ROADMAP NANOTECHNOLOGY – *update October 2014*

Introduction

Nanotechnology is generally considered to be one of the key enabling technologies which will drive innovations in the 21st century. Even at an early stage the Netherlands adopted a pro-active stance in relation to nanotechnology by initiating various national programmes. As a result, the Dutch R&D community has acquired a high level of knowledge and an excellent position in the international field of nanoscience and technology. Internationally, there is now a clear transition happening where results from more academic nanoscience are effectively being used in more applied, market-driven R&D. The Netherlands faces the challenge to be more effective in making that transition. The present Roadmap Nanotechnology is part of the Innovation contract of the top sector HTSM but, in view of its cross-topsector position, the planned activities for the period of 2013-2020 are closely connected to challenges and opportunities addressed in other roadmaps and top sectors as well. It therefore addresses generic nanotechnology research themes and multiple application areas which are important for the competitive position of the broader Dutch knowledge economy and the solutions for societal challenges - including risk and technology assessment - in an integrated way.
The proposed innovations items have been determined in consultation between relevant industrial partners, knowledge institutes, government, social institutions and contacts with representatives of other roadmaps and top sectors. They are therefore aligned with what is addressed in current nanotechnology programmes of NanoNextNL, NanoLabNL , NWO-NANO and TNO and what is proposed in roadmaps and innovation contracts of HTSM and other Topsectors.

This new version of the roadmap (October 2014) is a "minor update" especially made to capture some key new developments in the Dutch nanotechnology landscape. Special emphasis is given to clarify links between Nanotechnology and other HTSM roadmaps and other topsectors. It is planned that a major update will take place in 2015.

1. Societal and economic relevance

Connection with the key societal themes

The European Commission has selected Nanotechnology and closely related Micro and nanoelectronics as two of its six "Key Enabling Technologies" (KET's).

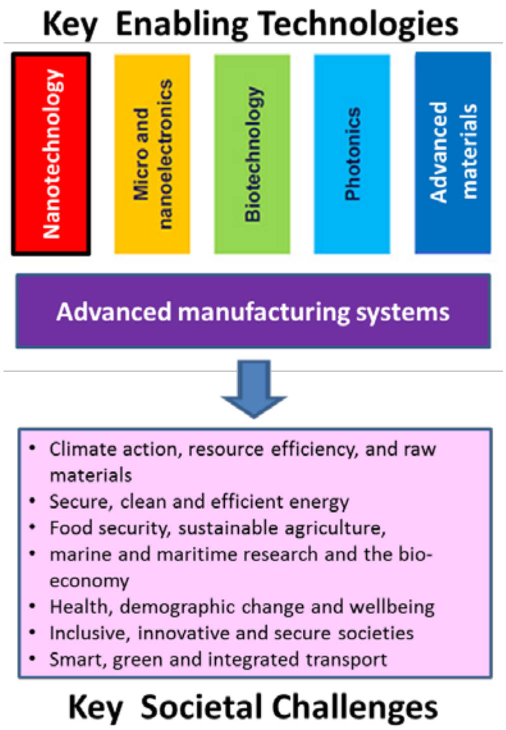

Fig 1: EU Key Enabling Technologies and Key Societal Challenges

The KET's form the basis of the Horizon 2020 program in which they will be deployed to make EU industries more globally competitive and provide new options to address present and future Key Societal Challenges. The key enabling position of nanotechnology is expected to provide new opportunities for a broad scope of application areas. In view of this, nanotechnology is expected to make significant contributions to solve societal challenges related to ensuring affordable healthcare, sustainable energy, healthy food and clean water for a growing and ageing population.

In the Dutch innovation landscape Nanotechnology has its home in the top sector HTSM in view of its close relation and enabling importance with the other HTSM-roadmaps. However in view of its relevance to a broad scope of societal challenges, it is also a recognised enabling technology for the top sectors 'Life Sciences & Health', 'Energy' , 'Agro & Food', 'Horticulture and Source Materials', 'Water and Chemistry' as is depicted below.

