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Evaluation of the RCN's NANO2021 programme

Final report

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Anders Håkansson, Jelena Angelis and AnnaKarin Swenning

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Acronyms and abbreviations

BIA	User-driven Research-based Innovation (Brukerstyrt innovasjonsarena)
BIONÆR	Sustainable Innovation in Food and Bio-based Industries (Bærekraftig verdiskaping i mat- og biobaserte næringer)
BIOTEK2021	Biotechnology for Innovation (Bioteknologi for verdiskaping)
CoC	Code of Conduct
DNA	Deoxyribonucleic acid
ENERGIX	Large-scale programme for energy research (Stort program energi)
ELSA	Ethical, Legal and Social Aspects
EPSRC	Engineering and Physical Sciences Research Council, UK
ERA-NET	European Research Area Network
EuroNanoMed	European network for transnational collaborative RTD projects in the field of nanomedicine
FRIPRO	Independent projects (Fri prosjektstøtte)
FUGE	Programme for Functional Genomics (Funksjonell genomforskning)
GenØk	Centre for Biosafety
HAVBRUK	Large-scale Programme on Aquaculture Research (Stort program for havbruksforskning)
HiB	Bergen University College
Horizon 2020	EU Research and Innovation programme
HSE	Health, Safety and Environment
ICT	Information and communications technology
IDELAB	RCN's "Ideas laboratory" (Forskningsrådets idélab)
IFE	Institute for Energy Technology (Institutt for energiteknikk)
IKTPLUSS	Large-scale initiative on information technology and digital innovation (IKT og digital innovasjon)
INFRASTRUKTUR	National Financing Initiative for Research Infrastructure (Nasjonal satsing på forskningsinfrastruktur)
IP	Intellectual Property
IPN	Innovation Projects for the Industrial Sector
KPN	Knowledge-Building Project for Industry
M-ERA.NET	ERA-NET for materials research and innovation
MILJØ2015	Norwegian environmental research towards 2015 (Norsk miljøforskning mot 2015)

MILPAAHEL	Environmental Exposures and Health Outcomes
NANO2021	Programme for Nanotechnology and Advanced Materials (Nanoteknologi og avanserte materialer)
NANOMAT	Programme for Nanotechnology and New Materials (Nanoteknologi og nye materialer)
NILU	Norwegian Institute for Air Research (Norsk institutt for luftforskning)
NIVA	Norwegian Institute for Water research (Norsk institutt for vannforskning)
NMBU	Norwegian University of Life Sciences (Norges miljø- og biovitenskapelige universitet)
NorFab	Norwegian Micro- and Nanofabrication Facility
NORTEM	Norwegian Centre for Transmission Electron Microscopy
NORUT Narvik	Northern Research Institute in Narvik
NTNU	Norwegian University of Science and Technology (Norges teknisk-naturvitenskapelige universitet)
OUS	Oslo University Hospital (Oslo universitetssykehus)
PETROMAKS2	Large-scale Programme for Petroleum Research (Stort program for petroleumsforskning)
PFI	Paper and Fibre Research Institute
PoC	Point of Care
R&D	Research and Development
R&D&I	Research, Development and Innovation
RCN	Research Council of Norway
RRI	Responsible Research and Innovation
SAMANSVAR	Programme for Responsible Innovation and Corporate Social Responsibility
SFF	Centre of Excellence
SFI	Centre for Research-based Innovation
TTO	Technology Transfer Office
UiB	University of Bergen
UiO	University of Oslo
UiT	Arctic University of Norway
VERDIKT	Core Competence and Value Creation in ICT (Kjernekompetanse og verdiskaping i IKT)
VRI	Programme for Regional R&D and Innovation (Virkemidler for regional FoU og innovasjon)

Executive summary

This report presents the results of the evaluation of the ongoing programme Nanotechnology and Advanced Materials (NANO2021) run by the Research Council of Norway (RCN). The key purpose of the evaluation was to assess how NANO2021 through its choice of priorities and instruments has worked so far in achieving its set objectives. The evaluation has been conducted by Faugert & Co Utvärdering AB (part of Technopolis Group) on behalf of the RCN's Division for Innovation and has also included an external Expert Group assigned by RCN. The work was performed in December 2016 – June 2017.

The programme

NANO2021 is one of the RCN's Large-scale Programmes. Originally planned for a programme period of ten years (2012–2021) it was recently converted into an ongoing programme with no current end date. The programme is a continuation of the programme Nanoteknologi og nye materialer (NANOMAT), which was terminated in 2011 and directly replaced with NANO2021.

The structure of NANO2021 stems from the priorities laid out in the Government's strategy for R&D in nanotechnology from 2012. The strategy identifies three principal priorities: Basic knowledge development, Innovation and commercialisation and Responsible technological development. The Government want nanotechnology to contribute to increased competitiveness of the industry sector and improved dealing with global societal challenges, without generating undesirable effects on health, the environment and society.

The primary objective of the programme is to promote the use of nanotechnology and advanced materials to develop cutting-edge knowledge and sustainable solutions designed to meet the needs of trade and industry and society at large. The ambition is to stimulate the process of developing knowledge and technology in close cooperation with industry, to satisfy society's needs for know-how and innovative solutions. At the same time, the programme applies a focus on social values and puts an emphasis on responsible implementation of these solutions.

The public funding of the programme for granted projects currently amounts to approximately 700m NOK. SINTEF, the Norwegian University of Science and Technology and University of Oslo have received more than half and companies – one quarter of the public funding.

Contribution to the fields of nanotechnology, microtechnology and advanced materials

In view of both the evaluation team and the Expert Group, it is still **too early to evaluate the programme's contribution towards scientific quality** of Norwegian research in terms of such deliverables as publications, citations, patents and licensing agreements. The projects in the programme need more time to generate measurable results and impacts. The Expert Group identifies some research areas that seem to be less covered in the programme, as well as other areas with quite strong representation of Researcher Projects. The bias for some topics may reflect certain research stronghold areas in Norwegian science that have developed over many years.

The **competition for funding is fierce among the Researcher Projects**, with roughly 10% success rate in that category. It is evident that this has resulted in a general high quality of projects and a concentration of funding to a few dominant institutions. The main expected results for the R&D performers –universities, university colleges and research institutes – are widened and deepened networks, knowledge transfer between actors in the projects, enhanced international competitiveness and scientific publications. The number of peer-reviewed publications reported for the period of 2012–2016 is over 350; however, the bulk of these publications is based on the research conducted in the projects funded under the NANOMAT programme.

There is also some evidence supporting a conclusion that NANO2021 is **contributing to internationalisation of research**. Interviews and survey results suggest that there is a notion among researchers that the NANO2021 projects are contributing to individual research groups strengthening their positions and becoming more competitive in emerging research fields. Some of the top funded institutions were internationally leading already before the programme, they have strengthened their position and in addition brought less-established institutions into an international context and thereby made them visible internationally.

The **industry participation in NANO2021 is concentrated to small companies**. Large companies are active in some projects but all but four IPN projects are led by small or medium-sized companies. This is, however, very much a reflection of the nanotechnology sector in Norway, which is dominated by small and newly established companies. The Expert Group highlights the reclusive position of larger Norwegian companies (in particular oil and gas companies). This circumstance should be seen in the context of the RCN's total portfolio on nanotechnology, microtechnology and advanced materials. Oil companies are active in other thematic RCN programmes, for example PETROMAKS2, and it is plausible that large companies in general have more prominent positions in other R&D activities related to nanotechnology, microtechnology and advanced materials.

IPN-projects is a subject to a low degree of competition and the contrast is striking when the success rates of Researcher Projects and IPNs are compared. The average success rate among IPN Projects has varied between 40% and 60%. Considering that a large share of companies active in the programme are small or newly established, there is a reason to doubt that this group by itself will be able to generate any significant increase in competition for IPN funding. Increased competition for industry funding, which potentially could benefit the quality of projects and potential for innovation and value creation, probably demands a broader industry engagement.

The NANO2021 participants express satisfaction with the programme's contribution to innovation and value creation. Virtually all respondents in industry-led projects expect that the companies will strengthen their competitiveness and that industry relevant research will increase in participating organisations. It is also interesting to note that a greater number of participants in industry-led projects expect results to be commercialised internationally rather than nationally, indicating that the companies leading IPN projects in the programme act (or at least strive to act) on an international market. The share of respondents who expect commercially oriented results from Researcher Projects are smaller than among IPN projects but a convincing majority expect their project to lead to increased industrial relevance of research and just less than half expect a patent or licencing agreement to be achieved.

Responsible Research and Innovation is a strategic priority under the NANO2021 programme and applicants to NANO2021 are required to describe how relevant research questions will be addressed in relation to HSE, ELSA and/or other RRI perspectives. **The programme is slightly short of the goal of 15% of funds to be allocated to RRI and thematic area 5**. A Joint call with other RCN programmes focused on ELSA projects was instrumental in increasing the share of RRI in the programme.

The **programme participants find it difficult to express a clear view on the impact of RRI** practices as a result of the NANO2021 programme. A large share of the respondents answered "Do not know" or "Neither agree nor disagree" when asked about how the programme as a whole contributes to spreading knowledge or increasing awareness of the RRI topic. However, in terms of how RRI has benefitted individual projects the expressions of opinion are plenty. The Expert Group's reflection on the different views of researchers on RRI is that it mirrors with researchers in other national contexts. While some are very positive towards the effects of the programme and the help in integrating the RRI aspects in their project, others state that researchers are already responsible and that the specific focus on RRI does not – and should not – change this. The general implementation of RRI in the project portfolio has to a large degree followed the interpretation and initiative of the researchers themselves, which is applauded by the Expert Group as it leaves much room for scientists themselves to define how they want to work. The design and enactment of the entire process is well in line with the ambitions in the Government's national strategy on nanotechnology and can certainly serve as a case of best practice for funding bodies internationally.

National and international alignment

When reviewing the programme's alignment with RCN's research strategies it becomes evident that the programme should be seen in a larger context, supplementing other RCN programmes and funding instruments. The Expert Group highlights that important areas of the Government's strategy (such as food, marine and maritime applications), prominent Norwegian export industries (such as, oil and gas industry and the marine sector), and key international research fields (such as ICT and biotechnology) are not specifically targeted as thematic priority areas in NANO2021. These are instead research fields where RCN has initiated separate thematic programmes that work alongside NANO2021.

It is the Expert Group's impression that many of the funded projects are centred on a limited number of topics and that some internationally observed growth areas are missing or, at best, appear underrepresented. However, the Experts point out that the project portfolio covers a broad range of nanomaterials, application and research areas. Considering the relative low number of projects in the programme, the portfolio as a whole manages to cover quite a large part of the international trends in the nano research. Most project participants believe that NANO2021 is aligned with the current developments in the nanotechnology field.

Programme additionality

The **programme is more critical as a support instrument for establishing Researcher Projects** while those working with IPN projects to a larger share state that the project would have been conducted with other funding if the proposal had been rejected. As stated by project applicants in the survey, other RCN programmes are the most important alternative funding sources followed by Horizon 2020. Half of the funded project leaders considered alternative funding sources when preparing their application to NANO2021.

The positive feedback from the participants in the programme was strengthened by **a general high level of satisfaction with the RCN's administration of the programme**. The non-beneficiaries agree with beneficiaries that the calls are clear, but show a significantly lower level of satisfaction with the RCN's process of proposal assessment, selection and motivation. Rejected applicants complain about perceived uneven judgments made by the reviewers and that RCN has not paid enough (or too much) attention to the reviewers' comments. Furthermore, there is a notable lack of knowledge regarding the project review process among project leaders in IPN projects; only 50% of project leaders from industry state that they know how the review process works. This group is also less content with the design of the calls for proposals and the requirements for project reporting.

Concluding remarks

The evaluators share the Expert Group's observation that the programme is designed with a large selection of instruments which RCN has used proactively to optimise the programme in relation to the programme objectives. In addition, there are certainly convincing signs that the programme is promoting development in line with its set objectives.

Sammendrag

Denne rapporten presenterer resultatene av evalueringen av Norges forskningsråds (NFR) pågående program Nanoteknologi og avanserte materialer (NANO2021). Hovedmålet med evalueringen har vært å vurdere hvordan NANO2021 gjennom valg av prioriteringer og instrumenter har fungert så langt med tanke på å nå oppsatte mål. Evalueringen er gjennomført av Faugert & Co Utvärdering AB (en del av Technopolis Group) på vegne av NFRs divisjonsstyre for innovasjon. Evalueringen har også inkludert en ekstern ekspertgruppe nedsatt av NFR. Arbeidet ble utført i perioden desember 2016–juni 2017.

Om programmet

NANO2021 er et av NFRs store programmer. Opprinnelig var det planlagt en programperiode på ti år (2012–2021), men nylig ble programmet omgjort til et løpende program med åpen sluttdato. NANO2021 er en videreføring av programmet Nanoteknologi og nye materialer (NANOMAT), som ble avsluttet i 2011 og umiddelbart erstattet av NANO2021.

Programmets struktur følger prioriteringene i regjeringens FoU-strategi for nanoteknologi fra 2012. Strategien identifiserer tre hovedprioriteringer: Grunnleggende kunnskapsutvikling, innovasjon og kommersialisering samt ansvarlig teknologiutvikling. Regjeringen ønsker at nanoteknologi skal bidra til økt konkurranseevne for industrisektoren samt til bedre håndtering av globale samfunnsutfordringer uten å gi uønskede effekter på helse, miljø og samfunn.

Programmets hovedmål er å fremme bruken av nanoteknologi og avanserte materialer for å utvikle nyskapende kunnskap og bærekraftige løsninger designet for å møte behovene innenfor handel, industri og i samfunnet for øvrig. Ambisjonen er å stimulere prosessen med å utvikle kunnskap og teknologi i tett samarbeid med industrien for å tilfredsstille samfunnets behov for kunnskap og innovative løsninger. Programmet har samtidig fokus på sosiale verdier og legger vekt på ansvarlig implementering av løsningene.

Hittil har programmet utbetalt omtrent 700 mNOK i støtte til innvilgede prosjekter. SINTEF, Norges teknisk-naturvitenskapelige universitet og Universitetet i Oslo har mottatt over halvparten av midlene mens en fjerdedel av støtten har gått til selskaper.

Bidrag til områdene nanoteknologi, mikroteknologi og avanserte materialer

Både evalueringsteamet og ekspertgruppen mener det er **for tidlig å evaluere programmets bidrag til vitenskapelig kvalitet** i norsk forskning med tanke på resultater som publisering, sitering, patenter og lisensavtaler. Prosjektene i programmet trenger mer tid når det gjelder å generere målbare resultater og effekter. Ekspertgruppen har sett at enkelte forskningsområder ser ut til å være dårligere dekket, mens andre områder har en ganske stor andel forskerprosjekter. Denne skjevheten kan gjenspeile sitasjonen i norsk forskning hvor enkelte områder tradisjonelt står sterkt og har blitt utviklet gjennom mange år.

Blant forskerprosjektene er det stor konkurranse om midlene. Prosjektkategorien har en suksessrate på rundt 10 prosent, og det er tydelig at dette har resultert i generelt høy kvalitet på prosjektene og at midlene er blitt konsentrert på noen få dominerende institusjoner. Forventede resultater for FoU-utførerne – universiteter, høyskoler og forskningsinstitutter – er i hovedsak utvidede og fordypede nettverk, kunnskapsoverføring mellom aktørene i prosjektene, forbedret internasjonal konkurranseevne og vitenskapelig publisering. Antallet rapporterte fagfellevurderte publikasjoner ligger på over 350 for perioden 2012–2016. Hovedvekten av disse er imidlertid basert på forskning utført i prosjekter finansiert av NANOMAT-programmet.

Det er mulig å finne enkelte bevis for at NANO2021 **bidrar til internasjonalisering av forskning**. Intervjuer og resultater fra spørreundersøkelsen tyder på at forskere har en oppfatning av at prosjektene i NANO2021 bidrar til at individuelle forskergrupper får styrket sin posisjon og blir mer konkurransedyktige innenfor nye forskningsområder. Enkelte av institusjonene som har mottatt mest

støtte var internasjonalt ledende allerede før programmet startet. Disse har både fått styrket sin posisjon og i tillegg brakt mindre etablerte institusjoner inn i en internasjonal kontekst og gjort dem synlige internasjonalt.

Industrideltakelsen i NANO2021 er konsentrert hos små selskaper. Store selskaper er aktive i enkelte prosjekter, men med unntak av fire stykker er alle IPN-prosjektene ledet av små eller mellomstore bedrifter. Dette gjenspeiler i stor grad den norske nanoteknologisektoren, som er dominert av små og nyetablerte firmaer. Ekspertgruppen påpeker den tilbaketrukkede rollen til større norske selskaper (særlig olje- og gasselskaper). Dette må ses i sammenheng med NFRs totale portefølje innenfor nanoteknologi, mikroteknologi og avanserte materialer. Oljeselskaper er aktive innenfor andre tematiske NFR-programmer, for eksempel PETROMAKS2, og store selskaper har trolig mer fremtredende posisjoner generelt innenfor øvrige FoU-aktiviteter relatert til nanoteknologi, mikroteknologi og avanserte materialer.

IPN-prosjektene er preget av lav konkurranse, og kontrasten er slående når man sammenligner suksessraten til forskerprosjektene og IPN-prosjektene. Gjennomsnittlig suksessrate for IPN-prosjekter har til nå ligget på mellom 40 og 60 prosent. Siden en stor del av selskapene som er aktive i programmet er små eller nyetablerte, er det grunn til å tvile på at denne gruppen alene vil kunne skjerpe konkurransen om IPN-støtte i særlig grad. Økt konkurranse, som potensielt kunne gagnet kvaliteten på prosjektene og potensialet for innovasjon og verdiskaping, krever trolig et bredere industriengasjement.

Deltakerne i NANO2021 gir uttrykk for å være fornøyd med programmets bidrag til innovasjon og verdiskaping. Nesten alle respondentene fra de industriledede prosjektene gir uttrykk for en forventning om at selskapene vil styrke sin konkurranseevne og at graden av industrirelevant forskning vil øke i de deltakende organisasjonene. Det er også interessant å legge merke til at en større andel deltakere i industriledede prosjekter forventer at resultatene snarere blir kommersialisert internasjonalt enn nasjonalt, noe som indikerer at selskapene som leder IPN-prosjekter i programmet opererer (eller i det minste ønsker å operere) på et internasjonalt marked. Respondentene forventer i lavere grad kommersielt orienterte resultater fra forskerprosjekter enn fra IPN-prosjekter. Et overbevisende flertall forventer imidlertid at prosjektene deres vil føre til økt industriell relevans for forskningen, og nesten halvparten forventer en patent- eller lisensavtale som resultat.

Ansvarlig forskning og innovasjon (RRI) er en strategisk prioritering i NANO2021. Søkere til programmet må beskrive hvordan relevante forskningsspørsmål vil bli adressert med tanke på HSE, ELSA og/eller andre RRI-perspektiver. **Programmet har nesten nådd målet om at 15 % av støtten skal gå til RRI og det femte tematiske området**. En fellesutlysning i samarbeid med andre NFR-programmer som fokuserer på ELSA-prosjekter har bidratt til å øke andelen RRI i programmet.

Programdeltakerne synes det er vanskelig å si noe tydelig om programmets effekt på RRI-praksis. En stor andel av respondentene svarte "vet ikke" eller "verken enig eller uenig" på spørsmål om hvordan programmet som helhet bidrar til å spre kunnskap eller større bevissthet om RRI. Når det gjelder hvordan RRI har vært fordelaktig for enkeltprosjekter, er det imidlertid mange som har en mening. Ekspertgruppen fremhever at de ulike forskernes syn på RRI gjenspeiler situasjonen for forskere i andre nasjonale sammenhenger. Mens noen er svært positivt innstilt til programmets effekter og til hvordan integrering av RRI-aspektene i prosjektene kan være til nytte, gir andre uttrykk for at forskere allerede er ansvarlige, noe det spesifikke fokuset på RRI verken endrer eller burde endre. Generelt har implementeringen av RRI i prosjektporteføljen i stor grad fulgt forskernes egne tolkninger og initiativer, noe ekspertgruppen applauderer ettersom dette gir forskerne stor mulighet til selv å definere hvordan de ønsker å jobbe. Design og gjennomføring av hele prosessen ligger godt på linje med ambisjonene i regjeringens nasjonale strategi for nanoteknologi. Dette kan absolutt fungere som et eksempel på beste praksis for finansieringsorganer over hele verden.

Nasjonal og internasjonal tilpasning

Når man undersøker hvorvidt programmet er i tråd med NFRs forskningsstrategier blir det tydelig at programmet må ses i en større kontekst og som et tillegg til NFRs øvrige programmer og støtteinstrumenter. Ekspertgruppen fremhever at viktige områder i regjeringens strategi (som mat, marin og maritim sektor), fremtredende norske eksportindustrier (som olje- og gassindustrien og marin industri), og viktige internasjonale forskningsområder (som IKT og bioteknologi) ikke er spesifikke tematisk prioriterte områder i NANO2021. Disse forskningsområdene har i stedet fått egne tematiske NFR-programmer som løper side om side med NANO2021.

Ekspertgruppen har inntrykk av at mange av de støttede prosjektene konsentrerer seg om et begrenset antall emner og at enkelte internasjonale vekstområder enten mangler eller i beste fall er underrepresentert i programmet. Uansett peker ekspertene på at prosjektporteføljen dekker et bredt spekter av nanomaterialer, bruks- og forskningsområder. Med tanke på programmets relativt lave antall prosjekter greier porteføljen som helhet å dekke en ganske stor del av de internasjonale trendene innenfor nanoforskning. De fleste prosjektdeltakerne har inntrykk av at NANO2021 er på linje med dagens utvikling innenfor nanoteknologi.

Programmets addisjonalitet

Programmet er viktigst som støtteinstrument for å etablere forskerprosjekter. De som jobber med IPN-prosjekter uttrykker i større grad at prosjektene ville blitt gjennomført med annen støtte dersom de hadde fått avslag på søknaden til programmet. Som søkere gir uttrykk for i spørreundersøkelsen, er andre NFR-programmer de viktigste alternative finansieringskildene, fulgt av Horisont 2020. Halvparten av prosjektlederne for innvilgede prosjekter vurderte alternative finansieringskilder da de utarbeidet søknaden til NANO2021.

Den positive tilbakemeldingen fra deltakerne i programmet blir styrket av **en generelt høyt grad av tilfredshet med NFRs administrering av programmet**. Både støttemottakerne og søkerne som har fått avslag er enige om at utlysningene er tydelige. De er imidlertid betydelig mindre fornøyd med NFRs prosess for vurdering av søknadene, utvalg og begrunnelse. Søkere med avslag klager på det de oppfatter som en ujevn vurdering samt at NFR ikke har viet nok (eller for stor) oppmerksomhet til kommentarene fra de som har vurdert søknadene. Videre er det en merkbar mangel på kunnskap blant ledere av IPN-prosjekter når det gjelder denne vurderingsprosessen – bare 50 prosent av prosjektlederne fra industrien gir uttrykk for at de vet hvordan prosessen foregår. Denne gruppen er også mindre fornøyd med designet på utlysningene og kravene til prosjektrapportering.

Avsluttende kommentarer

Både evaluatorene og ekspertgruppen ser at programmet er designet med et stort utvalg instrumenter som NFR har brukt proaktivt for å optimalisere programmet med tanke på å nå oppsatte mål. I tillegg er det overbevisende tegn på at programmet fremmer utvikling i tråd med disse målene.

1 Introduction

This report presents the results of the evaluation of the ongoing Large-scale Programme NANO2021 run by the Research Council of Norway (RCN). Faugert & Co Utvärdering AB (part of Technopolis Group) undertook this study for the RCN's Division for Innovation. The work was performed in December 2016–May 2017 with the support from the external Expert Group and delivered in June 2017.

1.1 The assignment

The key purpose of the evaluation was to assess how NANO2021 through its choice of priorities and instruments has worked so far in achieving its set objectives. The following questions were raised for this evaluation:

- How have the priorities between different instruments of the programme given a project portfolio that contributes to the achievement of the programme's objectives? The particular focus in answering this question should be put on the contribution of the programme towards:
  - scientific quality in Norwegian research in the field;
  - societal and commercial innovation and value creation in the short- and long-term;
  - a more social technology development through continuous focus on "Responsible Research and Innovation" (RRI).
- How well does the programme meet national research policy priorities and national needs and trends?
- How well does the programme correspond with the international trends in the field?
- Are there international trends in the field that needs to be addressed in future priorities in the programme?

In addition, the evaluation was set to assess if the NANO2021 programme's administration and available support forms (e.g. programme committees) have worked to achieve the objectives of the programme.

As most of the projects are still running and it is too early to expect any significant results or impacts, the scientific, commercial or societal results and effects of individual projects funded by the programme has not been evaluated. Nor was it included in the assignment to evaluate the different support instruments used by the RCN in the programme.

1.2 Evaluation steps

The evaluation incorporated various data collection and analysis techniques:

- Analysis of available background documentation and data related to the programme portfolio
- Exploratory interviews with members of the programme's steering committee and programme management
- Five case studies, including stakeholder interviews with individual programme participants
- Three web surveys bound for project managers, project partners and non-beneficiaries. The surveys were largely identical in design but the survey to project managers was more extensive. (See Appendix C for more details.)
- An external Expert Group assigned to the project by RCN who brought their sectoral knowledge and international experience from academia and the private sector. Members of the Expert Group included:
  - Professor Bo Wegge Laursen, Director of Nano Science Center at the University of Copenhagen (chair)

  - Professor Jørgen Kjems, Director of Interdisciplinary Nanoscience Center at Aarhus University
  - Dr Ralph Bernstein, CTO of Listen AS, CEO and Senior Consultant of AmeberCon and Adjunct Professor at NTNU
  - Professor Maja Horst, Head of Department of Media, Cognition and Communication, University of Copenhagen
- Preliminary thoughts and findings were presented and discussed during the validation workshop at RCN on 12th May 2017. Representatives of various research organisations, technology transfer offices, companies and the RCN participated in this workshop

The evaluation that is summarised in this report was conducted during the period of December 2016–June 2017.

The evaluation team consisted of Anders Håkansson, AnnaKarin Swenning and Dr Jelena Angelis, of which the latter acted as project manager. The team was assisted by Dr Tomas Åström (methodological advice during the study), Ingvild Storsul Opdahl (background analysis), Pierre Lindman (technical assistance setting up and running an online survey), Reda Nausėdaitė (analysis of the survey results) and Dr Max Kesselberg (methodological advice and quality assurance).

The evaluation team thanks all the contributors of this study for sparing their time and sharing their views about the NANO2021 programme during the telephone discussions, online survey and the validation workshop. Special thanks go to the RCN team behind this evaluation for providing an access to the data, an assistance during the online survey and an ongoing support throughout the evaluation in answering various enquiries from the evaluation team and the external Expert Group.

1.3 Structure of the report

The report is structured as follows:

- After this first section, Section 2 presents international trends in the nanotechnology field in order to set the context of the NANO2021 programme not only nationally but also internationally
- Sections 3 describes the NANO2021 programme, its sources, goals, structure and its funding instrument portfolio
- Section 4 brings forward the analysis of collected information around the evaluation questions assessing the programme's contribution to the improvement of scientific quality in the Norwegian nanotechnology research, commercial innovation, contribution to RRI. It also includes a brief assessment of the programme's administration
  - Finally, Section 5 summarises the conclusions and recommendations from the evaluation team and external Expert Group on how the programme can be further be shaped based on the feedback received from various key stakeholders and in line with the development of the nanotechnology field nationally and internationally.
  - Appendix A contains the full expert report
  - Appendix B contains the survey questionnaire answered by project managers
  - Appendix C presents the full results of the online survey

2 International trends in nanotechnology, microelectronics and advanced materials

This section presents the views of the external Expert Group on the international trends in nanotechnology, microtechnology and advanced materials. Please see Introduction for more details about the Expert Group and Appendix A for the full Expert Report.

2.1 Introduction

Nanoscience and nanotechnology refers to the understanding and technological exploration of nanosized structures (typically in 1 nm to 100 nm range) and phenomena unique to this size range. As nanoscience and technology is defined by this size range and not limited to any specific class of materials or fields of application it is rapidly expanding into various fields of science and technology. The early stages of nanoscience was to a large extend driven by the development of new microscope techniques, which opened up the possibility to study and even manipulate single nano objects ranging from atoms to viruses. The ability to study individual nano objects and surfaces rather than average/bulk properties and structures has drastically enhanced our insight into the structure and properties of materials and biological systems. Unique physical and chemical properties of nano structures and nano materials can now be understood and explored for new technologies, improved processes and optimized materials. On this background nanotechnology is considered a general purpose technology or enabling technology which has the potential to significantly accelerate the technological development in a very broad range of areas, and thus with huge potential contributions to key societal challenges and industry competitiveness. On the basis of these expectations very large public investments in nanoscience and nanotechnology have been launched from 2000 and onwards. In particular USA and China have been leading in this development. Most European countries have also launched various national programmes.

In the most recent EU programmes an increased political emphasis on economic growth and job creation has led to a demand of product focused research, as seen in the declared mission of *"bridging the gap between nanotechnology research and markets"*. This focus on markets and products is in the EU programmes combined with thematic focus on key societal challenges.

