strategicRESEARCH

Disruptive Technologies and Changing Institutions, TECH (2015–2021)

Evaluation of the strategic research programme

ACADEMY OF FINLAND

The Evaluation Panel: Frans Berkhout (Panel Chair), Kari Hiltunen, Magnus Holmén, Mervi Karikorpi

ISBN 978-951-715-947-0

Table of Contents

Executive summary

The Finnish Government adopted the strategic research theme “Utilisation of disruptive technologies and changing institutions” on 18 December 2014. The research under the theme focused on identifying and utilising disruptive technology and on what kinds of changes this will require in human activity, institutions and operational methods. The theme involved seeking solutions with which to tackle identifiable obstacles to the export of goods and services and to competence-based growth. The focus areas were transition and risk management, resilience and sustainable growth. Based on this theme, the Strategic Research Council (SRC) launched the SRC programme “Disruptive Technologies and Changing Institutions” (TECH). The TECH programme started in May 2015 and ended in October 2021.

In December 2022, the Division of Strategic Research at the Academy of Finland invited an expert panel to assess the performance of the programme. The expert panel conducted this evaluation between January and April 2023. For the evaluation, the Academy of Finland staff provided comprehensive material on the background, plans and results of the programme. After analysing the material, the panel drew up initial conclusions and raised additional questions for the programme actors. Based on these, the panel conducted interviews with the project representatives and the programme director. The evaluation panel held a total of four meetings during the review process and prepared an evaluation report together.

The evaluation panel assessed the performance of the programme based on the following evaluation criteria:

1. promoting high-quality, multidisciplinary research on the problems and needs in the programme’s domain
2. creating concrete steps towards tackling those problems and needs in Finnish society
3. strengthening research & stakeholder communities in the programme’s domain

Based on its observations on the performance of the TECH programme regarding items 1–3, the panel also drew lessons and suggestions for developing the strategic research programmes and their operations in the future.

Six projects were funded in the TECH programme during the period 2015–2021, each concerned with different aspects of the integration of digital technologies into business and public sectors. This included projects on:

- The wider integration of digital technologies and platforms: DDI project was concerned with the digital disruption of industry, COMBAT project developed 3D digital renderings of forests and cities, and PVN investigated the transformative role of digital platforms.
- The energy transition: SET project dealt with smart energy and BCDC was concerned with distributed energy systems.
- The application of robots in social care (ROSE project).

These were large, complex, 6-year projects which involved in total about 500 staff (including over 400 Finnish nationals), graduating over 35 doctoral degrees and 50 master's degrees and generating about 550 peer-reviewed scientific publications. This evaluation was tasked with reviewing the TECH programme as a whole but not the individual projects.

On scientific **quality** (criterion 1), the TECH programme successfully promoted high-quality, interdisciplinary research on the problems and needs in the programme's thematic area. The included projects were able to produce inter- and transdisciplinary knowledge understood as the formulation and solution of complex industrial and societal problems and applying more integrated approaches, also involving societal partners. The panel finds the scientific outputs of the projects substantial and of high quality, when judged by international standards. There is evidence of publications in international disciplinary and multidisciplinary journals, including high quality journals, as well as an appropriate range of published outputs for professional, policy and public audiences. There are significant variations in the publication strategies across the TECH projects, although wider societal impacts were generated by all projects through engagement with non-academic partners. The scientific quality of the projects is also demonstrated by complementary and follow-on projects that were funded, sustaining research and communities kick-started by TECH programme funding.

On **concrete steps** (criterion 2), panel finds that success was influenced by the broader institutional, business and societal context, and by serendipity. Impact depends on a supply of ideas and capabilities, as well as a demand for those ideas and capabilities in business, the public sector and wider society. Forecasting the salience of new knowledge is always difficult. Each of the TECH projects, separately and together, developed sustained interactions with business and policymakers, and there was considerable engagement activity at the TECH programme level, including a joint policy brief at the end of the programme. These activities generated concrete steps or impacts of various forms, including a vision for district heating in Finland (SET), a roadmap for robotics in elderly care (ROSE), an energy supply forecasting tool (BCDC), and on-going consultations with the Ministry of Economic Affairs and Employment about platform innovation and regulation (PVN). Unforeseen events affected the nature and the scale of impact. In the case of the energy supply forecasting tool, the energy crisis of 2022 created a perfect setting for its widescale impact on managing peak demand for electricity, while the expected reform of the social and health care system was delayed, leading to delays in the uptake of new technologies like robots.

On **communities** (criterion 3), the panel finds that the TECH programme may have had its greatest impact, both culturally and in the networks and capabilities which it enabled. Culturally, within both the scientific research community and in business and policy communities, the programme established and validated the practice of co-producing knowledge by scientific and non-academic partners about complex societal challenges. The idea that scientific knowledge can and should be useful is more widely appreciated, but there has been a long-held critique about the flow of ideas and ways of doing things between the academy and wider society. Generating

impact is often seen as difficult (it requires scientific research communities to speak to each other and to partners outside academia), costly (there are few incentives for researchers to engage outside their own communities, and little capacity in societal groups to make sense of esoteric new ideas and tools) and ineffective (how do you measure wider societal impact?). The TECH programme, due to its founding commitment to the co-production of knowledge as well as the efforts of its leaders and the relatively long period in which relationships and ways of working together could evolve, was able to overcome many of these (perceived) obstacles. It demonstrated and validated the generating of research impact and created networks and capabilities for impacts to continue in the future. Continued investment in these networks and capabilities is important.

The programme led to the development of new capabilities and hybrid academic-societal networks and communities bridging research and policy and practice, enabling the flow of new ideas in both directions. Multiple forms of productive engagement were implemented, including 'transition arenas' (SET), about 100 pieces by TECH researchers in Tekniikka&Talous magazine (TECH programme) and a large-scale field experiment involving domestic electricity consumers in association with an electricity utility Porvoon Energia (BCDC), later rolled-out at the national level. Both researchers and societal partners learned common languages, worked through how they could be useful to each other, and developed confidence in the validity of taking a broader view of knowledge production. For researchers involved in the TECH programme, there was general appreciation of the sense of making a contribution to significant societal debates and of enabling social change through the adoption of and adaptation to new technologies.

Overall, the panel finds that the TECH programme was successful in generating high-quality research, in generating multiple concrete outputs and impacts in Finland, and in forming new knowledge communities stretching across the traditional boundaries between research and society. Several of these knowledge communities continue to work on new emerging issues in the fields of digital transformations in energy and care.

Tiivistelmä (Executive summary in Finnish)

Valtioneuvosto päätti 18. joulukuuta 2014 strategisen tutkimuksen teemasta "Teknologiamurrosten hyödyntäminen ja muuttuvat instituutiot". Teemassa rahoitettavan tutkimuksen odotettiin kohdistuvan teknologiamurrosten identifioimiseen, hyödyntämiseen ja siihen, millaista inhimillisen toiminnan, instituutioiden ja toimintatapojen muutosta hyödyntäminen edellyttää. Teemassa tuli hakea ratkaisuja, joilla voidaan vastata viennin ja osaamisperusteisen kasvun tunnistettaviin esteisiin. Painopisteinä olivat muutoksen- ja riskienhallinta, uudistumis- ja sopeutumiskyky ja kestävä kasvu. Näissä olennaista olivat teknologiamurrosten vaikutukset teollisuuteen, palveluihin, työmarkkinoihin ja työelämään, kulutustottumuksiin, terveyskäyttäytymiseen, osaamistarpeisiin ja koulutukseen. Kestävässä kasvussa olennaisia olivat innovaatiotoiminnassa

hyödynnettävät ratkaisut ja osaaminen. Strategisen tutkimuksen neuvosto (STN) teki tämän teeman pohjalta päätöksen STN-ohjelmasta ”Teknologiamurrokset ja muuttuvat instituutiot” (TECH). TECH-ohjelma alkoi toukokuussa 2015 ja päättyi lokakuussa 2021.

Suomen Akatemian strategisen tutkimuksen vastuualue kutsui joulukuussa 2022 asiantuntijapaneelin arvioimaan ohjelman toteutusta, tuloksia ja vaikuttavuutta. Asiantuntijapaneeli työskenteli tammikuun ja huhtikuun 2023 välisenä aikana. Strategisen tutkimuksen vastuualue toimitti arviointia varten kattavan aineiston ohjelman taustoista, suunnitelmista ja tuloksista. Aineistoon tutustuttuaan paneeli laati alustavat johtopäätökset ja esitti lisäkysymyksiä ohjelmassa rahoitettujen hankkeiden vetäjille, ohjelmajohtajalle sekä sidosryhmien edustajille. Paneeli piti arviointiprosessin aikana yhteensä neljä kokousta ja laati yhdessä arviointiraportin.

Asiantuntijapaneeli arvioi ohjelman saavutuksia seuraavien arviointikriteerien perusteella:

1. korkeatasoisen, monitieteisen tutkimuksen edistäminen ohjelman teema-alueen ongelmista ja tarpeista
2. konkreettisten toimien luominen näiden ongelmien ja tarpeiden ratkaisemiseksi suomalaisessa yhteiskunnassa
3. tutkimus- ja sidosryhmäyhteisöjen ja niiden välisten yhteyksien vahvistaminen ohjelman teema-alueella.

Paneeli teki ohjelman saavutuksia koskevien arvioidensa perusteella myös johtopäätöksiä ja suosituksia STN-ohjelmien kehittämiseksi tulevaisuudessa.

TECH-ohjelmassa rahoitettiin vuosina 2015–2021 kuusi hanketta, jotka tarkastelivat eri näkökulmista digitaalisen teknologian integroimista yrityksiin ja julkiselle sektorille. Hankkeet käsittelivät seuraavia aiheita:

- Digitaalisten teknologioiden ja alustojen laajempi integrointi: DDI-hanke käsitteli digitaalista murrosta yritystoiminnassa, COMBAT-hankkeessa kehitettiin metsien ja kaupunkien kolmiulotteista digitaalista kuvantamista, ja PVN-hankkeessa tutkittiin digitaalisten alustojen transformatiivista roolia.
- Energiamurros: SET-hanke käsitteli älykästä energiaa ja BCDC-hanke hajautettuja energiajärjestelmiä.
- Robottien hyödyntäminen sosiaali- ja terveyspalveluissa (ROSE-hanke).

Ohjelman kuusivuotiset hankkeet olivat laajoja ja monipuolisia. Hankkeisiin osallistui yhteensä noin 500 henkilöä (joista yli 400 oli Suomen kansalaisia). Hankkeet tuottivat muun muassa yli 35 tohtorin- ja 50 maisterintutkintoa ja noin 550 vertaisarvioitua tieteellistä julkaisua. Arvioinnin tehtävänä oli tarkastella TECH-ohjelmaa kokonaisuutena.

Tarkasteltaessa **tieteellistä laatua** (arviointikriteeri 1) voidaan todeta, että TECH-ohjelma edisti menestyksekkäästi laadukasta, tieteidenvälistä tutkimusta ohjelman teema-alueen ongelmista ja tarpeista. Mukana olleissa hankkeissa pystyttiin

tuottamaan tieteidenvälistä ja poikkitieteellistä tietoa ja ymmärtämään siten paremmin monimutkaisia teollisia ja yhteiskunnallisia ongelmia ja kehittämään niihin ratkaisuja. Lisäksi hankkeissa sovellettiin eri näkökulmia integroivia lähestymistapoja, osallistaen myös yhteiskunnallisia sidosryhmiä. Paneelin arvion mukaan hankkeiden tieteelliset tuotokset ovat kansainvälisessä vertailussa merkittäviä ja korkealaatuisia. Tuotoksia on julkaistu kansainvälisissä, sekä tieteenalapohjaisissa että monitieteisissä tieteellisissä lehdissä. Osa tuotoksista on julkaistu korkean tason lehdissä. Hankkeissa on lisäksi julkaistu ammatilliselle, poliittiselle ja suurelle yleisölle suunnattuja tuotoksia. Kaikki hankkeet saavuttivat laajempaa yhteiskunnallista vaikuttavuutta toimimalla yhdessä muiden kuin akateemisten yhteistyökumppanien kanssa, vaikka TECH-hankkeiden julkaisustrategioissa onkin huomattavia eroja. Hankkeiden korkeasta tieteellisestä tasosta kertovat myös muualta rahoitusta saaneet täydentävät hankkeet ja jatkohankkeet, joilla ylläpidetään TECH-rahoituksella käynnistetyn tutkimuksen ja yhteisöjen jatkuvuutta.

Konkreettisten toimien (kriteeri 2) osalta paneeli toteaa, että ohjelman onnistumiseen vaikuttivat laajempi institutionaalinen, yritysmaailman ja yhteiskunnallinen konteksti sekä sattumanvaraisuus. Vaikuttavuus riippuu ideoiden ja valmiuksien tarjonnasta sekä niiden kysynnästä yrityksissä, julkisella sektorilla ja laajemmin yhteiskunnassa. Uuden tiedon leviämisen ennustaminen on aina vaikeaa. Jokainen TECH-ohjelman hanke kehitti jatkuvaa vuorovaikutusta yritysten ja poliittisten päättäjien kanssa sekä erikseen että yhdessä. Myös ohjelman tasolla toteutettiin huomattavaa vuorovaikutustoimintaa, johon kuului myös ohjelman lopussa laadittu yhteinen politiikkasuositus. Vuorovaikutustoimista syntyi konkreettisia askelia tai vaikutuksia, kuten visio kaukolämmöstä Suomessa (SET), tiekartta robottien käytöstä ikäihmisten palveluissa (ROSE), energiasään ennustetyökalu (BCDC) ja työ- ja elinkeinoministeriön konsultointi innovaatioalustoista ja sääntelystä (PVN). Ennakoimattomat tapahtumat muuttivat vaikuttavuuden luonnetta ja laajuutta. Esimerkiksi vuoden 2022 energiakriisi loi täydelliset puitteet energiantuotannon arviointityökalun laajamittaiselle vaikuttavuudelle sähkön kysyntähuippujen hallinnassa, kun taas odotettu sosiaali- ja terveydenhuollon uudistus (Sote-uudistus) viivästyi, mikä johti robottien kaltaisten uusien teknologioiden käyttöönoton viivästymiseen.

Paneeli katsoo TECH-ohjelmalla olleen ehkä suurin vaikutus **yhteisöihin** (kriteeri 3) sekä kulttuurisesti että sen mahdollistamien verkostojen ja valmiuksien osalta. Tutkimuksen, liike-elämän ja poliittisten yhteisöjen toimintakulttuuriin ohjelma vakiinnutti ja vahvisti yhteiskehittämisen käytäntöä, jossa tieteelliset toimijat yhdessä ei-akateemisten kumppanien kanssa tuottavat tietoa monimutkaisista yhteiskunnallisista haasteista. Ajatus siitä, että tieteellinen tieto voi ja sen pitäisi olla hyödyllistä, on nykyään jo laajemmin hyväksytty, mutta kritiikkiä kohdistuu yhä ideoiden ja käytäntöjen liikkumiseen akateemisen maailman ja laajemman yhteiskunnan välillä. Yhteiskunnallinen vaikuttavuus nähdään usein vaikeana (se edellyttää, että tutkimusyhteisöt keskustelevat keskenään ja akateemisen maailman ulkopuolisten kumppaneiden kanssa), kalliina (tutkijoilla ei ole juurikaan kannustimia sitoutua oman yhteisönsä ulkopuolisiin toimiin, ja eri yhteiskunnallisilla tahoilla on vähäiset valmiudet ymmärtää uusia, esoteerisia ideoita ja työkaluja) ja

tehottomana (miten mitata laajempaa yhteiskunnallista vaikuttavuutta?). TECH-ohjelma pystyi ylittämään monet näistä (koetuista) esteistä, koska ohjelmassa oli alusta lähtien sitouduttu tiedon yhteiskehittämiseen, ja toisaalta ohjelman ja hankkeiden johtajien toimien ansiosta. Ohjelman suhteellisen pitkä kesto mahdollisti myös suhteiden ja yhteisten työskentelytapojen kehittymisen. Ohjelma toteutti ja vahvisti tutkimuksen vaikuttavuutta sekä loi verkostoja ja valmiuksia vaikuttavuuden jatkumiselle. Jatkuva panostus näihin verkostoihin ja valmiuksiin on tärkeää.

TECH-ohjelma johti uusien valmiuksien kehittymiseen. Samalla ohjelma johti akateemisten ja yhteiskunnallisten tutkimusta, politiikkaa ja käytännön toimintaa yhdistävien hybridiverkostojen ja -yhteisöjen kehittymiseen, mikä taas mahdollisti uusien ideoiden virtaamisen molempiin suuntiin. Ohjelmassa toteutettiin useita tuloksellisen vuorovaikutuksen muotoja, joista esimerkkejä ovat "murrosareenat" (SET), noin 100 TECH-ohjelman tutkijoiden kirjoittamaa yleistajuista artikkelia Tekniikka&Talous-lehdessä sekä laajamittainen kokeilu, johon osallistui kotitalouksia yhdessä Porvoon Energian kanssa (BCDC) ja joka myöhemmin otettiin käyttöön kansallisella tasolla. Tutkijat ja yhteiskunnalliset yhteistyökumppanit oppivat yhteistä kieltä, selvittivät miten voivat hyödyttää toisiaan, ja kehittivät luottamusta siihen, että tiedon tuottamista voidaan tarkastella laajemmin. TECH-ohjelmaan osallistuneet tutkijat yleisesti ottaen arvostivat sitä, että he pääsivät vaikuttamaan merkittäviin yhteiskunnallisiin keskusteluihin ja mahdollistamaan yhteiskunnallista muutosta ottamalla käyttöön uutta teknologiaa ja sopeutumalla siihen.

Paneeli katsoo, että TECH-ohjelma onnistui luomaan korkealaatuista tutkimusta, tuottamaan useita konkreettisia tuotoksia ja vaikuttavuutta Suomessa sekä muodostamaan uusia tietoyhteisöjä, jotka ylittävät tutkimuksen ja yhteiskunnan perinteiset rajat. Useat näistä yhteisöistä jatkavat työtä uusien esiin nousevien kysymysten parissa energian ja hoivan digitaalisen muutoksen alueilla.

Foreword

The Strategic Research Council (SRC) established within the Academy of Finland funds thematic research programmes aiming at high scientific quality, great societal relevance and distinguishable impact. SRC-funded research seeks solutions to grand challenges that require multidisciplinary approaches. An important element of the research is active and ongoing collaboration between knowledge producers and knowledge users.

The SRC is responsible for monitoring and evaluating the impact of the research it has funded. However, it is not always feasible to provide conclusive evidence of impact. The societal impact of research can also manifest itself years after the completion of the work.

Evaluating social impact in the context of research funding requires a distinctive method. The evaluation of SRC programmes does not merely rely on performance indicators but looks at the effectiveness of interaction, its consequences, and potential future impact. Understanding the operations and outcomes of each programme necessitates considering its specific framework, rather than comparing the success of different programmes with each other. The challenges and prospects of finding solutions to specific societal challenges differ, as do the roles that various fields of research play in society.

Four SRC-funded programmes were completed in 2021, and their ex-post evaluation was carried out in 2022–2023. This report presents the results of the ex-post evaluation of the programme Disruptive Technologies and Changing Institutions, TECH (2015–2021).

The SRC wants to thank the panel members for their indispensable contribution to the programme evaluation. The results of their work, as presented in this report, are of substantial value for the SRC in building the overall picture of the impact and development prospects of its programme funding. In addition, the SRC wants to thank the TECH programme director, consortium members, and stakeholder representatives who participated in the interviews or surveys conducted as part of this evaluation.

Dr. Anu Kaukovirta
Chair of the Strategic Research Council

Dr. Päivi Tikka
Director, Division of Strategic Research, Academy of Finland

1. Introduction

1.1. Strategic research programmes

The goal of the strategic research funding, established in 2014, has been to strengthen the impact of research in Finland by producing knowledge that helps develop the functions of different sectors of society. To pursue this goal, the Strategic Research Council (SRC) established within the Academy of Finland is tasked with funding high-quality, long-term, and programme-based research that aims at finding solutions to the major challenges facing Finnish society. Each year, the SRC prepares a proposal on key strategic research themes to be approved by the Finnish Government. The Government decides the final themes, which the SRC formulates into research programmes. The programme funding is intended for extensive, multidisciplinary research consortia that carry out research that is relevant for the programme theme, with an emphasis on active interaction and engagement with knowledge users.

The consortia funded under SRC programmes receive funding for 3–6 years. The consortium's funding plan may also include the full-time salaries of the principal investigator (PI), the subproject PIs and the work package leaders. A part-time programme director employed by their own background organisation, such as a university or research institute, is selected for each SRC programme. The programme directors are responsible for programme-level development of interaction and cross-programme cooperation, and they promote the societal impact of strategic research. For further information on strategic research funding, see the current funding principles.[1]

The SRC is responsible for monitoring and evaluating the impact of the research it has funded, both during and after the funding period. According to the funding principles, the ex-post evaluation is implemented at the programme level. The aim of the evaluation is to assess the current or prospective scientific and societal impact of the completed programme and to produce knowledge to support the development of strategic research programmes. The evaluation focuses on the targeting, processes, outputs and outcomes of the research and interaction activities funded under each programme, as well as their observed or anticipated effects. A particular focus is on the results of multidisciplinary work and the ability to promote scientific renewal. Special characteristics of each programme and project, as well as different societal roles of science, are all considered in the impact review. The evaluation follows the principles of open and responsible science.

1.2. Evaluation of strategic research programmes 2015-2021

This report presents the outcomes of the ex-post evaluation of one of the very first SRC programmes, Disruptive Technologies and Changing Institutions. The evaluation was conducted in 2022–2023, simultaneously with the evaluation of three other

[1] Funding principles of the Strategic Research Council, 13 March 2023: https://www.aka.fi/en/strategic-research/for-applicants-and-projects/for-applicants/funding-principles/

programmes that ended in 2021, and the evaluation of all four programmes followed the same design, methods, and protocol.