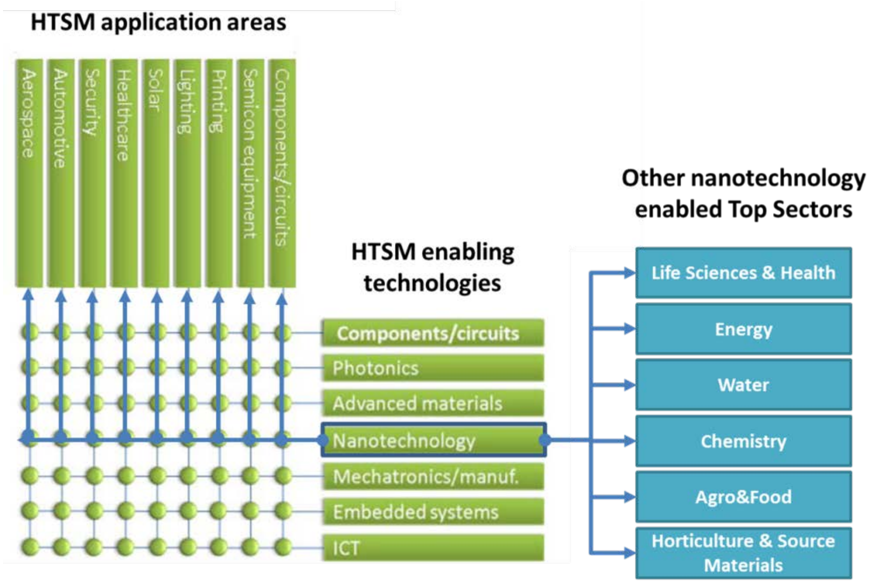

Fig2: Position of Nanotechnology in HTSM and connections to other topsectors

For this reason nanotechnology is expected to make contributions to various application areas and provide significant technological and commercial results, as well as to providing high-quality employment in the involved industrial sectors and scientific research communities.
In summary, nanotechnology is important for various societal themes and related application areas and top sectors. The cross connections of key topics on the nanotechnology roadmap with other HTSM-roadmaps and top sectors, will be addressed in section 2.

Global Market size

It is difficult to put a realistic market value on rapidly emerging technologies such as nanotechnology and the many promising - but partly still hypothetical - future products. Depending on the applied scope there are many estimates to choose from. At the upper end Lux Research projected in 2007 that by 2015 the market size in terms of "Sales of products incorporating nanotechnology" was expected to grow to a staggering $3 trillion. This is not an impossible figure if important economic sectors like semiconductor, consumer electronics and important areas of chemical industry are included. However very recently BCC Research has quantified the global market for nanotechnology based on a more focused inventory to be nearly $20.1 billion in 2011. For 2017 total sales are expected to reach $48.9 billion, which implies an annual growth rate of about 20%. Most of these figures are related to the sales value of nanomaterials and equipment for manufacturing on nanoscale (so excluding semiconductor and consumer electronics). Compared to these established markets, the sales value of the emerging area for nanodevices (eg nanofluidic devices) is still relatively small, but double digit growth numbers are expected for these new nanotechnology market segments as well.

Competitive position of the Dutch ecosystem

The top 3 leading countries for commercialisation of nanotechnology are the US, Germany, and Japan. Although not comparable to these nations in terms of absolute numbers, The Netherlands is at the forefront of nanotechnology developments and is the largest player among the medium-sized economies, thanks to the proactive activities in industry as well as in academic institutes and support from science foundations[1].

In the field of academic nanoscience a citation impact based study published by Elsevier[2] early 2014, revealed that the formerly leading position of Dutch based publications was lost in 2010. The Netherlands finds itself now at the fourth position behind Singapore, Switzerland and the USA. However, a leading position for citation of Dutch patents was obtained in 2010 and is showing an upward trend (in contrast to all other countries). Furthermore this study indicates that Dutch scientist publish a lot with foreign and industrial partners and are found at the second and third position behind Switzerland and Japan respectively.

At present most of the top 20 Dutch based multinational companies perform R&D in the field of nanotechnology. In the growing high tech systems sector, Philips, NXP, ASML , ASM International and FEI are the biggest industrial players. In addition, DSM, Shell and Akzo Nobel are active on the market of nanomaterials & coatings in the chemistry domain. In the food area companies like Frieslandcampina, Danone and Unilever have an active interest in understanding the link between interactions on (bio)molecular scale and food microstructure. In the Life science domain companies like Philips, Roche, DSM, Crucell, and Dupont Genencor have similar interests linking molecular scale functionality to medical opportunities. In addition to these companies, the Holst Centre has a unique role bringing together multinational industries and academia with global positions and strategies in the nano-microelectronic developments. The number of nano-related projects in industry is growing by approximately 10% per year and the academic research and valorisation support in former NanoNed/MicroNed programs in the last decade, has led to the formation of more than 50 spin-off companies in the domain of nanotechnology. Examples of these such as Mapper Lithography, Micronit Microfluidics, Aquamarijn, Fluxxion Medimate LioniX and SolMateS can now be found - with 70 other SME's - in the partner list of NanoNextNL, actively collaborating with the above mentioned multinational players in the nanotechnology field.

