terms of geographical scope, the policy interactions occurred mainly at European and national levels. One project reported on significant international policy collaboration with the International Seabed Authority (ISA), a United Nations based organisation.

Regarding the policy interactions promoted, less than half of the projects of this portfolio considered that policy interactions were considerably or moderately important to achieve the impacts of the projects. The main policy interactions employed were conferences, expert groups, public consultations and trainings.

Considering this portfolio as a whole, the expected policy-driven impacts stated in the SC5 Working Programme 2014-15 mainly addressed reducing import dependency and environmental footprint of (critical) raw materials. Given the small amount of policy outputs produced and modest scope of policy interactions exercised, it is difficult to assess if the environmental and societal impact pathway of this portfolio is on its way towards these medium- and long-term impacts in the policy domain.

Portfolio 4: WASTE

The WASTE portfolio is a high performer with respect to policy interactions promoted and citizen and end-user contribution, while being a medium performer in terms of policy outputs. The two project clusters of this portfolio are not significantly different in this regard.

The projects of this portfolio contributed to the objectives of reducing the generation of waste and environmental depletion, among others. Based on the information gathered in the survey and interviews of this study, the projects of this portfolio were active in their policy activities, including direct dissemination of project results to policymakers and issuing policy recommendations and briefs on a regular basis.

Especially, citizen engagement and co-participatory approaches with civil society organisations were actively exercised by the projects of this portfolio. Citizens took part in the projects as pilot users and participants in crowdsourcing activities, for instance.

The projects of this portfolio associated long-term expectations for environmental and societal impacts in the following areas, among others:

a) minimising CO2 emissions, energy use, use of fossil fuels and the need for virgin raw materials
b) minimising waste disposal and managing waste as a resource
c) counselling European waste-related legislation
d) promoting circular economy and urban waste management on the political agenda

In terms of the geographical scope, the policy interactions of this portfolio took place at multiple levels, including local, national, European and international collaboration. Especially, the engagement of policymakers at local and regional levels (cities) was a highly relevant activity for the projects of this portfolio.

Most of the projects of this portfolio reported that their project had contributed to a moderate or considerable extent to policy development. For instance, recommendations for future policies were presented to and discussed with regional policy makers, as well as with the EC.

Considering this portfolio as a whole, the expected policy-driven impacts stated in the SC5 Working Programme 2014-15 mainly addressed reducing the generation of waste and environmental depletion. Given the considerable amount of policy and stakeholders events organised at multiple levels as reported by the projects, the environmental and societal impact pathway of this portfolio is well on its way towards these medium- and long-term impacts in the policy domain.

Portfolio 5: WATER

The WATER portfolio is a low performer with respect to policy outputs, policy interactions promoted and citizen and end-user contribution. The two project clusters of this portfolio are not significantly different in this regard.

The projects of this portfolio contributed to the objectives of reducing water and energy use, and achieving more efficient water management, among others. Based on the information gathered in the survey and interviews of this study, the majority of the projects of this portfolio were active in their policy

activities, including expert consultations related to the relevant EU Directives and strategies and organising policy workshops, public debates and focus group meetings on several policy-relevant topics. Less than half of the projects reported about the use of participatory approaches with citizens during the project. The participatory approaches with citizens were exercised in the form of workshops, surveys, online platforms and face-to-face interactions. The projects reported that collaboration with water utilities was frequent and strategically important as they represent the end users of the most technologies developed in this portfolio.

The projects of this portfolio associated long-term expectations for environmental and societal impacts in the following areas, among others:

a) supporting resource-efficient use of the water
b) introducing sustainable water technologies
c) protecting water resources

In terms of the geographical scope, the policy interactions of this portfolio took place at multiple levels, including local, national, European and international collaboration. Because water systems operate regionally, close collaboration with national and local authorities played a major role in most projects.

The majority of the projects of this portfolio reported that their project had contributed to policy development at least to a small extent. However, there is as yet no evidence on direct effects on policies or regulation since it takes quite a long time to translate the scientific and technological discoveries into new strategies, priorities, objectives or directives.

Considering this portfolio as a whole, the expected policy-driven impacts stated in the SC5 Working Programme 2014-2015 mainly addressed reducing water and energy use and achieving more efficient water management. Given the relatively low amount of policy outputs and policy and stakeholders events reported by the projects, it is difficult to assess if the environmental and societal impact pathway of this portfolio is on its way towards these medium- and long-term impacts in the policy domain. However, the quality and scope of the policy activities employed by the projects can be considered appropriate for creating impact.

Comparison of portfolios

Based on our analysis, the environmental and societal impact pathway towards medium and long-term impacts is well on its way in case of the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY, CLIMATE CHANGE and WASTE portfolios. The quality of policy interactions, such as the wide participation by different stakeholder groups, the positive expectations associated with the policy contributions of the projects, as well as the advanced employment of participatory approaches with citizens, provide a good basis for expecting policy development to take place in case of these project portfolios.

The environmental and societal impact pathways of the RAW MATERIALS portfolio is difficult to assess because of the relatively low amount of policy contributions reported and lack of knowledge on the quality of these contributions. Moreover, lack of data (survey responses) entails additional difficulties for the assessment of this portfolio.

While the WATER portfolio is a low performer in terms of policy outputs, policy interactions and citizen and end-user contributions, the quality and scope of the policy activities employed within this portfolio can be considered appropriate for creating impact.

Overall assessment of societal and environmental impacts

As a whole, the majority of the projects and portfolios of the SC5 Work Programme 2014-2015 addressed the EU policy priorities actively and noticeably in the policy domain. Not only were the SC5 projects active in producing high-profile policy outputs and organising versatile policy interactions, but also the involvement of citizens by employing participatory approaches was on a high level. In particular, the EU policy priorities listed below were addressed extensively by the policy contributions of the projects funded under the SC5 Work Programme 2014-2015:

- climate change mitigation and adaptation;
- development of ecosystem-based management approaches and evidence-based environmental policy making;
- reducing the generation of waste and environmental depletion;
- reducing water and energy use and achieving more efficient water management.

3.3 Economic impact pathway

3.3.1 Short-term impacts

In this section, the five project portfolios are reviewed and compared with each other in terms of short-term economic impact pathway indicators.

Portfolio 1: CLIMATE CHANGE

The CLIMATE CHANGE portfolio is divided into two project clusters:

- Project cluster 1.1 Fighting, adapting and mitigating climate change (10 projects, 8 RIA, 2 IA)
- Project cluster 1.2 Advanced Earth System Models (2 projects, 2 RIA)

By means of the short-term economic impact pathway indicators, related to generating innovation-based growth, the two clusters show different results in that cluster 1.1 did and cluster 1.2 did not have an economic impact. The main short-term economic impact of cluster 1.1 Fighting, adapting and mitigating climate change has been on generating innovative products (reported by 6 out of 8 projects) and processes or methods (7 out of 8 projects). Limited (1 project) to modest (4 out of 6 projects reporting on this) impact has been made on respectively i) claiming and protecting intellectual property and ii) contributing to regulation/standard harmonisation. It would be interesting to (find a reliable method to) monitor if the effort leads to changes in regulation or standardisation in the longer term as respondents indicate that this is by its nature not a short-term effort.