This round of ex-post evaluations was the second time SRC programmes have been evaluated after their completion. The first round of ex-post evaluations was conducted in 2020–2021, and the target of that evaluation was four smaller and shorter programmes which had run between 2016–2019. One of the key findings was that the three-year funding period was too short to enable the programmes to fully realise their ambitious goals.[2]

In 2021–2022, the strategic research funding scheme as a whole was evaluated by an external research group. The evaluation was part of the implementation of the Government Plan for Analysis, Assessment and Research (VN TEAS). The evaluation examined if and to what extent the goals set for the SRC funding have been realized during its first years of implementation (2014–2020). Overall, the results were very positive.[3]

The present round of ex-post evaluation focused on the following programmes:

- Disruptive Technologies and Changing Institutions, TECH (2015–2021)
- A Climate-Neutral and Resource-Scarce Finland, PIHI (2015–2021)
- Equality in Society, EQUA (2015–2021)
- Changing Society and Active Citizenship, CITIZEN (2017–2021)

The evaluation of each of the four programmes was conducted by a panel of 4–6 invited foreign and Finnish experts, who had strong experience in the programme's themes within and/or beyond academia (Appendix 1). At least one member of each panel had also participated in the review of research proposals submitted to the original SRC programme call.

The evaluation panels worked independently, without interaction with the other panels. The scope of each evaluation was the given SRC programme as a whole, including: the performance of the projects funded in the programme; the performance of the programme-level work, coordinated by the programme director; and possible added values emerging from the programme.

The panels were tasked with evaluating the performance of the programme in relation to the key goals of SRC funding:

1. promoting high-quality, multidisciplinary research on the problems and needs in the programme's domain
2. creating concrete steps towards tackling those problems and needs in Finnish society (and even beyond)

---

[2] Strategic research programme evaluation: https://www.aka.fi/en/strategic-research/strategic-research/strategic-research-in-a-nutshell/programme-evaluation2/

[3] Kivistö, J., Kohtamäki, V., Lilja, E., Lyytinen, A., Tirronen, J., Holmberg, K., Teräsahde, S. (2022). Strategisen tutkimuksen rahoitusinstrumentin arviointi. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 2022:60, Valtioneuvoston kanslia. http://urn.fi/URN:ISBN:978-952-383-487-3

3. strengthening research and stakeholder communities in the programme's domain (even beyond the programme's life span)

The panels were instructed to focus on the input, activities, outputs and outcomes of the research and interaction activities funded in the programme, as well as their observed or anticipated effects (Appendix 2). In addition, the panels were asked to draw lessons and recommendations for developing the strategic research programmes and their operations in the future.

The panels worked between January and April 2023. The evaluation work contained the review of a substantial body of evaluation material (Appendix 3), interviews with key programme actors, participation in three online meetings with the other panel members, compiling the results of the evaluation into this report, and presenting and discussing the key findings with the SRC.

A major part of the quantitative and qualitative evaluation material was assembled from the project's funding applications and various reports from the duration and comple-tion of the programme. In addition, the material included the results of two separate surveys, conducted after the ending of the programme: a self-evaluation questionnaire for consortium members, and a survey for the projects' and the programme's key stakeholders. An important part of the evaluation material were also the interviews with the consortium representatives and the programme director in March 2023.

The evaluation panels were supported by the Academy of Finland staff at the Division of Strategic Research. The staff collected and processed the evaluation materials, designed the evaluation framework and criteria, prepared and attended the panel meetings, organized and documented the interviews, and finalised the evaluation reports.

1.3. Structure of the report

The report is composed of four sections plus several appendices. After this introduction (section 1), we present an overview of the programme. The overview includes the programme description as it appeared in the programme funding call in 2015, a short, non-technical description of each of the six consortia and the programme director funded in this programme, as well as summary tables on the programme's composition and resources (Section 2).

Sections 3 and 4 were written by the evaluation panel and they constitute the crux of this report. Section 3 focuses on the performance of the programme in relation to the three key goals of SRC funding, and the structure of the section loosely follows the criteria defined in the evaluation framework (Appendix 2). Section 4 presents the conclusions, lessons, and recommendations of the panel, based on their observations and key findings evidenced by the evaluation material.

In addition, the report includes several appendices, which offer more detailed information on the evaluation protocol (Appendices 2–4), as well as on the input, activities, output and outcomes of the projects and the programme that are the focus of the evaluation (Appendices 5–13). The latter include personnel key figures,

list of projects' collaborators, publication lists and analyses, lists of other research output, new research funding, titles of impact stories, and methods and results of the two surveys conducted for the purpose of this evaluation.

2. Overview of the programme

The Finnish Government adopted the strategic research theme “Utilisation of disruptive technologies and changing institutions” on 18 December 2014. Based on this theme, the SRC launched the programme “Disruptive Technologies and Changing Institutions (TECH)”. The programme started on 1 May 2015 and ended on 30 April 2021, but due to the COVID-19 pandemic, the funding period was extended to 31 October 2021.

Under the TECH programme, six research consortia and a part-time programme director were granted funding.

2.1. Programme description of the funding call

The Academy of Finland April 2015 call included the following description of the SRC programme TECH:

The research under the theme focuses on identifying and utilising disruptive technology and on what kinds of changes this will require in human activity, institutions and operational methods. The theme involves seeking solutions with which to tackle the identifiable obstacles to export of goods and services and to competence-based growth.

The focus areas are transition and risk management, resilience and sustainable growth. In these areas, key consideration should be given to the effects on industry, services, labour markets and working life, consumer habits, health behaviour, competence needs and education. In addition, the solutions and competence utilised in innovation activities form the basis for sustainable growth.

Based on this thematic framework, the Strategic Research Council adopted the SRC programme Disruptive Technologies and Changing Institutions on 9 February 2015.

Disruptive technologies deeply affect society and the economy. Examples of disruptive technology are digitalisation-related areas such as mobile and cloud technology, automatisation of knowledge work, Internet of Things, big data analytics, robotics, 3D printing, geographic information, nano- and biotechnology, advanced materials and new energy technology. Making the best possible use of disruptive technologies requires a change in operational methods and institutions. Disruptive technologies may initiate changes that improve productivity and competitiveness as well as boost economic growth. Institutional structures must adapt to meet and support the wave of disruptive technology.

Programmatic questions

In its research plan, the consortium must address questions A and B, and can choose to address either or both of questions C and D.

Under each question, there are a number of examples of possible perspectives on and approaches to the research.

A. In the case of a concrete disruptive technology, how is it manifested in Finland and what are its potential benefits?

Possible premises: How will the disruptive technology improve productivity, create competence-based growth, and promote competitiveness and exports? How can disruptive technologies be harnessed to promote sustainable growth and a sustainable society? How will the disruptive technology influence the environment and society at large? Under which conditions can Finland best develop and utilise new technologies, and what are the main obstacles to those conditions?

B. In order to make the best possible use of that particular disruptive technology, what changes are required in human activity, institutions and operational methods?

Possible premises: How can institutional structures, i.e. established norms (legislation, administrative decisions, and interpretations by individual officials) and social and cultural norms, hinder or help the comprehensive utilisation of the disruptive technology? How should institutions supporting the transition be developed, and what kinds of new institutions will perhaps be needed? How will the changes in human activity, institutions and operational methods affect the utilisation of other disruptive technologies? What obstacles related to manufacturing and the competence base will eventually lead to an adherence to old operational ways and inhibit the adoption of new solutions and practices? What obstacles are there to exports, innovative domestic markets and competence-based growth, and how should these obstacles be addressed? What kinds of skills will Finland need to make the best possible use of disruptive technologies?

C. In what ways can the public sector best support a well-managed transition and thus create the best possible conditions for Finland to utilise disruptive technologies?

Such ways can include innovative experimentation, such as pilot projects, learning by experimentation and institutional change. How will disruptive technologies affect industry, services, labour markets and working life, consumer habits, health behaviour, competence needs and education? Are there any risks involved in this transition, and how can they be anticipated and managed? How will the costs resulting from the transition be distributed between different business companies and the public and private sectors? How can we ensure national-level value creation in global value networks? How do we promote innovation processes and opportunities for competence-based growth in Finland?

D. How can we ensure that businesses, employees, the public sector and consumers possess the resources and skills that promote an ability to adapt to the changes and risks brought about by disruptive technologies?

2.2. Public descriptions of the funded projects and their results

In their final reports, submitted in January 2022, the funded projects and the programme director summarized their work as follows:

Cloud computing as an enabler of large scale variable distributed energy solutions: Bright Clouds – Dark Clouds (BCDC)

Wind and solar power play key roles in achieving a carbon free energy sector. Their electricity production is dependent on the weather and thus variable by nature. This increases the production uncertainty and price volatility in the electricity system. Balancing production variability creates cost pressures for the entire electricity system. In the BCDC Energy project we provided solutions to the problem of renewable electricity production variability. Our main results (i) show, how the cost-effectiveness of variable renewable energy production can be improved when integrating it into the system, (ii) provide mechanisms to activate consumption flexibility and generate mechanisms for improving awareness of energy consumption, and iii) indicate differences in consumers' energy information literacy. Moreover we (iv) developed and disseminated an Energy Weather Forecast, and (v) produced new generation ICT and digital solutions for the need of the energy market transition.

Competence-Based Growth Through Integrated Disruptive Technologies of 3D Digitalization, Robotics, Geospatial Information and Image Processing/Computing - Point Cloud Ecosystem (COMBAT/Pointcloud)

The COMBAT / Pointcloud project was a research project on point cloud modeling and 3D digitization in cities, forests and corridors. The aim of the project was to make scientific and economic breakthroughs, serve employment, cooperate with industry and provide information to support decision-making in four sectors: 1) We supported the digitalisation of the forest industry, strengthening Finland's position as the best international expert and promoting 3D forest technology exports. 2) We developed Finnish data products for river mapping, which improve the cost efficiency of the public sector by automating the monitoring of the river environment and improve the competence of actors. 3) We developed new city model applications, production processes and publishing platforms to support urban planning and decision making. 4) We developed mapping technology for corridors and their environments; we automated the inventory, mapping and visualization of power lines, streets and their immediate surroundings.

Digital Disruption of Industry (DDI)

Digitalisation is a primary factor chancing society that has already transformed many sectors and people’s everyday life. The Digital Disruption of Industry consortium studied the impacts of digitalization to the Finnish society through the lens of industry. It covered the theme from a multidisciplinary viewpoint and at several levels of granularity from general themes to specific developments. At the general level, the key results of the work include research on the diffusion of disruptive technologies, business models and ecosystems for platform economy, knowledge-based management, and the role of users and consumers. At the level of specific technologies and domains, the work focused on disruptive themes such as 5th generation networks, blockchains, AI and machine learning, and digital twins. A theme crossing all these topics is the role of exploiting and sharing data across

actors and fields. On the basis of the work, we have synthesised policy recommendations and interventions in co-operation with various stakeholders, domain specialists and the general public.

Platform Value Now: Value Capturing in the Fast Emerging Platform Ecosystem (PVN)

The Platform Value Now project focused on understanding the fast emerging platform ecosystems, their value creation dynamics and the requirement of a supportive institutional environment. We analysed ecosystems with systems tools and developed new methods for platform-centric ecosystems management. Data collection was based on active scanning of global technology and platform ecosystems and fast solution-oriented case experiments with Finnish corporations and policy planners. The aim of the project was to operationalize the collected understanding into a profile platform framework that will enable more efficient method and tool development for ecosystem management.

Robots and the Future of Welfare Services (ROSE)

The main goal of the "Robots and the future of welfare services" project was to evaluate the possibilities offered by robots and their application in the production of services for older adults, and to evaluate the development of the field. In the project, six Finnish research entities joined forces to do multidisciplinary research on the phenomenon on three levels, from the perspectives of individuals, organizations and society. Experiments and other research in the project showed that robotics as a technology is still, in many respects, immature for services for older adults and the currently operating applications are limited in their intended use. The primary findings of the project have been summarized in the Finnish Care Robotics Roadmap, which sets out a vision of what is likely to be technically possible in both five and ten years. In order for the benefits of robotics to be realized, the ability of organizations to adopt new technology and integrate it into service production must be supported.

Smart Energy Transition - Realizing its Potential for Sustainable Growth for Finland's Second Century (SET)

The SET project, alongside many others, has affected change in the energy field by providing new knowledge of transition technologies, such as renewable energy, solutions for heating systems and buildings, and power-to-X-technologies. The SET project supported the uptake of new technologies by supporting and analysing learning from energy experiments and initiated co-creation by organizing transition arenas. In addition, SET analysed and evaluated the impact of public policy and institutions on energy transition and explored business models of demand response. The SET project collaborated actively with users of results and sought to help decision makers and businesses to understand the transition and benefits of it. The policy briefs of the project focused on topical themes, and in various discussions that were organized, the challenges of the energy transition were highlighted from many angles.

Programme director's project

The TECH programme's projects have generated information on how Finland can benefit from technology disruptions related to digitalization, artificial intelligence, automation and robotics, platform economy and energy markets and what measures are needed to realize the benefits. I have used various means to enhance the understanding of technology disruptions studied in the TECH projects and communicate the research results and new knowledge generated to the scientific community and the wider audience and decision-makers. The primary means included the following: i) regular meetings with the TECH project managers and directors of communication; (ii) cooperation with the research directors of other SRC programmes; (iii) meetings and (scientific) conferences to seek synergies and increase collaboration and dialogue between the SRC projects, programmes and relevant stakeholders, iv) coordinating and editing the "Technology disruptions" serial in Tekniikka&Talous news magazine targeted for a wider audience, and v) public presentations to and interactive discussions with the relevant decisionmakers (at, e.g., the Ministry of Transport and Communications, Ministry of Economic Affairs, and Employment, Business Finland).

2.3. Composition of the programme

The total funding awarded to the TECH programme was 36,8 million euros. The consortium projects were composed of two funding periods (3 + 3 years) and they were awarded 5,6–6,5 million euros each. The part-time programme director was awarded around 700 000 euros (Table 1).

Overall, 21 organisations received funding from the TECH programme. These mostly included Finnish universities and state research institutes, while other domestic organisations and international/foreign research organisations were also represented (Table 2).

The self-reported key research fields represented by the projects (five per project) cover a total of 21 fields, including mainly fields of natural sciences and engineering as well as social sciences and humanities (Table 3).

Table 1. Funding awarded under the TECH programme.

Project	Applicant	Funding, €		
		1. period	**2. period**	**Both periods**
BCDC Energy	Svento Rauli; Kopsakangas-Savolainen, Maria	3 182 091	2 561 690	5 743 781
COMBAT	Kaartinen, Harri	3 499 665	2 867 560	6 367 225
DDI	Mäntylä, Martti	3 668 412	2 841 560	6 509 972
PVN	Salo, Ahti	3 096 768	2 472 900	5 569 668
ROSE	Kyrki, Ville	3 144 809	2 953 810	6 098 619
SET	Lovio, Raimo; Temmes, Armi	3 318 207	2 536 390	5 854 597
Programme director	Koski, Heli	305 050	390 217	695 267
TECH programme				**36 839 129**

Table 2. Organisations involved in the TECH programme.

Situation at the latter half of the programme. The darkest colour indicates the organisation that led the consortium.

Organization type	Organization	BCDC	COM-BAT	DDI	PVN	ROSE	SET	Prog. director
University	Aalto University							
	LUT University							
	University of Oulu							
	University of Helsinki							
	University of Turku							
	Tampere University							
	University of Jyväskylä							
Univ. of applied sciences	Laurea University of Applied Science							
State research institute	VTT Technical Research Centre of Finland							
	Finnish Environment Institute (SYKE)							
	VATT Institute for Economic Research							
	Finnish Meteorological Institute (FMI)							
	Finnish Geospatial Research Institute (FGI)							
Other domestic organisation	Research Institute of the Finnish Economy (ETLA)							
	Heureka, the Finnish Science Centre							
	City of Lappeenranta							
	Motiva Oy							
Foreign/international organisation	International Institute for Applied Systems Analysis (IIASA)							
	Imperial College London							
	University of Sussex							
	Wilson Center							

Table 3. The five most important research fields of the TECH research projects.

The heatmap shows the top5 research fields of the six TECH projects. The research fields were selected by the projects from the Academy of Finland's research field classification[4]. The tone of the color indicates the importance of the research field for the project, the darkest colour referring to the most important research field etc. Research fields that were not mentioned by any of the projects are excluded from the heatmap.

Category	Research field	BCDC	COMBAT	DDI	PVN	ROSE	SET
Natural sciences and engineering	Communications engineering	2					
	Information systems science			1			
	Automation and systems technology		3			1	
	Computer science	4					
	Computational data analysis		5				
	Geosciences	3	1				
	Meteorology and atmospheric sciences, climate research						
	Remote sensing		2				
	Industrial management			2	1	4	
	Mechanical engineering and manufacturing technology			3			
	Energy engineering						1
	Applied mathematics		4		3		
Health sciences	Nursing science					2	
Social sciences and humanities	Economics	1					4
	Business administration			4	2		3
	Politology						2
	Social sciences					3	
	Social policy, social work			5			
	Science studies						5
	Informatics	5					

[4] Academy of Finland's research field classification: https://www.aka.fi/en/research-funding/apply-for-funding/how-to-apply-for-funding/az-index-of-application-guidelines2/research-field-classification/

3. Performance of the programme

3.1. Promoting high-quality, multidisciplinary research on the problems and needs in the programme's domain

Key findings:

- The programme did promote high-quality research, which in turn partly depended on prior research.
- The TECH programme successfully promoted the interdisciplinary competence of research teams on the programme level and for the projects.
- Almost by definition the programme included ICT competences together with complementary disciplines.
- The design of TECH programme has been successful as it aligned project applications with demands on the activities, outputs and outcomes of the TECH projects. In addition, there was an appropriate balance between consistency and flexibility in the TECH projects, which also allowed for adjustment to external changes.
- Research collaboration and exchange seemed to have worked well but there may be a need for more inbound visits and visitors.
- The programme led to the creation of new skills (PhDs, master's and bachelor's degrees) although productivity could have been greater without loss of quality.

Interdisciplinarity and research approaches

The research programme was successful in promoting the interdisciplinary competence of research teams on the programme level, for the six projects and various research groups involved in the projects. For example, each of the six projects were initiated and worked with highly diverse competence profiles.

As shown in Table 2, all but one of the projects drew on a combination of research fields that included both the natural sciences and engineering, and the social sciences and humanities. Indeed, programme participants found that it was useful to combine engineering and science with business and social aspects. One project (ROSE) exploited knowledge in health sciences as well.

Interdisciplinary competences were intrinsic to the setup of the projects. For example, SET analysed innovation chains in the energy transition from the perspectives of public policy, business models, uptake and connection among new technologies, while COMBAT was concerned with point cloud modelling and 3D digitization in applications of significant importance to Finnish industry (e.g. forestry). This approach combined data capture and monitoring technologies, automation of data analysis, and publishing platforms.

Across the projects, a number of appropriate methods and practices for interdisciplinary research and collaboration were used, including project meetings, collaboration in projects, joint supervision of students, as well as structured engagement between researchers and societal partners leading to knowledge production. A mix of more specific, technical methods specific to research fields and more widely-used research approaches was applied in the projects.

Examples of research approaches include:

- BCDC combined domain expertise and used a multitude of methods, such as cooperative game-theory and short-term weather forecast models.
- COMBAT proposed and used many research methods related to geospatial mapping and visualisation.
- DDI proposed a long list of methods, and linked their work packages to the call's questions, relative to e.g., machine learning, 5G, and policy.
- PVN combined systems studies, modelling, and inductive studies.
- ROSE combined participatory observation, collection and analysis of visual and audio material, case studies, and surveys in line with the emphasis of the co-creative approach of the programme.
- SET began with a rich set of research designs, methods and competences as the requirements for smart energy transition were difficult to specify ex ante, but shifted from energy production to e.g. storage technologies, buildings, organizational change, and institutions and policy transition.
- All six projects drew on and contributed to computer and information science as a field, which in turn drew on and contributed to electronics, automation and communication engineering. Digitization and digitalization stood at the centre of the TECH programme's framing of 'disruptive technologies', which is reflected in the projects funded and in the approaches used by each project.

Collaboration and interaction

According to the interviews and a self-evaluation questionnaire for consortium members, the respondents deemed integration across projects to work quite well. Project representatives argued that one of the main outcomes of their project and the programme as a whole was that it 'brought people together', promoting a wider and more integrated view of the problems being researched and encouraging interactions which improved the quality and the relevance of project outputs.

To keep up with the state of the art of research, the programme aimed for national and international networking. According to the self-evaluation questionnaire, the TECH programme had plenty of resources for managing collaboration and networking. In line with this, the programme enabled many short-term and long-term research visits. The travels were primarily outbound from Finland and only two of the projects had a significant number of inbound international visitors. To some extent, the programme mitigated the issue through business and policy project collaborators (partners).

Knowledge production, scientific output and scientific impact

To create new skills and capabilities, training and supervision was an important part of the programme. As can be seen in Figure 1 in Appendix 5, excluding the Other category (e.g. research assistants), almost half of the staff were junior researchers: doctoral students and postdoctoral researchers. Consequently, the programme produced quite a large number of doctors and master's graduates, although the numbers varied greatly across the six projects. Only one of the projects were able to produce both a high level of doctors and masters. The programme contributed to the development of new undergraduate and postgraduate programmes in Finnish universities, responding to growing interest in, for instance, platform technologies and applications and the transition to net-zero.

In terms of output, the peer-reviewed scientific publications were mostly written in English and aimed at an international audience. More than 50% of the peer reviewed publications were open access, the rest were most readily available to academics via subscription to scholarly databases. The peer-reviewed publications frequently had multiple authors – typically 2–6 authors (Figures 6, 7 and 10 in Appendix 9). This may be a feature of interdisciplinary research bringing together researchers from different fields in an analysis of a complex societally-relevant problem.

With the caveat that citations are important but hard to assess, the panel finds an impressive number of citations to the programme's publications, indicating improved and diffused state of the art knowledge of questions of industrial and societal importance. The number of citations per publication and the share of most cited 10% of publications are higher for TECH publications than for Finnish universities' publications on average.[5] A likely reason includes the timely topics, but other plausible explanations include the interdisciplinary approach and high quality involved in the research.

In terms of disseminating research data, with the exception of a couple of the projects, the programme did not deliver much in terms of putting data into the public domain according to specification.

The respondents to the self-assessment questionnaire found that in line with the original research applications, the programme worked very well for creating 'interdisciplinary knowledge' in the sense of formulating complex problems, followed by using approaches, networking and methods to address them.

While it is very difficult to assess the outcome of the programme in terms of added value, the programme was important in that it allowed for long term funding for research on problems of great social relevance. Arguably, the long term funding was important for allowing for problem-driven and coordinated activities.

The programme was able to renew itself in the sense that participants were able to attract significant amounts of additional funding. The sums were high in particular

[5] Kivistö, J., Kohtamäki, V., Lilja, E., Lyytinen, A., Tirronen, J., Holmberg, K., Teräsahde, S. (2022). Strategisen tutkimuksen rahoitusinstrumentin arviointi. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 2022:60, Valtioneuvoston kanslia. http://urn.fi/URN:ISBN:978-952-383-487-3

for BCDC Energy, COMBAT, and DDI, where the latter applied for funding from many sources (Appendix 11).

