





## A large red hexagonal graphic is centered on the right side of the page. It consists of a thick red outline forming a hexagon. Inside this outline, the words "End Term" and "Report" are stacked vertically in a bold, red, serif font. Below the bottom vertex of the upper hexagon, there is a smaller, solid red hexagon. Inside this smaller hexagon, the years "2010" and "2016" are stacked vertically in a bold, white, sans-serif font.

Netherlands nano/microtechnology research  
and innovation programme **NanoNextNL**

# Executive summary and highlights

NanoNextNL is a Dutch national research and technology programme in which academic and industrial participants and knowledge institutes collaborated to *accelerate the creation of durable economic and societal value by developing and commercialising innovative nano and microtechnology, and by forming a sustainable ecosystem of researchers, entrepreneurs and policy makers*. A total of 13 universities, 8 medical centres, 12 knowledge institutes and 110 industrial partners have collaborated within the NanoNextNL programme. NanoNextNL was funded by a subsidy from the Dutch government from the "Fonds Economische Structuurversterking" (125 M€) and by matching funds from academic (69 M€) and industrial (57 M€) partners.

Since its start in 2010, NanoNextNL has created a very large knowledge base in nano/microscience and technology. It has led to fundamentally new insights in renewable energy, nanomedicine, clean water, food technology, beyond-Moore technology, bio/nanomaterials, nanofabrication, and sensors and actuators. So far, over 1250 peer-reviewed scientific publications have appeared from NanoNextNL research in international journals. Their quality is very high (average citation impact 1.79 times the world average). In addition, 21% of all publications involved a collaboration with industry. Over 130 PhD theses have been completed so far, with a little short of 100 still to appear.

NanoNextNL has strongly accelerated the transfer from nano/microscience and technology to the creation of new applications and businesses. A large number of product innovations were developed, such as patient-friendly blood tests, tailor-made food and an innovative electron microscope. The participating companies report a more than four-fold return-on-investment for their NanoNextNL innovations, creating a business value of more than 400 M€. In addition, many demonstrators and prototype devices have been made, such as improved solar panels and a quantum cryptography

system, which may lead to commercial products in the future. So far, 127 unique patent applications have been filed. NanoNextNL has developed and executed an innovative business development programme, including an entrepreneurial training course, which stimulated the development of 23 novel business cases. So far, eighteen start-ups have emerged from the programme, and six more have strongly benefited from NanoNextNL research.

Risk analysis and technology assessment has been strongly integrated with the NanoNextNL research and development programme, bringing responsible research and safe-by-design innovation into practice, also in the development of new businesses. Tools for the detection of nanomaterials and understanding mechanisms of (eco)toxicity were developed to support new regulations and develop international policy. A dedicated educational track on risk analysis and technology assessment was developed. These courses, together with those on intellectual property, valorisation and storytelling, have helped to create a new generation of researchers educated with a very broad range of skills. Based on the results so far, it is expected that around 140 highly skilled experts trained by NanoNextNL will be employed in technology-focused knowledge institutes and the high-tech industry.

Overall, thanks to NanoNextNL, nanoscience and nanotechnology has become firmly embedded in the Dutch research landscape. The programmatic approach, integrating academic and industrial research within topical programmes, has led to knowledge exchange between academia and industry, and vice versa, on a scale that would otherwise not have been possible. Most importantly, NanoNextNL has led to the evolution of a national nano/microscience and technology ecosystem. This self-strengthening network, based on an effective mutual exchange of knowledge is unique in the world. The Netherlands now has a very strongly interwoven multidisciplinary network of academic

scientists, technical researchers, and industrial innovators who have close ties with each other and who now benefit from each other's expertise on a regular basis. Furthermore, a nationwide technical infrastructure of nano/microfabrication and characterisation facilities has been built up from which partners from academia and industry (start-ups, SMEs and large companies) all benefit.

**NanoNextNL has built up a unique and vibrant nano/microtechnology ecosystem at a scale that has never been achieved in any technical field in the Netherlands and has therefore set a new standard for public-private collaboration in the Netherlands and beyond.**

This ecosystem is now in an ideal position to target the major new challenges that our society faces in areas such as energy, health, food, high-tech manufacturing, and more. The successful NanoNextNL integrated approach involves strongly interlinked programmes composed of collaborative projects between academic and industrial partners, with integrated studies on risk analysis and dedicated training in intellectual property and valorisation, and entrepreneurship. This is complemented with a business development programme, from which start-ups, SMEs and large companies will all benefit. Using the NanoNextNL method in a follow-up programme will guarantee a high-return-on investment for Dutch industry and society, and provides an efficient and effective road

towards a more sustainable society. The Board of NanoNextNL is now holding discussions with private partners, the Ministry of Economic Affairs and other government ministries to explore the possibilities of starting such a follow-up programme of NanoNextNL that will target these goals.

Researchers from NanoNextNL are active within two routes of the Dutch National Research Agenda (NWA), and have taken the leading role in the route 'Quantum/nanorevolution' and the route 'Materials - Made in Holland!'. In addition, partners from NanoNextNL have taken the initiative to elaborate six so-called NanoInside themes. These NanoInside themes are: 3D-Nanostructures and metrology, BioNano Devices, Food Body Interactions, Green ICT, Nanomaterials for Solar Energy, and Organs-on-Chips.



NanoNextNL has led to the evolution of a national nano/microtechnology ecosystem that is unique in the world

**Introduction:  
NanoNextNL**

**Education:**  
training highly  
skilled innovators

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**Innovation:**  
creating business  
from technology

**Responsible  
research and  
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**Top science:**  
the basis of a strong  
innovation  
programme

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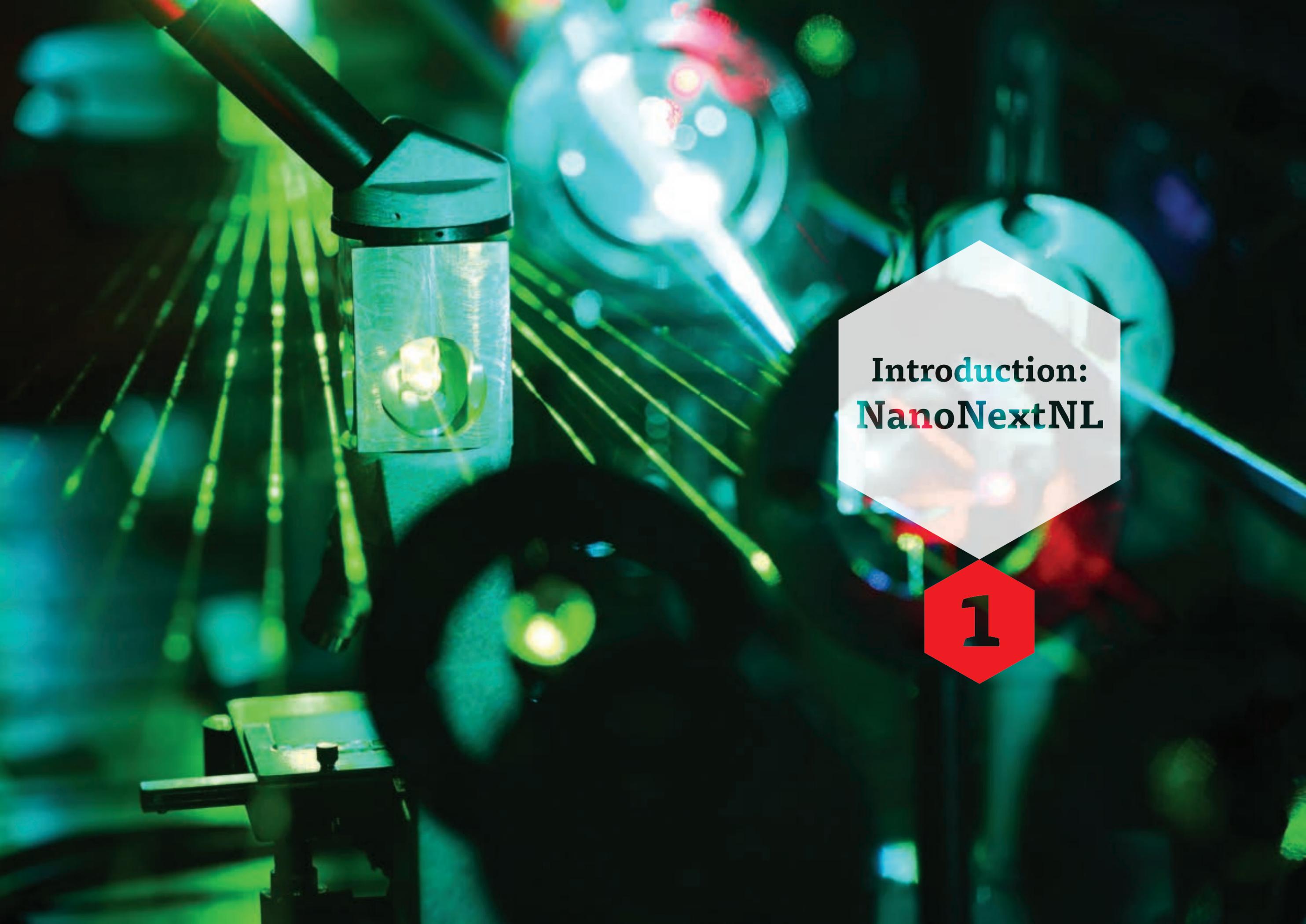
**Added value  
of the  
NanoNextNL  
approach**

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**p.14**

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A close-up photograph of a microscope's objective lens and eyepiece, set against a dark background with vibrant, out-of-focus bokeh lights in shades of blue, green, and red. The microscope's body is dark, and the lens elements are visible, reflecting light.

**Introduction:  
NanoNextNL**

**1**

# Introduction: NanoNextNL

13 universities, 8 medical centres, 12 knowledge institutes and 110 business partners have collaborated within the NanoNextNL programme

From 2010-2016, participants from academia and industry collaborated in the Dutch research and technology programme NanoNextNL with the following mission:

*"To accelerate the creation of durable economic and societal value by developing and commercialising innovative nano and microtechnology, and by forming a sustainable ecosystem of researchers, entrepreneurs and policy makers."*

The NanoNextNL programme was drafted in 2010 by the participating academic and industrial partners and comprised 28 research programmes within 10 themes. Each research programme consisted of multiple projects that were carried out by partners from universities, institutes, medical centres, small- and medium-sized enterprises (SMEs) and industry (see Fig. 1). These projects were selected to lead to strong synergy and collaboration within the programme, and academic and industrial partners have worked together towards closely coordinated common targets. Overall 13 universities, 8 medical centres, 12 knowledge institutes and 110 SME/industrial partners have collaborated within the NanoNextNL programme. Over 1100 people were actively involved in NanoNextNL, including more than 225 PhDs, 135 postdocs and 120 researchers active at companies that were directly funded by the NanoNextNL programme. In addition, hundreds of additional coworkers made a contribution to NanoNextNL.

The total budget of NanoNextNL for the period 2010-2016 was 251 M€. A subsidy of 125 M€ was awarded by the Dutch government from the 'Fonds Economische Structuurversterking (FES)'. Matching funds were contributed by academic (69 M€) and industrial (57 M€) partners of NanoNextNL (status March 2017).

This report evaluates the output of NanoNextNL in the five key areas that form the heart of the mission of NanoNextNL:

- Top science: the basis of a strong innovation programme
- Innovation: creating business from technology
- Responsible research and innovation
- Education: training highly skilled innovators
- Added value of the NanoNextNL approach

Each chapter describes main results and highlights as well as "lessons learned": opportunities that we recognise for future public-private partnership initiatives.

A separate research appendix provides an overview of all partners in NanoNextNL, the management structure of the programme, a detailed output report of each NanoNextNL programme, a list of key performance indicators achieved, a financial summary, and an overview of top publications.