In terms of the key economic indicators analysed, cluster 1.1 has produced some of the most prototypes, ranking it in the top percentile compared to the other portfolios. When it comes to innovation entering the market and innovations leading to new products, this cluster ranks below average in the bottom 40%.

Data on the creation of more and better jobs is limited, making an analysis of short-term, let alone mid- to long-term, assessment difficult. Only two projects reported on scientific jobs (23), technical jobs (5) and administrative jobs (5) – all short-term. Interview reports mention that PhDs and postdocs have been involved, but it is uncertain what happened once the project funding ran out.

An indicator of economic impact is the ability to attract additional or further funding (as both Research and Innovation and Innovation Actions fund precommercial / premarket activities), whether it be public or private. In this case, the Climate Change portfolio has had limited economic impact, as no investment was leveraged (with two projects stating outright that they had not received any additional funding and the others simply not reporting on this question). On a positive note, one project reported that of the innovative ideas they supported some have gone on to establish successful small companies, with one receiving a grant to further develop their concept and subsequently getting an order from the national government.

On the development and adoption of innovative technological solutions again limited data is available, with two out of the ten projects (considering cluster 1.1 only, as cluster 1.2 did not have any short-term economic impacts) stating they have achieved a change in technology readiness level (TRL) over the course of the project. Neither specify the change in TRL. Joint public-private publications, indicating that the private sector absorbs knowledge from the public sector, were reported by three out of ten projects (all cluster 1.1), with two projects generating four-five joint publications and one project more than five joint publications.

Overall, all projects – including the Innovation Actions – seemed more focused on advancing the understanding of what is needed to mitigate and adapt to climate change and interacting with policy than on bringing products and services to the market.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY

The ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY portfolio is divided into two project clusters:

- Project cluster 2.1 Protecting the environment, sustainably managing natural resources, water, biodiversity and ecosystems (7 projects, all RIA)
- Project cluster 2.2 Environment, ecosystems and biodiversity: observation and monitoring data (9 projects, 5 RIA, 4 IA)

When it comes to generating innovation-based growth from the projects in this portfolio, the most impact has been achieved in contributing to regulation and standard harmonisation (which could be explained by the high level of policy interactions and outputs that characterises this portfolio). A more modest contribution is made to the creation of innovative products, processes or methods (although it should be noted that no data is available for half the number of projects in this portfolio).

In terms of Intellectual Property Rights, in cluster 2.1 no activity has been reported. In cluster 2.2 data is not available for six out of nine projects, reporting two of them not having produced any IPR. However, the remaining project claims to have generated six copyrights.

In the survey responses, six out of seventeen projects report to have produced innovative products, processes, or methods in the form of 48 prototypes and 123 testing activities. Overall, 31 innovations will enter the market.

However, when looking at the key economic indicators this study used in the radar charts, using EC data, cluster 2.1 shows very few innovations (two prototypes and six testing activities) whereas cluster 2.2 accounts for 46 prototypes, 117 testing activities, 27 innovations that will enter the market among others. These figures could show the impact of the IAs in the second cluster of this portfolio.

The creation of more and better jobs cannot be analysed in the context of this portfolio since the information is available from a small share of projects. Thus, no substantive conclusions can be drawn as it is unknown if the absence of reporting means that no jobs were created (whether short- or long-term) or simply no records were kept and collected from partners.

From a portfolio of seventeen projects, five report that they have been able to leverage additional or further investment in R&I; three mobilised a further private (national or transnational) investment, one received national public funding and one other mobilised public-private national investment.

Advancing technology from science (basic principles) to research and development (validation, prototyping and demonstrating in operational environment) to innovation (entering the market) is a method to measure the development and adoption of innovative technological solutions. To assess the short-term economic impact from projects, IMPACT-SC5 asked projects to report on progress in technology readiness level (TRL). In this portfolio, four out of seventeen projects (two in each cluster) report that indeed their project resulted in a change, although they did not specify the level at the start and end of the project.

Joint public-private publications, used as proxy for the private sector absorbing knowledge from the public sector, were reported by four out of seventeen projects.

Portfolio 3: RAW MATERIALS

The RAW MATERIALS portfolio is divided into two project clusters:

- Project cluster 3.1 Sustainable production of Raw Materials (12 projects, all RIA)
- Project cluster 3.2 Sustainable substitution of Raw Materials (4 projects, all RIA)

In this portfolio of sixteen projects, eleven reported to have generated innovation-based growth, most notably leading to innovative products, processes, or methods. They have contributed to technological progress, to deliver technological innovations and to generate partnerships, as well as to the publication of outputs and to address gaps in the knowledge base. The projects have resulted in new or modified testing methods, new or modified products and prototypes or demonstrators, through 190 testing activities and 30 prototypes. In total, 37 companies (of which 16 SMEs) have introduced innovations to the market and 36 companies (of which 18 SMEs) introduced innovation that was new to the company.

In the area of intellectual property, 10 patent applications have been filed (with 1 more in preparation), and 2 patents granted. In addition, 1 copyright and 1 trademark have been registered. Perhaps reflecting the more practical and applied nature of this portfolio (despite the high number of RIAs) 2 projects

contributed to regulation and standard harmonisation. Where they did contribute, this was reported as being considerable such as helping to set up a standard committee.

Portfolio 3 had a modest contribution when measured on the key economic indicators, although it should be noted that out of the three pathways under review, the economic impacts are at least equal to or better than the scientific or societal impacts. It had a slightly higher contribution to the number of innovations entering the market and the innovations leading to new products, demonstrating to some extent the innovative scope of the projects. In economic impact, the portfolio ranks midway in comparison to the other portfolios. Cluster 3.2 was made up of 4 of the smallest projects evaluated (in terms of budget) affecting the relative weight.

Regarding the contribution of the portfolio to the creation of more and better technical and scientific jobs, no data for twelve of the sixteen projects in this cluster were collected. Thus, no relevant conclusions on the results achieved by the projects under this portfolio can be drawn.

Some of the projects in this portfolio have reported leveraging investments from public and/or private national and European agents but amounts or source of funding is not specified.

To assess the extent to which portfolios contributed to the development and adoption of innovative technological solutions IMPACT-SC5 investigated two indicators: change in Technology Readiness Level (TRL) from start to end of project and the number of joint public-private publications. In terms of the first indicator, TRL, this portfolio has five projects reporting a change, with levels achieved ranging from TRL 4-5 (1 project), TRL 5-6 (2 projects) and TRL 7-8 (2 projects). Although this portfolio has a relatively high number of private companies (48% in cluster 3.1 and 39% in cluster 3.2) the number of joint public-private publications is modest with only three projects reporting such publications (number and type of publications not specified).