In spite of the above mentioned positive developments, a 2010 international benchmark study[3] already showed that although the volume and quality of the Dutch scientific nanotech activity is high, the Netherlands industry scored relatively low on technology development capacity and strength on an international scale. The EU Innovation Score Board 2014[4] confirmed this "Innovation Paradox", for the general R&D landscape. The open innovation Research ecosystem is ranked very high (2nd place), but when it finally comes to economic effects Netherlands ranks only 16th. Over-all, we can conclude that the last years have shown a shift from more isolated academic research to "open innovation" R&D including industry, but that the step to added business value deserves more attention. In the specific field of nanotechnology, the valorisation program of NanoNextNL aims to significantly improve this situation by active identification, improvement and exploitation of emerging business cases by involving business coaches and investors from the wider (inter)national

[1] Lux research (2010); Global trends in nanotech.

[2] International comparative benchmark of Dutch research performance in TKI themes : nanotechnology. http://www.rvo.nl/sites/default/files/2014/02/Elsevier%20benchmark%20nanotechnology.pdf

[3] Lux Research 'Ranking the Nations on Nanotech' (2010)

[4] http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-scoreboard/index_en.htm

ecosystem in an early stage. The continuation of the NanolabNL program in 2014 is also very beneficial since it assured continued low threshold access to high quality nanotechynology infrastructure form existing SME's and new start-ups.

NanoNextNL

The present NanoNextNL-program has its foundation in the Strategic Research Agenda of the Netherlands Nano Initiative (NNI) which was written by FOM, STW and NanoNed in 2008 at the request of the Dutch Government. The agenda identified the generic research themes and application areas which were considered of crucial importance for the global position of the Netherlands as a knowledge economy. In addition it was proposed that simultaneous attention should be given to Risk Analysis and Technology Assessment R&D to investigate the possible impact on people, natural environment and society to ensure safe and acceptable application of new enabling nanotechnologies in the various application areas.

NanoNextNL has brought together more than 90 companies, of which 80 SMEs, which are participating together with about 30 partners from universities, knowledge institutes and medical centres. NanoNextNL has a budget of 250 M€ based on 50/50 contributions from the government and the involved partners to execute the program in the timeframe 2010-2016 and to ensure that a durable ecosystem is formed that will continue to lead national innovation in this area .

The organisation of the NanoNextNL program and its main generic and application themes is depicted below.

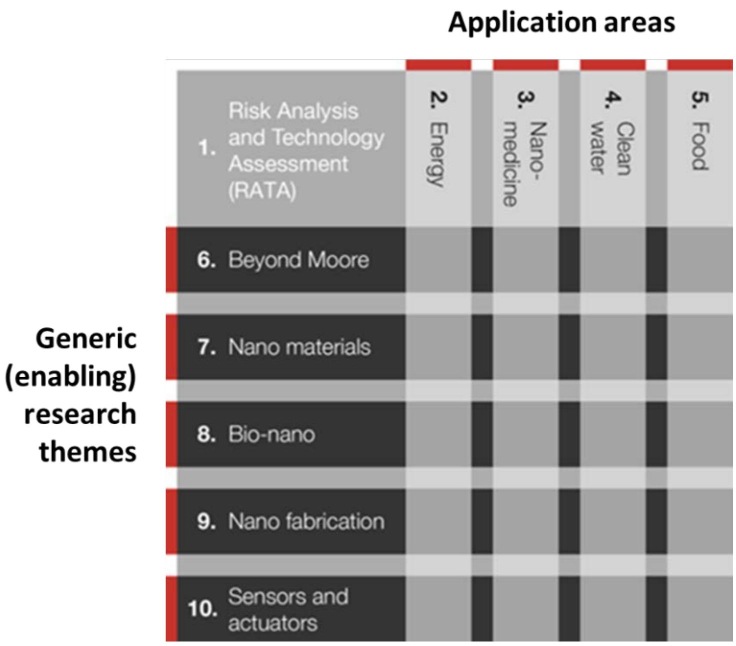

Fig3: NanoNextNL research themes and application areas.