## Programme overview

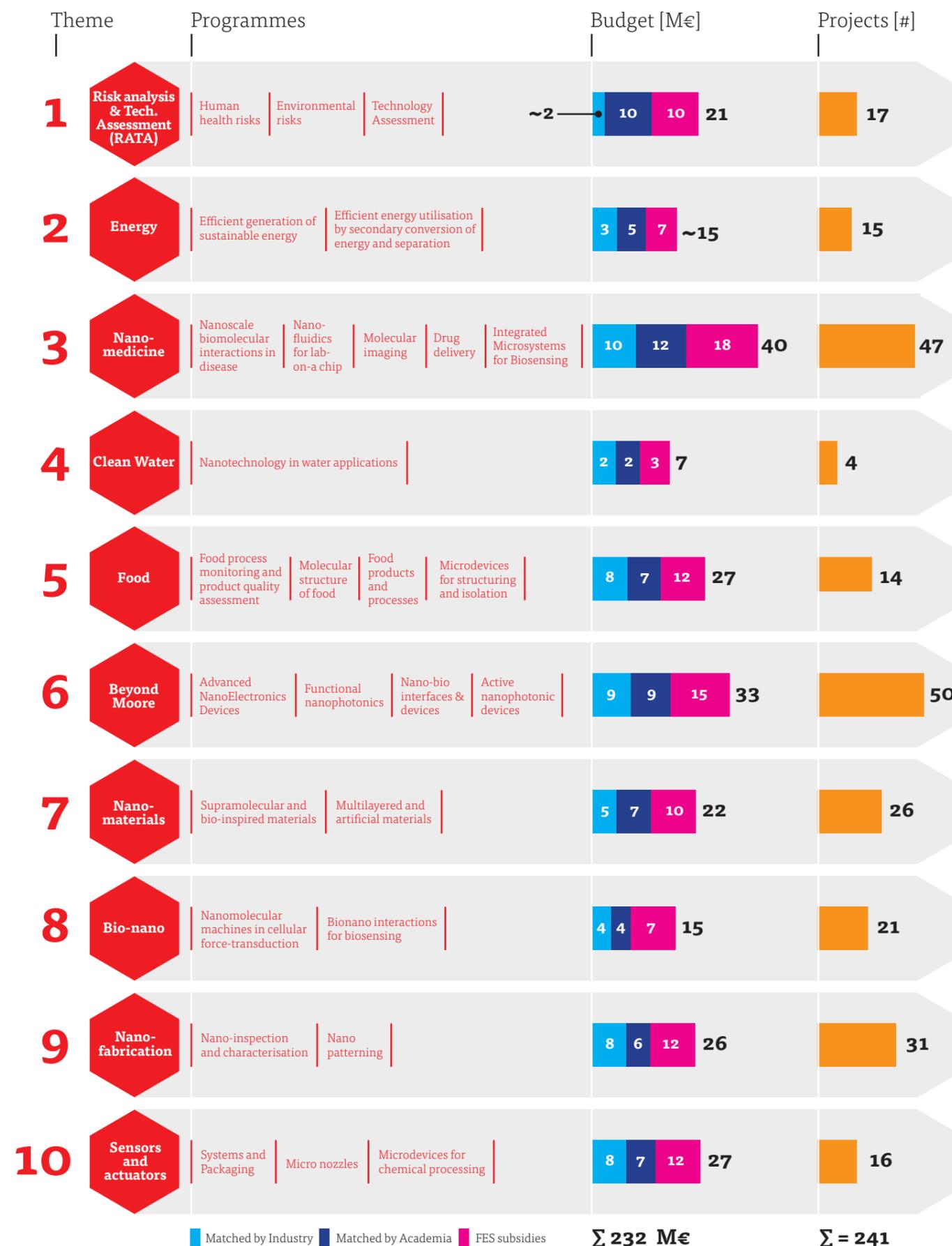


Fig. 1 Overview of the 10 NanoNextNL themes, 28 programmes and 241 projects and their budgets (status March 2017). The total research budget (including matching) was 232 M€; another 16 M€ was spent on valorisation, education, meetings, PR and management activities.



**Top science:**  
the basis of a strong  
innovation  
programme

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# Top science: the basis of a strong innovation programme

Scientific research lies at the basis of almost all new product innovations. NanoNextNL has carried out a strong scientific programme that provided long-term strategic knowledge that can serve as a starting point for the development of new applications. NanoNextNL has strongly focused on developing technology and at

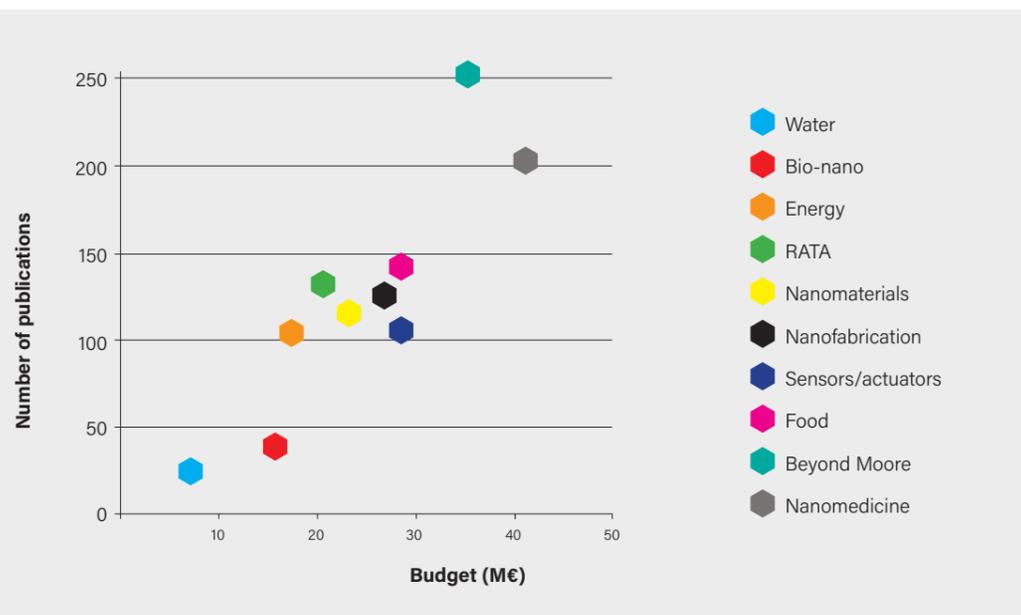
the same time it has created scientific knowledge at a very high level, as described below.

### Scientific output

NanoNextNL has produced scientific output in many different forms (status March 2017):

- Over 1250 publications in peer-reviewed international journals, of which over 150 in journals with a high impact factor (>10). The number of publications for each theme is listed in Fig. 2 as a function of Theme budget.
- Hundreds of publications in conference proceedings, books, magazines, etc.
- Over 130 completed PhD theses; with a little short of 100 still to appear in the coming years.
- Over 2000 presentations at international nanoscience and nanotechnology conferences, many as an invited keynote or plenary presentation. No less than 200 presentations have been held for non-specialists.

### Number of peer-reviewed publications

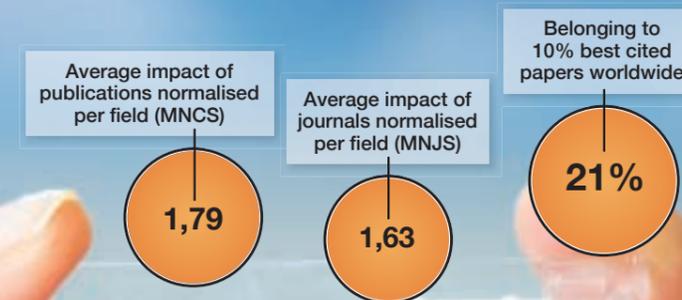


**Fig. 2** Number of peer-reviewed publications from each NanoNextNL theme as a function of theme budget (status March 2017).

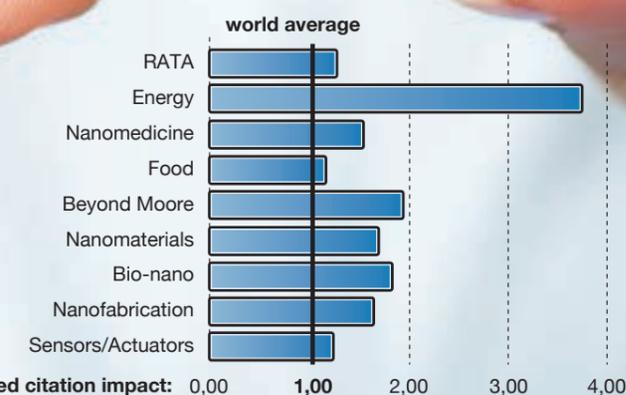
## Technology driven research in NanoNextNL has led to top science with very high impact

### Citation impact of NanoNextNL publications

- Over 1250 published (status March 2017)
- Over 150 published in high impact journals, impact factor >10
- 734 analysed (published in 2010-2015)
- 21% of the publications concern collaboration with industry



### Citation impact of publications from NanoNextNL themes



Source: CWTS, 2017

## Scientific research lies at the basis of almost all new product innovations

### Citation impact of NanoNextNL publications

An independent study of the citation impact of publications by NanoNextNL was performed by Centre for Science and Technology Studies (CWTS, Leiden). Citations of all NanoNextNL papers published in the period 2010-2015 were analysed and normalised relative to the average citation impact of the corresponding research field in the same period. Three key conclusions are drawn from this analysis:

- Average impact of publications normalised per field (MNCS): 1.79
- Average impact of journals normalised per field (MNJS): 1.63
- Representation within 10% best cited papers worldwide (P10%): 21%

These numbers testify to the very high scientific quality and impact of NanoNextNL publications.

The citation analysis was also carried out separately per NanoNextNL theme. Data for the Water Theme are not included because the number of publications published by the 4 projects in this theme up to 2015 was too small for this citation analysis. The impact varies between Themes but all Themes perform above world average level:

- **High-impact themes (MNCS > 1.5):** Energy, Nanomedicine, Beyond Moore, Nanomaterials, Bio-nano en Nanofabrication.
- **Above average-impact themes (MNCS > 1.0):** RATA, Food and Sensors/Actuators.

Aside from the citation impact per theme, the fraction of top-10% best cited papers was analysed for each theme as well. The data (not shown here) shows the same trends per theme as the figure for citation impact.

During the period in which the NanoNextNL programme was carried out, several major national research programmes focussing on fundamental nanoscience were initiated. Collaborations within the NanoNextNL programme have played an important role in the initiation of many of these programmes that include: NWO Gravitation programmes, Sector Plan Physics and Chemistry, FOM programmes, etc. In addition, NanoNextNL researchers attracted

funding through NWO Talent Scheme (Veni/Vidi/Vici) grants, R&D and valorisation programmes executed by STW, and through ERC Starting/Consolidator/Advanced Grants. Furthermore, professor Ben Feringa was awarded the Nobel Prize for Chemistry in 2016. Evidence that NanoNextNL has played a key role as a multiplier of research is also evident from the following examples. Existing national nanoscience research laboratories (UT/MESA+, TUD/Kavli, FOM/AMOLF) have expanded their nanoscience research programmes. Open innovation center Holst and Energy Research Center of the Netherlands also gained strength in the same period. In addition, two new nanoscience institutes (TUD/QuTech, FOM/ARCNL) have been founded. In parallel, several joint academic/industrial research projects and programmes have been initiated (FOM-IPP, STW Perspectief, TKI, etc.), in addition to a new NWO Nanoscience programme. Furthermore, NanoNextNL has played a leading role in updating and positioning of the National Nanotechnology Roadmap as part of the Top Sector High Tech Systems and Materials. Finally two routes of the Dutch National Research Agenda ('Nationale Wetenschapsagenda', NWA), the 'Quantum/nano-revolution' and the 'Materials - Made in Holland' route were chaired by researchers from NanoNextNL and many researchers from the programme are involved in other Dutch NWA routes.

Overall, nanoscience and technology research has become firmly embedded in the Dutch scientific research landscape. The strong network of collaborators is also clear from an analysis of the network of joint authorships of NanoNextNL publications. Overall, the number of collaborative papers between research groups involved in NanoNextNL more than doubled in the period 2011-2016 compared to the period 2005-2010. In addition, 21% of all publications involved a collaboration with industry.

### Lessons learned, future opportunities

- A technology-driven research and development programme such as NanoNextNL can deliver scientific results at a very high level, see Fig. 3.
- The large-scale programmatic approach of NanoNextNL has created a strong network of collaborating nanoscience and technology researchers that is ready to address future challenges.

### Selection of NanoNextNL journal covers



Fig. 3 Journal covers with NanoNextNL results from project leaders Dekker, Engelen, Huskens, Koenderink, van de Meent, Polman, Stimberg, Velikov.