Portfolio 4: WASTE

The WASTE portfolio is divided into two project clusters:

- Project cluster 4.1 Industrial Waste (seven projects, two RIA, five IA)
- Project cluster 4.2 Urban Waste (seven projects, three RIA, four IA)

In terms of the short-term economic impact pathway indicators, related to generating innovation-based growth, both clusters have performed very similarly. The main economic contributions of both project clusters are linked to the generation of technological progress and innovations. Indeed, at least 12 of the 14 projects under scrutiny in this portfolio have succeeded in delivering innovative products, processes and / or methods.

In the case of Intellectual Property Rights (IPR), the industrial waste portfolio has been more prolific in terms of patents, having generated 6 patent applications and having achieved 3 patents granted. Within the urban waste portfolio only 1 patent application has been issued but other types of IPRs have also been gained (i.e. copyrights, trademarks, intellectual properties in the form of know how).

By means of the type of innovative results delivered in this portfolio, prototypes (55 in the portfolio), testing activities (159 in the portfolio) and innovations to the market (44 in the industrial waste cluster)

or the company (22 in the urban waste cluster) are the most common ones in both project clusters. However, the industrial waste projects seem to have been more focused on the development of new or modified products and processes that represent an innovation to the market and the urban waste related projects on delivering new or modified services and new decision-support tools that represent an innovation for the company.

When it comes to the contribution of projects to regulation and/or standard harmonisation, the industrial waste cluster has contributed most to this objective, having 2of the projects involved to some extent in 2 existing standardisation committees. In the case of the urban waste portfolio, the projects have contributed by developing strategy papers to inform expert groups oriented to the creation of standards and the development of regulations.

As to the capacity of projects to create more and better jobs, it has to be noted that the data available regarding job creation cannot be considered as statistically significant enough to draw to relevant conclusions, neither in the short time nor in the medium-long term, since information is available only for four out of the fourteen projects.

By means of leveraging Research and Innovation investment, information collected under the framework of the IMPACT-SC5 represents half of the projects in this portfolio. In addition, information collected in the survey and in the interviews is not consistent. Thus, it can be said that definite conclusions cannot be drawn in this regard.

Last but not least, the indicators related to the development and adoption of innovative technological solutions show that the industrial waste cluster has achieved more TRL progress, which could be linked to the focus of these projects on the development of new or modified products or processes. The work programme stipulated to achieve 5-6 TRL for the industrial waste related projects. At least four of the seven projects have progressed up to TRL 6, 7, 8 or even 9. In the case of the urban waste cluster, no target TRL was defined in the work programme. However, at least 2 projects out of seven succeeded in achieving TRL increases (for three projects, the information was not available).

Following a similar pattern, more projects in the industrial waste cluster seem to have produced joint public publications (four projects in the industrial waste cluster against two in the urban waste cluster). However, no information on the exact number of publications is available.

Portfolio 5: WATER

The WATER Project portfolio comprises two project clusters:

- Project cluster 5.1 Water resources / resilience (16 projects, 5 RIAs, 11 IAs)
- Project cluster 5.2 Water treatment [technologies] (13 projects, 5 RIAs, 8 IAs)

Related to the economic impact pathway, within the water portfolio, both project clusters have performed very similarly when it comes to innovation-based growth. Both of them have contributed greatly to generating innovative products, processes or methods. In the case of the water resources cluster, the project partners reported to have produced mostly technological progress and technological innovations whereas the water treatment related project partners reported that apart from generating

technological innovations, projects have also strongly contributed to supporting i) innovators and businesses to bring green solutions to the market and ii) the career development of researchers.

Both project clusters have filed patents applications and trademarks, (14 in the case of project cluster 5.1 and 5 in project cluster 5.2), as well as generated prototypes and demonstrators (59 in project cluster 5.2), testing activities (112 in the portfolio) and innovations new to the market (82 in cluster 5.1 and 44 in cluster 5.2) and new to the company (71 in cluster 5.1 and 24 in cluster 5.2) as main innovative outputs.

Regarding the contribution of the clusters to the development of regulations and standards, again, both have contributed to it to some extent through policy development or harmonisation of standards. Four projects in cluster 5.1 and three in cluster 5.2 have reported in the interviews on taking an active role in standard setting process. Contributions to existing standard committees have also been reported in one case in the water resource related cluster of projects.

In terms of creating more and better jobs, as in the rest of the portfolios, the available data represents only half or less of the projects under each project cluster. With this in mind, no relevant conclusions can be drawn regarding the extent to what WATER related projects have contributed to generate jobs.

A very similar situation has been faced when measuring the indicators in the field of leverage of investment in Research and Innovation. From the available data it seems that at least four projects in the cluster 5.1 and two in the cluster 5.2 have achieved to leverage complementary or follow up funding, However, the information gathered in the interviews and the survey are not consistent and represent half or less of the projects in the clusters. This fact makes difficult to draw any definite conclusion on this issue.

Finally, when it comes to the development and adoption of innovative technological solutions, 9 out of the 16 projects included in the water resources and resilience cluster and 7 out of the 13 projects comprised in the water treatment cluster have reported to have achieved TRL increases from 4, 5 or 6 to 7, 8 or 9 depending on the project or on the technology. Additionally, both project clusters have succeeded in delivering joint public-private publications, even if the exact number is not available.

Comparison of portfolios

Regarding the short-term economic impacts of the projects funded by the SC5 under the work programme 2014-2015, quite different approaches have been applied and different results have been achieved by the five portfolios under analysis.

Overall, there are project portfolios in which the economic pathway has been predominant (i.e. the WASTE and WATER portfolios) and others in which the scientific or the societal and environmental impact pathways have been more relevant (i.e. CLIMATE CHANGE and ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY). In the case of the RAW MATERIALS portfolio, it can be said that it has shown a more balanced position contributing to a similar extent to the three impact pathways under consideration.

Focusing on the portfolios with the strongest economic focus, the main short-term impacts mainly fall on the provision of innovative solutions (models, methodologies, processes, technologies, software platforms, tools, products, etc.) and the contribution to the generation of technological progress and innovations. These portfolios have generally achieved higher records in terms of IPR applications and

filings and have reported on higher increases on TRL advancements and higher TRL achieved as well as on more public private publications as a proof of the private sector absorbing knowledge from the public sector.

When it comes to the sort of innovative results delivered in this type of portfolios, demonstrations, testing activities, prototypes and the introduction of innovations new to the company or new to the market are the most common ones.

