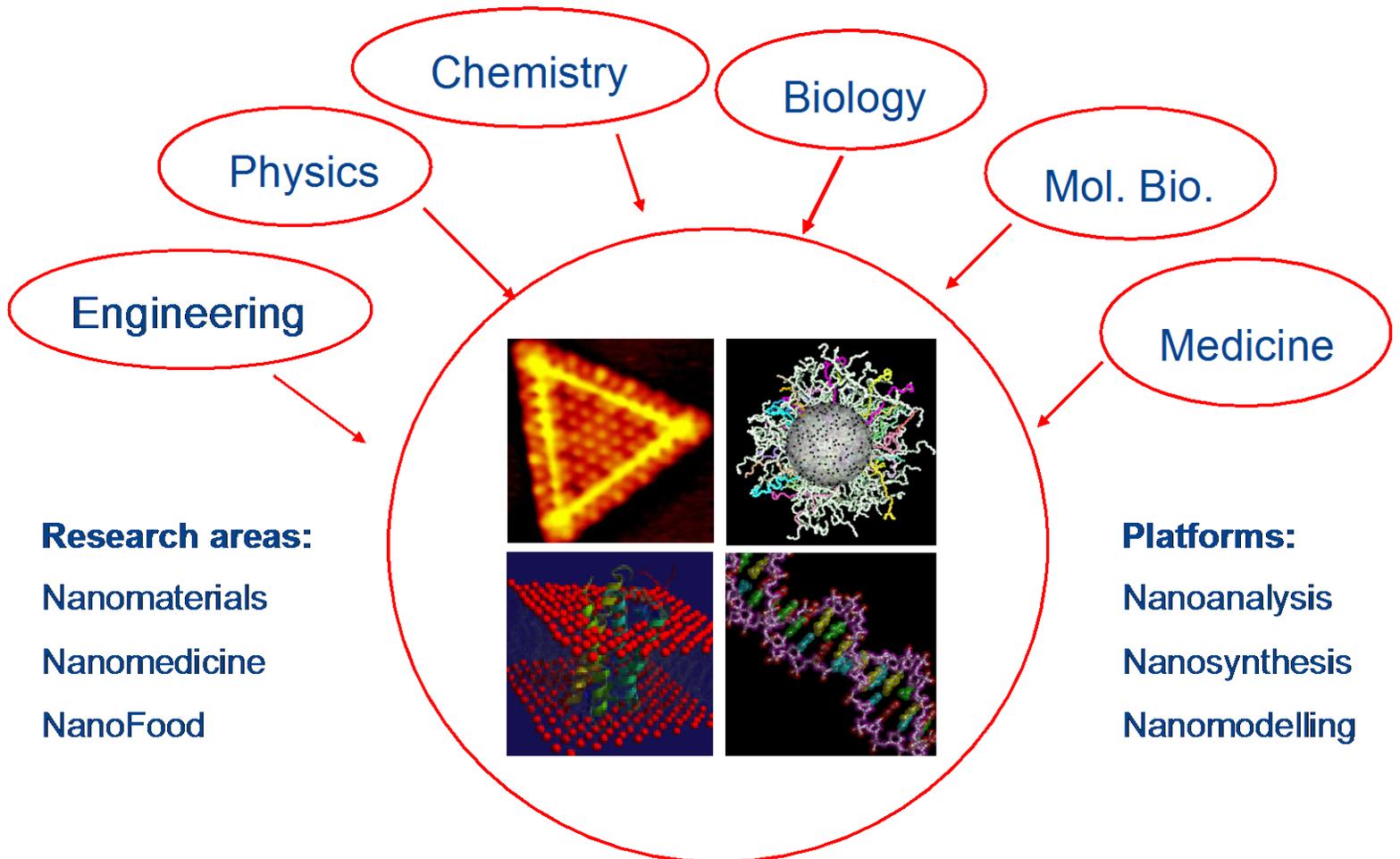


iNANO strategy 2016-2020



Strategy report – iNANO

1. Foreword

This strategy report is the result of a process involving all members of the iNANO associated faculty staff. A first draft was produced by the iNANO management team and various heads of committees including head of the educational committee, Associate Prof. Trolle R. Linderoth and head of the business committee Prof. Kim Daasbjerg. The draft was subsequently discussed with the members of a number of iNANO committees including the Research and Education committees. Also, an overview of the strategy was given at an iNANO staff meeting on 4 December 2015.

The overall strategic goal is to maintain iNANO's position as an internationally recognized nanoscience center and to build on this base to become an even larger contributor to the advancement of excellent basic science, internationalized education, and applied projects, which meet the needs of the society and the industry in particular. These three pillars are mutually dependent and synergetic, so running all three in the same organization is a major strength of iNANO.

2. Vision, Mission and executive summary

Vision for iNANO:

Through excellent research, education, and innovation to contribute to solving the Grand Challenges of our time.

The mission for iNANO is based on the following three equally important pillars:

1. To conduct excellent interdisciplinary research in nanoscience and nanotechnology in collaboration with the strongest national and international research groups in this area.
2. To play a key role in the education of the next generation of scientists in nanoscience at the BSc, MSc, PhD, and postdoctoral levels.
3. To provide an innovative interface for transfer and transformation of basic scientific knowledge to Danish industry and society.

Executive summary:

iNANO aims at being among the top-10 league of nanoscience centres in the world in terms of research. To ensure such a position, we will make more strategic recruitments of Professors and Associate Professors, enhance our research momentum through increased attraction of funding from Danish and European research foundations (public and private), participate in an increasing number of international research projects, form deep alliances with nanoscience centres at high-profile institutions, improve instrumental facilities/infrastructures to perform unique interdisciplinary research and attract young talented researchers to iNANO, establish stronger formalized ties with Danish Industry, encourage iNANO scientists to launch interdisciplinary collaborations on key strategic research areas and, finally, increased the quality of research to increase the ratio of publication in high-impact journals. To focus our research, we have established groupings within three key strategic research areas (nanomaterials, nanomedicine, and nanofood) that will be prioritized in our guidance of researchers and allocations of resources. All these strategic areas can exploit the three unique iNANO infrastructure platforms (nanosynthesis, nanoanalysis, and nanomodelling). These focus areas, each of which contain many separate research themes, have been defined based on their interdisciplinary and potential to

contribute to meeting the Grand Challenges of our time. At the educational level iNANO will continue to educate highly-qualified PhDs and Master's students for the benefit of Danish Society and industry at large. We will implement new educational tools to improve learning and continue our personal guidance of students to meet more restricted rules for the completion of courses. Also, we will continue to internationalize our students at all levels by promoting increased student uptake and facilitate student exchange through the alignment of nanoscience educations with, e.g. European, American and Chinese partners.

