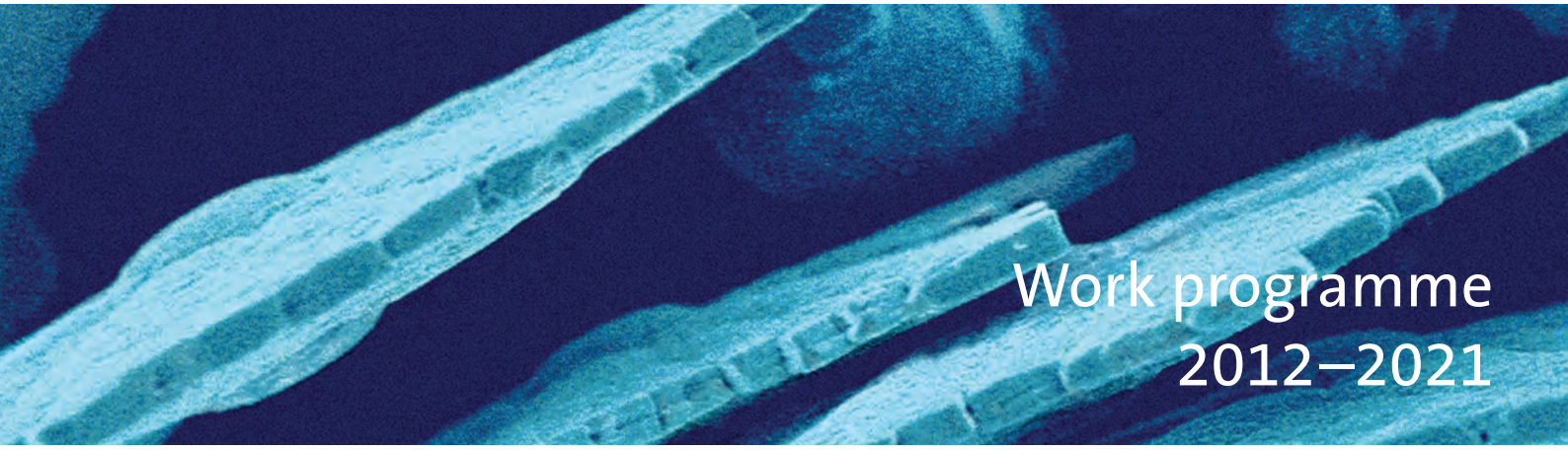
The Research Council of Norway



Work programme 2012–2021

Large programme

Nanotechnology and Advanced Materials – NANO2021

Large-scale Programmes

The RCN initiative to meet national research priorities

The Research Council of Norway

Work programme 2012-2021

Programme Nanotechnology and Advanced Materials – NANO2021

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Contents

1 Summary

This work programme is the underlying document for the NANO2021 programme, and explains why it is important to invest in the programme's thematic priority areas, how the programme will be organised and which objectives are expected to be achieved. The work programme establishes the formal framework and focus of the programme and provides guidelines for R&D players seeking funding under the programme.

The research programme on Nanotechnology and Advanced Materials (NANO2021) was established as a 10-year large-scale programme, with start-up in 2012. Large-scale programmes are an important instrument for achieving national research policy priorities, and are designed to build knowledge in a long-term perspective in order to encourage innovation, enhance value creation and help to solve prioritised societal challenges. This work programme is valid for the period 2012-2021, and is planned to be revised in 2016.

The NANO2021 programme is the Research Council of Norway's strategic research initiative in the field 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 strategy names three priority areas for public investment in R&D: basic knowledge development, innovation and commercialisation, and responsible technology development.

The programme has a long-term perspective and covers a comprehensive thematic area, and will employ a wide array of the Research Council's application types and strategic measures to achieve its objectives. The programme promotes the development of fundamental knowledge and innovative technological solutions as a basis for dynamic industrial development and for tackling wide-ranging societal challenges relating to energy, the environment, use of natural resources, and health. This entails ensuring that new knowledge and new technology are utilised to the benefit of society. Importance will therefore be attached to research on health-related, environmental and social issues relating to the development and application of nanotechnology in keeping with society's growing expectations in this area.

Funding of research projects and other activities will be used to help to build knowledge, develop technology and put this knowledge and technology to use in a socially responsible manner.

Great importance will be attached to encouraging integrated research activities that link together long-term basic research, applied research and innovation activities across company, institutional and disciplinary boundaries in order to generate new knowledge and cutting-edge solutions that otherwise would not have been possible.

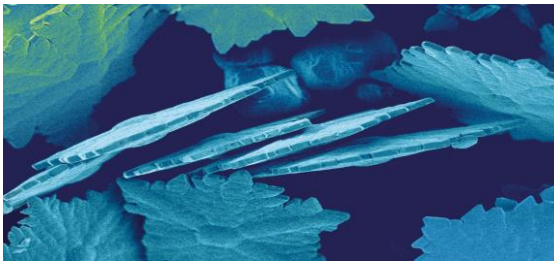
The programme is designed to achieve the goals set out in the government white paper on research, Report No. 30 (2008-2009) to the Storting: *Climate for Research*, and *the Norwegian Government's national R&D strategy for nanotechnology for 2012-2021* (2012). This work programme is based on a state-of-the-art-review on nanotechnology and advanced materials compiled by the Research Council of Norway: *Veien videre 2020* ("The Road Towards 2020"); relevant subject-specific evaluations; *the Innovation Strategy for the Research Council of Norway* (2011); *the Research Council of Norway's Strategy on International Cooperation* (2011); the final evaluation of the programme Nanotechnology and New Materials (NANOMAT) (2011); the Research Council's experience from the 10-year NANOMAT programme; and preliminary focus areas for the forthcoming EU Framework Programme, *Horizon 2020*.

2 Background

The objective of the Norwegian Government's national R&D strategy for nanotechnology for 2012-2021 is to promote the responsible development of nanotechnology that can contribute significantly to industrial and commercial development and will be of relevance and benefit to society. The Government is seeking the implementation of nanotechnology that will enhance the competitiveness of Norwegian trade and industry and the capacity to deal with global societal challenges effectively, without generating undesirable impacts on human health, the environment and society at large.