In hindsight, what characterizes the chosen projects and the programme overall is that the combination of research fields is non-surprising from an interdisciplinary perspective given the scope and focus of the projects. Arguments could be made for drawing on and contributing to other fields, but it is more difficult to argue for the removal of the chosen fields. In particular, when addressing the heatmap in Table 3, the most important research field for each project seems to be 'obvious' given the projects' foci. However, if we focus on the second most important discipline we may find a more crucial insight. The disciplines of communication engineering (BCDC), remote sensing (COMBAT), industrial management (DDI), and politology (SET) can all be viewed as complementary disciplines to the core discipline for the projects. For two of the projects, arguably business administration (PVN) and nursing science (ROSE) are non-surprising given the similarity (overlap) and complementarity to the main discipline.

Conclusions

In summary, the panel concludes that the TECH programme successfully promoted high-quality, interdisciplinary research on the problems and needs in the programme's domain. This was found from comparing the programme's research call, the six successful research project applications, and the result of the projects and the programme. The aspect of addressing societal needs was done from the focus of having each of the selected projects to be based on societal needs and problems in general, and Finnish ones in particular. Arguably, this alignment was built in from the start in the evaluation of the funding applications, which motivated the project teams to build in these aspects from the start. Thus, in the end, the projects and the programme met up to the needs of Finnish society in line with what was stressed in the original applications.

A part of the original selection of projects was also that the research had to have an interdisciplinary basis. Indeed, the six projects were interdisciplinary in terms of outcomes and applications. At times, but far from always, this was also visible in how individual research groups and researchers worked. From the panel's point of view, not all activities have to be interdisciplinary, since a lot of research needs to have a disciplinary focus. Thus, the 'research portfolio' approach where different disciplines meet in carefully selected instances was a wise choice.

The programme did promote high-quality research, as is shown by the large number of publications in established journal outlets. Taken together, the citation impact of TECH publications shows that the programme did contribute to high quality research.

3.2. Creating concrete steps towards tackling problems and needs in Finnish society

Key findings:

- *Main achievements:* The TECH programme and projects have developed and strengthened common understanding of the technological disruptions and changes (societal, environmental, and to a lesser extent economic) underway. Furthermore, the collaboration between the research teams and private and public sector stakeholders have resulted in concrete outputs benefitting the partners in the TECH projects and provided policy makers and industry with new knowledge and insight to foresee and address the impacts of disruptive technologies.
- *Main area for improvement:* To further improve the impact of strategic research e.g., in terms of evidence based policy making, institutional changes or industrial renewal, the TECH projects and programme as well as future programmes would benefit/have benefitted from the following:
    - A more systematic and strategic investment in co-creation with the stakeholders beyond the academic community.
    - Ensuring sufficient resources and effective ways to orchestrate collaboration between researchers and other stakeholders.
    - Spending more time at the design phase of the programme/projects to identify focal issues and challenges in a timely manner from the perspective of policymakers and industry.
    - Paying more attention to the scaling of innovation on the systemic level in Finland and internationally.
    - Being prepared to respond to opportunities offered by sudden changes in the operating environment such as the COVID-19 pandemic and the energy crisis.
- *Other characteristics of the programme:* Major changes in the global operating environment (COVID-19 pandemic, the Russian invasion of Ukraine, etc.) during the programme period of 2015–2021 and beyond have affected policy making and accelerated the race for technological development and scaling, reinforcing the need to address sustainability challenges (economic, environmental, social). Societies now face multiple, overlapping systemic challenges and crises, with the digital and green transitions being of central importance, requiring sustained investment (private and public) and institutional and cultural adaptation.

Development of common understanding

The six-year period of programme implementation provided the researchers with sufficient time to develop multidisciplinary networks, a “common language”, and new research practices. Based on the evaluation materials and interviews, one of the main objectives and achievements of the TECH projects and the programme was to

develop and strengthen common understanding among scientific and stakeholder communities about the disruptions and changes underway.

Concrete examples of activities undertaken in the TECH projects and the programme to develop common understanding among researchers and society at large include:

- A podcast and series of articles in Tekniikka&Talous magazine on technology disruption by TECH researchers.
- Joint conferences and regular seminars both at the programme and the project levels as well as other interactions involving business representatives and policymakers.
- Energy transition arena on the SET website and a district heating vision developed as a discussion paper. Board games for the wider public and stakeholders developed with Heureka science centre.
- Collaboration in Executive Education and involving doctoral students and postdocs in research activities.
- A roadmap for robots and future welfare services was prepared in the ROSE project.[6]
- Events such as 'Science meets elections' with Parliament and municipal council candidates (with the other SRC programmes).
- Policy briefs and participation in hearings at the Parliament, committees and working groups set up by ministries and the European Commission.
- A policy brief on investing for sustainable growth and prosperity resulting from technological revolutions prepared by the TECH programme.[7]

Bringing a high number of researchers from different research organisations together has contributed to the relevance of the research and improved the overall effectiveness and impact of the Finnish university system. Several SRC programmes, including the TECH programme, also demonstrated how a large group of researchers can be agile and respond to a social demand for expert opinion. Namely, about 50 researchers co-produced a widely publicised rapid review on the impact of COVID-19 in 2020 to the Parliament Committee for the Future. In times of rapid and complex societal change, the capacity to bring diverse expertise together to understand and solve problems brings significant benefits.

---

[6] Niemelä, M., Heikkinen, S., Koistinen, P., Laakso, K., Melkas, H., & Kyrki, V. (eds.) (2021). Robots and the Future of Welfare Services – A Finnish Roadmap. Aalto University publication series CROSSOVER, 4/2021. http://urn.fi/URN:ISBN:978-952-64-0323-6

[7] Kaartinen, H., Kopsakangas-Savolainen, M., Koski, H., Lakaniemi, I., Mäntylä, M., Svento, R., Temmes, A., Turja, T. (2021). Investoinneilla kestävää kasvua ja hyvinvointia teknologiamurroksista. https://www.aka.fi/globalassets/3-stn/1-strateginen-tutkimus/tiedon-kayttajalle/politiikkasuositukset/politiikkasuositukset/21_10_investoinneilla_kestavaa_kasvua_ja_hyvinvointia_teknologiamurroksista.pdf

Interaction with stakeholders

Technological and methodological development, demonstrations, and pilots conducted in the TECH programme have to some extent involved businesses or other stakeholders beyond academia. However, only nine stakeholder representatives (14 %) responded to the stakeholder survey conducted by the Division of Strategic Research at the Academy of Finland, and none of the stakeholders were available for an interview. Four companies and an association, however, responded by email to the panel's questions about the nature of interaction/collaboration and the benefits of the project. It is therefore impossible to undertake any comprehensive assessment of the role of the stakeholders or the depth of the collaboration. Project representatives, on their part, reported strong and sustained engagement with business and policy stakeholders.

It is likely that companies and organisations which had an identified need/problem and a commitment to collaboration right from the project design benefited the most. It is positive that the five stakeholders who responded by email reported on a variety of benefits such as better understanding and know-how of technology potential, technology trends and their current adoption stage, and the expected impacts to different sectors and customers. According to these respondents, this understanding and interaction with the research project contributed to strategies and their implementation in the concerned organizations. Two companies also reported on a related, simultaneous business-driven co-innovation project.

Examples of concrete outputs and innovation resulting from the collaboration include:

- First demonstration of unoccupied aerial vehicle laser scanning (UAV LS) for powerline mapping (COMBAT)
- Precision forestry concept adopted by major European forest companies (COMBAT)
- Open data/open platforms for city modelling (COMBAT).
- Application for an energy supply-weather forecasting (BCDC).
- Empirical analyses of the impact of platform economy on taxation (PVN).
- Experiments with care robots in several settings, e.g., in a new type of building for elderly people in Kalasatama in Helsinki (ROSE).
- A proposal for how to extend the set of assessment criteria in the national Digi-Health Technology Assessment to include sustainability criteria (ROSE).
- Aalto University Industrial Internet Campus – a platform for students, researchers, and companies to innovate and co-create smart, connected products and services – initiated by DDI.
- Database that compiles information of companies in Finland that could benefit from and add value to the energy transition (SET).

- Several spin-offs have emerged based on the research carried out in TECH projects.

Impact on systemic changes

Although the project representatives and the TECH programme director were cautious to draw any firm conclusions of the direct impact of the projects/programme on systemic changes, institutional development, awareness about emerging issues and progress in evidence-based decision-making, the project/programme researchers have no doubt contributed in various ways to the recent strategy work and programs. Some of these are summarized below.

Actions have been taken both in the private and public sectors to tackle problems, needs and opportunities related to the development and adoption of disruptive technologies and to institutional development (higher value added, improved productivity, new practices, structures) in Finnish society since 2015. During the 2019–23 Marin Government, the following steps have been taken:

- Carbon neutral Finland 2035 and the national climate and energy strategy
- Low-carbon roadmaps by key industrial sectors
- Finland's Digital Compass 2030
- The Parliament approved the Government's proposal for Health and social services reform. The new management structures started at the beginning of 2023.
- R&I plan by the Parliamentary Working Group on Research, Development and Innovation to increase R&D intensity to 4 percent of GDP by 2030.
- The Technology Council was set up by the Ministry of Finance in 2020. Its task is to improve technological expertise and strengthen public-private collaboration and the adoption of new technologies in all sectors of Finnish society. The Council set objectives for the year 2030 and recommended actions needed to reach them.
- The AI4.0 program initiated by the Ministry of Economic Affairs and Employment also defined concrete objectives and actions to facilitate the development and use of digital technologies in industry.

The above-mentioned strategy work has been carried out in close collaboration between public and private sector stakeholders. The focus should now shift to the ambitious implementation of these strategies, programs, and recommendations. To what extent these will be on the agenda of the new Government of Finland (from 2023 on) will be seen later, as the formation of the Government is still underway.

A valuable contribution of the researchers has been the ability to foresee the pace of technological developments and uptake. For example, Power-to-X technologies (eg. transforming electricity to hydrogen), energy sector integration, as well as data and platform technologies and economies were on research agendas already in 2015, but wider awareness about their importance only developed towards the end of the

programme period. It is very likely that the work and engagement of the TECH programme significantly contributed to this. The national Technology Council involving researchers, business representatives, and public sector decision makers could, in the future, provide a platform for anticipating emerging technologies and joint prioritization.

The five key requirements listed by the TECH programme in the 2021 policy brief for the exploitation of technology breakthroughs in Finland are still valid. Although they have been at least partially considered in policy level strategy work, their implementation is still underway.

Conclusions

It is demanding to contribute to solving societal "wicked problems" or practice-oriented concerns of public and private stakeholders with high-quality scientific research. The problem orientation of projects/programmes funded by the SRC is essential in view of the expected societal relevance and impact of strategic research.

To further improve the impact of strategic research e.g., in terms of evidence based policy making, institutional changes, or industrial renewal, the TECH projects and programme and future SRC programmes would benefit from the following:

- A more systematic and strategic investment in co-creation with stakeholders beyond the academic community.
- Ensuring sufficient resources and effective ways to orchestrate collaboration between researchers and stakeholders.
- Spending more time at the design phase of the programme/projects to identify focal issues and challenges in a timely manner from the perspective of policymakers and industry.
- Paying more attention to the scaling of innovations to the systemic level in Finland and internationally, e.g., by spreading the concrete outputs of the programme/projects through networks and strategic partnerships more widely as well as supporting policymakers and industry in designing the required policies, practices and solutions informed by research findings.
- Being prepared to take into account sudden changes in the operating environment such as the COVID-19 pandemic.

The programme approach adopted by the SRC has contributed to strengthening the common understanding of technological disruptions and changes underway. The TECH programme director played an important role in facilitating interaction among the project leaders and project teams, which resulted in important statements such as the TECH policy brief on investing in sustainable growth and prosperity resulting from technological revolutions, and in the dissemination of the programme conclusions to the wider audience. The programme approach also helps to identify and synthesize practices, institutional and systemic chances, and policy measures that can enhance or hinder the adoption and utilization of disruptive technologies.

Sustainable systemic changes often take time – the six-year project period may only be sufficient to build awareness and strategy in leading companies and public sector stakeholders to develop, initiate and accelerate concrete actions. Systemic changes also have an organic logic and momentum, often slowing down or accelerating in unexpected ways, or changing direction. In view of the TECH focal areas, rapid and unforeseen changes in the global operating environment during the program period and beyond have affected policy making and speeded the race for technological development and scaling:

- The pandemic and the Russian invasion of Ukraine have reinforced the need to address sustainability challenges, to speed up the digital and green twin transition, and to increase investment (private and public) in the latter.
- Due to the shortage of materials, components and intermediate products during the pandemic, and the increased geopolitical tensions, considerations related to "strategic autonomy" and global technological leadership have become more determinant factors in policy making and the targeting of public resources in the EU, US, and Asia.

Furthermore, the current European Commission has proposed extensive regulatory packages concerning data and digitalization (the Data Act, the Data Service Act, the Data Governance Act, etc.) and the net-zero energy transition (the Fit for 55 packages, the EU taxonomy for sustainable activities). These will affect all sectors. Also, the somewhat harsh realities of the Finnish economy will affect future decision-making in one way or another.

It is evident that big changes in energy and resources production and consumption, health and social care, and other private and public sectors can be expected in the coming years. The key question is how to make the transformations in a sustainable way and tap the opportunities related to these changes. There is a continuing need for high-quality and relevant strategic research.

The long-term commitment of universities, the private sector, and policymakers to strategic research is important. It is unfortunate that many of the websites created by the TECH programme have not been updated since 2021. Investment in problem or challenge oriented strategic research and co-creation between researchers and private and public stakeholders beyond the academic community should originate both from public and private resources. The funding and professional model of the universities should also have stronger incentives for such research.

3.3. Strengthening research and stakeholder communities

Key findings:

- The TECH programme did strengthen research and stakeholder communities by
    - Educating a large number of people.
    - Communicating research results effectively, working efficiently together in developed communities, and creating needed networks.

  - Increasing the mobility of skilled people to private and public sector organisations after graduation, carrying/showing the value of research.
  - Kickstarting communities which remained and grew.
- The programme managed to break silos and bring something new to the Finnish research community and research landscape.

Societal developments in the programme's domain

A core intended outcome of the research programme was to increase Finnish society's innovativeness and resilience in the programme's domain, by enabling the formation of new knowledge communities including researchers and stakeholders. The focus of the programme was primarily on digital disruptive technologies, with the potential to transform business sectors, markets and behaviours, as well as public and private institutions. The nature of these transformations is uncertain and to some extent unpredictable, as are the speed and scale of their effects. Transitions are messy, confusing and conflictual. Black swan events — unpredictable external events with major societal impacts — can modify the speed and direction of systemic changes.

In hindsight, the panel sees that societal wild cards like the COVID-19 pandemic and the Russian invasion of Ukraine has necessitated rapid adoption and adaptation of technologies as market, political and social conditions changed. The war in Ukraine brought into view weaknesses in the energy sector and increased the societal pressure towards green energy and energy savings. The TECH programme did play a role here in that several projects addressed the issues of energy production and use.

Before the pandemic, many digital tools, including those to enable virtual meetings and the use of platform economy transaction frameworks, were available but not routinely used in organizations. There was considerable societal resistance to their adoption. The pandemic changed the situation when many people were required to work from home due to lockdowns, and the utilization of these tools became universal very rapidly. Digital tools and platforms were suddenly in global public use in market, organizational and social settings.

Besides these wild cards, there are also slower and deeper trends in society like the ageing of population, growing inequality, and social change leading to demands for greater inclusion. These social trends are influenced by technological change (platform technologies as a driver of inequal wealth distribution), as well as stimulating socio-technical innovations (new drugs and health technologies related to the elderly). This deep, dynamic and reciprocal relationship between society, institutions and technologies makes their understanding a process requiring continuous updating and reflection.

Skilled people

While the research outcomes are essential, strengthening research and stakeholder communities starts from skilled, open and competent people. There needs to be a critical mass of area specialists who can build needed relationships to other

researchers and communities and act as a contact point for decision makers in business, policymaking, and civil society. What has been the role of the TECH programme in these aspects? Even though the exact role is difficult to quantify, with the benefit of hindsight, the panel has found that the programme was successful in strengthening research and stakeholder communities within the programme's domain.

The TECH programme directly supported graduate training and development. The six projects supported 39 doctoral, 51 master's and 12 bachelor's degrees (BDCD: 13 doctoral & 4 master's; COMBAT: 11 doctoral, 16 master's, 5 bachelor's; DDI: 7 doctoral, 4 master's; PVN: 3 doctoral, 5 master's; ROSE: 2 doctoral, 7 master's, 6 bachelor's; SET: 3 doctoral, 14 master's). Importantly, these graduates came from multiple disciplines, including natural sciences, engineering, management, economics and the social sciences.

In addition, during the interviews with project representatives, it become clear that after the TECH programme, there has been a growing number of students enrolled in programmes related to the project fields (digitisation, sustainable energy, technology and care) and new master's programmes have been developed. On the other hand, students and researchers have moved to private companies after completing their studies, taking their skills, perspectives and networks with them. These people widen the stakeholder community further and connect new industries to topics developed by the TECH projects. From the people point of view, the TECH programme has kick-started the creation of active, connected knowledge communities in Finland.

Collaboration among the research community and stakeholders, communication with Finnish society

As Finland is a small country, it is not possible to do everything alone. Active research communities need contacts to other research communities, relevant industries, and political decision makers. To be part of the international research community, researchers need to publish articles in good quality international journals, work together with international colleagues, visit conferences, and actively build collaboration with other research institutes and universities. Nowadays it is good practice that many projects are multidisciplinary and cooperation between different project groups and universities is active. In the TECH programme, the projects published 548 (BCDC: 73; COMBAT: 148; DDI: 117; PVN: 52; ROSE: 85 and SET: 73) peer-reviewed publications (verified by national publication service VIRTA). In addition to these publications, the projects published articles and other types of publications intended for the general public and for other audiences. Publications were often done in collaboration between universities and between research groups. Working together in research and the resulting publications is a good way to share ideas and connect researchers to fruitful co-operation. In general, the projects in the TECH programme have strengthened interdisciplinary collaborations which have, based on the projects' interviews, continued and even widened after the programme has finished.

For society, it is important that research results are communicated also to the public using language and tools that are understandable by everyone. In the TECH programme, the projects have published 23 peer-reviewed scientific publications in Finnish, and there has been the “Technology disruptions” series (about 100 short articles) in the Finnish magazine Tekniikka&Talous. These magazines tend to have quite a significant number of readers. In addition to this, the six projects organized webinars, seminars, summer schools and pilots, and participated in fairs, markets, competitions, and other events to bring programme messages visible to Finnish society. Based on this, the panel finds that the TECH programme performed well in overall communication and seeking contacts to other research communities and relevant industries.

However, the contacts and communication towards Finnish policy makers appear to have been variable. Some projects established strong and continuous engagement (for instance PVN with the Ministry of Economic Affairs and Employment), while engagement with policymakers was more discontinuous and 'supply-driven' in many other cases. At the programme level, the 'Solutions from Science’ activity (jointly between the three SRC programmes EQUA, PIHI and TECH) and the report for the Committee of the Future were designed for policy audiences. This pattern of engagement may be explained as much by the bandwidth and absorptive capacity of policymakers as by the potential usefulness and timeliness of research findings and outputs.

A very important stakeholder community for a strategic research programme is Finnish society. The TECH programme activated a broader discussion about energy and digitalization in Finnish society very well. Overall, the programme gave Finnish society important tools which contributed significantly to overcoming the challenging situations generated by the COVID-19 pandemic and the energy crisis.

Continuation of the work

One good measure of the strength of research community is to look at what happens after a major funding comes to an end. The funding that projects got from the TECH programme gave them six years secured time to do research and communication and to build research and stakeholder communities. Such a long funding gives the opportunity to build a credible research community and even plan interdisciplinary cooperation much more carefully compared to shorter term funding. Looking now, a couple of years after the programme has ended, the communities that were built during the programme period have been active and have secured 59 million euros of additional funding. In this respect, the TECH programme has been very successful, building capabilities in areas that remain relevant and flourishing in the context of national and international competition.

4. Conclusions and recommendations

Sustainability transitions are complex, long-term processes affecting all of society, involving the innovation and adoption of new technologies and requiring significant institutional, behavioural and cultural change. The central insight of the TECH programme continues to be highly relevant. Over the past 10 years, digital technologies continue to generate disruptive economic and social impacts across societies globally, and the importance and urgency of transitions to net-zero, a more circular economy and the protection of Nature and ecosystems has become more evident, as has the societal challenge of achieving these transitions.

While much has been achieved, including for instance the growth of renewables and electric mobility, Finland and global societies are not yet on track to achieve agreed political goals, such as the Paris climate goals and the Kunming-Montreal biodiversity targets. If societies are to accelerate sustainability transitions, the wider political and economic challenges will be even more intense than they were in the past. Understanding and informing the messy, contradictory and frequently confusing process of transition — part of what has come to be characterised as a period of 'permacrisis' — is perhaps more important than ever.

A first conclusion to draw from this review of the TECH programme is that the programme was timely and important at the moment of its inception in 2015. But we also conclude that the knowledge and capabilities the programme was designed to produce in Finland are perhaps even more needed today. We would encourage the SRC to continue to fund similar broad programmes in the future, because they create knowledge and understanding about digital and sustainability transitions, kick-start the creation of novel research and practitioner communities which would otherwise not come into existence, and produce broader societal, economic and cultural impacts that emerge from such interactions. Transitions have the potential to create radically new worlds, based on new knowledge, new actors, new rules and new ways of doing things. These novel socio-technical configurations depend on the foundation of what Schumpeter termed 'neue kombinationen'. Active research funding in large multi-year programmes like the TECH programme creates the space for these new combinations of technology, institutions and practices to be fostered, enabling new technologies to be absorbed in to society while also ensuring that their benefits are both shared and sustainable.

A second key conclusion is that assessing and measuring the outputs and impacts of a broad, multiyear, interdisciplinary programme like TECH requires a set of broader criteria than would be used for a conventional research programme. Beyond the production of formal scientific knowledge, such programmes are funded to generate skills, networks and capabilities that have a broader impact in society. A programme may have unexpected impacts that were not anticipated but are nonetheless very valuable to society and the economy. Measuring these kinds of impacts and effects is more difficult. This is acknowledged in the assessment framework the review panel has been given and by the narratives and qualitative information made available. In drawing conclusions about the achievements of the TECH programme and in making suggestions for future actions, this information has been of great use. Future

assessments and reviews of integrated programmes should continue to extend and be creative about the evaluation frames used and the information that is deemed appropriate to such evaluations.