NanoLabNL

NanoLabNL is a consortium of MESA+ NanoLab Twente (Enschede), Kavli NanoLab Delft (Delft), NanoLab@TU/e (Eindhoven) and Zernike NanoLab Groningen (Groningen), partnering with TNO and Philips. It provides a full-service and open-access infrastructure for high tech R&D in nanotechnology. The state-of-the–art facilities (cleanrooms, equipment, offices etc.) and the close proximity of research hubs in the Netherlands make NanoLabNL a unique platform for collaborative

nanotechnology research. All facilities within NanoLabNL are open to all NanoNextNL partners, as well as to external users for attractive tariffs. On average 100 companies make use of the facilities each year. Each of the four NanoLabNL locations offers a range of basic infrastructure and expert techniques. unlikely to be found elsewhere in the country. The decision to make use of only a limited number of research laboratories and to make them accessible to all researchers, both public as well as private, has proven extremely effective.
The total investment in NanoLabNL sofar amounts to 150M€. An estimate of the total required investment and operating costs for the next decade is approximately 210 M€, for which a request for continuation of support has been granted as part of the Netherlands Roadmap for Large-scale Research Facilities.

NWO nanotechnology
In addition to the investments in application driven R&D and infrastructure in NanoNextNL/NanoLabNL, fundamental research in the field of nanotechnology has been empowered recently from the “Zwaartekracht” program of the Netherlands Organisation for Scientific Research (NWO). In 2012, total a budget of 63M€ has been made available for funding of the “Frontiers of Nanoscience” and “Functional Moleculair Systems” projects to be executed in the next decade by leading nanoscience university groups. Additionally, in 2013 50M€ has been awarded to the projects “integrated nanophotonics” and “Multi-scale Catalytic Energy Conversion” which are both strongly linked to nanotechnology.

New initiatives
Three new initiatives involving significant participation of nanotechnology have started late 2013. Based on considerable scientific strength in the Dutch universities (mainly TU Delft and Eindhoven), a Center for Quantum Technology (QuTech) has been founded with the ambition to exploit new quantum-based devices for future applications around quantum-computing and inherently secure communication. Also a new consortium for human Disease Model Technologies (hDMT, formerly “Organ on a Chip”) has been founded, which will use various (nano)technologies to build models on which human diseases can be studied. And a new Advanced Research Center for nanolithography has started in Amsterdam combining forces of FOM/Amolf, UvA and VU, and ASML as the lead industrial partner.

2. Application and technology challenges
State of the art for industry and science and future evolution, in present and new markets
Following earlier roadmap publications (Innovation Contract 2011; SRA NNI), the next paragraph summarize the state-of-the-art in some of the main program-lines.

Nanoelectronics
In the early years, the micro-electronics and semiconductor sector were the main driving force behind nanotechnology because of their need for ever increasing miniaturisation technology. Over the past thirty years it has become possible to create progressively smaller structures for the production of computer chips by means of lithographic techniques. In this time frame the density of transistors on a chip has doubled every eighteen months, known as Moore’s law. However this principle will come to an end sooner or later, increasing the need for new breakthrough ideas and technologies. This new era in electronics is identified as ‘beyond Moore’. On-going developments in

the field of nanoelectronics, nanophotonics and nanofabrication will provide the HTSM top sector with new impulses to produce nanostructured chips (ASML, ASM International), microscopes to visualise and manipulate nanostructures (FEI), to be applied in the development of future electronic devices (NXP).

Bionanotechnology and micro- and nanofluidics

In the previous decade, nanotechnology and biology have become more intertwined. Living cells are full of 'micromachines' constructed of protein molecules and other nanometer-sized self-organising structures. Physicists, biologists and technicians are therefore increasingly seeking inspiration in biological systems for their research and applications based on biomimetic designs and newly developing synthetic biology techniques. On the other hand, new nanotechnology research methods, techniques and instrumentation are used to provide new avenues for biomedical and medical research. For example, novel detection principles and lab-on-a-chip concepts are being developed in order to sensitively analyse the composition of minute quantities of bodily fluids in a quantitative and self-contained manner. Further possibilities include the development of new nanomedicines and antibiotics, the early detection of viruses, new methods for sequencing of DNA and proteins, the control and administration of medication, and intelligent surgical equipment. For that reason, the implementation of the nanotechnology roadmap will increasingly include both public and private sector participants from the medical and healthcare sectors. A specific example is the new technology that is to be developed by the consortium for human Disease Models hDMT. This presents a clear cross-over between nanotechnology techniques needed to grow and study disease models and potentially organs on a chip; and applications which are to be found in the topsector LSH and potentially the roadmap Healthcare in HTSM.