While there is no doubt that nanoscience and nanotechnology still has the most overlap with materials research and technology, it is a clear trend that nanoscience and nanotechnology is expanding from physical and materials science into new nano cross disciplines such as; nano-bio technology and nano-medicine. In general, nanoscience research is characterised by a cross-disciplinary and problem/application driven approach, where expertise from several classical disciplines are combined with the new materials, tools and theories from nanoscience.

Below major trends in nanotechnology research are outlined in four fields of applications.

2.2 Nanomaterials and nanofabrication

At the heart of nanotechnology lies the unique properties of nanostructured materials and the rational development of such. The forefront of this field is strongly linked to the developments in structural analysis of nanomaterials, which in turn rely on the availability and developments of tools such as electron microscopy, scanning probe microscopes, synchrotron and neutron sources, and computational resources. At the moment, the scope of nanomaterials is fast expanding, e.g. from graphene to a whole range of other 2D materials such as hBN (hexagonal Boron Nitride) and MoS_2 (molybdenum disulphide).

As nanomaterials are discovered and their structure and properties explored they become candidates for improved or new technologies in a wide range of fields. In many of these applications the nanomaterials play a key role by providing special properties and functionalities, yet constituting a very small fraction of the whole device/material. Large-scale application of nanomaterials is in particular associated with relative simple materials where downscaling of particle size enhance functionality and/or reduce material consumption, this includes, e.g. pigments, and wood preservatives. For more advanced materials large scale applications are in particular envisioned for low dimensional materials such as nanotubes and graphene in lighter and stronger composite materials, e.g. for airplanes, cars, wind turbines, bicycles, and sporting equipment.

Industrial upscaling and standardisation of nanomaterial production has been suggested to be a bottleneck for commercialisation of nanotechnology, and this area has consequently received some attention in recent European research programs. This field can be seen as a natural extension of nanofabrication focusing on new synthesis and fabrication processes. Nanofabrication includes top-down" approaches (carving the material using particle beams or light, or stamping) and "bottom-up" approach where self-assembly of atomic and molecular species form rationally designed, uniform nanostructures on larger scales. Also additive manufacturing, such as three-dimensional (3D) printing, and layer-by-layer coating may merge with nanotechnology either by used of nanomaterials and/or enhancing resolution towards the nano regime.

Related to the development and technological implementation of new nanomaterials the question of nanotoxicology and environmental impacts becomes highly important. Understanding the fundamental interactions of nanostructures with biological systems is thus a key challenge both for development of nano-medicine, bio-nanotechnology and for the assessment of potential hazards to workers in nano-technology research and manufacturing processes, to consumers, and to the environment. This field is particularly challenged by the complexity of nanomaterials and the lack of well-established standards for evaluating these materials. Nanoscience tools on the other hand now also allow for detailed studies of nanopollutants like nano and micro particles formed by combustion engines.

2.3 Energy

The social need for new and sustainable energy technologies is obvious and linked to the emanating threat to the global climate posed by the extensive used of fossil resources. Research in novel technology for energy production, transformation, and storage is to a large extent turning to nanostructured materials, which offer high surface/interface areas, tuneable electronic properties and surface properties. Key areas of research include:

- Catalysis: Nanoparticles and nanostructured surfaces are explored for optimisation of a broad range of important heterogeneous catalysts. Nano catalysts are in particular considered for applications in fuel cells and water splitting, where stable end energy efficient catalysts are highly needed. In this field a key parameter is to reduce the need for large amounts of costly and limited metals such as platinum. 1D and 2D carbon materials are promising both as catalysts and as support and electrode materials for nano-particle catalysts.
- Energy storage: Nanomaterials and nanostructure analysis play a significant role in optimisation of high-power rechargeable battery systems and supercapacitors as well as in development of materials for hydrogen storage. These technologies are highly needed for a non-hydrocarbon based society as well as for the continued development of mobile devices.
- Thin-film and flexible photovoltaics for smart solar panels that convert sunlight to electricity more efficiently may be used in areas not suitable for silicon based devices, such as printed electronics, textile/clothing, and disposable devices. Just like harvesting of solar energy is predicted to be an important part of future sustainable energy systems the harvesting of waste energy in the form of heat may be a key element. For such applications thermoelectric nanomaterials that both may be use to convert waste heat into electricity and for temperature control are targets of research.

2.4 Health and biotechnology

The growing cost of health care is a major societal challenge, which in part may be mitigated by development of efficient early stage screening and diagnostics, and by more efficient drugs for major diseases presently requiring long-term and costly treatments.

A key area of research is nanosensors for diagnostic applications that at low cost can detect, identify, and quantify disease markers or environmental contaminants in body fluids and breath very early in disease progression. Low cost sensors are considered for wide use and e.g. integration in wearables including clothing, shoes, contact lenses, glasses, watches, earphones. Similarly development of point-of-care lab-on-a-chip diagnostic devices, and super sensitive instrumentation, e.g. for detection of very small amounts of pathogenic cells in blood sample (very early stage detection of cancer) to a large extend rely on nanomaterials and nanotechnology. This field also includes techniques for faster and more accurate DNA sequencing, and solid-state or organic nanopores for single protein and nucleic acid sensing. In the field of nanosensors and bioimaging the special optical properties of nanoparticles play a key role and further development of optical properties for sensitive readout and surface functionalisation for improved selectivity/targeting are important research areas.

Tissue engineering is a rapidly growing area and includes, for example, repairing damaged tissues by creating stem cell niches with nanostructured surfaces, bioactive cues and gene expression modifiers (e.g. for bone, cartilage, muscle, or spine/nerve regeneration).

Nanotechnology with the aim to treat disease includes drug delivery by nanoparticles that more efficiently and specifically target diseased cells thereby reducing the toxic effects of traditional drugs. Development of improved nanocarriers is particular relevant for delivery of biomolecule drugs (biologics) and for reduced immune response.

2.5 Electronics and optics

The continued growth in computational processing speed, transmission and storage of data is fuelled by the development of ever smaller and faster electronic and optical circuits/devices and has major societal impact forming the foundation for ICT.

Nanofabrication and nanostructure characterisation techniques are key tools for the constant down scaling of silicon device feature size. New nanomaterials and nanoarchitectures are sought out to develop faster, smaller and less energy consuming electronic as well as new areas of applications for electronic devices. This includes photonic and electronic nanostructures based on 2D materials, such as graphene, MoS_2, and hNB, or on 1D materials such as carbon nanotubes or semiconductor nanowires. These materials and quantum dots may also form the physical basis for the development of quantum computing which is a highly specialized field in very fast development.

Beside the areas of high performance optoelectronic nano materials, another trend is the development of organic solution processable materials for flexible/printable/disposable electronics including low-cost large volume applications such as flexible displays, solar cells, and RFID for contactless identification of goods. Materials for these applications include conducting polymers, carbon nanotubes, graphene, metal nanowires and particles.

2.6 Trends in Responsible Research and Innovation

Since it came to wider public attention, the responsible development of nanotechnology has been subject to regulatory attention in EU and its member states as well as in US and the rest of the world. In the US the 2003 nanotechnology act specifically stated that the development of this technology should be done in a socially responsible way, and in the EU a code of conduct on responsible nanosciences and nanotechnologies research was adopted in 2009. An explicit motivator for such efforts was to avoid wide scale public controversies such as those experienced around the introduction of biotechnology. A large amount of reports and consultative engagement exercises have been conducted in various national settings – particularly in the first decade after the turn of the century – but, so far, the development of nanotechnology has proceeded without major public outcry or protests.

In later years, such regulatory attention to the areas of bio- and nanotechnology has been widened to a more general focus on RRI. While this term has achieved a certain stable usage (particularly in Europe), it covers a loosely defined set of phenomena, and is being developed and implemented differently in different contexts. Generally, its most stable and entrenched usage can be found in policy circles within the EU and the UK – while the concept has a more precarious life in other national contexts.

The concept of RRI has been particularly important in the Horizon 2020 framework, where it has been the focus of specific actions (RRI in EU is defined around the themes of public engagement, open access, gender ethics, science education) as well as a cross-cutting issue to be addressed and promoted in many other framework objectives. What the experience from Horizon 2020 demonstrates is that the interpretation of the idea of RRI is flexible. Some of the targeted Horizon 2020 projects have produced specific guidelines and implementation tools, whereas others have been focused more on the institutional changes and discursive patterns. Impact studies have begun to emerge, but there is no overall knowledge of the more general effects of attention to RRI as a concept or a process in the Horizon 2020 programme. Recently, policy documents from the EU have adopted a slightly changed use of language towards focusing more on the terms Open Science and Open Innovation as overall framework terms.

In the UK, the Engineering and Physical Sciences Research Council (EPSRC) has done pioneering work with its development of a Framework for Responsible Innovation as a process that *"seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest"*. Importantly, this framework supports an understanding focused on RRI as a process and uses the AREA principles (Anticipate, Reflect, Engage and Act) developed by Richard Owen, Phil Macnaghten, Jack Stilgoe and colleagues as guidelines. The same authors were engaged in the well-described case of RRI-principles used in relation to a particular case of a geo-engineering project, where the RRI-evaluation ultimately led to a closing down of the project. Such explicit cases, however, are still few and in general, the RRI agenda must be said to be under development.

Many countries, such as for instance Denmark, do not have a well-developed policy on RRI, although in some cases some of the content is covered through the use of other concepts, such as 'Ethics' or 'Scientific Social Responsibility' (a term that has caught on in some Danish funding bodies). It is not uncommon for funding bodies to discuss how they can integrate forms of reflection and action aimed at achieving social desirability in the grant applications. Such considerations, however, also often lead to discussions about how to evaluate and assess such aspects in the peer review process.

Furthermore, there seems to be a general discrepancy between the uptake of the term RRI in some policy circles and the research community as a whole. In general, it would be most accurate to say that the awareness of RRI is uneven in nano-scientific communities in the European countries (as well as in other parts of the world). While some nano-scientists have been engaged in discussions of social desirability of their research for more than a decade, many other groups have not heard about this concept and are rather critical towards what they see as 'more administrative demands' and grant application 'box-ticking' which will at best have no real impact on science. It is not uncommon for nano-scientists to comment that the entire RRI agenda seems very remote from what they do in their laboratories.

3 Support to the Norwegian nanotechnology research field and the role of the NANO2021 programme

3.1 Support to the nanotechnology research field in Norway

NANO2021 is one of the RCN's Large-scale Programmes. Originally planned for a programme period of ten years (2012–2021) it was recently converted into an ongoing programme with no current end date. It is the RCN's strategic research initiative in the fields of nanotechnology, microtechnology and advanced materials, and is a key instrument for following up the Norwegian Government's national R&D strategy for nanotechnology. The programme is a continuation of the programme Nanoteknologi og nye materialer (NANOMAT), which was terminated in 2011 and directly replaced with NANO2021.

In 1986, the Nobel Prize in Physics was awarded to Heinrich Rohrer and Gerd Binnig for their invention of the scanning tunnelling microscope. That microscope made imaging at the atomic level possible and also helped to establish that individual atoms within materials could be manipulated, building structures which give the materials new properties and behaviour. Different research groups started in many countries. Norway at that time had no R&D strategy for materials technology or nanotechnology and was far behind the rest of Europe and the USA. The evaluations of Norwegian physics and chemistry research, which were conducted in 1998–1999 recommended that a new research initiative should be established, giving priority to research on nanotechnology and new materials. Despite that, the Norwegian White Paper on Research presented in 1999 did not mention nanotechnology or materials technology. In 2002, however, the RCN made nano- and materials technology a priority through the NANOMAT programme.

The RCN launched a foresight project on materials technology in 2005[1] to put Norway's need for the expertise in nano- and materials technology on the agenda. One measure was to strengthen the NANOMAT programme. It should be the RCN's main field of nanotechnology, functional and new materials. The conclusions stimulated that the nanostructured materials, materials and nanotechnology for new energy technology and ICT/microtechnology should become the main priorities for the basic research in the programme. The budget for the NANOMAT should be increased to 150m NOK in 2007 and to 250m NOK in 2010. The programme should have a good balance between basic, strategic and user-driven research and should also be made attractive to the business community to participate in the programme's initiatives.

The Ministry of Education and Research was the NANOMAT programme's most important funder. When interest from the industry became clear, the Ministry of Trade and Industry got more actively involved, particularly during the latter part of the programme period.

The RCN's overall investment in nanotechnology and new materials research increased from 215m NOK per year to 310m NOK per year during the period 2006–2010. During that same period the NANOMAT programme had an annual budget of 80-120m NOK. The largest investments in 2009–2010 were made in the area of functional materials, nanotechnology, nanoscience, micro- and nanoelectronics, and health, safety and environment (HSE)[2]. The NANOMAT programme has also provided support for the R&D activities along the entire value chain.

During its ten years of existence, the programme helped to build a national knowledge base in a field that was quite new in Norway. Cooperation and task-sharing between research groups was developed at the national level, and Norway now has dynamic research groups in selected areas, particularly in solid-state physics and chemistry.

[1] RCN, Avanserte materialer Norge 2020, 2005.

[2] Nanotechnology and New Materials (NANOMAT) (2002-2011), Research Council of Norway.

It is of course difficult to know the exact reasons, but the relative citation impact in materials science from the period 2004–2007 to the period 1999–2003 increased much more for Norway than for other Nordic countries (except Iceland).[3]

In the white paper *Climate for Research*[4] the government presented five strategic goals. One of these *Research for business sector*, included new materials and nanotechnology. A strategy for R&D in nanotechnology was also anticipated.[5]

3.2 The NANO2021 programme

3.2.1 Rationale and priorities

A state-of-the-art review carried out by RCN in 2010 pointed out that after the NANOMAT programme, there is still a need both for continued development and an ongoing need for basic research on which to develop further knowledge. Both the review and the evaluation of the NANOMAT programme stressed the need for more generous long-term funding and that increased efforts were needed to harvest commercial results in the form of patents, new companies and innovations to a greater extent than was achieved under the NANOMAT programme. Greater focus on socially responsible technology development was also recommended.

In the above mentioned strategy the Government wanted nanotechnology to contribute to increased competitiveness of the industry sector and improved dealing with global societal challenges, without generating undesirable effects on health, the environment and society. The Government identified three priorities: Basic knowledge development, Innovation and commercialisation and Responsible technological development. The Government also considered nanotechnology to be an important tool in strengthening the future competitiveness of the industry sector and improving the ability to deal with global societal challenges related to energy, the environment, health and food in a sustainable way. Furthermore, the Government will take steps to ensure that the scope of technological development occurs within responsible boundaries for society. The Government stated that publicly financed R&D will concentrate on opportunities within national priority areas such as energy and the environment, health, food, the maritime and marine sectors, ICT, biotechnology and advanced materials. There will also be focus on overcoming challenges linked to potentially undesirable effects on health, safety and environment (HSE), and ethical, legal and social aspects (ELSA).

To achieve these goals, the NANO2021 programme, was launched as a ten-year, Large-scale Programme for the 2012–2021 period, administered by RCN. The programme receives its allocations from the Ministry of Education and Research and the Ministry of Trade and Industry. The programme is planned to be revised in 2017.

The primary objective of the programme is to promote the use of nanotechnology and advanced materials to develop cutting-edge knowledge and sustainable solutions designed to meet the needs of trade and industry and society at large. **The secondary objectives** for the programme period 2012–2021 are presented as follows:[6]

1. The programme will work to enable selected Norwegian R&D groups to achieve a position in the international forefront.
2. The programme will promote scientific development, renewal and quality by seeking out talented candidates, increasing mobility and boosting internationalisation.
3. The programme will enhance national value creation through the renewal of products, processes and services.

[3] Bibliometric Research Performance Indicators for the Nordic Countries (www.nordforsk.org).

[4] Klima for forskning (St.meld. nr. 30 (2008-2009).

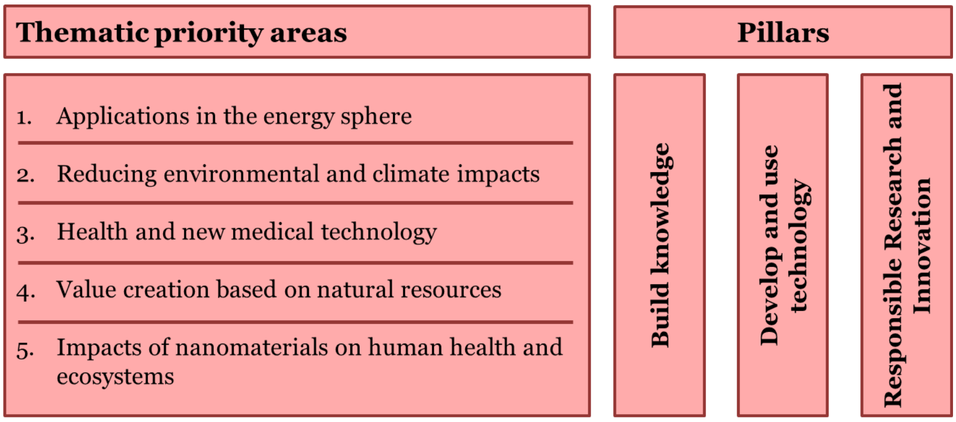
[5] The Government's strategy for nanotechnology 2012–2021.

[6] NANO2021 Work Programme 2012–2021.

4. The programme will promote the development of sustainable technology to be applied in a safe, responsible manner.
5. The programme will facilitate the optimal utilisation of national expertise, R&D resources and infrastructure through cooperation, constructive task distribution and highly focused research activities.
6. The programme will work to increase the attractiveness of Norwegian research environments to encourage knowledge-intensive companies in a global market to establish R&D activities in Norway.
7. The programme will promote social dialogue on nanotechnology and create new meeting-places.

The strategic priorities of the programme stem from the need to generate basic, cutting-edge knowledge in a long-term perspective. The ambition is to stimulate the process of developing knowledge and technology in close cooperation with industry, to satisfy society's needs for know-how and innovative solutions. At the same time, the programme applies a focus on social values and puts an emphasis on responsible implementation of these solutions. Figure 1 illustrates the interplay between the five thematic priority areas and the three pillars of the programme. The pillar *Responsible Research and Innovation* is both an integrated process in all projects supported by the programme and subject to individual research activities, further described below.

Figure 1 Interplay between the thematic priority areas and three pillars of the programme



Source: Programme Annual Report 2015.

3.2.2 Responsible Research and Innovation

Unrealistic expectations are often attached to new technologies. DDT for example turned out, not only to kill mosquitos, but to have adverse effects on birds (Silent Spring, Rachel Carson). Antibiotics revolutionised medicine in the 20th century. Easy access, however, led to overuse and to problems with antibiotic resistance. With nanotechnology, concerns arose about health effects. At the same time, nanotechnology is promising for applications in industry and nanoparticles are widely used in cosmetics, electronics, optical devices, medicine, and in food packaging materials. However, results indicate that nanoparticles with size of few nanometres may reach inside biomolecules and may cross cell membranes altering cell structure.

Therefore, the Government stated in the nanotechnology strategy that there should be no undesirable effects on health, the environment and society. In all projects, importance will be attached to generating a better understanding of the different impacts of nanomaterials on human health and the ecosystem, and to addressing broad-based ethical and social issues relating to the development, production and application of the technologies, when this is relevant.[7] Activities under this pillar of the

[7] The Government's Strategy for Nanotechnology 2012–2021.

programme will provide the knowledge platform needed for responsible, sustainable technology development as well as input for legislation in and regulation of the technology area.

Since the beginning of year 2000, ELSA (Ethical, Legal and Social Aspects) programmes have been established in many European countries as separate programmes or sub-programmes of national genomics research programmes. The historical background to this is the term ELSI research (Ethical, Legal and Social Implications) that was introduced in the context of the US Humane Genome Project (HGP) around 1990. During 2008, RCN launched an ELSA-programme for research into ethical, legal and social aspects of new technologies. The programme was focusing on biotechnology, nanotechnology and cognitive science. It can be seen as a continuation of the research activities that previously had been divided between the Ethics, Society and Biotechnology programme and the Large-scale Programmes FUGE (Functional Genomics) and NANOMAT (Nanotechnology and New Materials). The ELSA-programme collaborated closely with FUGE and NANOMAT, and from 2012 with BIOTEK2021 and NANO2021, in order to create coordinated and integrated initiatives on ELSA-related issues.[8] ELSA ended in 2014, and after that, RCN launched SAMANSVAR, a new programme with a focus on responsible innovation and Corporate Social Responsibility. This programme is built upon the experiences gained from the ELSA-programme[9].

Over the years, the RCN has developed its work on RRI in several ways. In 2015 the RCN developed a common framework for RRI inspired by the formal commitment to a framework for responsible innovation that was prepared by the UK's Engineering and Physical Sciences Research Council (EPSRC) in 2013. In parallel to developing the RRI framework, the RCN has also developed a new overall strategy, Research for Innovation and Sustainability (2015–2020), which clearly stresses the role of research in society and the societal mission of the RCN.[10]

3.3 Programme management and implementation

The programme board for the NANO2021 programme reports to the Research Board of the Division for Innovation. The programme board is commissioned to administer the programme's activities in compliance with the programme objectives and in accordance with the intentions and objectives of the RCN's overall strategy, the guidelines from the RCN's Executive Board and the Research Board of the Division for Innovation and the approved Work Programme.

The programme administration consists of a programme coordinator assisted by personnel with scientific and administrative expertise. The programme administration carries out the administrative functions of the programme and enables the implementation of the programme board's decisions.

3.3.1 Internationalisation of research

The programme administration is continuously assessing the need to develop programme-specific measures to help Norwegian researchers, companies and research institutions to become active participants on international cooperative and competitive arenas. The most important measure to equip researcher to take an active role in international R&D cooperation is the participation and funding of the two ERA-NET programmes M-ERA.NET and the EuroNanoMed. Applicants in national calls are also encouraged to include international partners in their proposed projects in NANO2021.

The programme setup and thematic priority areas are intended to reflect the priorities of the Horizon 2020, and in particular the Nanotechnologies and Advanced Materials under the Industrial Leadership pillar, which is deemed to stimulate and increased participation of Norwegian actors in EU funded R&D projects.

[8] RCN, Work programme 2008 –2014 for ELSA, 2008.

[9] RCN, Programme on Responsible Innovation and Corporate Social Responsibility – Work Programme 2015 – 2014, 2015.

[10] RCN, Research for Innovation and Sustainability (2015–2020), 2015.

3.3.2 Internal coordination and joint venturing with other activities

Cooperation in the form of, for example, common meeting-places, joint communication activities and, in certain cases, joint funding announcements is conducted with other neighbouring RCN programmes, included in Figure 2. NANO2021 (as well as other thematic programmes) also functions complementary to open competitive arenas such as the funding scheme for independent projects (FRIPRO), the Programme for User-driven Research-based Innovation (BIA), the Centres of Excellence (SFF) scheme, the Centres for Research-based Innovation (SFI) scheme, the SkatteFUNN Tax Incentive Scheme, the Programme for Regional R&D and Innovation (VRI), and the regional research funds.[11]

Figure 2 RCN programmes that interface with NANO2021

Source: NANO2021 Work Programme 2012–2021.

3.3.3 Research infrastructure

During the years of the NANOMAT and NANO2021 programmes, RCN has worked to expand research infrastructure relevant for nanotechnology and advanced materials science (e.g. the Norwegian Micro- and Nanofabrication Facility (NorFab) and Norwegian Centre for Transmission Electron Microscopy (NorTEM), among others). Applicants in the programme's national calls are encouraged to make use of such infrastructure, when relevant.

3.3.4 Communication and dissemination activities

The NANO2021 programme works in accordance with a communications strategy that helps to assure that the communications activities are contributing to the overall fulfilment of the programme's objectives. Communication should also contribute to demonstrating the links between research and society. During the course of the programme, a number of conferences and network meetings have been hosted or co-hosted by the programme. In addition, the programme administration also posts on the programme website news items, information and popular science on project activities supported by the programme.

[11] Work Programme 2012–2021 for NANO2021.

3.3.5 *Efforts to increase the participation of industry*

The group of companies that use nano- and advanced materials as the core technology in their end-products in Norway is dominated by small and newly established businesses. However, it is challenging for newly-established technology companies to make the transition from the laboratory to production, and finally to market, for a successful commercialisation.

One of the principal objectives of the programme is to contribute to strengthening these companies in creating new value in nanotechnology based products or services. At the same time, it is a well-known circumstance that small and newly established companies often find it difficult to participate or take the lead in publicly co-funded R&D projects for a number of reasons.

Several measures have been taken in order to bridge some of the challenges that small companies face in leading or participating in innovation projects. Companies are able to apply for a Pre-Project to do early investigations that provide them with a better basis for the decision to proceed with a full application for an IPN project or not. Prior to the deadline of the calls, companies can submit application sketches and receive feedback from RCN. Calls for Innovations Projects for the Industrial Sector (IPNs) run on the same time schedule across all RCN's funding schemes, which provides companies with a predictable planning horizon and enables RCN to guide companies to the funding opportunities that is deemed to best serve the companies' needs. In addition, there have been a number of events arranged by RCN directed towards the business sector to inform about the funding opportunities that NANO2021 offers or to engage companies and other actors in match-making etc.

3.4 Programme portfolio

3.4.1 *Project types*

In order to achieve knowledge building, value creation and innovation, the programme includes funding instruments that cover the entire value chain. RCN employs a set of standardised application types in all funding schemes, which determine the level of funding, the scope and the ownership of the project. Researcher Projects allow for full funding from RCN and promote high-quality research that lies within the scope of the NANO2021 programme's thematic priority areas. IPNs demand a level of co-funding from participating companies by at least 50% and Knowledge-Building Projects for Industry (KPNs) require co-funding in cash equivalent to 20% of project costs. Table 1 provides an overview of the funding instruments used in the programme.

Table 1 Overview of support measures used by RCN in NANO2021

Application type	*Objective*	*Description*
Researcher Project	To promote scientific renewal and development of disciplines and/or to generate new knowledge about issues relevant to society.	Projects developed by one or more researchers at one or more institutions. The projects may be independent or affiliated with a research programme. The grant is reserved for the non-economic activities of the research organisation.
Innovation Project for the Industrial Sector (IPN)	To stimulate R&D activity in trade and industry, particularly activities that promote innovation and sustainable value creation.	An R&D project designed to lead to innovation (value-creating renewal) for the companies participating in the project. The Project Owner and any partners will generally fund at least 50% of the project costs.
Knowledge-Building Project for Industry (KPN)	To contribute to industry-oriented researcher training and long-term competence development in the Norwegian research community within topics that are crucial to the development of business and industry in Norway.	Projects contribute to industry-oriented researcher training and long-term competence development in the Norwegian research community, and are designed around identified needs for new knowledge in Norwegian companies. The companies play an active role in the management of the project. The support provided by RCN may not exceed a maximum of four times the total cash contribution from the companies.
Pre-Project	To facilitate the preparation of a main project by supporting preliminary research/studies and other initiatives.	In NANO2021 the Pre-Projects are one of the measures taken to facilitate for small businesses to participate in the programme. Pre-Projects are funded with a maximum amount of 200,000 NOK.
Support for Events	To facilitate the efforts of Norwegian research institutions/companies to organise and host national or international conferences (workshops, seminars).	Expenses pertaining to the conference may be covered by RCN. Any further details will be described in the specific call for proposals.
Other Support (ERA-NET and IDELAB)	To provide funding for Norwegian participation in the M-ERA.NET and the ERA-NET EuroNanoMed. IDELAB is a novel approach for cross-discipline discussions and exchange of ideas to stimulate disruptive and innovative R&D projects.	The focus of ERA-NETs is funding of transnational research and innovation projects in selected areas with high European added value and relevance for Horizon 2020. Project consortia apply in response to Joint Transnational Calls and, if approved, actors subsequently apply for funding from each national funding body respectively. RCN funds the Norwegian participation in international ERA-NET projects.

Source: RCN.

3.4.2 The evolution of programme calls and other activities during 2012–2016

Calls for proposals regarding Researcher Projects are processed on a regular annual cycle, though with (sometimes) shifting focus and priorities. One call per year for IPN projects is processed in close coordination with RCN's other thematic and independent programmes that support IPN project. Applicants for IPN projects can submit a preliminary sketch of their project idea beforehand to RCN that, based on that sketch, respond with guidance to which funding scheme or programme the applicant should submit their full application to. In accordance with the RCN's participation in ERA-NET, NANO2021 offers Norwegian applicants for Joint Transnational Calls in two ERA-NET programmes the opportunity to apply for funding linked to their participation in these programmes. In addition, the programme continuously accepts applications regarding Pre-Projects, Mobility Grants, Fellowship Grants (since 2014) and Support for Events.