In September 2012, the iNANO House was commissioned, and it has brought with it unique opportunities for closer interaction between key iNANO research groups and strongly supports the momentum of external collaborations. To that end, it is our intention to continue the strong fundraising and integrative research activities of iNANO in collaboration with its partnering departments to create a win-win situation from the already proven concept that *the success of iNANO is a success for its partners*.

3. Organization and physical facilities/surroundings

Thirteen years after its inauguration, iNANO has successfully been established as a collaborative interdisciplinary research center at Aarhus University, allowing for successful completion of research, which would not be possible without different fields of expertise joining forces and strong support from the Faculty and the University. Within the last 13 years, iNANO has attracted more than MDKK 1400 in external funding and publishes more than 350 papers per year, close to 15% of all publications from Science and Technology (appendix I2). iNANO has fuelled many industrial research collaborations, and importantly iNANO carries two well-run and highly recognized educational schools, undergraduate studies on the BSc and MSc levels and PhD education with currently around 130 PhD students enrolled in the iNANOschool graduate program.

iNANO is an interdisciplinary research center based on shared personnel, laboratories, and projects with a number of partnering departments at Science and Technology (including Department of Physics and Astronomy, Department of Chemistry, Department of Molecular Biology and Genetics, Department of Biosciences, Department of Engineering, and Department of Mathematics) and several departments at Health.

Organization: The daily management of iNANO is carried out by the Director of iNANO supported by a small administrative unit (4 administrators and 2 scientific coordinators) in close interaction with the iNANO Management Team (see appendix A). The Management Team consists of, besides the Director, three senior scientists representing the core scientific fields of iNANO, the Vice-director and the Head of Secretariat. The team meets every second week to discuss issues of strategic relevance including employments, financial affairs, the overall strategy and the implementation hereof, etc. The Director reports to an Advisory Board, consisting of the involved Deans at Aarhus University and Aalborg University, and representatives from leading Danish industrial companies, such as Haldor Topsøe, Arla, Grundfos, and others. The Management Team interacts closely with the iNANO Research Committee (comprised of leading senior researchers within iNANO's strategic research areas), as well as a number of other committees coordinating iNANO's efforts in BSc, MSc, and PhD level teaching, industry and seminar related activities, as well as, safety and work-related issues. Strategic research areas have been selected according to current strategic priorities and core competences of participating research groups and iNANO's many industrial partners.

Personnel: The research, education, and innovation activities of iNANO are carried out by personnel, who are employed either at the partnering departments or at iNANO. The former group includes 17

professors, 16 assoc. professors, 5 assistant professors and 7 technical staff, while the latter includes 1 professor, 10 assoc. professors, 6 assist. professors and 5 technical staff (see appendices C1, C2 & C3), who also contribute to activities at the partnering departments. In addition, a steadily growing number of postdocs are associated with iNANO (see appendix C5). The iNANO administration consists of a head of secretariat, three secretaries to handle central elements of the iNANO operation, as well as two scientific coordinators responsible for fundraising, project management, and outreach activities.

It is of utmost importance for iNANO to keep a balance between the number of associated professors, in particular between the three main areas, Physics, Chemistry, and Molecular biology/Biology, and to ensure that associated and employed staff located outside of the iNANO House feel as much as an integrated part of iNANO as those located physically within the house.

Major centres: iNANO members are heading 5 centres of excellence, a Lundbeck Centre and an EU network:

Centre for Membrane Pumps in Cells and Disease – PUMPKIN - with the focus to analyse the structure and function of pumps that are found in all cells of all plants and animals and accordingly investigate how the pumps work,

Centre for Insoluble Protein Structures iNSPIN, with the mission to develop and apply new methods for analysis of proteins in insoluble biological structures, including membrane proteins, fibrillating proteins, and extracellular matrix proteins,

Centre for DNA Nanotechnology - CDNA – which is dedicated to exploring DNA as a programmable tool for assembling molecules and materials,

Centre for Materials Crystallography - CMC - a centre for fundamental materials research, where strong competences within synthesis, characterisation and theoretic modelling are combined to a unique platform that can handle some of the great challenges in materials science.

Carbon Dioxide Activation Center – CADIAC – a center dedicated to the development of solutions for the conversion of carbon dioxide into valuable chemicals through the interface of homogeneous and heterogeneous catalysis.

Lundbeck Foundation Nanomedicine Centre for Individualized Management of Tissue Damage and Regeneration (LUNA) with the main objective to create nanomedicine based techniques and drugs for individualized prevention, diagnosis and treatment of cardiovascular and musculoskeletal diseases.

The European School of DNA Nanotechnology (EScoDNA) is an Initial Training Network (ITN) under the European Commission's Marie Curie Actions research within the 7th framework program.

Physical facilities/surroundings: To foster interdisciplinary research at the international forefront, iNANO has constantly expanded its activities in terms of personnel, infrastructure facilities, and laboratory space over the last 13 years, and in the fall of 2012 the long-awaited iNANO House was finally taken into commission. The iNANO House hosts excellent research groups from the departments of Physics and Astronomy, Chemistry, Engineering, and Molecular Biology and Genetics. About one third of the iNANO-associated groups are still housed at the departments owing to limited space in the iNANO house. The groups hosted in the house carry out research within the three strategic research areas of iNANO. The iNANO House strongly serves to facilitate and strengthen the synergies for interdisciplinary nanoscience education, research, and innovation activities. The iNANO building also houses a new 120 m² class-100 cleanroom, and a number of highly specialized laboratories with truly unique world-class equipment. The cleanroom research facility enables the fabrication of nanostructured materials and devices with state-of-the-art lithography resolution. The iNANO House also offers modern amenities to organic chemistry, protein chemistry, inorganic materials chemistry, and cultivation and analysis of cells and bacteria.