The commercially driven portfolios also tend to contribute to the regulation / standard harmonisation development by interacting with already existing committees or by informing expert groups with strategy papers.

Some common characteristics of the commercially driven portfolios are as follows:

- Higher share of IA over RIA.
- Share of private for-profit entities (excluding Higher or Secondary Education Establishments) (PRC) higher than 40% of total participants.
- Economic specific objectives and expected impacts defined at work programme level.
- Specific request to involve SMEs in the work programme.
- Higher TRL is an objective in the work programme.

Within the portfolios that are not showing a commercial focus, the most common economic results have materialised in terms of:

- Generating innovative products and processes or methods. Even if this type of projects shows more modest figures in the economic impact pathway indicators, the innovative nature of projects under the SC5 seems to remain relevant for all the portfolios.
- Claiming and protecting intellectual property.
- Contributing to regulation/standard harmonisation, sometimes due to the high level of policy interactions and outputs undertaken by the projects under scrutiny.

Common features of this type of non-economic driven portfolios are as follows:

- RIA predominant over IA
- The highest share of participating organisations lies on Higher or Secondary Education Establishments (HES) or Research Organisations (REC) (over 30% of participants each).
- Share of private for-profit entities (excluding Higher or Secondary Education Establishments) representing the 20-25% of the total of participants
- Not so clear economic specific objectives and expected impacts outlined at work programme level.
- Lower level of TRL requested in the work-programme or TRL not requested at all.

According to the above, it seems that the way the work programme defines the call has a strong influence on the results and impacts achieved by the projects. In any case it has also been noticed, both in the economic driven and not economic driven portfolios, that many times no discernible differences between RIA/IA can be found since, in many occasions, applied research undertaken in RIA gets to deliver

innovative products or processes in relative high TRL and the way round, sometimes IA do not seem to pursue the commercialisation of the projects results.

Other reasons behind the differences in terms of the economic impacts of the project portfolios could be based on the immaturity of the sector, the insufficient attention to dissemination and exploitation, or other factors that cannot be determined from the data collected within the IMPACT-SC5 and the recent completion of all projects.

3.3.1 Medium- and long-term impacts

In this section, the five project portfolios are reviewed and compared with each other in terms of medium- and long-term economic impact pathways

Portfolio 1: CLIMATE CHANGE

In the medium and long-term, the CLIMATE CHANGE portfolio can be expected to support the generation of innovation-based growth and the development and adoption of innovative technological solutions in the form of new products, processes or methods. While some uptake is expected to take place in the consortium partners, most impact can be expected from the scientific publication, technology development/advancement and processes and methods resulting from the projects having been made available as openly and broadly as possible. Ten out of twelve projects were Research and Innovation Actions and did not have the specific objective of creating new businesses, products or services (in fact the cluster 1.2 was not expected to have a direct contribution to the achievement of economic impacts and no specific objectives were included in the call topic). One way through which partners can strengthen the medium and long-term impact is through consultancy services, helping organisations use and implement the new frameworks, methods and tools.

Moreover, projects have contributed to the uptake and scaling of innovative solutions by engaging in standardisation. The standardisation process takes several years, therefore the work done with (pre-) standardisation bodies for example on adaptation requirements for disaster resilience problems related to climate change and sustainable cities will yield results in later years.

Although for most projects the development and market introduction of innovative products and services was not an objective, one project mentions that their work resulted in a spin-off company to exploit the result. One project provided, through their Test and Implementation Framework (TIF), direct support to twenty-five 25 SMEs, some of which have gone on to become successful. Indirectly, the method supported more than 120 innovators to develop and test their ideas (technical, commercial, and societal). The TIF method could be taken up by some partners as consultancy, to continue working with and supporting SMEs. And even one of the highly scientific projects in cluster 1.2 indicated they engaged with end-user organisations such as reinsurance and energy to get a better understanding of their requirements to produce risk assessment and potential impacts of future climate change fit for purpose by users.

None of the projects has been able to leverage complementary or follow-up funding. In some cases, (part of) the consortium has applied for funding from later Horizon 2020 calls.

The two Innovation Actions had the highest number of private company involvement, with 10 (of which 5 SMEs) and 14 companies (of which 13 SMEs) respectively. Even though the Innovation Action requires investment from private companies (with funding rate 70% of direct eligible cost), the companies apparently did not participate to strengthen their own innovation capacity or growth as neither report direct exploitation of the results.

In terms of creating more and better jobs, the lack of data makes the analysis of short-term, let alone mid- to long-term analysis impossible. No data are available to measure the extent to which the projects have contributed to the professional career of the participants.

Overall, the portfolio has been relatively weak in delivering and translating messages and solutions to the market and the question is if this, now that projects have been completed, will or can improve. The portfolio is placed in the last position in terms of innovation related indicators. These figures are strongly influenced by the non-economic focus of project cluster 1.2, nevertheless is also visible in cluster 1.1. Interestingly, the data do not point to a difference in performance between Research and Innovation Actions and Innovation Actions, begging the question if the latter had the intended result of addressing higher TRL projects aimed at bringing innovation to the market.

Portfolio 2: ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY

The above analysis of the short-term impacts of portfolio 2 already shows that the economic impact is the least strong, in comparison with the scientific and societal impacts as well as in comparison with other clusters. The portfolio, conform the objectives of the work programme and the call topics, mainly focused on reinforcing and extending the existing science base and therefore establishing high quality new knowledge, reducing knowledge gaps and information environmental policy and legislation.

The fact that portfolio 2 is lagging when it comes to economic outputs is likely to have an impact on its mid- and long-term impacts in generating innovation-based growth, job creation, leveraging additional investment and development and adoption of innovative technological solutions.

Nevertheless, although projects did not prioritise commercialization activities, several tools, models, methods and processes developed may have future market potential and with some further development can be rolled-out to the markets or be used for the sustainable production of new products and industrial applications. Moreover, the datasets produced may have market potential, for example in green energy infrastructures or improved energy security. In addition, tools, services and resources to mobilize and engage citizens through citizens observatories and citizens science activities were developed. In this context, different mobile applications, platforms and serious games were developed that are now commercially exploited by some of the beneficiaries.

The policy related tools that were developed can help local governments in better decision-making through the empowerment and active role of citizens by allowing them to make trade-offs between policies. In that sense, portfolio 2 can be considered to have an impact on societal and public sector innovation, by introducing new tools and approaches to provide quality public services and better respond to society's needs. These innovations aim at providing better decisions making tools through the

empowerment and active role of citizens in environmental policy as well as environmental monitoring and assessment tools and methodologies adapted for local, regional and national use.

Another way in which some projects may contribute to the uptake and scaling of innovative solutions is their engagement in standardisation.

Leveraging complementary follow-up funding (national private or public funds) is another way to further develop a concept, products or services. In this portfolio, 2 projects have been able to do so, while other projects have applied for funding under other Horizon 2020 calls.