Recommendations

Below we provide some concise recommendations for a variety of audiences.

Finnish business and industry

- Big changes in energy production and usage, health care, and other private and public sectors can be expected in the coming years. The key question is how to make the transformations in a socially and environmentally sustainable way, and tap the opportunities related to these changes. There is a continuing need for high-quality and relevant strategic research with business and industry playing a leading role at least for complex and 'wicked' problems. The scale and complexity of the challenges is likely to continue to grow, demanding more diverse and agile combinations of technological capabilities and corporate strategies. Academic researchers, increasingly incentivised and equipped to work with business, are an important partner in navigating this dynamic complexity.
- Investment in problem or challenge oriented strategic research and co-creation between researchers and private and public stakeholders beyond the academic community should originate both from public and private resources. Business needs to develop the capacity to be an 'intelligent partner, commissioner and consumer' of strategic research, viewing itself as an engaged stakeholder as part of its social purpose. The funding model of universities should also have stronger incentives for such research.

Participants of the TECH projects

- Research and societal impact are increasingly connected as we seek to understand, shape and benefit from transformative changes happening in global societies. Research training and leadership needs to integrate the capacity to work across disciplines and with societal partners, as a way of improving research quality and its social robustness. Researchers need to continue to innovate ways of building these bridges with society through conceiving the co-production of knowledge as intrinsic to all scientific practice.
- The TECH programme marked an important transition in the research and knowledge production landscape in Finland. It created enduring knowledge networks and communities, which have proven to be sustainable beyond the programme. Most of these networks were Finnish and within Finland. While significant outward international relationships were built across the different projects, there was more limited evidence of inward (into Finland) networking. In future projects, greater effort to attract inward networking would be recommended, bringing awareness of Finnish leaders in relevant fields.

Strategic Research Council

- **Continue investing in strategic research**: The pace of technological development, global sustainability challenges, and geopolitical tensions underline the need to continue investing in strategic research, especially on the very relevant thematic areas of the TECH programme.
- **Take actions to further improve the impact of strategic research on the systemic level:** To improve the impact of strategic research e.g., in terms of evidence based policy making, institutional changes or industrial renewal, future programmes and projects would benefit from a more systematic and strategic investment in co-creation with stakeholders beyond the academic community throughout the project/program lifecycle. Effective orchestration of such deep collaboration requires sufficient time and resources during the design, implementation and follow up of programmes/projects. Focal issues and challenges need to be identified in a timely manner from the perspective of policymakers and industry already during the design phase, enabling also adequate flexibility for programmes to adapt to sudden changes in the operating environment.

  The SRC can also together with the programmes, accelerate the scaling of research findings into innovations on the systemic level in Finland and internationally. This could be done for example by spreading the concrete outputs of the programmes/projects more widely through networks and strategic partnerships, and by pooling resources to support policymakers and industry in designing the required policies, practices and solutions informed by research findings.

  These aspects need to be taken into account in programme designs, in the evaluation of proposals and in the reviews and evaluations of programmes.

Appendix 1: Bios of the panel members

Frans Berkhout is Assistant Principal (King's Climate & Sustainability) and Professor of Environment, Society and Climate at King's College London. Over the past 25 years, his research has been concerned with science, technology, policy and the environment, with a focus on sustainable innovation and climatechange. He has held academic leadership positions in The Netherlands, France and the United Kingdom.

Kari Hiltunen (DSc.), Senior Manager Strategic Sales & Business Development has worked over 20 years at Nokia and specialized on from idea to cash practises. During his career he has worked in areas such as research, product development, technology platforms, technology management, sourcing, corporate business development, strategic partnerships, and technology sales. He has built up a wide range of expertise at Nokia in areas such as materials technology, electronics, supply chain management, technology demand forecasting, technology purchasing & sales, strategic planning, international relations, and people leadership. Hiltunen also has a special interest in the future of technology. Together with his wife, he is the author of book called Technolife 2035: How Will Technology Change Our Future?

Magnus Holmén is Professor of Innovation Science with a focus on Industrial Management at Halmstad University, Sweden and previously held the position of director of research. He has been researching industrial transformation, innovation systems and ecosystems, innovation processes, and business model innovation the last 25 years. He has worked in Sweden, Australia and the USA.

Mervi Karikorpi is Head of EU Innovation and Industrial Policies at Technology Industries of Finland TIF. Having worked in several leadership, advisory and research positions at TIF, consulting engineering companies, research institutes and public sector organizations in the EU, Asia, and the US, she has gained an extensive international experience in the areas of the digital-green transformation, innovation capabilities and management, and R&I and industrial policy analysis. She is a member of the EU Industrial Forum Task Force on Investment, Vice Chair of DigitalEurope WG on R&I and a Board member of Helsinki Institute of Information Technology and Finnish Centre of AI. She has a postgraduate Lic. Sc. degree in Theoretical and Material Physics and has done further studies in business economics and strategy, innovation management and logistics.

Appendix 2: Evaluation framework

Table 4. Performance of the SRC programme: key criteria

	1. Promoting high-quality, multidisciplinary research on the problems and needs in the programme's domain	2. Creating concrete steps towards tackling those problems and needs in the Finnish society (and even beyond)	3. Strengthening research & stakeholder communities in the programme's domain (even beyond the programme life span)
Input	• multidisciplinary competence of research teams • relevance and synergy of research plans • resources for managing multidisciplinary collaboration	• reach and commitment of societal stakeholders • appropriate plans for societal interaction and outreach • resources for managing societal interaction and for stakeholders to take up and utilize the results	• involvement of a broad variety of actors in programme activities • resources for training and organizational learning
Activities	• appropriate methods and practices for multi- and transdisciplinary research and collaboration, and for researchers' capacity building • national and international networking, keep up with the state of the art • training and supervision	• timely involvement of knowledge users; responsiveness to their needs • active and constructive participation by knowledge users • public engagement	• promotion of responsible research: equality and nondiscrimination, research ethics, open knowledge and innovation • setting up practices and tools for co-production, mutual learning, and capacity building
Output	• productivity • significance, novelty, and innovation of results beyond single disciplines • dissemination, visibility and accessibility of publications and other outputs	• useful results and outputs • effective, timely, and easy-to-understand communication of results to stakeholders and relevant publics	• useful results and outputs made and kept available for use by multiple beneficiaries • clear ownership and licensing of intellectual property • scalability and applicability of solutions
Outcomes	• enhanced knowledge of the state of the art and best practices • integration or transformation of existing disciplinary knowledge, methods, and practices • advancement of multidisciplinary research careers	• new knowledge used in concrete solutions, such as models, practices, guidelines, technologies, etc. • changes in practices, policies, behaviours, attitudes, etc., influenced by the research • specific expectations of the programme	• enhanced capacity of stakeholders to absorb and utilize research-based knowledge • acquiring new resources for continuing the work • promotion of new and versatile career paths, including mobility across organisations and sectors

Appendix 3: List of materials used in the evaluation

Background information of the SRC funding scheme and the specific programme

- Strategic research brochure (updated in 2023)
- 2015 calls by the SRC (original calls for funding for this programme)
- 2017 call for a second funding period
- SRC funding principles 2022
- Kivistö et al. 2022: Evaluation of SRC funding instrument (machine translation) + original evaluation report in Finnish

Information from funding applications etc.

- Original funding applications of the six projects (2015)
- Publicly available "situational picture reports" written by the projects at the start of the programme in 2015 (machine translation) + original situational picture reports in Finnish
- Composition of the programme: involved organizations, involved key research fields, amounts of funding awarded
- List of the projects' collaborators

Information from the projects' research reports

- Research implementation and results (text, ~35 pages altogether)
- Important new research funding (list)
- Research visits from Finland to abroad and vice versa (list)
- Degrees completed within the projects (list)
- Produced data sets (list)
- Immaterial rights (list)
- Personnel key figures (number of staff, career stages, gender)

Publications

- 10 most important publications of each project (as a table and full text pdf-documents)
- List of all publications produced under the programme
- Publication analyses (overall statistics of all publications produced under the programme, and more detailed statistics of verified peer reviewed scientific publications)

Survey results

- Results of a self-evaluation questionnaire for consortium members (21 respondents from the TECH programme, 75 respondents in total)
- Results of a survey for stakeholders of SRC programmes (9 respondents from the TECH programme, 33 respondents in total)

Impact stories etc.

- All impact stories by the projects (altogether 25 stories) at the end of the programme (machine translation) + original impact stories in Finnish
- Summaries of the impact stories, written by Academy staff
- Impact story by the programme director at the end of the programme (machine translation) + original impact story in Finnish
- Annual reports from the programme director: 2019, 2020, 2021 (machine translation)

Interview material

- Video recording of the interviews on 13 and 14 March
- Notes of the interviews on 13 and 14 March
- Powerpoint presentation of one interviewee
- List of 10 key stakeholders of each project and the programme director, and emailed responses from selected stakeholders to the panel's questions

Appendix 4: List of interviewees

Consortium representatives

- Robin Gustafsson, DDI
- Juha Hyyppä, COMBAT
- Kimmo Karhu, DDI
- Maria Kopsakangas-Savolainen, BCDC
- Arto Laitinen, ROSE
- Ilkka Lakaniemi, PVN
- Ahti Salo, PVN
- Armi Temmes, SET

Programme director

- Heli Koski

Stakeholder representatives who responded via email

- Kalle Kärhä, Stora Enso
- Anni Lausvaara, The Confederation of Elderly Work
- Jukka Ruusunen, Fingrid
- Simo Säynevirta, ABB
- Timo Sääski, Geotrim

Appendix 5: Personnel key figures

The figures below show simple statistics of the academic and other staff who worked in the projects under the TECH programme during the years 2015–2021. The figures are based on salary payment data and refer to the number of persons (headcount) instead of full-time equivalent person years. The total number of staff in Figure 1 is different from the total number in Figures 2–3, because several persons among the aca-demic staff had worked at different career stages during the funding period.

Figure 1. Number of staff by career stage and gender in TECH programme.

The academic staff have been divided into four categories according to a model of a four-stage research career path which is used at Finnish universities. The stages of the research career path are as follows:
Stage I: Doctoral student, early-career researcher, etc.
Stage II: Postdoctoral researcher, etc.
Stage III: University lecturer, Academy Research Fellow etc.
Stage IV: Professor, Academy Professor, research professor, research director, etc.
Other: Support and management staff, who did not act as researchers in a project; for example, re-search assistants, interaction coordinators, “technical” PIs

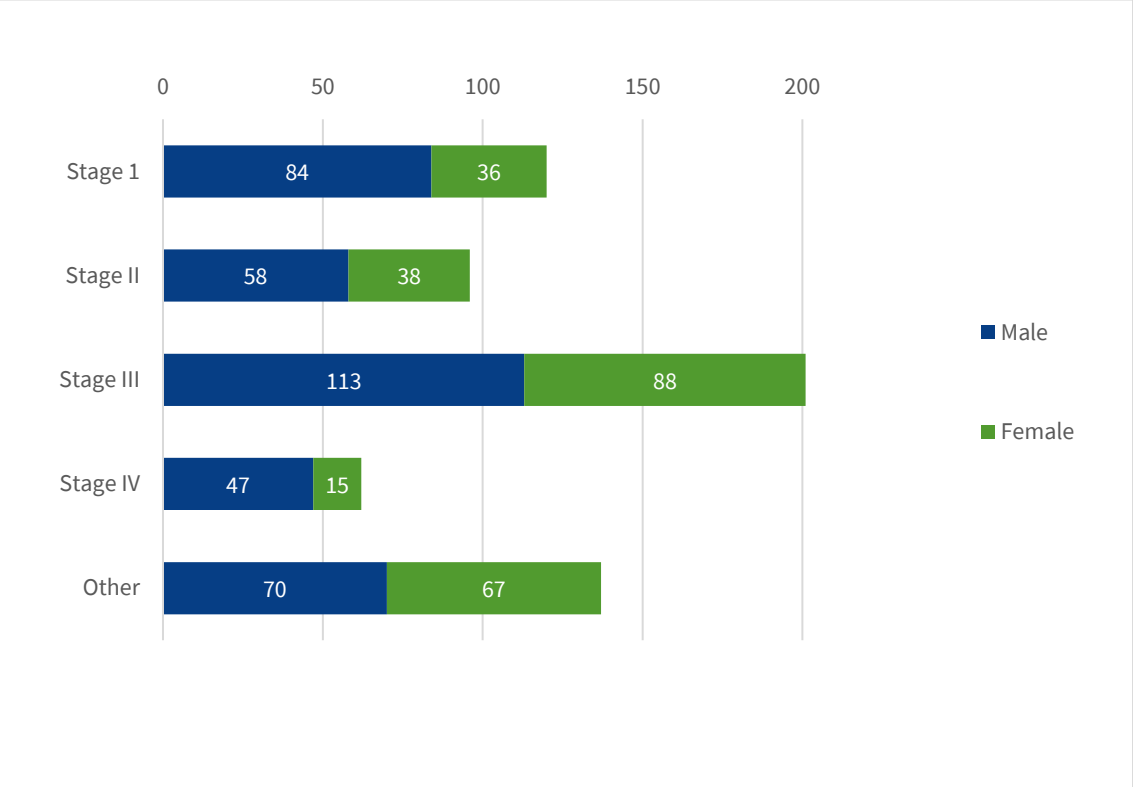


Figure 2. Number of staff by nationality in TECH programme.

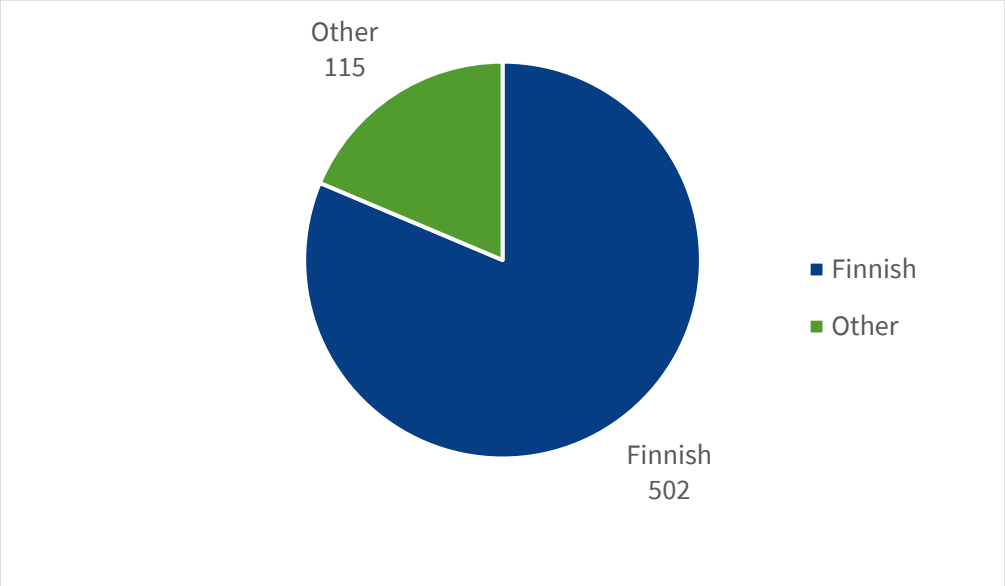
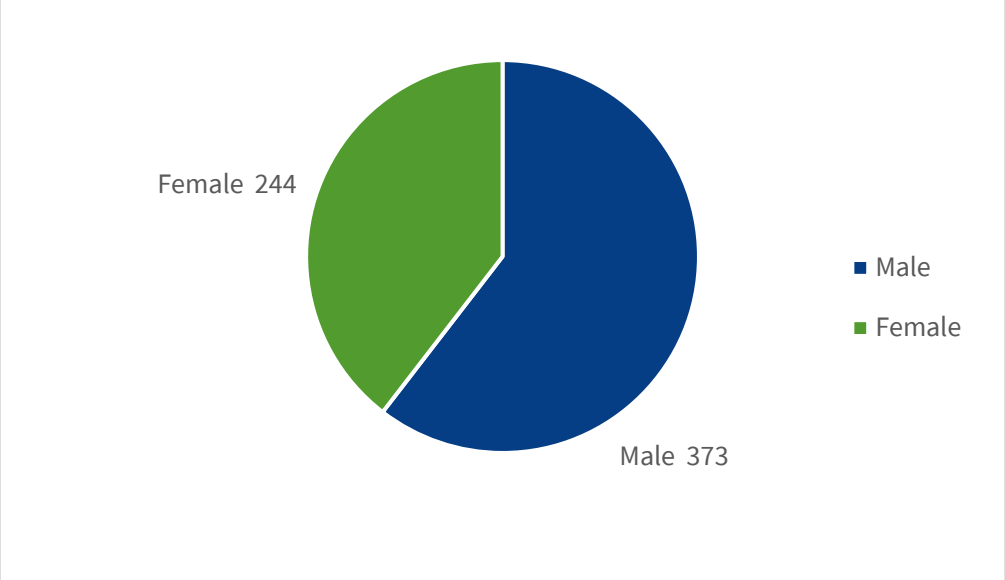


Figure 3. Number of staff by gender in TECH programme.



Appendix 6: List of projects' collaborators

List of projects' collaborators (organisations) mentioned in the funding applications.

In Finland

- 3Point Oy
- Aalto university
- Adminotech Oy
- Argone Oy
- Bank of Finland
- Capisso Oy
- Carbon Neutral Municipality Forum
- Caruna Ltd
- Central Organisation of Finnish Trade Unions (SAK)
- Cinia Ltd
- City of Espoo
- City of Helsinki
- Cleworks Ltd
- CLIC innovation Ltd
- Codento Ltd
- Confederation of the Finnish Industries (EK)
- Cortex Ventures Oy
- Destia Oy
- Digile Oy
- DIMECC Oy
- EKE-Yhtiöt
- Fastems Oy
- FCG Finnish Consulting Group Oy
- Federation of Finnish Technology Industries
- FIHTA - Healthtech Finland
- FIMECC Oy (Finnish Metals and Engineering Competence Cluster Ltd)
- Fingrid Ltd

- Finland Chamber of Commerce
- Finnet Ltd
- Finnish Board of Taxation
- Finnish Confederation of Salaried Employees (STTK)
- Finnish Environment Institute (SYKE)
- Finnish Federation for Communications and Teleinformatics
- Finnish Industrial Internet Forum
- Fortum Ltd
- Futurice
- Geotrim Oy
- GIM Oy (GIM Robotics)
- HBE
- Helen Ltd
- Heureka
- Humak University of Applied Sciences
- InfraKAT Oy
- IPR University Center, Hanken School of Economics
- Kemppi Oy
- Lähienergialiitto
- Merius Oy
- Mesensei Oy
- Metsähallitus
- Metsäteho Oy
- Ministry of Agriculture and Forestry
- Ministry of Defence
- Ministry of Economy and Employment
- Ministry of Environment
- Ministry of Foreign Affairs
- Ministry of Social Affairs and Health (STM)
- Ministry of Transport and Communications
- Ministry of Transport and Communications (LVM)

- Mitaten Oy
- Municipality of Sipoo
- National Land Survey of Finland, Topografic Data
- Nets Finland Oy
- Nexit Ventures
- Next Eagle Oy
- NIB Ltd
- Nokia Oyj
- Nordic Investment Bank
- Ottoboni
- Peab Oy
- Ponsse Oyj
- Porvoon Energia Ltd
- Rapid Action Group Ltd
- Research Institute of the Finnish Economy (ETLA)
- RYM Oy
- Seedi Oy
- Sharper Shape Oy
- Siili Ltd
- SITO Oy
- Sitra
- South-Eastern Finland University of Applied Sciences (XAMK)
- Sova3D - Studio of Virtual Architecture Oy
- Sovelto Oyj
- SRV Rakennus Oy
- Stora Enso
- Stora Enso Wood Supply Finland
- Taaleri Ltd
- Talokeskus
- Teknologian tutkimuskeskus VTT Oy
- TerraTec Oy

- The Age Institute (Ikäinstituutti)
- The Association of Social Service Employers (Sosiaalialan työnantajat)
- The City of Vantaa
- The Federation of Finnish Enterprises (Suomen Yrittäjät)
- The Finnish Association for the Welfare of Older People (Vanhustyönkeskusliitto)
- The Finnish Institute of Bioethics
- The trade union for the public and welfare services (JHL)
- The Union of Health and Social Care Professionals in Finland (Tehy)
- Tieto Oyj
- Trafix Oy
- University of Arts
- University of Jyväskylä
- University of Tampere -2018
- University of Tampere -2018
- University of Turku, Turku School of Economics
- UPM-Kymmene Oyj
- Valtra Inc.
- Vantaan Energia Ltd
- Wärtsilä Ltd

Beyond Finland

- Aarhus University
- Alpen-Adria Universität Klagenfurt
- Boston University, MIT Sloan School
- Brandenburg University of Technology
- Carleton University
- Complexity Science Hub Vienna
- Cornell College of Business
- Czech Tecnical University
- Deutsche Forschungszentrum für Künstliche Intelligenz GmbH
- DG DIGIT, European Commission

- DG GROW, European Commission
- DXC Technology Ltd
- Educore BV
- European Committee of the Regions
- George Mason University
- German Chamber of Commerce, DIHK
- German Ministry for Economy and Industry
- HTF Stuttgart
- Joint Research Center (JRC), European Commission
- Linköping University
- Mälardalen University
- National Institute of Advanced Industrial Science and Technology (AIST)
- Opinar
- Pacific Forestry Center
- Ramboll, Infrastructure and transport
- Science and Technology Policy Institute
- Shinshu University
- SSAB
- Stanford University
- Tallinn University of Technology
- Technische Universität Wien
- Technological University of Delft
- Texas A&M University
- Tohoku Fukushi of University
- Tokyo Institute of Technology
- Università Politecnica delle Marche
- University Estadual Paulista
- University of Bath
- University of Brescia
- University of California at Berkeley
- University of Darmstadt

- University of Lausanne
- University of Napoli “Federico II”
- University of Skövde
- University of Southampton, UK
- University of Southern Denmark
- University of Southern Denmark, the Maersk Mc-Kinney Moller Institute
- University of St. Gallen / Boston Consulting Group
- University of Stuttgart
- University of Technology Sydney
- University of Technology Sydney
- University of Texas
- University of Twente
- University of Vienna
- University of Würzburg
- Virginia Tech
- ZHAW, Zürich