During 2012, the first year of the programme, three calls were launched: two calls for Researcher Projects and one call towards IPN projects. The first call for Researcher Projects was limited to two of the programme's prioritised areas (Energy and Health), the second (bound for Researcher Projects and KPNs) and the third for IPNs were open for applications in all of the programme's five prioritised areas. In 2013 there were two calls processed for IPN projects (one in the spring in addition to the regular call in the autumn), in order to stimulate an increase in industry-led projects in the programme. One call for nationally-coordinated Researcher Projects was launched to support projects of significant size and duration (20–35m NOK) as means to achieve a greater number of Norwegian research groups to be positioned in the international forefront. This call yielded substantial response from the research community and for the second time the RCN had reasons to increase the allocation of funds due to a large share of high quality applications. This year also saw the first joint call for proposals in collaboration with another RCN programme (PETROMAKS2[12]), designated for KPN projects. In 2013 and 2014, the NANO2021 programme contributed to the development of IDELAB, a novel approach for cross-discipline discussions and exchange of ideas to stimulate disruptive and innovative R&D projects. This work continued in 2014 in cross-collaboration with the RCN programmes BIONÆR, BIOTEK2021 and VERDIKT.[13]

In order for the programme to meet its target of a 15% resource allocation to RRI activities (including HSE and ELSA), the call for Researcher Project proposals in 2014 earmarked 26m NOK (out of 80m NOK). This allocation rendered two projects in subjects concerning knowledge on environmental and health issues in connection with production, use and disposal of nanomaterials in end-use products. In addition, a joint call in collaboration with the programmes ELSA and BIOTEK2021 was conducted in order to further stimulate projects related to RRI. On the international arena, the programme's contribution to ERA-NET continued in 2014 supporting Norwegian participation in projects under both EuroNanoMed and M-ERA.NET.

In 2015, the first calls in Horizon 2020 were completed and the RCN's ambition to align NANO2021 with the prioritisations in Horizon 2020 (in particular regarding the programme Nanotechnologies, Advanced Materials, Advanced Manufacturing and Processing, and Biotechnology, NMBP) seemed to pay off in terms of substantial Norwegian participation. In 2015, Norwegian partners had received 3.4% of the total allocated budget in NMBP and there were 22 funded projects with Norwegian participation.[14]

Two regular annual national calls for proposals were processed in both 2015 and 2016, two bound for Researcher Projects and two for IPN and KPN projects. In addition, calls for proposals bound for IPN and KPN projects in collaboration with BIONÆR was issued in both 2015 and 2016, the focus of these calls was value creation trough nanotechnology in food and bio-based industries.

Table 2 gives an overview of the results of calls processed by the NANO2021 programme, in joint national calls in coordination with other programmes and the Joint Transnational Calls under the ERA-NET cooperation. The competition for funding is fierce among the Researcher Projects, the average success rate in that category is approximately 10%. There are many proposals that are given high remarks by the evaluators that end up below the funding threshold. For IPN and KPN projects, the average success rate varies between 40% and 60%. However, a substantial number of applications in this category receive a lower rating than what RCN considers fundable, consequently the competition for funding among innovation projects is small.

Table 2 Number of applications per call and application type, number of funded projects in brackets

	2012	*2013*	*2014*	*2015*	*2016*
Researcher Projects	76 (6)	35 (5)	56 (7)	59 (6)	62 (5)
IPN and KPN projects	12 (3)	35 (15)	10 (6)	10 (4)	12 (6)
M-ERA.NET	25 (4)	19 (2)	33 (3)	30 (4)	33 (9)
EuroNanoMed	No call	16 (2)	18 (1)	16 (3)	20 (4)

Source: RCN's presentation of NANO2021 to the evaluation team.

[12] PETROMAKS2 is the Large-scale Programme for Petroleum Research.

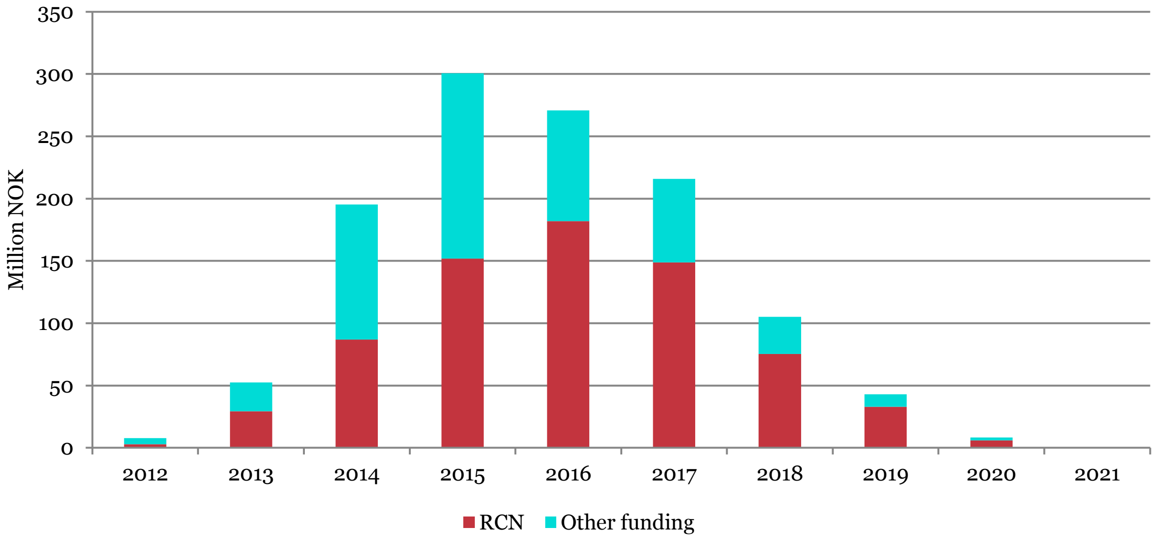
[13] BIONÆR is the Research Programme on Sustainable Innovation in Food and Bio-based Industries and VERDIKT the Research Programme on Core Competence and Value Creation in ICT.

[14] Annual report 2015 for NANO2021.

3.4.3 Project portfolio[15]

Figure 3 exhibits the distribution of the programme's allocated funding in 2012–2021. So far, RCN has allocated 716m NOK to funding of projects in the NANO2021 programme. As the programme is now in its fifth year, the presented numbers will increase during the course of the programme as new projects will be granted funding. In 2016 alone, RCN disbursed close to 182m NOK. Taking the projects' co-funding into account, the programme peaked in 2015 at just over 300m NOK in project funding. In 2015, a number of IPN projects from the first call ended, resulting in a decline in the share of active IPN projects (relative to other project types) from 2015 and onwards, which explains the decrease in co-funding from 2015 to 2016. As of now, most projects granted funding from 2018 and beyond are Researcher Projects, this distribution is however likely to change as new projects are accepted in the future programme calls.

Figure 3 Granted funding and co-funding per year

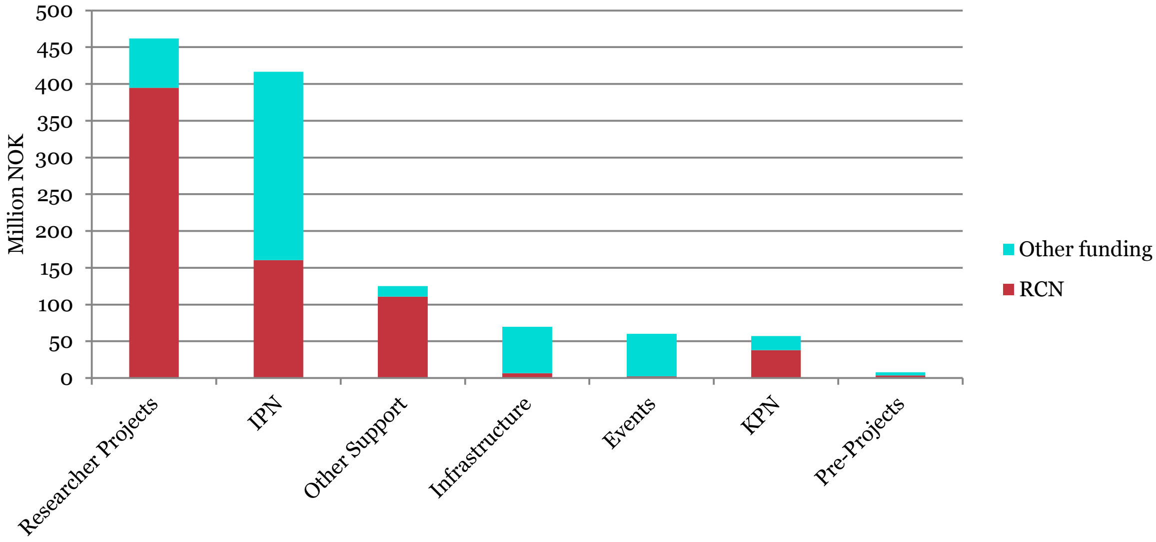


Source: Technopolis' analysis of RCN data.

Figure 4 shows the allocation of the RCN funding and co-funding among different project types. A majority of the RCN funding has been allocated to Researcher Projects, but if the co-funding (in IPN projects mainly companies' in kind and cash contributions) is taken into account, IPN projects are not far behind in terms of how much resources is put into the different type of projects. The NANO2021 programme also funds international projects under the ERA-NET cooperation. These projects (together with funding of IDELAB) constitute the Other Support category, although ERA-NET projects are dominating the category with well over 80% of the resources. Infrastructure (one project) and Support for Events account for small contributions from RCN. However, taking the co-funding into account, these projects represent a significant part of the programme activities. So far, the programme has granted five KPN projects. Lastly, the Pre-Projects make out a very small part of the programme's total funding, still 18 Pre-Projects have been granted funding so far.

[15] For reasons of consequence, calculations on the RCN's project funding and related co-funding in this section are based on the budget in the initial contract for all projects, even if more recent financial information is available for some projects.

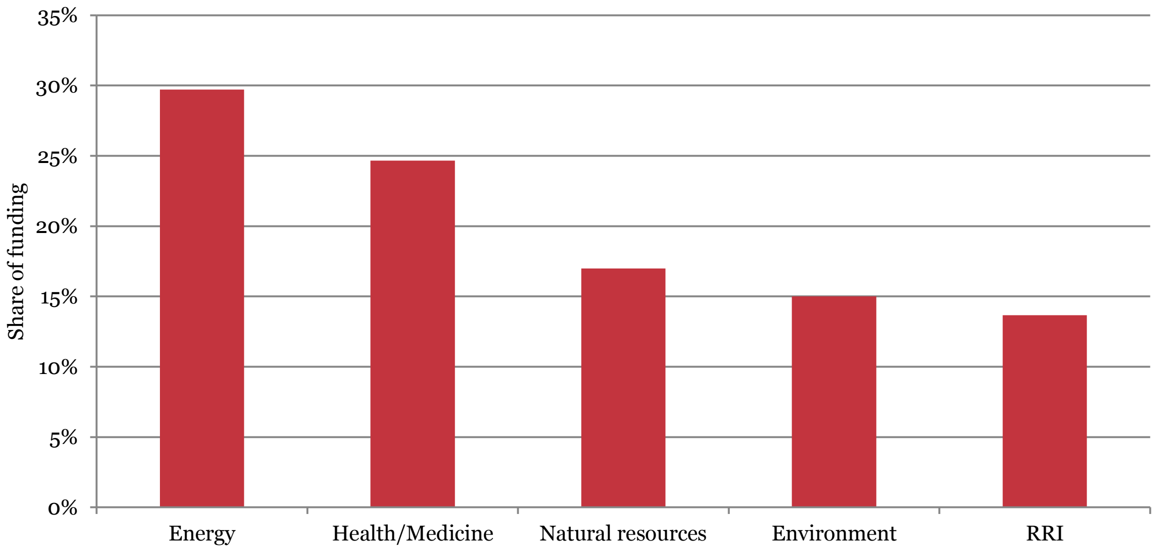
Figure 4 Granted funding and co-funding per project type



Source: Technopolis' analysis of RCN data.

All funded projects have been mapped by RCN based on which of the five thematic priority areas they are addressing. A breakdown of the allocation of resources reveals that 30% is attributed to Energy, followed by Health/Medicine at 25%. An almost equal amount of project funding (around 15%) has been allocated to the three thematic areas: Natural resources, Environment and RRI, as shown in Figure 5.

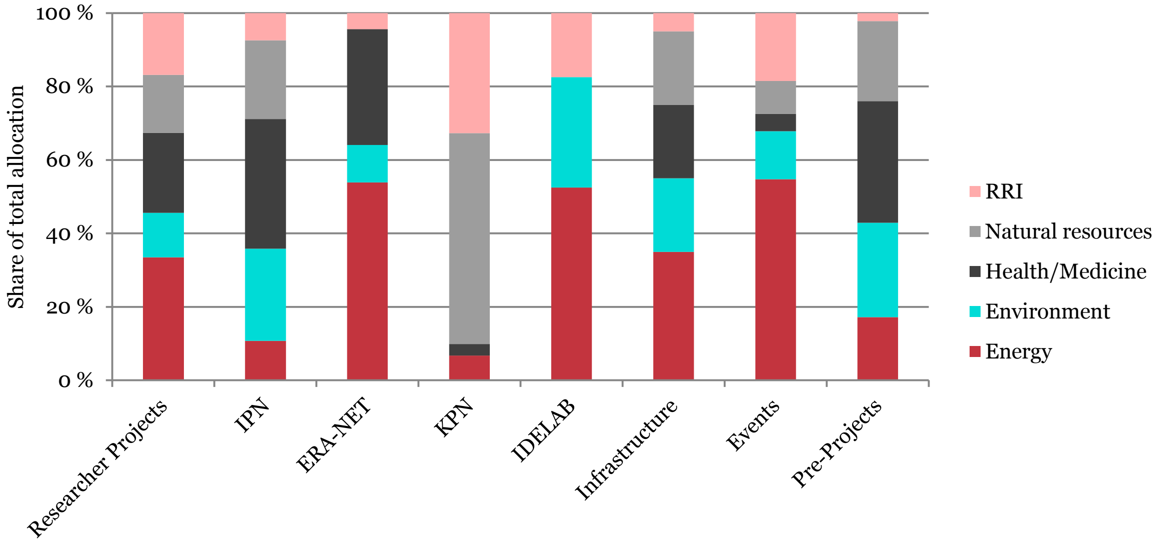
Figure 5 Share of funding per thematic area



Source: RCN.

Figure 6 shows the distribution of thematic areas for every project type individually. Research Projects exhibit an equal distribution of themes with only a slightly larger proportion of Energy related projects. IPN projects are mainly spread across Natural resources, Health/Medicine and Environment while ERA-NET projects are dominated by Energy and Health/Medicine. Most KPN projects share the same themes: RRI and Natural resources.

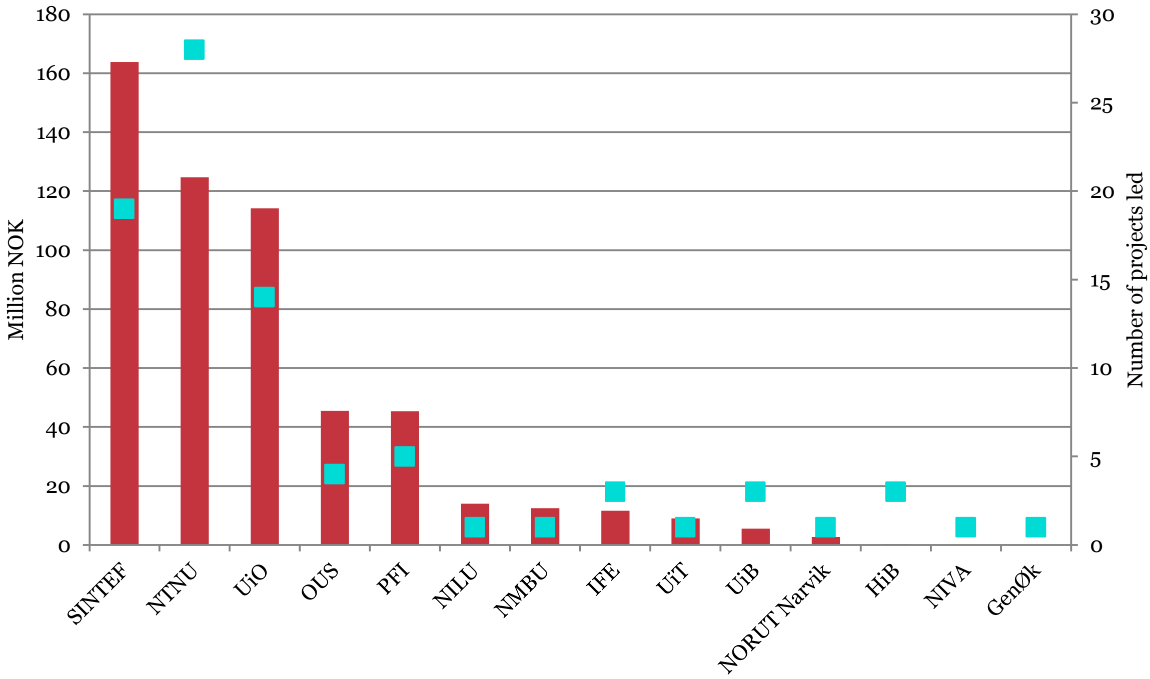
Figure 6 Share of funding per thematic area for each project type



Source: RCN.

Feil! Fant ikke referansekilden. shows the participation of R&D performers in NANO2021 both in terms of amount of funding granted and in number of projects led. However, the analysis contains some caveats, the figure only show to what organisation RCN has disbursed funding, not taking project internal transferals into account. The figure also shows how many projects each organisation is leading, but not how many participations as a partner they have. Because of how the RCN data is organised it is not feasible to perform that kind of analysis at this stage. With those limitations in mind, the SINTEF Foundation is the largest recipient of funding in the programme with over 160m NOK in granted funding. The Norwegian University of Science and Technology (NTNU) has so far received 125m NOK and coordinated 28 projects in the programme. The University of Oslo (UiO) joins NTNU as the second dominant university in the programme with 114m NOK granted and 14 project ownerships. Both Oslo University Hospital and the Paper and Fibre Research Institute (PFI) were awarded 45m NOK in funding each. The rest of the R&D performers have one or up to three project ownerships but are, as mentioned earlier, likely participating in other projects as partner organisations.

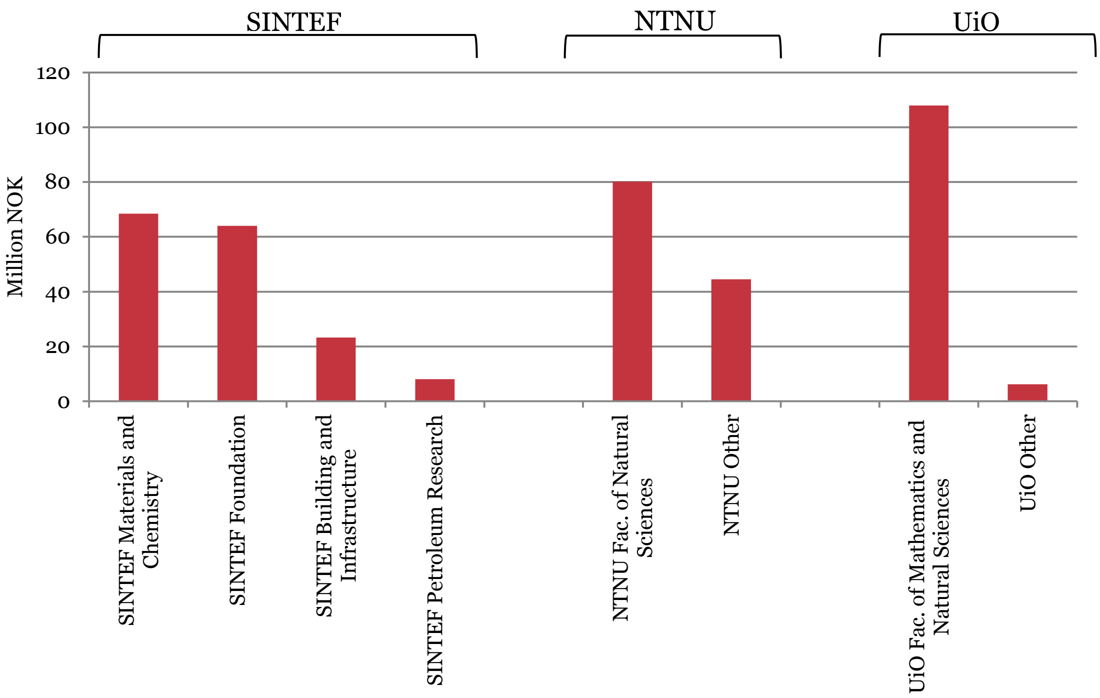
Figure 7 Granted funding and number of projects led for R&D performers



Source: Technopolis' analysis of RCN data. Note: red bars and left axis – granted funding; turquoise squares and right axis – number of projects.

A breakdown of funding per faculty at the three largest beneficiaries reveals that SINTEF Materials and Chemistry (formally part of SINTEF Foundation) has been granted 68m NOK. Within SINTEF Foundation (granted 64m NOK), another prominent actor is SINTEF Digital, although it does not show in the RCN data. The faculties of natural sciences are the primary recipients in both universities, see Figure 8. In the Faculty of Natural Sciences at NTNU, the Department of Physics, the Department of Chemical Engineering and the Department of Materials Science and Engineering have received the largest individual research grants. In the Faculty of Mathematics and Natural Sciences at UiO, the Centre for Materials Science and Nanotechnology is the principal beneficiary with seven large-scale research grants in total.

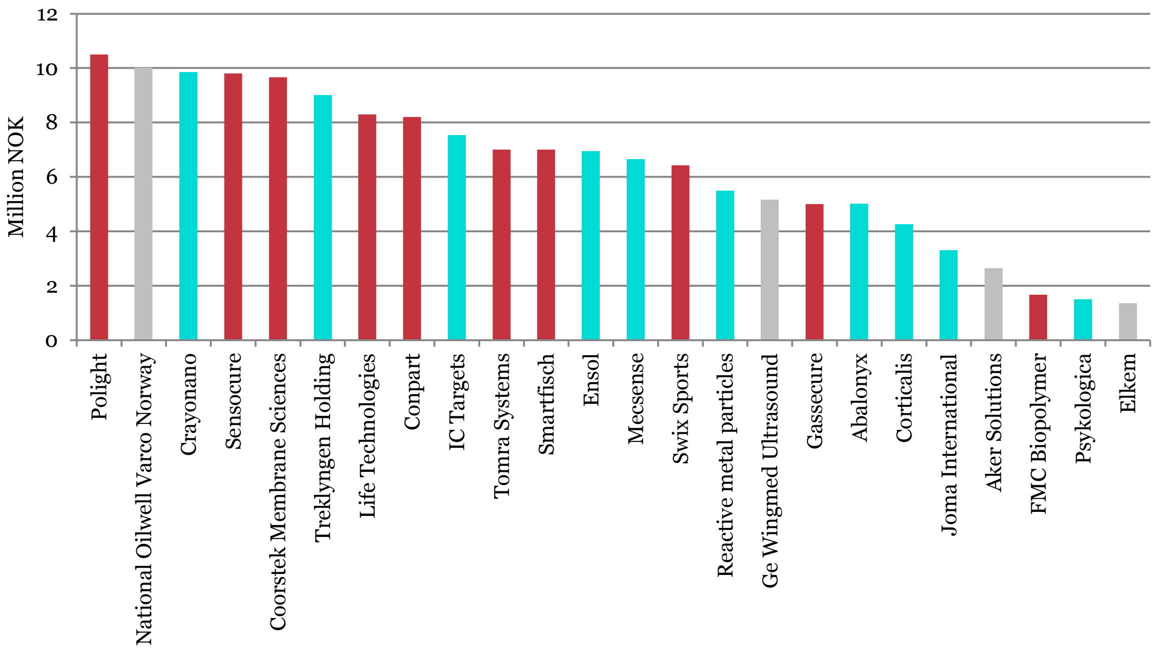
Figure 8 Breakdown of granted funding per entity of SINTEF and faculty at NTNU and UiO



Source: Technopolis' analysis of RCN data.

Figure 9 reveals the participating companies in descending order based on how much funding they have been granted. Companies granted less than one million NOK are not included in the figure. The same caveats mentioned for the R&D performers apply to this figure. With a few exceptions, companies have so far acted as project owners on one occasion, no company has up to this point been granted more than two projects in NANO2021. The turquoise bars indicate companies with less than 10 employees and the grey bars represent large companies (more than 250 employees). It is worth noting that several of the other companies (red bars) also are quite small in terms of number of employees and economic turnover. Thus one can conclude that the industry participation is concentrated to small companies and that very few large companies are visible in NANO2021. This is, however, very much a reflection of the nanotechnology sector in Norway, which is dominated by small and newly established companies.

Figure 9 Granted funding (more than NOK1m) for companies



Source: Technopolis' analysis of RCN data.

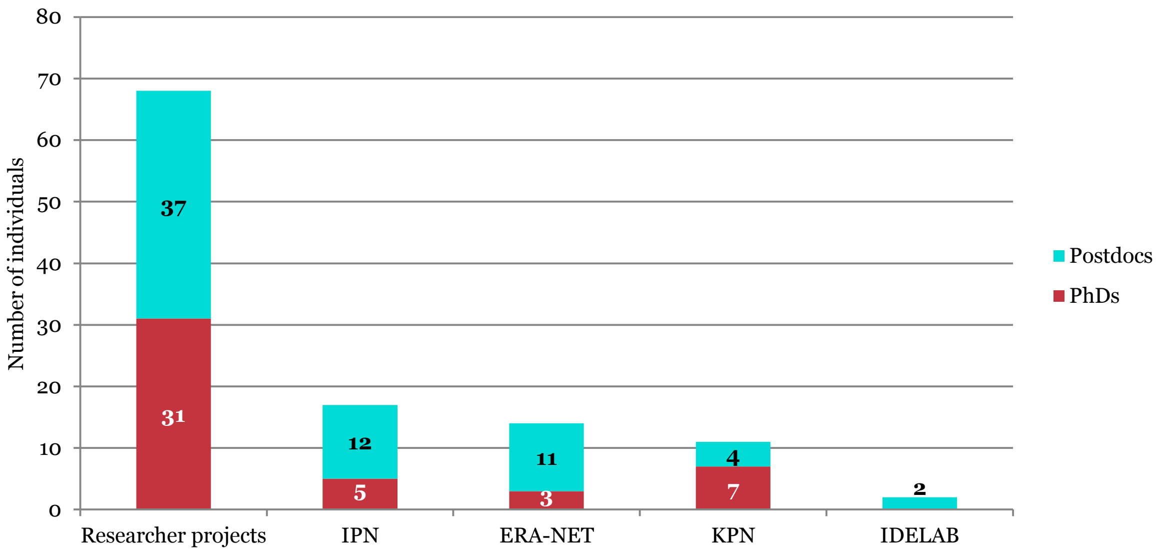
4 Contribution of the NANO2021 programme

4.1 Achieved results

Although assessment of the results achieved through the NANO2021 projects was not the purpose of this evaluation (especially due to the fact that most of the projects are still ongoing), it is nevertheless useful to have a brief glimpse into the results.

The RCN is monitoring how many PhDs and postdoctoral fellowships the programme is funding. Figure 10 shows the number of fellowships and in which type of projects they are located. In August 2016 a total of 46 PhDs and 66 postdoc fellowships were funded by NANO2021.

Figure 10 Distribution of PhD and postdoc fellowships



Source: RCN.

The RCN also presents some result indicators in the programme's annual reports. A compilation of these indicators can be found in Table 3. The indicators are based on the reports from the funded projects through the programme. In the first two annual reports (2012 and 2013), results from some projects that were funded by the predecessor programme – NANOMAT – were reported, hence the rather impressive rate of scientific publications during the 2012–2013.

The programme accounts for a substantial and steadily growing collection of grey literature (technical reports, popular science etc.). The innovation indicators in 2015 are a bit skewed by operational support for NorFab which is a national infrastructure for research and innovation within micro-and nanotechnology. There is a close connection between some of the projects funded by NANO2021 as they utilise the NorFab facilities in their research and development activities. In 2015 there were 15 Researcher Projects, two KPN projects, seven IPN projects and two ERA-NET projects that had or planned to utilise NorFab.

Table 3 Compilation of reported results achieved by projects in NANO2021

	2012	2013	2014	2015
Scientific publication				
Journal articles	39	17	20	36
Articles in anthology	128	107	0	10
Monographs	1	1	8	5
Other publications				
Other reports	75	122	97	189
Popular science	3	3	6	14
Media covering	5	37	28	27
Innovation indicators				
New or improved methods, models, prototypes	5	9	3	10
New or improved products	2	2	2	15*
New or improved processes	1	2	3	88*
New or improved services	0	0	1	0
Patent applications	0	2	6	10
Licence agreements	0	0	0	1
New companies as a result of the project	1	0	0	0
New business areas in the existing companies	0	0	0	2
Introduction of new/improved methods/technologies in participating companies	2	0	3	49*
Introduction of new/improved methods/technologies in other companies	0	1	1	43*
Introduction of new/improved working processes/business areas in participating companies	1	0	0	3

Source: Programme Annual Reports. Note: *The project "Driftstøtte til NorFab" contributed to very high numbers in certain innovation indicators in 2015.

Applicants are encouraged to utilise the available national research infrastructures in their proposed projects. Besides NorFab there are several resources available relevant to research and development in nano- and microtechnology and advanced materials. As of August 2016 43% of IPN and KPN projects reportedly makes use of research infrastructures; for the Researcher Projects (including ERA-NET) the share is 69%. In the survey, 33% of participants in Researcher Projects stated that the project gave them access to national research infrastructure, which they otherwise would not have had access to. In addition, 50% of respondents in Researcher Projects stated that the project gave them access to international research infrastructure facilities.

There seems to be a resounding consensus among participants in the programme that their projects indeed yield increased networking and knowledge transfer between actors in the projects. In other aspects the different emphases of the two types of projects (i.e. industry-led commercially oriented IPN projects and researcher-led projects) become evident. Industry-led projects are more likely to increase value creation through development of new products, services or processes and Researcher Projects have achieved dissemination of new knowledge outside the scientific community and increased networking among actors in the nanotechnology sector. Two of the case studies serve as good examples of these two types of achievements.