Finally, 66 SMEs participated in this portfolio (SMEs participation overall is around 18%) indicating the interest of SMEs to the tools and services generated by the projects.

Portfolio 3: RAW MATERIALS

At portfolio level, this group of projects scores highest on economic impact (compared to its scientific and societal impact). It has the highest scores in terms of the number of innovations entering the market and to innovations leading to new products, in which it is in the middle of the portfolios overall.

The reasons for this can be that the portfolio had a high participation of the private sector, half of participating organisations (49.8%) are private sector companies with SMEs accounting for 38% of the participants. This is important, since SMEs are considered the backbone of the EU economy and a driver for jobs and growth. This indicates the high level of industrial interest. It increases the chance of the solutions being commercially exploited by the industrial partners, particularly those companies that own the patents applied for.

This portfolio achieved the development of new solutions and technologies such as for new integrated mining and mineral processing, new sustainable technologies for exploring and mining of mineral deposits that are small, complex or difficult to access, new technologies for deep mining in the seabed, new technologies for more efficient exploration of mineral deposits and new or modified manufacturing processes, modelling, simulation and decision support tools.

Some technologies were already tested in pilot plants achieving TRLs higher than initially expected. In some cases, the new approaches were implemented by the partners of the project to enhance their competitiveness.

The main outputs in this portfolio of projects have been the following:

- Advances in the field of deep-sea mining or the extraction of critical raw materials;
- New approaches to several processes related to the extraction of raw materials;
- New materials and technologies;
- Geomodels, modelling and simulation tools and decision support tools; and
- Proving and testing methods for mining equipment and tools.

As can be expected from this portfolio, in which all projects are Research and Innovation Actions, the outputs are not yet ready to reach the market and still need an intermediate step. Therefore, several projects have tried to mobilise additional investments (own private funds, national and European public

funds) to further develop the research results and move closer to the market. It should also be noted that several participating companies plan to implement the results of the projects in their own processes and facilities in order to become more competitive.

Several projects have reported that patents have been applied for to protect their results, so that they can be used by the patenting companies themselves or commercialised through royalty fees.

Portfolio 4: WASTE

When comparing the WASTE portfolio with the other portfolios of our analysis, it comes second in relation to a series of economic indicators, such as number of innovations entering the market and number of innovations leading to new products, mainly due to the due to the performance of the cluster 4.1, which shows a strong industrial focus with high participation of for-profit entities.

Thus, in the medium- and long-term , the WASTE project portfolio developed innovative solutions (models, methodologies, processes, technologies, software platforms, tools, etc.) dealing with the better management of waste, the better recovery of raw materials or the transformation of waste into secondary raw materials that should directly lead to a more efficient and sustainable waste treatment and recycling and to a more efficient exploitation of secondary raw materials in the future if they are finally applied, as expected in the SC5 work programme 2014-2015.

When looking at the preparedness of the innovations to be rolled out, it can be said that the projects in the WASTE portfolio have produced assets that have already reached the market (some products containing recycled materials), others that could be marketed in a two-year time frame (some products or technologies), others that could be commercialised in a period of four years (some technologies) and others that need further research to be rolled out (some technologies and processes that need to optimise performance and achieve validation under a wider range of conditions).

Within this portfolio, there has been a high participation of the industry and in particular of SMEs, with emphasis on the industrial waste related cluster (57% of participants are PRC and 38% represent SME), but also in the urban waste related one, (32% of participants are PRC and 26% are SMEs). The potential incorporation of the innovations developed in the framework of the projects by the companies should contribute to strengthen their competitiveness in the future and to enhance their capacity to create good quality and green jobs. It should also increase the chance for commercialisation of the innovations or even the creation of new companies. Indeed, the creation of a new local business was envisaged as a result of the innovative assets produced in this portfolio.

The market orientation of the WASTE portfolio is proven also by the conduction of market related studies that foresee the future exploitation of outputs, by the patents, copyrights and trademarks that have been filed, or by the use that some consulting companies are doing of the developed methodologies to provide added value services to their clients.

One specificity of the urban waste related projects is that the market for the results (products and services) is mostly in the public domain. Therefore, the application of green public procurement processes

and the implementation of an extended producer responsibility system have been proposed to boost the market uptake of the projects outputs.

In addition, the projects, especially the industrial waste related ones, contributed to some extent to the improvement and adjustment of already existing standards and the creation of new concepts that should support the future development of standards validated by key industrial players. However, it is seen as a difficult and long-lasting process to turn the results and knowledge raised by research into new regulations, since it has to be very rigorously proven and validated before it becomes a standard or a regular rule.

All the above-mentioned results should lead to the impact of enhancing the identification of potential markets for the waste collection strategies, treatment technologies and recycled products and to increase the uptake and replicability of eco-innovative solutions as stated in the SC5 Work Programme 2014-2015.

Portfolio 5: WATER

The medium- and long-term economic impacts of the water portfolio are very likely to happen considering that twenty-one projects reported on producing innovative products and twenty-six on producing innovative processes or methods. These are relatively high figures considering the twenty-nine projects that make up this portfolio. These figures are further supported by the high number of patent applications, nineteen in total, and the trademarks submitted by the projects.

In most cases, the technologies have been tested at practice-relevant scale, validated in real environment and proven to be commercially viable. Projects with well-defined business plans and objectives are also present in this portfolio.

Thus, all the above should contribute to achieving market penetration and demonstration of innovative solutions and the application of innovative technological approaches / solutions adapted to local conditions. Also, it should support the development and uptake of water efficiency standards as foreseen in the SC5 work programme 2014-2015.

In addition, the majority of the projects under the WATER portfolio reported great advancements in raising the TRLs of the technologies under development, including many accounts of close-to-market TRL 8 or 9. This is not surprising if it is considered that most of the projects in this portfolio are IA (nineteen out of twenty-nine) and that under this call, the RIA projects are asked to boost international cooperation with countries suffering of water stress conditions. This reinforces the applied and market-oriented scope of the conducted research.

Several projects have reported on successful full-scale pilots and demonstrators. This does not, however, detract from the need for further research for improving the lifetime or the operational efficiency of some of the technologies under development within this portfolio.

As in the rest of the portfolios, the impacts associated to job creation is hindered by the lack of information. In any case, within this project portfolio, there is a strong participation of the industry and SMEs which in cluster 5.1 accounts for 39% of the participating organisations – of 30% SMEs - and in project cluster 5.2 accounts for 45% of the consortium organisations - of which 38% SMEs. This fact should

lead to the creation of jobs in the water sector if they get to adopt the developed technologies as a way to enhance their competitiveness and better performance in the markets. It should also show the industrial interest in the projects' results and enhance the likeliness of the generated innovations to be commercialised by the industrial partners.