**Innovation:**  
creating business  
from technology

**3**

# Innovation: creating business from technology

Advancements in nanotechnology research will not automatically lead to novel products and services addressing future societal challenges and consumer needs. One important mission of the NanoNextNL programme has been to accelerate the transfer of knowledge from nanoscience and technology into the creation of new applications and business. This was first of all realised by the fact that 110 companies contributed to NanoNextNL (total budget for industrial research: € 91 million). Their research and development, partly funded by NanoNextNL (this applies to 92 companies) and carried out with the academic

partners of NanoNextNL, is directly linked to the development of new products and technologies (Fig. 4). Furthermore, academic partners of NanoNextNL have realised over 86 demonstrators and prototype devices that can lead to commercial products. NanoNextNL has executed a dedicated and innovative business development programme that stimulated the development of 24 business cases. The possibilities for starting new companies from these are currently being explored, so far 18 start-ups have been realised and 6 start-ups have been able to strongly benefit from the programme (Fig. 5).

## New start-ups that have resulted from NanoNextNL and existing start-ups exploiting IPR created in this programme and predecessors



Fig. 5 A total of 18 start-ups have emerged from the NanoNextNL programme and 6 start-ups have been able to strongly benefit from NanoNextNL. These new start-ups and existing start-ups benefit from the intellectual property rights (IPR) and other knowledge created in this programme and its predecessors.

“This funding allowed us to develop faster than we would have done without it. In addition the consortium gave valuable advice when we were considering the development of new products and solutions”  
Chemtrix BV

## Examples of product innovations from industrial NanoNextNL participants



“At Philips, working together with universities and other companies, we developed a new sensitive method within NanoNextNL to measure proteins, so that heart infarcts, psychological disorders or brain damage can be diagnosed with a finger prick of blood” - Matthias Irmsher

“At FutureCemistry we have developed a scalable process within NanoNextNL for the production of nanoparticles using raw materials. These have a wide range of applications” - Pieter Nieuwland



“At Unilever, we can now tailor-make spheres that can provide colour to drinks and food. With the new method developed within NanoNextNL the colour remains stable. And because the particles that carry the pigments are so microscopically small, the liquid remains transparent” - Krassimir Velikov

“FEI has worked with several different partners within NanoNextNL. These interactions have provided several new ideas for innovative microscopy products that we are now developing further” - Frank de Jong

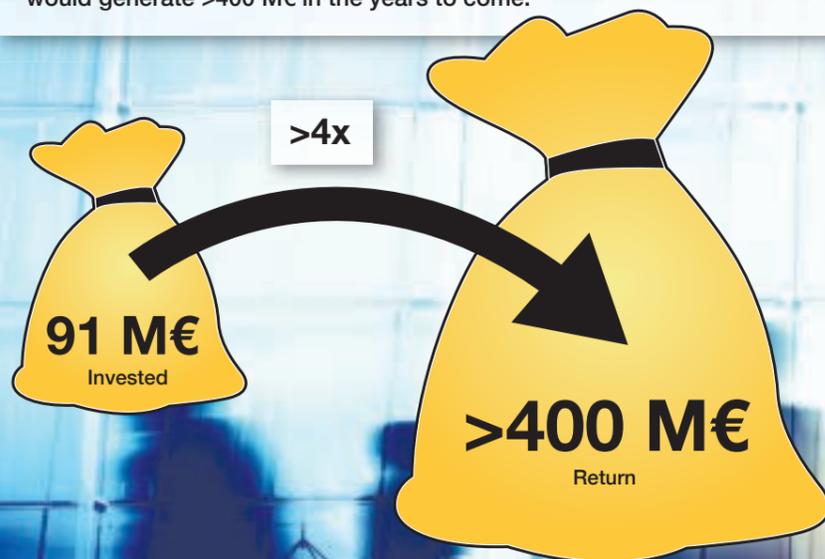


Fig. 4 Several examples of product innovations of the NanoNextNL programme.

# NanoNextNL's industrial research led to a 4-fold return-on-investment

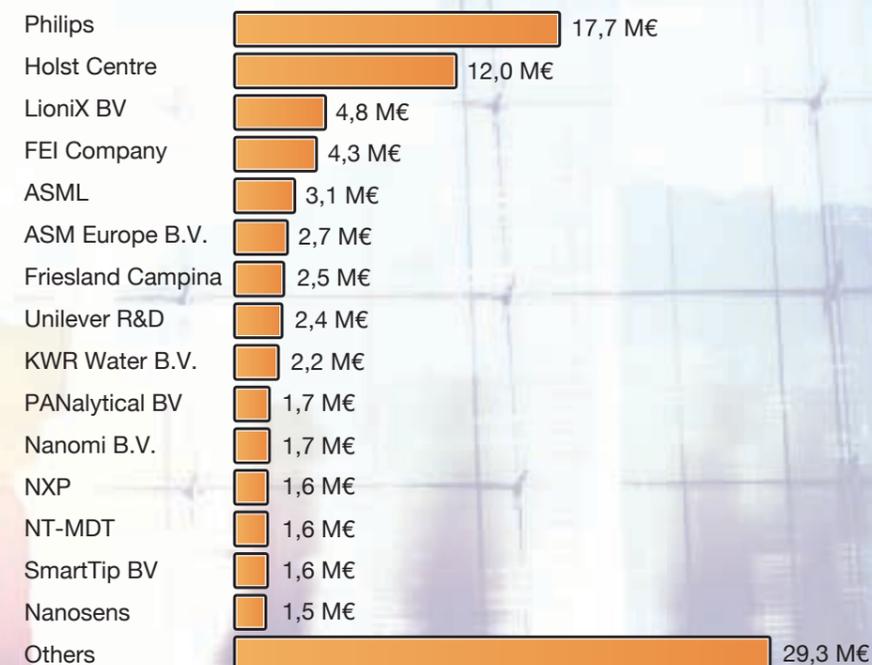
## Return-on-investment

When extrapolating the expectations on the return-on-investment, the 91 M€ invested in industrial NanoNextNL research (subsidy + matching) would generate >400 M€ in the years to come:



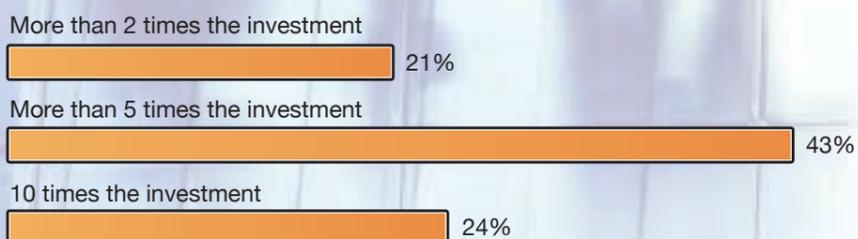
## Financial investments

A total of 110 companies were involved in NanoNextNL. Their total budget for this programme was 91 M€ of which 40 M€ was subsidy.



## Companies' expectations

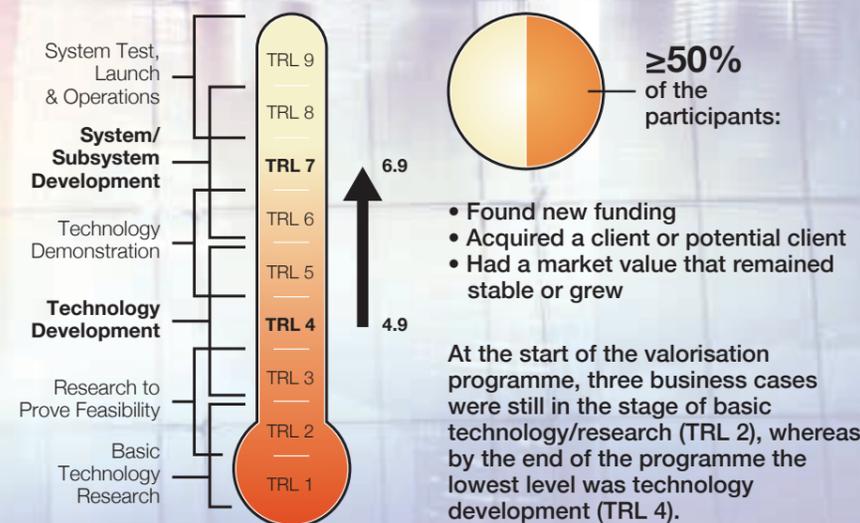
A large majority of the companies expects a substantial net return-on-investment of the NanoNextNL funding (subsidy + matching):



The average reported return-on-investment (weighted by subsidy received from NanoNextNL) is more than a factor 4. This is similar to for example the return-on-investment reported by Philips (4.1 between 2013 and 2015). It is considerably higher than the factor 1.3 benchmark average reported by Frontier Economics.

## Results valorisation programme

Participants in the NanoNextNL valorisation programme state that the average Technology Readiness Level rose from technology development (TRL 4.9) to system development (TRL 6.9).



## Results from an inventory under companies involved in NanoNextNL

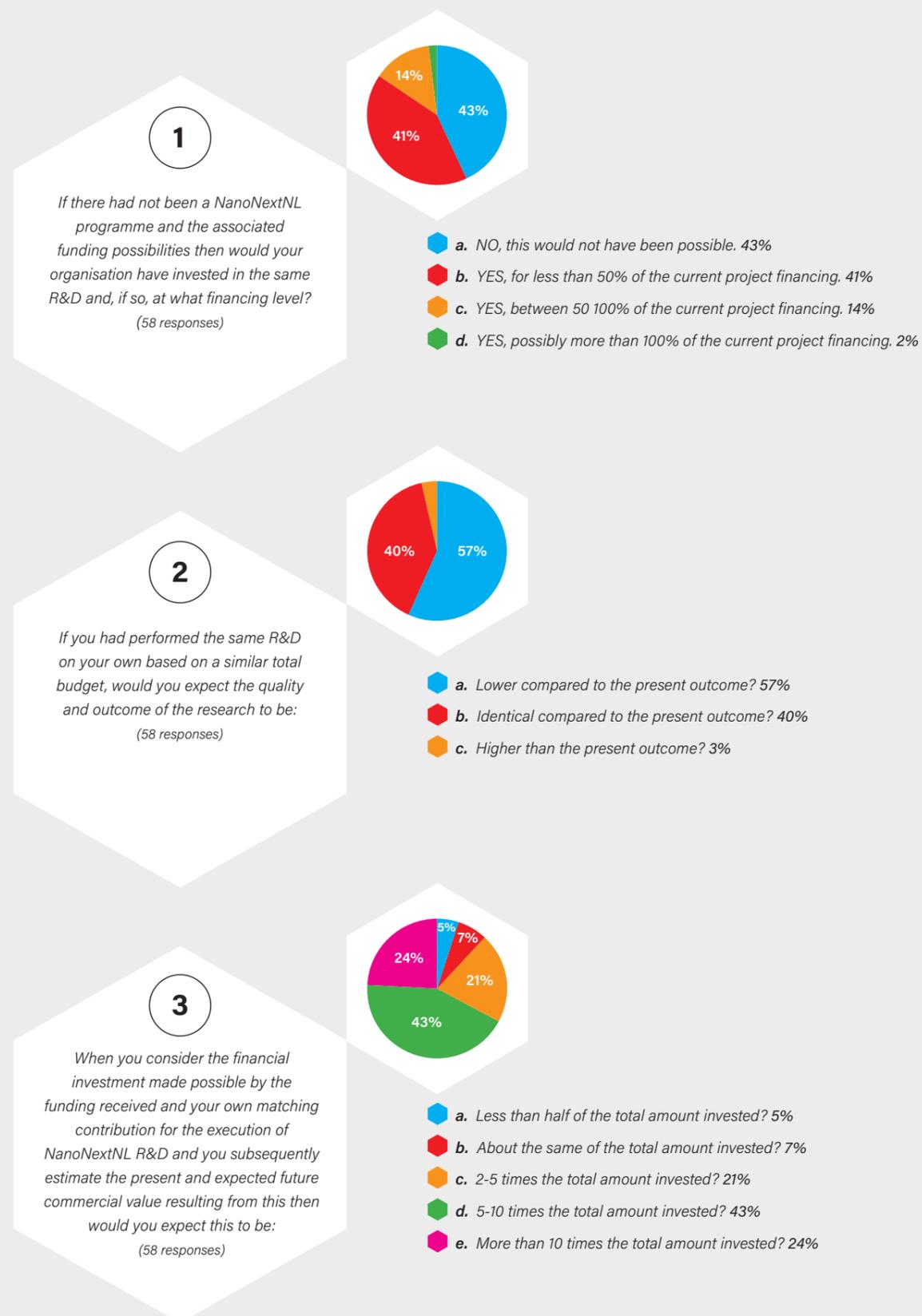


Fig. 6 A total of 92 NanoNextNL companies (58 respondents) were asked about the role of NanoNextNL on the size and quality of their research and development.