The strategy document states specifically that the Government will maintain its targeted R&D focus on nanotechnology via the NANO2021 programme under the Research Council of Norway. Basic knowledge development, innovation and commercialisation, and responsible technology development have been identified as the three priority areas for public investment in R&D.

The expertise, quality and capacity of research activities in Norway's R&D community in the field of nanotechnology and advanced materials have been enhanced considerably in recent years. R&D players have entered into binding national cooperation and task-sharing with regard to both research and infrastructure. The wide-ranging expertise that has been accumulated provides a basis for comprehensive as well more narrowly targeted activities, also with a view to creating innovative solutions and promoting advancements in a number of national priority areas. These were the main conclusions of an external evaluation of the research programme on Nanotechnology and New Materials (NANOMAT), 2002-2011, which were emphasised by the funding ministries at the programme's final conference.



The NANO2021 programme is the Research Council's strategic funding instrument for the implementation of the national R&D strategy for nanotechnology.

The Research Council's large-scale NANO2021 programme will run from 2012 to 2021. The programme consolidates and strengthens research activities within its area of responsibility, and is targeted towards Norwegian research groups, research institutes and companies with R&D-based activity in nanoscience, nanotechnology, microtechnology and/or advanced materials.

The programme is intended to generate knowledge that will meet the needs of trade and industry and society at large in the short and the long term. Cutting-edge knowledge and innovative solutions are to be applied in important areas of society in a safe, responsible manner.

As of 2012, the programme is receiving funding from the Ministry of Education and Research, the Ministry of Trade and Industry, and the separate budget item for cross-sectoral allocations from the Ministry of Education and Research.

A state-of-the-art review carried out by the Research Council in 2010 points out that even after ten years of research activity under the NANOMAT programme, there is still a need both for continued development and for new expertise in a long-term perspective. The technology area is still relatively young, and there is an ongoing need for basic research on which to develop further knowledge. Both the state-of-the-art review and the evaluation of the NANOMAT programme further stress the importance of providing more generous long-term funding and stepping up

efforts 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.

The largest Norwegian research actors are the Norwegian University of Science and Technology (NTNU), the University of Oslo (UiO), the SINTEF Group and the Institute for Energy Technology (IFE), followed by the University of Bergen and Vestfold University College. In recent years, several of these institutions have drawn up their own nanotechnology strategies, prioritised investment in clean rooms and other advanced infrastructure, and established their own educational programmes in nanotechnology.

In Norway, research within the field of nanotechnology is primarily rooted in the disciplines of physics, chemistry and materials science, although there is considerable research activity in microtechnology, bionanotechnology and on challenges relating to the ethical, legal and social aspects of technology development (ELSA) and health, safety and (the indoor and external) environment (HSE).

Several Norwegian research groups are at the forefront of the competitive arena in Europe, particularly in the development of nanotechnology for renewable energy applications. An emerging area of growth is nanotechnology and the utilisation of general insight at the nano- and micro-scale regarding control over biological processes, which is expected to result in exciting medical applications (bionanotechnology and nanomedicine). Norwegian trade and industry is also now better equipped to translate interdisciplinary knowledge of materials and structures at the micro- and nano-levels into competitive advantages and industrial applications.

Nanotechnological expertise has been put to good use, for example by the Norwegian light metals industry, to develop customised materials and achieve more environment-friendly production and product recycling. Industrial clusters have been established in the fields of microtechnology and nanoelectronics as well, based on in-depth insight into silicon chip-based processing systems, among other things. In addition, several companies with a business model based primarily on R&D results and innovations in nanotechnology or advanced materials have been founded.

The number of nano products and nano companies is expected to rise in the years to come. To achieve this, it will be essential to clarify questions relating to legislation, regulation and potential negative side effects of these products.

3 Objectives of the programme

Vision

The NANO2021 programme – a powerful hub for new knowledge and knowledge-based trade and industry.

Primary objective

The NANO2021 programme will 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.

Secondary objectives for the programme period 2012-2021

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.
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 secondary objectives are designed to advance the achievement of the programme's primary objective. All of the secondary objectives apply to nanoscience, nanotechnology, microtechnology and advanced materials (either collectively or individually). These are hereafter referred to as nanoVT and advanced materials (please refer to Attachment 3 for definitions). The targets for the individual secondary objectives are described in greater detail in Attachment 1.

Target groups

- Research environments with the ambition and capacity to development new knowledge about nanoVT and advanced materials; e.g. universities, university colleges and independent research institutes.
- Existing industries that utilise – or could utilise – nanoVT and advanced materials to enhance their competitiveness.
- New industries in which nanoVT and advanced materials comprise the core technology.
- An innovative health sector in which nanoVT and advanced materials are put to use.
- With regard to communication activities and social dialogue, the programme will target the R&D community, the business sector, the health sector, the public administration and the political authorities.

4 Priority research tasks

4.1 Strategic priorities

The strategic priorities of the programme are all rooted in the need to generate basic, cutting-edge knowledge in a long-term perspective. Knowledge and technology are to be developed in close cooperation with industry players to satisfy society's needs for know-how and innovative solutions. Knowledge and technology will also be developed in a manner that harmonises with social values and with an emphasis on responsible implementation of solutions. Figure 1 illustrates the interplay between the various pillars of the programme.