Innovative low friction materials with reduced environmental and health impacts (IPN project)

Recent considerations on environmental and health issues concerning perfluorinated chemicals revealed the abundance of those substances such as backbone of 8 carbon atoms (C8) in nature. Furthermore, the Norwegian environmental authorities together with its German counterpart have taken a leadership on reducing the use of perfluorinated compounds in general and of C8-based carbon matrixes in particular. The primary objective of the project was to identify and develop at least one new class of friction reducing materials that have properties good enough to warrant production and marketing as replacements for the fluorine-containing products that are on the market today.

The project owner, SWIX, is a leading supplier of wax product for cross-country skiing. In the project the company primarily cooperated with a subcontractor, supplying the fluoride component used in the waxes, and researchers at SINTEF Materials and Chemistry and NTNU in order to develop and test nano-based fluoroalkane technologies that could make wax products containing fluorine more environmentally friendly and comply with stricter environmental regulation that will likely be imposed in the future.

The project ends in September 2017 and has already provided enough knowledge enabling the company to replace the most damaging fluorine component in one of SWIX's high performance waxes on the market today. This knowledge could, in theory, be applied to products that appeal to a larger share of the market; however, the high production cost involving nano-based components makes it unfeasible to introduce this technique in mass-market products at this point. Further testing and technical evaluation are planned. The company is also assessing possibilities for future participation in the NANO2021 programme.

Generation, protection and health effects of nano-sized dust in the ferroalloy industry (KPN project)

Dust caused by metal production is unwanted but also unavoidable in the processes. Whenever molten metal is in contact with air, dust tends to form. In addition, dust will also form during handling and transport of both the ores, which are used as raw materials, and the metal which is produced. Some types of dust are suspected to be dangerous to inhale – especially in the case of long-term exposure.

More attention has been directed to so-called nano-particles or "ultrafine" dust. Until recently, ultrafine dust was difficult to detect and the presence and properties of ultrafine dust, as well as the effects on humans, is largely unknown. The DEMASKUS project studies these issues by collecting dust from both the industry and the laboratory, characterising it with special attention to the ultrafine particles and study how human lung cells react to the different kinds of dust. The project is also testing the effectiveness of the respiratory protection devices. According to the project leader, there is great demand for extended knowledge about these issues in the ferroalloy industry as well as among work environment authorities. There have been discussions for many years between knowledge institutions, industry and public authority about the need for cooperation on this subject and the opportunity for creating a joint project arose in the NANO2021 programme. Industry actors are contributing in cash but are at the same time very active in the project, especially in connection to the researchers' fieldwork.

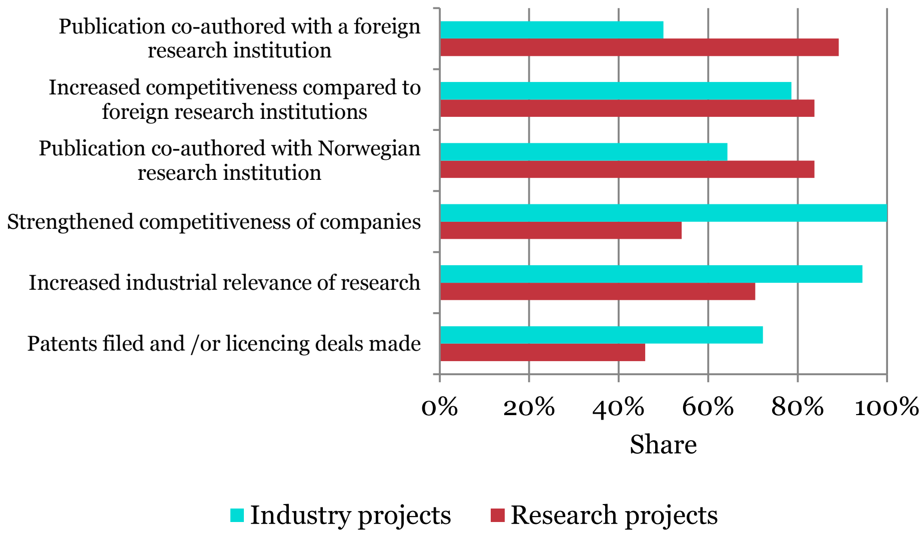
The project is interdisciplinary and has led to extensive knowledge transfer between research institutions working in different disciplines. The project has already increased the researchers' theoretic understanding of other academic disciplines and will improve the usefulness of, for example, technical metallurgic research for occupational hygiene researchers, and vice versa.

Results delivered by the projects are fundamental in trying to answer the first evaluation question on the contribution of the portfolio of funded projects towards the achievement of the NANO2021 programme's objectives. Such contribution can take different forms. This evaluation has specifically asked for the programme's contribution towards scientific quality in Norwegian nanotechnology research; societal and commercial innovation and value creation in the short- and long-term; and a more societal technology development through continuous focus on RRI. Evidence of these various contributions is presented further in this section.

4.2 Programme's contribution to scientific quality

When examining results and impact it is important to keep in mind that the project portfolio (especially among Researcher Projects) is heterogeneous, ranging from 9–30m NOK in funding and projects with a handful of partners to some quite large multidisciplinary projects engaging researcher and other organisations nationwide. Figure 11 shows a sample of the results most frequently expected to be achieved, according to project participants. The full set of results can be found in Appendix D. Well over 80% of participants in Researcher Projects expect to achieve co-authored scientific publications with other R&D performers, both foreign (89%) and national (84%), and to increase competitiveness compared with international peers.

Figure 11 Respondents' views on what results they expect their project to achieve



Source: Online survey. Note: The figure presents the share of aggregate responses "Agree" and "Strongly agree".

Another case study describes one of the larger Researcher Projects in the programme and how it represents a national effort in the area of future cancer treatment.

Biodegradable Nanoparticles in Cancer Diagnosis and Therapy (NANOCAN) (Researcher Project)

Cancer is one of the most frequent diseases known to man. It is estimated that roughly one-third of the population in the Western world will at some point in life be diagnosed with cancer. The major challenge for cancer treatment is to deliver enough drugs to cure the cancer without having too high toxic side effects. The aim of the NANOCAN project is to increase knowledge about the behaviour of nanoparticles in the healthy and diseased bodies. Thus, the project should facilitate the development of nanoparticle-based products for imaging and therapy of cancer and contribute to an increased life standard for many patients.

The project consists of an interdisciplinary cluster of experts in the fields of NP synthesis and design, cell biology, immunology, mouse tumour models, preclinical imaging, bio distribution, pharmacokinetics and clinical studies. The lead unit at Oslo University Hospital involved in this project has many years of experience in studying the transportation and uptake of NPs in human cells. In addition, the neighbouring unit at the hospital has extensive experience of animal testing.

The project includes interdisciplinary research and encompasses both fundamental research and implications for clinical therapy. This approach is venturous, and evidently, some work packages have shown to be more successful than others. However, a majority of work packages are delivering results of high scientific interest.

What has been very fruitful is to have individuals in the project who have experience of working in a clinical environment as well as with fundamental research. The consortium contains several key individuals who have split positions and work with patients and research in parallel and who can convey the perspective of the practitioners to other members in the team. The project is a truly national effort and will help to further strengthen research groups which already hold internationally leading positions.

International cooperation and increased international competitiveness (of their own research institution) are the most expected results according to participants in Researcher Projects. Interviews with project leaders confirm that there is a notion among researchers in several sectors that NANO2021 projects are contributing to individual research groups strengthening their positions in emerging research fields by stimulating international cooperation (e.g. by requiring international partners in Researcher Projects). However, some of the top funded institutions in the programme were already before the programme arguably among the leading groups in their fields internationally. Having said that, there are some indications that these groups – through projects in the NANO2021 programme – bring less-established institutions into an international context and thereby make them visible to foreign partners and empower them to participate in subsequent international project, for example, in Horizon 2020. The NorNANoREG project illustrates how an experienced participant in a EU-funded research, through national funding, can help bring other national actors into an international context and how national funding can enhance the Norwegian participation in a related international project.

National initiative towards developing a common approach to the regulatory testing of manufactured nanomaterials (NorNANoREG) (Researcher Project)

There is a conflict between the innovative and economic potential of Manufactured Nano Materials (MNMs) and a limited understanding of the related environmental, health and safety issues connected with these new products. While toxicity data is becoming continuously available, the relevance to regulators is often unclear or unproven. The relatively short time to market of new MNM products increases the need for urgent action by regulators. NANoREG ran in 2013–2017 and included 71 partners from 17 countries. It was the first project funded by Horizon 2020 the EU Framework Programme to deliver the answers needed by regulators and legislators on issues concerning environmental, health and safety issues, by linking them to a scientific evaluation of data and test methods.

In parallel to this EU project, the NANO2021 programme funded a national project with close links to the work done in the NANoREG project. The NorNANoREG project is a national initiative towards the development of a common approach to the regulatory testing of MNMs. The project is coordinated by the Norwegian Institute for Air Research (NILU) and involves other six national partner institutions: the University of Bergen, the Norwegian University of Life Sciences, SINTEF Foundation, the National Institute of Occupational Health, GenØk Centre for Biosafety, and Comet Biotech. All partners have also participated in the aforementioned NANoREG project.

The NANO2021 funding gave the participating organisations the ability to take a more active role in the EU project. Norwegian organisations (especially research institutes) have suffered from poor funding conditions in the FP7. The national project helped to increase the level of combined funding and thereby enhanced the Norwegian presence in the international project. This has increased the potential to generate positive effects on the participation of Norwegian organisations in future EU funded projects. Partners experienced in international projects (e.g. NILU) can have a role as a facilitator by bringing in less experienced organisations into international consortia, thus making them visible internationally and increasing their chances of being invited to subsequent projects.

In addition, the NANO2021 funding has contributed to deepening and strengthening the cooperation between the Norwegian partners, as well as facilitating the actors to utilise and develop the results from the EU project in a national context.

The survey results suggest that Researcher Projects are more likely to lead to international cooperation compared to industry-led IPN projects, still 50% of participants in IPN projects expect co-authored publications with a foreign research institution and 70% expect that their projects will strengthen participating R&D performers' competitiveness compared to their national and international peers.

The programme offers allocated funding for researcher mobility, support for inviting scholars to Norway and support for Norwegian researcher to visit research institutions abroad. Researchers in ongoing projects in NANO2021 can apply for funding. The programme allocates 1m NOK annually and so far only a third of that has been triggered, resulting in three projects receiving mobility support on average per year. In addition, some Researcher Projects have planned for mobility activities within the original budget. Relatively few survey respondents expect their project to lead to researcher mobility, only one in five among participants in Researcher Projects. The share is actually slightly higher among respondents representing IPN projects (31%), which could be an indication of companies expecting to hire researchers in connection with the funded project.

The Expert Group identifies some research areas that seem to be less covered in the programme (electronics, both high-end nano electronics (quantum devices) and low-end large volume polymer/molecular based printable/flexible electronics), as well as other areas with quite strong representation of Researcher Projects (hard nano materials for energy applications, in particular; fuel cells, batteries, thermoelectrics). The bias for some topics may reflect certain research stronghold areas in Norwegian science that have developed over many years.

4.3 Programme's contribution to societal and commercial innovation and value creation

The survey supports the longer-term view of the participating organisations in seeking not only the scientific outputs from their projects but also industrial relevance of their research results. Participants of the projects express satisfaction with the programme's contribution to innovation and value creation. Virtually all respondents in industry-led projects expect that participating companies will strengthen their competitiveness and that industry relevant research will increase in participating organisations. Almost three quarters also state that patents or licencing agreements are likely outcomes of their industry-led project (which as seen from Table 2 has already happened in several cases). It is also interesting to note that a greater number of participants in industry-led projects expect results to be commercialised internationally rather than nationally, indicating that the companies leading IPN projects in the programme act (or at least strive to act) on an international market.

The share of respondents who expect commercially oriented results from Researcher Projects are smaller but still 70% expect their project to lead to increased industrial relevance of research within the participating organisation and 46% expect a patent or licencing agreement to be achieved.

The project participants were also asked about their views on what the NANO2021 programme as a whole contributes to. While many participants in industry-led projects recognise that the project contributes to a general increase in value creation in the nanotechnology sector and retained or expanded R&D activities within the private sector, only half agrees that the programme facilitates meeting places for national dialogue. In the latter, 70% of participants in Researcher Projects agree with the same statement. They are, however, less convinced that the programme creates value or has positive effect on R&D activities in the private sector. These seemingly different views can largely be explained by the fact that participants simply do not have the full picture. Looking at the responses it becomes evident that the ones that “do not agree” with the statements most often have responded “do not know” rather than “disagree”. Lastly, a significant share of respondents does believe that the programme contributes to both internationalisation of nanotechnology related research and increased cooperation among research environments active in the field, much in line with what they expect that their own projects will accomplish.

The external Expert Group highlight in their assessment the reclusive position of the larger Norwegian companies (oil and gas companies in particular) in the project portfolio, despite Energy being one of the prioritised areas in the programme. There are however several plausible explanations for this. Larger companies in general may not be depending on this type of funding for their R&D and find the administration too demanding in the light of the potential benefits. It is beyond the scope of this evaluation to look at the RCN’s total portfolio on nanotechnology and advanced materials but it has been established that at least the oil companies are active in other thematic RCN programmes, for example PETROMAKS2. It is plausible that large companies will have more prominent positions in other R&D activities related to nanotechnology, microtechnology and advanced materials.

4.4 Programme’s contribution to Responsible Research and Innovation

As described in Section 3, 13% of the funds have been allocated to RRI and theme 5. This is slightly short of the goal of 15%, but as the programme is ongoing, the overall target might still be reached. There has also been variation over the years. In the action plan 2013–2014 it is noted that only 9% of funds are allocated to this area and that no projects have their main focus on theme 5. In 2014 a joint call with BIOTEK2021 and the ELSA programme focused on ELSA projects was instrumental in getting the RRI-component of the programme to 16% in 2014. This is the only specialised call in the programme so far, and the fact that the percentage is currently 13% implies that the 15% objective cannot be reached without special attention or actions in the programme.

RRI is a strategic priority under the NANO2021 programme and applicants to NANO2021 are required to describe how relevant research questions will be addressed in relation to HSE, ELSA and/or other RRI perspectives. The survey respondents find it difficult to express a clear view on the impact of RRI practices as a result of the NANO2021 programme. A large share of the respondents answered “Do not know” or “Neither agree nor disagree” when asked about how the programme as a whole contributes to spreading knowledge or increasing awareness of the RRI topic.

However, in terms of how RRI has benefitted individual projects the expressions of opinion are plenty. Many researchers (in both surveys and in interviews) raise questions whether researchers as a collective already are aware of the principles of RRI and have incorporated RRI aspects into their research practices. In the words of a couple of survey respondents:

For our organisation this is already a focus in all our research activities, especially a strong focus on HSE. As such the NANO2021 project has not been conducted in a different way in this respect. (Funded project applicant)

There is already a very high awareness of RRI in the nanotechnology area. I do believe that other chemistry researchers have the same level of awareness so it is difficult to know if the additional requirements from RCN actually make a difference. (Funded project applicant)

Some went on to elaborate further on this subject by suggesting that researchers working with nanotechnology are applying RRI principles in their research; however, they may not necessarily be aware of the RRI terminology.

Thus, to some, the inclusion of RRI in their projects may not result in raised awareness simply due to the fact that they were already keenly knowledgeable on RRI. However, several interviewees suggest that just having RRI as a prerequisite during application can serve to raise awareness of RRI for those applicants who were not previously exposed to the terminology. One researcher expressed that he, during the application process, was forced to read up on the RRI topic to make sure that the aspects of the proposed project were in compliance with the requirement. This researcher felt that this has provided some new insight, but not likely affected the way the research has been conducted.

This issue has also been the subject of an independent research project funded jointly together with the BIOTEK2021 programme.

Performing ELSA. Governance of and governmentality in biotechnology and nanotechnology research (PerformE) (Researcher Project)

The PerformE project is run by the Department of Interdisciplinary Studies of Culture at the Norwegian University of Science and Technology (NTNU). It started in 2014, runs for 3 years and received 5.6m NOK jointly from two large-scale programmes NANO2021 and BIOTEK2021. The project seeks to investigate the interface between steering R&D and R&D's self-regulation. In the last decades, researchers increasingly have faced demands to consider ethical, legal, and social aspects (ELSA) of their work and to increase the responsibility and accountability of R&D.

The PerformE project is a direct result from previous activities in a preceding project in the NANO2021 programme (Socially Robust Solar Cells, SoRoSol), where stakeholders engaged in solar cell technologies and their concerns and arguments regarding ELSA issues in the development process of solar technology were studied. Results from the SoRoSol project have influenced the way in which the two programmes are processing their calls in relation to the requirement of inclusion of RRI.

The current project applies a meta perspective on the NANO2021 programme, as one of the main objectives is to study how researchers in the programme interpret, include and execute issues regarding ELSA and RRI in their research. The project has so far observed that many researchers face difficulties in their operationalisation of ELSA and RRI. The policy guidelines from RCN are of some help but are also perceived as too vague. However, results from the project suggests that one of the principal objectives has been met. Researchers are, to a greater extent, reflecting on issues related to ELSA and are in some sense "forced" to look objectively at their research conduct and how they interact with the surrounding society.

The Experts' reflection on the fact that researchers involved in the NANO2021 programme have different views on RRI mirrors with researchers in other national contexts. While some are very positive towards the effects of the programme and the help in integrating RRI aspects in their project, others state that researchers are already responsible and that the specific focus on RRI does not – and should not – change this.

The Experts also refer to the evaluation of five nationally coordinated projects done in 2016 by the RCN, where a similar picture is found. According to that evaluation, RRI has helped provide better opportunities for commercialisation, just as it has helped provide new topics as well as increased the discussion of unforeseen effects. Interestingly, a majority of respondents in the RCN-evaluation deny that the RRI elements have made it more attractive for users to engage in the project. A breakdown of the answers into the five different projects, however, demonstrate that the answers vary quite a lot between different projects hence enforcing the interpretation, that knowledge about and attitudes towards the RRI framework is very unevenly distributed in the Norwegian community of nano-researchers.

4.5 Programme's alignment with national strategies and international trends

Another question for this evaluation was to look at how well the programme has so far met research policy priorities and national needs and trends as well as how it correspondents with the international trends in the nanotechnology field.

When reviewing the programme's alignment with research strategies it becomes evident that the programme should be seen in a larger context, supplementing other RCN programmes and funding instruments. For example, one observation made by the Expert Group is that key international research fields, such as ICT and biotechnology, are not specifically designated as thematic priority areas in the NANO2021 programme plan. These are both research fields where the RCN has initiated separate thematic programmes that work alongside the NANO2021 programme (BIOTEK2021 and IKTPLUSS). The ICT area covers important industrial applications like nanoelectronics, data storage and quantum computing. ICT also includes micro- and nanosensors. One might argue that the ICT technologies are relevant within other areas, such as "Reducing environmental and climate impact" or "Health and new medical technology" This prioritising may, however, be the reason why very few projects in NANO2021 concern nanoelectronics, if any. On the other hand, sensor technology is the topic of several IPNs and some Researcher Projects within the existing thematic areas.

Furthermore, the Expert Group highlights that important areas of the Government's strategy; food, marine and maritime applications, are not directly covered among the thematic areas, but is part of "Value Creation based on natural resources". Prominent Norwegian export industries such as, oil and gas industry and the marine sector, is not included as separate thematic priority areas. "Oil and Gas" is not included in the thematic area "Applications in the energy sphere". The topic is, however, mentioned as part of the area of natural resources, in which also the marine sector, mining, etc. are included. The Expert Group's review of the programme portfolio, show that these research fields are scarcely represented. Joint calls have been made in these areas together with the RCN programme BIONÆR and PETROMAKS2, which however only resulted in a few funded projects.

Most project participants believe that NANO2021 is aligned with the current developments in the nanotechnology field (92% of project participants). This is a very positive response from the project participants which further suggests that the programme corresponds with the demand for R&D in the field. The non-beneficiaries are not equally convinced but still, almost 80% agree that the programme is in line with the current developments in the field.

The fact that a very high share of respondents perceives NANO2021 aligned with international trends also reflects back to the intentions, expressed by some, to use their NANO2021 projects as a stepping stone for international funding, indicating the programme could act as a successful gateway for Norwegian R&D performers looking to expand its participation in international projects.

As already mentioned, it is the Experts' impression that many of the funded projects are centred within a limited number of topics and that some internationally observed growth-areas are missing or, at best, appears underrepresented. However, the Experts' assessment is that the project portfolio covers a broad range of nanomaterials, application and research areas. Considering the relative low number of projects in the programme, the portfolio as a whole manages to cover quite a large part of the international trends in nano research.

4.6 Programme additionality

Having discussed some of the contribution delivered by the programme to the scientific, commercial positioning of Norwegian research in the field, the question which arises is how crucial NANO2021 has been. Has the programme contributed to change in behaviour among project participants? What would the nanotechnology research landscape in Norway look like if it has not been for the programme? In other words, what any evaluation of this type should look into is the additionality of the programme. It is with this in mind that a part of the online survey focused on investigating where the research ideas and applications for NANO2021 came from and how much they were linked to the predecessor programme NANOMAT.

4.6.1 Development of research idea and project application

The survey results reveal that the most important motivational factors for all actors to participate in projects funded by the NANO2021 programme are to access funding for R&D activities, followed by strengthened cooperation with R&D performers. For industry-led projects, value creation is also an important motive. It could be seen as on the verge of trivial to conclude that researchers are motivated by opportunities to receive funding but several interviewees have emphasised that NANO2021 is a strategically important programme for their research groups and that the large investments made in the programme from the Government is an important act of signalling, that is affecting the strategies of research organisations engaged in the nanotechnology sector.

The NANO2021 programme is *de facto* a continuation of the former Large-scale Programme NANOMAT. The evaluation of NANOMAT concluded that the programme had strengthened the research quality and research capacity among R&D performers in the nanotechnology sector in Norway. Subsequently, it was suggested that NANOMAT provided a level of competence that could be maintained and evolved through further R&D investments.

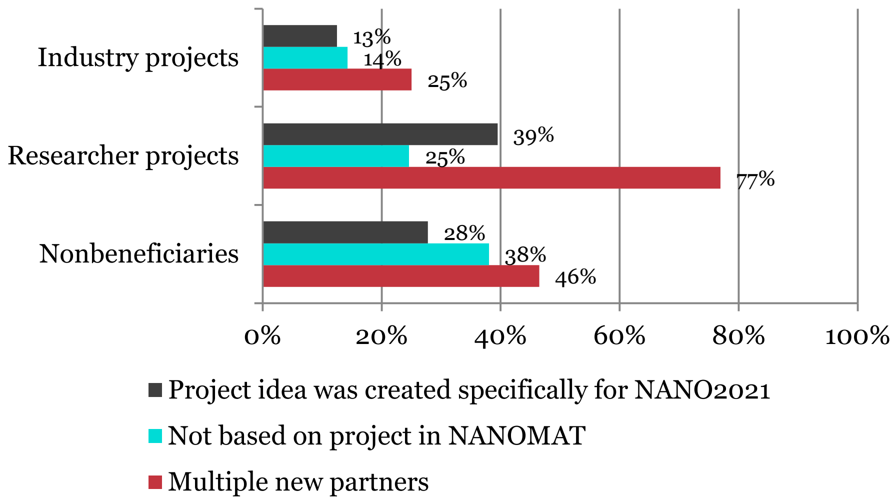
Hence, when looking at NANO2021 from the perspective of continuous funding of nanotechnology R&D, one of the principal aspects to consider is funded projects that were made possible because of the applicants' experience from previous projects funded by NANOMAT. Perhaps unsurprisingly, the survey reveals that both in the case of industry-led and Researcher Projects the largest share of respondents stated that the research activities funded by the NANO2021 programme (at least to some extent) were based upon knowledge developed under the predecessor NANOMAT.

Some other observations from the survey include:

- The majority of projects proposals were based on ideas that were in development prior to the call in NANO2021
- When choosing partners for projects in NANO2021 we see that researchers are more prone to include new partners (whom they never worked with before) compared to companies who are leading IPN projects

How many projects in the programme can be considered as novel or tailored to the programme (i.e. not based on results from NANOMAT, created specifically for the NANO2021 call and/or containing several new partners) is difficult to determine. However, the survey results suggest that these projects are more likely to be found among the Researcher Projects and rejected project applications, rather than among IPN projects. Figure 12 demonstrate a compilation of indicators for novel projects. Industry led IPN projects are more often than not based upon knowledge developed in a project funded by NANOMAT, which could indicate that the NANO2021 programme is allowing these results to be brought into application and commercial use.

Figure 12 Share of projects designed specifically for the NANO2021 call, not based on results from NANOMAT and/or containing multiple new partners



Source: Online survey.

When granted Researcher Projects and unsuccessful project applications are compared with each other, it is evident that the successful applications were (to a higher degree) tailored to fit the call. One survey respondent described how this was done:

> *Our activity was concerned with the computational investigation of mechanical properties of materials, with special emphasis on polymers and fibrous materials. To match the subject of the call, we focused on nano fibers made of biomolecules, and on biomedical applications, that already were part of our activity. In other words, we decided to develop the part of our activity closer to the subject of the call. (Funded project applicant)*

According to 78% of project leaders and non-beneficiaries, the programme calls have coincided with what they wanted to achieve with their projects when preparing their applications in response to the calls. A positive interpretation of this result is that RCN provides applicants with sufficient manoeuvrability and freedom to pursue research questions and organise appropriate consortiums. The interviews do confirm the result from the survey. However, some criticism has been put forward in relation to the requirements of including research groups that represent several geographical regions in Norway (in projects that claim a national scope). RCN runs the risk of imposing project coordinators to include research groups based on their physical location rather than their scientific merits according to one interviewee.

Four out of ten respondents in industry-led projects believe that their project would not have been possible to conduct without funding from the NANO2021 programme. The situation differs for Researcher Projects where over 60% of respondents believe their project would not have been possible without funding from the programme. This suggests that NANO2021 is more critical as a support instrument for Researcher Projects while those working with industry-led IPN projects could in all likelihood benefit from other support measures or fund parts of the project with solely private funding.

It is interesting to compare the hypothetical responses from the funded project with the answers from the project applicants who were in fact not successful. However, this comparison should be done with some caution as a fair share of the project applications was recently found to be rejected, and the final fate of these projects is still to be known. With that being said, 63% of project leaders in industry-led projects and 22% of project leaders in Researcher Projects believe that their projects would have been conducted (in a reduced form) even without funding from NANO2021, compared to 28% of non-beneficiaries, who stated that their project indeed was conducted or is ongoing (in a reduced form) subsequent to the unsuccessful application to NANO2021. It is important to note that the group of non-beneficiaries consists of both industry-led and researcher-led projects, but that Researcher Projects dominate. With that in mind, the assessments made by the funded project leaders seem quite accurate.

It is not known for sure how the rejected projects eventually got funded, but from the survey it can be concluded that the alternative funding sources primarily used for rejected project applicants in NANO2021 were RCN funding schemes, followed by other public funding opportunities and the EU framework programme (Horizon 2020). Half of the funded project leaders considered alternative funding sources when preparing the application to NANO2021, according to the survey. To judge by the comments, the principal choice that applicants faced was to either apply for funding via RCN (NANO2021, ENERGIX etc.) or pursue funding via Horizon 2020, which is also confirmed by the interviews with project leaders.

An interesting point to note is that a few respondents assumed that their current project would probably not have been successful in the EU framework programme, but they also believed that their work under NANO2021 could provide the necessary know-how and networks to subsequently apply for EU funding. One survey respondent writes:

> *We considered the FRINATEK programme (still RCN), and we also considered setting up a team for an EU application. We decided against these options because our project was too applied for FRINATEK, and we did not have enough collaborations to hope for a Horizon 2020 grant. The application to the NANO2021 programme also meant to provide the basis for a future EU effort. (Funded project applicant)*

4.7 Administration of the programme

Finally, this evaluation was set to look into the administration of the programme. The assessment of this question is based on the feedback received from respondents among both funded and rejected projects. Beneficiaries demonstrate a generally high level of satisfaction with RCN's administration related to the funded projects in NANO2021. The non-beneficiaries agree with beneficiaries that the calls are clear, but show a significantly lower level of satisfaction with RCN's process of proposal assessment, selection and motivation. Rejected applicants complain about perceived uneven judgments made by the reviewers and that RCN has not paid enough (or too much) attention to the reviewers' comments. While this can be seen as an expression of a general disappointment for not receiving funding, several rejected applicants made some constructive points:

> *There is some lack of clarity with respect to how thematic priorities apply in practice, i.e., what does it really take for a project in nanotechnology to be deemed within the scope of the five thematic priority areas? (Rejected project applicant)*

> *One and the same text (written in different words) in different proposals about dissemination, gender equality etc. are getting different scores. I suggest checking the proposals for anti-plagiarism. (Rejected project applicant)*

> *The scientific evaluation process is transparent, but the selection process seems to follow other criteria than the scientific evaluation. No real reason for rejection is given, which would be natural if the score is 6/7 (Statements like "for strategic reasons…" are not sufficient). (Rejected project applicant)*

There is a notable lack of knowledge regarding the project reviewing process among project leaders in industry-led projects, only 50% of industry project leaders state that they know how the review process functions. This result is perhaps worrying but at the same time not surprising, as project leaders in industry-led projects (i.e. IPN projects) sometimes outsource the responsibility of the project application to a partnering R&D performer, who usually has more experience in writing and submitting applications to RCN. However, this is a potential weak point in the programme design as it can pose deterrents for certain potential applicants from pursuing research grants. For project leaders in Researcher Projects and among non-beneficiaries the knowledge is considerably higher, 78% and 69% respectively state that they are familiar with the review process. Also in these categories some applicants express lack of clarity related to the review process, as the first of the three quotes above illustrates. In practice, if the application is reviewed, it is in fact judged to be relevant to the scope of the call; however, this was not clear to the applicant in this case.