An important enabling technology in this area is micro- and nanofluidics: the technology of handling small amounts of liquids for sensing or processing. Many applications mentioned above need this technology as part of an integrated system. However, micro- and nanofluidics applications are broader. The technology is also increasingly explored in the chemical industry, where its very efficient heat transfer and the short resident time of the reaction constituents in the reactor offers more energy efficient processing with a higher specificity and yield. The Netherlands are particularly strong in microfluidics, with several companies developing and selling innovative products.

Nanomaterials and surface modification

Recently, mankind has been able to control the composition of manufactured materials at an atomic scale. It is therefore becoming possible to exploit the special properties of nanomaterials, which can lead to e.g. more efficient solar cells, fuel cells and batteries. Furthermore there are environmental and chemical applications (catalytic convertors, membranes), applications in data storage (quantum dots, multiferroics) and data transport (photonic crystals). In addition the use of low-energy nanomaterials will help to resolve the major global problem of energy consumption for data processing (computers, mobile phones, internet). The Netherlands has already established an international reputation in this area and many Dutch companies (multinationals, SMEs) are active in this new field. Surface modification of materials, often at the nano-scale, plays an important part in many industries. Coatings based on nanotechnology can make sensors more specific, or can extend the lifetime of products. New opportunities, based on research results from the past, start to materialize as (especially smaller) industrial players formulate new application opportunities in existing markets. There is a growing interest from companies operating in a wide range of industrial sectors from marine technology and solar to life sciences; however the development of really new markets based on nano-structured surfaces will still take quite some time and investments.

Relevance for other HTSM roadmaps and topsectors

The importance of the generic enabling position of nanotechnology for other enabling technologies, but especially for many application areas (inside the HTSM topsector but also related to other topsectors) is reflected in its relevance for achieving the goals of *other* HTSM roadmaps and top sectors. A screening of available (2011) roadmaps/TKI-contract versions with respect to connections to nanotechnology priorities (as defined in the former version of the nanotechnology roadmap) resulted in the table below.

Table 1: Relevance of Nanotechnology priorities for other HTSM roadmaps and Topsectors

	Enabling oriented HTSM Roadmaps						**Application oriented HTSM Roadmaps**									**Application oriented top sectors/TKI's**					
Nanotechnology Priorities	**High Tech Materials**	**Embedded Systems**	**Photonics**	**Mechatronics & Manufacturing**	**Components & Circuits**	**ICT**	**Semi Conductor Equipment**	**Printing**	**Lighting**	**Solar**	**Health Care**	**Security**	**Automotive**	**Aeronautics**	**Space**	**Agro & Food**	**Water**	**Energy (TKI Solar)**	**Horticulture and source materials**	**Chemistry**	**Life Sciences & Health**
Nano optics / photonics (21)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Nano materials / surfaces / membranes (18)	●		●	●	●		●	●	●	●	●		●	●	●	●	●	●	●	●	●
Nano sensors / actuators (17)	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●		●		●
Nano electronics /components (15)	●	●	●	●	●	●	●	●	●		●	●	●	●	●			●			
Nanoscopy / imaging / inspection (15)	●	●	●	●	●		●	●	●	●	●				●	●		●		●	●
Nano fabrication / patterning/ assembly (13)	●	●	●	●	●	●	●	●	●	●	●							●		●	
Nano mechanics & physics (10)	●		●	●	●		●	●	●	●			●					●			
Nano fluidics / reactors (10)			●	●	●			●		●	●					●	●			●	●
Bio-nanotechnology (5)	●		●								●								●		●
Nano medicine / drug delivery (4)	●							●			●										●
Nano Risk Analysis / Technology Assessment (17)	●		●	●				●	●	●	●	●	●	●	●	●	●	●	●	●	●
Reference to nanotechnology in roadmap/TKI (15)	●		●	●	●		●	●	●	●	●					●	●	●	●	●	●

In most of the *other* roadmaps and TKI-contracts a direct reference is made towards the relevance of nanotechnology and in some cases further indications are highlighted concerning the relevance of specific nanotechnology priorities. In order to further quantify these interactions an estimate has to be made on what percentage of the total roadmap/top sector activities relate to nanotechnology. Together with the total R&D spending in these roadmaps, this can indicate where the best opportunities exist for expanding the cross-connections.

3.0 Priorities and implementation

Existing priorities

The list in table 1. is still regarded as the list of existing priorities for future R&D in nanotechnology. From table 1 it is clear which investments in the priorities - described in more detail in former versions of the Nanotechnology roadmap - have a broader or more specific impact for other roadmaps and top sectors. Each of the nanotechnology priorities are already part of on-going NanoNextNL and TNO-, NWO-NANO programs, but within each of the stated priorities there are novel areas which need to be explored. In particular those areas within the priorities which clearly link to the identified cross-connections in the table deserve more attention and funding.