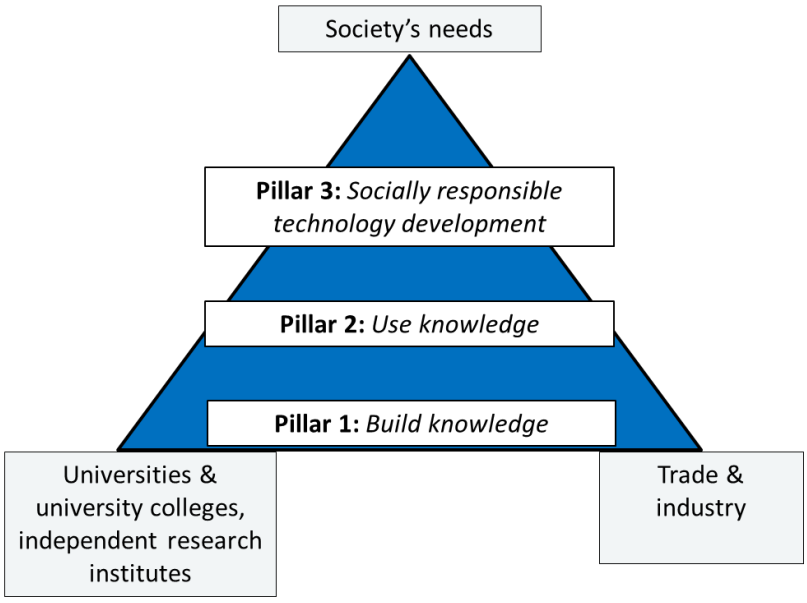


Figure 1. *Interplay between the three pillars of the programme.*

Pillar 1 **Focus on science ("Build knowledge")** to generate cutting-edge knowledge within priority areas. Activities under this pillar of the programme will create a national competency base for solving current and future societal challenges and lay the foundation for tomorrow's knowledge-based industry.

Pillar 2 **Focus on technology ("Develop and use technology")** to further develop trade and industry through research to achieve innovative solutions within priority areas. Activities under this pillar of the programme will help to tackle current societal challenges and will create new industrial activity (in new and existing industries).

Pillar 3 **Focus on socially responsible technology development** to learn more about the health, the indoor and external environment and safety aspects associated with priority areas. This pillar of the programme also encompasses focus on ethical and social aspects of the development, production and application of nanotechnology. Activities will provide the knowledge platform needed for responsible, sustainable technology development as well as input for legislation in and regulation of the technology area.

Activities under the programme will include experimenting with the integration of Pillar 3 as a separate work package in research projects or other forms of interplay with Pillars 1 and 2. In this context it may be relevant to further refine best practice for integrated projects. Under the NANOMAT programme, predecessor to the NANO2021 programme, projects were launched in

which technologists and social scientists worked together to develop technological solutions that focus both on the technology itself and on its social aspects . In other cases, funding announcements will be issued for standalone research projects targeting knowledge needs under Pillar 3.

4.2 Challenges and measures

The programme will give priority to areas in which Norway's competitive advantages or major societal challenges can most directly incorporate nanoVT and advanced materials. These priority areas must be based on competitive advantages found throughout the country (expertise, infrastructure, natural resources and industrial strengths), have good market potential, be of significant relevance and benefit to society, and be defined through dialogue with the larger society.

Societal challenges
Generating fundamental knowledge and technological solutions targeting the needs of society and trade and industry is at the core of the programme. By bringing together basic research, applied research, and innovation activities across company, institutional and disciplinary boundaries, the programme will create visible added value for dealing with comprehensive societal challenges such as increased access to environment-friendly energy, innovative environmental technology solutions, sustainable use of natural resources, and improved health and new medical technology.

Comprehensive and more narrowly targeted activities
The programme will support outstanding national R&D groups that are – or have the potential to become – international leaders in their field. Scientific excellence is to be achieved and further refined within priority areas. At the same time, adequate focus must be given to areas that have high societal value, even if Norwegian research in these areas lags behind the international forefront, as a means of promoting increased mobility, recruitment, investment in younger researchers and scientific renewal in the field.

Among other things, the programme will encourage large-scale interdisciplinary projects addressing a well-defined societal challenge (top-down projects). The establishment of research centres may be of relevance in this context. Large-scale projects require special skills in terms of research management. The programme will also further develop the monodisciplines to create a pool of expertise and enhance the ability to meet future societal challenges, the contours of which as yet remain unknown. This will typically involve bottom-up projects of smaller size and scope.

National cooperation
National coordination and task-sharing will be further enhanced by facilitating the participation of a larger number of (and new) R&D players in cooperative efforts. Coordination at the national level will also help to ensure optimal benefits from national investments in advanced scientific equipment, including follow-up research in connection with Norway's participation in international facilities. The programme will facilitate the use of relevant national research infrastructure by trade and industry. Various good practices from nationally-coordinated projects funded under the NANOMAT programme will be further refined.

Innovation and industrial development
Norwegian trade and industry possesses expertise and carries out R&D activities in several segments of the field of nanoVT and advanced materials, using the knowledge to improve existing products or achieve processes that consume less energy and smaller amounts of raw materials. Although a number of companies are already utilising nanoVT and advanced materials as a tool to enhance their competitiveness, there is still significant potential to better exploit this technology.

Several new companies that use nanoVT and advanced materials as the core technology in their end-products have been established in recent years. It is especially difficult for newly-established technology companies to make the transition from the laboratory to production, and many start-ups are not able to take the step to the market and successfully commercialise their products. The programme will generally provide funding to projects up to the proof-of-concept phase. In many cases, innovation and industrial development activities will require additional financial support to achieve upscaling from the laboratory to the market. This is not within the purview of the NANO2021 programme. However, the programme will actively cultivate productive dialogue with other public funding players in the research and innovation system, such as SIVA – the Industrial Development Corporation of Norway, Innovation Norway and Investinor AS.

The programme will work to increase value creation in companies, knowledge-based competitiveness in new and existing industry, and development of applications and innovations for the public sector (e.g. the health trusts). The implementation of the Research Council's innovation strategy, which addresses focus, breadth and impact, will be of key importance here.

Efforts to increase the mobility of researchers and other resource persons between the academic community, research institutes and trade and industry, as well as between companies, will be an important part of the programme. Strong industrial clusters in the technology area are currently lacking. Funding for research projects will be viewed in relation to cluster development, thereby laying the basis for a value chain that leads to industrial development. An active dialogue will be established between the programme and existing clusters.

New measures and work forms
In order to promote knowledge-building, value creation and innovation, the programme will employ funding instruments that encompass the entire value chain (Researcher Projects, Knowledge-building Projects for Industry, Innovation Projects for the Industrial Sector and Innovation Projects for the Public Sector). Interdisciplinary research projects that extend across the boundaries of subject areas and disciplines in which researchers do not traditionally cooperate will be encouraged. Consideration will also be given to trying new forms of user involvement and social dialogue within the framework of the research projects. In addition, new funding schemes may be introduced and tested for building networks and industrial clusters, for participation of small companies in research projects, for recruitment and career/starting grants, for compensation for payroll expenses for scientific personnel in the R&D sector, and other measures to promote scientific excellence in research and industrial development.