iNANO infrastructure: iNANO possesses some of the strongest infrastructure platforms in Northern European, providing optimal conditions for carrying out world-class research. The iNANO infrastructure platforms can be divided into three main platforms: nanocharacterization, nanosynthesis, and nanomodelling.

iNANO characterization: iNANO commands a wide variety of analytical instruments for the elucidation of nanostructures and functionalities at nanometer resolution and often at single molecule level. These include Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy (AFM), Small Angle X-ray Scattering spectroscopy (SAXS), various mass spectrometry equipment (including hybrid quadrupole time of flight and triple quadrupole mass spectrometer), X-ray photoelectron spectroscopy (XPS), high-field liquid- and solid-state nuclear magnetic resonance (NMR), high-field magnetic resonance imaging (MRI), electron microscopy (EM), cryo-electron microscopy (cryo-TEM), X-ray crystallography (XRD), mass spectrometry (MS), confocal laser scanning microscopy (CLSM), single molecule Förster resonance energy transfer (SM-FRET) microscope, IVIS *in vivo* fluorescence imaging and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS). A number of these instruments are unique in a Danish and Nordic context; as an example, the world-famous “Aarhus STM” was developed here, and the Cryo-TEM is the highest resolution instrument of its kind in the Nordic region. In the beginning of 2015 the Danish Center for Ultrahigh-Field NMR Spectroscopy was established as a national/Scandinavian Center with state-of-the-art NMR equipment for solid- and liquid-state NMR and micro-MRI, including Northern Europe’s largest (950 MHz/22.3 Tesla) NMR magnet.

iNANO synthesis: iNANO commands a variety of facilities for the synthesis of nanostructured/nanopatterned 0D (i.e. nanoparticle), 1D, 2D and 3D materials. These include high-end equipment for 3D printing and electrospinning, photo- and electron beam-lithography, organic synthesis, catalyst synthesis, nanoparticle synthesis (supercritical synthesis), solid-phase peptide synthesis, DNA and RNA synthesizer, bioreactors for large-scale protein expression, isotope labelling, and procedures for synthesis of functionalized nanoparticles for targeted drug delivery and bioimaging.

iNANO modelling: To complement analysis and form models for phenomena at the nanoscale, iNANO is currently working with modelling activities spanning from materials to biological macromolecules and from high-resolution structural models to 3D video animations. Such methods are highly valuable to obtain detailed insight into complex multicomponent systems for research as well as for education and outreach activities which rely heavily on visualization.

4. International position & strenghts

iNANO has one of the longest histories of any nanoscience center in the world. Through our many international contacts and numerous conference participations, iNANO has become a well-known brand, which is often referred to as a role model for interdisciplinary collaboration, both locally and internationally.

Research areas:

iNANO research can be divided into three key strategic research areas (nanomaterials, nanomedicine, and nanofood):

Nanomaterials: iNANO has many strong and expanding activities within chemical and physical surface modification, catalysis, nano-energy materials, semiconductor physics, nano-composites, self-assembled nanostructures, bio-mineralization, and fiber materials. Within several of these topics, iNANO is at the absolute forefront internationally, such as heterogeneous catalysis, self-assembled DNA nanostructures, novel construction materials, and thermoelectric materials. In the next five years iNANO will seek to

strengthen its activities within nanostructured and nanoporous materials, composite materials, and functional materials. In particular, in the field of energy and sustainable materials, iNANO runs a comprehensive research portfolio in both energy conversion (photovoltaics, thermoelectrics, biofuel conversion, catalysis, fuel cells) and energy storage (hydrogen, ion batteries). The research spans from the very fundamental (e.g. materials crystallography method development) to the applied (e.g. design of high-pressure containers for solid and gas-phase hydrogen storage). iNANO is thus already very active in the field, and is well positioned for further involvement in energy-related R&D, which is currently receiving increased public funding, nationally as well as in the EU. In terms of industrial collaboration, iNANO works closely with several companies on concrete projects. Companies include Haldor Topsøe, Grundfos, SP Group, TEGnology (an iNANO spin-out), Aalborg Portland, Unisense, FL Smidth.

Nanomedicine: This area is another iNANO stronghold with activities within drug delivery, diagnostics, bioimaging, synthetic organic nanochemistry, nanoscale topology/3D scaffolds/tissue engineering, biopolymers, biomimetic self-assembly, structural biology, stem cells, biosensors, implant surface modifications, anti-biofouling, antimicrobial peptides, drug administration, innate immunity, pharmaceutical technology, bio-microfluidics, membrane proteins, amyloid fibrils in relation to dementia and diabetes, micelles, biological fiber materials, active surfaces, polymers and -omics technologies (metabonomics, proteomics, lipidomics, transcriptomics, genomics and system biology analysis). Numerous links already exist to the AU Faculty of Health, collaborations, which we plan to cultivate in the future so as to increase the chances of translating the research into the clinic. Company contacts within this area include Novo Nordisk, Lundbeck, AstraZeneca, Novartis, StemMatters, Microsoft Research.

Nano food: This area includes research into enzyme encapsulation and immobilization strategies, biosensors, novel ingredients, protein digestive systems of animals and plants, milk protein biophysics, enzyme modelling, antifouling surfaces, antimicrobial compounds and encapsulation, oral microbiology, as well as nutrigenomics. iNANO seeks to markedly expand activities in this area to foster collaboration with new AU research groups as well as national and international key players in the area of nanoscience with relevance to food and nutrition. The research involves a high level of industry collaboration, as currently demonstrated by joint research programs with, e.g., Arla, Dupont, Coloplast, and Nestlé.

Knowledge/technology-transfer: iNANO runs extensive collaboration with Danish and international private and public companies and research institutions. During the last 13 years iNANO have been collaborating with more than 100 industrial companies. Another measure of societal impact is the number of patents filed, which for iNANO reaches 38 (see Appendix I5).