Emerging priorities

In *addition* to the existing priorities listed in table 1, two new topics have been identified in the evaluation process considered suitable for allocation of additional funding for further R&D.

Nanotechnology endurance

For many envisaged large scale application areas for nanotechnology based devices such as consumer electronics, automotive/aerospace sensors, solar cells, chemical processing and water quality monitoring, it is essential that their performance and functional lifetime is understood and can be warranted over long periods and under sometimes extreme and/or varying conditions. In view of the stage of developments, not much dedicated attention has been given so far to fundamental aspects of structural and functional integrity and endurance of nanotechnology based devices. In such devices individual properties of new nanomaterials and nanostructures, in many cases processed by new nano-manufacturing methods, have to be understood and taken into account in combination with those of more conventional bonding and packaging materials and processing techniques.

Nano standardisation, inspection and regulation

For further commercial manufacturing and application of nanotechnology based products, the need for standardisation is becoming more evident to prevent non-productive diversification and ineffective and inefficient processes future manufacturers and end-users will otherwise be faced with. First examples are already found in the world of e.g. microfluidic/lab-on-chip devices and associated inter-changeability of equipment and components. Also in the area of management of potential risks of “nano inside” a next step must be taken, especially in the area of engineered nano materials and nano particles.

Dedicated nanoscale oriented measurement and -inspection techniques and procedures have to be developed as a basis for future (inter)nationally accepted NEN, CEN and ISO methods and procedures to certify compliance with present and future technological, health and ethical standards. In many cases a cross-over and integration of technologies developed in other roadmaps will be possible. As an example new possibilities for detection of nanoparticles can be expected from the focus on contamination control on the nanoscale in the semiconductor area, whereas similar detection methods may be also needed in fields where nanoparticles are used in (chemical) products. Furthermore a recent crowdsourcing based demonstration project in which an attempt will be made to measure “fine dust” levels by an optical add-on device on smartphones, shows what may be expected from further convergence of exponentially developing technologies.

Proposed implementation in public-private partnerships/ Transition of connected program institutes

In view of the "modus operandi" of the topsector HTSM, additional funding generated by cash investments of industrial partners will generate additional budget for existing and new NWO (FOM, STW)/TNO funded programmes in the field of nanotechnology. The way how these funds will be re-invested should favour new possibilities for commercial and societal impact, fully in line with the general topsector policy and helping to face the challenge of creating more "nanotechnology business". To ensure efficient use of resources and maximum impact of the R&D related to the above specified priorities, it is proposed to ensure a link to the existing NanoNextNL program which will continue well into 2016. In the coming year a discussion must be initiated to investigate how to make sure that the TKI-activities for nanotechnology which are somewhat scattered over various roadmaps in the different topsectors become more visible, aligned and effective. At present NanoNextNL has already established (formal) collaborations and contacts with all other Public Private Partnership organisations with nanotechnology based activities or interests in specific application[5] or technology[6] domains. Depending on their continuity in the applicable top sectors and transformation in TKI's, these collaborations will be renewed where appropriate to ensure adequate operating space for cross-roadmap/top sector collaboration in the field of nanotechnology.

QuTech, the centre for quantum computing

Quantum computers offer the potential to perform calculations at an incredible speed, which increases exponentially with the number of Qbits. These computers could be used to solve extremely difficult numerical problems which then could help to solve urgent societal challenges e.g. durable energy or personalized medicine. Similar technology can be used for quantum encryption, for communication inherently safe against eavesdropping. The Netherlands is very well positioned to take a leading role in the development and industrialization of quantum computing and quantum technology, combining excellent quantum *science* at TU Delft (and Eindhoven) with TNO's capabilities in prototyping of multi-disciplinary technologies. The development of a quantum computer uses nanotechnology extensively: materials, nano-electronics, characterization and measurements at nanometer scales, contamination control. This will be combined with the capabilities to develop devices and complex systems. QuTech presents a clear cross-over point between Nanotechnology and other HTS&M roadmaps such as Materials, Photonics, Mechatronics Circuits&Components and Advanced instrumentation. The development of a quantum computer also fits in the Dutch industrial landscape. Big companies like ASM, ASML, and FEI, as well as SME's like Leiden Cryogenics can help to develop the necessary tools and instrumentation. It is expected that quite some spin-off technology and opportunities will be created for these same companies, e.g for applications in semiconductor equipment. A first spin-off example is Single Photon, an SME developing detectors. The ministry of EZ will fund this center with 5M€ in the period 2014-2018., while the top-team HTSM has decided to dedicate 3M€ of the TKI toeslag for this initiative in the same period. Other investments are made by NWO, TU Delft and TNO and private parties.