The programme aspires to implement strategic measures to encourage high-risk R&D and radical innovations. Relevant measures may include weighting the level of innovation of industry-oriented projects particularly heavily when assessing grant applications, at least in certain segments of the portfolio. The allocation of targeted funding for high-risk R&D in Researcher Projects and Knowledge-building Projects is another possibility. The aim is to create fruitful conditions for the knowledge-based industrial sector of the future and to challenge the international knowledge front methodically and scientifically.

Responsible technology development
Knowledge and technology must be built and used in a responsible manner. The programme will follow the EU's *Code of Conduct for Responsible Nanoscience and Nanotechnologies Research*, which provides a set of guidelines to ensure socially responsible technology development, with importance attached to risk and uncertainty aspects, among other things. The challenge lies in deriving maximum positive benefits for society from the technology while staying focused on potential, unintended negative impacts and risks posed by that same technology to the working environment related to production, to applications in society, and to the individual. The

NANO2021 programme will therefore attach greater importance than the NANOMAT programme to research on health-related, environmental and social issues relating to the development and application of nanotechnology. Research on the health outcomes and ecotoxicological impacts of nanomaterials will be given priority, along with responsible technology development. The programme will furthermore promote broad-based public dialogue on research and technology development, for example by establishing a meeting-place where companies and investors can meet.

Social development today is characterised by rapid-pace change on a large scale, also in the technology sphere. The programme will employ humanities and social science-based research to address technology and industrial development in broad terms. The programme will also generate knowledge-based risk assessments in a wide social perspective. All technologies may have intended and unintended impacts. In reality these impacts arise from a tremendously complex interaction between technology, human beings and the natural surroundings. This is a challenge for risk research, for which new and improved methods are being developed.

Internationalisation
The programme will work to enhance the internationalisation of Norwegian research in the technology sphere by encouraging international participation in research projects and by participating in transnational programme cooperation in keeping with the Research Council of Norway's strategy on international cooperation. The programme will also work to advance the main priorities of the EU framework programmes and related activities.

Recruitment to new and existing industry and to research and development
Access to widely knowledgeable new, younger candidates is vital to the development of established trade and industry and the cultivation of innovative, knowledge-intensive industry. Knowledge of the international research front and the ability to think along new lines are key factors when recruiting candidates to industry. Adequate recruitment is critical if the programme is to succeed in achieving its vision.

4.3 Thematic priorities

The NANO2021 programme is built on the three pillars illustrated in Figure 1, and has the five following thematic priority areas:

Thematic priority area 1: NanoVT and advanced materials for applications in the energy sphere.
Thematic priority area 2: NanoVT and advanced materials for reducing environmental and climate impacts.
Thematic priority area 3: NanoVT and advanced materials for improving health and new medical technology.
Thematic priority area 4: NanoVT and advanced materials for increasing value creation based on natural resources.
Thematic priority area 5: Knowledge about different impacts of nanomaterials on human health and ecosystems.

Funding announcements targeting other thematic areas may also be issued if this is deemed expedient to achieving the programme's objectives. In such cases, this will be clearly specified in the funding announcement.

Please refer to Attachment 2 for detailed descriptions of the five thematic priority areas.

Implementation
It is up to the NANO2021 programme board to determine the scientific and thematic priorities of the programme at any given time. These will be specified in the funding announcements issued under the programme.

A midterm evaluation is scheduled for 2016 to assess the programme's preliminary results in relation to its objectives, expectations and budget as well as the effect of the interplay between the three pillars in Figure 1. Performance indicators will be developed to make the benefit and relevance of the programme visible and concrete.

5 International cooperation

Successful international research cooperation is a key to achieving the NANO2021 programme's objectives. It is vital that Norway has research groups that measure up to international standards and are viewed as attractive partners for cooperation with the capacity to take on leadership roles in international research activities. Increasing the visibility and attractiveness of Norwegian research and value creation is also important, as it will enable Norway to bring home a larger share of global knowledge production, bring internationally leading researchers and global knowledge-based industry to the country, and ensure market access and increased competitiveness for Norwegian companies.

The programme will follow up the Research Council of Norway's strategy on international cooperation, which emphasises that it is the responsibility of the programmes themselves to implement operative measures that promote the internationalisation of Norwegian R&D within their respective areas of responsibility.

When allocating project funding, importance will be attached to the incorporation of international cooperation that boosts project quality. Advances in the technology area take place at a rapid pace, and most breakthroughs will occur in the international arena. Norway must therefore be well positioned to recognise new opportunities and must have an extensive international network. To this end, the programme will:

- provide funding for Norwegian participation in the M-era.Net and the ERA-NET EuroNanoMed II;
- provide funding for a Joint Technology Initiative (JTI) on nanoelectronics under the ENIAC Joint Undertaking;
- participate in bilateral funding announcements with countries in Europe and North America and India, China and Japan, when this is important for solving common challenges or for strengthening Norwegian research and knowledge-based trade and industry;
- provide funding for Norwegian follow-up research in connection with participation in large-scale international facilities, such as neutron and synchrotron research facilities.

Above and beyond these concrete measures, the programme will closely follow the dynamic developments within the EU, including the evolution of the *Horizon 2020* framework programme and related activities. Many of the NANO2021 programme's objectives harmonise with planned focus areas for *Horizon 2020*, such as the development of outstanding science, academic and industrial leadership and solutions to societal challenges. There will be an ongoing assessment of the need to develop programme-specific stimulation measures to help Norwegian researchers, companies and research institutions to become active participants in international cooperative and competitive arenas, for example by increasing the mobility of researchers and fellowship-holders in the international arena vis-à-vis the EU, North America, India, China and Japan. In this context it will be equally important to encourage optimal use of existing EU-related funding instruments such as the *Eurostars Programme*, *Marie Curie Actions* and *JTIs*. The NANO2021 programme will help to equip more Norwegian researchers in relevant subject areas with what they need to successfully apply for *European Research Council* (*ERC) Starting Grants* and *Advanced Investigators Grants*, which are the EU's funding instruments to promote high-calibre research in Europe.