Finally, iNANO has spun out five SME start-up companies; InVitroQ ApS, CABRA ApS, Nanofence ApS, LevOss ApS, and SyTracks A/S. Earlier this year an iNANO Business Committee was established with the purpose of strengthening the ties to the industry. To facilitate contact with industry, an industrial office has been established in the iNANO building where our industrial partners can place employees for a period of time.

iNANO educational program:

The nanoscience Bachelors (BS) program offers a truly multidisciplinary selection of courses from physics, chemistry and molecular biology in combination with dedicated nanoscience courses. At the ensuing Master's (MS) program students specialize in nano-physics, nano-chemistry or molecular biology through individual course programs combining elective courses offered by iNANO and the

departments. Approximately 200 students are currently enrolled in the nanoscience BS or MS programs. The nanoscience BS program was started as an internationally truly unique initiative in 2002. Since its commencement 160 students have completed the combined BS and MS programs in nanoscience (per august 2015). The fraction of completed bachelor students who later become iNANO PhD students is as large as 45 %. The employment rate for completed Master's is close to 100% [~2 % unemployment for N=93 Master's from 2008 to 2011 according to "Dimensioneringsanalysen"].

Graduate school – iNANOschool:

With currently 130 PhD students enrolled, iNANOschool is a graduate school of international stature. A range of specialized graduate courses are offered alongside access to highly advanced research facilities. This combination makes iNANOschool a nexus of interdisciplinary competences in nanoscience and nanotechnology at the highest international level.

More than ten years after the establishment of iNANOschool, the main objectives remain the same. The major driving force is the education of highly qualified, internationally competitive PhDs with a broad range of interdisciplinary competences within nanoscience and nanotechnology. The research areas of iNANO and iNANOschool are highly integrated as well as truly interdisciplinary and cover diverse research fields.

Many of the PhD research projects involve more than one research group and in frequent cases also industrial research laboratories. Overall, the research activities are at the international forefront of science and serve as an ideal framework for education and industrial collaboration. In addition to research, iNANOschool offers several PhD courses within nanoscience and nanotechnology and provides access to facilities for and supervision of approximately 130 PhD students. During 2013-2014, 61 new PhD students were enrolled in iNANOschool and 74 PhD students completed their PhD studies.

In addition to the focused PhD courses, activities include a major annual meeting, an autumn school, student networks, and initiatives to promote exchange with international institutions.

5. Analysis of the center's strengths and weaknesses

SWOT analysis:

Based on the benchmarking results (*vide infra*) and our own analysis of iNANO's performance, we report here a so-called SWOT analysis mapping our assessment of iNANO's strengths, weaknesses, opportunities, and threats:

<p>Strengths:</p> <ul style="list-style-type: none"> • The iNANO building & a high degree of synergy and collaboration among the research groups • A unique research infrastructure platform • Interdisciplinary approach • Technological focus • Strong research environment • Highly motivated/large pool of BSc, MSc and PhD students • Strong industry collaboration • Excellent fundraising track record • Support by scientific coordinators • Young promising scientific staff 	<p>Weaknesses:</p> <ul style="list-style-type: none"> • Few links to EU industry • Physical spread of activities at different departments across S&T • Limited space in iNANO House for new groups • Low participation in EU network programmes • Limited recruitment opportunities • Difficult to recruit top international students • Faculty that does not speak Danish have difficulties teaching in the first years of the Bachelor's program • Bachelor course program with many compulsory courses offered by the Departments requires strong coordination during revision of programs • Multi-disciplinary breadth in course program is difficult for some students.
<p>Opportunities:</p> <ul style="list-style-type: none"> • Exploitation of a unique and complementary infrastructure platforms in research projects and for recruiting personal • Exchange programs with China (SDC and several other Centres) • Explore funding from a diverse set of sources • Synergies at department level • Establishment of strategic research areas • EU-Horizon2020 LEIT and societal challenges • Interdisciplinary high school programs – outreach – recruitment of students 	<p>Threats:</p> <ul style="list-style-type: none"> • Walkout of students to other studies • Increased control and management by the departments or faculty • Potential loss of administrative authority - High dependency on goodwill from departments • Project related expense model may lead to fewer iNANO-headed applications and PhD students • Reduced administrative and scientific support to researchers due to difficult financial situation • Lack of industry interest in scientists with a degree in nanoscience • Breaking up into new centers (energy, membranes, drug delivery, etc.) • Lack of space for new initiatives • Failing to meet balance in economy

6. Strategy and implementation

iNANO aims to maintain its position in the top 10 of nanoscience centres in the world in terms of research. To ensure such a position, we will continue our effort to improve our output in our three main focus areas: Research, Education and Innovation. To increase our chances of success, we have carefully selected key strategic focus areas based on the following criteria:

- Realistic advancement – which parameters are more easily improved using self-controlled measures.
- Key performance indicators (KPIs) should be measurable to monitor progress and should not bias activities in unintended ways.
- Most impact for least money/effort. We have limited human and financial resources so everything cannot happen at once –prioritizing is key.
- Selected focus areas must be aligned with staff preferences. Changes and establishment of new initiatives must be discussed and modified according to input from the staff.
- New initiatives should put a minimum of extra, or even diminish, administrative workload on group leaders.
- iNANO strategy should be aligned with strategies launched by ST and AU. The integrated structure of iNANO and the departments requires careful alignment of strategy to ensure synergy.
- Adaptation to changing funding environment, industrially/strategically relevant research and development.
- Balance between basic and strategic research. We must ensure a strong line of basic research to be competitive in the long term.

6.1 Increase external funding (ST KPI 1)

With declining basic financial support from AU and a costly infrastructure, iNANO is particularly sensitive to fluctuations in external funding. It is therefore imperative to maintain, or preferably improve, the current funding level. To reach this goal, we will marginally increase the number of submitted applications but significantly increase their quality. Importantly, this should happen with a minimal burden on the group leaders. We will prioritize the following initiatives:

a. Strengthen interdisciplinary research: iNANO is in a unique situation having many disciplines represented at the centre and often in the same building. The iNANO management team will encourage interaction and collaboration between iNANO groups by arranging lab visits and instruct selected groups at iNANO and other ST departments on new cross-discipline funding opportunities. The iNANO management team will monitor the collaboration propensity of the groups housed in the iNANO building and make that a parameter for a future reorganization of groups between the iNANO house and elsewhere.

b. Strengthen internationalization: Collaborations with world-class international groups have become a strong success criterion for most national funding and a requirement for EU funding. iNANO will facilitate the internationalization process by the establishment of deep partnerships with some of the strongest nano-institutions in the world (iNANO KPI 1, appendix H). iNANO will provide VIPs with administrative support and financial help to arrange bilateral workshops. Based on personal contacts and excellence, we have selected the following target institutions:

- 2014 Technion, Israel (Workshop held in June 2014)
- 2015 KAIST, South Korea (Workshops have been held and a new meeting planned in 2016)

- 2016 Bristol University, UK
- 2016 Harbin Institute of Technology, China (workshop to be held August 2016)
- 2017 ETH, Zurich, Switzerland

c. iNANO support in submitting applications: iNANO will strengthen the administrative support for submission of applications. A full time scientific coordinator with an academic background in Chemistry and/or Physics will be employed to supplement existing coordinators (potentially in collaboration with Chemistry or other ST departments).