Linkage with other innovation instruments

In addition to the proposed linkage to the on-going NanoNextNL-program the formerly mentioned NanoLabNL programme is considered highly relevant for the execution of the roadmap nanotechnology. Furthermore the EU-Horizon 2020 framework is expected to provide access to

[5] (Wetsus, TIFN, CTMM, BMM, TIPharma, Point One, Solliance)

[6] (M2i, ISPT, COAST)

partners and networks with similar activities and facilities on a European scale. Of course, it is very important also that the more fundamental nanoscience activities, which are eventually needed for real break-through technologies, will continue obtain enough funding from the government eg via NWO. In that sense, it is very promising that an important part of NWO "Zwaartepunt" program has been granted to nano-science topics recently.

3.1 TKI program

Committed and expected R&D activities contributing to the TKI program

Implementation of TKI grants, connection with other roadmaps

The committed and expected financial contributions to the nanotechnology TKI-program are specified in Section 5. In addition it must be mentioned that due to the crosscutting enabling position of the nanotechnology roadmap illustrated in table 1, industrial investments in nanotechnology, eligible for generation of the TKI-grant, are frequently connected to and registered in the related specific application area oriented HTSM roadmaps. Once the registration of the industrial contributions in these roadmaps and topsectors has been completed, a proposition will be made to provide additional funding for R&D in the identified nanotechnology priorities specified in the introduction of section 3.

3.2 European program

Alignment with European strategies and policy instruments

In the 'Seventh Framework Programme' (FP7) an important investment of over €1 billion has been made available in the nanotechnology area by the launch of the "Graphene Flagship" as part of the ICT-driven 'EU Future Emerging Technology program'. Dutch participants from TU Delft and Groningen will coordinate two of the fifteen subprograms.

The next Programme - Horizon 2020 - started in 2014 and has a total budget of €77.6 billion for a period of 7 years. In this program nanotechnology has been identified as one of the key enabling technologies (KET's) and specific calls will be present in the following 3 main Priorities:

In Priority I "Excellent Science", no specific budget for nanotechnology proposals has been allocated which means they will have to compete with proposals in other scientific domains. 31.7 % of the total budget is allocated to this priority.

Priority II "Industrial Leadership", consists of dedicated support for the "Key Enabling Technologies". As illustrated in fig 1. , "Nanotechnologies" is one of the 6 KET's. 22 % of the total budget is allocated to this priority with a joint budget of €4 billion for nanotechnologies and 2 closely related KET's (material and manufacturing-processing). The roadmap established by the Nanofutures EU platform has a target volume of 1.5 billion for a R&D program focused on 7 specific "Value Chain" topics identified in interaction with all relevant other Technology Platforms with nanotechnology activities. More attention is needed to secure that Dutch nanotechnology priorities are well represented in the calls of this priority. In addition, it has now been recognized that major parts of the Dutch Nanotechnolgy roadmap link to other KET's such as ICT (nano-electronics), photonics (nano-photonics) and materials (nano-structured materials).

Priority III "Societal Challenges", focuses on the 6 themes illustrated in fig 1., that have been identified as policy priorities in the Europe 2020 strategy. The emphasis will be on bringing together resources and knowledge across different fields, technologies and scientific disciplines to address these challenges. For a number of these challenges (e.g. health, food, energy), it can be expected that nanotechnologies will form the underlying basis for innovation. 39% of the total budget is allocated to these challenges.

4. Partners and process

Engaged partners from industry, science, and public authorities (national and regional)

The main national industrial/scientific partner base for execution of the roadmap nanotechnology is provided by the ecosystem in and around NanoNextNL. Once the funding allocation process described in section 3.1 has been completed, the specific involvement of partners can be specified. Since November 2013, the “Klankbordgroep Nanotechnology” has been established which meets several times per year. Meetings of this board are public and are attended by representatives of industry (large and SME), knowledge institutes and government. During these meetings, new developments in the nanotechnology are discussed, links are established to other roadmaps and sectors, and feedback is collected for a next version of the Nanotechnology Roadmap.