### Return on investment for industrial partners

In March 2016, an inventory was held under the 92 companies directly involved in NanoNextNL (response: 58, Fig. 6) to inquire about the role of NanoNextNL on the size and quality of their research and development. Three key results of this inventory are:

- If there had been no funding from NanoNextNL 43% of the companies would not have carried out the same research at all; 41% would have carried it out at a level lower than half the NanoNextNL level.
- A total of 57% of the responding companies stated that if they had performed the same research on their own budget the quality would have been lower than through the NanoNextNL collaboration. Almost all companies place high value on the R&D leverage provided by the NanoNextNL programme and the quality of research generated in collaborative fashion.
- A large majority of the companies expects a substantial net return-on-investment from the NanoNextNL funding (subsidy + matching), ranging from more than 2 times the investment (21%) to more than 5 times (43%) or even more than 10 times the investment (24%). The average reported return-on-investment (weighted by subsidy received from NNNL) is more than a factor of 4. This is similar to the return-on-investment reported by Philips (4.1 between 2013 and 2015) for example. It is considerably higher than the factor of 1.3 benchmark average reported by Frontier Economics (*Rates of return to investment in science and innovation*, White Paper 2014).

If the expectations on the return-on-investment are extrapolated, the 91 M€ invested in industrial NanoNextNL research (subsidy + matching) will generate a business value of over 400 M€ in the years to come.

For NanoNextNL as a whole, this amount should be supplemented with revenues that will appear on a longer time scale from two additional sources. First of all, start-up companies that result from the business plans developed within NanoNextNL will create future revenues. Second, long-term research carried out by the academic NanoNextNL partners will generate business on a longer time scale,

through future NanoNextNL-type programmes and other academic/industry collaborations. The ecosystem developed through NanoNextNL will strongly help the realisation of such long-term revenues.

### Business incubation and acceleration, patent applications

In 2014, the NanoNextNL Valorisation Programme was initiated to identify, nurture and develop product and business ideas that resulted from scientific and technological research within NanoNextNL. State-of-the-art business tools such as the Lean Business Model Canvas and related online software tools such as the Golden Egg Check (Fig. 7) were employed to help NanoNextNL researchers shape their ideas into business cases and to attract funding from investors. Continuous support was provided to business case owners to help improve and validate their business cases. These business cases were then evaluated by a Business Council that was composed of expert scientists, investors and other professionals, all external to NanoNextNL. A total of 62 business ideas were submitted, of which 36 were evaluated and eventually 24 were selected for a Valorisation Grant (total budget € 5.47 million, of which 48% subsidy, average € 227,970 per business case, see Fig. 8). The business plans covered a wide range of product solutions, including biomedical sensors, targeted drug therapy innovations, novel cell isolation and culturing techniques, and gas composition analysis instruments. The Business Council rated the overall quality of the business cases as very high, as represented by the fact that 65% of the evaluated business plans was selected for a Valorisation Grant. A survey among the business case owners revealed that more than half had succeeded in acquiring additional funds and had acquired at least one client or potential client. For more than half of the business case owners, the original estimated market value had remained the same or had risen. The average Technology Readiness Level (TRL) rose during the course of the Valorisation Programme from 4.9 (technology development, validation in a laboratory environment) to 6.9 (system development, a system or prototype is tested in the relevant working environment).

The NanoNextNL Programme has yielded a total of 127 unique patent filings. Normalised by the total budget of NanoNextNL the patent-filing-over-budget ratio was 15 times higher than the

average within the EU FP7 programme. The majority of patents reported were filed by the academic partners of NanoNextNL. It is very likely that not all patents filed by industrial partners on inventions that (partly) resulted from NanoNextNL research were reported and so the actual number of filed patents from NanoNextNL is probably even higher still.

Another reflection of the business generated was visualised at the NanoCity 2015 and 2016 events

where in total 57 of reported 86 demonstrators, tangible results of the NanoNextNL programme, were displayed (for an impression see Fig. 9).

**Lessons learned, future opportunities**

- When turning a successful idea into a business plan, researchers focusing on academic and technology-driven research can strongly benefit from the advice from successful entrepreneurs in an early stage of the programme.

**"For pharmabiotechs like us, these grants and subsidies are very supportive for obtaining major financial funding from VCs and licence income from pharmaceutical companies"**  
**BiOrion Technologies BV**

Example of Golden Egg Check for the evaluation of business plans developed within NanoNextNL

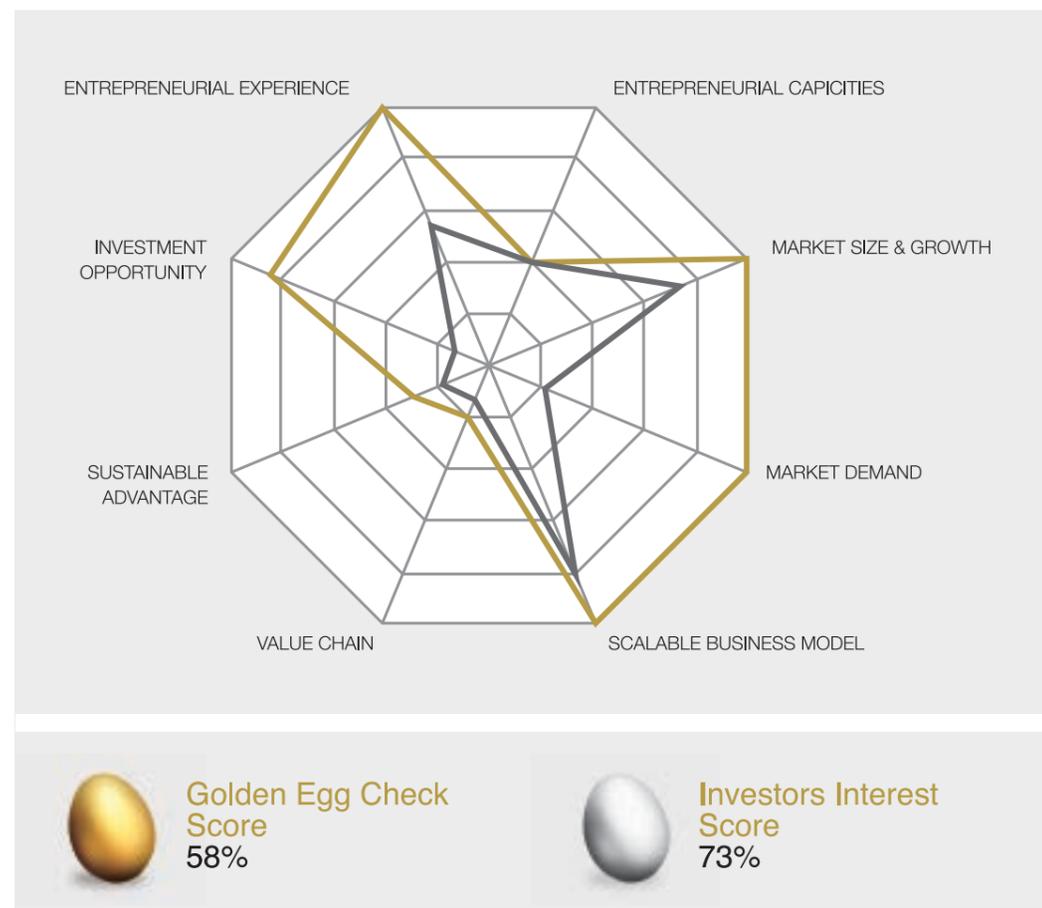


Fig. 7 The Golden Egg Check was used as an online software tool to shape ideas into business cases and to attract funding from investors.

Industrial matching for each of the 10 NanoNextNL themes

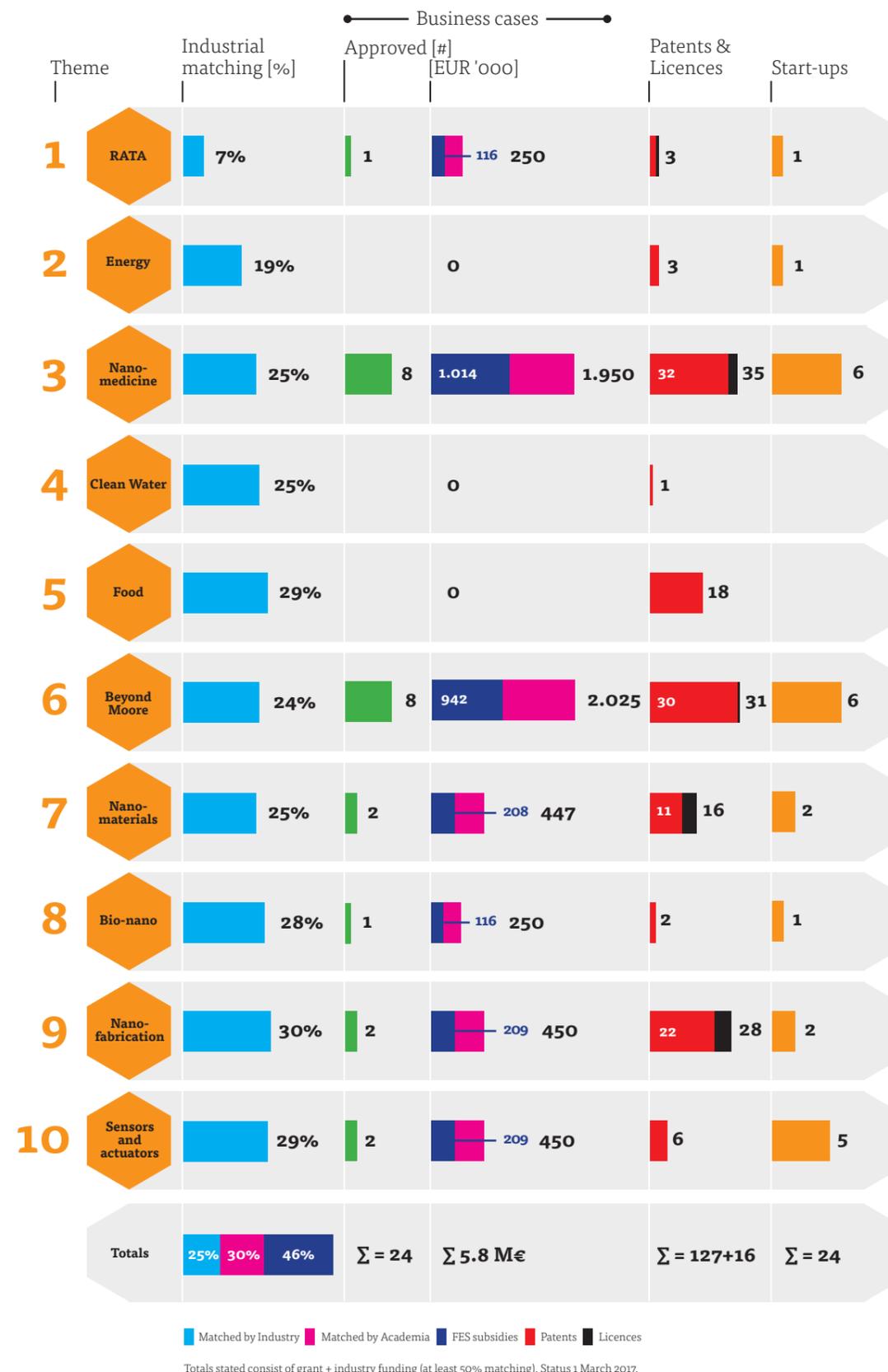


Fig. 8 Industrial matching for each of the 10 NanoNextNL themes; number of approved business cases; subsidy for awarded Valorisation Grants; number of patents and licences; start-up companies associated with the themes. Totals stated consist of grant + industry funding (at least 50% matching). Status 1 March 2017.