The great majority (90%) of funded project leaders believe that the RRI component in their application received a fair evaluation. However, among the non-beneficiaries, 27% express that they are not satisfied with how their inclusion of RRI was judged.

In industry-led projects, respondents are less content with the design of calls for proposals and the requirements for project reporting. These lower scores can be understood in the light of what is described above, that contacts with RCN often is the responsibility of participating R&D performers, even in industry-led projects. Thus company representatives are in general less used to prepare applications in compliance with calls and submitting project reports.

Most project leaders state that active projects are progressing as planned. RCN is appreciated by the interviewees for their general tolerance with changes in project implementation that can arise. Several interviewees point out that the unit at RCN working with the NANO2021 programme seems unusually engaged in programme activities and funded projects, without implying that other parts of RCN necessarily are underperforming in that regard.

Two thirds of project participants believe the programme provides them with the necessary support to produce results that could be commercialised. Far from all projects are, however, in need of support as their project is not commercially oriented or because the organisations within the project consortia already has access to such support.

5 Conclusions and recommendations

5.1 Concluding remarks

As a reminder, the purpose of this evaluation reads as follows:

> *To assess how NANO2021 through its choice of priorities and instruments has worked so far in achieving its set objectives and if priorities between different instruments of the programme given a project portfolio that contributes to the achievement of the programme's objectives.*

In short: is the programme on the right track? This evaluation suggests that it is. The evaluators share the Expert Group's observation that the programme is designed with a large selection of instruments which RCN have used proactively to optimise the programme in relation to the programme objectives (e.g. by shifting of funds to researcher projects in response to high number of highly qualified applications, and thematic calls within RRI to reach the target funding level). It is premature to place any definite judgements on the programme's contribution to scientific quality, innovation and value creation or societal impact, but there are certainly convincing signs that the programme is promoting development in line with its set objectives.

To further elaborate on this assessment, the evaluation give rise to some issues for discussion. First, it is evident that the funding for Researcher Projects is highly concentrated to a few dominant institutions at two nationally leading universities and one research institute. Even though our analysis does not include project internal transfers, it is safe to assume that the overall observation would remain the same even if the actual distribution of funding between research actors would be uncovered. It is highly plausible that the strong competition for research funding in the programme is the principal explanation for this result. Competitive research environments are in general successful in acquiring funding wherever they place their attempts and thus when the funding is distributed solely based on quality it benefits these environments. While there are good reasons to believe that strong completion among researchers work in favour for a general increase in quality of research one needs to remain vigilant to not let this turn into a Matthew effect of accumulated advantage, were the already strong and well-funded research groups, in their success, are hindering other slightly less established groups to develop and prosper.[16] This would also work against the specific objective that the programme should facilitate the optimal utilisation of national expertise, R&D resources and infrastructure through cooperation, constructive task distribution and highly focused research activities. At the moment no signs of this have been observed, on the contrary there are several indications suggesting that Researcher Projects in general are representing innovativeness and novelty terms of scientific output and consortium constellations.

The strong competition for funding is also a sign of engagement from the scientific community, there seems to be a great demand for research funding within the themes that the programme is supporting. The great majority of researchers are positive towards the priorities of the programme and seems convinced that the programme is in line with trends and developments in the field internationally. There is also a general content among the participants with the programme administration and the selection process. The low success rate, however, also means that many research ideas (some times of very high quality) are rejected. This situation perhaps puts extra attention to the selection process and its ability to live up to the principles of fairness and transparency. There have been several statements made indicating that the reasons for rejecting project applications have not been communicated well enough. An applicant can of course agree with the judgments made; however, if the reasons behind rejection are not clear and there is a lack of sufficient feedback, it will become increasingly difficult for this applicant to know what to change in the subsequent application. Furthermore, when applications of very high quality still end up under the funding threshold it is very important to explain these decisions clearly and not risk leaving the impression that funding decisions are arbitrary.

[16] Ljungberg, D., Johansson, M. and McKelvey, M., "Does Structure Matter for Science? The Matthew Effect in the Swedish University Sector", 2007.

There are several indications of increased internationalisation of research. All Researcher Projects include international cooperation, close to 90% also expect publications co-authored with foreign research institution as a result of their project. The programme gives researchers (and companies) the opportunity to participate in ERA-NET projects and there has been substantial Norwegian engagement in response to calls in both M-ERA.NET and EuroNanoMed. These are all signs that the programme is nudging researcher towards a more international context. IPN and KPN projects are in general more nationally oriented but given the purpose of these type of projects this is not surprising. There is also reason to believe that the strong competition at national level works as an incentive for researchers to seek opportunities for funding in Horizon 2020. Thus the programme indeed is contributing to the Government's target of 2% of the competitive funds in Horizon 2020 will accrue to Norwegian actors.[17]

IPN-projects is subject to a low degree of competition and the contrast is striking when comparing the success rates of Researcher Projects and IPNs. While the average success rate among Researcher Projects is just over 10%, the same for IPN projects has varied between 40% and 60%. Several potential problems could emerge with this situation. First, it is a question of legitimacy of the programme. It is beyond the scope of this evaluation to assess the RCN's total project portfolio of nanotechnology R&D funding, but the context matters, and there is R&D within the fields of nanotechnology, microtechnology and advanced materials being done in the RCN's other thematic programmes, BIA, FRIPRO and within several SFI centres. Still, the impression that remains is that industry engagement is limited in the programme. At the same time, there is great demand for research funding. The programme administration has been proactive and made some shifts of funds which effectively increased the support for Researcher Projects. But, given that innovation and value creation in industry is one of the most prominent priorities in the programme, this cannot be done in any great extent without compromising the programme's contribution in this regard.

Furthermore, in order to justify the ambitious investments made in research there has to be an industry in place that can utilise and absorb the knowledge and competence that the research institutions are producing. This is already happening but the project portfolio reveals that a majority of companies that are leading IPN projects are small, newly established or both. There is reason to doubt that the group of companies already active in the programme by itself will be able to generate any significant increase in competition for IPN funding. Only with a few exceptions, companies have been leading only one project in the programme so far and, based on the average size of the companies, that is probably exhausting their R&D capacity as it is. The experiences from many previous evaluations and studies show that the IPN instrument poses several thresholds for small and medium sized companies, especially when taking the role as project owner. If the competition for IPN projects is to increase, which potentially could benefit the quality of projects and potential for innovation and value creation, the industry engagement would have to be broadened. An increase in large companies that take leading roles in the programme (i.e. through own IPN projects) could be a valuable addition to the programme portfolio. They might even function as catalysts boosting the overall industry participation by taking on-board smaller companies as project partners. The RCN's own project portfolio analysis of R&D funding in nanotechnology, microtechnology and advanced materials show that large companies are more active in other support measures under the RCN umbrella, but the fact remains that they hold inconspicuous positions the project portfolio of NANO2021.

The already versatile toolbox that the RCN has implemented in the programme is perhaps not enough to fully utilise and stimulate research results to transform into innovative and novel applications. There might be further consideration needed on how to support companies which are not able to take responsibility of a full IPN project, or how to stimulate researchers to establish spin off activities based on knowledge with commercial potential. One approach to make IPN projects more accessible for small or unestablished companies is to introduce the opportunity of conducting projects in two or three stages according to the principle "fail fast", i.e. give an initial small grant without any co-funding requirements, much like the principle of Pre-Projects, but with the opportunity for continuation

[17] Ministry of Education and Research, "Strategi for forsknings- og innovasjonssamarbeidet med EU", 2014.

(where the stakes are raised) if the initial phase is proven to be successful. Furthermore, the BIOTEK2021 programme has introduced the concept of optimisation projects where technology transfer offices (TTOs) are given a central role in promoting research results with commercial potential to be developed further.

As of 2016, 13% of the funds have been allocated to RRI and theme 5. This is slightly short of the goal of 15%, but as the programme is ongoing, the overall target might still be reached, but probably not without special attention or actions in the programme. The Expert Group reflects on the wider implications of the fact that theme 5 and RRI-aspects of the projects are reported in one number (percentage). While this might make sense for administrative reasons it might also lead to a definition of RRI as a particular set of issues (such as HMS and ELSA), which are dealt with in particular work-packages by particular researchers. This is not necessarily in accordance with the original ideas of the AREA framework, which is focused on RRI as a reflective process that relates to all aspects of the research. The important question here is whether the programme encourages multidisciplinary (where each discipline contributes to the solution from their own disciplinary perspective) or transdisciplinary (where the disciplinary differences starts to disappear) inclusion of RRI in the research projects. The RRI framework developed by RCN clearly points to a transdisciplinary approach, but then it might be counter-productive to report RRI jointly with theme 5.

The general implementation of RRI in the project portfolio has to a large degree followed the interpretation and initiative of the researchers themselves, as they are the ones which had to define how RRI was relevant for their project (or not). This approach is applauded by the Expert Group as it leaves as much room for scientists themselves to define how they want to work with this. From the Expert Group's point of view it seems clear that RRI has been taken seriously throughout the execution of the programme and it has been an important part of the general assessment of the projects. In particular, the inclusion of particular RRI expertise in the evaluation seems like a very good idea. The design and enactment of the entire process is well in line with the ambitions in the Government's national strategy on nanotechnology and can certainly serve as a case of best practice for funding bodies internationally.

5.2 Recommendations

Based on the observations made in this report and by the Expert Group, the evaluators would like to offer the following recommendations for the RCN to consider:

- Analyse the background for the relatively low participation by large companies in order to understand how NANO2021 can improve its offering to this particular target group
- Take further measures to increase and broaden the participation of industry in the programme, with the aim to escalate the competition for funding in calls for IPN projects and improve the overall quality of projects
- Further investigate the possibilities for supporting and stimulating the transition from research to conceptual verification and further commercialisation, for example by introducing multiple funding phases in the IPN instrument, making it more attractive for small or unestablished companies
- Examine the conclusions made in the evaluation of BIOTEK2021, especially with regards to the experiences made with the optimisations projects, and analyse how and if this approach could be incorporated in the NANO2021 programme
- Ensure that evaluation of proposals is properly motivated and justified. Consider if evaluation feedback is optimally designed from the perspectives of both applicants and RCN administrators

The above-mentioned recommendations concur with the observations, recommendations and points for further investigation made by the **Expert Group**:

Focus areas:

- Increased participation of industry in the programme (raise number and quality of IPN projects)
- Increased interaction between industry and academia.
- Increased internationalisation of the nanoscience and nanotechnology community

Observations, recommendations and points for further investigation

- Considering the low success rate of researcher projects, compared to IPN, and the obvious need for further stimulation of innovation in this area it is worth to consider:
  - Allocation of additional resources to the programme to stimulate a broader research and knowledge base from which strong innovation projects and industry collaborations can develop
  - Further analyse barriers for companies and academic groups to enter into IPN type projects
  - Simplify and more clearly describe the IPN instrument in the call text
  - Fine-tune the IPN instrument making it more attractive to companies and academia (ease administration, variable size of grants). [It is important that it is attractive to be a partner in an IPN – to the extend where academia will stimulate more and stronger IPN applications]
- To further stimulate interaction of academia and industry and the development of nanotechnology industry/innovation:
  - Increase focus on "*tilleggsfinansiering*" PoC-type grants accessible for RP grantees – to stimulate researchers to take project ideas to product innovation, IPR protection, industry collaboration and/or spin-out/licensing
  - Strengthen the academic-industry match-making initiative hosted by the NRC
- Thematic priority areas are to some extent not aligned with the government's strategy and the international trends of the field. The Expert Group recommends that thematic areas should not be promoted in call texts, used as criteria's in calls or in the selection process. Scientific excellence and the best ability of projects to fulfil the objectives of the NANO2021 Programme Plan (see Section 1.3) should be prioritised, as long as the project are within nano/micro/materials science/technology.
- Consider adjustment of tools for enhancing internationalisation:
  - NANO2021 is very strongly involved in ERA-NET projects. Consider also other instruments focusing on individual researcher mobility to expand research base and recruit international talents
  - "*Mobilitetsstötte*" for researchers having a NANO2021 project (2014-2017: only approx. 33% of the 1m /year have been used corresponding to approx. 3 exchanges/year)
- The background for the difference between research groups and industry in selected areas should be analysed.
- The background for the relatively low participation by major Norwegian companies should be analysed.
- Allocation of 15% of the funds for RRI is ambitious, and if RCN wants to continue this, it is necessary to consider special calls or parts of calls in order to reach this overall goal.
- RCN should clarify whether RRI is a thematic area (ethics and nanotoxicology) or a processual aspect of all projects similar to the AREA approach.
- RCN should not force all researchers to actively work with RRI, but build on positive momentum (Forced inclusion might be counterproductive).

- Special workshops on RRI are received positively and should be continued as a way of letting researchers develop their own sense-making and practices of RRI.

Appendix A Expert report[18]

A.1 Introduction

This report is divided into three main sections: A.2 summarising international trends in nanotechnology and RRI; A.3 analysis of the objectives of Nano2021 and its relation to international trends; and A.4 analysis of the programme portfolio and its relation to the international trends and the objectives of NANO2021. Conclusions and recommendations from the Expert Group are given in Section A.5. The Expert Group notes that this evaluation is based mainly on qualitative comparisons of project portfolio with programme objectives and international trends, survey responses from applicants and grantees, and that no quantitative data on programme impact have been available.

A.2 International trends in the research area

Nanoscience and nanotechnology refers to the understanding and technological exploration of nano sized structures (typically in 1 nm to 100 nm range) and phenomena unique to this size range. As nanoscience and technology is defined by this size range and not limited to any specific class of materials or fields of application it is rapidly expanding into various fields of science and technology. The early stages of nanoscience were to a large extent driven by the development of new microscope techniques, which opened up the possibility to study and even manipulate single nano objects ranging from atoms to viruses. The ability to study individual nano objects and surfaces rather than average/bulk properties and structures has drastically enhanced our insight into the structure and properties of materials and biological systems. Unique physical and chemical properties of nano structures and nano materials can now be understood and explored for new technologies, improved processes and optimised materials. On this background nanotechnology is considered *a general purpose technology* or *enabling technology* which has the potential to significantly accelerate the technological development in a very broad range of areas, and thus with huge potential contributions to key societal challenges and industry competitiveness. On the basis of these expectations very large public investments in nanoscience and nanotechnology have been launched from 2000 and onwards. In particular the USA and China have been leading in this development. Most European countries have also launched various national programmes.

In the most recent EU programmes an increased political emphasis on economic growth and job creation has led to a demand of product focused research, as seen in the declared mission of "bridging the gap between nanotechnology research and markets". This focus on markets and products is in the EU programmes combined with thematic focus on key societal challenges.

While there is no doubt about nanoscience and nanotechnology still has the most overlap with materials research and technology, it is a clear trend that nanoscience and nanotechnology is expanding from physical and materials science into new nano cross disciplines, such as nano-bio technology and nano-medicine. In general, nano science research is characterised by a cross disciplinary and problem/application driven approach, where expertise from several classical disciplines are combined with the new materials, tools and theories from nanoscience.

Major trends in nanotechnology research in four fields of applications are outlined below.

A.2.1 Nanomaterials and nanofabrication

At the heart of nanotechnology lies the unique properties of nanostructured materials and the rational development of such. The forefront of this field is strongly linked to the developments in structural analysis of nanomaterials, which in turn rely on the availability and developments of tools, such as electron microscopy, scanning probe microscopes, synchrotron and neutron sources, and

[18] The authors of this expert report are Bo Wegge Laursen, Jørgen Kjems, Ralph Bernstein and Maja Horst. Together they constitute the external Expert Group assigned by RCN specifically for this evaluation. Please see Section 1. Introduction of the main report for more details

computational resources. At the moment the scope of nanomaterials is fast expanding, e.g. from graphene to a whole range of other 2D materials such as hBN and MoS_2.

As nanomaterials are discovered and their structure and properties explored they become candidates for improved or new technologies in a wide range of fields. In many of these applications the nanomaterials play a key role by providing special properties and functionalities, yet constituting a very small fraction of the whole device/material. Large scale application of nanomaterials is in particular associated with relative simple materials where downscaling of particle size enhance functionality and/or reduce material consumption, this includes e.g. pigments, and wood preservatives. For more advanced materials large scale application is in particular envisioned for low dimensional materials such as nanotubes and graphene in lighter and stronger composite materials e.g. for airplanes, cars, wind turbines, bicycles, and sporting equipment.

Industrial upscaling and standardisation of nanomaterial production has been suggested to be a bottleneck for commercialisation of nanotechnology, and this area has consequently received some attention in recent European research programmes. This field can be seen as a natural extension of nanofabrication focusing on new synthesis and fabrication processes. Nanofabrication includes top-down" approaches (carving the material using particle beams or light, or stamping) and "bottom-up" approach where self-assembly of atomic and molecular species form rationally designed, uniform nanostructures on larger scales. Also additive manufacturing, such as three-dimensional (3D) printing, and layer-by layer coating may merge with nanotechnology either by used of nanomaterials and/or enhancing resolution towards the nano regime.

Related to the development and technological implementation of new nanomaterials the question of nanotoxicology and environmental impacts becomes highly important. Understanding the fundamental interactions of nanostructures with biological systems is thus a key challenge both for development of nano-medicine, bio-nanotechnology and for the assessment of potential hazards to workers in nano-technology research and manufacturing processes, consumers, and the environment. This field is particular challenged by the complexity of nanomaterials and the lack of well-established standards for evaluating these materials. Nanoscience tools on the other hand now also allow for detailed studies of nanopollutants like nano and micro particles formed by combustion engines.

A.2.2 Energy

The social need for new and sustainable energy technologies is obvious and linked to the emanate threat to the global climate posed by the extensive used of fossil resources. Research in novel technology for energy production, transformation, and storage is to a large extent turning to nanostructured materials, which offer high surface/interface areas, tunable electronic properties and surface properties. Key areas of research include:

Catalysis: Nanoparticles and nanostructured surfaces are explored for optimisation of a broad range of important heterogeneous catalysts. Nano catalysts are in particular considered for applications in fuel cells and water splitting, where stable end energy efficient catalysts are highly needed. In this field a key parameter is to reduce the need for large amounts of costly and limited metals such as platinum. 1D and 2D carbon materials are promising both as catalysts and as support and electrode materials for nano particle catalysts.

Energy storage: nanomaterials and nanostructure analysis play a significant role in optimisation of high-power rechargeable battery systems and supercapacitors as well as in development of materials for hydrogen storage. These technologies are highly needed for a non-hydrocarbon based society as well as for the continued development of mobile devices.

Thin-film and flexible photovoltaics for smart solar panels that convert sunlight to electricity more efficiently may be used in areas not suitable for silicon based devices, such as printed electronics, textile/clothing, and disposable devices. Just like harvesting of solar energy is predicted to be an important part of future sustainable energy systems the harvesting of waste energy in the form of heat may be a key element. For such applications thermoelectric nanomaterials that both may be used to convert waste heat into electricity and for temperature control are targets of research.

A.2.3 Health and biotechnology

The growing cost of healthcare is a major societal challenge, which in part may be mitigated by development of efficient early stage screening and diagnostics, and by more efficient drugs for major diseases presently requiring long-term and costly treatments.

A key area of research is nanosensors for diagnostic applications that at low cost can detect, identify, and quantify disease markers or environmental contaminants in body fluids and breathe very early in disease progression. Low cost sensors are considered for wide use and e.g. integration in wearables including clothing, shoes, contact lenses, glasses, watches, earphones. Similarly, development of point-of-care lab-on-a-chip diagnostic devices and super sensitive instrumentation e.g. for detection of very small amounts of pathogenic cells in blood sample (very early stage detection of cancer) to a large extent rely on nanomaterials and nanotechnology. This field also includes techniques for faster and more accurate DNA sequencing, and solid-state or organic nanopores for single protein and nucleic acid sensing. In the field of nanosensors and bioimaging the special optical properties of nanoparticles play a key role and further development of optical properties for sensitive readout and surface functionalisation for improved selectivity/targeting are important research areas.

Tissue engineering is a rapidly growing area and includes e.g. repairing damaged tissues by creating stem cell niches with nanostructured surfaces, bioactive cues and gene expression modifiers (e.g. for bone, cartilage, muscle, or spine/nerve regeneration).

Nanotechnology with the aim to treat disease includes drug delivery by nanoparticles that more efficiently and specifically target diseased cells thereby reducing the toxic effects of traditional drugs. Development of improved nanocarriers is particular relevant for delivery of biomolecule drugs (biologics) and for reduced immune response.

A.2.4 Electronics and optics

The continued growth in computational processing speed, transmission and storage of data is fueled by the development of ever smaller and faster electronic and optical circuits/devices and has major societal impact forming the foundation for ICT.

Nanofabrication and nanostructure characterisation techniques are key tools for the constant down scaling of silicon device feature size. New nanomaterials and nanoarchitectures are sought out to develop faster, smaller and less energy consuming electronic as well as new areas of applications for electronic devices. This includes photonic and electronic nanostructures based on 2D materials such as graphene, MoS_2, and hNB, or on 1D materials such as carbon nanotubes or semiconductor nanowires. These materials and quantum dots may also form the physical basis for the development of quantum computing which is a highly specialised field in very fast development.

Beside the areas of high performance optoelectronic nano materials another trend is the development of organic solution processable materials for flexible/printable/disposable electronics including low-cost large volume applications such as flexible displays, solar cells, and RFID for contactless identification of goods. Materials for these applications include conducting polymers, carbon nano tubes, graphene, metal nano wires and particles.

A.3 Trends in RRI

Since it came to wider public attention, the responsible development of nanotechnology has been subject to regulatory attention in the EU and its member states as well as in the US and the rest of the world. In the US the 2003 nanotechnology act specifically stated that the development of this technology should be done in a socially responsible way, and in the EU a code of conduct on responsible nanosciences and nanotechnologies research was adopted in 2009. An explicit motivator for such efforts was to avoid wide scale public controversies such as those experienced around the introduction of biotechnology. A large amount of reports and consultative engagement exercises have been conducted in various national settings – particularly in the first decade after the turn of the century – but, so far, the development of nanotechnology has proceeded without major public outcry or protests.

In later years, such regulatory attention to the areas of bio- and nanotechnology has been widened to a more generally focused Responsible Research and Innovation (RRI). While this term has achieved a certain stable usage (particularly in Europe), it covers a loosely defined set of phenomena, and is being developed and implemented differently in different contexts. Generally, its most stable and entrenched usage can be found in policy circles within the EU and the UK – while the concept has a more precarious life in other national contexts.

The concept of RRI has been particularly important in the Horizon 2020 framework, where it has been the focus of specific actions (RRI in the EU is defined around the themes of public engagement, open access, gender ethics, science education) as well as a cross-cutting issue to be addressed and promoted in many other framework objectives. What the experience from Horizon 2020 demonstrates is that the interpretation of the RRI idea is flexible. Some of the targeted Horizon 2020 projects have produced specific guidelines and implementation tools, whereas others have been focused more on the institutional changes and discursive patterns. Impact studies have begun to emerge, but there is no overall knowledge of the more general effects of attention to RRI as a concept or a process in the Horizon 2020 programme. Recently, policy documents from the EU have adopted a slightly changed use of language towards focusing more on the terms Open Science and Open Innovation as overall framework terms.

In the UK, the Engineering and Physical Sciences Research Council (EPSRC) has done pioneering work with its development of a Framework for Responsible Innovation as a process that 'seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest'. Importantly, this framework supports an understanding focused on RRI as a process and uses the AREA principles (Anticipate, Reflect, Engage and Act) developed by Own, Macnaghten, Stilgoe and colleagues as guidelines. The same authors were engaged in the well-described case of RRI-principles used in relation to a particular case of a geo-engineering project, where the RRI-evaluation ultimately led to a closing down of the project. Such explicit cases, however, are still few and in general, the RRI agenda must be said to be under development.

Many countries, such as for instance Denmark, do not have a well-developed policy on RRI, although in some cases some of the content is covered through the use of other concepts, such as 'Ethics' or 'Scientific Social Responsibility' (a term that has caught on in some Danish funding bodies). It is not uncommon for funding bodies to discuss how they can integrate forms of reflection and action aimed at achieving social desirability in the grant applications. Such considerations, however, also often lead to discussions about how to evaluate and assess such aspects in the peer review process.

Furthermore, there seems to be a general discrepancy between the uptake of the term RRI in some policy circles and the research community as a whole. In general, it would be most accurate to say that the awareness of RRI is uneven in nano-scientific communities in the European countries (as well as other parts of the world). While some nano-scientists have been engaged in discussions of social desirability of their research for more than a decade, many other groups have not heard about this concept and are rather critical towards what they see as 'more administrative demands' and grant application 'box-ticking' which will at best have no real impact on science. It is not uncommon for nano-scientists to comment that the entire RRI agenda seems very remote from what they do in their laboratories.

A.4 Analysis of the programme's contribution

A.4.1 The Norwegian Government's R&D strategy for Nanotechnology 2012-2021

The Norwegian Government's strategy within the field of nanotechnology is presented in "Rejoinders FoU-strategi for nanoteknologi 2012–2021"[19]. The main objectives and priorities are briefly summarised in chapter 3.2.1 of this report.

The Government's strategy document also recommends that "publicly financed R&D will concentrate on opportunities within national priority areas such as:

- Energy and environment
- Health
- Food
- Maritime and marine sectors
- ICT
- Biotechnology
- Advanced materials"[20]

A.4.2 NANO2021 and its relation to the Government's strategy and international trends

The NANO2021 programme is the main instrument in implementing the Government's R&D strategy for Nanotechnology. It is, hence, of interest to assess to what extent the NANO2021 Programme Plan[21] facilitates realisation of the strategies' objectives, and also how it relates to the international trends discussed in A.2 above.

Objectives

From a top-level perspective, the NANO2021 objectives are well aligned with the Government's strategy. The focus is both on basic knowledge development, increased competitiveness of industry, and to contribute in solving societal challenges.

The NANO2021 Programme Plan also outlines seven secondary objectives:

1. The programme will work to enable selected Norwegian R&D groups to achieve a position in the international forefront.
2. The programme will promote scientific development, renewal and quality by seeking out talented candidates, increasing mobility and boosting internationalisation.
3. The programme will enhance national value creation through the renewal of products, processes and services.

[19] "Regjeringens FoU-strategi for nanoteknologi 2012–2021", Rapport, Nærings- og handelsdepartementet, 03.07.2012

[20] "NANO2021 – Nanoteknologi og avanserte materialer (2012 – 2021)", Programplan, Norges forskningsråd, 2012, p.55

4. The programme will promote the development of sustainable technology to be applied in a safe, responsible manner.
5. The programme will facilitate the optimal utilisation of national expertise, R&D resources and infrastructure through cooperation, constructive task distribution and highly focused research activities.
6. The programme will work to increase the attractiveness of Norwegian research environments to encourage knowledge-intensive companies in a global market to establish R&D activities in Norway.
7. The programme will promote social dialogue on nanotechnology and create new meeting-places.

These objectives may be regarded as an operationalisation of the overall goals in the Government's strategy. The programme aims both to bring Norwegian scientific groups to the international forefront, as well as to promote national value creation of value for the Norwegian society.

Internationalisation (secondary objective 2) has to a large degree been promoted through a clear focus on support to European collaborations through the ERA-NET instrument, where the NANO2021 programme has a portfolio of more than 20 ERA-NET projects.

Achievement of the secondary objective 5 is facilitated by promoting use of national research infrastructures such as NORFAB, NORTEM and others. This is specifically addressed in the call texts, in which the RCN commits funding to use of national laboratories within NANO2021 projects. In 2015 e.g., 26 NANO2021 projects planned to utilize NORFAB.

Thematic priorities and pillars

The Thematic Priority Areas and the three Pillars of NANO2021 are published in the Programme plan and Fig.1. of this report. The three Pillars are consistent with the three main priorities of the Government's Strategy. The Thematic Priorities of the Program Plan appears, however, to deviate from national priority areas given in Government's strategy and also from the research areas focused internationally.