The programme will also be open to research cooperation with countries that primarily focus on developing knowledge and implementing solutions to address issues in the Third World, such as water purification and development of mobile and low-cost solutions for renewable energy.

6 Communication and dissemination activities

The programme will primarily employ communication measures targeted towards its users, i.e. current and potential applicants from the academic community and trade and industry. Measures will be linked to funding announcements and special funding opportunities and will be designed to advance the achievement of the programme's objectives.

The programme administration will collaborate with communication officers at the Research Council on developing supplementary communication measures to ensure that the programme's activities are part of an integrated communication effort in the area of nanotechnology, microtechnology and advanced materials.

The list below outlines some important measures and target groups that are part of the Research Council's integrated communication activities in the technology area. Specific measures will be set out in the relevant communication plans, which will indicate which measures will be administered by the programme, which by the Research Council and which by external partners.

- Launch communication activities to inform research environments about the programme's focus areas and priorities.
- Launch communication activities targeting trade and industry and the health sector to promote broad-based mobilisation of these players in connection with the programme's activities.
- Improve communication between the various players in the innovation system in the programme's subject areas.
- Develop communication activities about the programme's overall subject field for investors and investor environments.
- Create meeting-places, such as scientific conferences and events for the business sector.
- Provide information targeting the general public and focusing on application of technologies via implementation of research results.
- Launch communication activities to promote dialogue between the research community and society at large on developments in the technology sphere.
- Launch communication activities targeting children and young people in particular to promote recruitment to the subject field and disseminate information about research as a career path.
- Launch communication activities targeting international research environments in particular to enhance the reputation and attractiveness of the Norwegian nanotechnology community.
- Design and use visual communication platforms and social media in communication activities.

7 Budget

The NANO2021 programme was launched as a large-scale programme in 2012 and is scheduled to run through 2021. As from 2011, the programme will be funded by allocations from the Ministry of Education and Research, the Ministry of Trade and Industry, and the separate budget item from the Ministry of Education and Research (which has replaced allocations from the yield of the former Fund for Research and Innovation). The programme has a budget of NOK 92.1 million for 2012. Given zero growth, the annual budget for the period 2013-2021 is stipulated to be NOK 92.1 million.

Zero-growth budget

Income	**2012**	**2013**	**2114**	**2015**	**2016**	**2017-2021**	**TOTAL**
Ministry of Education & Research	37 650	37 650	37 650	37 650	37 650	188 250	376 500
Ministry of Trade & Industry	36 900	36 900	36 900	36 900	36 900	184 500	399 000
Separate budget item, Ministry of Education & Research	17 500	17 500	17 500	17 500	17 500	87 500	175 000
Total	**92 050**	**92 050**	**92 050**	**92 050**	**92 050**	**460 250**	**923 000**

R&D groups must be in continuous activity if the programme's objectives are to be achieved. Funding announcements are planned issued on a regular basis – either by the programme alone or as part of participation under transnational joint programmes. The budget-related and scientific guidelines for allocation of project funding will be specified in the funding announcements.

8 Coordination with other related instruments at the Research Council

Nanotechnology and new materials are generic and enabling technologies; cf. the EU definition of *Key Enabling Technologies*. The Research Council allocates funding to research of high relevance to nanotechnology, microtechnology and advanced materials under a number of thematic programmes and activities (see Figure 2). The main focus of these projects will be on application of the technology in relation to the respective programme's objectives. The NANO2021 programme will have a broader focus on technology development itself. The dividing lines between the NANO2021 programme and other programmes and activities will be made clear to applicants seeking funding.

The programme will assess the need to expand cooperation with the programmes and activities shown in Figure 2 on an ongoing basis. Such cooperation may take the form of, for example, common meeting-places, joint communication activities and, in certain cases, joint funding announcements. The role of the NANO2021 programme will also need to be clarified vis-à-vis 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.

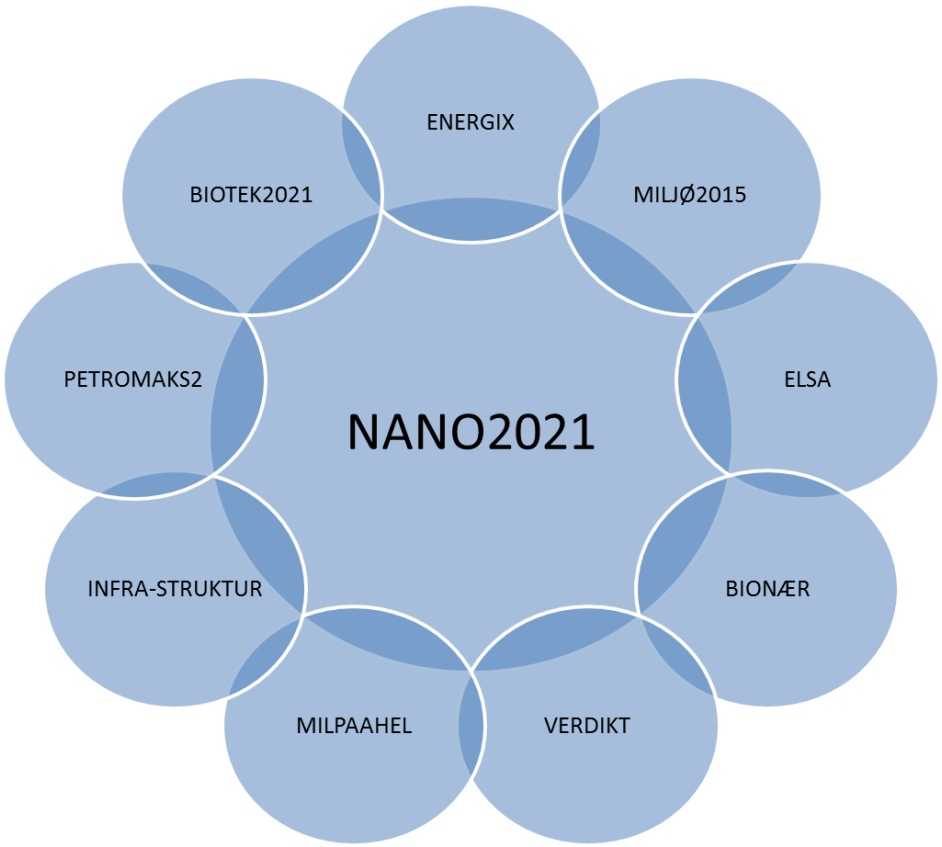


Figure 2. *Selected programmes at the Research Council that share a scientific interface with the NANO2021 programme.*

9 Coordination with other national instruments

The programme seeks to promote dynamic industrial development in areas in which nanotechnology, microtechnology and advanced materials can be utilised. Achieving this aim will require better coordination between the actors in the research and innovation system, including the public agencies (Innovation Norway, SIVA and the Research Council), the government-funded investment company Investinor AS, regional innovation players and investors.