Appendix 7: Top10 outputs from each project

Table 5. BCDC Energy

Year	Authors	Title	Journal or Publisher
2016	Nardelli P.H.J., de Castro Tomé M., Alves H., de Lima C.H.M. & Latva-aho M.	Maximizing the Link Throughput between Smart Meters and Aggregators As Secondary Users under Power and Outage Constraints	Ad Hoc Networks
2017 - 2018	Tuomela S., Huotari M.-L., Ali S., de Castro Tomé M., Ding C., Ikonen K., Innanen K., Kangasharju J., Karhinen S., Kühnlenz F., Lindfors A., Markkula J., Nardelli P., Niemelä S., Pouttu A., Ramezanipour I., Suorsa A., Teirilä J., Waltari O. & Svento, R.	Clean Energy Research terminology	The Helsinki Term Bank for the Arts and Sciences
2018	Kuhnlenz, F., Nardelli, P.H.J., Karhinen, S. & Svento, R.	Implementing flexible demand: Real-time price vs. market integration	Energy
2019	Karhinen, S. & Huuki, H.	Private and social benefits of a pumped hydro energy storage with increasing amount of wind power	Energy Economics
2019	Suorsa, A., Svento, R., Lindfors, A., & Huotari, M.-L.	Knowledge creation and interaction in an R&D project: the case of the Energy Weather Forecast	Journal of Documentation
2020	Huuki, H., Karhinen, S., Kopsakangas-Savolainen, M., Svento, R.	Flexible demand and supply as enablers of variable energy integration	Journal of Cleaner Production
2020	Huuki H., Karhinen S., Böök H., Lindfors A.V., Kopsakangas-Savolainen M. & Svento R.	Utilizing the flexibility of distributed thermal storage in solar power forecast error cost minimization	Journal of Energy Storage
2020	Koivumäki, K. & Wilkinson, C.	Exploring the intersections: researchers and communication professionals' perspectives on the organizational role of science communication	Journal of Communication Management
2021	Tuomela S., de Castro Tomé M., Iivari N. & Svento R.	Impacts of home energy management systems on electricity consumption	Applied Energy
2022	Ruokamo E., Meriläinen T., Karhinen S., Räihä J., Suur-Uski P., Timonen L. & Svento R.	The effect of information nudges on energy saving: Observations from a randomized field experiment in Finland	Energy Policy

Table 6. COMBAT

Year	Authors	Title	Journal or Publisher
2015	Yu X, Hyyppä J, Karjalainen M, Nurminen K, Karila K, Vastaranta M, Kankare V, Kaartinen H, Holopainen M, Honkavaara E, Kukko A, Jaakkola A, Liang X, Wang Y, Hyyppä H & Katoh M	Comparison of Laser and Stereo Optical, SAR and InSAR Point Clouds from Air- and Space-Borne Sources in the Retrieval of Forest Inventory Attributes	Remote Sensing
2016	Liang X, Kankare V, Hyyppä J, Wang Y, Kukko A, Haggrén H, Yu X, Kaartinen H, Jaakkola A, Guan F, Holopainen M & Vastaranta M	Terrestrial laser scanning in forest inventories	ISPRS Journal of Photogrammetry and Remote Sensing
2017	Palonen T, Hyyti H & Visala A	Augmented Reality in Forest Machine Cabin	Proceedings of the 20th World Congress of the International Federation of Automatic Control (IFAC 2017)
2018	Pouke M, Ylipulli J, Minyaev I, Pakanen M, Alavesa P, Alatalo T & Ojala T	Virtual Library - Blending mirror and fantasy layers into a VR interface for a public library	Proc. 17th International Conference on Mobile and Ubiquitous Multimedia (MUM 2018)
2018	Lotsari E, Calle M, Benito G, Kukko A, Kaartinen H, Hyyppä J, Hyyppä H & Alho P	Topographical change caused by moderate and small floods in a gravel bed ephemeral river – a depth-averaged morphodynamic simulation approach	Earth Surface Dynamics
2018	Julin A, Jaalama K, Virtanen J-P, Pouke M, Ylipulli J, Vaaja M, Hyyppä J & Hyyppä H	Characterizing 3D City Modeling Projects: Towards a Harmonized Interoperable System.	ISPRS International Journal of Geo-Information
2020	Hyyppä E, Hyyppä J, Hakala T, Kukko A, Wulder M, White J, Pyörälä J, Yu X, Wang Y, Virtanen J-P, Pohjavirta O, Liang X, Holopainen M & Harri Kaartinen H	Under-canopy UAV laser scanning for accurate forest field measurements	ISPRS Journal of Photogrammetry and Remote Sensing
2020	Lotsari E, Hackney C, Salmela J, Kasvi E, Kemp J, Alho P & Darby S	Sub-arctic river bank dynamics and driving processes during the open-channel flow period	Earth Surface Processes and Landforms
2021	Pouke M, Mimnaugh KJ, Chambers AP, Ojala T & LaValle SM	The Plausibility Paradox for Resized Users in Virtual Environments	Frontiers in Virtual Reality
2021	Virtanen J-P, Jaalama K, Puustinen T, Julin A, Hyyppä J & Hyyppä H	Near Real-Time Semantic View Analysis of 3D City Models in Web Browser	ISPRS International Journal of Geo-Information

Table 7. DDI

Year	Authors	Title	Journal or Publisher
2017	Lavikka R. et al.	Co-creating Digital Services with and for Facilities Management	Facilities
2017	Tura N., Kutvonen A., Ritala P.	Platform design framework: conceptualisation and application	Technology Analysis & Strategic Management
2017	Räsänen P. et al.	Between class and status? Examining the digital divide in three European societies	The Information Society
2018	Karhu K., Gustafsson R., Lyytinen K.	Exploiting and Defending Open Digital Platforms with Boundary Resources: Android's Five Platform Forks	Information Systems Research
2018	Järvi K. et al.	Organization of knowledge ecosystems: Prefigurative and partial forms	Research Policy
2018	Blomqvist K. et al.	Swift Trust - State-of-the-Art and Future Research Directions	In: The Routledge Companion to Trust, Edited by Rosalind H. Searle, Ann-Marie I. Nienaber, and Sim B. Sitkin. Routledge.
2018	Kalimo H., Meyer T., Mylly T.	Of Values and Legitimacy – Discourse Analytical Insights on the Copyright Case Law of the Court of Justice of the European Union	The Modern Law Review
2018	Kilkki, K., Mäntylä, M., Karhu, K., Hämmäinen, H., Ailisto, H.	A disruption framework	Technological Forecasting and Social Change 129, 275–284.
2018	Vesselkov A. et al.	Technology and value network evolution in telehealth	Technological Forecasting and Social Change
2018	Oertzen A. et al.	Co-creating services—conceptual clarification, forms, and outcomes	Journal of Service Management

Table 8. PVN

Year	Authors	Title	Journal or Publisher
2018	Autio, E., and Thomas, L.D.W.	Management of Entrepreneurial Ecosystems	The Wiley Handbook of Entrepreneurship
2018	Watanabe, C.; Naveed, K.; Neittaanmäki, P.	Digitalized bioeconomy: Planned obsolescence-driven circular economy enabled by Co-Evolutionary coupling	Technology in Society
2018	Zavala A. and Ramirez- Marquez J. E.	Visual Analytics for Identifying product disruptions and effects via social media	International Journal of Production Economics
2018	Töytäri, P.; Turunen, T.; Klein, M.; Eloranta, V.; Biehl, S.; Rajala, R.	Aligning the Mindset and Capabilities within a Business Network for Successful Adoption of Smart Services	Journal of Product Innovation Management
2018	Su, Y.S., Kajikawa, Y., Tsujimoto, M. & Chen, J.	Innovation ecosystems: Theory, evidence, practice, and implications	Technological Forecasting and Social Change
2018	Watanabe, C.; Naveed, K.; Tou, Y., Neittaanmäki, P.	Measuring GDP in the digital economy: Increasing dependence on uncaptured GDP	Technological Forecasting and Social Change
2019	Eloranta, V., Hakanen, E., Töytäri, P., and Turunen, T.	Aligning Multilateral Value Creation and Value Capture in Ecosystem-level Business Model	Academy of Management Proceedings
2019	Watanabe, C., Tou, Y.	Transformative direction of R&D: lessons from Amazon's endeavor	Technovation
2021	Könnölä, T., V. Eloranta, T. Turunen and A. Salo	Transformative Governance of Innovation Ecosystems	Technological Forecasting and Social Change
2021	Neittaanmäki, P., Lehto, M., & Savonen, M.	Yhteiskunnan digimurros	Jyväskylän yliopisto

Table 9. ROSE

Year	Authors	Title	Journal or Publisher
2018	Racca M., Kyrki V.	Active robot learning for temporal task models	Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction
2018	Rantanen, T., Lehto, P., Vuorinen, P. & Coco, K.	The Adoption of Care Robots in Home Care - a survey on the attitudes of Finnish home care personnel	Journal of Clinical Nursing
2019	Pekkarinen, S., Tuisku, O., Hennala, L., Melkas, H.	Robotics in Finnish welfare services: dynamics in an emerging innovation ecosystem	European Planning Studies
2019	Laitinen, A., Niemelä, M., & Pirhonen, J.	Demands of Dignity in Robotic Care: Recognizing Vulnerability, Agency, and Subjectivity in Robot-based, Robot-assisted, and Teleoperated Elderly Care	Techné: Research in Philosophy and Technology
2019	Turja, T., & Oksanen, A.	Robot acceptance at work: A multilevel analysis based on 27 EU countries	International Journal of Social Robotics
2020	Melkas, H., Hennala, L., Pekkarinen, S. & Kyrki, V.	Impacts of robot implementation on care personnel and clients in elderly-care institutions	International Journal of Medical Informatics
2020	Rantanen, T., Leppälahti, T., Porokuokka, J. & Heikkinen, S.	Impacts of a Care Robotics Project on Finnish Home Care Workers' Attitudes towards Robots	International Journal of Environmental Research and Public Health
2020	Hietanen A., Pieters R., Lanz M., Latokartano J. and Kämäräinen J.K.	AR-based Interaction for Human-robot Collaboration	Robotics and Computer-Integrated Manufacturing
2021	Niemelä, M., Heikkinen, S., Koistinen, P., Laakso, K., Melkas, H., & Kyrki, V. (eds.)	Robots and the Future of Welfare Services - A Finnish Roadmap	Aalto University publication series CROSSOVER, 4/2021
2021	Krutova, O; Koistinen, P; Turja, T; Melin, H; Särkikoski, T.	Two sides, but not of the same coin: Digitalization, productivity and unemployment	International Journal of Productivity and Performance Management

Table 10. SET

Year	Authors	Title	Journal or Publisher
2017	Neij, L., Heiskanen, E., & Strupeit, L.	The deployment of new energy technologies and the need for local learning	Energy Policy
2017	Heiskanen, E., & Matschoss, K.	Understanding the uneven diffusion of building-scale renewable energy systems: A review of household, local and country level factors in diverse European countries.	Renewable and Sustainable Energy Reviews
2018	Annala, S.; Lukkarinen, J.; Primmer, E.; Honkapuro, S.; Ollikka, K.; Sunila, K. & Ahonen, T.	Regulation as an enabler of demand response in electricity markets and power systems	Journal of Cleaner Production
2019	Hyysalo, S., Marttila, T., Perikangas, S., & Auvinen, K.	Codesign for transitions governance: A mid-range pathway creation toolset for accelerating sociotechnical change	Design Studies
2019	Rinne, S.; Auvinen, K. ; Reda, F. ; Ruggiero, S. ; Temmes, A.	Clean district heating - how can it work?	Aalto University publication series BUSINESS + ECONOMY, 3/2019
2020	Sillman, J., Uusitalo, V., Ruuskanen, V., Ojala, L., Kahiluoto, H., Soukka, R. & Ahola, J .	A life cycle environmental sustainability analysis of microbial protein production via power-to-food approaches	International Journal of Life Cycle Assessment
2021	Spodniak, P., Ollikka, K., and Honkapuro, S.	The Impact of Wind Power and Electricity Demand on the Relevance of Different Short-term Electricity Markets: The Nordic Case.	Applied Energy
2021	Kangas, H.-L., Ruggiero, S., Annala, S., & Ohrling, T.	Would turkeys vote for Christmas? New entrant strategies and coopetitive tensions in the emerging demand response industry	Energy Research & Social Science
2021	Laitinen A, Lindholm O, Hasan A, Reda F, Hedman Å.	A techno-economic analysis of an optimal self-sufficient district.	Energy Conversion and Management
2022	Kivimaa, P., Rogge, K.	Interplay of policy experimentation and institutional change in sustainability transitions: The case of mobility as a service in Finland	Research Policy

Appendix 8: Publication profile

All publications

The projects under the TECH programme reported several types of publications in their final reports according to the national publication type classification:[8]

A. Peer-reviewed scientific articles

B. Non-refereed scientific articles

C. Scientific books (monographs)

D. Publications intended for professional communities

E. Publications intended for the general public

F. Public artistic and design activities

G. Theses

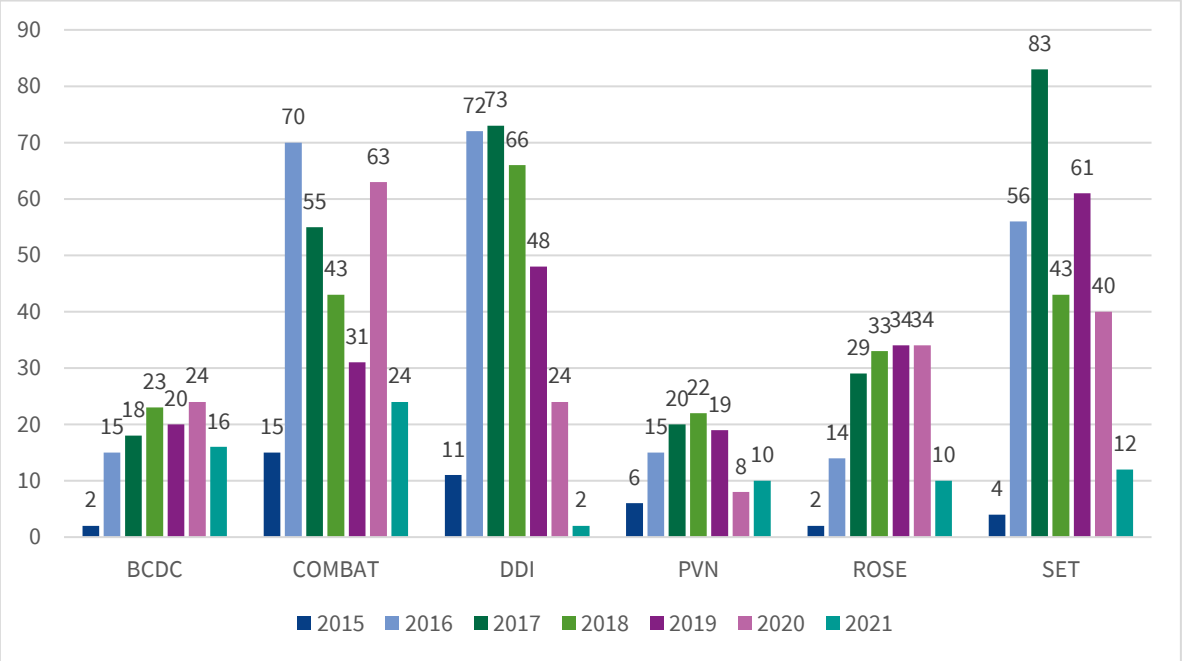
H. Audiovisual publications and ICT applications.

Table 11. Number of publications reported by the TECH projects and the programme as a whole in 2015–2021.

Project	All publications	Scientific publications (A, B, C)
BCDC	118	114
COMBAT	301	181
DDI	296	203
PVN	100	98
ROSE	156	123
SET	299	103
TECH programme	**1270**	**822**

[8] More information about the publication type classification (see pages 7-11): https://wiki.eduuni.fi/display/cscsuorat/Julkaisutiedonkeruun+tutkijaohjeistukset?preview=/39984924/256871940/2021_Publication%20data%20collection%20instructions%20for%20researchers.pdf

Figure 4. Number of publications by year reported by the TECH projects and the programme as a whole.



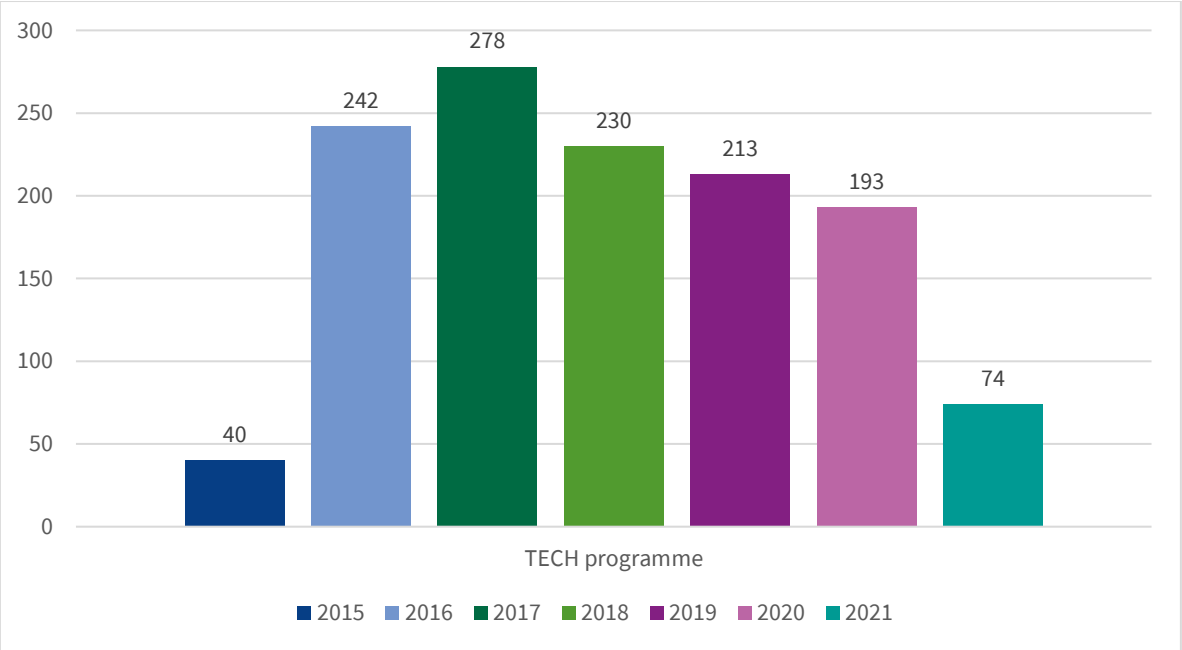
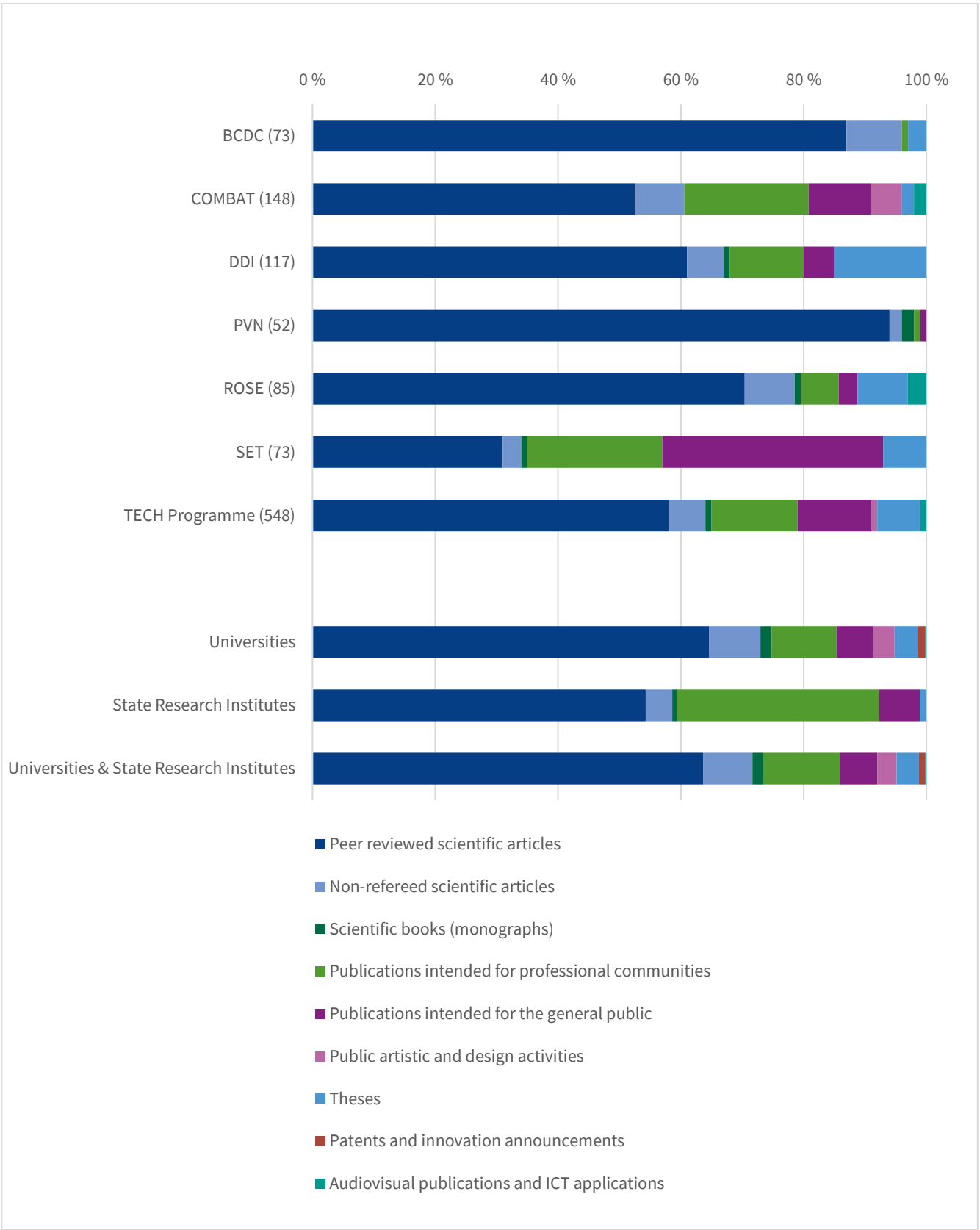


Figure 5. Share (%) of different publication types reported by the TECH projects and the programme as a whole, as well as in Finnish universities and state research institutes (as separate categories and together).