- One observation is that key international research fields, such as ICT and biotechnology, are not specifically designated as Thematic Priority Areas in the NANO2021 programme plan. The ICT area covers important industrial applications like nanoelectronics, data storage and quantum computing. ICT also includes micro- and nanosensors. One could argue that the ICT technologies are relevant within other areas, such as "Reducing environmental and climate impact" or "Health and new medical technology". This prioritising may, however, be the reason why very few projects concern nanoelectronics, if any. On the other hand, sensor technology is the topic of several IPNs and some RPs within the existing Thematic Areas.
- Important areas of the Government's strategy; food, marine and maritime applications, are also not directly covered among the Thematic Areas, but is part of "Value Creation based on natural resources." By reviewing the programme portfolio, it is noted that these research fields are scarcely represented. In this context it should, however, be mentioned that these areas also are addressed in other Large Scale RCN programmes.
- Another observation is that the Thematic Areas, in addition to cover research topics, further address certain aspects through language like: "applications", "reducing impact", "value creation". Such wording may intend to point at a preferred direction of the research. It is, however, not straight forward to see how such approach could be reflected in the project selection, or rather be regarded as restrictive and even unclear (see e.g. first quotation under 4.7.)
- It should be noted that in the Programme Plan chapter 8 it is stated that NANO2021 projects are to focus on <u>technology development</u>, while other, related RCN programmes should aim at developing applications. In the light of this division of roles the reasoning behind the applied approach of the NANO2021's Thematic Areas is somewhat unclear. This is also reflected in the project portfolio, which seems to be more biased towards applications than basic knowledge

creation. It could be argued that NANO2021's focus on applications could be challenging for groups working mainly with basic research. In a programme where both building new knowledge and enabling value creation are top key objectives, it could be questioned if the current thematic areas are appropriate or rather impose unnecessary boundaries?

- Significant Norwegian export industries such as, Oil and Gas industry and the marine sector, are not included as separate Thematic Priority Areas. "Oil and Gas" is not included in the Thematic Area "Applications in the energy sphere". The topic is, however, mentioned as part of the area of natural resources, in which also the marine sector, mining, etc. are included. It looks like this has had an impact on project topics priorities, as the share of the portfolio covering these industrial sectors, is limited. In order to facilitate nanotechnology research related to exploiting Norwegian oil resources, the Large Scale programme, PETROMAKS, had in 2014 a joint call with the NANO2021. Two projects were funded.
- Finally, it should be mentioned that NANO2021 is not a pure nanotechnology programme, but aims to cover the areas nanotechnology, microtechnology and advanced materials equally. This is reflected in NANO2021 project portfolio, as all three areas are included. It is worth noting, however, that field of micro-technology is mainly addressed in the IPNs.

The governments national strategy on nanotechnology was specific in stating that Norway should be a leader and first mover (*foregangsland*) in responsible technology development and included four specific guidelines for the promotion of responsible technological development:

- *The share of research funding directed at HMS and ELSA should be leading internationally.* The programme has implemented this as an operational goal of 15% of the funding being allocated to theme 5 and RRI-activities. We do not currently have comparable numbers for similar funding schemes, but 15% seems a reasonably ambitious goal.
- *HMS and ELSA perspectives should be integrated in the development of nanotechnology.* The programme has implemented a call for considerations on responsible innovation in all its calls. Either the proposal has to include aspects of RRI in its objectives and suggested activities, or it has to argue convincingly why these aspects are not relevant for the suggested project. In light of the ongoing development of the concept of RRI and the fact that far from all scientists are aware of this concept – or supportive of the ambition – this seems to be a very sensible way of implementing this goal.
- *The EU Code of Conduct (CoC) for Responsible Nanosciences and Nanotechnologies Research should be giving directions.* The EU CoC is voluntary and the general implementation of the NANO2021 programme seems to be in accordance with the content of the CoC. However, it is not possible to evaluate whether the CoC has been specifically used to formulate directions or whether it has been implicitly used as background material. Furthermore, while the programme's call texts in the first couple of years used the phrase 'responsible technological development', the specific concept of RRI is adopted from 2015 onwards. It is likely that these changes in discourse are a necessary result of the fact that the content of RRI and related concepts are far from stable, but rather being developed in these years. However, these changes will not make it easier for scientists and other applicants to navigate the demands of the call.
- *Collaboration with the Norwegian Board of Technology.* The seventh objective of the programme has been to promote social dialogue and create new meeting-places. In the action plans of the programme there is evidence that some of these efforts have been made with the board of technology.

A.5 Analysis of the programme's portfolio

We will here compare the programme plan for NANO2021 (discussed above in Section A.3) with the actual project portfolio.

A.5.1 Instruments

The NANO2021 programme has in the first 5-year period funded projects for 716m NOK peaking with approx. 300m NOK in 2015. The majority of the funds were given to the Researcher Projects instrument (approx. 400 m NOK) followed by the IPN/KPN instruments (approx. 160 m NOK). A small proportion of the funding is given to the Infrastructure, Events, Pre-project and ERA.NET projects (M-Era.Net and EuroNanoMed).

The success rate was the lowest for the RP (8-15%) and significant higher for the IPN/KPN instruments (20-50%). It is desirable that the success rate between the instruments becomes more even to ensure that only the applications of highest quality are funded. However, since IPN projects are a central instrument in the NANO2021 programme the problem may not be solved solely by transferring funding to the RP. Rather, it is desirable to improve the awareness among potential applicants and ease the implementation of the IPN/KPN instruments.

The reason for the lower success rate for RP compared to KPN and IPN projects may be multifaceted. The active pre-evaluation of the KPN and IPN applications by the RCN may eliminate obvious non-legitimate projects and thereby increase the success rate. It could also reflect that the IPN/KPN applications are more complex to arrange, requiring mutual commitment between academia and industry and establishment of co-founding. It is well known that small and middle-sized companies often are reluctant to make long-term commitments in contractual research. The option of obtaining a Pre-project with funding up to 200,000 NOK will most likely lower the barrier and should be encouraged as an entry to IPN/KPN applications. The "*tilleggsfinansiering*" of up to 200,000 NOK to explore the innovation potential, which can be applied for in connection with a granted RP, is an interesting instrument in this context. This option should be implemented more strongly in connection with a majority of the RP and may even be raised substantially in the amount of funding (e.g. to one-year Post Doc salary + running cost according to approved commercialisation plan). This will stimulate researchers to take the project idea to product innovation, IPR protection, industry collaboration and/or spin-out/licensing.

Increased interest in the KPN and IPN instruments may also be accomplished by strengthening the already established match-making initiative hosted by the NRC. KPN and IPN instruments should be clearly described in the call-text using terms generally understood by academic people and administration should be eased to a minimum. Finally, the size of grants should be flexible to fit both small and large initiatives.

A.5.2 Thematic Priority Areas

Looking at the project titles and research topics in the RP, IPN and KPN projects listed at prosjektbanken (https://www.forskningsradet.no/prosjektbanken/) it is found that the 42 RP's, 31 IPN and 9 KPN cover a broad range of nanomaterials, application/research areas. Considering the relative low number of projects in the programme quite a large part of the international trends in nano research areas described in Section A.2 are actually covered.

Each project is assigned fractional contribution to the various priority themes by the Research Council administration. According to this declaration the thematic areas, Energy and Health/Medicine, were funded with approximately equal shares (30% and 25%, respectively) whereas Natural resources, Environment and RRI were funded with approximately 15% each. The pre-set goal of at least 15% share to RRI was nearly reached (13%), in part through a dedicated programme on nanotoxicology.

However, it should be pointed out that many projects are highly interdisciplinary and the obligatory assessment of how the project contributes to the various thematic areas is subjective. It is clear from the survey that many of the applicants are confused about some of the terms used in the call information material, especially estimating the RRI content. Basic research without immediate commercial value can potentially contribute strongly to innovation because it opens up for new, less competitive, research areas, which in more long-term perspective potentially can create more value for the society.

A closer analysis of the individual projects however leaves an impression that many of the funded projects are centred within a limited number of topics and that some internationally observed growth-areas are missing or, at best, underrepresented. In the programme portfolio we find low representation of electronics, both high-end nano electronics (quantum devices) and low-end large volume polymer/molecular based printable/flexible electronics. One may speculate that these topics are missing because they are not listed as priorities. In contrast, in the RP's we find a strong representation of hard nano materials for energy applications, in particular; fuel cells, batteries, thermoelectrics etc. It is worth mentioning that these areas are less represented in the IPN and KPN projects where polymer materials and sensor and micro technology seems more dominating.

The bias for some topics may reflect certain research strongholds areas in Norwegian science that have developed over many years. Notably, such spearheads can raise the impact and avoid dilution of expertise. On the downside it may also lead to loss of opportunities and lack of national expertise in new growth technology areas.

Based on these observations we find it desirable not to restrict the applicants to specific research areas but rather define micro-, nanotechnology and functional materials in broader terms.

A.5.3 Impact on Norwegian science and innovation

Assessment of the increase in scientific quality in Norwegian research directly base on the NANO2021 programme is difficult in a mixed landscape of other research programmes. However, the strong focus on RRI undoubtedly strengthens the awareness of innovation in Norway, in particular for small- and middle-sized companies. The IPN project portfolio is to a large extent represented by small sized companies. The reason for this may be that larger companies are not depending on this type of funding for their R&D and find the bureaucracy too demanding in the light of the potential benefits. It is also clear that a few companies are receiving substantial founding reflecting a dedicated strategy to engage with academia for enhancing R&D. It would be desirable if this strategy could grow among other companies to create a more competitive applications portfolio for the IPN/KPN funding.

A.5.4 Achieving a more socially responsible technology through focus on RRI

As per 2016, 13% of the funds has been allocated to RRI and theme 5. This is slightly short of the goal of 15%, but as the programme is ongoing, the overall target might still be reached. There has also been variation over the years. In the action plan 2013-2014 it is noted that only 9% of funds are allocated to this area and that no projects have their main focus on theme 5. In 2014 a joint call with BIOTEK2021 and the ELSA programme focused on ELSA projects was instrumental in getting the RRI-component of the programme to 16% in 2014. This is the only specialised call in the programme so far, and the fact that the percentage is currently 13% implies that the 15% goal cannot be reached without special attention or actions in the program.

It is worth considering the wider implications of the fact that theme 5 and RRI-aspects of the projects are reported in one number (percentage). While this might make sense for administrative reasons it might also lead to a definition of RRI as a particular set of issues (such as HMS and ELSA), which are dealt with in particular work-packages by particular researchers. This is not necessarily in accordance with the original ideas of the AREA framework, which is focused on RRI as a reflective process that relates to all aspects of the research. The important question here is whether the programme encourages multidisciplinarity (where each discipline contributes to the solution from their own disciplinary perspective) or transdisciplinary (where the disciplinary differences starts to disappear) inclusion of RRI in the research projects. The RRI framework developed by RCN clearly points to a transdisciplinary approach, but then it might be counter-productive to report RRI jointly with theme 5.

The general implementation of RRI in the project portfolio has to a large degree followed the interpretation and initiative of the researchers themselves, as they are the ones which had to define how RRI was relevant for their project (or not). This approach must be applauded as it leaves as much room for scientists themselves to define how they want to work with this. The calls include short descriptions of what is meant with RRI or responsible development and it seems that potential applicants have been able to receive help from RCN in how to work with this. However, the downside of such an open approach is that it is hard to streamline and compare these aspects across the various applications and calls. In light of this, it is quite remarkable that a very large majority of survey respondents found that the RRI aspects received a fair assessment in the review process. Reading through the documents concerning the review process it seems clear that RRI has been taken seriously and has been an important part of the general assessment of the projects. In particular, the inclusion of particular RRI-expertise in the evaluation seems like a very good idea. The design and enactment of the entire process, however, can certainly serve as a case of best practice for funding bodies internationally.

Making RRI perspectives an integrated part of the development of nanotechnology is also supported by the specific aim of having 2/3 of PhD-scholars participate in a workshop on responsible technology development (action plan 2015). It is unclear whether the specific goal is achieved but the workshops seems to be continuing and they are commented on positively in the evaluation survey. Such efforts support the ambition of helping scientists reflect on how RRI is relevant for them and their project rather than having fixed tick-boxes and prescriptive actions formulated by the programme committee or RCN. In the separate interview with the administrative officers responsible for RRI it was made clear that they see the inclusion of RRI as a process and a mode of being rather than a set of specific objectives to be achieved or actions to be followed. How this is reflected in the success-criteria and specific objectives of the programme is, however, less clear.

Between half and 2/3 of the respondents believe that the programme has increased awareness and attention towards RRI. This must be said to be very satisfactory, but the survey comments demonstrate that the scientists involved in the NANO2021 programme have different views on RRI just as is the case with scientists in other national contexts. While some are very positive towards the effects of the programme and the help in integrating RRI aspects in their project, others state that scientists are already responsible and that the specific focus on RRI does not – and should not – change this. A similar picture is found in the evaluation of the five nationally coordinated projects done in 2016 by RCN. According to this evaluation, RRI has helped provide better opportunities for commercialisation, just as it has helped provide new topics as well as increased the discussion of unforeseen effects. Interestingly, a majority of respondents in this RCN-evaluation deny that the RRI elements have made it more attractive for users to engage in the project. A breakdown of the answers into the five different projects, however, demonstrate that the answers vary quite a lot between different projects hence enforcing the interpretation, that knowledge about and attitudes towards the RRI framework is very unevenly distributed in the Norwegian community of nano-scientists.

It was a specific objective of the programme to promote social dialogue on nanotechnology and create new meeting-places for such discussions. It is obvious from the material that a number of events and efforts have been made to meet this objective. In general, it is very difficult to assess the outcomes and impacts of such actions but ¾ of the respondents in the survey (who worked in researcher projects) state that their project has increased dissemination of research outside the scientific community. Simultaneously, more than half state that their project has helped networking and knowledge transfer within the nanotechnology sector. On this basis, it seems that the programme in its entirety certainly has had a positive effect on the creation of meeting places and social dialogue.

A.6 Conclusions and recommendations

It is the general perception of the Expert Group that the NANO2021 programme overall is successful in the sense that a large number of high quality applications are obtained from academic research groups and that the research community has a positive view on the programme and its impact. An actual assessment of impact is however beyond the scope of the material provided for this review.

The Expert Group also notice that the programme is designed with a large selection of instruments which RCN may use proactively to optimise the programme, e.g. by shifting of funds to researcher projects in response to high number of highly qualified applications, and thematic calls within RRI to reach the target funding level.

The Expert Group have discussed the provided material and identified a number of focus points, where improvements may be obtained by adjustments of the programme.

The focus areas are:

- Increased participation of industry in the programme (raise number and quality of IPN projects)
- Increased interaction between industry and academia.
- Increased internationalisation of the nanoscience and nanotechnology community

Observations, recommendations, and points for further investigation:

- Considering the low success rate of researcher projects, compared to IPN, and the obvious need for further stimulation of innovation in this area it is worth to consider:
  - Allocation of additional resources to the programme to stimulate a broader research and knowledge base from which strong innovation projects and industry collaborations can develop
  - Further analyse barriers for companies and academic groups to enter into IPN type projects
  - Simplify and more clearly describe the IPN instrument in the call text
  - Fine-tune the IPN instrument making it more attractive to companies and academia (ease administration, variable size of grants). [It is important that it is attractive to be a partner in an IPN – to the extend where academia will stimulate more and stronger IPN applications]
- To further stimulate interaction of academia and industry and the development of nanotechnology industry/innovation:
  - Increase focus on "*tilleggsfinansiering*" PoC-type grants accessible for RP grantees – to stimulate researchers to take project ideas to product innovation, IPR protection, industry collaboration and/or spin-out/licensing
  - Strengthen the academic-industry match-making initiative hosted by the NRC
- Thematic priority areas are to some extent not aligned with the government's strategy and the international trends of the field. The Expert Group recommends that thematic areas should not be promoted in call texts, used as criteria's in calls or in the selection process. Scientific excellence and the best ability of projects to fulfil the objectives of the NANO2021 Programme Plan (see Section 1.3) should be prioritised, as long as the project are within nano/micro/materials science/technology.
- Consider adjustment of tools for enhancing internationalisation:
  - NANO2021 is very strongly involved in ERA-NET projects. Consider also other instruments focusing on individual researcher mobility to expand research base and recruit international talents
  - "*Mobilitetsstötte*" for researchers having a NANO2021 project (2014-2017: only approx. 33% of the 1m /year have been used corresponding to approx. 3 exchanges/year)
- The background for the difference between research groups and industry in selected areas should be analysed.

- The background for the relatively low participation by major Norwegian companies should be analysed.
- Allocation of 15% of the funds for RRI is ambitious, and if RCN wants to continue this, it is necessary to consider special calls or parts of calls in order to reach this overall goal.
- RCN should clarify whether RRI is a thematic area (ethics and nanotoxicology) or a processual aspect of all projects similar to the AREA approach.
- RCN should not force all researchers to actively work with RRI, but build on positive momentum (Forced inclusion might be counterproductive).
- Special workshops on RRI are received positively and should be continued as a way of letting researchers develop their own sense-making and practices of RRI.

Appendix B Survey questionnaire

About your project

1. To what extent are your research group's/organisation's activities funded by the NANO2021 programme based upon knowledge developed under the predecessor NANOMAT programme?

- ◯ Not at all
- ◯ To a small extent
- ◯ To some extent
- ◯ To a large extent
- ◯ Do not know

2. Does the project include new partners (whom you never worked with before)?

- ◯ Yes, multiple new partners
- ◯ Yes, one new partner
- ◯ No

3. How do the following statements reflect your organisation's (or research consortium´s/ team´s) rationale for participating in the project?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Do not know/Not applicable
To access national research infrastructure (e.g.: databases, software for analyses and simulations measurement, clean rooms and testing facilities)	◯	◯	◯	◯	◯	◯
To access networks with other R&D providers (universities and institutes)	◯	◯	◯	◯	◯	◯
To enable recruitment of PhD candidate(s)	◯	◯	◯	◯	◯	◯
To enable recruitment of senior researcher(s) with competence in nanotechnology	◯	◯	◯	◯	◯	◯
To establish or strengthen cooperation with (other) research institutions (i.e. university, university college, research institute)	◯	◯	◯	◯	◯	◯
To establish or strengthen cooperation with companies	◯	◯	◯	◯	◯	◯
To increase value creation through the development of products, processes and services	◯	◯	◯	◯	◯	◯
To contribute to tackling societal challenges	◯	◯	◯	◯	◯	◯
To access funding	◯	◯	◯	◯	◯	◯

Other (Please specify)

4. How do the following statements reflect the development of your project proposal?

◯ The project idea was created specifically for this programme´s call

◯ The project idea was in development prior to the call

5. To what extent did the NANO2021 programme call coincide with what you wanted to achieve with your research project?

	To a small extent	To some extent	To a large extent	Do not know
Your assessement	◯	◯	◯	◯

Please explain in what way (if any) your project idea was adapted to the call:

6. What do you imagine would have happened if your project had not been funded by the RCN's NANO2021 programme?

Tick all that apply.

- ◯ The project would not have been conducted
- ◯ The project would have been conducted with reduced scope
- ◯ The project would have been conducted with fewer partners
- ◯ The project would have been conducted but it would have taken longer
- ◯ The project would have been conducted in the same way, but with other type of funding
- ◯ Not applicable/don't know

7. Did you consider other funding sources?

- ◯ Yes
- ◯ No

If yes, please name funding sources considered

About the NANO2021 programme

8. Does the programme allow you to deliver your project to the initial timeplan and achieve the anticipated results?

◯ Yes

◯ No

If not, what can be improved?

[ ]

9. How do the following statements reflect your view on the RCN´s administration of the NANO2021 programme?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	Do not know/Not applicable
The RCN's calls for proposals are clear	◯	◯	◯	◯	◯	◯
The RCN's process for proposal assessment and selection is transparent	◯	◯	◯	◯	◯	◯
The RCN's assessment and selection is well motivated	◯	◯	◯	◯	◯	◯
The RCN's assessment involved necessary expertise	◯	◯	◯	◯	◯	◯
The RCN's process for project reporting (technical and financial) is efficient	◯	◯	◯	◯	◯	◯
The RCN's requirements for project reporting (technical and financial) are clear	◯	◯	◯	◯	◯	◯
The RCN's support during project implementation is appropriate	◯	◯	◯	◯	◯	◯

Other (Please specify)

[ ]

10. Do you think the NANO2021 programme´s subjects are in line with the current developments in the nanotechnology field internationally?

- ◯ Yes
- ◯ No

Please explain your answer:

11. How can the programme be scientifically improved in the future?

12. How can the programme be strategically improved in the future?

About Responsible Research and Innovation (RRI)

The NANO2021 programme contributes to the increase of awareness of social, ethical and legal aspects (ELSA), health, safety and environment (HSE), and other RRI aspects i.e. cooperation with different stakeholders. All known as Responsible Research and Innovation (RRI).

13. The NANO2021 programme as a whole contributes to an increase in the following

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Do not know/Not applicable
Awareness of social, ethical and legal aspects (ELSA)	○	○	○	○	○	○
Awareness of health, safety and environment (HSE)	○	○	○	○	○	○
Awareness of other RRI aspects (cooperation with different stakeholders)	○	○	○	○	○	○
Spreading the knowledge of the RRI topic	○	○	○	○	○	○

Other (Please specify)

14. Which activities within the programme are particularly helpful in raising the awareness of RRI?

15. To what extent has your participation in the NANO2021 funded project:

	To a smalll extent	To some extent	To a large extent	Do not know
Strengthened your organisation's awareness of RRI	◯	◯	◯	◯
Changed your attention towards RRI	◯	◯	◯	◯
Increased spreading information about RRI within your community	◯	◯	◯	◯

Please explain your answer

16. What do you see as the main barriers in increasing awareness of RRI in nanotechnology research?

17. What can be done to improve the situation?

18. Did you think that the RRI element of your application got a fair and thorough review?

◯ Ja

◯ Nej

19. Do you know how the process of reviewing applications submitted for the NANO2021 programme´s funding work?

◯ Yes

◯ No

Competence building

20. What do you see as the main barriers for improving the quality of nanotechnology research in Norway?

[ ]

21. If one of the goals of your project is to produce results that may be commercialised, does the programme setup allow you to get needed help (e.g. mentors, sign-posting etc.)?

- ◯ Yes
- ◯ No

Please explain your answer. What can be improved with this regard?

[ ]

Expected results of the funded project

22. Do you expect your project to achieve the following results?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Do not know / Not applicable
Strengthened competitiveness of participating companies	○	○	○	○	○	○
Additional R&D&I funding from the Norwegian funding agencies to your organisation	○	○	○	○	○	○
Additional R&D&I funding from international funding agencies to your organisation	○	○	○	○	○	○
Increased industrial relevance of research conducted in your organisation	○	○	○	○	○	○
A spin-off company established in Norway	○	○	○	○	○	○
A spin-off company established in another country	○	○	○	○	○	○
Patents filed and /or licencing deals made	○	○	○	○	○	○
Results of your project commercialised in another way nationally	○	○	○	○	○	○
Results of your project commercialised in another way internationally	○	○	○	○	○	○
Other (please specify below)	○	○	○	○	○	○

Other

[ ]

23. Do you expect your project to achieve the following academic results?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Do not know / Not applicable
Scientific publication(s) co-authored with (other) Norwegian research institution						
Scientific publication(s) co-authored with a research institution outside Norway						
Scientific publication(s) co-authored with a Norwegian company						
Scientific publication(s) co-authored with a company outside Norway						
Scientific publication(s) in Open Access journals						
Increased competitiveness of your organisation nationally, i.e. compared to other Norwegian universities, university colleges and research institutes						
Increased competitiveness of your organisation internationally, i.e. compared to foreign universities, university colleges and research institutes						
New PhD thesis defended						
Access to external national research facilities, which were not accessible before						
Access to external international research facilities, which were not accessible before						
Researcher mobility (i.e. staying abroad for more than 6 month)						
Other (please specify below)						

Other

24. To what extent has your project increased the following:

	Not at all	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree	Do not know / Not applicable
Networking between actors participating in the project	○	○	○	○	○	○	○
Networking with actors within the nanotechnology sector in general	○	○	○	○	○	○	○
Knowledge transfer between actors participating in the project	○	○	○	○	○	○	○
Knowledge transfer with actors within the nanotechnology sector in general	○	○	○	○	○	○	○
Value creation through the development of products, processes and services	○	○	○	○	○	○	○
Inclusion of views from actors outside the scientific community	○	○	○	○	○	○	○
Attention to the RRI aspects of the R&D activities in the project	○	○	○	○	○	○	○
Dissemination of research results to actors outside the scientific community	○	○	○	○	○	○	○

Expected outcomes of the programme

25. To what extent do you believe that the NANO2021 programme as a whole contributes to:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Do not know / Not applicable
An increase in cooperation among research environments related to nanotechnology in Norway	◯	◯	◯	◯	◯	◯
An increase in internationalisation of research environments related to nanotechnology in Norway	◯	◯	◯	◯	◯	◯
An increase of researcher mobility between research environments related to nanotechnology in Norway	◯	◯	◯	◯	◯	◯
Meeting places for national dialogue in subjects relevant to nanotechnology	◯	◯	◯	◯	◯	◯
Retained or expanded research and development activities within the private sector in Norway	◯	◯	◯	◯	◯	◯
An increase in value creation through the development of products, processes and services	◯	◯	◯	◯	◯	◯
Other (please specify below)	◯	◯	◯	◯	◯	◯

Other

Concluding remarks

26. Please add any additional comments regarding the RCN's NANO2021 programme.

27. As part of this evaluation, we would like to look into a selection of funded projects as case studies. Would you like to volunteer your project as an interesting case study?

- ◯ Yes
- ◯ No

If yes, please leave your contact email address here:

Appendix C Results of the online survey

C.1 Survey methodology

They survey analysis includes results from three separate online surveys, one to project leaders, one to project partners and one to project leaders of rejected project applications:

- The project leader survey was sent to 72 individuals and yielded 55 responses (response rate: 76%)
- The project partner survey was sent to 107 individuals and yielded 34 responses (response rate: 32%)
- The survey to rejected project applicants was sent to 176 individuals and yielded 72 responses (response rate: 41%)

The mailing lists supplied by RCN are to be complete. However, certain individuals were excluded:

- Project leaders of small projects (i.e. Events, Pre-projects etc.)
- Project leaders and partners in projects that had a start date of November of 2016 or later
- Project leaders or partners that also have received funding from the BIOTEK2021 programme were placed in the respondent group of one of the surveys at random (as the surveys for both programmes were launched simultaneously) and were asked to respond based on the experiences from that programme only
- Project leaders of rejected project applications that subsequently have received funding in either NANO2021 or BIOTEK2021 were excluded from the group of "rejects" and only received the project leader survey

The three surveys contained an almost identical set of question, but the survey to project leaders, in addition, contained several questions that were not included in the other two surveys. The survey to rejected project applicants did not include questions on project implementation and expected results and impact, for obvious reasons.

In the following presentation, responses from project leaders and partners have been aggregated where possible. Please note that some questions only were asked to project leaders and thus only contain the results of that survey. Survey responses are presented in three subgroups throughout this appendix:

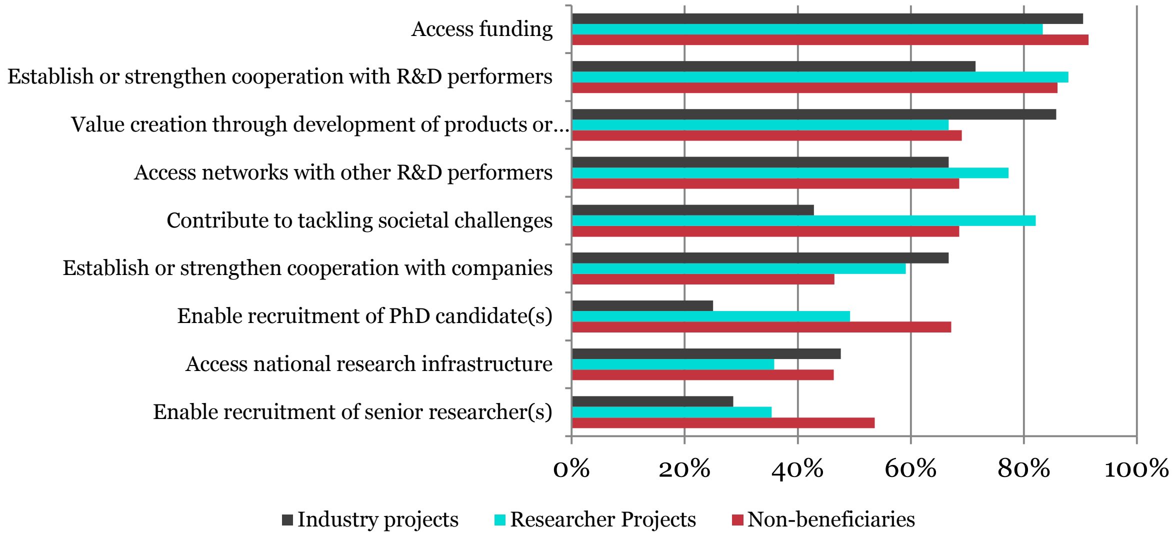
- Researcher Projects (i.e. responses from project leaders and partners in Researcher Projects, KPNs and ERA-NET Projects)
- Industry projects (i.e. responses from project leaders and partners in industry led IPN projects)
- Non-beneficiaries (i.e. responses from project leaders of rejected project applications of all application types)

C.2 Survey results

C.2.1 Project application

Both participants and rejected applicants were asked about their motives for participating in the project or project application in the NANO2021 programme. The result (shown in Figure 13) reveals that the most important motivational factors for all actors are to access funding for R&D activities, followed by strengthened cooperation with R&D performers. For industry-led projects, value creation is also an important motive. There is a notable difference in how researchers and industry representatives appreciate tackling societal challenges as a motivational factor. Less surprising is the difference on the opportunity to recruit PhD candidates, where researchers value this motive more compared to industry representatives.