The programme will consider whether to establish ties to existing industrial clusters or to support the development of new clusters within its thematic priority areas. In its dealings with industrial clusters, the programme will attach importance to collaborating with the players in the clusters themselves as well as with Innovation Norway, which administers cluster programmes. A potential tool for developing this type of activity would be to organise annual events for the business sector organised in cooperation with existing clusters. This type of joint event is very effective for bringing together many players in the innovation system, such as the regional innovation players, investors and representatives of the SIVA system of knowledge parks affiliated with regional university colleges and business incubators affiliated with universities and research institutions.

The Norway Centres of Expertise (NCE) and Arena programmes work actively to build knowledge, and not least to put new knowledge to use. The NANO2021 programme will look at opportunities for cooperating with and establishing links to these programmes.

The involvement of the finance sector is crucial to successful industrial development in the field of nanotechnology. Competent investors are essential. To this end, the programme may employ measures to promote knowledge-building among both public and private investors, such as hosting an annual nanotechnology day featuring presentations of Norwegian companies and market-oriented research groups that utilise nanotechnology.

In order to safeguard the long-term relevance and value of the knowledge developed under the large-scale programmes, it is vital to maintain a constructive dialogue with the leadership of universities and university colleges to ensure that the national priorities are incorporated in the institutions' overall funding systems as well. This is a challenging task that will be given special attention in the design and implementation the NANO2021 programme.

10 Organisation

The programme board for the NANO2021 programme is appointed by and reports to the Research Board of the Division for Innovation. The programme board is charged with administering the programme's activities to achieve the programme's objectives. This is to be carried out in accordance with the intentions and objectives of the Research Council's overall strategy, the guidelines from the Council's Executive Board and the Research Board of the Division for Innovation and the approved work programme. The programme board's activities shall at all times be in compliance with the overall principles and guidelines for the establishment, operation and conclusion of research programmes as set out by the Research Council.

The programme board acts on behalf of the Research Council and reports to the Research Board via the Executive Director.

The programme administration of the NANO2021 programme is responsible for carrying out the day-to-day tasks of the programme and 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 the programme board and facilitates the implementation of the programme board's decisions.

Application types
The programme will employ Research Council application types that extend across the entire value chain, including Researcher Projects, Knowledge-building Projects for Industry and Innovation Projects for the Industrial Sector. The programme may also choose to employ other Research Council funding instruments that are suitable for achieving its objectives.

Application assessment process
Grant proposals for Researcher Projects and Knowledge-building Projects are normally assessed by international referee panels that convene together at a meeting to assess the proposals in accordance with Research Council guidelines. Grant proposals for Innovation Projects are assessed by panels comprised of Norwegian and/or international referees. When assessing grant proposals, consideration is given to their scientific merit, relevance relative to the call for proposals and the programme's primary and secondary objectives, relevance and benefit to society, the public administration and industry, and the programme's portfolio of ongoing projects.

New measures and work forms
As part of the effort to encourage high-risk R&D, radical innovations and socially responsible technology development, among other things, new work forms may be introduced on a trial basis in funding announcements, application processing and project follow-up.

The programme administration submits recommendations regarding project funding to the NANO2021 programme board, which is responsible for final approval of grant allocations.

11 Attachments to the work programme

Attachment 1 – Description of the secondary objectives
Attachment 2 – Description of the thematic priority areas
Attachment 3 – Delimitation of the programme, selected terms and definitions

Attachment 1 – Description of the secondary objectives

Secondary objective 1 To enable selected Norwegian R&D groups to achieve a position in the international forefront.

Challenges

As of 2012, relatively few Norwegian research groups in nanoscience, nanotechnology and advanced materials rank among the international leaders in their field. The programme will work to assist a greater number of Norwegian researchers and research groups in taking the step up into internationally leading positions within their area of nanoscience, nanotechnology or advanced materials.

Targets

- Three to five R&D groups will be ranked as world-class in 2021.

An R&D group must satisfy most of the following criteria to be deemed world-class:

- The group must publish in the most prestigious scientific journals in its research area.
- The director(s) of the group must be invited on a regular basis to be keynote speakers at the most important international conferences in the group's research area.
- The group must be well-recognised in internationally-leading academic communities, thereby attracting the most talented younger researchers and post-doctoral candidates from these communities.
- Internationally-leading academic institutions and research-heavy companies must consider the group an important recruitment pool.
- The group must be well-known and viewed as an attractive partner for cooperation by international research-heavy companies in its research area.
- The group must be of sufficient calibre to qualify for prestigious prizes and grants such as the Kavli Prize and ERC grants, etc. in its research area.
- Top researchers in the group must be offered guest professorships at internationally-leading academic institutions.

Secondary objective 2 To promote scientific development, renewal and quality by seeking out talented candidates, increasing mobility and boosting internationalisation.

Challenges

The main challenges are to facilitate – and be a driving force behind – the participation of Norwegian research groups (from universities/university colleges, independent research institutes and trade and industry) in international research cooperation and close contacts with relevant international partners.

Targets

- At least two-thirds of the publications under the programme will be published in level 2 scientific journals (according to the ranking by the Norwegian Association of Higher Education Institutions (UHR)).
- Fellowship-holders will be encouraged to conduct a research stay abroad during their fellowship period.