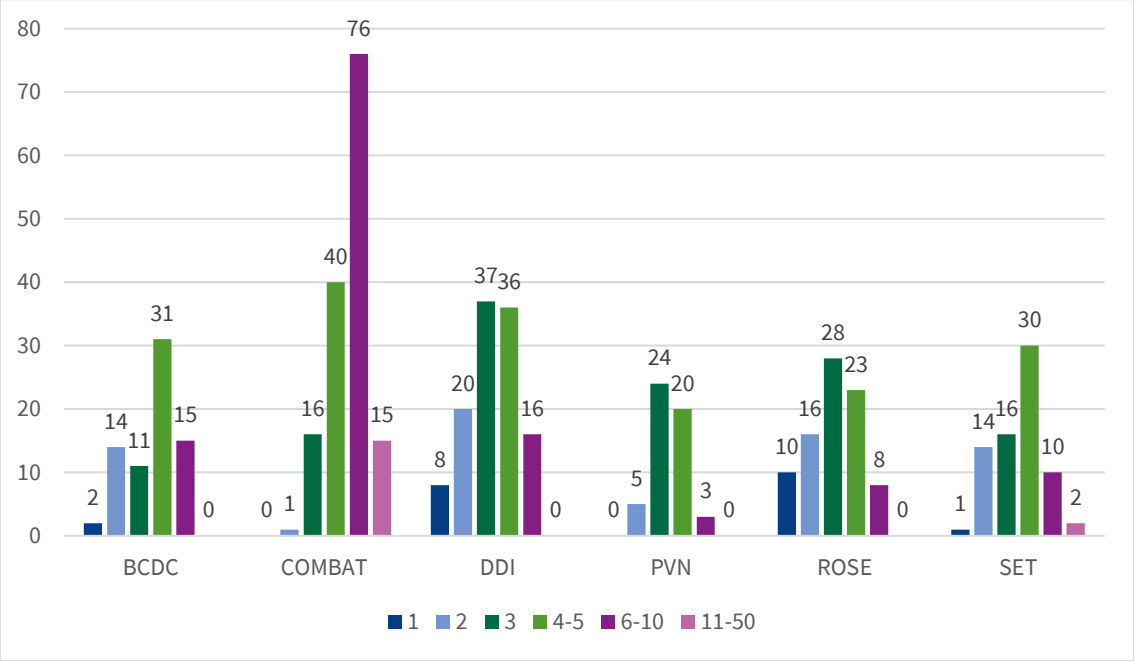
Appendix 9: Analysis of peer-reviewed publications

For a more detailed analysis of peer-reviewed scientific publications of the TECH programme, publication data reported by the projects was supplemented with metadata from the national publication data collection VIRTA. VIRTA covers most publications from Finnish universities, universities of applied sciences, university hospitals and most state research institutes. The coverage of VIRTA data in terms of the publications reported by the TECH projects is presented in Table 12. The analyses presented in this appendix include only those TECH programme publications that were found in VIRTA.

Table 12. Number of peer-reviewed TECH publications in the VIRTA and their share of the peer-reviewed publications reported by the projects in 2015–2021.

Project	Number of peer-reviewed publications in VIRTA	Share in reported publications
BCDC	73	71%
COMBAT	148	94%
DDI	117	63%
PVN	52	54%
ROSE	85	77%
SET	73	77%
TECH programme	**548**	**73%**

Figure 6. Number of authors per publication in the TECH projects and the programme as a whole.



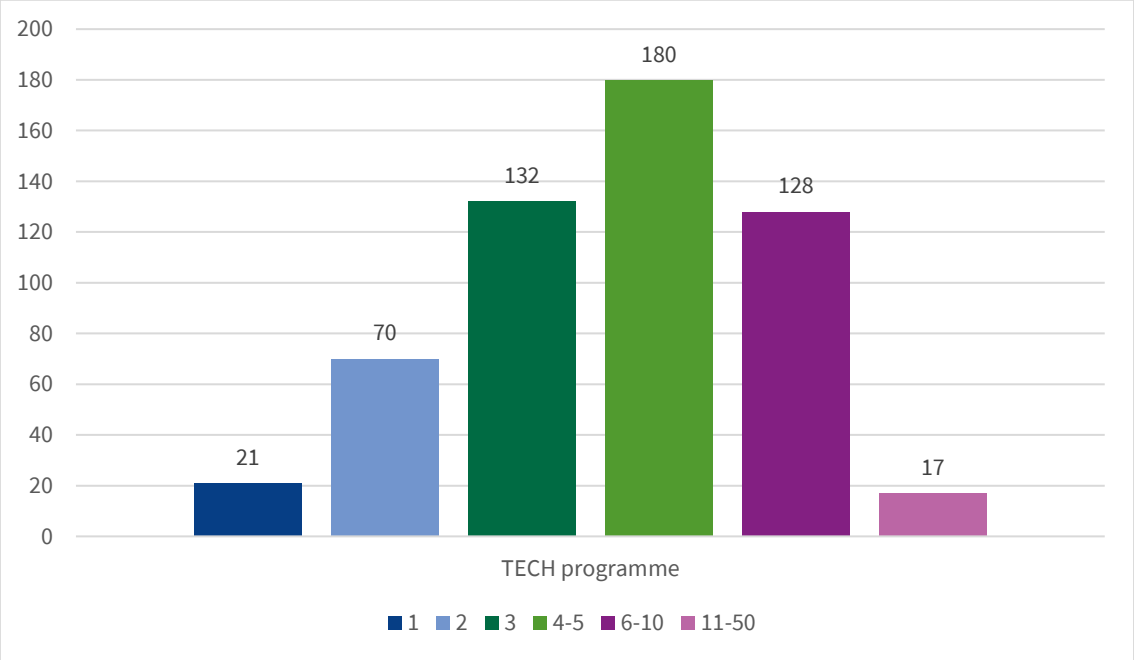


Figure 7. Language of publications in the TECH projects and the programme as a whole.

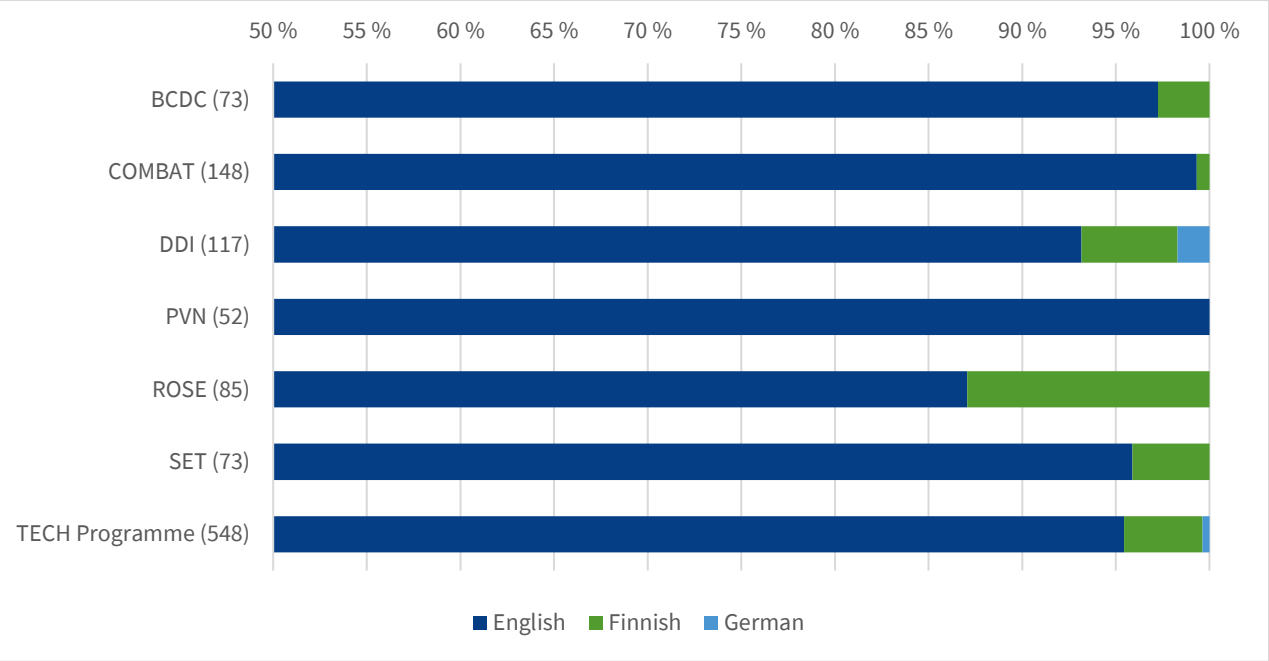


Figure 8. Share of national and international publications (%) in the TECH projects and the programme as a whole, as well as in Finnish universities and state research institutes (as separate categories and together).

A national publication means a publication that is published by a Finnish publisher or is primarily published in Finland. An international publication means a publication that is not published by a Finnish publisher or is primarily published elsewhere than in Finland. For conference publications, publisher means the publisher of the conference publication.

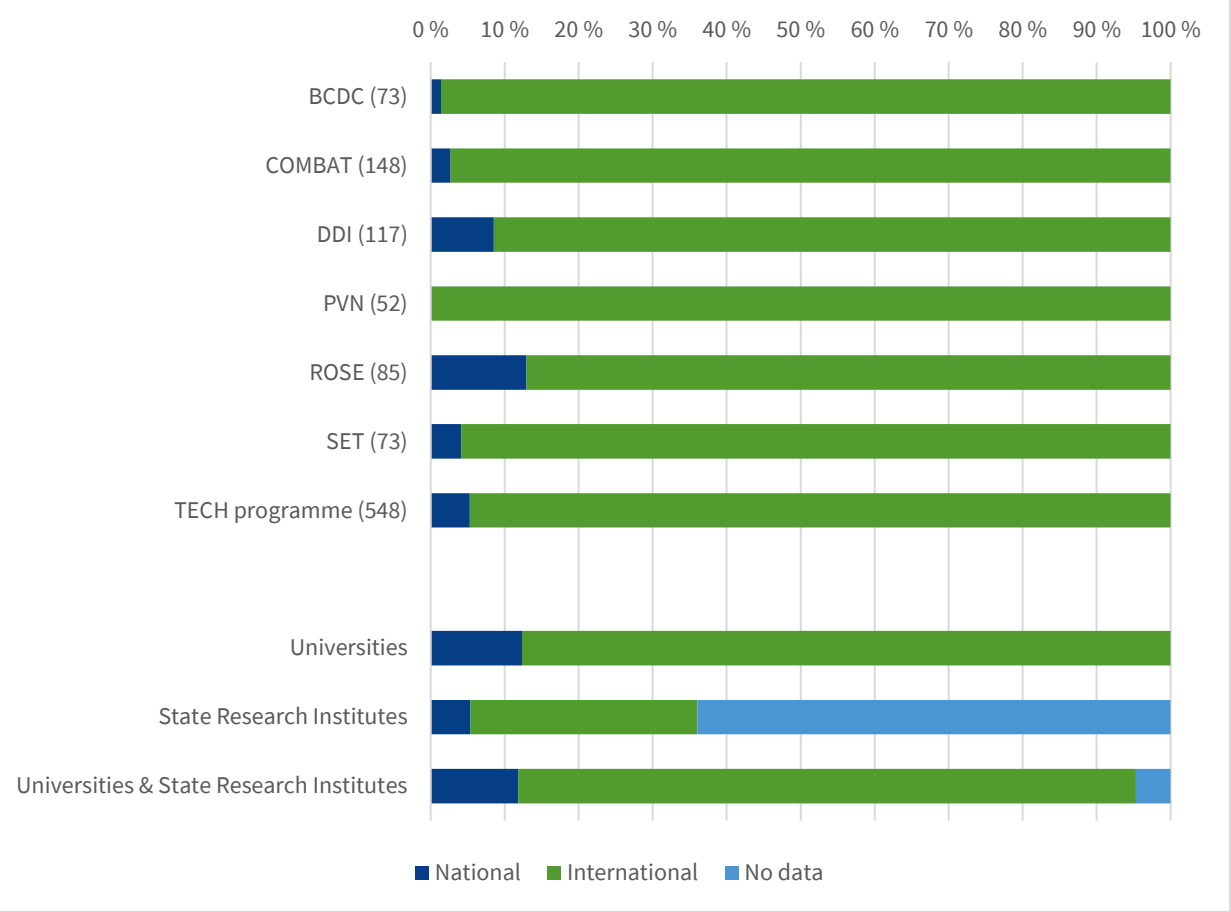


Figure 9. Share of international co-authoring (%) in the TECH projects and the programme as a whole, as well as in Finnish universities and state research institutes (as separate categories and together).

At least one author of an internationally co-authored publication is affiliated to a non-Finnish organisation (the author may also be affiliated to both a Finnish and a foreign organisation). The foreign editor of the publication channel does not yet meet the criteria for international co-publication.

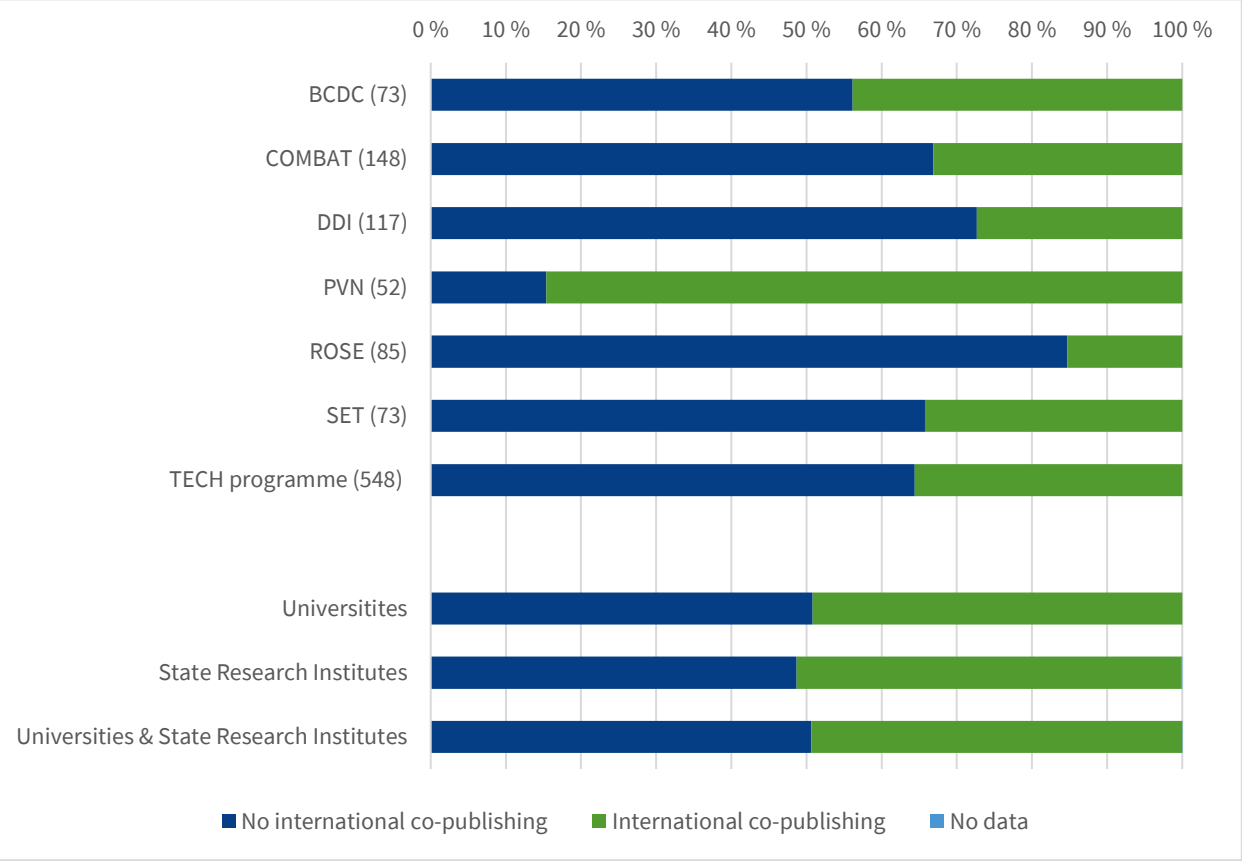
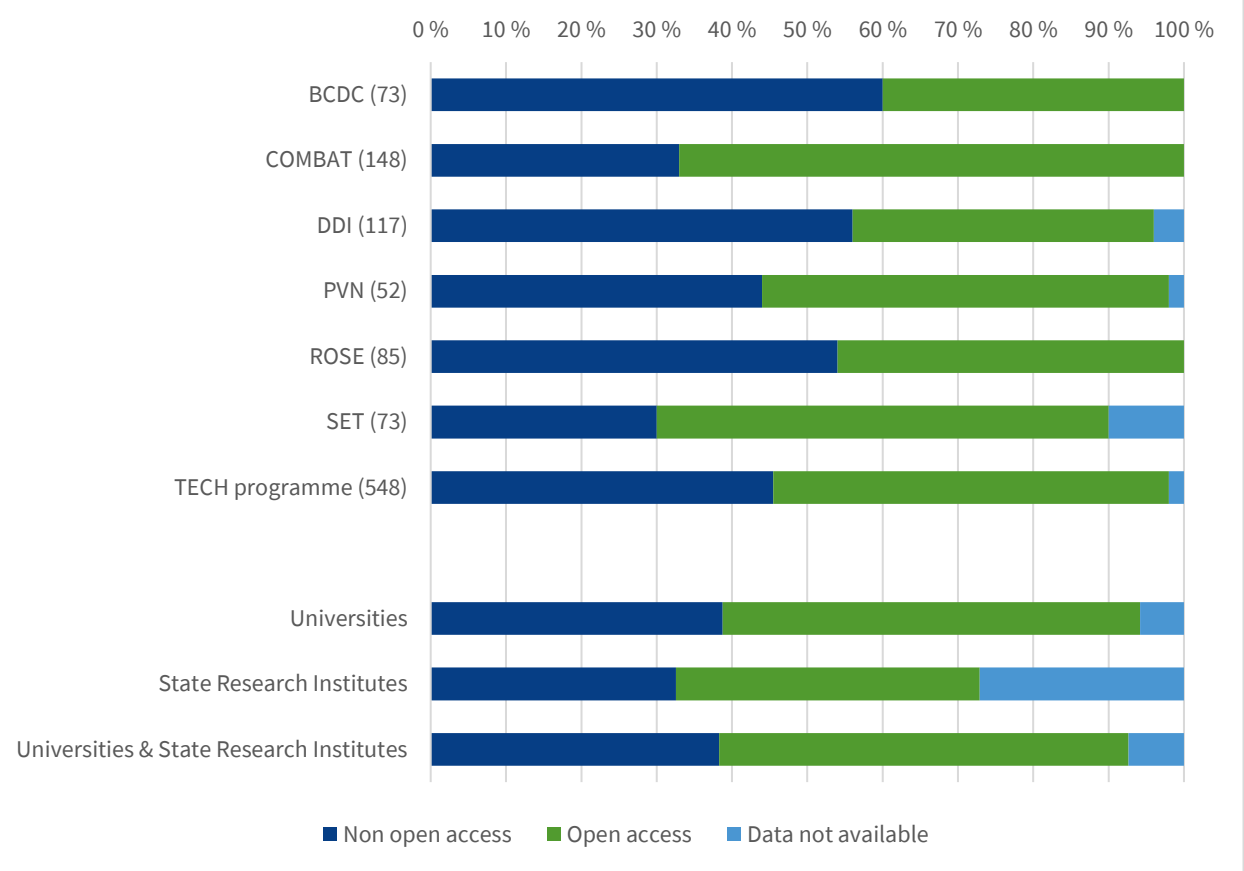


Figure 10. Share of open access publications (%) in the TECH projects and the programme as a whole, as well as in Finnish universities and state research institutes (as separate categories and together).

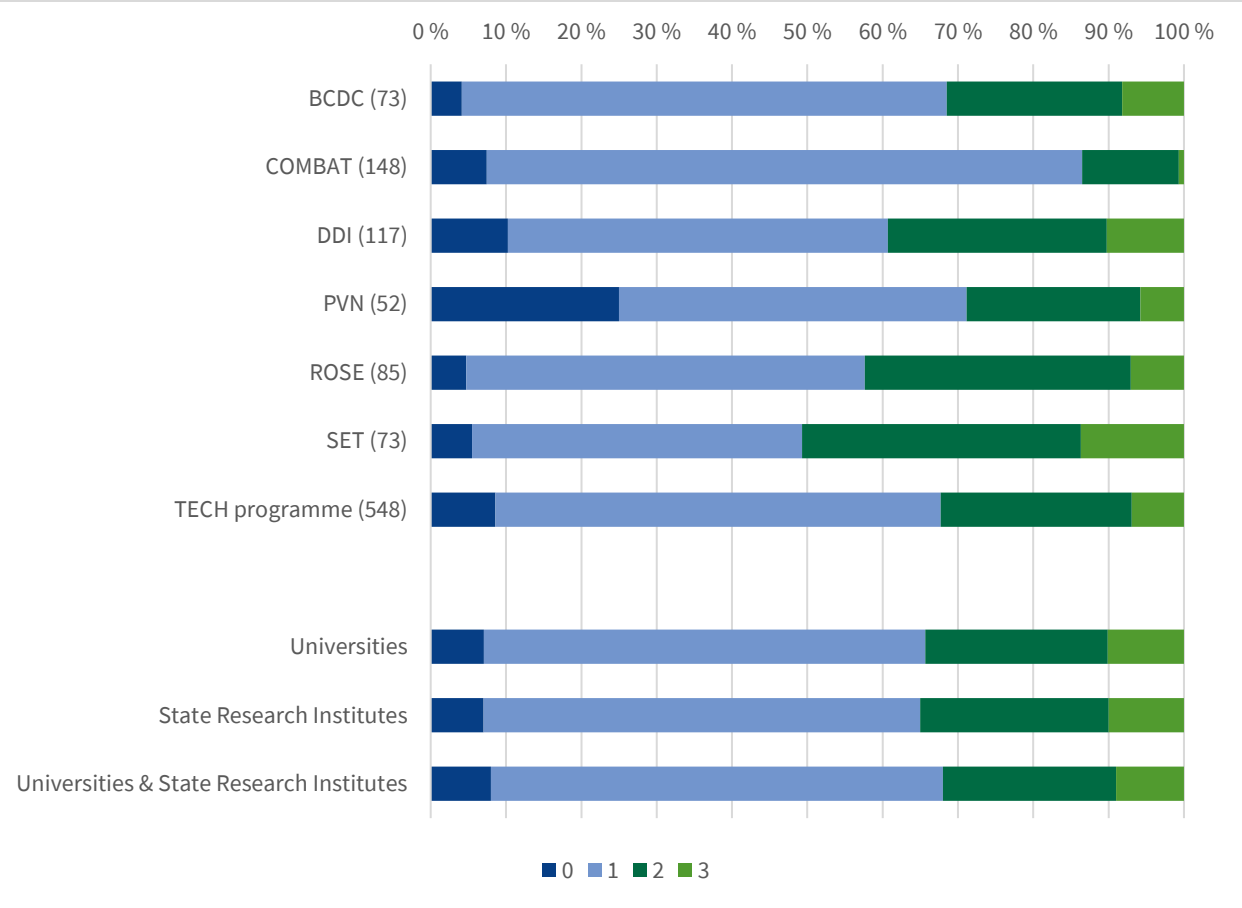
Open access refers here to all modes of open access publishing defined in the national publication data collection. [9]



[9] More information about open access publishing: https://wiki.eduuni.fi/display/cscsuorat/Julkaisutiedonkeruun+tutkijaohjeistukset?preview=/39984924/256871940/2021_Publication%20data%20collection%20instructions%20for%20researchers.pdf, pages 12–13.