Important tasks for this person will be:

- Guide all iNANO groups about innovation opportunities.
- Proactive in setting up networks for interdisciplinary applications.
- Strengthen advice and help writing all major applications (research committee members will offer to review major funding applications).
- Attendance in EU workgroups for Horizon 2020 calls and reporting back to iNANO group leaders.
- Help setting up close industrial collaborations suitable for applications aimed at the Danish Innovation Fund (see 6.5 below).
- Team up with other ST scientific coordinators to ensure synergy and knowledge transfer.

The iNANO business committee will proactively try to match iNANO researchers with key Danish industries.

6.2. Attract more talented researchers to iNANO.

Recruitment of excellent staff is of greatest importance to iNANO, especially in the light of the requirement for continued external funding.

The strategy will be to keep a balance between external recruitment of well-established group leaders and recruitment among young iNANO talent.

We will strengthen our efforts to attract international high-ranked researchers by the following initiatives:

- Establish search committees within selected research areas to identify potential candidates. The international network provided by all iNANO researchers is of key importance.
- Advertise widely about the unique iNANO infrastructure and standing opportunities for employment.
- Encourage VIPs to volunteer as external board members for other international institutions/centres and on assessment committees.
- Ensure funds for immediate action when the right person is available
- Match recruitment with national recruitment programs for top researchers (Niels Bohr stipend, Lundbeck fellow, etc.).

In the recruitment of young talents (assistant professors at tenure track level) we will not compromise on the requirement for international experience and independence. The following actions will be taken:

- Broad (as opposed to targeted at a specific local candidate) job announcements within major strategic areas to attract many applicants.
- Provide guidance in obtaining career grants as a starting point for tenure-track recruitment.

- Provide administrative support for successful postdocs applying for career grants.
- Follow successful Danish researchers abroad and negotiate their return to Denmark after successful postdoctoral stays.

For a detailed recruitment plan, please refer to appendix J.

6.3 Publication output

Scientific production will, to a large extent, depend indirectly on other specific measures described above and below.

In addition, the iNANO leadership will implement specific measures to increase the number of publications (ST KPI2, see appendix H) and the ratio of publications in high-impact journals (iNANO KPI 4, see appendix H).

- We will focus on the quality of scientific writing in order to increase the number of high-impact publications.
- We will strongly encourage a culture of local peer review of articles written by younger scientists before submission. This will also act so as to create awareness of colleagues' research activities.
- We will establish more deep partnerships with international institutions, which most likely will lead to an increase in the number of future publications with external partners (ST KPI 5).

6.4 Direction of research

In the future, the research conducted at iNANO will continue to be partially governed by a) top-researcher recruitment opportunities b) Larger network/centre funding from governmental and private foundations given to iNANO members. However, the iNANO leadership will encourage and actively promote an increased focus on global challenges and growth technologies through recruitment in specific areas and through pro-active support by the scientific coordinators.

The following **global challenges** will be given particular focus:

- Nanomedicine: Prevention, diagnosis and treatment of disease
- Energy: Materials for energy conversion and storage
- Environment: Control, monitoring, and abatement of pollution
- Growth opportunity in nanofood: Food security and ingredients

To support our research in these areas we will in particular strengthen the following **growth technologies**:

- Smart materials (2D materials)
- DNA as a structural nanomaterial and information carrier
- Biomimetics (hybrid materials, biosynthesis, biotechnology)
- High-resolution TEM
- Applications of synchrotron and neutron radiation at MAX4 and ESS in Lund

6.5 Definition of “flagship” areas of research:

Based on a thorough assessment of iNANO's current research expertise and impact, we have nominated two particular research areas of strength, the so-called “flagship” areas, which may become nucleation points for new centre constellations within the next five years:

6.5.1. Functional materials

Modern energy technologies are critically dependent on the properties of advanced functional materials. The limited resources available on Earth further emphasize the importance for the development of more sustainable materials and processes. Transition to a better energy and consumption-balanced society requires the development of new energy and sustainable materials with specific properties.

iNANO holds an exceptionally strong position to be a leader in materials research both nationally and internationally. A cornerstone in this expertise is the strong iNANO capacity in materials synthesis, the availability of a broad range of complementary infrastructure for structural characterization and the strong expertise in computer simulations and modelling. The development of advanced energy- and sustainable materials requires a fundamental understanding of the atomic-, nano-, micro- and macrostructure and it is therefore rare that one single technique can solve the puzzle. The physical placement of so many pieces of world-class nanocharacterization equipment under the same roof in the iNANO House provides a unique environment for materials science. Also the symbiosis between chemical synthesis, broad structural studies and theoretical modelling provides a perfect incubator for scientific breakthroughs, both academically and commercially.

These advantages, coupled with the leading position at the key materials beam lines in Lund, will make the iNANO materials program highly effective for attracting outstanding foreign researchers as well as direct collaboration with industry.

iNANO groups are particularly strong in the fields of energy conversion (photovoltaics, thermoelectrics, biofuel conversion, catalysis, fuel cells), energy storage (hydrogen, ion batteries) and sustainable materials (cement, chemical synthesis, magnetic materials, catalysts, biosurfactants), and we will push research in this direction to build up world-class activities. Importantly, Danish industry has strong interests in these areas, e.g. Grundfos (pumps), Danfoss (thermostats), Vestas, Siemens (wind turbines), Aalborg Portland, FLS (cement), Haldor Topsoe, Synfuels China, Dinex (catalysis) and others, but collaboration can also be expanded to other areas such as for chemical production in the polymer and pharmaceutical industry, and for engineered biomaterials in the biotech industry.