- The Business Council started ranking business cases in the fourth year of NanoNextNL. Given the high quality of the business cases presented at that time (65% awarded with a Valorisation Grant) additional successful business cases could have been submitted in earlier years as well. In future programmes, a valorisation programme should start at an early stage of the programme.
- Industrial partners were not always able to report their achievements from the NanoNextNL projects due to time-to-market pressure. Patents on results obtained (partly) through NanoNextNL research may not always have been reported as output. This is also probably due to conflicts of interest with partners within the collaboration agreement.
- NanoNextNL has led to a strong ecosystem of academic and industrial collaborators, setting an example for how to create business from research. As one of the industrial partners stated: "this network should not be wasted"

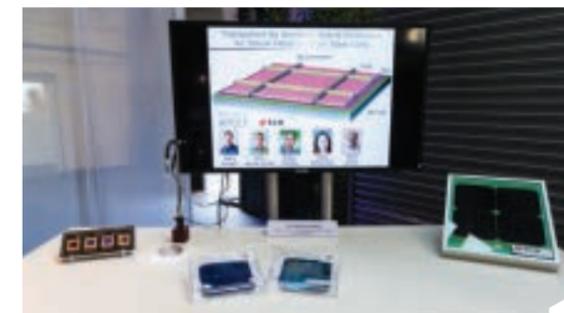
More than half of the 23 business case owners found new funding and estimate that the market value remained the same or had risen compared to the market value at the start of the Valorisation Programme. Half of the business case owners already have one or more clients or are negotiating with potential clients. Finally, the average technology readiness level (TRL) of the business cases rose. At the start of the Valorisation Programme the average TRL was 4.9 (technology development) and this rose to an average of 6.9 (system development) by the end of the Valorisation Programme. At the start of the Valorisation Programme, three cases were still in the stage of basic technology/research, whereas at the end of the Valorisation Programme the lowest TRL level was technology development.



"NanoNextNL type of research funding opens possibilities for companies to do background research, which is not possible internally (capacity and expertise wise). It also opens new opportunities / new insights through a network of other companies and research institutes" **Darling Ingredients International**



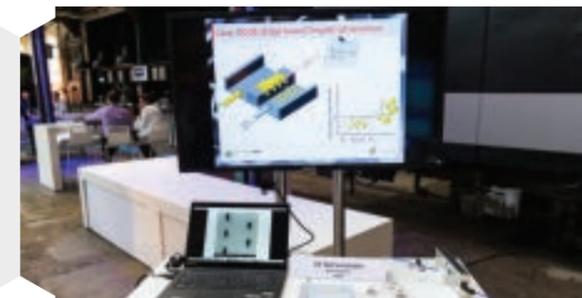
Demonstrators from academic and industrial NanoNextNL participants presented at NanoCity 2015 and 2016



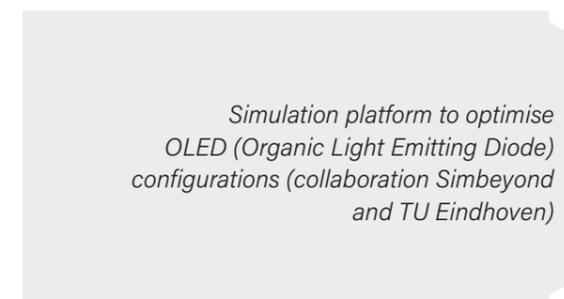
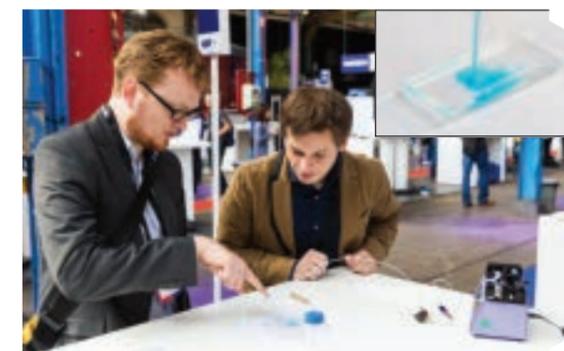
*Transparent conducting nanowire coatings serve as transparent contacts on solar cells, replacing expensive and brittle ITO films (collaboration AMOLF, ECN)*



*EDGE chip designed to generate perfect emulsions for amongst others the preparation of food products, cosmetics, paints (Wageningen University)*



*Computer-designed 3D printed microreactor (close-up in insert) with optimised geometry (TU Delft and TU Eindhoven)*



*Simulation platform to optimise OLED (Organic Light Emitting Diode) configurations (collaboration Simbeyond and TU Eindhoven)*



*Scaling-up possibilities for a coating technique to protect battery components and the production of high-value catalysts (Delft IMP)*



Fig. 9 Examples of demonstrators of academic and industrial partners of NanoNextNL that were presented at NanoCity 2015 and 2016, the NanoNextNL network event. A total of 48 demonstrators were displayed.



**Responsible  
research and  
innovation**

**4**

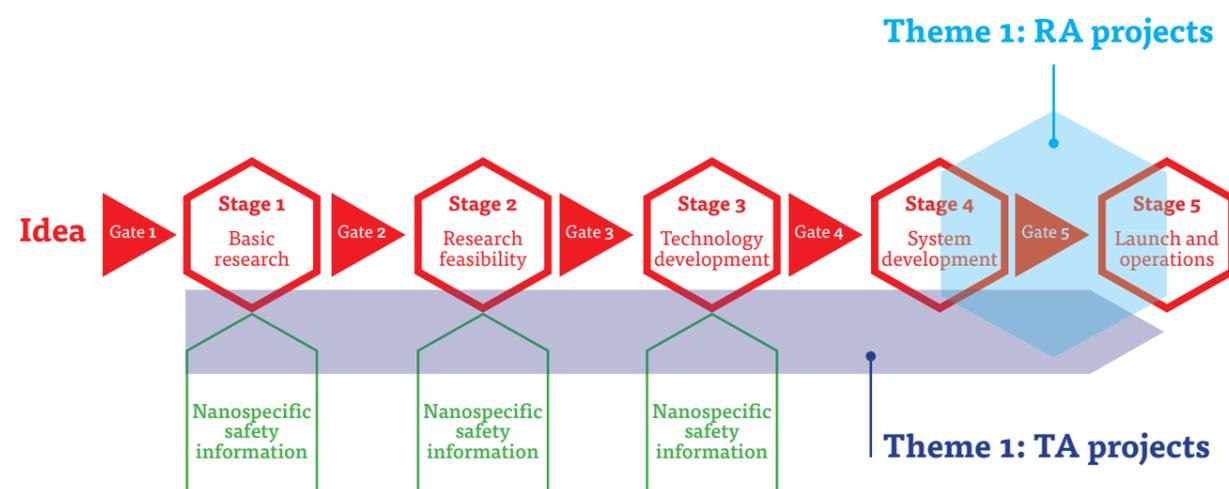
# Responsible research and innovation

A clear view on safety for people and the environment is critical for the development and commercialisation of nanotechnology and its products. Responsible research and innovation was therefore a key aspect of NanoNextNL. Risk Analysis and Technology Assessment (RATA) have been designed as integral activities of the entire research programme; 18% of the NanoNextNL budget was awarded to RATA-related themes. In this theme, an effort was made to consider new and existing safety issues associated with nanotechnology as an integral part of innovation models, such as the Stage-Gate innovation model, see Fig. 10. NanoNextNL offered a unique ecosystem to explore how to put concepts of responsible research and innovation into practice. Within the

RATA theme knowledge and tools for detection of nanomaterials and understanding mechanisms of (eco) toxicity were developed to support regulatory questions, fuelling directly into national and international policy discussions. Collaboration between RATA and projects in the other research themes was established to create awareness for the important role of RATA in nanoscience research and nanotechnology and to support innovators with relevant information and knowledge to develop safe products in a responsible way. RATA courses contributed to a new generation of young scientists and engineers, trained in responsible innovation. Moreover, RATA was also positioned as an integral part of the Lean Business Model Canvas, thereby reducing uncertainties and creating more robust business cases.



## Positioning of RATA within Stage-Gate innovation model



**Fig. 10** The two-fold role of RATA within NanoNextNL within the Stage-Gate innovation model developed by Cooper (<http://www.prod-dev.com/stage-gate.php>). Technology assessment is applied to explore possible routes and barriers in the entire chain from basic research to marketed products. Usually safety information is gathered in the stages nearing market application. Within NanoNextNL it was explored how responsible innovation could be stimulated by integrating safety from the early stages of innovation onwards.



RATA research has provided pivotal input to European research agendas on nanosafety, such as the Regulatory Research Roadmap and the Closer-to-Market Roadmap in the EU NanoSafety Cluster

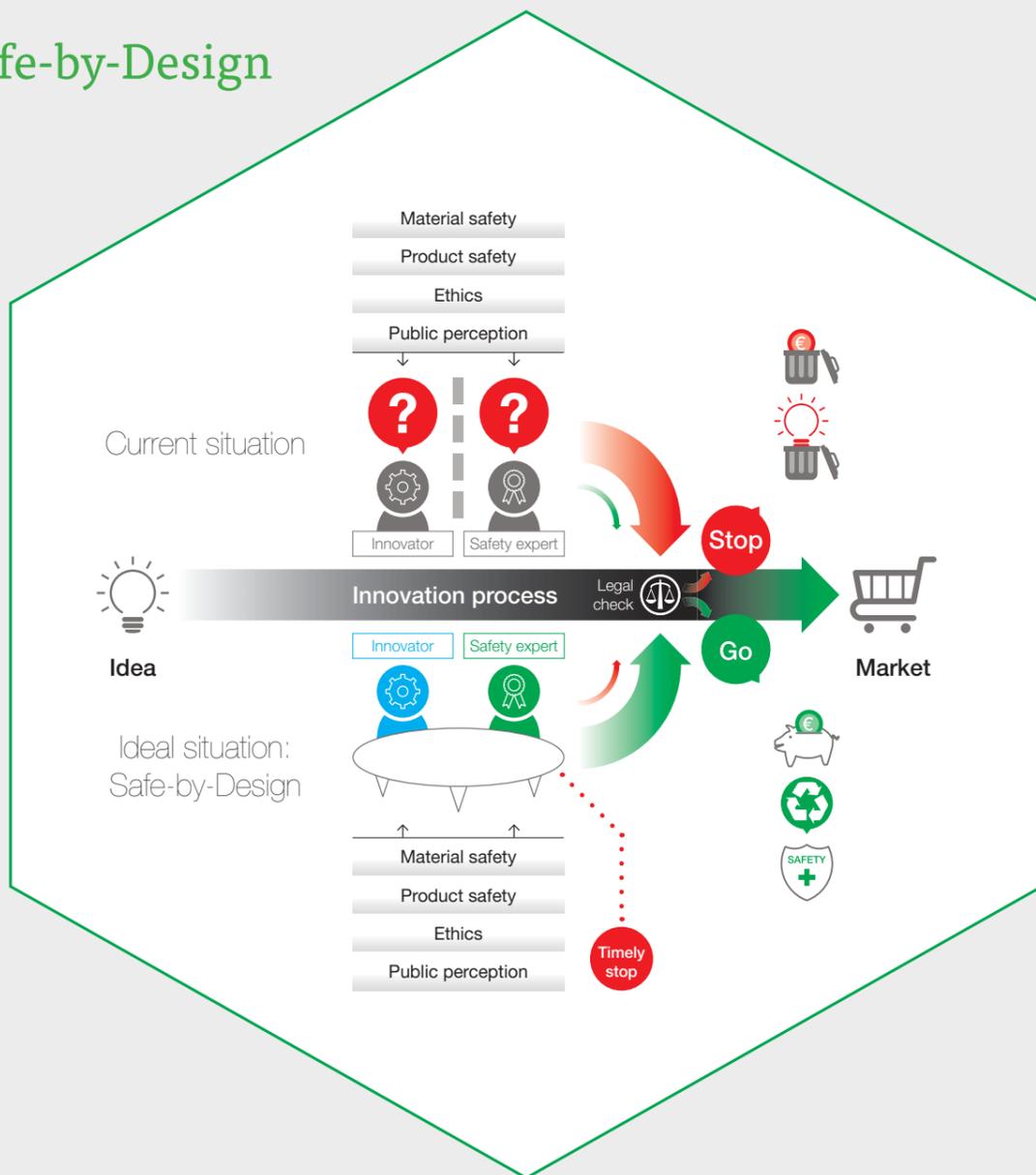
### Nanotechnology: safe development and use of nanotechnology

NanoNextNL was initiated in a time when concerns were expressed in our society about (perceived) risks related to the introduction of nanotechnology and its products into our daily lives. When the NanoNextNL proposal was drafted, the Dutch Parliament requested that at least 15% of the budget be allocated to RATA in order to stimulate the further responsible development of this promising technology. At the same time, there was also an urgent need to provide safety and health regulators with insights into the potential risks of nanomaterials in products that were already on the market. Sound knowledge on nanotoxicology was lacking at that time and reliable methods to test

nanomaterials for (eco)toxicity were insufficiently available.