Figure 11. Share of publications at different Publication Forum (JUFO) levels (%) in the TECH projects and the programme as a whole, as well as in Finnish universities and state research institutes (as separate categories and together).

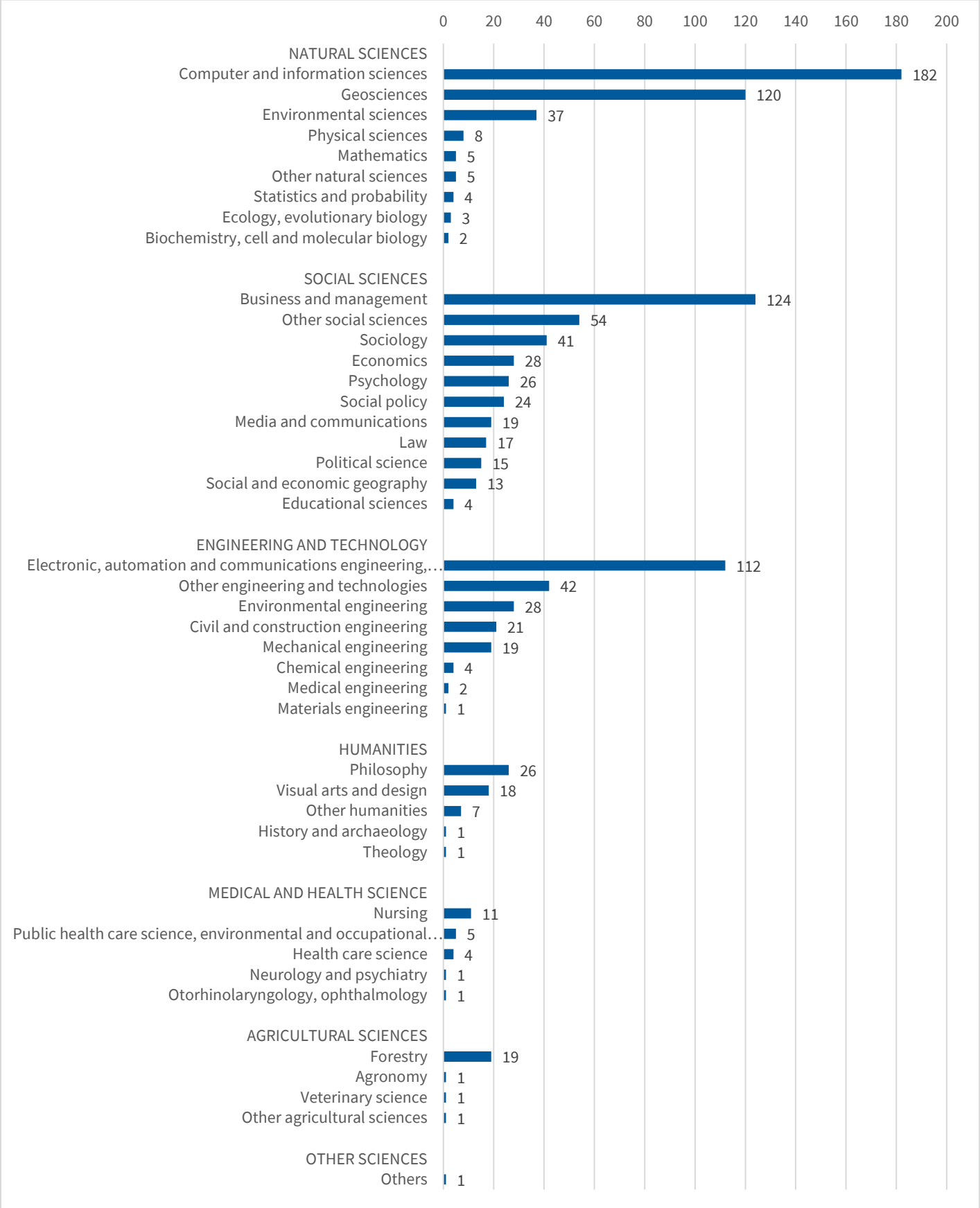
JUFO is a rating and classification system to support the quality assessment of research output. The four-level classification rates the major foreign and domestic publication channels of all disciplines as follows: 1 = basic level; 2 = leading level; 3 = highest level; 0 = publication channels that don't (yet) meet the criteria for level 1. To account for the different publication cultures characteristic of various disciplines, the classification includes academic journals, book series, conferences as well as book publishers.[10]



[10] Publication Forum 2022: https://julkaisufoorumi.fi/en/publication-forum)

Figure 12. Fields of science assigned to publications of the TECH programme.

In the national VIRTA publication data collection, one or more fields of science[11] is assigned to a publication. The number of publications is 548, and the number of field assignments is 1058.



[11] Fields of science are derived from Statistics Finland field of science classification: https://www.stat.fi/en/luokitukset/tieteenala/.

Appendix 10: Other research output

Table 13. Research data reported by the TECH projects.

The SRC requires that the projects take charge of the responsible management and opening of research data. The degrees of data openness may justifiably vary, ranging from fully open to strictly confidential. If the research data cannot be made openly available, the metadata must be stored in a Finnish or international data finder.

Project	Research data	Openness	Location
BCDC	No information	No information	No information
COMBAT	A Simple Semantic-based Data Storage Layout for Querying Point Clouds	Yes	https://zenodo.org/record/3540413#.XrK0p6gzZPY
COMBAT	Havis Amanda mesh model (Version 1)	Yes	http://doi.org/10.5281/zenodo.3768777
COMBAT	Eye-tracker complementary restraint components (Version 1)	Yes	http://doi.org/10.5281/zenodo.1246953
COMBAT	Open source software VIATOC	Yes	https://sourceforge.net/p/viatoc/wiki/Home/
DDI	No information	No information	No information
PVN	No information	No information	No information
ROSE	Kysely roboteista innovaationa hyvinvointipalveluissa	No, but metadata is open	https://etsin.fairdata.fi/dataset/597991bb-cb41-4a7c-a414-1da0edf9ca05
ROSE	Monitasohaastattelut hoivarobotiikan tilannekuvasta	No, but metadata is open	https://etsin.fairdata.fi/dataset/c1e60849-bd55-4ec0-b8a9-8994ba83e6ca
ROSE	Kysely kotihoidon työntekijöille 2016 (N=200),	No	
ROSE	Kysely kotihoidon työntekijöille 2019 (N=162)	No	
ROSE	Koodi ja data-aineisto paikallisten piirteiden vertailuun	Yes	https://github.com/kamarain/descriptor_vocbenchmark
ROSE	Koodi ja data-aineisto visuaaliseen paikantamiseen	Yes	https://github.com/JunshengFu/camera-pose-estimation
ROSE	Kysely (T1) hoitotyöntekijöille 2016 (N=3800)	No	
ROSE	Kysely (T2) hoitotyöntekijöille 2020 (N=500)	No	

Project	Research data	Openness	Location
ROSE	Eksoskeleton-kokeilun videoaineisto 2019	No	
ROSE	Eksoskeleton-kokeilun kyselyaineisto 2019	No	
ROSE	Eksoskeleton-kokeilun kenttähavainnot 2019	No	
ROSE	Apteekkikysely	No	
ROSE	Haastatteluaineisto Double3 käytöstä	No	
SET	No information	No information	No information

Table 14. Number of higher education degrees reported by the TECH projects and the programme as a whole.

Project	Master's degree	Doctoral degree
BCDC	4	13
COMBAT	17	11
DDI	4	7
PVN	5	3
ROSE	7	2
SET	14	3
TECH Programme	**51**	**39**

Table 15. Number of research visits reported by the TECH projects and the programme as a whole.

Long-term visits are visits with a total uninterrupted duration of at least one month. Short-term visits are visits with a total uninterrupted duration of at least five working days but less than one month.

Project	Incoming long-term visits	Incoming short-term visits	Outgoing long-term visits	Outgoing short-term visits
BCDC Energy	2	4	7	7
COMBAT	4	10	7	22
DDI	-	1	9	9
PVN	-	2	1	17
ROSE	-	-	4	7
SET	1	1	7	3
TECH Programme	**5**	**14**	**28**	**58**

Table 16. Immaterial rights reported by the TECH projects.

Project	Type	Identifier / Title
BCDC Energy	Invention disclosures	Energy weather forecast service
COMBAT	Spin-offs	Solid Potato Oy
COMBAT	Spin-offs	Gaze Inc, San Francisco
COMBAT	Spin-offs	Arctic RED Oy
COMBAT	Spin-offs	Sharper Shape Group, Palo Alto
COMBAT	Invention disclosures	10 invention disclosures to the National Land Survey of Finland
DDI	Others	Ilmatar Open Innovation Environment (published as open source) is a combination of physical and digital resources that can be used for open innovation around industrial cranes.
SET	Intellectual property rights	Creative Commons BY licensed tools for the transformation arena
SET	Intellectual property rights	Creative Commons BY licensed process description of the transformation arena

Appendix 11: New research funding

Table 17. New research funding reported by the TECH projects and the programme as a whole.

The projects were asked to report important new research funding applications (including at least two members of the SRC project) that continue or advance the research carried out in the SRC programme. The table presents the total amount of reported new funding from national and international funding sources.

Project	National funding, €	International funding, €
BCDC	18 279 000	0
COMBAT	17 140 000	3 640 000
DDI	6 987 584	6 219 756
PVN	218 000	4 960 831
ROSE	813 000	550 000
SET	360 000	37 500
TECH programme	**43 797 584**	**15 408 087**

Appendix 12: Titles of impact stories

The societal impact of SRC consortia is monitored with the help of impact stories. The impact stories are reports that describe and discuss the research and interaction carried out in the project in relation to the joint impact objectives of the programme and the project's own impact targets. Each consortium in the TECH programme was expected to prepare at least three impact stories and update them during the entire period the consortium was active. Most impact stories will be available at the strategic research website.[12]

BCDC Energy

- Large scale integration of renewable energy resources into the electricity system
- The possibilities of BCDC Energy cloud services in improving energy efficiency
- Promoting flexibility and communality in changing electricity markets

COMBAT

- Digitalization of Forests and Forest Machinery
- Technological transition in the measurement of river environments and fairways
- Urban models to support decision-making and inclusion
- Laser scanning of fairways prepares society for the optimisation of fairway data and the world of smart vehicles

DDI

- Industry and decision-makers have a common view of the digital transition
- Finland makes smart use of the opportunities offered by the digital transition
- Industry pioneers make strategic investments in the digital transition and its spearheads

PVN

- Raising Awareness of Policy and Industry Stakeholders
- Developing Strategies and Business Models
- Empowering and Engaging Policy Makers
- Deploying Tools for decision and policy makers
- Generating Insights into Un-captured GDP

[12] Impact in strategic research, Impact stories: https://www.aka.fi/strateginen-tutkimus/strateginen-tutkimus/strateginen-tutkimus-pahkinankuoressa/vaikuttavuus-strategisessa-tutkimuksessa/vaikuttavuuskertomukset

ROSE

- Robotics services for older people, listening to user
- The role of the public sector: from a regulator to an enabler
- Creating technological expertise on welfare robotics in Finland

SET

- How will Finland benefit from the energy transition
- How does Finland steer the energy transition?
- Finland learns from energy pilots and experiments
- Co-creation as a driver of change
- Vision of fossil-free district heating
- Energy efficiency of buildings and flexible energy use
- Promoting multidisciplinary research careers

Appendix 13: The self-evaluation questionnaire

The aim of the self-evaluation questionnaire was to collect information on the success of the completed SRC programmes (EQUA, PIHI, TECH, CITIZEN) and on needs to develop SRC programme funding. The self-evaluation questionnaire was tar-geted at the consortium PIs and deputy PIs, work package and team leaders, and interaction coordinators, to whom we sent a personal invitation to respond.

The questionnaire was open between May 2 – May 27, 2022. The total number of recipients was 148, of whom 75 responded to the survey (response rate 51%). The number of recipients in the TECH programme was 54, of whom 21 responded to the survey (response rate 39%).

The questionnaire data will be available at the Finnish Social Science Data Archive (FSD).

Respondents: 21

Select the consortium you were part of. (n=21)

DDI	7
SET	4
ROSE	3
BCDC	3
COMBAT	2
PVN	2

What was your (primary) role in the consortium? (n=21)

Research team leader, Work Package leader, or both	10
Consortium Principal Investigator	4
Consortium deputy Principal Investigator	3
Interaction coordinator	3
Other	1

In what kind of organisation did you work during the funding period? (n=21)

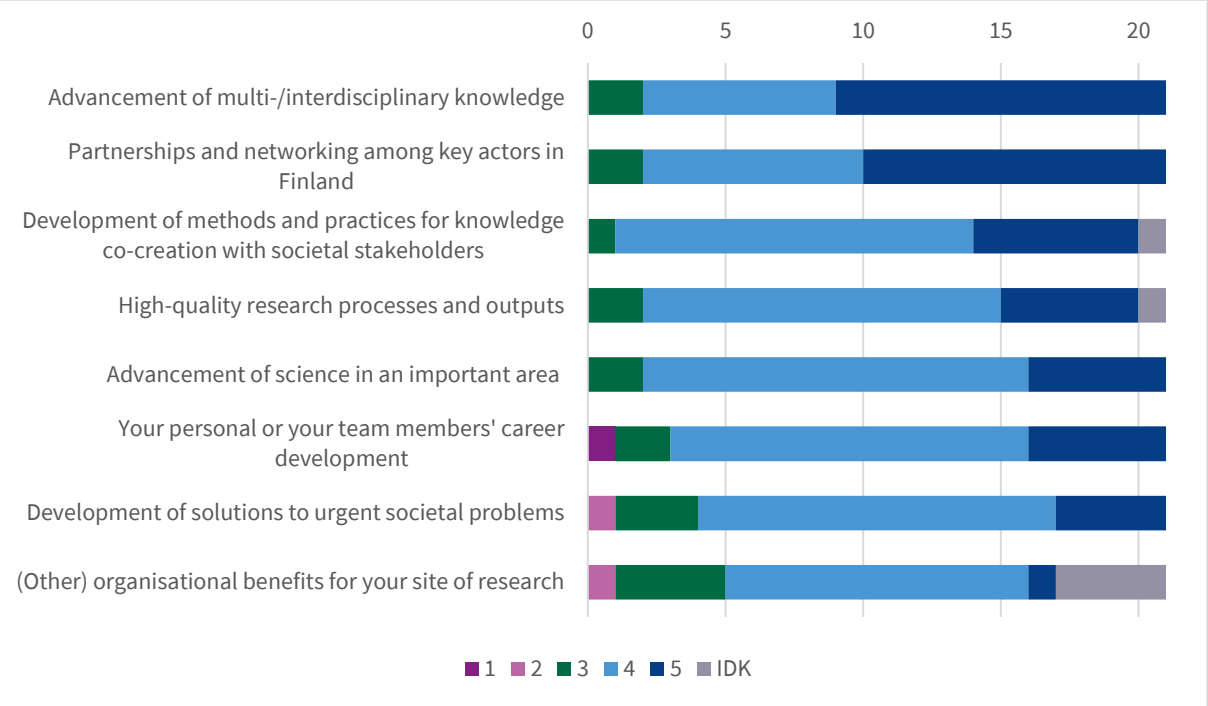
University	14
Government research institute	6
Think tank, interaction/communication agency	1

Did you know the other partners of your consortium before this SRC programme? (n=21)

I knew one or a few of the partners before the programme	13
I knew all or most partners before the programme	5
I did not know the partners before the programme	3

Assess the effectiveness of your consortium in advancing the following goals of SRC funding, based on your own experiences and impressions. (n=21)

(1=ineffective, 5=very effective, IDK=I don't know)

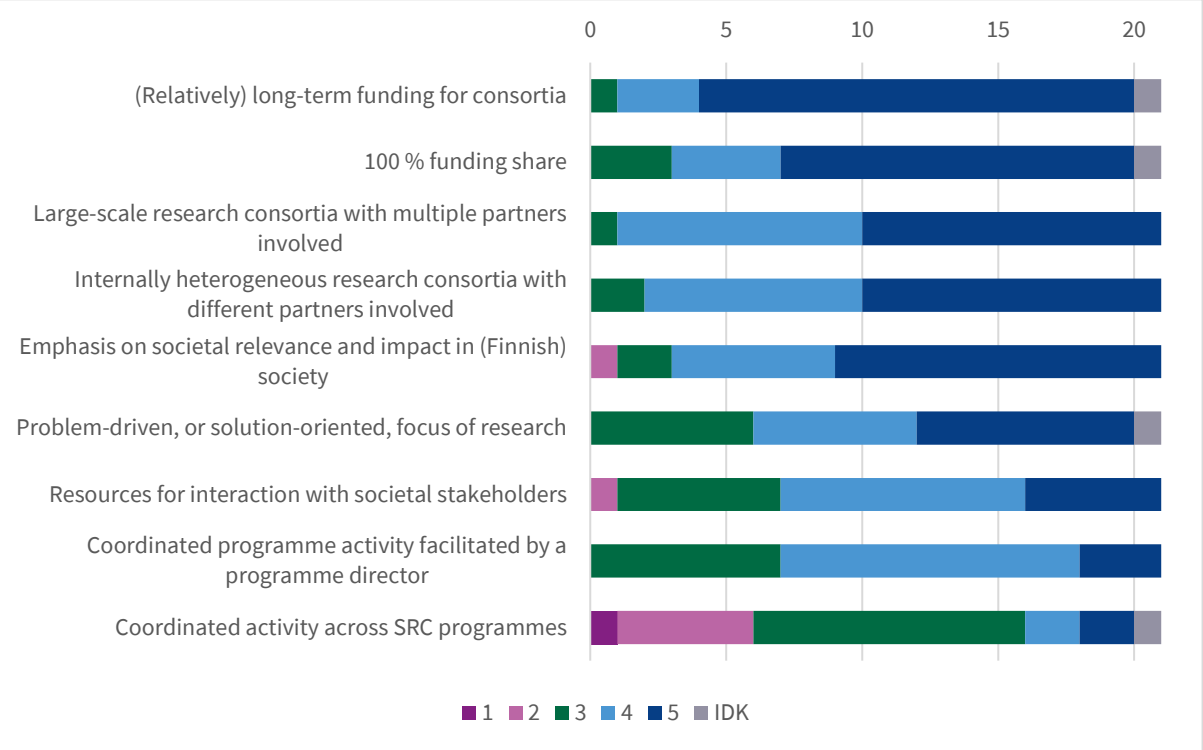


Tell us more about the effectiveness of your consortium in advancing the goals of SRC funding. (n=10)

The respondents stated that collaboration between consortiums, stakeholders and researchers added value for each partner. Active engagement and interaction were mentioned in relation to advancing societal impact, as well as the use and development of novel methods. For example, applying transition arena and developing digital platforms were described as furthering co-creation and discovering research questions for future.

Assess the added value of the following features of SRC funding, based on your own experiences and impressions of the SRC programme you were part of. (n=21)

Please consider the added value vis-à-vis your other/regular research activities. (1=no added value, 5=high added value, IDK=I don't know)

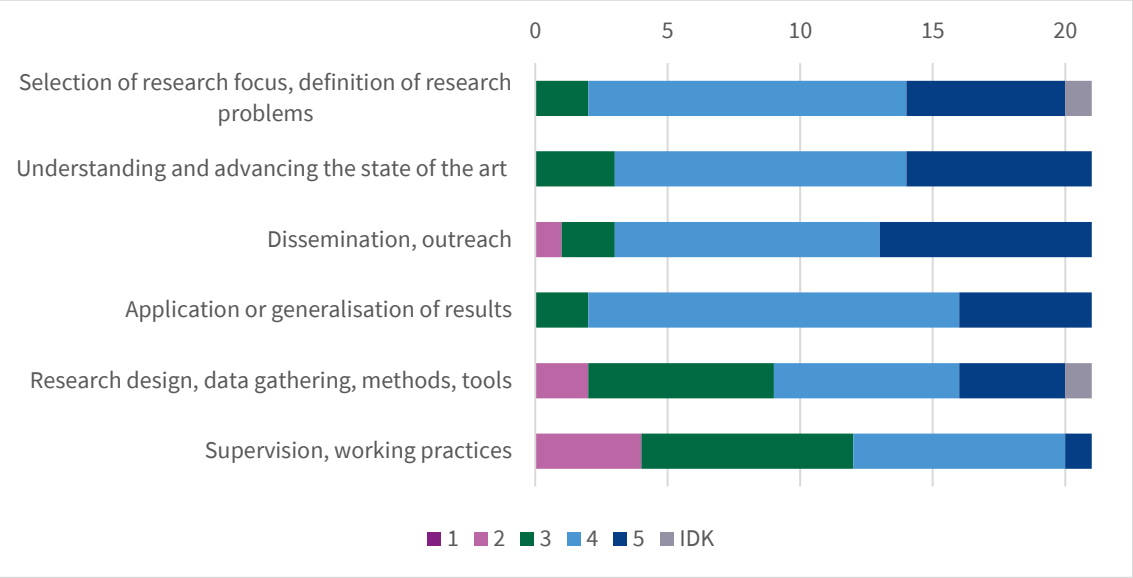


Tell us more about the most important added value of SRC funding. (n=9)

Long-term funding was the most important and valued quality of SRC funding in terms of investing resources into collaboration and the creation of networks and enabling experimenting with research setting. Multidisciplinary research group with expertise from different fields were also perceived as adding value.