Examples of more specific research areas within materials science are:

- Wind turbines or efficient engines
- Catalysts that can remove harmful gasses in exhaust
- Rational development of novel catalysts from earth-abundant materials
- Exploitation of harmful and/or waste compounds such as CO₂ as a chemical resource
- Conversion of biomass to new high value chemicals
- Advanced nano-based cements that reduce the very high CO₂ emission
- Materials that can store or sieve gasses such as hydrogen or CO₂
- Nanostructuring for manufacturing high-efficiency solar cells
- Development of materials and devices for photocatalysis
- Materials and devices for high-performance batteries and energy storage solutions in chemical bonds
- Thermoelectric materials for conversion of waste heat to electrical energy

For recruitment within the flagship field of functional materials, see appendix J.

6.5.2. Nanomedicine

Nanomedicine has the potential to revolutionize the treatment of disease. Biosensors that will detect disease at a very much earlier stage and new effective designer drugs inside nanoparticles delivered only to the diseased tissue are becoming reality. iNANO groups are particularly strong in the fields of rational drug design, drug delivery, biomimetics, biosensors, tissue engineering, biopolymers, macromolecular self-assembly, biochemistry and biophysics and has already established a strong record in translating scientific discoveries into patents and products. Many iNANO groups have close collaborations with local medical research groups and industry (E.g. Novo Nordisk, Lundbeck, Roche, Novozymes, Dupont, and Coloplast) and the iNANO management team will encourage the researchers to strengthen these ties and create new contacts when appropriate. Based on our past track record and new growth technology opportunities we envision the following directions of research:

- Characterization of atomic structures of biomolecules and modelling (e.g. membrane proteins and enzymatic complexes) will enable rational design of drugs and bioactive macromolecules.
- Encapsulation of bioactive molecules including peptides and nucleic acids can facilitate targeted drug delivery to disease tissue and cell penetration
- Nanoscale structuring of bioactive molecules to enhance cell signalling by the principle of biomimetics (or biomimicry).
- Construction of biosensors at the nanoscale that can detect, e.g. pathological condition and enable early diagnosis, or report on metabolic states.
- Construction of nano-structured and/or functionalized 2D or 3D scaffolds to be used for stem cell mediated regeneration of tissue (tissue engineering).
- Development of novel biopolymers for drug delivery
- Self-assembly of large complexes with complex, robotic properties.
- Development of fiber-optics control of light-sensitive delivery systems and photoswitchable activity.
- Disassembly or prevention of protein aggregation or protein degradation by small molecules for treatment of neurodegenerative diseases
- Biomaterials, such as self-assembling RNA/DNA complexes and proteins and membranes with engineered properties.

For recruitment within the flagship field of nanomedicine, see Appendix J.

6.5.3. Nanocharacterization platform

As described above, iNANO commands an impressive and competitive suite of characterization equipment. Importantly, for many of the techniques, iNANO scientists are internationally recognized capacities, which is of course crucial for the optimal exploitation of the instrumentation. iNANO has historically been world-leading in SPM methods, and we recently upgraded our NMR and TEM facilities with world-class instruments. We will continuously monitor the progress of the technologies represented in our suit of infrastructure and seek funding to upgrade to most advanced level.

Transmission electron microscopy: In the field of transmission electron microscopy (TEM) in particular, iNANO wishes to pursue two interconnected venues: Materials TEM and biological cryo-TEM. With the addition of two TEMs in October 2014, we currently command the strongest selection of TEMs in Scandinavia. In both areas, we are currently experiencing rapid developments in detector sensitivity and aberration-corrected optics. In November 2015 we secured the majority of funding for a K2 single electron detector that will increase the resolution significantly. Within materials TEM, we aim to strengthen our instrumentation with the only missing piece in our selection: an in-situ TEM with which

materials can be observed at atomic resolution even under relative high gas pressures. The first step, however, is to hire a recognized scientist within the area (see recruitment plan) so as to optimize the chances for securing funding for such an expensive instrument, which would be the first in the world.

Biological cryo-TEM is now able to achieve close to atomic resolution of biological macromolecules. Combined with iNANO's world-leading expertise in molecular biology and X-ray crystallography, we are in a unique position to carry out ground-breaking research in the field. To strengthen this area, we wish to recruit a cryo-TEM professor as soon as possible (see recruitment plan, appendix J).

Beam line at MAX4 and ESS: iNANO researchers are very active in the application of synchrotron and neutron based studies of materials and in certain areas in fact world-leading. They are PIs on the coming Danmax beam line at MAX4 and the HEIMDAL beam line at ESS, which are both targeted at structural studies of advanced energy and sustainable materials using diffraction and imaging.

We are thus in a position to contribute substantially to the upcoming industrial portals, which aim to increase collaboration and service offerings to industry through the use of state-of-the-art scientific characterization instrumentation.

6.6 Increase collaboration with Danish industry (iNANO KPI 5, see appendix H)

As a starting point, it would be preferable to have a common industry portal to related ST departments and centres since it would seem artificial and unnecessarily complicated to third parties if they had to distinguish between the different affiliations of a specific research group. This is why iNANO and the Department of Chemistry have decided to implement a joint strategy for industrial collaboration. Previous activities (e.g. Industry Office, Brainnovation Day, see below), have already been planned and implemented according to this line of thinking. This kind of joint strategy has materialized with the Department of Chemistry in 2015, but the intention is also to engage in dialogue about Danish industry collaborations with other partnering departments as soon as possible.

The iNANO Center and the Department of Chemistry wish to strengthen the collaboration with industry, both nationally and internationally, to an extent that it will constitute an even larger, integrated part of the education and research profile of the department. An intensified collaboration should reach beyond narrow regional and national borders and must focus on international collaboration within some of the research qualifications of the department.

We believe that a necessary prerequisite for significantly strengthened industrial collaboration is a broad mindset in which management and researchers, to a higher extent, take the specific needs of companies as a starting point (technology “pull” as opposed to “push”); ideally, one would of course look for a combination of push and pull. This new approach certainly requires intimate knowledge about the needs of companies, which is why all of our activities seek to raise such awareness.

We also believe that time is ripe for this approach - we clearly sense a heightened interest among students and researchers to enter into industrial collaboration where one can see specific impact of own research on society.

In addition, these new initiatives will serve to create projects with higher societal impact, motivated research communities and, as an indirect effect, higher funding volume since a progressively higher share of public grants are channelled towards innovation projects.