- At least 30 per cent of publications under the programme will comprise international co-authorship.
- The programme will participate in two ERA-NETs (M-era and EuroNanoMed II) and provide funding for at least two Norwegian projects under each joint call issued by these ERA-NETs.
- At least 5 per cent of the total budget will used for direct bilateral funding announcements between Norway and selected countries.
- National mobility will be encouraged to increase mobility between R&D institutions and between R&D institutions and trade and industry.
- At least 20 per cent of the portfolio of Innovation Projects for the Industrial Sector will address radical innovations with appurtenant high risk and major market potential.

Secondary objective 3 To enhance national value creation through the renewal of products, processes and services.

Challenges

Nanotechnology and advanced materials are enabling technologies with great potential for application in many areas. The programme seeks to encourage established industry and entities in the public sector (e.g. the hospital trusts) to develop and implement these technologies to optimise their activities, thereby achieving innovation and increased value creation.

Targets

- At least 200 new methods, models and prototypes.
- At least 100 patents and patent applications.
- At least 60 new products and processes.
- At least 20 licences.
- At least 10 new business areas.
- At least 10 new companies.

Secondary objective 4 To promote the development of sustainable technology to be applied in a safe, responsible manner.

Challenges

The programme will follow the EU's *Code of Conduct for Responsible Nanoscience and Nanotechnologies Research* to ensure that new research and development activities in the field of nanoscience and nanotechnology are based on well-reasoned, defensible ethical and environmental principles and are safe for human health and the environment.

The programme will work to ensure that all projects obtain a broad understanding of the close links between environmental, ethical and social aspects of sustainable technology development. Such understanding may be achieved, for example, by encouraging participation in and design of integrated research projects in which interdisciplinary research teams address the various aspects of significance for sustainable development.

Targets

- All projects will incorporate reflections on socially responsible choices of and solutions for knowledge production, technology development, implementation and use.
- Platforms will be established where project managers and other researchers can exchange thoughts on socially responsible implementation of technology and sustainable technology development in relation to their own projects. The aim is to develop a best practice model for integrated projects in the field of nanoVT and advanced materials.
- At least 5 per cent of the programme's disposable budget will be allocated to projects that deal with ethical, legal and social aspects (ELSA) and incorporate humanities and social science-based research.
- At least 10 per cent of the programme's disposable budget – distributed among all of the project types – will be allocated to projects that build knowledge about the properties and different impacts of nanomaterials on human health and/or ecosystems to ensure that these materials are used safely and responsibly.

Secondary objective 5 To facilitate the optimal utilisation of national expertise, R&D resources and infrastructure through cooperation, constructive task distribution and highly focused research activities.

Challenges

Research on nanoVT and advanced materials is very resource-intensive in many ways, in terms of what is needed in the way of researchers and access to advanced scientific equipment. In the past decade, the Norwegian research system has developed various forms of national cooperation, constructive task distribution and highly focused research activities. The programme will continue to develop these by mobilising new R&D groups to take part in national cooperation, among other things.

Targets

- Priority will be given to R&D groups that are strong as of 2012, while mobilising new players in the field.
- At least 25 per cent of the total budget will be allocated to nationally-coordinated projects.
- Collaborative projects between institutions and between institutions and companies will be given priority; at least 25 per cent of all Researcher Projects will have partners from several institutions.
- Radical interdisciplinarity, i.e. collaboration on projects between researchers from disciplines that do not traditionally work together, will be encouraged in selected funding announcements.
- All Knowledge-building Projects for Industry will involve the participation of at least two companies.
- Priority will be given to research that makes good use of national investments in infrastructure.

Secondary objective 6 To increase the attractiveness of Norwegian research environments to encourage knowledge-intensive companies in a global market to establish R&D activities in Norway.

Challenges

Knowledge-based industries generally compete on the international market, and seek out relevant, competitive R&D expertise wherever it may be found globally.

Targets

- The programme will establish contact with relevant industrial clusters and when appropriate contribute to the development of new clusters within the programme's thematic priority areas.
- The programme will work to create new arenas for cooperation between trade and industry, the research community, actors within the research and innovation system and investors.
- The programme will help to motivate Norwegian companies to incorporate Norwegian R&D groups into their international activities, thereby making Norwegian R&D groups internationally competitive and attractive.
- The programme will cultivate outstanding research groups to attract international companies and inspire them to establish activities in Norway.

Secondary objective 7 To promote social dialogue on nanotechnology and create new meeting-places.

Challenges

One of the programme's main challenges is to reach out to players representing the wider general public (citizens and civil society). Experience has shown that this is a difficult task, particularly because society itself is evolving rapidly and new challenges associated with the social media are emerging in the media sphere. This calls for creative thinking around social dialogue and use of new media. It also necessitates a certain amount of cooperation with players specialising in social dialogue, such as the Norwegian Board of Technology.

Targets

- To organise at least one national meeting-place/conference/seminar each year.
- To set aside funding for at least one meeting each year where representatives of R&D environments and other interest groups can meet to discuss the ramifications of nanotechnology for society at large.
- To publish at least two pieces in the national media each year on the role of nanotechnology in society.
- To use new media for dissemination and communication activities.
- To implement measures to involve citizens and civil society in technology development.

Additional communication targets will be specified in the communication plans.

Attachment 2 – Description of the thematic priority areas

Thematic priority area 1 NanoVT and advanced materials for applications in the energy sphere.

Challenges

Secure access to energy is a global challenge. Energy from environment-friendly and renewable sources comprises only a relatively small share of total energy consumption. The development of new energy technologies is crucial if a larger proportion of the global population is to have secure access to energy and if the UN climate targets are to be met and the rise in global temperatures controlled.

Priorities for the NANO2021 programme

Norway has built up significant expertise in environment-friendly energy in recent years, with the use of nanoVT and advanced materials as enabling technologies. This area is characterised by highly focused research activities, for example the Centres for Environment-friendly Energy Research (FME) scheme, and a large number of spin-off companies. Established industry is also investing heavily in environment-friendly energy. The programme will enhance and build on national know-how and promote research of high international calibre. The programme will also work to achieve innovation and value creation in the energy sphere, placing priority on:

- energy production from renewable sources;
- energy storage and production/transport;
- raising energy efficiency.