By means of leverage of funding for Research and Innovation, it is not possible to reach definite conclusions since not enough information is available. Some projects report having been able to mobilise some complementary funding oriented to commercialisation activities and for the continuation of a demonstration after the end of the project. However, this information needs to be carefully considered since it does not represent the majority of the projects in this portfolio.

In any case, the market orientation of the WATER projects is boosted by several means depending on the projects (RIA included) such as the high participation of the industrial players, the number of patents and copyrights filed and in some cases, the signature of licensing agreements and supply arrangements with companies, the alliances stablished wit technology developing companies that provide the capacity to produce and bring the technologies to the market or even the creation of a spin-off company for the commercialisation of the technology, among others.

To sum up, there are good expectations to achieve economic impacts in terms of deploying sustainable innovative solutions in the water management sector or of creating new market opportunities by this portfolio by commercialising the new water related technologies developed in close-to-market projects.

Comparison of portfolios

The expectations to achieve medium-and long-term economic impacts are linked to the capacity of the project portfolios to achieve reasonable economic results in the shorter term.

Thus, the project portfolios that have succeeded in delivering economic related results at the end of the project presents good prospects to generate innovation-based growth and the deployment of innovative technological solutions by means of:

- the market penetration and demonstration of innovative solutions;
- the application of innovative technological approaches adapted to local conditions, and/or
- the development and uptake of new standards.

Even if further research is needed before market deployment in the case of some of the developed technologies, the high TRL achieved, the implementation of full-scale pilots and demonstrators, the number of patents filed or granted, the conduction of market research studies and the implementation of different commercialisation mechanisms reinforce the good expectations of reaching longer term economic impacts. Additionally, the high participation of industry, and more specifically SME, should also contribute to a higher likeliness for project results to be commercialised.

Also linked to the participation of SMEs in project implementation, it is expected that this reinforces the competitiveness of the involved companies, increasing their capacity to generate good quality jobs. However, due to the information available and the recent completion of the projects, this pathway should be further analysed.

In the case of the project portfolios that have not been focused on providing results contributing to the economic impact pathway, indirect economic impacts are expected to be achieved by, among others:

- Making scientific publications, technology development/advancement and processes and methods resulting from the projects available as openly and broadly as possible, so they can contribute to other technological developments.
- Providing consultancy services aiming at helping organisations use and implement the new frameworks, methods and tools that cannot be directly commercialised.
- Projects results featuring relatively high TRL and showing market potential applying for follow-up funding to carry out further development so it can be rolled-out to the markets or be used for the sustainable production of new products and industrial applications in the future.
- Implementing the results of the projects in the processes and facilities of the consortium partners in order to become more competitive.
- Engaging in standardisation issues supporting (pre-) standardisation bodies in regulation and /or standards development.
- Supporting innovators to develop and test their ideas (technical, commercial, and societal)

According to the above, even the portfolios that are not economically driven in many cases find the way to indirectly deliver innovations that generate economic value. In order to maximise the economic impacts of the funded projects some measures could be considered, among others:

The continuation of the topics and priorities addressed in the calls that allows to advance projects results up to a close-to market stage.

- The existence of follow up funding that enhance the market deployment of project results.
- The application of green public procurement processes and the implementation of an extended producer responsibility system in the case of public sector innovations.

Data issues

Regarding data issues, within the economic impact pathway, the project team has faced especially relevant constraints to measure the indicators related to job creation and leverage of investments. In both cases, those indicators have been explicitly addressed and retrieved from the survey and interviews. Thus, data availability limitations have had a two-fold origin: i) no participation of project coordinators and partners in the interviews and surveys, in which case, no information at all could be collected and ii) even if the IMPACT-SC5 team were able to engage project coordinator and partners in the survey and/or interviews, the information needed on these regards was not easy to collect.

When it comes to the job creation indicators, it is not evident that the project coordination is fully acquainted with the number of professionals (researchers and non-researchers) that have been hired for project implementation by all the project partners. Even more difficult is to know how many of those have been retained after project completion and the impact that the project has had in their professional career development.

The same situation has been faced when dealing with the leverage of investment in research and innovation. The project coordination was not always familiar with the capacity of the partners to mobilise additional funding for the projects under exploration.

Other kind of limitations are linked to the results achieved by the projects beyond its official implementation. This is the case for some of the results under IPR that have been generated once the project has come to an end. This fact caused some inconsistencies among data in the CORDIS databases and information retrieved in the interview and the survey. Additionally, in the interviews it has been noticed that the project coordinating organisation is not completely aware of the IPR issued by the partners in the framework of the project and even less, the ones achieved as a result of the project after the project has ended.

In the case of the TRLs progress, difficulties to identify the extent of the TRL increase have been faced since, depending on the technology (and several technologies could be developed within a project), different levels of TRL are achieved. It has been noticed that the application of the TRL approach to projects more focused on the delivery of processes and methods is not as straight forward as in those developing new technologies or products and could cause uncertainties.

The exact number of some results such as patents and other IPR or the joint public-private publications has also been difficult to determine by project coordinators.

4 Case study findings on EU-added value and horizontal collaboration

Based on the partner interviews of four carefully selected projects, participation in the SC5 Work Programme 2014-2015 has produced the following added value for **the research activities** of project partners:

- Project A: The research project would not have been implemented without the SC5 funding or there would have been a significantly smaller project with limited impact.
- Project B: Without the SC5 funding, the project would have been smaller and longer by many years. The project would also have been less ambitious in scientific terms. With the SC5 funding, multiple European research teams established themselves as world leaders in the research field in question.
- Project C: The SC5 funding enabled bringing together a truly multidisciplinary consortium, including experts from universities, research institutions, public sector organisations and business. Moreover, the SC5 funding provided the opportunity to test the solutions in a number of locations around the Europe.
- Project D: The SC5 funding enabled collaboration between academia and industry, which was an eye-opening and rewarding experience for the participants of the project.

Participating in the SC5 Work Programme 2014-15 has produced the following added value for the **research capabilities** of project partners:

- Interdisciplinary collaboration skills: Learning to work with experts in different domains, e.g. by co-authoring research articles.
- Acquiring experience in standardisation activities: Developing standards for new technological fields.
- Junior career development: Enabling junior researchers to work with senior scientists and gain experience.
- Media skills: Learning to interact with journalists on a regular basis.
- Market knowledge: Gaining reliable knowledge on market demand for new technologies.
- User knowledge: Becoming more sensitive to different user needs.
- Coordination skills: Learning coordinating skills for running large-scale research initiatives.
- Networking skills: Building new collaborative relationships, e.g. between industry and academia.
- Gaining academic visibility: Making a research topic visible in the academic community.

Considering **horizontal collaboration**, the project coordinators have a key role to play according to the partner interviews. The coordinators contribute to horizontal collaboration with other European research projects, initiatives and clusters mainly though information sharing activities. More profound horizontal collaboration, which would also involve the project partners, could be anticipated only in presence of a shared agenda connecting the collaborating parties.