The intensified business collaboration of the center is based on three different types of collaboration:

Dialogue and contact activities, which are intended to facilitate the interaction between the business sector and researchers and students. Typically, the collaboration partners can be involved in teaching and open themed conferences, or contact events between students and companies can be arranged. These activities should be arranged in close collaboration with the relevant (chemistry, physics) activities at the Department of Engineering and other academically related departments. It is also the wish that the students are actively involved in this type of activities.

Other collaboration activities profit from the **research infrastructure**. iNANO and the Department of Chemistry have several facilities which are part of the national research infrastructure. To a higher degree these facilities, together with the other available infrastructure, could be made available to external users for, e.g. analyses, structure determination or advanced tests of new materials. Systematization of these activities could considerably facilitate contact between the center and the business sector. In this regard it is again important to expose some of the special research qualifications, which make the use of the research infrastructure particularly attractive (NMR, XPS, X-rays, FS-Lasers, SAXS, STM, etc.) An increased exposure of the research infrastructure could also take place as collaboration between more departments or in a coordinated collaboration with ST.

iNANO and the Department of Chemistry are active partners in setting up **Industry Portals** for the exploitation of the unique radiation facilities currently being built in Lund, Sweden. A broad range of Danish companies are challenged every day in developing advanced materials and materials processes in order to generate a competitive advantage in a global economy generally operating on lower cost levels. The Industry Portals aim to develop and mature technologies in Danish companies to improve their R&D capability by exploiting the potential of advanced neutron and X-ray techniques as well as in-house techniques, which are crucial for providing complementary and preparatory insight before moving to large-scale facilities.

The final type of collaboration is the direct **research collaboration** between a company and research group(s) or individual researchers at the center. Many collaboration projects of this type already exist, and are characterized by close collaboration, comprising technology transfer both to and from the center, contributions to the development of products and knowledge in companies, and often also joint publications. Research collaboration is the primary and most important type of business collaboration of the center, and it is also our main focus area for increased international cooperation.

The above target areas will also mean that some areas at the center will less be prioritized. Consultant tasks, where staff contributes to the solution of small, less development-oriented problems, will not be prioritized as part of the overall strategy of the center. This type of task is better solved by one of the 9 GTS institutes. Staff at iNANO and the Department of Chemistry may of course choose to take on such a task if it is of their interest.

Implementation of strategy for business collaboration

The work with the strategy for business collaboration originates from the Business Committees of iNANO and the Department of Chemistry. The committees collaborate closely with equivalent committees at IFA and ENG. It is important to gather the relevant academic profiles regardless of current departmental and faculty affiliations. The first task is to document and visualize the current business collaborations. At the moment the information is spread among the different administrative units, and the idea is to collect all information to enable the center to describe all current collaboration projects at all times. Identification of themes for thematic events or invitation to industrial researchers to give lectures could be examples.

An underlying theme will be to nourish a mindset, which takes as a starting point the specific needs of industry into consideration to a higher extent. This includes a critical look at whether applications live up to the evaluations criteria of, e.g. the Danish Innovation Fund and if applied research initiatives are at all competitive. iNANO, the Department of Chemistry and other departments will offer detailed feedback on these particular applications.

The homepage of the center will onwards contain both information relevant for possible collaboration partners and cases illustrating current collaboration projects. Information about contact persons for different types of collaboration projects will be clearly visible as well as references to homepages of the faculty and other departments.

In collaboration with KI, IFA and ENG, we will arrange a series of dialogue meetings with the aim of increasing the visibility of current and potential collaborative interfaces with industry. The *Brainnovation Day* in October 2015 was an example of this and we will repeat this initiative with other foci. We will strengthen information about how to create new companies, partly through contact to successful entrepreneurs and partly through the description of possible channels of finance.

Frequent interaction between AU researchers and collaborating companies will serve to create open communication channels and close ties. The use of the already existing ST Industry Office (placed at iNANO in close proximity to research infrastructure) will be strengthened through invitation to let company researchers spend time at the Industry Office.

The iNANO Distinguished lecture series (Fridays 10.15-11.00 a.m.) will start to include more company researchers, who will be asked to give a scientific lecture on the research and development activities of their company. The purpose is again to create closer ties and to spread the knowledge of the company's challenges where iNANO researchers could be part of the solution.

On the center homepage the description of the available research infrastructure will be well described and updated. We are currently investigating the possibility of displaying availability across departmental and university boundaries. In collaboration with TTO we will investigate the possibility of drawing up standard contracts, which, in a simple and smooth way, can handle the most typical relations of collaboration, e.g. in connection with IPR, payment and deadlines.

The increased focus on international research collaboration with companies is a challenge, especially regarding IPR and legal matters. Again standardized descriptions of possible collaboration models are a good starting point. This will be done in collaboration with TTO. The next step is the build-up of an international network of contacts to companies, which will be gathered on the basis of the center's leading research qualifications, which initially can be used to invite specific companies to the center and AU. These initiatives will be driven by the business committee of iNANO.

The increased collaboration should result in a larger portfolio of contract-based collaboration projects, equivalent of a larger turnover and an increase in the number of industrial PhD students. As the current data material is incomplete, the specific aim in numbers will not be defined until the current level of collaboration between the iNANO/Department of Chemistry and the business sector is known.

6.7 Develop and further strengthen BSc, MSc, PhD programmes

The multi-disciplinary nanoscience BS program is an essential asset for iNANO, providing a student base with an ideal background to pursue interdisciplinary Master's and PhD projects. Our portfolio of Master's courses complements Master's courses offered at the departments and should showcase nanoscience as well as iNANO's strategic research areas and competences. Master's courses target

nanoscience students as well as students from the surrounding departments.

The nanoscience BS and MS program is in the process of undergoing the newly implemented 5-year program evaluation during 2015/16. As part of the evaluation we are analysing student performance in detail (grades on individual courses, study times and retainment). The Nanoscience curriculum and course program will be revised during 2016 in conjunction with the transition to a semester-model which will be implemented from summer 2017. We will use the results from the evaluation process to optimize the BS program regarding focus and coherence, which will be done in dialogue with the departments offering courses on the program.

We are aware of the requirements towards reduced times for completion of BS and MS studies brought about by the study progress reform and the associated AU-wide targets for study times. A large group of the nanoscience students already finish on time (a high fraction of 4+4 Ph.D's affect the MS study times). The factor that has primarily affecting study times adversely is few students with very long study times, in particular on the Master's program.