Assess the importance of multidisciplinary collaboration within your consortium. As a consortium partner, how important was the collaboration for the following aspects of your work? (n=21)

(1=unimportant, 5=very important, IDK=I don't know)



Tell us more about the importance of multidisciplinary collaboration in your consortium. (n=10)

The multidisciplinary approach was perceived to enable mutual learning and integration of different competence and viewpoints. It was also stated that the complexity of the issues requires knowledge from multiple fields. One of the respondents pointed out that it was challenging to have all teams involved with every issue and therefore consideration of relevant participants needed to be done.

Did your consortium have research collaboration with other SRC consortia (within or beyond the SRC programme you were part of)? (Number of respondents 21, number of selected answers 23)

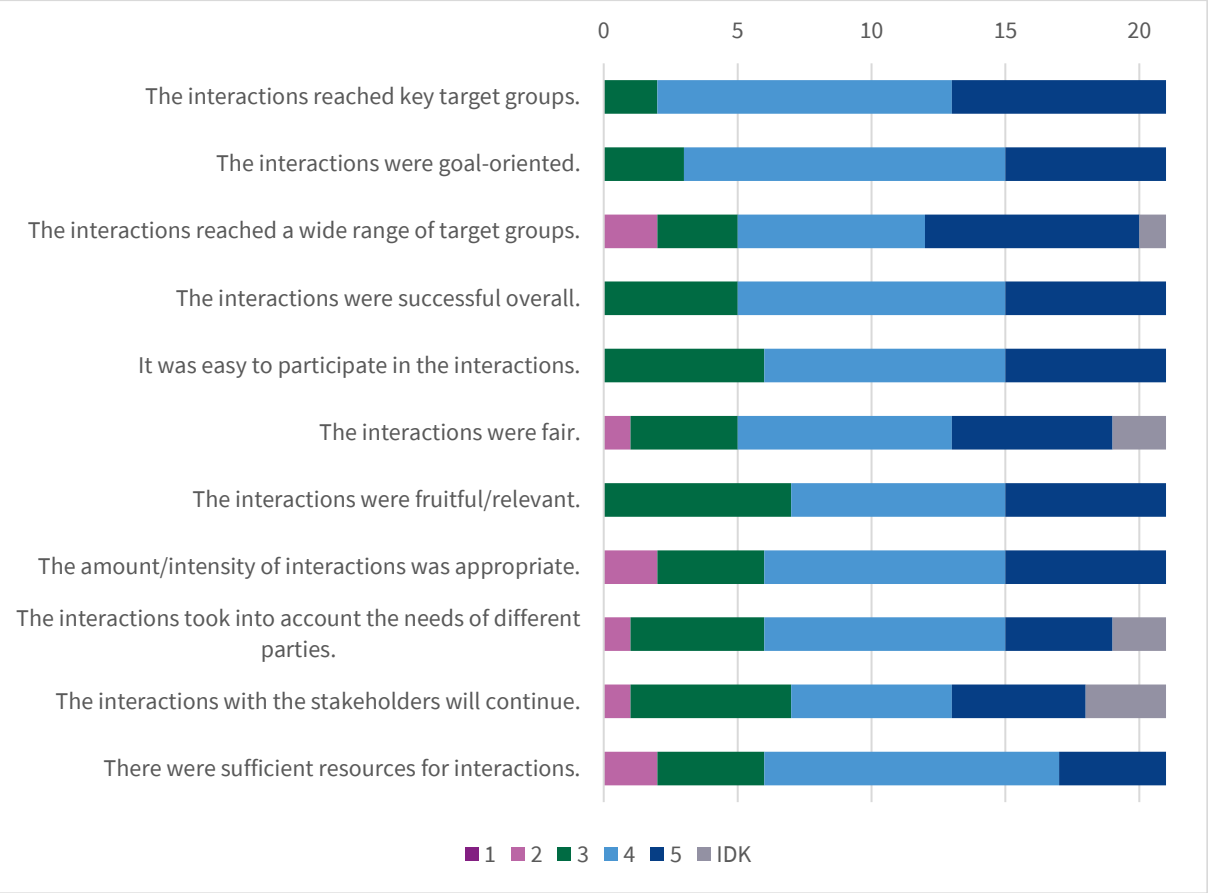
Yes, within the SRC programme	13
No, or I am not aware of it	6
Yes, across the SRC programme borders	4

Tell us more about the added value of your research collaboration with other SRC consortia. (n=7)

Collaboration between consortiums was described as producing policy briefs together as well as attending conferences and other joint activities. All the respondents did not conduct research collaboratively with other consortiums. Nevertheless, consortiums exchanged viewpoints for example about best practices and methodology with other consortiums

Assess the consortium's interactions with societal stakeholders (those you were involved in) using the following statements. (n=21)

(1=I disagree, 2=I disagree to some extent, 3=I neither agree nor disagree, 4=I agree to some extent, 5=I agree, IDK=I don't know)



Tell us more about the consortium's interactions with societal stakeholders. (n=10)

The answers of the respondents varied in terms of interaction methods as well as challenges. Some of them described interaction as fruitful and intensive, whereas some of them reported that stakeholders were not engaged, hard to reach or not included as initially was described in the application or interaction plan. The respondents also stated that it is difficult to evaluate whether they reached the goals.

In your view, what should be done to further strengthen the societal relevance and impact of strategic research programmes? (n=11)

More resources should be allocated to collaboration with the stakeholders and including international stakeholders. Awareness of SRC programmes should be raised among policymakers and other relevant stakeholders to synergize research with policy cycles. It was suggested that consortiums would be also involved when negotiating the themes of programmes. One respondent also suggested that the collaboration should be extended outside the programmes' limits, for example in the form of industry advisory group, as well as sharing previous knowledge gained from finished programmes .

Appendix 14: The survey for stakeholders

The survey was designed to collect information on the societal interaction of the completed SRC programmes (EQUA, PIHI, TECH, CITIZEN) and the significance of the programmes' research and interaction for project partners and stakeholders. The aim was to examine the achieved and expected societal impact of the programmes. The target group of the survey were the main stakeholders and partners designated by the projects and programme directors funded in these programmes.

The survey was open between March 15 – April 22, 2022. The total number of recipients was 195, of whom 33 responded to the survey (response rate 17%). The number of recipients among the TECH stakeholders was 64, of whom 9 responded to the survey (response rate 14%).

The survey data will be available at the Finnish Social Science Data Archive (FSD).

Responses (N=9):

Select one strategic research programme (and one or more research projects under that programme) with which you have interacted. (n=9)

DDI	9
ROSE	3
BCDC	3
SET	2
PVN	2

To which of the following does your organisation/ stakeholder group primarily belong? (n=9)

Ministeries	2
Municipal/City agencies and actors	2
Other	2
Government agencies and institutes	1
Companies	1
Trade and industry organisations	1
(Several other alternatives)	-

What (formal) role did you have in relation to the research programme or project? (n=9)

Stakeholder representative (without formal relationship)	5
Collaborator	2
Other	2

Which of the following best describes your previous relationship with the researchers with whom you interacted within the programme or project? (n=9)

I did not know the researchers, but my organisation has worked with them before.	4
I knew the researchers from before.	3
I did not know the researchers, and my organisation has not worked with them before (or I am not aware of such collaboration).	2
Other relationship	-

What kind of cooperation or interaction has your organisation engaged in overall with researchers or research organisations before this programme? (n=9)

Occasional contacts, meetings, joint events, etc.	4
At least one joint project	3
None/I don’t know	1
Long-term institutional collaboration	1

What role did you play in relation to the research carried out in the research programme or project? (n=9)

End-user of research knowledge	5
Expert or information source	5
Knowledge broker	5
Experimenter or tester	1
Supporter, participant or assistant	1
Other role	1
Supervisor, leader or adviser	-

If necessary, tell us more about your role in the research of the programme or project.

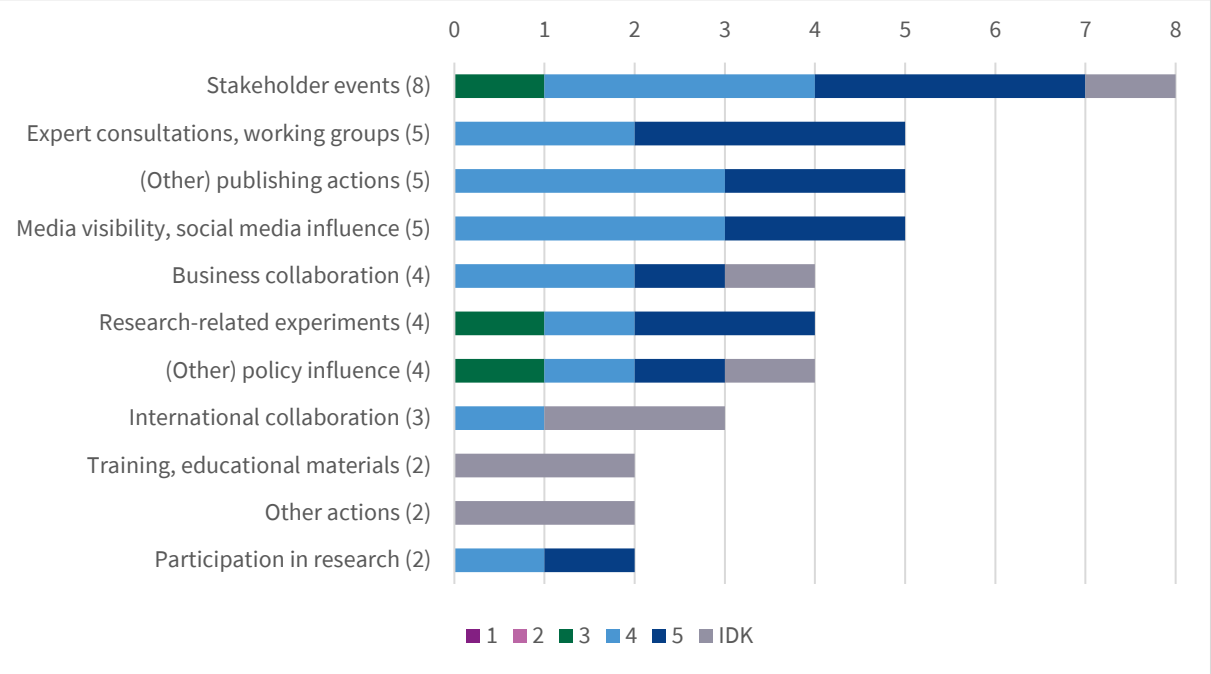
-

How often did you interact with or work on the research programme or project? (n=9)

Monthly	4
Several times a year	4
Once a year or less often	1
Weekly	-
Once during the whole programme period	-

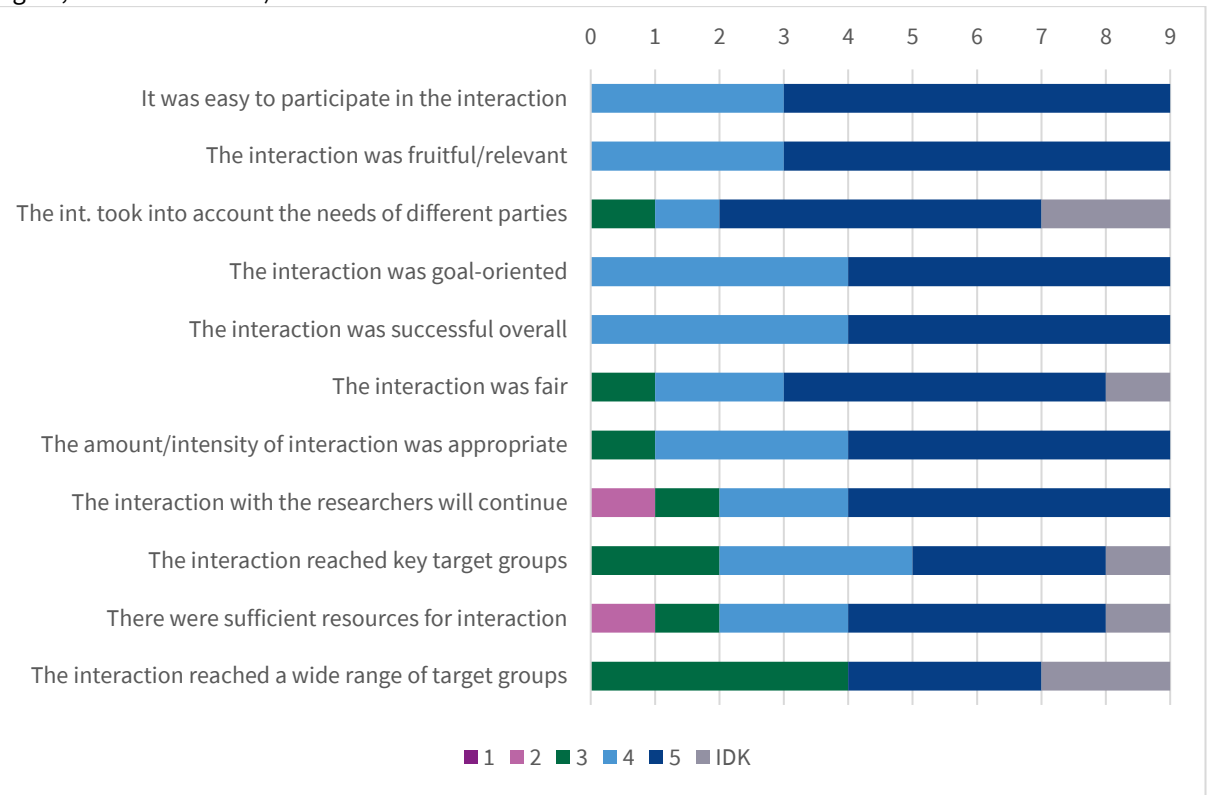
In what form were you involved in the research programme or project? Also assess the usefulness of the actions in terms of the societal impact of research. (n=7)

(1=useless, 2=quite useless, 3=neither useless nor very useful, 4=quite useful, 5=very useful, IDK=I don't know)



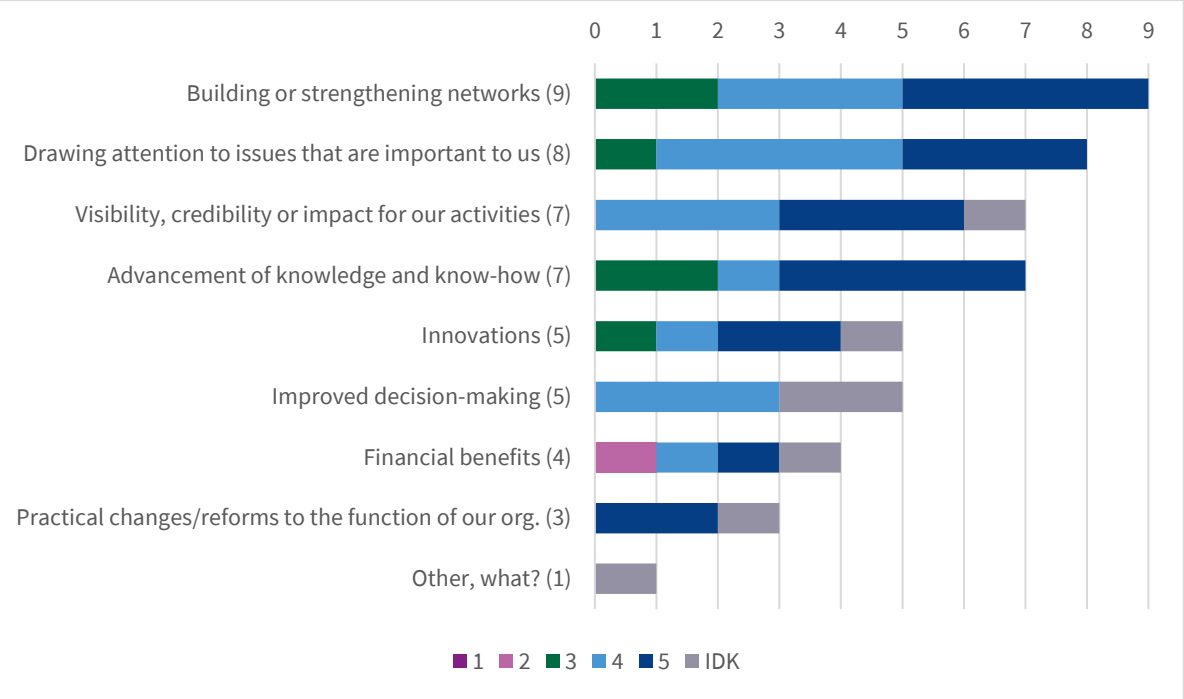
Assess the interaction with the research programme or project using the following statements. (n=9)

(1=I disagree, 2=I disagree to some extent, 3=I neither agree nor disagree, 4=I agree to some extent, 5=I agree, IDK=I don't know)



What were your aims for the interaction with the research programme or project? Please also assess how well your objectives were achieved. (n=7)

(1=not realised, 2=not realised to the expected extent, 3=realized to some extent, 4=realized fairly well, 5=fully realised, IDK=I don't know)



Please describe briefly one of the results, perspectives or solutions of the research programme or project that you consider significant. (n=3)

The respondents mentioned a roadmap where the project results and experiences were compiled and which shows the current situation and trends, a quide for streamlining innovations, and information on the use of technology in their operations.

What practical significance has the work of the research programme or research project had for you? To what change has the research led or contributed? Please provide concrete examples, if you can. (n=9)

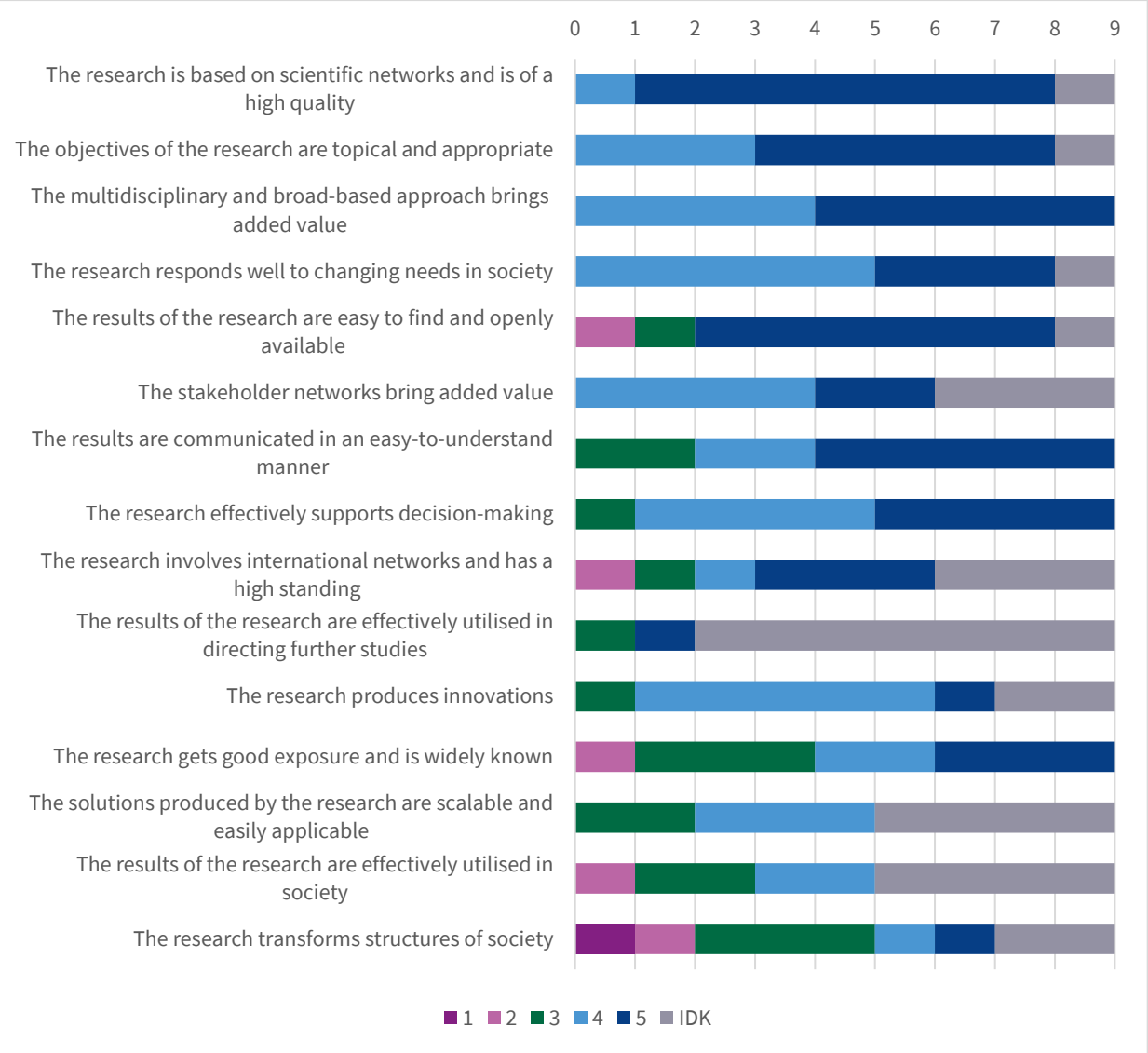
The respondents reported different types of learning outcomes and further transfer of knowledge gained in cooperation. Knowledge produced during the research supported the preparation of decision making. Stakeholders were also able to create personal relationships and continue collaboration after the projects. Piloting the use of robots is one of the mentioned practical examples.

How do you think the research programme or project managed to influence society more generally, in other ways than from your own perspective or from the perspective of your organisation? Tell us why you think this. (n=5)

Affecting public discussion around the topics was considered as a major societal impact. The pathway to this impact was seen to be achieved through the production of new knowledge. The respondents stated that the results should be spread more widely to a larger public and practical implementation should be furthered.

Please assess the below statements on strategic research based on your own experience and views. (n=9)

(1=I disagree, 2=I disagree to some extent, 2=I neither agree nor disagree, 4=I agree to some extent, 5=I agree, IDK=I don't know)



What do you think should be done to further strengthen the social relevance and impact of strategic research? (n=6)

The respondents think that research activities should be more deeply engaged with them, and this should be considered already in the planning phase of the project.

What could you do yourself to strengthen the social relevance and impact of strategic research? (n=6)

The respondents also state that they should be more engaged in the processes. The respondents mentioned for example raising awareness and spreading knowledge, as well as allocating time for reading projects' outputs.