Within NanoNextNL, the RATA theme developed toxicological insights, analytical methods and new analytical equipment to detect nanomaterials. In parallel, learning from collaborations between RATA and innovators, the development of a novel Safe-by-Design concept was initiated. This concept provides guidance on how to take safety aspects into account during the early stages of development of nanotechnology and especially nanomaterials. Together with the Dutch-coordinated EU-flagship project NANoREG a safety screening strategy for early stages of innovation was designed and explored for its applicability.

# Safe-by-Design



## Risk analysis: supporting health regulators and industry

The risk analysis projects in NanoNextNL developed insights and support for regulating nanomaterials. The results of these projects were coupled to more regulatory oriented projects like NANoREG and other EU projects, thereby forming a sound scientific basis for further development of applications for regulatory testing. RATA also developed nano-specific versions of risk management tools for industry and regulators.

The programme on environmental risks led to the development of analytical methods (e.g. detecting

fullerenes, nanoparticles), to improved insights in the environmental fate of nanoparticles depending on environmental circumstances, and to the acquisition of insights into the effect of nanoparticles on soil organisms. Several international collaborations were established such as the specialist group "Nano and Water - Application of Nanoparticles, Nanoengineered Materials and Nanotechnology" within the International Water Association (IWA), and a global advisory group on nanotechnology within the Society of Environmental Toxicology and Chemistry (SETAC). The programme on human health risks focused on measurement strategies for determining exposure of people who work professionally with commercially available

# NanoNextNL developed unique Safe-by-Design tools ready for application in science and industry

**Tool 1**

**Technology assessment tools**

With these tools insights into the economic, societal, ethical and legal aspects can be gained at an early stage in the development process. The tools are classified according to the development stage and applications. For more info: [www.cta-toolbox.nl](http://www.cta-toolbox.nl)

**Researchers and technology developers**

**Project phase**

Early Advanced

**Properties**

Broadening Engaging Anticipating

**Tool 2**

**Safe-by-Design for entrepreneurs**

As part of the valorisation programme, business case owners have been asked to perform a safety and society check by placing arrows to estimate the risk.

**Starting entrepreneurs**

**Safety | Society**

Low risk — A — B — C — D — E — High risk

**Look at the Safe-by-Design tools**  
[www.nanonextnl.nl/safebydesign](http://www.nanonextnl.nl/safebydesign)

**Safety & Society**  
Risk levels for safety and society are indicated with arrows based on expertise of business case owners and an independent expert; left for safety and right for society.

**Tool 3**

**Safety and Society Check**

The Golden Egg Check, an online tool used within the valorisation programme, has been extended with innovation models based on the Stage-Gate model for risk analysis and technology assessment.

**Entrepreneurs**

**Tool 4**

**Societal Incubator**

It is the intention that representatives from business, science, government and civil society discuss societal responses and challenges to nanotechnology. This experimental tool is used to explore the sentiments of involved stakeholders and is under construction.

**Interaction with society**

**Toolbox**

**NANoREG - EU Flagship project on Regulatory Issues and Nanosafety.** Close collaboration between NanoNextNL and NANoREG fostered development of the Safe-by-Design tools.



nanomaterials, e.g. in construction or manufacturing, and of consumers using nanoproducts. In parallel, a device to measure airborne nanoparticles was developed.

Most recently, knowledge gained in RATA programmes on environmental 'nanofate' processes and on human exposure to airborne nanoparticles was recognised by the European Chemicals Agency (ECHA) as relevant to supporting the development of their nanospecific exposure models that support REACH regulation. In addition, measurement techniques and instruments were developed for measuring exposure to nanomaterials at the workplace; TNO uses these to advise companies.

### Technology assessment

The Technology Assessment Programme aimed to perform in-depth studies of current developments in nanoscience and nanotechnology, to deepen insight into dynamics and governance of nanotechnology, to understand conditions of responsible innovation of nanotechnology and to interact better with society. It created the notion of a "societal incubator" to allow experimentation and collective learning in various areas of nanotechnology. A societal incubator is an analogue of a business incubator where a research finding is guided towards a commercial product. Here a range of applications in a pre-commercial phase is collectively investigated for its societal acceptance, thereby supporting the robustness of a business case. The Rathenau Institute (The Hague) has been commissioned to develop the approach further and has published a report in Dutch entitled 'Van draagvlak naar meer – Ontwerp van een maatschappelijke incubator voor beloftevolle (nano)technologieën' that describes the experiences with such a societal incubator.

Within RATA, awareness has grown for the benefits of linking technology assessment and risk analysis

activities. Technology assessment helps to gain insight in potential pathways of innovations and identifies hurdles for innovators or regulators to support further steps of innovation. In NanoNextNL such an exercise was performed for cases in the Food, Energy and Nanomedicine themes. It helped to identify whether the lack of information on human and environmental safety formed an obstacle for investors to support the creation of start-ups, for example.

Furthermore, a toolbox for technology assessment was developed consisting of six publicly available tools. This toolbox supports researchers, technology developers and engineers to consider and integrate economic, societal, ethical and legal aspects in the development process. An overview of the tools developed is provided on the website [www.cta-toolbox.nl](http://www.cta-toolbox.nl). This overview also states whether a specific tool is suitable for early stages of development when the technical details and applications are not yet clear, or whether it is instead suitable for later development stages when more is known about the technology and its possible applications. In addition, it is stated whether the tools lead to a broadening of the research focus, to insights in future developments and implications, or whether the tool can be used to further engage interested parties.

Researchers from this programme have also supported the WODC (Research and Documentation Centre) of the Ministry of Security and Justice in investigating the significance of nanotechnology for civil security applications. Examples of this are detection technologies for synthetic drugs and illegal drugs laboratories to support the work of the police and detection methods for biological traces to support forensic research. As sensors can be manufactured in increasingly smaller sizes, it is now possible to develop portable detection methods.



**"As a result of the knowledge we gained in the RATA domain we are now emphasizing some extra unique selling points of our product Carin, a solution to prevent incontinence"**  
**Valer Pop, LifeSenseGroup**



**"The RATA innovation cycle has not only helped us in identifying and addressing possible risks at an early stage, but it also gave us tools to calculate the net environmental impact of our product"**  
**Jasper van Weerd, LipoCoat**

Another example of the application of nanomaterials is protective clothing for fire-fighters and police officers. By integrating new materials and sensors in clothing, the location and physical wellbeing of individuals can be monitored. Nanotechnology can also have an added value in the area of identifying people and verifying the genuineness of official documents such as proofs of identity, visas and money. It is possible to fabricate unique identification and authentication characteristics that cannot be copied using the currently available technology. Finally, technologies with civil applications are also vitally important for defence purposes, although stricter requirements apply here with respect to the robustness and usability under different conditions.

### NanoNextNL's RATA research sets an example

RATA expertise developed within NanoNextNL is valued very highly at an international level and RATA researchers are regularly invited to share their expertise and views in European research projects, for example in the H2020 research programme on Nanomaterials and Biotech products (NMBP); that now participates in a dozen EU projects. The high quality of the RATA research is also apparent from the high citation impact (1.26) of the publications in peer-reviewed international journals. RATA research within NanoNextNL has provided pivotal input to European research agendas on nanosafety, such as the Regulatory Research Roadmap and the Closer-to-Market Roadmap in the EU NanoSafety Cluster. The RATA programme actively participates in two EU projects, NanoDiode and SeeingNano, which are aimed at supporting the societal dialogue on nanotechnology. Researchers from the RATA theme of NanoNextNL have participated in about 30 EU projects, including several recently started projects, such as Calibrate, NanoReg2 and FIT4RRI.

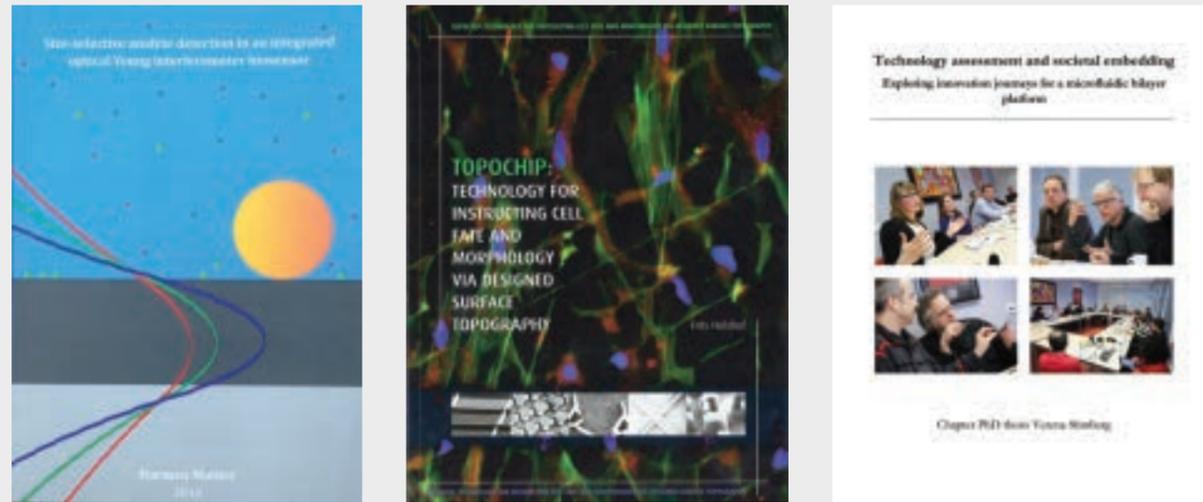
### Safe-by-Design

The "Safe-by-Design" concept as developed by RATA partners aims to use inherently safe materials and products during the entire design phase. It puts the focus on identifying potentials for health risks by means of a safety screening strategy. Moreover it stimulated the identification of nanomaterials or products with the lowest inherent toxicity and the highest functionality. These kinds of materials and products are more likely to be compatible with requirements for application in a circular economy. For example, nanomaterials that do not tend to accumulate in the body but are stable enough to be applied in a coating have a better Safe-by-Design profile than a comparable compound that does tend to accumulate in the body.

Based on experiences in NanoNextNL, RIVM developed a Safe-by-Design concept and a safety screening strategy that allows innovators to check their products for potential safety issues from the early phases of innovation onwards. The previously mentioned Flagship NANoREG project was another essential link for successful development. Together with PhDs from other themes the feasibility for implementation was tested. It became apparent that innovators already have information that is valuable for identifying potential safety issues. Early identification of potential safety issues in turn leads to more robust business cases. Exchange of expertise and views at an early stage of innovation is important and such an interaction supports rather than kills innovation.

Four participants of the Valorisation Programme of NanoNextNL gave several concrete examples of the added value of RATA for the development of their business cases. These business case owners stated that they are convinced of the added value of the RATA programme. They also believe it is important

### Examples of theses with a dedicated chapter on RATA



**Fig. 11** Three examples of NanoNextNL theses with a dedicated chapter on RATA. PhD thesis (H. Mulder, University of Twente, 2016) on optical biosensor based on metal nanoparticles, with dedicated RATA chapter on safety aspects (left), thesis of F. Hulshof with an appendix dedicated to social-technical RATA aspects of plastics for the culture of IPS cells (middle) and PhD thesis (V. Stimberg, University of Twente, 2014) on technological assessment and societal embedding for a microfluidic bilayer platform (right).

that researchers familiarise themselves with RATA. All four stated that the NanoNextNL programme has created awareness in the area of risk analysis and technology assessment. Furthermore, knowledge of RATA led to the identification of unique selling points for three of the four business case owners and to certification for two of the four business case owners.

#### RATA training in research and business development

RATA training was specifically developed for NanoNextNL research and business development. All educational activities were offered to the entire NanoNextNL community.