5 Conclusions

5.1 Key results

The IMPACT-SC5 project assessed the scientific, societal and economic impact pathways of 87 projects funded or co-funded under the SC5 work programme 2014-2015. The main focus of this impact assessment was on the project portfolio level, and, to achieve this, the 87 projects were divided into five project portfolios based on their topics and scientific fields:

1) CLIMATE CHANGE
2) ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY
3) RAW MATERIALS
4) WASTE
5) WATER

In the following sections, the key results of the IMPACT-SC5 project addressing the impact pathways of these five portfolios are summarized with a special emphasis on the policy implications and cross-cutting issues.

Scientific impact pathway

The target of the SC5 work programme 2014-2015 was to support research on resource 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. Within these domains,

scientific impacts were expected in terms of addressing gaps in the knowledge base, developing new methods, tools and policies, generating world-class excellence in science, developing skills and improving working conditions, promoting the use of open data, as well as establishing international partnerships.

As a whole, the SC5 projects under this impact assessment produced 33 peer-reviewed publications per EUR 10 million invested on average (EC contribution). At the portfolio level, there are considerable differences between the project portfolios with regard to the publication output, however. The ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY portfolio was the top performer with its 37 peer-reviewed publications per EUR 10 million invested, while the WASTE portfolio produced only 4 peer-reviewed publications per EUR 10 million invested.[12] The ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY portfolio was also the top performer with regard to the diffusion of knowledge and open data as circa half of its peer-reviewed publications were open access complemented by more than 200 open access datasets. Considering the female-male participant ratio (2 females to 3 males on average) and the share of international partners (more than 20% on average), there are no major differences between the portfolios. The information gathered via the participant survey and interviews suggests that the effective uptake of the research results by the research community, public authorities and other relevant stakeholders will continue in the coming years.

Societal impact pathway

The societal impacts of the SC5 work programme 2014-2015 were expected in terms of providing evidence-based advice and recommendations to better position EU in the international agenda to address global societal challenges concerning sustainable development and strengthening the uptake of green innovations and solutions by society.

The majority of the SC5 projects (over 60%) produced policy outputs and promoted policy interactions with decision makers. Slightly less than half of the projects (45%) supported the uptake of innovation in society via the means of citizen engagement and co-participatory approaches. The ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio was the only project portfolio where the majority of the projects reported on supporting the uptake of innovation in society by the means of citizen engagement and co-participatory approaches. As a whole, the EU policy priorities on climate change mitigation and adaptation, development of ecosystem-based management approaches and evidence-based environmental policy making, reducing the generation of waste and environmental depletion and reducing water and energy use and achieving more efficient water management were addressed extensively by the versatile policy contributions of the SC5 projects.

Economic impact pathway

Considering the economic impacts of the SC5 work programme 2014-2015, expectations were associated with the generation of innovation-based growth to improve the EU's competitiveness and achieve its

[12] The WASTE portfolio had a strong focus on applications and local policy development (cities). 9 out of 14 projects of the WASTE portfolio were IAs.

global leadership, the capacity to create more and better direct and indirect jobs and leverage investments in R&I from public and private funding sources.

Overall, the SC5 projects reported on 22 patent applications, 9 trademark and 10 copyright registrations. These are relatively low figures when taking into account that the majority of the projects reported on new innovation products (54) and processes (49), and almost half (41) on innovative methods as their project outputs. The project portfolios diverge significantly in terms of their economic or commercial orientation. Two portfolios, the CLIMATE CHANGE and ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolios, did not carry out commercialization activities to any significant extent as their research results were disseminated and utilized as public goods. However, this does not mean that their results did not have economic importance or usability. For instance, the high SME participation rate (18%) of the ENVIRONMENT, ECOSYSTEMS, BIODIVERSITY portfolio runs counter to this kind of interpretation. The WATER and WASTE portfolios stand out in terms of their commercially driven activities, including high number of reported patents, prototypes, testing activities and rises in Technology Readiness Levels (TRLs). The job creation and leverage of investments by SC5 project or portfolios cannot be assessed due to lack of data.

Cross-cutting issues: Effect of project type, SME participation rate, clustering activities and EU added value

Circa 39% of the projects under this impact assessment were funded as Innovation Actions (IAs) and, respectively, 61% were funded as Research and Innovation Actions (RIAs). Interestingly, the project portfolios with high share of IAs do not differ substantially from those with high share of RIAs in terms of the SME participation rate, number of patent applications or peer-reviewed publications per EC contribution, for instance. Several IA projects excelled in academic publication output (e.g., in case of the WATER portfolio), while many RIA projects (e.g., in case of the RAW MATERIALS portfolio) showed high SME participation rate and active commercialisation activities. On this basis, the IA and RIA project categories did not force participants to focus solely on either application- or research-driven activities, quite on the contrary.

All the project portfolios included a significant share of SME participants. When zooming in on portfolios at the cluster level, only one project cluster consisting of two climate modelling projects did not have SME participants as their project partners. In case of all the other project clusters, the share of SME participants varied from 15% up to 47%. The funding share of SME participants was slightly smaller than what their participation rate would have suggested, but, nevertheless, the presence of SME participants was significant throughout the project clusters funded under the SC5 work programme 2014-2015.[13]

Based on the partner interviews of selected SC5 projects, the project coordinators played a key in horizontal collaboration with other European research projects, initiatives and clusters. Horizontal collaboration could develop into clustering activities attracting partners to join in if there was a shared agenda connecting the research interests of the collaborating parties, such as the NEXUS approach in case

[13] IAs have smaller EU funding rate (70%) for business participants, which affects their funding share as a whole.

of the WATER portfolio. The partner interviews also highlighted that the EU added value of the SC5 Work Programme was, on one hand, related to the research activities, including the larger project size, more ambitious research agenda and more diverse collaborative relationships thanks to the EU funding when compared to the projects funded by national funding sources. On the other hand, increased research capabilities were mentioned as equally important when the EU added value was considered. By participating in the SC5 project, the research capabilities of the partners were increased through improved interdisciplinary collaboration skills, enhanced junior career development, and better access to new sources of knowledge, such as market or user knowledge, among others.

5.2 Recommendations for future programme actions

The recommendations for future programme actions, including their justifications and proposed actions, put forward by the IMPACT-SC5 project are presented in Table 3 below.

Table 3: Policy recommendations for future programme actions.