As part of the ongoing program evaluation we have developed new tools to systematically extract information on student progress from the AU databases and display it in orderly form for the individual year groups. To reduce study times we will use this tool to closely monitor student progress and performance. We thereby expect to be able to pro-actively take early action towards students where this is needed. This will be done in collaboration with the ST study office (educational coordinator and student counsellors) and may involve counselling, adjustments of study programmes or possibly mentoring schemes. We consider pro-actively targeting particular groups of students with mentoring schemes or other dedicated activities, based on admittance GPA or other parameters shown by the program evaluation to affect student performance. Our weekly "nano-café", where first year students can meet with their teaching assistants, will be targeted towards courses that have proven particularly challenging and possibly the concept will be extended to selected second/third year courses.

The administration and individual counselling in relation to of study programmes and contracts has already been considerably sharpened through the joint efforts of the iNANO study responsible and the ST study office, ensuring that all students sign up for and follow courses/projects on time. We believe this is already leading to a changed culture among the student base. We will continue this process and certainly expect to see effects on the study times in the coming years. As a complementary element we will increase the awareness among supervisors of the importance that projects are carried out on time.

The intake on the nanoscience BS program will be capped to 66 students from the summer uptake 2016 (set by the capacity of the iNANO building). Our program evaluation shows that comparatively few students with GPA's below 6-7 complete the program. If the cap leads to a minimum GPA requirement, it will be seen as an advantage towards optimizing the student base. We will analyse if the cap should be adjusted to meet this target, possibly in combination with uptake interviews for selected applicants (Kvote 2 optag).

Showcasing job opportunities through the career paths of the nanoscience alumni is believed to increase student motivation and aid in student retainment. To this end we have commenced the development of an alumni Linked-In group, also visible to present students, in order to use the alumni as a resource and an inspiration for current students.

Our strategies for student recruitment, retainment and study time reduction will be further developed as part of the program evaluation.

Faculty employed at iNANO is expected to contribute to teaching activities at the Nanoscience BS/MS programs and teaching at the departments is encouraged. iNANO faculty is expected to contribute to teaching to the same extent as faculty employed at the departments. To promote the unique identity of the Nanoscience BS program, we value that many teaching assistants (instruktörer) on the program are PhD students who have followed the nanoscience BS. All PhD students, especially those with degrees obtained at other universities than AU should follow the Instruction Pedagogics courses offered by STLL.

As an international environment iNANO motivates and encourages student mobility. Outgoing student mobility typically occurs on the first year of the MS program. Many different channels are used including ERASMUS, AU overseas agreements, TASSEP and Free-mover. Approximately 20 % of the Master's students spend one or two semesters abroad. We will further facilitate student mobility by exchange agreements with selected partner institution (in addition to our ERASMUS portfolio) and the development of suggested course packages, if possible also for the last semester of the Bachelor's program.

Incoming student mobility occurs as ERASMUS students on agreements held by iNANO and the departments as well as ERASMUS+ students and others who enter into individual internship agreements with iNANO supervisors. A few international students have been admitted as full degree MS students. We see international students as a valuable resource, not least in relation to PhD recruitment. We will develop student mobility, keeping in mind the overall needs of AU/ST regarding balance and revenue.

We will develop partnership agreements on balanced international student exchange, in the first instance targeting the strategic partner KAIST. Agreements will be developed taking into account the requirement of full time study (Fremdriftsreformen), which may render otherwise strong universities using a trimester model unsuitable.

International applications to the nanoscience MS have increased in recent years [20 in 2015, 7 offers, 2 accepted]. We will gradually increase the uptake of international full-degree students on the MS program in order to gain experience with the international student base. We will develop new relevant Master's courses, keeping in mind the overall teaching load of the faculty. The courses will be developed with an eye towards their eventual integration in a dedicated nanoscience MS program targeting outside (international) students with suitable science degrees.

iNANO has formulated the following KPIs for our educational program:

- BSc, MSc: iNANO KPI 2 (higher admission grade average), ST KPI 4 (number of completed studies)
- PhD: ST KPI 3 (increased number of PhDs per VIP), iNANO KPI 3 (higher grade average upon admission)

6.8 iNANO structure and relationship to the departments

The limited space of the iNANO building means that many iNANO groups will have to remain physically located at the departments and new recruitment may also depend on space availability at the departments. It is therefore of utmost importance that the existence of iNANO is beneficial for our partner departments and all administrative rules should be aligned according to this. To improve the current situation, we advocate for the following:

- The i-Center agreement (double overhead) is expanded to include all ST departments.
- All applications submitted by iNANO members are submitted via the iNANO administration. This requires close coordination with the departments.

- Project related expenses (inddækning) shall belong to the department where the work is conducted.
- The physical placement in the iNANO House should be more dynamic in the future. The extent of interdisciplinary involvement and nano-related research conducted by the groups at iNANO will be evaluated regularly and the physical placement (departments/iNANO building) may be adjusted by moving groups in part or fully between the iNANO building and the departments.
- The annual production (funding, applications, publications, PhD students, etc.) by iNANO members with cross-departmental affiliations should be included in the statistics for both the departments and iNANO.

7. Evaluation of the implementation plan

The implementation of our strategies will be carefully monitored so action can be taken to fulfil the goals:

- iNANO strategy plan will be evaluated bi-annually at meetings open to all iNANO VIP staff.
- iNANO strategy implementation will be evaluated annually by iNANO's external board
- iNANO administration will assemble and publish annual productivity reports on publications, citations, funding, CAs and NDAs.
- Evaluation of each individual employee will occur in connection with the annual staff development dialogues (MUS) where research production, teaching and innovation will be addressed. Clear bonus rules for salary enhancements will be implemented.
- iNANO will be subjected to external review every 4-5 years. Seven-to-nine renowned scientists will be invited for a site visit where our strategies will be presented and discussed followed by feedback and advice from the committee.

Overview of Appendices:

Appendix A:	Organisation, iNANO management structure
Appendices C1-C5:	Employees
Appendix D:	Large infrastructure research platforms
Appendix H:	KPIs for iNANO 2014-2016
Appendices I1-I5:	Key figures for iNANO
Appendix J:	Recruitment plan Strategy form