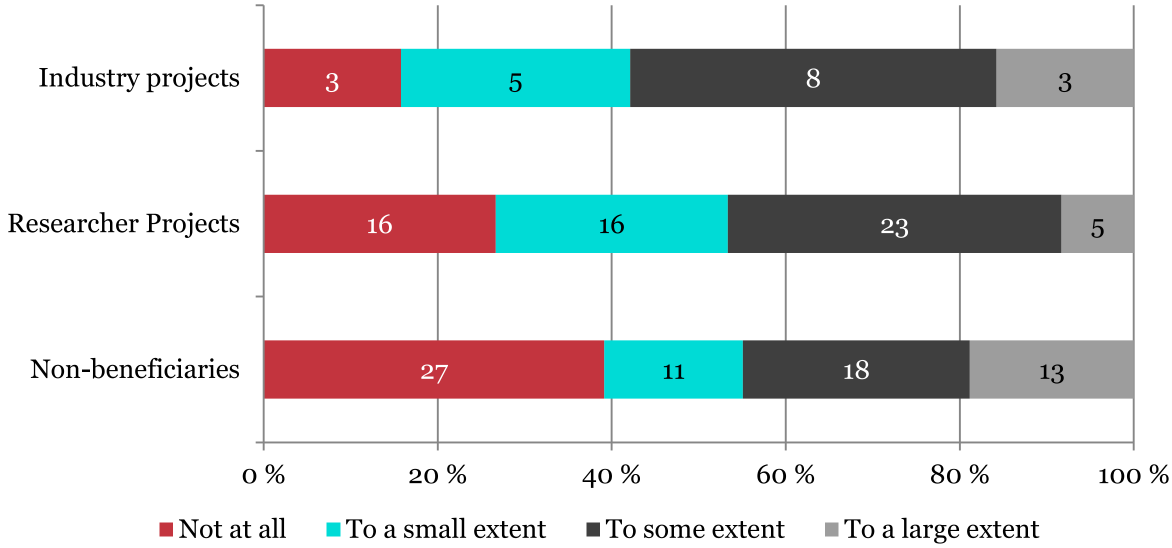
Figure 13 How do the following statements reflect your organisation's (or research consortium's/ team's) rationale for participating in the project?



Note: The figure presents the share of aggregate responses "Agree" and "Strongly agree".

The NANO2021 programme is a *de facto* continuation of the former large programme NANOMAT. The evaluation of NANOMAT concluded that the programme had strengthened the research quality and research capacity among R&D performers in the Norwegian nanotechnology sector. Subsequently, it was suggested that NONOMAT provided a level of competence that could be maintained and evolved through further R&D investments. Hence, when looking at NANO2021 from the perspective of continuous funding of R&D in nanotechnology, one of the first aspects to consider is funded projects that were made possible because of the applicants' previous experience from projects funded by NANOMAT.

Figure 14 To what extent are your research group's/organisation's activities funded by the NANO2021 programme based upon knowledge developed under the predecessor NANOMAT programme?

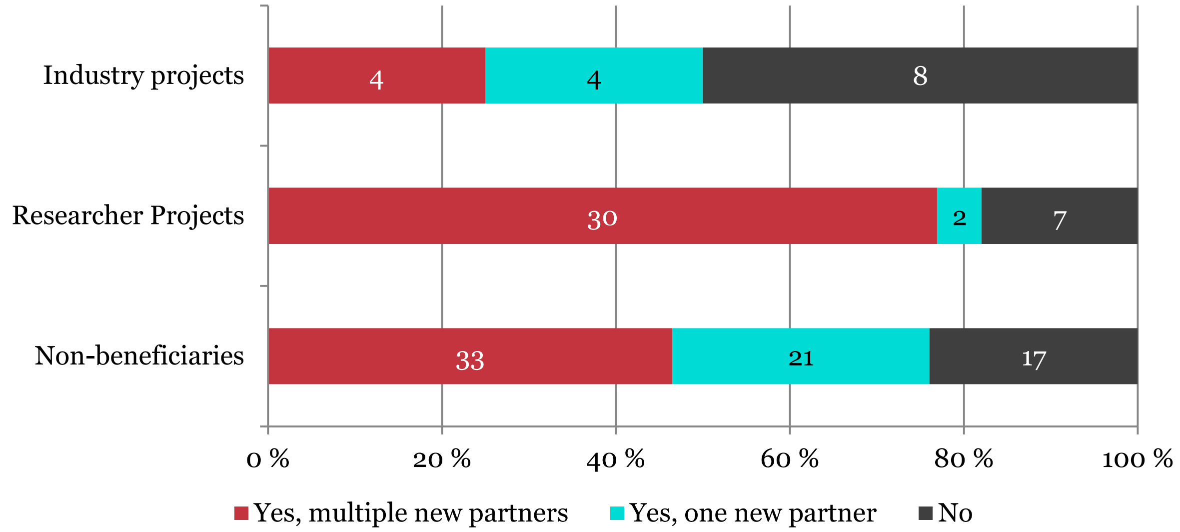


Perhaps unsurprisingly, the survey revealed that both in the case of industry-led and Researcher Projects, the largest share of respondents (11 from industry; 28 from research) recognised that the research activities funded by the NANO2021 programme (at least) to some extent were based upon knowledge developed under the predecessor NANOMAT, see Figure 14. What is interesting, however, is the fact that the non-beneficiary group had the largest share of research projects that benefitted from NANOMAT to a large extent (two out of five respondents from the non-beneficiary group as opposed to 8% from research and 14% from industry projects).

While it should be acknowledged that out of all non-beneficiaries the majority (as perhaps is expected) do not believe they have benefitted at all from previous NANOMAT programme. At the same time, the fact that nearly 20% of the non-beneficiary respondents felt benefits to a large extent and 26% felt they benefitted to some extent demonstrates just how widespread the results of the NANOMAT programme were.

Moving forward to the topic of continuation, the project leaders commented on how many new partners they included in their projects.

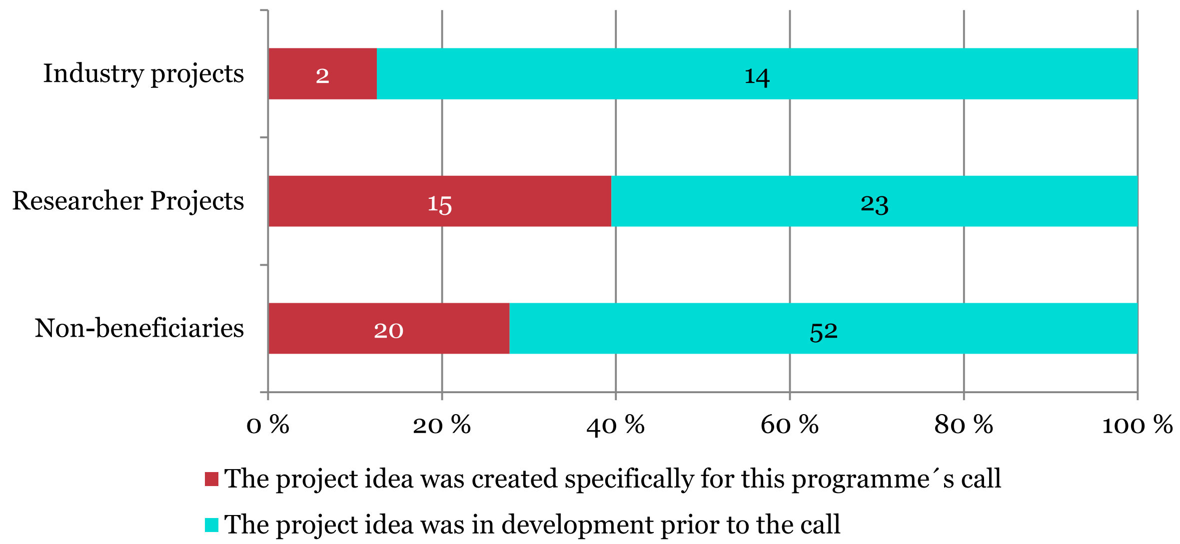
Figure 15 Does the project include new partners (whom you never worked with before)?



A stark contrast can be observed when comparing IPN and research projects. The vast majority of research projects (77%) had multiple new partners, compared to 18% of projects which did not. This is quite a bit different for industry-led projects where 50% of projects did not contain new partners (from the project managers' perspective), while 25% had one and 25% multiple new partners. The rejected project applicants included new partners (at least one) in their proposed projects to the same level as funded Researcher Projects (it should be noted at this point that the group of rejected projects is dominated by Researcher Projects).

Project development is a topic with a larger consistency across the categories of respondents as in all cases the majority of projects proposals were based on ideas that were in development prior to the call in NANO2021, see Figure 16.

Figure 16 How do the following statements reflect the development of your project proposal?



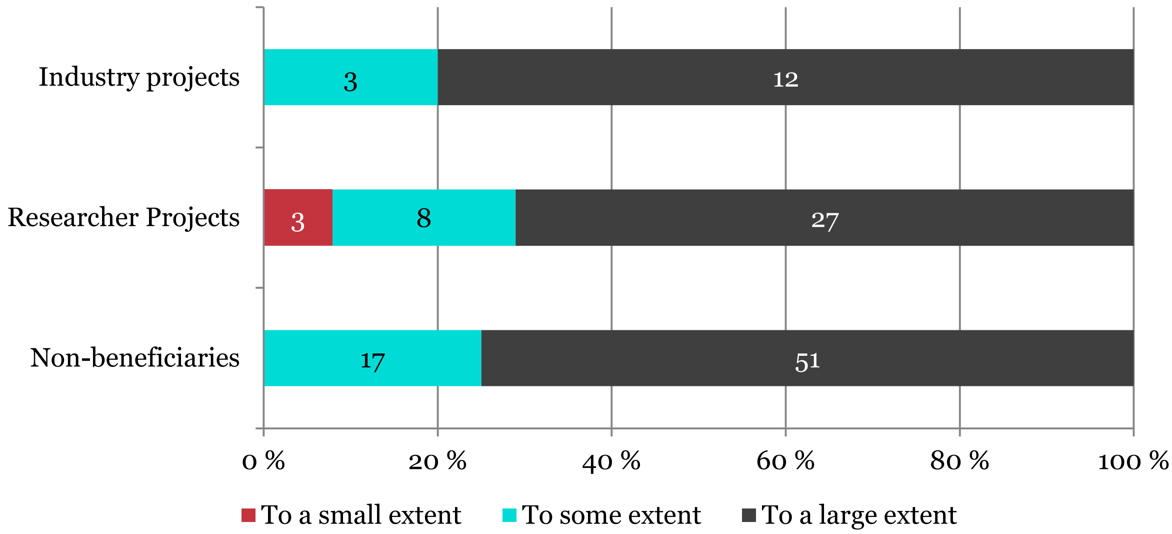
Project leaders in industry-led projects had the largest share of project ideas in development prior to the call (88% of the respondents). For Researcher Projects, 60% of applicants reused or redeveloped a project idea to fit the call in NANO2021 while the same was true for 72% of non-beneficiaries.

While this cannot be stated with absolute certainty, the reported impact of NANOMAT on research activities funded by the NANO2021 programme is a potential explanation for the root of project ideas:

- 14 industry respondents had their project ideas in development and 11 industry respondents benefitted from NANOMAT activities at least to some extent
- 23 Researcher Project respondents had their project ideas in development and 28 respondents benefitted from NANOMAT activities at least to some extent
- 52 non-beneficiaries had their project ideas in development and 31 non-beneficiaries benefitted from NANOMAT activities at least to some extent

Considering that for the most part the funded projects were not specifically designed for NANO2021 programme call it is important to understand the extent to which the programme corresponded to the needs of the applicants. Figure 17 shows the respondents' views on how the specific call conceded with the applicants' overall project idea.

Figure 17 To what extent did the NANO2021 programme call coincide with what you wanted to achieve with your research project?



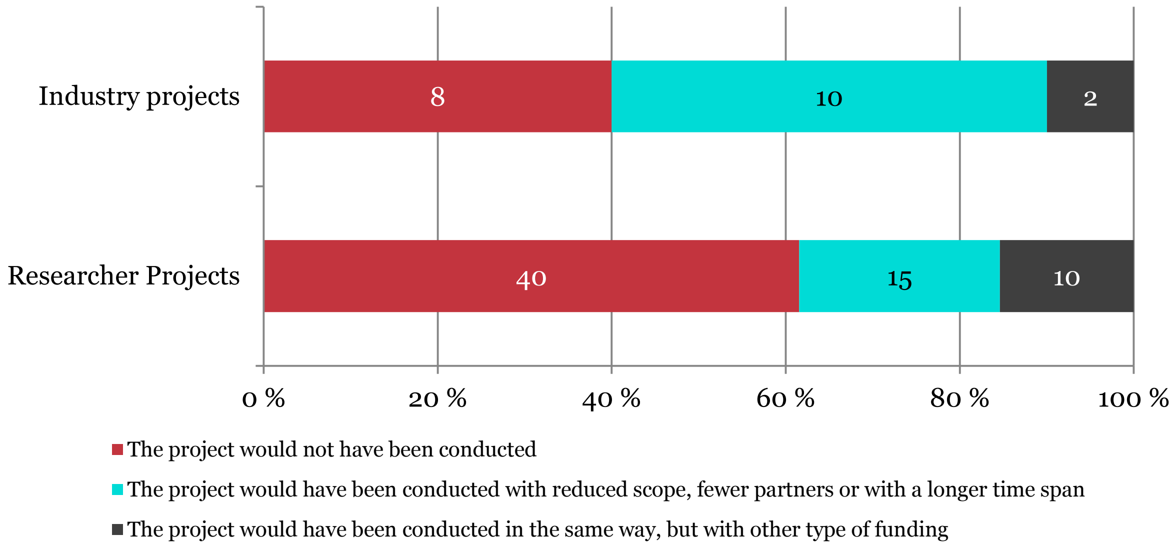
The immediately striking fact is that for only a few Researcher Projects the programme call corresponded to a small extent to what the respondents wanted to achieve with their research project. The positive message the surveys reveals is that for the most part, the majority of applicants felt the programme call coincided with their research intentions or project ideas.

- 12 industry project leaders felt the programme coincided with what they wanted to achieve with their research project to a large extent while 14 industry projects had their ideas in development prior to NANO2021 call. This indicates the programme related highly to the needs of the industry
- 27 Researcher Project respondents felt the call was in line with what they wanted to achieve with their research project to a large extent, while 23 research projects had their ideas in development prior to NANO2021 call. This indicates the programme in fact has reflected the needs of researchers

The survey results do indicate the NANO2021 programme, so far has been in line with the needs of the nanotechnology industry and R&D performers that have been active in the programme.

This is further proved when considering whether the projects would have been successful without NANo2021 funding, see Figure 18.

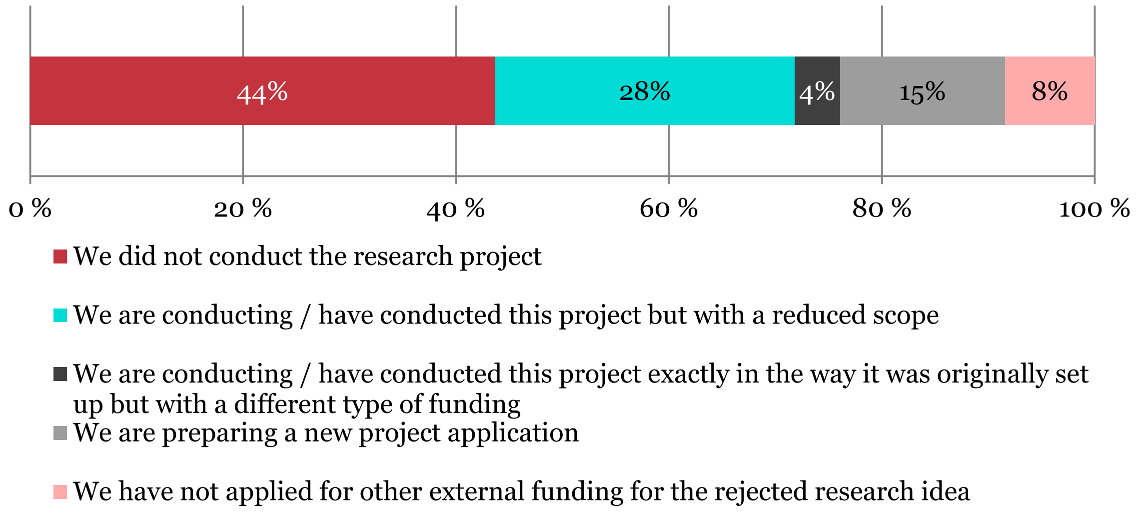
Figure 18 What do you imagine would have happened if your project had not been funded by the RCN's NANO2021 programme?



Four out of ten respondents in industry-led projects believe that their project would not have been conducted without funding from the NANO2021 programme. The situation differs for Researcher Projects where over 60% of respondents believe their project would not have been possible without funding from the programme, while 22% considered that the project would have been conducted with a reduced scope, fewer partners or during a longer time span. These results suggest that NANO2021 is a more critical support instrument for Researcher Projects while those working with industry-led IPN-projects could in all likelihood benefit from other support measures or fund parts of the project with solely private funding.

It is interesting to compare the hypothetical responses from the funded project with the answers from the project applicants who were in fact not successful. However, a fair share of the project applications was recently found to be rejected, and therefore the long-term destiny of these projects is still to be known. As shown in Figure 19, for those applicants whose projects were not funded, four out of ten reported that the project was not conducted in any other way. It is reasonable to assume that some respondents in this category will later try to apply for funding with the same project idea, refitted to another call. However, 15% actively responded that they indeed are preparing a new application and 8% that they have not done this.

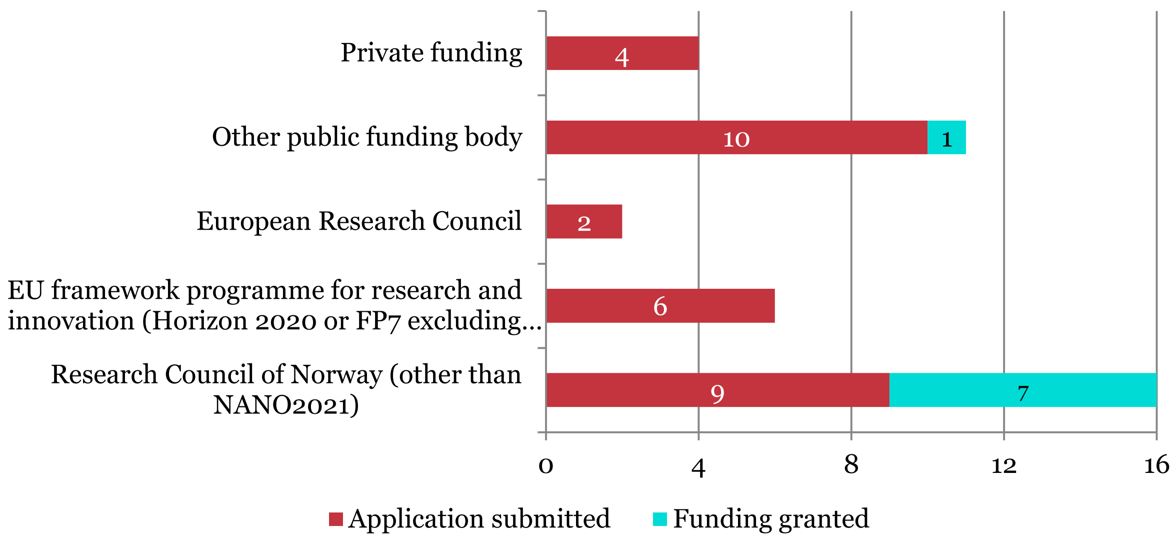
Figure 19 What happened to your research project since its rejection for funding?



The second largest group echoes to the attitudes of respondents with successful research projects in that their projects are (or were) conducted with a reduced scope, fewer partners or during a longer time span.

Knowing that 28% of the rejected project applications did, in fact, materialise in a project (however with reduced scope) and that 4% were conducted in the same way as intended, but with other funding, the question then arise who funded these projects? Figure 20 gives some insight as rejected applicants responded to which funding sources they turned into when resubmitting their original (or redeveloped) project idea.

Figure 20 Did you (subsequent to the application in NANO2021) apply with your research project idea to other funding bodies?

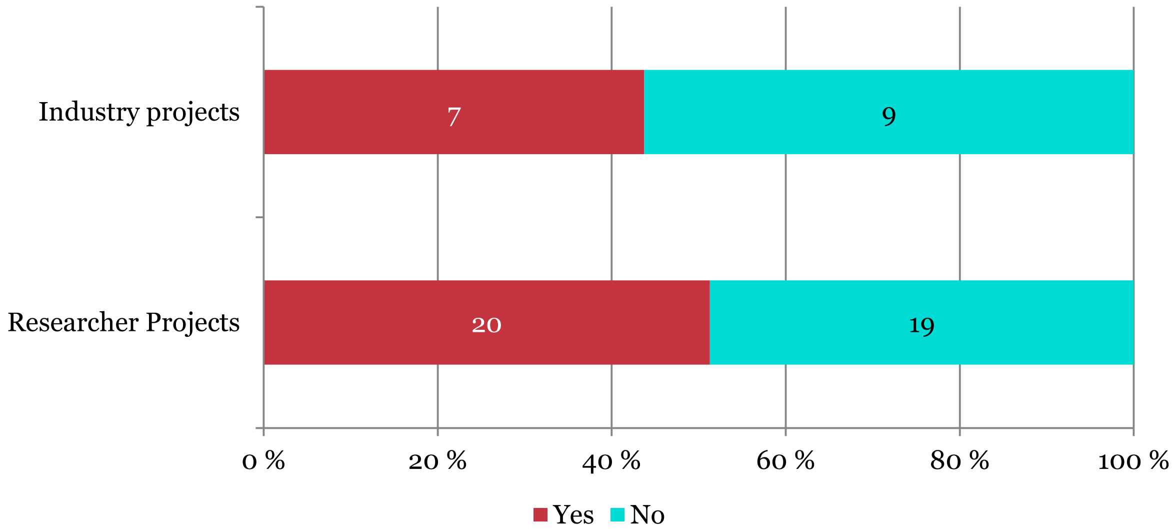


Note: Whole numbers.

The red bar represents applications submitted but where the decision is pending, the turquoise bar represents applications that recieved funding. From the total stacks it can be concluded that RCN has been the most favourable funding body, followed by other public funding opportunities and the EU framework programme (European Research Council and Horizon 2020/FP7 combined). Out of the subsequent applications only eight respondents have so far been successful with seven succeeding in additional grants from other RCN programmes while one respondent has received funding from another public funding body. However, these eight responses only account for 11% of all respondents in the non-beneficiaries category. In addition, there are several researchers who show remarkable perseverance as they have submitted several applications in response to multiple NANO2021 calls without being granted funding.

For the purposes of analysing the level of support provided by NANO2021 it was also important to know whether successful applicants considered submitting project applications for funding from other sources as well. The result is shown in Figure 21.

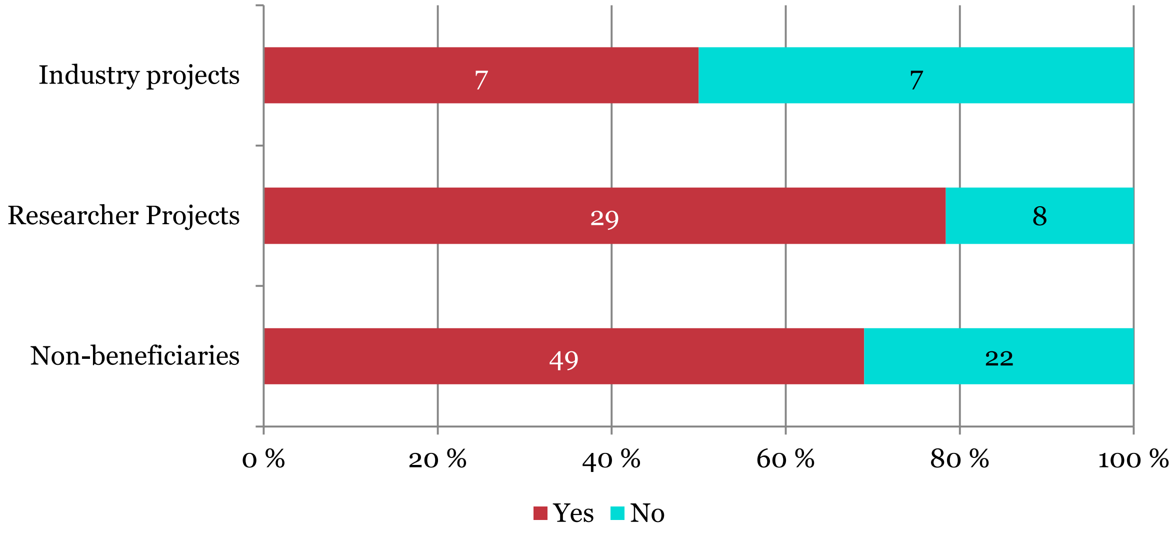
Figure 21 Did you consider other funding sources?



About 44% of project leaders in industry-led projects and 51% of respondents Researcher Projects did, in fact, consider other funding sources before deciding on the NANO2021 programme. To judge by the comments, the principal choice that applicants faced was to either apply for funding via RCN (NANO2021, BIA, PETROMAKS, BIONÆR, ENERGIX etc.) or pursue funding via Horizon 2020.

Regarding applying for funding the respondents were also asked whether they understood how the process of reviewing applications submitted to the NANO2021 programme work, results are presented in Figure 22.

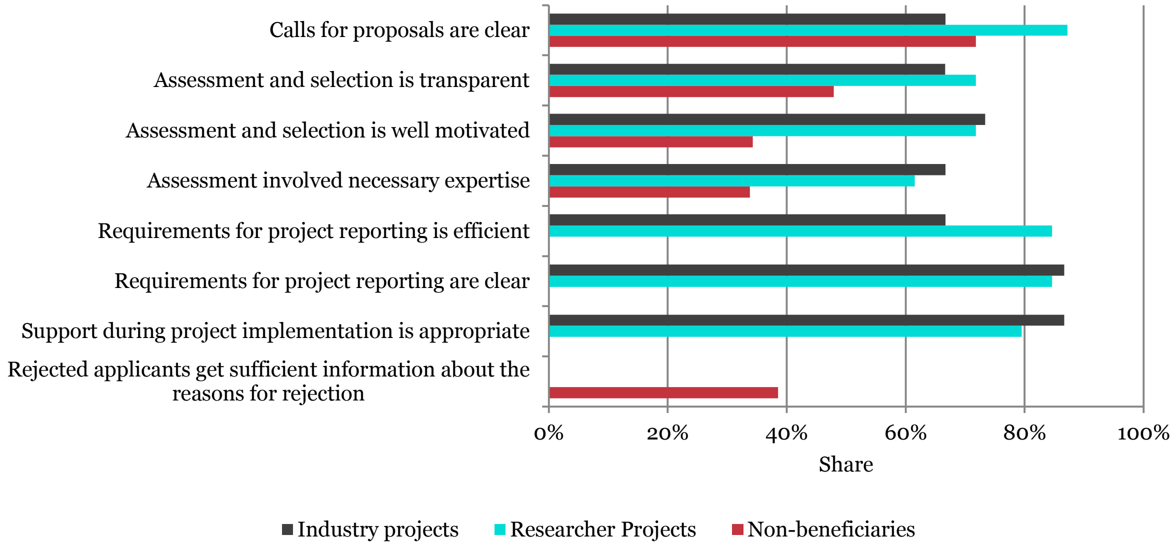
Figure 22 Do you know how the process of reviewing applications submitted for the NANO2021 programme's funding work?



For industry-led project applicants, there is a notable lack of knowledge regarding the project reviewing process (only 50% of IPN project leaders state that they know how the review process functions). This result is perhaps worrying but at the same time not surprising as we know from experience that project leaders in industry-led projects (i.e. IPN projects) often outsource the responsibility of project applications to a partnering R&D performer, who usually has more experience in writing and submitting applications to RCN. For project leaders in Researcher Projects and among non-beneficiaries, the knowledge is considerably higher, 78% and 69% respectively state that they are familiar with the review process.

The project leaders and non-beneficiaries also shared their views on the RCN's administration of the NANO2021 programme, the result is shown in Figure 23 in shares of respondents who agree or fully agree with the statements. There is a striking similarity in the responses of project leaders in industry-led projects and Researcher Projects. In industry-led projects, respondents are less content with the calls for proposals and the requirements for project reporting. These lower scores can, however, be understood in the light of what is described above, that contacts with RCN often is the responsibility for participating R&D performers, even in industry-led projects. Thus company representatives are in general less used to prepare applications in compliance with calls and submitting project reports. All things considered, beneficiaries demonstrate a generally high level of satisfaction with RCN's administration.

Figure 23 How do the following statements reflect your view on the RCN´s administration of the NANO2021 programme?