Recommendation	Rationale	Suggested action
The impact pathways approach should inform the full programme cycle, starting already during the agenda-setting phase.	The call texts of work programmes have a strong guiding effect on proposal writers. The more knowledgeable of expected impacts the call text is, the better impact-informed proposals can be expected. Especially, the proposal writers need guidance on the societal impact pathway and related indicators, which requires particular care already before the call texts are being prepared.	The issue of measuring and monitoring impacts (indicators) should be addressed when designing the programme, with a clear balance and distinction between RIAs and IAs (e.g. through a more consistent use of TRL) and a particular focus on the indicators concerning the societal impact pathway.
Training materials and illustrative examples on impact pathways should be made readily accessible to boost the adoption of impact pathways approach.	Learning new concepts and ways of thinking related to impact pathways can be enhanced by providing practical guidelines and real-life examples.	Showcasing of “impact stories” in online dissemination platforms, such as Horizon Results Platform.
Allocation of networking and communications duties and responsibilities should be more equally distributed	In order to improve the use of personnel resources and safeguard the flow of information, project partners	Encouraging project planning where project partners are given dedicated networking and

Recommendation	Rationale	Suggested action
between project consortium members.	should take a more active role in networking activities in addition to the project coordinator.	communication tasks in addition to the project coordinator.
The projects should be encouraged and credited for reporting on good practices in gender equality and ethical human resources management	In addition to the formal reporting, the work on gender equality and ethical human resources management in research projects should be made visible and credited to raise public awareness.	Giving recognitions or "good practice" labels for the projects forerunning in gender equality or other ethical human resources management activities.
The various EU platforms for dissemination of research results, data and other project materials should be made accessible in one place.	Information on the past research projects is scattered on general and domain-specific online project legacy platforms. For more effective use of this information, a shared web portal including effective information search tools should be made available.	Establishing a shared web portal for the existing legacy online platforms or crosslinking them otherwise.
Capability building for improving the interaction with civil society associations and related actors.	Many research organisations and research-driven businesses are not accustomed to work with civil society stakeholders or actors, and, therefore, training is needed.	Provision of an online handbook on the interaction with civil society stakeholders, including communities of different types.
Boosting SMEs' follow-up activities.	SMEs are vulnerable to suffer from gaps and shortcomings in terms of personnel and financial resources to effectively utilize the research results and other outcomes.	Fine-tuning SME instruments to better support SMEs' follow-up activities.
More focussed and balanced Research and Innovation in work programme.	We have seen that the balance between RIA and IA in the work programme has been uneven, and that their differences in terms of scientific, societal and economic results has not been	The focus and balance of RIA and IA calls needs to be enhanced by providing clearer distinctions in call texts, especially in the

Recommendation	Rationale	Suggested action
	significant. To ensure that the programme drives research and innovation activities towards market uptake (whether commercial or not) there should be a better balance and clearer distinction between RIA and IA in call texts.	description of the expected impacts.
Design of new evaluation methodologies and processes	The complexity of new R&I projects requires new evaluation processes to be designed and implemented that will – on the one hand – utilise the benefits of new technologies, e.g. AI, big data, and on the other will properly and efficiently address the rising challenges and complexity of these new projects.	Extensive consultation between the DGs as well as between European Commission and project practitioners will help towards this end. (Systematic) reviews of the user-friendliness, effectiveness and efficacy of the monitoring and evaluation processes used would also contribute in identifying the hurdles and issue associated with current processes.
Definition of coherent and specific objectives and expected impacts in the call texts.	The specific objectives of the call texts should be in line with their expected impacts (e.g., expected TRLs should match with the expected results in terms of market uptake of the project results).	Boosting cooperation among practitioners and project officers in the definition of the calls. Trainings in the call writing.

5.3 Recommendations for future evaluation exercises

The recommendations for future evaluation exercises, including their justifications and proposed actions, as identified during the IMPACT-SC5 implementation and discussed and validated during the final workshop of the project held in June 2021, are presented in Table 4 below.

Table 4: Recommendations for future evaluation exercises.

Recommendation	Rationale	Suggested actions
Definition of impact terminology and setting a "common language" is needed for avoiding or minimising differences in interpretation (e.g. impact pathways, results, outputs, outcomes and impacts).	Better understanding among users of the impact indicators and impact pathways, and consistency in terms of reporting.	Indicator and impact pathways trainings at various levels (policy, programme managers, project partners).
Short-listing measurable impact indicators (per impact pathway) to be used as a reference for monitoring project results.	An elaborated list of indicators helps towards good reporting and targeting of impacts. Having a clear reference about the indicators that will be used for monitoring project results supports the applicants targeting impacts at the proposal phase.	Iterations of impact indicators. Continuous research and study of the topic to ensure lessons learned being integrated with indicator development. Trainings on the use of the indicators.
GDPR and privacy issues need to be updated to accommodate the needs of proper monitoring of impact pathways.	Impact-related data collected and reported during publicly funded projects should be available for evaluation processes both internally and externally for better accountability.	Policy discussions at national and EU level.
New project reporting processes and templates need to be designed to capture the medium- and long-term impacts of the projects *[Traceability principle]*[14].	Currently, evaluation processes integrated with project level activities focus on monitoring project's progress during the contract period. New processes need to be developed for better	Policy discussions at programme level on new processes to be designed, and how reporting regulations need to change to accommodate these changes.

[14] Bruno, N., & Kadunc, M. (2019). Impact Pathways: Tracking and communicating the impact of the European Framework Programme for research and innovation. *fteval Journal for Research and Technology Policy Evaluation*, (47), 62-71

Recommendation	Rationale	Suggested actions
	monitoring project's anticipated impacts in the near future.	Evaluation of current processes and templates used will help identify how they could be improved.
Improvement of reporting about gender (indicators, methodology followed).	Indicators should not focus only on female/male representation at the project level but go beyond and measure the contribution of projects towards alleviation of male/female discrepancies. Define / Clarify what is really meant by gender reporting.	Design of new indicators and new evaluation methods to capture gender knowledge collectively with representatives of relevant advocacy organisations. Train on new indicators / concept of gender reporting.
Provision of high-quality, regularly updated and consistent project data available for evaluation use (e.g. on innovations and intellectual property) [*Principle of Stability*[15]].	The successful elaboration of evaluations relies upon the existence of available, accessible, timely and consistent information and data. At the moment, project level data is only available to the Commission and not to evaluation teams, seriously undermining the work of evaluators.	Design of processes that will ensure that data concerning projects and applications are provided to evaluators. Updating interpretations of GDPR regulations to ensure that information concerning publicly funded projects and beneficiaries is made available to evaluators. Update of contracts articles to accommodate for such provisions to external evaluators.
During the programme implementation, all three impact pathways should be equally represented at the level of project portfolios.	Monitoring project portfolios and ensuring that these portfolios address impact pathways in a complementary and balanced manner, should	Active information sharing between project officers on impact-driven actions taken by the projects within the same project portfolio.

[15] ibid

Recommendation	Rationale	Suggested actions
	have a priority over individual project monitoring. This would enable a more systemic view over the realisation of impact pathways during the programme implementation.	