Thematic priority area 2 NanoVT and advanced materials for reducing environmental and climate impacts.

Challenges

Reducing emissions of greenhouse gases will not, in all likelihood, be possible without the development of new technology, such as cleaning and capture technology. At the same time, the dispersal of environmentally hazardous substances is becoming more widespread, which may have major environmental impacts locally and globally. NanoVT and advanced materials may be part of the "problem" in this respect, as nanomaterials may have unintended negative impacts on the indoor and external environments.

Priorities for the NANO2021 programme

The programme will further develop existing national expertise and encourage increased use of nanoVT and advanced materials by R&D institutions and industry in this area. Environmental technology comprises all technologies that directly or indirectly improve the state of the environment. The programme will give priority to technologies that limit pollution with the help of cleaning technology, more environmentally sound products and production processes, more effective resource management and innovative solutions that reduce undesirable environmental impacts.

Thematic priority area 3 NanoVT and advanced materials for improving health and new medical technology.

Challenges

Improving health is a major global challenge. In Western countries, research questions are linked to new methods of treatment and monitoring. Welfare technology is another topic of focus. The global population is ageing at an increasingly rapid pace, which places a tremendous burden on the entire health sector and society at large. In many parts of the world, health-related research questions concern the implementation of known technology to cure widespread diseases. Access to clean water, for example, is an important issue in this context.

Priorities for the NANO2021 programme

The programme seeks to develop knowledge and solutions to improve health, including medical equipment, health diagnostics, patient monitoring, treatment, sensors, biomaterials and tissue engineering. A key area of focus is the integration of nanoVT and advanced materials into biotechnological and biomedical research. Another key area is the development of new medical equipment and treatment methods to keep the ageing population healthier longer in a socio-economically sustainable manner. The programme will attach importance to research on the safe use of nanotechnology and nanomaterials in medical applications.

Thematic priority area 4 NanoVT and advanced materials for increasing value creation based on natural resources.

Challenges

Improved utilisation of natural resources is an essential component of value creation, nationally and globally. At the same time, certain raw materials are being aggressively extracted. Provided that we can achieve sustainable extraction of natural resources and utilise renewable natural resources in a more sustainable way, the natural environment will continue to be a source of inspiration and value creation for generations to come.

Priorities for the NANO2021 programme

The programme will give priority to building and refining knowledge for use by existing industry in Norway, such as knowledge related to material durability under extreme conditions and more efficient resource utilisation. This will entail giving priority to developing nanotechnology as a tool for expanding established branches of industry, such as the oil and gas sector, the bioeconomy sector, the marine sector and the mineral recovery industry.

Thematic priority area 5 Knowledge about different impacts of nanomaterials on human health and ecosystems.

Challenges

NanoVT and advanced materials offer tremendous enabling potential in a wide range of applications. There is, however, growing concern about potential unintended impacts of nanomaterials, particularly with regard to the effects of functionalisation. The uncertainty surrounding the environmental impacts of nanomaterials will be an obstacle to dynamic innovation and industrial development. Balancing efforts to maximise the technology's positive contribution to society's needs and efforts to minimise potential unintended negative impacts on the individual and society at large (with regard to human health and ecosystems) is a major challenge. Thus there is a need to step up the level of research activity focusing on potential environmental impacts of nanomaterials, including research on existing nanomaterials. Risk related to the application of nanomaterials is a complex concept that encompasses factors such as toxicity and exposure. It is therefore vital to develop knowledge about the potential toxicity of nanomaterials and view this in relation to the danger of exposure.

Priorities for the NANO2021 programme

The programme attaches priority to generating new knowledge about issues relating to health, safety and the environment, to provide greater insight into potential health hazards and preventive measures in connection with the production, use and application of nanomaterials in end-products or as components in other products or processes. There is also a great need to improve understanding of risk and potential impacts on the indoor and external environments and to develop instruments, methods of measurement and other methods for quantifying and tracing nanomaterials. This will involve:

- developing analytical methods of mapping, tracing and characterising nanomaterials in living organisms;
- mapping risk relating to nanomaterials by acquiring new knowledge about their potential toxicity and viewing this in light of the danger of exposure and potential cocktail effects;
- obtaining new knowledge about consumer perspectives on nanoproducts, for example as a basis for future regulations.

Attachment 3 – Delimitation of the programme, selected terms and definitions

The programme's area of activity is limited to nanoscience, nanotechnology, microtechnology and advanced materials. Definitions of these terms as they are employed in the context of the programme are given below. In many cases, it will not be possible to classify research unambiguously in relation to these categories. Nevertheless, the definitions will provide a general framework for the programme's priorities. Additional requirements and guidelines will be specified in the individual funding announcements.

Nanoscience
Nanoscience is the science of understanding, controlling and exploiting the unique physical, chemical and biological properties specific to structures at the nanoscale.

Nanotechnology
Nanotechnology is a collective term for the set of technologies that can be defined as techniques for synthesis and processing, including moving and building, using nature's own building blocks (atoms, molecules or macromolecules) for the intelligent design and modelling of functional and structural materials, components and systems with attractive qualities and functions, and where dimensions and tolerances ranging from 0.1 to 100 nanometres (nm) play a decisive role.

Microtechnology
Microtechnology comprises techniques for synthesis and processing of materials. Like nanotechnology, microtechnology is an enabling technology.

Advanced materials
Advanced materials are materials with specific, potentially applicable chemical, biological or physical properties. These include electrical, mechanical, photovoltaic, magnetic, thermal and optical properties, as well as energy storage and optimal in vivo interaction properties.

There is no exact distinction between advanced materials and more conventional materials. A particular feature of advanced materials is that they can be used to design entirely new products, for example in areas such as data technology, telecommunications, renewable energy, intelligent sensors, environmental technology, targeted drug delivery, implants and medical equipment.

Advanced materials may also be used to enhance the properties of existing products and processes. Structural materials are *not* included under the definition of advanced materials unless nanotechnology has been used to develop novel or significantly improve existing material properties.

Other materials whose properties are deliberately manipulated with the use of nanotechnology fall under the definition of nanotechnology.

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