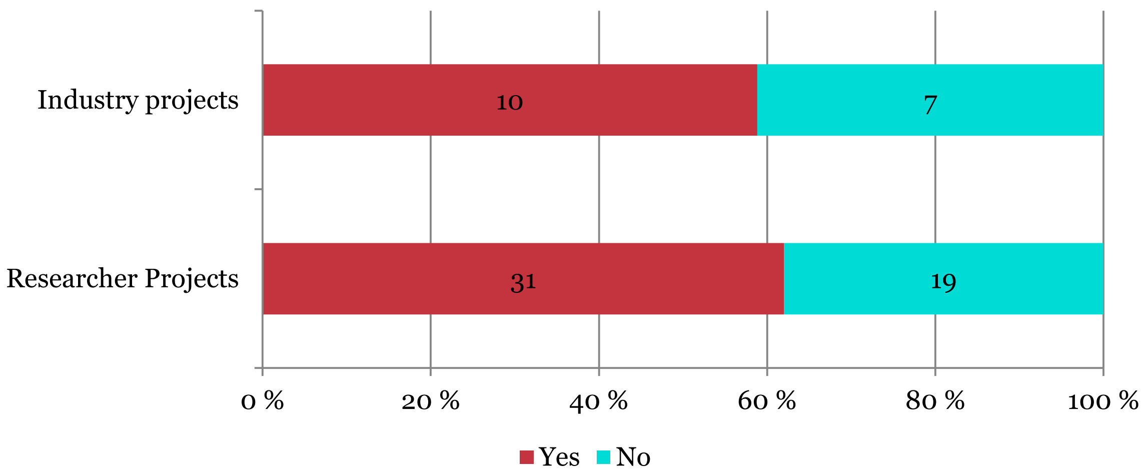
Note: The figure presents the share of aggregate responses "Agree" and "Strongly agree".

The non-beneficiaries are, however, another story. They agree with beneficiaries that the calls are clear but show a significantly lower level of satisfaction with RCN's process of proposal assessment and selection. Half of the non-beneficiaries agree that the process of project assessment and selection is transparent and only one-third agrees that the assessments are well motivated and that RCN involved the necessary expertise. Also just under 40% believe that unsuccessful applicants receive sufficient information about the reason for the rejection.

C.2.2 Project implementation

Project participants were asked if they believe that RCN, through the programme setup of NANO2021, is providing sufficient support for projects to produce results that may be commercialised. Figure 24 shows received responses.

Figure 24 If one of the goals of your project is to produce results that may be commercialised, does the programme setup allow you to get needed help (e.g. mentors, sign-posting etc.)?



In both groups of respondents the larger group believes the programme provides them with the necessary support to produce results that could be commercialised, 62% of project leaders in Researcher Projects consider the NANO2021 programme allow them to get needed help for commercialisation of results and 57% among Project leaders in industry-led projects. A potential explanation for these results is the fact that a number of respondents suggested having little information that RCN provided any sort of assistance regarding commercialisation. Here are a couple of voices from the survey:

> *Not aware of this possibility. Unclear what RCN can assist with and where does responsibility of a TTO take over. (Funded project applicant)*

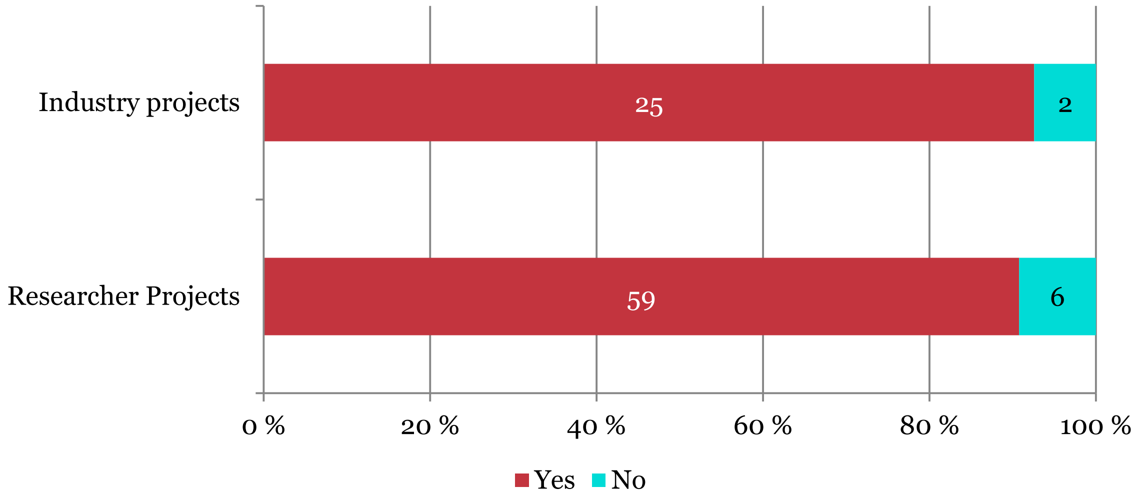
> *Yes, but it is not emphasised from RCN's side. I can get IPR help from my TTO. (Funded project applicant)*

For others the commercialisation of results was simply not a question they considered due to the focus of their project:

> *Commercialisation of project results is not a specific goal. I have not investigated the possibility for such help. (Funded project applicant)*

Regarding the implementation of their projects and adherence to set schedules nearly every respondent stated that the programme allowed them to implement their project to the initial time plan and achieve the anticipated results (93% of project leaders in industry-led projects and 91% in Researcher Projects), see Figure 25.

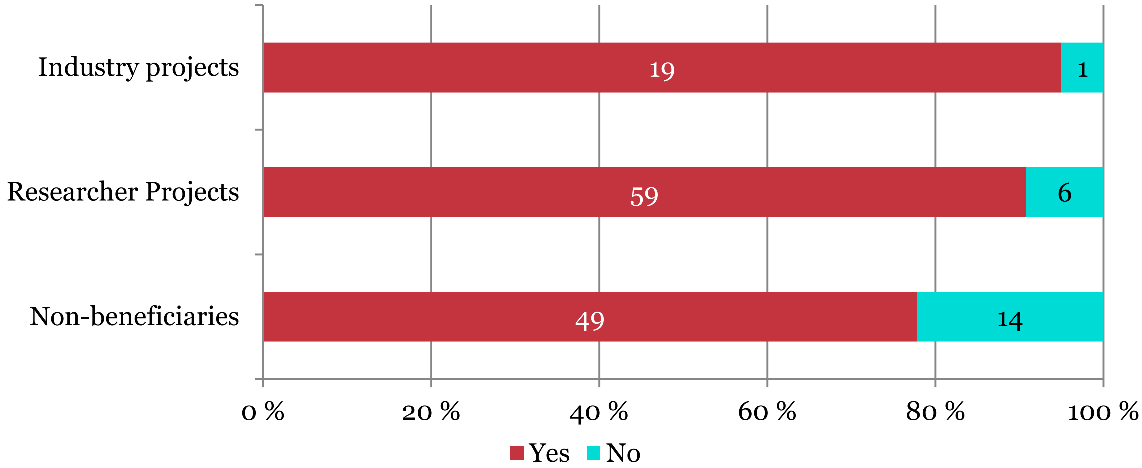
Figure 25 Does the programme allow you to deliver your project to the initial time plan and achieve the anticipated results?



These results suggest that the programme and its support facilitates achieving the results set by the applicants under their expected conditions.

All but one respondent in industry-led projects and 90% of participators in Researcher Projects asses that NANO2021 is in line with the current international developments in the nanotechnology field, as shown in Figure 26. This is a very positive response from the project participants, which further suggest that the programme participants believe that NANO2021 programme corresponds with the demand for R&D in the nanotechnology field. The non-beneficiaries are not equally convinced but still, almost 80% agree that the programme is in line with the current developments in the field.

Figure 26 Do you think the NANO2021 programme's subjects are in line with the current developments in the nanotechnology field internationally?



However, some negative opinions are also present among the respondents in the surveys, regarding the alignment to international trends, suggesting that NANO2021 is not as well received across the board. In the words of two respondents:

> *Too little focus on providing a solid basis in nano science – for which there exists no other dedicated funding in RCN. That will eventually have strongly negative consequences on innovative research and radical concepts, and at the end of the day not support Norwegian industries to the level that it ought too. (Survey respondent)*

> *Support towards Nano safety should be strengthened and have equal weight as other project applications in nanotechnology. (Survey respondent)*

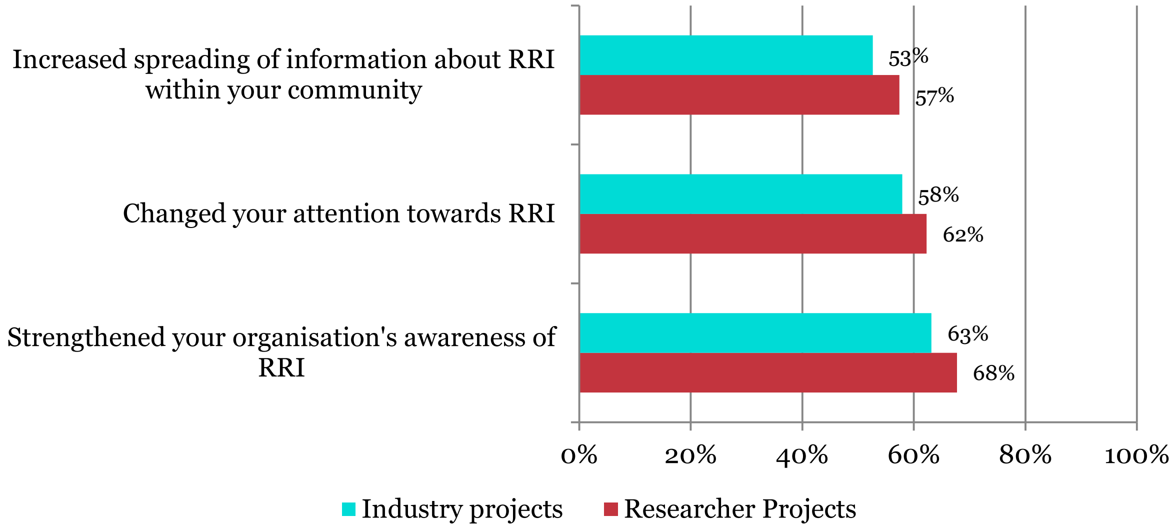
C.2.3 Responsible Research and Innovation

The programme participants and non-beneficiaries were asked a set of questions specifically related to RRI aspects linked to the NANO2021 programme and their projects. Figure 27 shows the share of respondents who believe that their project so far has led to increased knowledge, attention and awareness of RRI.

The emergent trend is that those participating in Researcher Projects regards the impact of including RRI into the project slightly higher than participators in industry projects, 57% of Researcher Project respondents state that participating in NANO2021 programme has increased the spread of RRI information in their community (as opposed to 53% of industry project respondents). For 62% of participators in Researcher Projects, the project was instrumental in changing their personal attention to RRI (as opposed to 58% of respondents in industry-led projects). Lastly, 68% of Researcher Project respondents hold the opinion that working in the project has strengthened their organisation's awareness of RRI (as opposed to 63% of participators in industry projects).

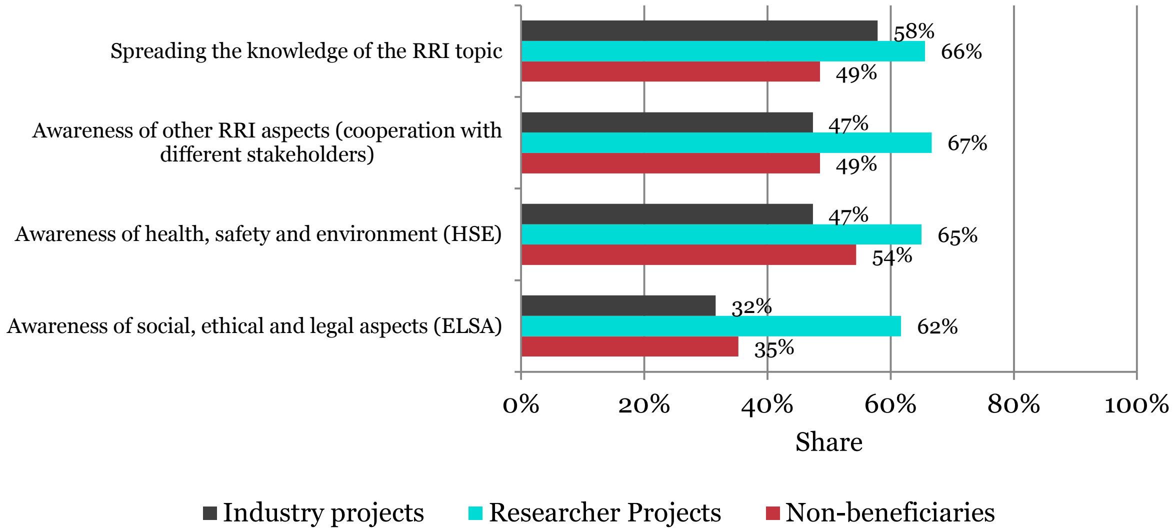
Beneficiaries and non-beneficiaries were also asked to assess how the programme as a whole contributes to the spread of knowledge of RRI topic and raise the awareness of RRI (including health, safety and environmental (HSE), as well as ethical, legal, social aspects (ELSA)) linked to nanotechnology. The results are illustrated in Figure 28 as share of respondents who agree or fully agree with the statements.

Figure 27 To what extent has your participation in the NANO2021 funded project led to the following?



Note: The figure presents the share of aggregate responses “to some extent” or “to a large extent”.

Figure 28 The NANO2021 programme as a whole contributes to an increase in the following.

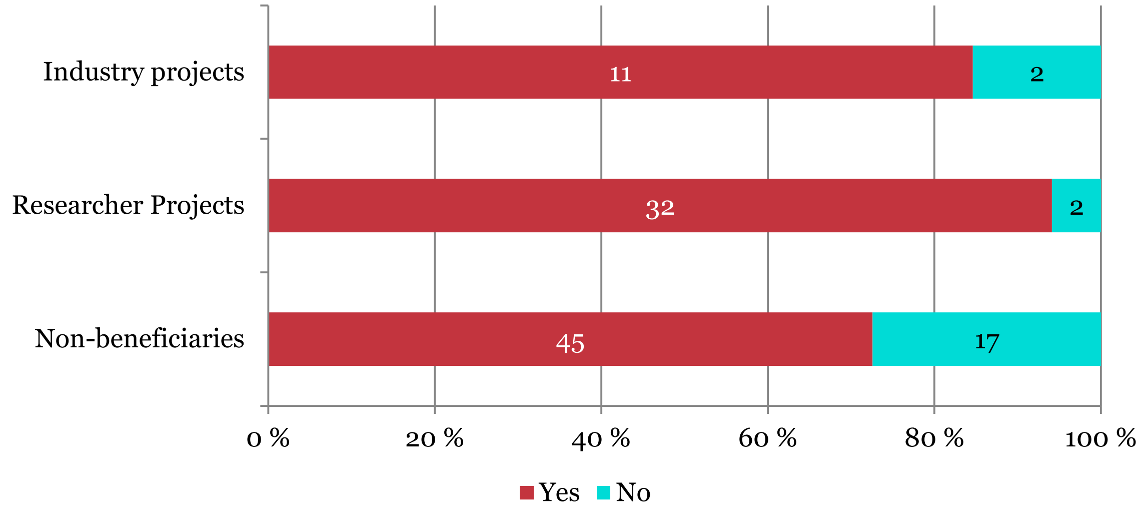


Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

The results suggest a large gap in opinions between participants in industry-led projects and Researcher Projects, but the cause of the seemingly lower approval of impact in industry-led projects is the fact that a large share of the respondents answered “Do not know” or “Nether agree nor disagree” rather than “Disagree”, indicating that they lack a strong opinion at this stage. However, in the case of the non-beneficiaries, they are more inclined to express an opinion in either direction, resulting in just under 10% who disagrees with the statements throughout, but also in this group a fairly large share or respondents express a “no-opinion”.

While the respondents find it difficult to express a clear view on the impact of RRI practices in NANO2021, the great majority of successful applicants believe that the RRI component in their project application received fair evaluation see Figure 29. Among the non-beneficiaries, 27% express that they are not satisfied with how the RRI component in their application was judged.

Figure 29 Do you think that the RRI element of your application got a fair and thorough review?



C.2.4 Future results and impact

As the programme is only in its sixth year and just a small part of the funded projects has been completed, it would not be fair to expect the programme to have yielded any major results yet. Thus, the project participants were prompted to indicate what kind of results they expect from their projects and the results are showcased in Figure 30. Note: The figure presents the share of aggregate responses "Agree" and "Strongly agree".

Figure 31 shows the respondents' views on which academic results the projects is expected to yield.

It is important to remember that the project portfolio (especially among Researcher Projects) is heterogeneous, ranging from relatively small projects (running for 2–3 years and with few partners) to some relatively large multidisciplinary projects engaging researcher and other organisations nationwide. However, participants in these large projects are underrepresented among the respondents, thus the result from these large projects may be underappreciated in this aggregated results.

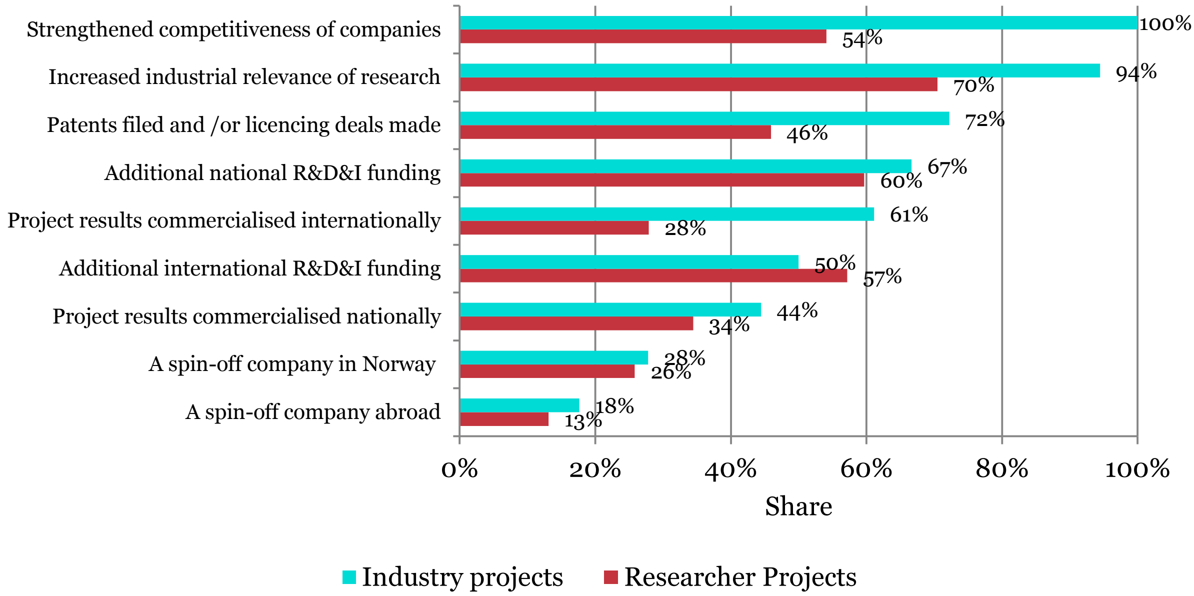
Having said that, the surveys show that virtually all respondents in industry-led projects expect that participating companies will strengthen their competitiveness and that industry relevant research will increase in all participating organisations. Three-quarters also state that patents or licencing agreements are likely outcomes of the industry-led projects, and 61% that project results will be commercialised internationally (see Figure 30). The participants in industry-led projects do also, to a fairly high degree, expect that their projects will strengthen the participating R&D performers' competitiveness (compared to their national and international peers) and contribute to co-authorship between research institutions (cf. Note: The figure presents the share of aggregate responses "Agree" and "Strongly agree".

Figure 31).

The respondents participating in Researcher Projects are less inclined to agree that their projects will lead to commercially oriented results (commercialisation of project results, patents or strengthened competitiveness of companies) this is however not surprising given that the focus of Researcher Projects often includes less direct links to application or potential for commercial benefits. However, 70% of participants expect that the project will lead to increased industrial relevance of research within their organisation. The majority of participants in Researcher Projects also expect that the results from the project will lead to additional R&D funding for new projects (see Figure 30). When asked about academic results, participants in Researcher Projects are notably more positive about the outcome of their projects (cf. Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

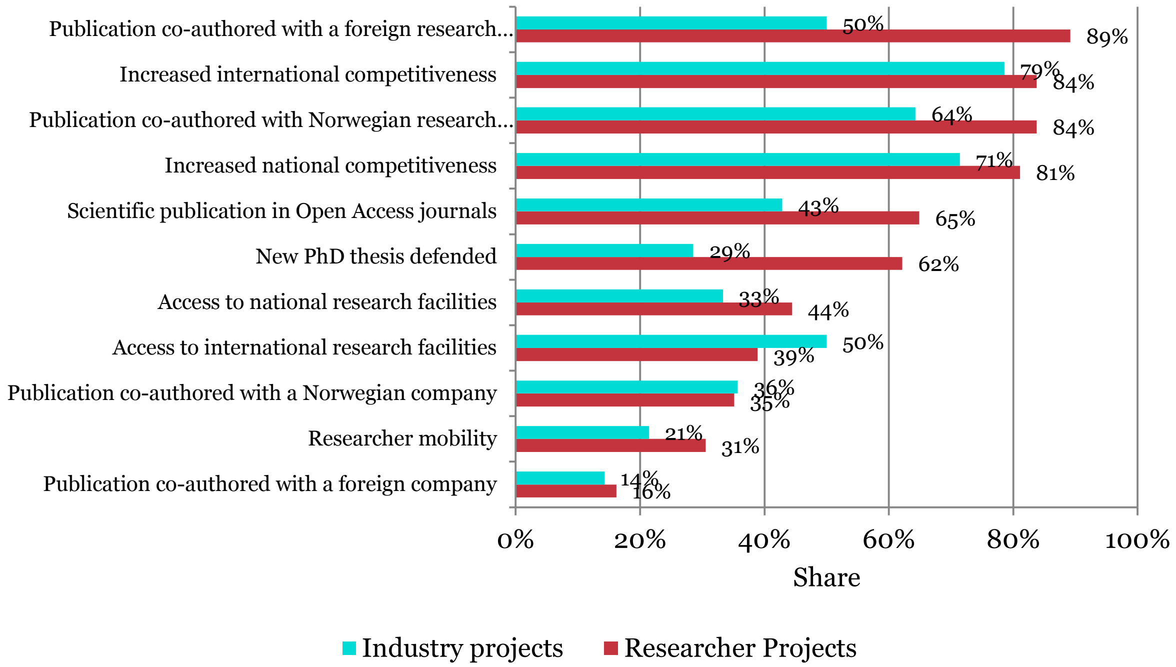
Figure 31). Over 80% of respondents expect the projects to lead to co-authored scientific publications with other R&D performers, both foreign (89%) and national (84%), and to increased competitiveness compared national and international peers.

Figure 30 Do you expect your project to achieve the following results?



Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

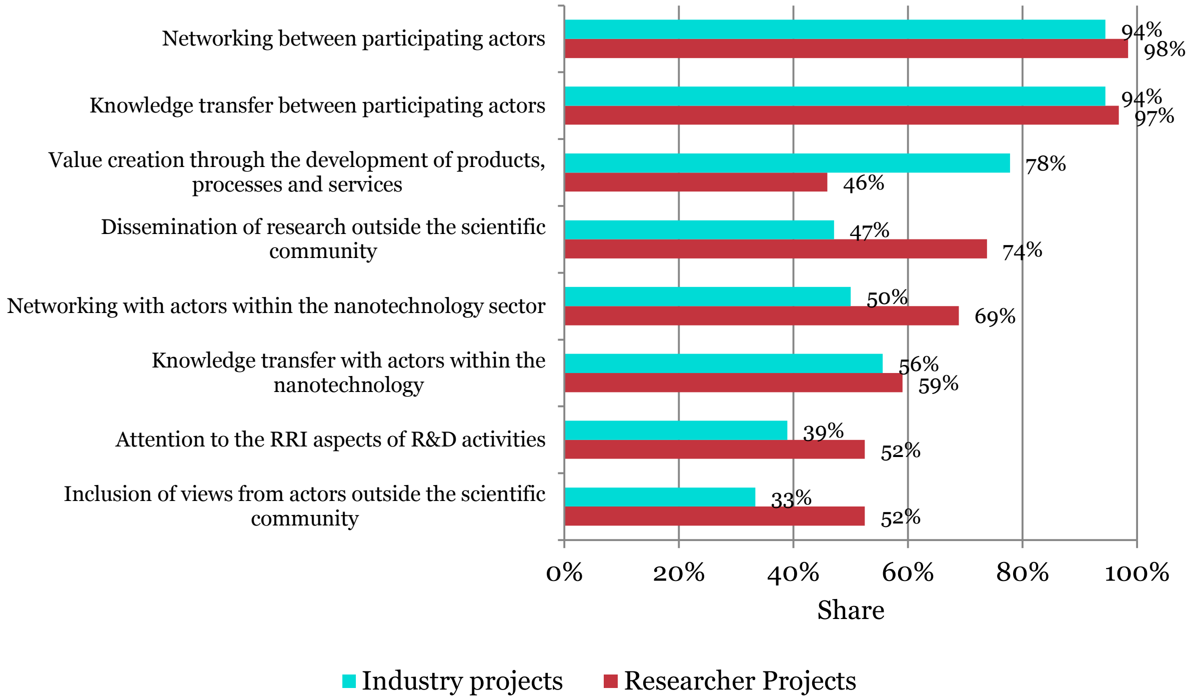
Figure 31 Do you expect your project to achieve the following academic results?



Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

The project participants also indicated what their projects funded through the NANO2021 programme have accomplished so far. These views are shown in Figure 32. There seems to be a resounding consensus among respondents in both in industry-led and Researcher Projects that projects yield increased networking and knowledge transfer among participants. In other aspects, the different orientations of the two types of projects become evident. Industry led (i.e. commercially oriented) projects are more likely to increase value creation through development of new products, processes or services and Researcher Projects have achieved dissemination of new knowledge outside the scientific community and increased networking among actors in the nanotechnology sector.

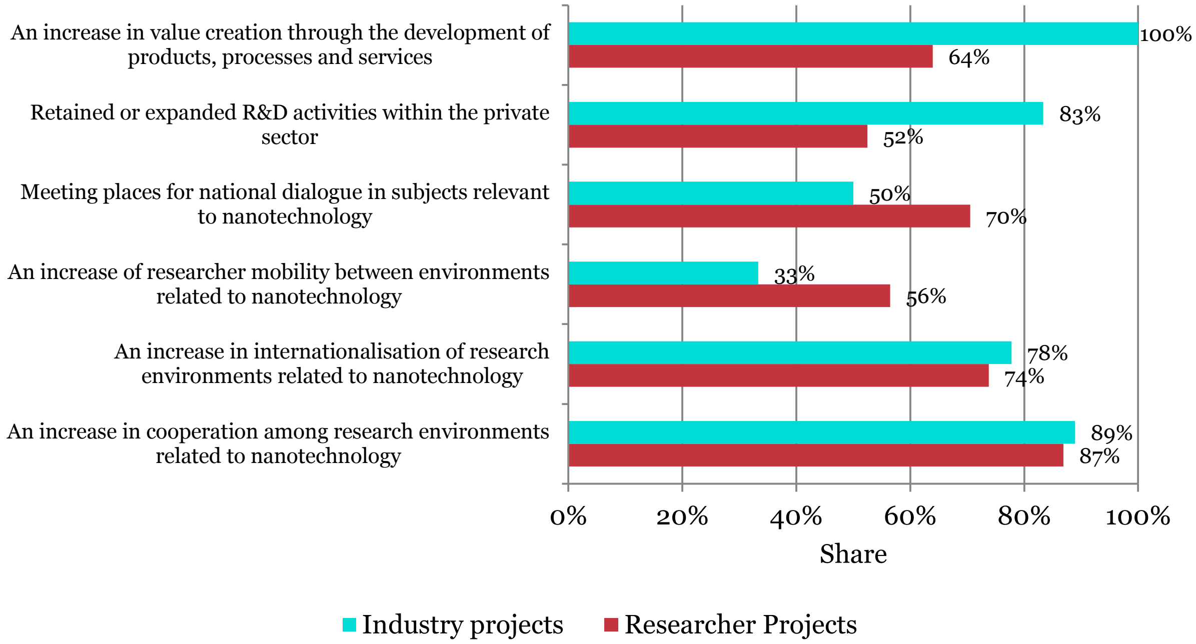
Figure 32 To what extent has your project increased the following?



Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

The project participants were also asked about their view of what the NANO2021 programme as a whole contributes to. The alternatives the respondents were asked to judge (showed in Figure 33) somewhat corresponds to the specified objectives of the programme. While many participants in industry-led projects recognise that the project contributes to a general increase in value creation in the nanotechnology sector and retained or expanded R&D activities within the private sector, only half agrees that the programme facilitates meeting places for national dialogue. In the latter, 70% of participants in Researcher Projects agree to the same statement, they are however less convinced that the programme delivers regarding value creation or has a positive effect on R&D activities in the private sector. These seemingly different views can largely be explained by the fact that participants simply do not have the full picture. Looking at the responses it becomes evident that the ones that do not “agree” most often have responded “do not know” rather than “disagree”. Lastly, a significant share of respondents does believe that the programme contributes to both internationalisation of nanotechnology related research and increased cooperation among research environments active in the field, much in line with what they expect that their own projects will accomplish.

Figure 33 To what extent do you believe that the NANO2021 programme as a whole contributes to the following?



Note: The figure presents the share of aggregate responses "Agree" and “Strongly agree".

Faugert & Co Utvärdering AB
Skeppergatan 27, 1 tr.
114 52 Stockholm Sweden
T +46 8 55 11 81 00
E info@faugert.se
www.faugert.se
www.technopolis-group.com