- The RATA course was compulsory for PhD students within four themes where RATA aspects were particularly important; many PhD students from other themes also followed the RATA course (total: 76 PhD students). Further encouragement of PhD students on RATA themes was realised by coupling PhD students with RATA experts and by facilitating intervision among groups of PhD students that integrate RATA studies within their thesis (see Fig. 11).
- Knowledge and insights from the “Safe-by-Design” concept developed within the RATA theme have played a key role in the NanoNextNL Valorisation Programme. A “Safety and Society” check was

### RATA as Safety & Society Check



**Fig. 12** RATA as Safety & Society Check incorporated into the NanoNextNL Lean Business Canvas. One of the many ways in which RATA became incorporated into the NanoNextNL Valorisation Programme in order to stimulate responsible innovation.

incorporated in the Lean Business Canvas and a RATA Life Cycle Analysis was incorporated in the Golden Egg Check, with the aim to further strengthen these business cases with responsible innovation (Fig. 12). NanoNextNL’s RATA research has led to seven business cases, ranging from safety consulting services to nanoparticle production. One of these cases has led to a start-up company.

- To further encourage innovation and to better anticipate societal barriers to new developments, NanoNextNL has taken the initiative to realise a Societal Incubator, which the Rathenau Institute is developing on behalf of NanoNextNL.

#### Lessons learned, future opportunities

- Through NanoNextNL, Risk Analysis and Technology Assessment (RATA) has been firmly established as a key concept that is essential for responsible innovation.
- RATA should be fully incorporated in research project descriptions that involve nanotechnology.
- RATA must be an integral part of business plans in order to develop products that contribute to a circular economy.
- The extensive RATA experience developed in NanoNextNL will be invaluable in future research and technology programmes that involve nanotechnology.

**Education:**  
training highly  
skilled innovators

5

# Education: training highly skilled innovators

Within the 28 NanoNextNL programmes, over 225 PhD students and over 135 postdocs, and 120 researchers at companies were or will be trained to become highly skilled scientific and technical specialists and innovators in the field of nanomicrotechnology. Training in intellectual property rights, valorisation, risk analysis and technology assessment, and entrepreneurship was an integral part of education within NanoNextNL. It is expected that around 140 NanoNextNL PhD students/postdocs will find a new job in industry or at high-tech knowledge institutes. NanoNextNL has therefore provided a very large new base of highly trained technical employees for industry and society. Vice versa, a large number of industrial researchers were exposed to research activities of the academic partners within NanoNextNL, providing them with scientific and technological insights they would not have acquired within their company alone.

## Training PhD students, master students, and postdocs

PhD students and postdocs who were trained within NanoNextNL were in a unique position. On the

one hand, their research projects focused on well-defined scientific and technological challenges. On the other hand, the strong interaction with industrial partners within all NanoNextNL programmes provided an environment focused on application-oriented research and product innovations as well as hands-on experience with intellectual property rights and patent applications. PhD students and postdocs have therefore received a training that is unique in breadth and depth, and which puts them in an excellent position to find a job in the high-tech industry. Furthermore, the PhD students and postdocs have supervised over 250 master students who carried out nanoscience and technology projects and are now trained in many aspects of nanotechnology.

## Training of industrial researchers

NanoNextNL has also provided many training activities for industrial researchers. Through programme and theme meetings and the NanoCity conferences, they have been exposed to a broad academic knowledge base, much broader than they would be exposed to in their company alone.



“Commercialisation of (fundamental) research is greatly helped by offering RATA, IP-awareness and valorisation courses. These courses make researchers (from PhD student to supervisor) aware of factors like risk evaluation, technology assessment and valorisation in the settings of their own work. Although commonly not found as part of the standard PhD training, these topics should be an imperative part of an academic training to ensure a sustainable Dutch research landscape.”

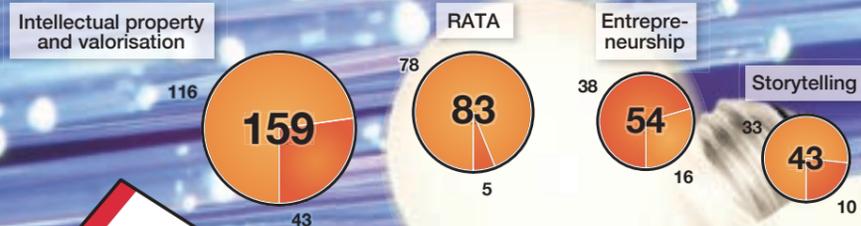
**Alan Rowan (Supervisor NanoNextNL course participants)**



# NanoNextNL provides highly skilled innovators who are valuable for Dutch industry

Number of NanoNextNL researchers that have followed courses

PhDs/postdocs Industrial researchers/others



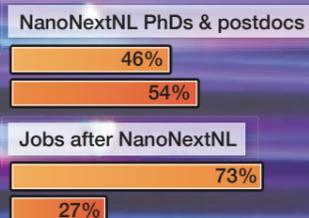
Distribution of jobs of NanoNextNL PhDs and postdocs that have finished their NanoNextNL project

Industry High-tech knowledge institute Academic institute



Number of PhDs and postdocs working in NanoNextNL that is originally from the Netherlands/abroad

From the Netherlands From abroad



"I should have done this Entrepreneurship course six years ago when I started my company"- Luc Scheres (Surfix BV)

## Courses

The large size of the NanoNextNL programme with strongly interlinked programmes provided the opportunity to organise a dedicated programme-overarching educational track made up of several courses. These courses were specifically developed with IPecunia, De Proeffabriek, TIASNimbas Business School and Analytic Storytelling, all organisations with excellent know-how of their respective field. All courses were developed with a focus on nano and microtechnology. Furthermore, examples and exercises within the courses were developed with experts in the field. The following courses were offered:

- Intellectual property and valorisation: a two-day course focusing on the process of IP generation and economic and societal issues related to valorising research outcomes.
- Risk analysis and technology assessment: a one-day course focussing on risk analysis and technology assessment as they apply to nanotechnology.
- Entrepreneurship: a three-day course focusing on the key issues for successfully transforming ideas and inventions into marketable products.
- Analytic storytelling: a one-day course focusing on how to build a clear and convincing story from complex research content, tailored to specific audiences.

The course on entrepreneurship was followed not only by PhD students and postdocs, but also attracted strong participation from industrial researchers. The mix of participants (academic and industrial) at all courses always created an environment of interaction and exchange of ideas, and all courses were highly rated by the participants.

## Jobs after NanoNextNL

So far, well over 250 PhD students and postdocs have finalised their NanoNextNL project. They have found jobs in industry, academia or high-tech knowledge institutes (TNO, ECN, RIVM, IMEC, etc.). From a group of 258 PhD students and postdocs who have finalised their NanoNextNL project the distribution of jobs is given in the infographic (on the left). The majority of PhDs and postdocs (73%) have found a new job in the Netherlands. A little less than half of them have found a job in Dutch industry or in knowledge institutes and the other half went to academic institutions. Approximately half of the NanoNextNL researchers going abroad are PhD students who move on to a postdoc position at an academic institution. Extrapolating the data to the full cohort of over 330 NanoNextNL PhD students and postdocs, it can be expected that around 140 NanoNextNL researchers will find a new job in industry or at a high-tech knowledge institute in the coming years. A small minority (46%) of the PhD students and postdocs is of Dutch origin. Overall, NanoNextNL has led to a net influx of personnel to the Netherlands as a large majority (73%) finds a job in the Netherlands.

## Lessons learned, future opportunities

- The strong portfolio of dedicated courses developed by NanoNextNL will be invaluable in future research and technology programmes that involve nanotechnology.
- Courses on intellectual property and valorisation, risk analysis and technology assessment, and entrepreneurship are all an essential part of the training of academic researchers.
- Offering an entrepreneurship course right from the start of the research programme will maximise the conversion rate of research ideas to business.



**Added value  
of the  
NanoNextNL  
approach**



# Added value of the NanoNextNL approach

The NanoNextNL programme was a major initiative with a large number of participating universities, knowledge institutes, medical centres, SMEs and industries, covering a diverse set of topical programmes within a broad range of themes. The programmatic approach has created many benefits and advantages that would not have been achieved if the individual research projects or programmes had been realised independently. NanoNextNL has built up a unique and vibrant nano/microtechnology ecosystem at a scale that is unprecedented in the Netherlands and has set a new standard for public-private collaboration in the Netherlands and beyond. This nano/microtechnology ecosystem is ready to address future challenges that our society faces and should therefore be maintained.

## Nano/microtechnology ecosystem in the Netherlands

NanoNextNL was founded in 2010 as part of the FES programme for strategic investments funded by the income from natural gas exploitation in the Netherlands. Right from the start, NanoNextNL was set up as a collaboration between academic partners, knowledge institutes, SMEs and large national and multinational companies. Private and public partners worked closely together in defining the projects. NanoNextNL was the natural follow-up of the preceding NanoNed and MicroNed programmes that laid a strong basis for nano/

microscience and technology in the Netherlands. NanoNextNL coordinated its activities with other major national innovation programmes in the field of water, energy, medical and food research, such as Wetsus, TI-Pharma, Holst Centre, CTMM, BMM, ISPT, TiFN and M2i, and many collaborations have resulted from these interactions.

The very large-scale, public-private collaboration of NanoNextNL in various technology and application areas has led to unique results that would never have been achieved from a large number of independent projects. The integration of academic and industrial research within topical programmes has led to knowledge exchange between academia and industry, and vice versa, on a scale that would otherwise not have been possible. Furthermore, the strong interaction between programmes and between themes created new collaborations on multidisciplinary topics. Also, NanoNextNL as a consortium was an effective partner for the government in the provision of knowledge on societal and policy aspects related to nanotechnology.

Most importantly, NanoNextNL has led to the evolution of a unique national nano/microscience and nano/microtechnology ecosystem a self-strengthening network, based on an effective mutual exchange of knowledge is unique in the



Using the NanoNextNL method in a follow-up programme will guarantee a high-return-on-investment for Dutch industry and society and provides an efficient and effective road towards a more sustainable society

world. The Netherlands now has a very strongly interwoven network of academic scientists, technical researchers, and industrial innovators from many different disciplines who have developed close ties and now benefit from each other's expertise on a regular basis. Industrial companies that need specialised academic knowledge now know where to find it. Start-ups and SMEs have strongly benefited from programme meetings, which allowed them to expand their network and profit from new developments at partner organisations. And academic partners that generate invention disclosures now know which companies to approach to develop their ideas further. Furthermore, a nationwide technical infrastructure of nano/microfabrication and characterisation facilities has been set up from which all NanoNextNL partners: academic organisations, industrial companies, start-ups, and SMEs, continuously benefit.

Many additional valuable aspects to this ecosystem have been developed in the past few years. A dedicated business development programme was set up to stimulate the formation of start-ups and the development of new products. This programme has now evolved to a very high level, building on the experience of the evaluation of a large number of business cases that emerged from NanoNextNL. A unique aspect of NanoNextNL was the common attention for risk analysis and

technology assessment. Invaluable insights have been achieved for the evaluation of risks in nanotechnology research and product development, which have also proven to be essential in the development of business cases. Furthermore, a dedicated programme-overarching educational track was developed with specialised courses on intellectual property and valorisation, risk analysis and technology assessment, entrepreneurship, and storytelling.

While the NanoNextNL programme was being carried out, the Dutch government initiated the top sector policy to enable public-private partnerships for technology-driven research. This policy is translated into medium-term, industry-driven roadmaps for science and development within the top sectors. Nanotechnology was positioned as one of the two roadmaps crossing the various top sectors (together with ICT), which indicates the unique position of this technology. NanoNextNL has provided both the ecosystem which feeds and executes this roadmap, and the more visionary, long-term research for future innovations.