SME activities

SME’s play a large part in the innovation in the Naotechnology domain. In the NanoNextNL program, 80 SME’s are actively engaged in R&D activities. For the further communication with and involvement of the SME community, existing collaborations and contacts with Dutch SME-oriented organisations and (private) consultants which are active in the nanotechnology field such as MinacNed, Microcenter, EnablingNMT and NanoHouse will be used and extended. Links to SME have been strengthened by organizing several topical meetings “Nano4SME” during the summer of 2014 (MIT networking activity for HTSM - Nanotechnology), in which about 60 (new) SME’s attended. This effort (organized by NanoNextNL, NanoHouse, MinacNed, Enabling MNT and de Kamer van Koophandel) will continue in the coming years.

Process followed in creating this roadmap

The original roadmap Nanotechnology (version feburari 2013) has been the result of a long process starting with the Strategic agenda Nanotechnology and involving stakeholders from all sectors. For this minor update input was solicited from the regular members of the Klankbordgroep Nanotechnology and representatives of specific new initiatives. The final version of this roadmap has been written by the Roadmap team Nanotechnology: Dick Koster (TNO), Dave Blank (Universities), Leon Gielgens (NWO) and Frank de Jong (Industry and chair)

We acknowledge further contributions from Henne van Heeren, Marileen Dogterom, Menno Prins, and Rogier Verberk.

Budget update HTSM roadmap Nanotechnology 2015

5. Investments

The FES program NanoNextNL stops end of 2016, which generally leads to a dip in the Nanotech public/private partnership funding in 2017. Some of the public funding declines permanently (eg row Departments and Regions); however private, university and NWO funding is expected to stay constant or even grow. There are indications that generally investments in nanotechnology will stay the same or increase; while for the new institutes / initiatives described in the roadmap both public and private funding increases significantly over the next year.

Furthermore, there is be significant overlap (by design) between the roadmaps nanotechnology and various other roadmaps in the topsector HTSM (e.g. Semi equipment, printing, solar, photonics, materials, components and circuits etc; and with various other topsector roamdps (e.g. chemistry and LSH). This means that it is not always easy to allocate the investments made to the roadmap.

Roadmap (*M€)*	**2015**	**2016**	**2017**	**2018**	**2019**
Industry	18	20	18	18	18
TNO	3	4	3	4	4
NLR	0	0	0	0	0
NWO	25	25	25	25	25
Universities	20	20	20	20	20
Departments[7] and regions[8]	21	21	12	12	12
Grand total	**87**	**90**	**78**	**79**	**79**

European agenda within roadmap*	**2015**	**2016**	**2017**	**2018**	**2019**
Industry					
TNO					
NLR	0	0	0	0	0
NWO					
Universities					
Co-financing of European programs[9]					
European Commission					

At this moment not enough information on European spending is available

[7] Ministries, excluding contributions to TKI HTSM

[8] Regional and Local Authorities

[9] Ministry of Economic Affairs contributions to JU ECSEL and EUREKA clusters

Contributing PARTNERS

INDUSTRIES:

AEMICS B.V.
Amsterdam BioTherapeutics Unit
Aquamarijn Microfiltration BV
ASM Europe B.V.
ASML Netherlands B.V.
ATAS GL International B.V.
AVEBE UA
Basic Membranes
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Unilever R & D
U-protein Express
VibSpec-Training
VION Food Nederland
Vitens Laboratorium
X-Flow B.V.
XiO Photonics bv

UNIVERSITIES:

Radboud Universiteit Nijmegen
Rijksuniversiteit Groningen
Technische Universiteit Delft
Technische Universiteit Eindhoven
Universiteit Leiden
Universiteit Maastricht
Universiteit Twente
Universiteit Utrecht
Universiteit van Amsterdam
Vietnam National University, Hochiminh City
Vrije Universiteit Amsterdam
Wageningen Universiteit & Researchcentrum

MEDICAL CENTRES:

Academisch Medisch Centrum
Erasmus MC
Leids Universitair Medisch Centrum
Slotervaart Ziekenhuis
Universitair Medisch Centrum Groningen
Universitair Medisch Centrum St. Radboud
Universitair Medisch Centrum Utrecht
VU Medisch Centrum Amsterdam

RESEARCH ORGANISATIONS:

ASTRON - Netherlands Institute for Radio Astronomy
Energieonderzoek Centrum Nederland
FOM-instituut AMOLF
FOM-instituut DIFFER
Hogeschool Zuyd
Holst Centre
Hubrecht Instituut voor Ontwikkelingsbiologie en Stamcelonderzoek
IMEC
Koninklijk Instituut voor de Tropen
Nederlands Kanker Instituut
Rijksinstituut voor Volksgezondheid en Milieu
TNO

OTHER ORGANIZATIONS:

NanoNextNL
MinacNed
NanoHouse
Microcentrum
Enabling MNT