**NanoNextNL has built up a unique and vibrant nano/microtechnology ecosystem at a scale that is unique in the Netherlands and has therefore set a new standard for public-private collaboration in the Netherlands and beyond.**



“The great thing about NanoNextNL is that it bridges fundamental research and clinical practice”  
Gert Storm, Utrecht University

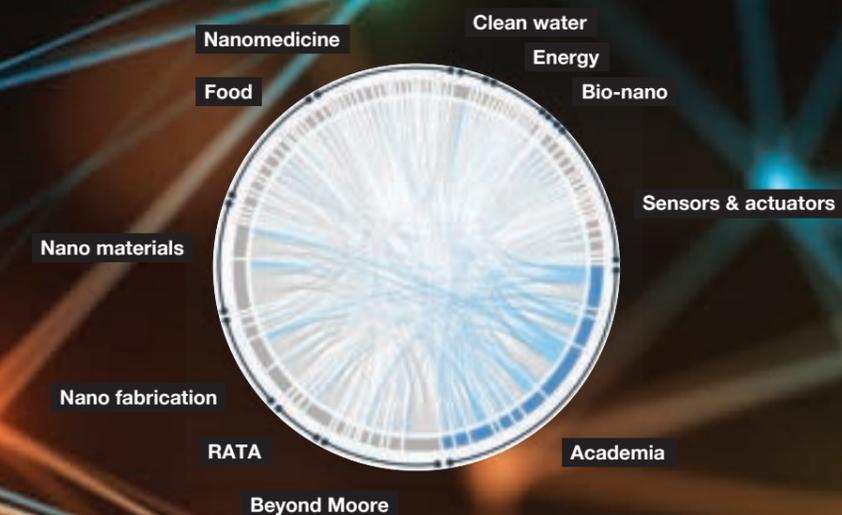


“There are not so many countries in Europe which are so deeply involved in nanotechnology as the Netherlands; a country that hosts fabulous institutions and an excellent infrastructure”  
Volker Saile, Micro and Nanotechnology Commercialization Education Foundation (VS)

# NanoNextNL has built a unique and ecosystem at a scale that is unique

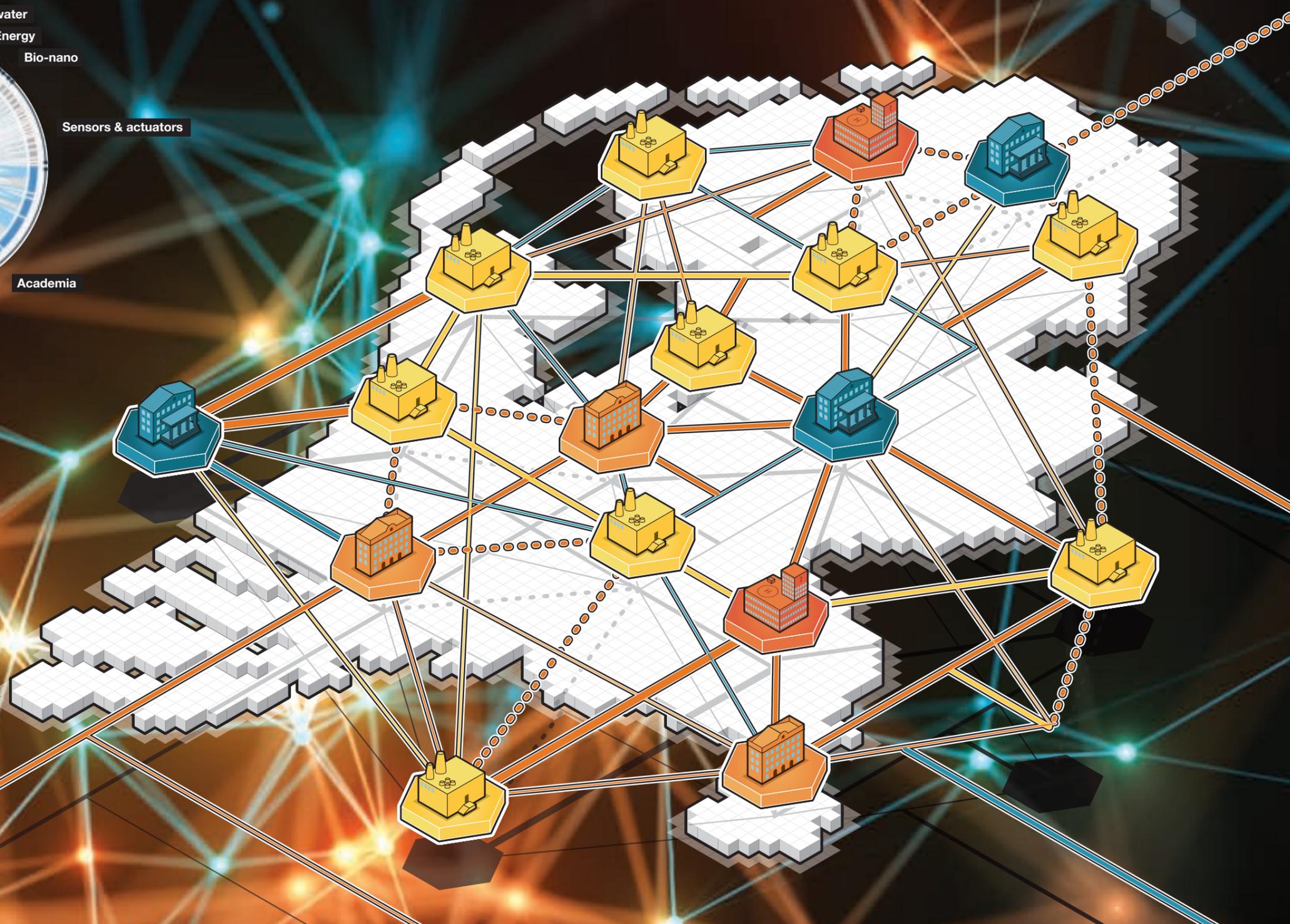
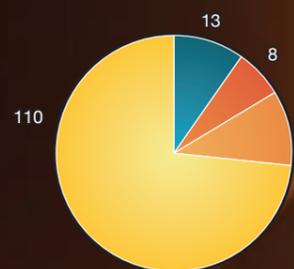
# vibrant nano/microtechnology in the Netherlands and beyond

435 multidisciplinary connections between academic and industrial partners



### Number of partners

- Universities
- Medical centres
- Knowledge institutes
- Industrial partners



### International initiatives

Right from the start, NanoNextNL has taken many initiatives to connect and collaborate with nano/microtechnology programmes and related business initiatives in other countries. NanoNextNL's mode of operation was therefore continuously benchmarked against that in other countries.

NanoNextNL presented itself on several occasions at the annual Nanotech fair in Tokyo and organised joint workshops with the leading Japanese nanotechnology organisation NIMS. Furthermore, NanoNextNL participated in the international COMS conferences on commercialisation of nano/microtechnology, and initiated an annual series of "NanoCity" events, where scientific results, demonstrators and prototypes from NanoNextNL research were presented. Participation in the biannual European NanoForum and Industrial Technology conferences of the EU further provided possibilities to exchange information and benchmark the NanoNextNL programme on a European scale. In 2016 this conference will be held in the Netherlands, in coordination with the NanoCity conference. NanoNextNL researchers had successfully applied for funding resulting in at least 95 granted EU projects (status March 2017).

In our interactions with international organisations it became clear that the NanoNextNL approach to nano/microtechnology research and innovation is unique at a worldwide level. In particular, the way in which public and private partners collaborate and share information to achieve common goals

and benefits is the main discriminator compared to the practice in many other countries.

NanoNextNL has actively explored possibilities to initiate joint major research programmes on nanoscience and technology in the framework of the European Horizon2020 programme. It was concluded that, while Horizon2020 provides many opportunities for networks of individual researchers collaborating on a single topic, the EU funding system does not enable initiatives that aim to create an ecosystem at the size of NanoNextNL or beyond ("NanoNextEU").

### NanoNextNL follow-up initiative

Compared to other countries, the Dutch investments in nano/microtechnology in recent years, normalised by the Gross Domestic Product, are high (Fig. 13) and amount to nearly the 0.04% of the GDP. Of course, the strong international position of the Netherlands in nano/microscience and nano/micro technology is due to consistent investments of the Dutch government over the years. This leading competitive position and the strong ecosystem developed by NanoNextNL can only be maintained if that funding is continued.

The NanoNextNL board is now actively exploring how the unique NanoNextNL ecosystem that has been built up can be used to target the new challenges that our society faces in areas such as energy, health, food, high-tech manufacturing, and more. Lessons learned from NanoNextNL have demonstrated the considerable benefit of an integrated approach, if the following guiding principles are applied:

- A new initiative should be composed of a limited number of well-defined themes that address key societal challenges, are defined in strong consultation with industrial partners and can build on the most successful activities within NanoNextNL.
- Each theme should be composed of a small number (2-3) of strongly interlinked programmes that are dedicated to well-defined challenges. Each programme is composed of collaborative projects between academic and industrial partners that are drafted in strong collaboration.
- Risk analysis should be integrated within each programme as it is drafted, and must remain integrated as the programme is carried out, focusing on responsible innovation through safe-by-design methods and lifecycle analyses.
- A significant fraction of the total budget (~20-30%) should be reserved to adjust the research programmes as they are carried out, to further stimulate exceptionally successful programmes, and to adapt to new developments and insights.
- The role of start-ups and SMEs must receive special attention during the drafting of the research programmes; their success and survival rate can strongly benefit from the programmatic approach.
- Several programme-overarching tracks which have been very successfully developed in NanoNextNL deserve a special role in a new initiative:
  - The dedicated educational track with specialised courses on intellectual property and valorisation, risk analysis and technology assessment, and entrepreneurship.
  - The dedicated business development programme, with an experienced Business Council that awards Valorisation Grants to promising business plans.
  - The series of innovative NanoCity conferences, as an important means to strengthen the ecosystem across focused themes and programmes.

Using the NanoNextNL method in a follow-up programme will guarantee a high-return-on investment for Dutch industry and society and provides an efficient and effective road towards a more sustainable society. The Board of NanoNextNL is now holding discussions with private partners, the Ministry of Economic Affairs and other government ministries to explore the possibilities of starting such a follow-up programme of NanoNextNL that will target these goals. In 2015, the Dutch National Research Agenda (NWA) was compiled and as part of this process the Dutch public were invited to contribute societally relevant research questions. The compilation of these questions has resulted in a total of 25 ambitious routes. Researchers from NanoNextNL played a leading role in the elaboration of two of these routes: the route 'Quantum/nanorevolution' and the route 'Materials - Made in Holland'.

As a follow-up to the NanoNextNL programme, six very successful themes were identified in which the Netherlands is a worldwide leader. Plans have been drawn up for public-private partnerships to further build upon this unique expertise and this knowledge network. The six so-called NanoInside themes are: 3D-Nanostructures and metrology, BioNano Devices, Food Body Interactions, Green ICT, Nanomaterials for Solar Energy, and Organ-on-Chips.

### Investments in nanotechnology as a fraction of GDP for various countries

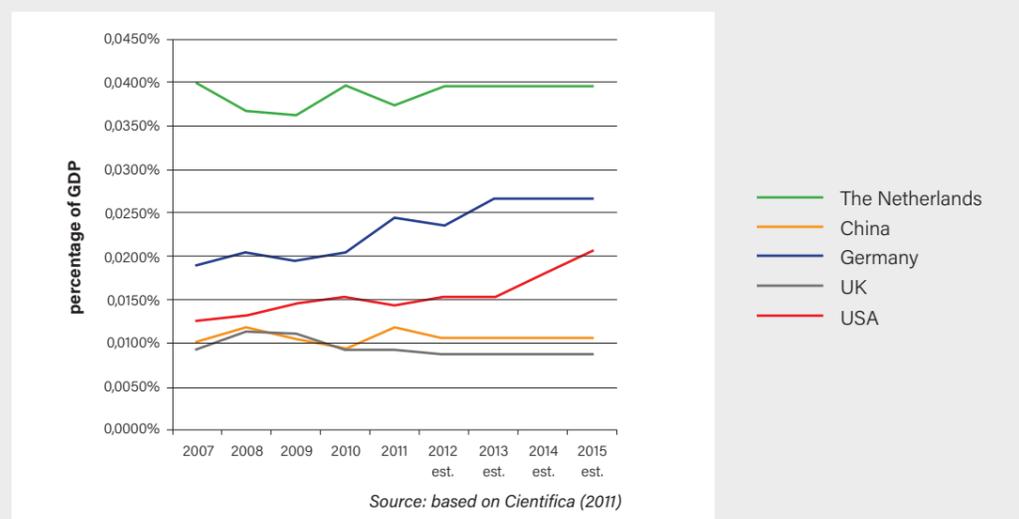


Fig. 13 National investments in nanotechnology as a fraction of GDP for five different countries.



The success and survival rate of start-ups and SMEs can strongly benefit from the programmatic approach

**NanoNextNL**  
**June 2017**

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**Infographics**

Ymke Pas (p.15, p.22, p.35, p.44, p.50)  
Robert Minnaard, Shootmedia (p.34)

**Design and print**

Tjerk de Vries, FOTON visuele communicatie



